

TUNABLE BAND PASS FILTER DESIGN BY USING RF SWITCH

NURBAITI BT ABD AZIZ

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

Faculty of Electronics and Computer Engineering
Universiti Teknikal Malaysia Melaka

April 2010



UNIVERSITI TEKNIKAL MALAYSIA MELAKA
FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : TUNABLE BAND PASS FILTER DESIGN BY USING RF SWITCH
Sesi Pengajian : 2009/2010

Saya NURBAITI BT ABD AZIZ
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

(TANDATANGAN PENULIS)

Alamat Tetap:

6/4958, KG PERMATANG BADAQ,
JALAN GAMBANG,
25150 KUANTAN, PAHANG.

Disahkan oleh:

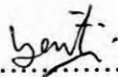
(COP DAN TANDATANGAN PENYELIA)

MOHAMAD ZAINOL ABIDIN BIN ABD AZIZ
Pensyarah
Fakulti Kejuruteraan Elektronik Dan Kejuruteraan Kompute.
Universiti Teknikal Malaysia Melaka (UTeM)
Karung Berkunci No 1752
Pejabat Pos Durian Tunggal
76109 Durian Tunggal, Melaka

Tarikh: 30 APRIL 2010

Tarikh: 19 / 05 / 2010

“I hereby declare that this report is result of my own effort except for works that have been cited clearly in the references.”

Signature : 

Author : Nurbaiti bt Abd Aziz

Date : 30 APRIL 2010

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

Signature :
Supervisor's Name : Mr. Mohamad Zoinol Abidin Abd Aziz
Date :

To my beloved family and friends.

ACKNOWLEDGEMENT

The most grateful and thankful is dedicated to Almighty ALLAH s.w.t. for blessing me with good health and ideas in completing this research successfully. First of all, I would like to thank Allah for HIS firm hands in guiding me in the course of completing this thesis writing. Alhamdulillah. I would like to show my highest appreciation to my supervisor, Mr Mohamad Zoinol Abidin b. Abd Aziz for his invaluable support, patient, assistance, guidance and especially his encouragement to this project. I truly have learnt a lot and all this will not achieved without his assistance. I also would like to thank all my fellow friends for their contribution both their support and help throughout my project development. A lot of beholden appreciation and thanks dedicated also to my family members who were always stand by me for giving moral support. Lastly, this task has taught a lot of lesson and knowledge which is much very precious for me in the future.

ABSRTACT

A microwave filter is a two-port network used to control the frequency response at a certain point in microwave system by providing transmission at frequencies within the passband of the filter and attenuation at the stopband of the filter. In this project, a tunable microwave band pass filter circuit for the WLAN bandwidth of 2.4GHz (IEEE 802.11b) is designed, purposely to tune within the 14 channels of WLAN range. The tuning is done by selecting four main reference channels that is not overlapping each other which are channel 1, 5, 9 and 13. By using Butterworth Response, the value of lumped elements of the band pass filter circuit is calculated. Shunt stub method is used for filter realization, Kuroda's Identity and Richard's Transformation is used for calculation. All the circuits are simulated by using Microwave Office software (AWR). From the simulation, the circuit layout is obtained and fabricated on FR4 board. For the tuning circuit, RF switch using PIN diode is chose as it has a faster speed and stable repeatable. The fabricated circuit is then measured by using Network Analyzer. This project produced the filter response of lumped elements filter presents better response compared to filter realization circuit.

ABSTRAK

Penapis gelombang mikro digunakan untuk memperolehi transmisi pada frekuensi yang dikehendaki. Dalam projek ini, sebuah *tunable band pass filter* dihasilkan untuk jalur lebar dari 2.4GHz WLAN (IEEE 802.11b) bagi 14 salurannya melalui saluran 1, 5, 9 dan 13. Dengan menggunakan *Butterworth Response*, nilai elemen induktor dan kapasitor pada rangkaian *band pass filter* dikira. Untuk *realization*, kaedah *stub shunt* digunakan dengan mengaplikasi Identiti Kuroda sebelum *Richard's Transformation* digunakan untuk menukar *lumped-element* kepada litar yang mempunyai *transmission line*. Simulasi dilakukan dengan menggunakan perisian Microwave Office (AWR). Dari hasil simulasi, susun atur litar dapat dipastikan dan difabrikasi pada papan mikrostrip FR4. Untuk pensuisan, suis RF menggunakan PIN diod telah dipilih kerana memiliki kelajuan lebih cepat dan lebih stabil. Pengukuran litar yang telah difabrikasi dilakukan dengan menggunakan *Network Analyzer*. Akhirnya, projek iini menghasilkan respon penapisan yang baik oleh litar dengan *lumped-element* berbanding litar penapis yang telah direalisasi.

