

DESIGN OF SINGLE LAYER INTERDIGITAL BAND PASS FILTER WITH  
ELLIPTICAL RESPONSE

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*Specially dedicated to my beloved parents, sisters and  
friends for their support and encouragement.*

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## ABSTRACT

The advancement in wireless technology has witnessed the development of many different types of wireless application. Among the more popular application in the recent years are Wireless Local Area Network (WLAN) application and Bluetooth technology. Both applications operate in the microwave region. Microwave filters have become one of the most important components in the whole system. The compactness of interdigital filter makes it a very popular filter where band pass is concern. This thesis focuses on the design of single layer interdigital band pass filter with elliptical response. The chosen frequency of operation is 2.45 GHz, suitable for wireless LAN and Bluetooth applications. MathCAD mathematical software was used to compute all the relevant formulations. In addition, the optimum order of filter was computed to be 4. Investigations on the designed filter were made using the electromagnetic simulation software, Sonnet Suite. The simulated results were satisfactory where the optimum designed filter exhibits the characteristics of an elliptical response band pass filter, albeit large ripples and poor reflections within the passband region. However, improvements can be made in order to achieve a well performed elliptic response bandpass filter.

## ABSTRAK

Kemajuan teknologi tanpa wayar telah memperlihatkan perkembangan pelbagai aplikasi tanpa wayar. Antara aplikasi tanpa wayar yang sedang mendapat tempat di pasaran pada masa kini adalah teknologi Rangkaian Tempatan Tanpa Wayar (WLAN) dan *Bluetooth*. Kedua-dua aplikasi ini beroperasi pada julat gelombang mikro. Lantaran itu, penapis gelombang mikro telah menjadi satu daripada komponen paling utama dalam sesuatu sistem gelombang mikro masa kini. Saiznya yang padat telah menjadikan penapis *interdigital* antara penapis gelombang mikro lulus jalur yang paling digemari. Fokus utama tesis ini adalah untuk merekabentuk penapis gelombang mikro jenis lulus jalur yang mempamerkan ciri-ciri eliptik. Frekuensi kendalian yang dipilih ialah 2.45 GHz yang sesuai bagi kegunaan WLAN dan *Bluetooth*. Perisian matematik MathCAD digunakan untuk penghitungan semua rumus berkaitan. Tambahan pula, tertib optimum penapis bersamaan 4 telah diperolehi. Kajian terhadap penapis yang direkabentuk dibuat menggunakan perisian simulasi elektromagnet, Sonnet Suite. Hasil simulasi adalah memuaskan, dengan penapis optimum yang direkabentuk mempamerkan ciri lulus jalur sambutan eliptik, namun terdapat riak yang besar serta pantulan buruk dalam kawasan lulus jalur. Walau bagaimanapun, penambahbaikan boleh dibuat untuk memperolehi penapis lulus jalur sambutan eliptik dengan prestasi yang baik.

## TABLE OF CONTENTS

TITLE	i
DECLARATION	ii
DEDICATION	iii
ACKNOWLEDGEMENT	iv
ABSTRACT	v
ABSTRAK	vi
TABLE OF CONTENTS	vii
LIST OF TABLES	x
LIST OF FIGURES	xi
LIST OF SYMBOLS	xiv
LIST OF ABBREVIATIONS	xvi
LIST OF APPENDICES	xvii

CHAPTER	TITLE	PAGE
<b>1</b>	<b>INTRODUCTION</b>	
	1.1 Objective of Project	1
	1.2 Problem Statement	1
	1.3 Background of Project	2
	1.4 Scopes of Project	2

1.5	Organization of Thesis	4
<b>2</b>	<b>MICROWAVE FUNDAMENTALS</b>	
2.1	Introduction	5
2.2	Scattering Parameters	6
2.2.1	Introduction	6
2.2.2	Two Port Networks	7
2.3	Microwave Transmission Lines	8
2.4	Microstrip Line	10
<b>3</b>	<b>FILTER THEORY</b>	
3.1	Introduction	12
3.2	Filter Parameter Definition	15
3.3	Basic Filter Types	20
3.4	Filter Synthesis	22
3.5	Elliptic Function Response	23
3.6	Band Pass Filter	25
3.7	Interdigital Band Pass Filter	27
<b>4</b>	<b>SOFTWARES USED</b>	
4.1	MathCAD	29
4.2	Sonnet Suite v9.2	30
<b>5</b>	<b>RESULTS AND DISCUSSIONS</b>	
5.1	Symmetrical Interdigital Band Pass Filter Using MathCAD	33
5.1.1	Simulated Interdigital Band Pass Filter with Third Order (SI-3)	33
5.1.2	Simulated Interdigital Band Pass	37

	Filter with Fourth Order (SI-4)	
5.1.3	Simulated Interdigital Band Pass	41
	Filter with Fifth Order (SI-5)	
5.2	Discussions on Simulated Results	44
5.3	Improving the Fourth Order Filter	46
5.4	Summary	58
<b>6</b>	<b>FURTHER RESEARCH</b>	
6.1	Conclusions	59
6.2	Suggestions for further research	60
	REFERENCES	61
	APPENDIX	64