CONTENT

CHAPTER	CONTENT	PAGE
	TITLE	
	REPORT STATUS	
	CONFESSION	ii
	PENGESAHAN PENYELIA	iii
	DEDICATION	iv
	ACKNOWLEDGEMENT	v
	ABSTRACT	vi
	ABSTRAK	vii
	CONTENTS	viii
	LIST OF TABLES	xii
	LIST OF FIGURES	xiii
	LIST OF ABBREVIATIONS/SYMBOLS	xvi
I	INTRODUCTION	
	1.1 Introduction	1
	1.2 Objective	2
	1.3 Problem Statements	2
	1.4 Scope	3
	1.5 Methodology	3
	1.6 Report Structure	4

CONTENT

CHAPTER	CONTENT	PAGE
	TITLE	
	REPORT STATUS	
	CONFESSION	ii
	PENGESAHAN PENYELIA	iii
	DEDICATION	iv
	ACKNOWLEDGEMENT	v
	ABSTRACT	vi
	ABSTRAK	vii
	CONTENTS	viii
	LIST OF TABLES	xii
	LIST OF FIGURES	xiii
	LIST OF ABBREVIATIONS/SYMBOLS	xvi
I	INTRODUCTION	
	1.1 Introduction	1
	1.2 Objective	2
	1.3 Problem Statements	2
	1.4 Scope	3
	1.5 Methodology	3
	1.6 Report Structure	4

II

LITERATURE REVIEW

2.1	Introduction	6
2.2	Microwave Filters	8
2.3	Types of Filters	8
2.3.1	Band Pass Filter	8
2.3.2	Low Pass Filter	10
2.3.3	High pass Filter	11
2.3.4	Band Stop Filter	12
2.4	Filter Theory	12
2.5	Scattering Parameter	15
2.6	Filter Response Types	16
2.4.1	Chebyshev (Equal-ripple amplitude)	16
2.4.2	Bessel-Thomson (Maximally Flat Group Delay)	17
2.4.3	Butterworth (Maximally Flat Amplitude)	17
2.4.4	Gaussian	17
2.7	Filter Synthesis	18
2.8	RF Switching Matrix	19
2.8.1	Benefits of RF/Microwave Switch Matrix	19
2.8.2	Signal Routing	20
2.9	PIN diode	20
2.9.1	Operation	21
2.9.2	Characteristics	21
2.9.3	PIN diode as in RF Switch Circuit	22
2.9.3.1	RF Choke	23
2.9.3.2	DC Block Capacitor	24
2.10	Microstrip Transmission Lines	24
2.10.1	Effective Dielectric Constant & Characteristic Impedances	26

III

METHODOLOGY

3.1	Introduction	28
3.2	Design Specification of Tunable Band Pass Filter	28
3.3	Design Calculation	29
3.3.1	Low Pass Filter Design	29
3.3.2	Band Pass Filter Design	30
3.3.2.1	Band Pass Transformation	31
3.3.2.2	Calculation of the lumped-element	32
3.3.3	Filter Realization	33
3.3.4	RF Switch	34
3.4	Simulation Process	34
3.4.1	Lumped-element of band pass filter	34
3.4.2	Filter Realization	36
3.4.3	Filters Combination	37
3.4.3.1	Combination in Series	37
3.4.3.2	Combination in Parallel	38
3.4.3.3	Combination in Parallel (half wave transmission line)	38
3.4.3.4	Combination in Parallel (quarter wave transmission line)	39
3.4.4	RF Switch	39
3.4.5	Tunable Band Pass Filter	40
3.4.5.1	Addition of RF Switch in Lumped-element BPF prototype	40
3.4.5.2	Addition of RF Switch in Filter Realization circuit of BPF	41
3.5	Fabrication	43
3.6	Measurement	44

IV**RESULTS AND ANALYSIS**

4.1	Introduction	45
4.2	Filters Designs	46
4.2.1	Band Pass Filters Design	46
4.2.2	Filter Realization	47
4.3	Simulation	48
4.3.1	Lumped-element of band pass filter	48
4.3.2	Realization of band pass filter	50
4.3.3	Combination in Series	52
4.3.4	Combination in Parallel	53
4.3.5	Combination in Parallel (half wave transmission line)	54
4.3.6	Combination in Parallel (quarter wave transmission line)	55
4.3.7	RF Switch	56
4.4	Fabrication	58
4.5	Measurement	58
4.6	Comparison	63
4.7	Observation & Analysis	64

V**CONCLUSION AND FUTURE DEVELOPMENTS**

5.1	Conclusion	65
5.2	Future Developments	65

REFERENCE	67
------------------	-----------

APPENDIX A	69
-------------------	-----------

APPENDIX B	70
-------------------	-----------

APPENDIX C	74
-------------------	-----------

LIST OF TABLES

NO	TITLE	PAGE
3.1	Design Specification of Tunable Band Pass Filter	29
3.2	Table of Butterworth Response	30
3.3	WLAN Bandwidth of each 14 Channels	31
4.1	Values of L and C of Filters' Circuit	46
4.2	Width and Length Value of Each Filters' Channels	47
4.3	S Parameters of Filters of Channels 1, 5, 9 and 13	50
4.4	S Parameters of Band Pass Filters of Channels 1, 5, 9 and 13 for Filter Realization	52
4.5	S Parameters of Band Pass Filters of Channels 1, 5, 9 and 13 for Measurements	62
4.6	Comparison of S Parameters between Measurements and Simulation of Channel 1	63
4.7	Comparison of S Parameters between Measurements and Simulation of Channel 5	63
4.8	Comparison of S Parameters between Measurements and Simulation of Channel 9	63
4.9	Comparison of S Parameters between Measurements and Simulation of Channel 13	63

LIST OF TABLES

NO	TITLE	PAGE
3.1	Design Specification of Tunable Band Pass Filter	29
3.2	Table of Butterworth Response	30
3.3	WLAN Bandwidth of each 14 Channels	31
4.1	Values of L and C of Filters' Circuit	46
4.2	Width and Length Value of Each Filters' Channels	47
4.3	S Parameters of Filters of Channels 1, 5, 9 and 13	50
4.4	S Parameters of Band Pass Filters of Channels 1, 5, 9 and 13 for Filter Realization	52
4.5	S Parameters of Band Pass Filters of Channels 1, 5, 9 and 13 for Measurements	62
4.6	Comparison of S Parameters between Measurements and Simulation of Channel 1	63
4.7	Comparison of S Parameters between Measurements and Simulation of Channel 5	63
4.8	Comparison of S Parameters between Measurements and Simulation of Channel 9	63
4.9	Comparison of S Parameters between Measurements and Simulation of Channel 13	63

LIST OF FIGURES

NO	TITLE	PAGE
1.1	Methodology of Project	4
2.1	Band Designations and Applications of Microwaves	6
2.2	Filter Response of Band Pass Filter	9
2.3	Filter response of low pass filter	10
2.4	Filter Response of High Pass Filter	12
2.5	Filter Response of band stop filter	13
2.6	Basic Filter Diagram	13
2.7	Two Port Network Model	15
2.8	Differences of Filter Types in terms of Power Loss Ratio	17
2.9	The process of filter design by the insertion loss method	18
2.10	Layers of PIN diode	21
2.11	Simple PIN diode attenuator and switch	23
2.12	Microstrip Transmission Line Structure	25
2.13	Electric Fields in Microstrip	25
2.14	Effective Dielectric	27
3.1	Low Pass Filter Prototype	29
3.2	WLAN Bandwidth of each 14 Channels	30
3.3	Summary of Prototype Filter Transformation	32
3.4	The Kuroda Identities	33
3.5	Lumped-elements band pass filter of Channel 1	35
3.6	Lumped-elements band pass filter of Channel 5	35
3.7	Lumped-elements band pass filter of Channel 9	35
3.8	Lumped-elements band pass filter of Channel 13	36