**LIST OF TABLES**

<b>TABLE NO.</b>	<b>TITLE</b>	<b>PAGE</b>
5.1	Prototype values for SI-3	34
5.2	Coupling coefficient	34
5.3	SI-3 filter design parameters	34
5.4	Prototype values for SI-4	37
5.5	Coupling coefficient	38
5.6	SI-4 filter design parameters	38
5.7	Prototype values for SI-5	41
5.8	Coupling coefficient	41
5.9	SI-5 filter design parameters	41
5.10	Single layer interdigital filter simulation results	45
5.11	Simulated results of filters with different air thickness	54

## LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
1.0	Configuration of an interdigital filter	3
2.1	An arbitrary N-port microwave network	7
2.2	Lumped circuit representation of a transmission line	10
2.3	Micro-strip transmission line structure	11
3.1	Basic filter structure	
	(a) General form of a filter network	13
	(b) Equivalent circuit power transfer calculations	14
3.2	Dissipative filter	15
3.3	Typical output of a filter when a single-frequency input signal is abruptly switched on at $t = 0$	19
3.4	Qualitative curves comparing a band pass filter response to pulsed and steady state signals.	20
3.5	Filter response	
	(a) The Ideal Filter	21
	(b) Non-ideal filter	21
3.6	Low pass LC Filter used for	
	(a) odd order analysis	23
	(b) even order analysis	23
3.7	Elliptic function response	24
3.8	Band pass LC filter with elliptical response	
	(a) Odd-Order	24
	(b) Even-order.	24
3.9	Several band pass prototype networks:	

	(a) capacitively coupled	26
	(b) inductively coupled	26
	(c) transformer coupled	26
	(d) impedance inverted coupled	26
3.10	Interdigital filter structure	
	(a) 3-D view	
	(b) top view	
3.11	Cross section of an array of parallel-coupled lines between ground planes.	28
4.1	Snapshot from MathCAD	30
4.2	Sonnet Suite components	32
5.1	Sonnet structure for SI-3	35
5.2	Return Loss and Insertion Loss for SI-3	35
5.3	Simulated VSWR for SI-3	36
5.4	Simulated input impedance for SI-3	36
5.5	Simulated current distribution for SI-3	37
5.6	Sonnet structure for SI-4 filter	48
5.7	Return Loss and Insertion Loss for SI-4 filter	39
5.8	Simulated VSWR for SI-4 filter	39
5.9	Simulated input impedance for SI-4 filter	40
5.10	Simulated current distribution for SI-4 filter	40
5.11	Sonnet structure for SI-5 filter	42
5.12	Return Loss and Insertion Loss for SI-5 filter	42
5.13	Simulated VSWR for SI-5 Filter	43
5.14	Simulated input impedance for SI-5 filter	43
5.15	Simulated current distribution of SI-5 filter	44
5.16	Fourth order structure with feeder length, $l$ increased (SI-4a)	46
5.17	Return loss and insertion loss for SI-4a	47
5.18	Simulated VSWR for SI – 4a	47
5.19	Simulated input impedance for SI-5 filter	48
5.20	Simulated current distribution of SI-4a filter	48
5.21	3-D view of SI-4b filter	49

5.22	Return loss and insertion loss of SI-4b filter	49
5.23	VSWR of simulated SI-4b filter	50
5.24	Input impedance of SI-4b filter	50
5.25	Simulated current distribution of SI-4b filter	51
5.26	3-D view of SI-4c filter	51
5.27	Return loss and insertion loss of SI-4c filter	52
5.28	Simulated VSWR for SI-4c filter	52
5.29	Simulated Output Impedance of SI-4c filter	53
5.30	Simulated current distribution of SI-4c filter	53
5.31	Design structure for SI – 4d	55
5.32	Return Loss and Insertion Loss for SI – 4d	56
5.33	Simulated current distribution for SI – 4d	56
5.34	Simulated VSWR for SI – 4d	57
5.35	Simulated output impedance for SI - 4d	57

## LIST OF SYMBOLS

$f_H$	-	High cut off frequency
$f_L$	-	Low cut off frequency
$f_0$	-	center frequency
$\epsilon_r$	-	dielectric constant
$IL$	-	Insertion loss
$RL$	-	Return loss
$P_i$	-	Incident power
$P_r$	-	Reflected power
$\epsilon$	-	Permittivity
$S$	-	Spacing between resonator
$W$	-	Substrate width
$h$	-	Substrate thickness
$t$	-	Conducting strip thickness
$\lambda_0$	-	Free space wave length
$\theta$	-	Electrical length
$v_p$	-	phase velocity
$E$	-	Electric fields
$L$	-	Resonator length
$l$	-	Input/output length
$c$	-	Speed of light
$Z_c$	-	Characteristic impedances
$\beta$	-	Propagation constant
$\eta$	-	Free space wave impedance
$\lambda_g$	-	Guided wavelength
$\Gamma$	-	Reflection Coefficient
$\alpha$	-	Attenuation constant
$RJ$	-	Filter rejection

$\Pi_m$	-	Midband/minimum insertion loss
$\phi_T$	-	Transmission phase (in radian)
$\tau_D$	-	Group delay
$L_m$	-	Minimum attenuation
L	-	Inductance
C	-	Capacitance

## LIST OF ABBREVIATIONS

SI	Single layer symmetrical interdigital filter
FBW	Fractional Bandwidth
IL	Insertion Loss
RL	Return Loss
RF	Radio Frequency
TEM	Transverse Electromagnetic Mode
VSWR	Voltage Standing Wave Ratio
WLAN	Wireless Local Area Network
DLP	Deviation from Linear Phase

**LIST OF APPENDICES**

<b>APPENDIX</b>	<b>TITLE</b>	<b>PAGE</b>
A	MathCAD File for designed Fifth Order Single Layer Symmetrical Interdigital Band Pass Filter	64



## **CHAPTER I**

### **INTRODUCTION**

This thesis presents the objective of the project, the problem statement, project background, the scopes of project, and the organization of the thesis.

#### **1.1 Objective of Project**

The objective of this project is to design and simulate single layer symmetrical interdigital band pass filters with elliptical response operating at 2.45 GHz using MathCAD [1] and Sonnet v 9.52 [2] softwares.

#### **1.2 Problem Statement**

The recent years had witnessed the emergence and rapid development of wireless technology. Among the popular wireless application at present are the

Wireless Local Area Network (WLAN) and the Bluetooth technology. Filter is one of the most important components in an electronic circuit. Compact filter structure is essential in a space-limited modern circuit. Microwave filters are the solutions to the compact filter structure problem. Interdigital configuration has been chosen for this project due to its compact size.

### **1.3 Background of Project**

This project is a continuation of that done by Mohd Fairus bin Mohd Yusoff [3]. The work presented the design of single and multilayer interdigital band pass filters with Chebychev response for both symmetrical and asymmetrical configurations. In this project, emphasize is given on the design of single layer symmetrical and asymmetrical interdigital band pass filters with elliptical response. It is aimed at investigating the characteristics of the response and its advantages compared to Chebychev response filters.

### **1.4 Scopes of Project**

The scopes of the project are as follows:

- (i) Literature review on basic microwave and filter theories as well as familiarization of MathCAD and Sonnet Suite softwares.
- (ii) Design of symmetrical and asymmetrical interdigital and pass filters using MathCAD.
- (iii) Simulating the designed filters with electromagnetic software, Sonnet Suite v9.52.

- (iv) Analyze the characteristics and performance of the designed filter to determine the ideal filter structure.
- (v) Analyze and compare the characteristics and performance of the optimum design structure with the results from the previous project.
- (vi) Thesis writing.

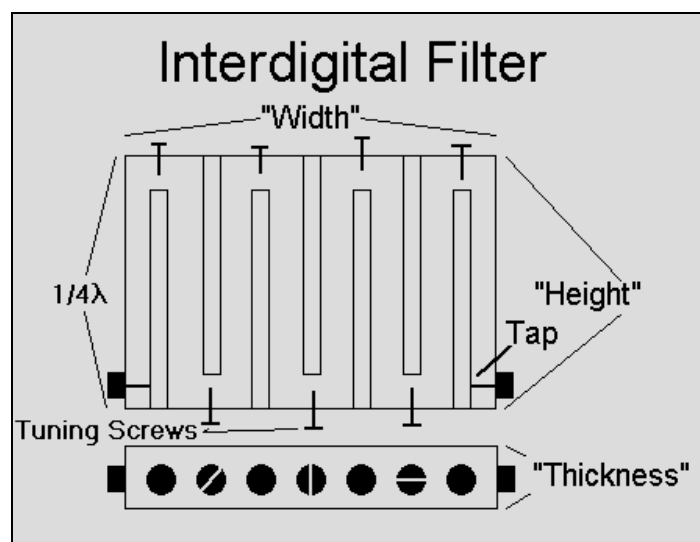
The specifications are as follows, which are similar to that of reference [3]:

- (i) Center Frequency : 2.45 GHz
- (ii) Filter Response : Elliptic
- (iii) Bandwidth : 0.3 GHz
- (iv) Pass band ripple : 0.2 dB
- (v) Stop band attenuation : 30 dB

The microwave board parameters are as follows:

- (i) Dielectric constant : 9.6
- (ii) Substrates thickness : 1.27 mm
- (iii) Metal thickness : 35 $\mu$ m

The configuration of a single layer symmetrical interdigital band pass filter is shown in Figure 1.1.



.Figure 1 : Configuration of an interdigital filter [4].

## **1.5 Organization of Thesis**

This thesis consists of six chapters. Chapter I presents the objective of the project, the problem statement, project background, the scopes of project, and lastly the organization of the thesis.

Chapter II discusses the microwave fundamentals. This includes Scattering parameters, frequency response and microwave transmission lines theory.

Chapter III discusses the filter theory. Discussion includes the various types of filters, ideal and non-ideal filters, microwave filters and filter synthesis.

Chapter IV discusses on the softwares used in the design, mainly MathCAD and Sonnet v9.52

Chapter V presents the results and discussions were made.

Chapter VI concludes the thesis and suggestions for future work were made.

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