3.9	Realization of band pass filter of Channel 1	36
3.10	Realization of band pass filter of Channel 5	36
3.11	Realization of band pass filter of Channel 9	37
3.12	Realization of band pass filter of Channel 13	37
3.13	Filters Combination in Series	38
3.14	Combination of filters in parallel	38
3.15	Combination in Parallel (with half wave transmission line)	39
3.16	Combination in Parallel (with quarter wave transmission line)	39
3.17	RF Switch	40
3.18	Addition of RF Switch in front of the circuits	41
3.19	Addition of RF Switch at the back side of the circuit	41
3.20	Addition of RF Switch in front of the filter realization circuit	42
3.21	Addition of RF Switch in the back side of the filter realization circuit	42
4.1	The band pass filter prototype beginning with a shunt element	46
4.2	Shunt Stub (Open Circuit) 3 rd Order Filter	47
4.3	S-Parameter Response of Channel 1	48
4.4	S-Parameter Response of Channel 5	48
4.5	S-Parameter Response of Channel 9	49
4.6	S-Parameter Response of Channel 13	49
4.7	S-Parameter Response of Channel 1 for Band Pass Filter Realization	50
4.8	S-Parameter Response of Channel 5 for Band Pass Filter Realization	51
4.9	S-Parameter Response of Channel 9 for Band Pass Filter Realization	51
4.10	S-Parameter Response of Channel 13 for Band Pass Filter Realization	52
4.11	S Parameters Response of Series Combination	53
4.12	Response of Combination of filters in Parallel Connection	54
4.13	Response of Combination in Parallel (with half wave transmission line)	55
4.14	Response of Combination in Parallel (with quarter wave transmission line)	56
4.15	Response of RF Switch (ON)	57
4.16	Response of RF Switch (OFF)	57
4.17	Fabricated filters of Channel 1, 5, 9 and 13	58
4.18	Data File of Channel 1 Transformed into Subcircuit	58

4.19	S Parameters Response of Measurements of Channel 1 Band Pass Filter	59
4.20	Data File of Channel 5 Transformed into Subcircuit	59
4.21	S Parameters Response of Measurements of Channel 5 Band Pass Filter	60
4.22	Data File of Channel 9 Transformed into Subcircuit	60
4.23	S Parameters Response of Measurements of Channel 9 Band Pass Filter	61
4.24	Data File of Channel 13 Transformed into Subcircuit	61
4.25	S Parameters Response of Measurements of Channel 13 Band Pass Filter	61
5.1	Power Loss Ratio According to Numbers of Order	66

LIST OF ABBREVIATIONS/ SYMBOLS

GPS	Global Positioning System
MHz	Mega Hertz
GHz	Giga Hertz
TV	Television
WLAN	Wireless Local Area Network
MMIC	Monolithic Microwave Integrated Circuits
RF	Radio Frequency
dB	Decibel
RC	Resistor-capacitor
RIAA	Recording Industry Association of America
AC	Alternate Current
PA	Public Address
DUT	Device Under Test
PIN	Positive-Intrinsic-Negative
FET	Filed Effect Transistor
EM	Electromagnetic

PN	Positive-Negative
DC	Direct Current
Ω	Ohm
IL	Insertion Loss
RL	Return Loss
Γ	Reflection Coefficient
a	Incident Wave
b	Reflected Wave
VSWR	Voltage Standing Wave Ratio
S-Parameters	Scattering Parameters
MIC	Microwave Integrated Circuit
W	Width
t	Thickness
ϵ_r	Dielectric Constant
TEM	Transverse Electro Magnetic
ϵ	Permittivity
μ	Permeability
ϵ_e	Effective Dielectric Constant

CHAPTER I

INTRODUCTION

1.1 INTRODUCTION

Nowadays, wireless communication is a technology that has been widely used anywhere and everywhere. Wireless gadget such as mobile phone, internet broadband, notebook, mobile radio, GPS, mobileTV and many more is not a new thing in electronic engineering fields. Such application helps human to have a pleasant life and improve the quality of technology gadgets.

However, the usage of wireless technology will also have the negative outcomes. Sometimes, the wireless signal might be interrupted for RF wireless communication system operating in the presence of a periodic noise environment and filter is used to overcome this problem in order to reject unwanted signal while permitting good transmission of wanted frequencies. Modern microwave technology is an exciting and dynamic field, due in large part to the advances in modern electronic device technology and the explosion in demand for voice, data and video communication capacity. Prior to this, microwave technique was the nearly exclusive domain of the defense industry. The recent and dramatic increase in demand for communication systems such as mobile

phone, satellite communications and broadcast video has transformed this field to the commercial and consumer market. As a result, the diversity of applications and operational environments has led, through the accompanying high production volumes, to tremendous advances in cost-efficient manufacturing capabilities of microwave products. This, in turn, has lowered the implementation cost of a new wireless microwave service. Inexpensive handheld GPS navigational aids, automotive collision avoidance radar and widely available broadband digital service access are among these. Microwave technology is naturally suited for these emerging applications in communications and sensing, since the high operational frequencies permit both large numbers of independent channels for uses as well as significant available bandwidth per channel for high speed communication [1].

1.2 OBJECTIVE

The main objective of this project is to design a tunable band pass filter for WLAN. This filter can be tuned to the desired frequencies of 14 channels of WLAN by using RF switch.

1.3 PROBLEM STATEMENTS

A lot of filters produced and designed at a limited frequency [2]. Some of them are designed at a fix frequency [3] [4]. Related to this situation, this tunable band pass filter is designed in order to give choice and options for users and customers to attach themselves into a tuning technology.

1.4 SCOPE OF THE PROJECT

The scopes of this project is for designing tunable band pass filter by the insertion loss method on WLAN bandwidth of 2.4GHz (IEEE 802.11b) within its 14 channels and simulate using Microwave Office (AWR). Calculation on the elements of the circuit is done based on Butterworth response. Fabrication of the circuit is done on microstrip FR4 board according to shunt stub method and the calculation of the element is referred to Kuroda's Identity.

1.5 METHODOLOGY

This project needs to be prepared from the basic information of filter theoretically and further on until the production of the band pass filter. All the related information via internet, web journal, books, articles and many more is used as guidance and possible references. All of the sources are then pointed out to supervisor and after a brief discussion; only the best materials will be selected for main references.

By referring to the related information, the tunable band pass filter will be designed considering all the calculation and simulation. Several parameters such as S parameter, center frequency, return loss, insertion loss, upper cut-off frequency and lower cut-off frequency and bandwidth are determined by using manual calculation and also simulation using suitable mathematical software such as MATLAB or Microsoft Excel and the schematic circuit can be simulated using Microwave Office software (AWR).

After all simulation can be run and debug properly without any errors using the AWR, the project can be preceded to the next part which is fabrication. Fabrication of the tunable band pass filter circuit will be done on printed circuit board using microstrip parallel-coupled method. The tunable band pass filter is then used to measure and test the functionality. The methodology of the project is summarized in following Figure 1.1.

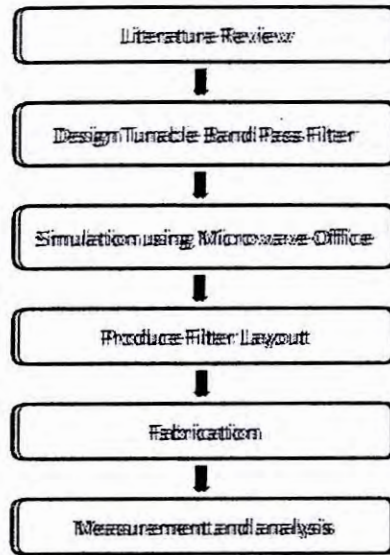


Figure 1.1: Methodology of Project

1.6 REPORT STRUCTURE

This report contains five chapters that explain detail of the project. The first chapter is the introduction of the project that included the objectives, scope, problem statement and the report structure.

The second chapter is the literature review contains the history of microwaves, microwave filter, types of microwave and types of filter response. For tuning circuit, PIN diode is reviewed and will be use, how it works through RF switch is also described in this chapter.

The third chapter is about project methodology. The working flow of this project is defined each terms of methodology from the review until the measurements process. All designs that have been analyzed throughout this project to produce a tunable band pass filter also includes in this chapter