

DESIGN OF STEP IMPEDANCE HAIRPIN RESONATOR

MOHD HAFIZAN BIN CHE HALIM

**This report is submitted in partial fulfillment of requirements for the award of
Bachelor Degree of Electronic Engineering (Telecommunication Electronic
Engineering) with honours**

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

MAY 2007



UNIVERSITI TEKNIKAL MALAYSIA MELAKA
FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

**BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II**

Tajuk Projek : DESIGN OF STEP IMPEDANCE HAIRPIN RESONATOR
Sesi Pengajian : 2006-2007

Saya MOHD HAFIZAN CHE HALIM

(HURUF BESAR)

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


(TANDATANGAN PENULIS)

Alamat Tetap: E-0-04, BLOK E KELUMPUK 9,
KUARTERS KLIA,
71800 NILAI NEGERI SEMBILAN

Disahkan oleh


ABD SHUKUR B JA'AFAR

Pensyarah

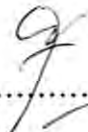
Fakulti Kej Elektronik dan Kej Komputer (FKEKK),
Universiti Teknikal Malaysia Melaka (UTeM),
(COP DAN TANDATANGAN PENYELIA)
Kampung Berkuha 1200,
Ayer Keroh, 75450 Melaka

Tarikh: 11/05/07

Tarikh: 11/05/07

DECLARATION

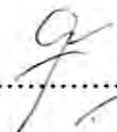
“I hereby declare that the material presented in this thesis are the result of my own work
except as cited as reference”

Signature:

Author : Mohd Hafizan Bin Che Halim

Date : 11 May 2007

“Saya akui laporan ini adalah hasil kerja saya sendiri kecuali ringkasan dan petikan yang tiap-tiap satunya telah saya jelaskan sumbernya.”

Tandatangan : 

Nama Penulis : Mohd Hafizan Bin Che Halim

Tarikh : 11 Mei 2007

“ 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 purpose of award of the Degree in Bachelor of Electronic Engineering (Telecommunication)”




ABD SHUKUR B JA'AFAR

Pensyarah

Fakulti Kej Elektronik dan Kej Komputer (FKEKK),
Universiti Teknikal Malaysia Melaka (UTeM),
Karung Berkunci 1200,
Ayer Keroh, 75450 Melaka

Signature :
Supervisor's name : Mr. Abd Shukur Bin Ja'afar
Date : 11 May 2007

“Saya akui bahawa saya telah membaca laporan ini dan pada pandangan saya laporan ini adalah memadai dari segi skop dan kualiti untuk tujuan penganugerahan Ijazah Sarjana Muda Kejuruteraan Elektronik (Elektronik Telekomunikasi) dengan kepujian.”



ABD SHUKUR B JA'AFAR

Pensyarah

Fakulti Kej Elektronik dan Kej Komputer (FKEKK),
Universiti Teknikal Malaysia Melaka (UTeM),
Karung Berkunci 1200,
Ayer Keroh, 75450 Melaka

Tandatangan

:

Nama Penyelia

: En. Abd. Shukur Bin Ja'afar

Tarikh

: 11 Mei 2007

Specially for my loving mum, dad and to all my sisters and brothers.

ACKNOWLEDGEMENT

First and foremost, I would like to give Thanks to ALLAH SWT, for helping me through all the obstacles that I encountered during the work of this project.

I would like to express my appreciation to my supervisor, Mr Abd Shukur Bin Ja'afar for his support and guidance throughout this whole project. His wisdom, insight and knowledge, the social grace with which he delivers his idea are a constant inspiration. He guided me so that I will continue to be in the correct path during the development of this draft. He provided a motivating and enthusiastic atmosphere during the many discussions we had. It was a great pleasure to do this thesis under his supervision.

I would like to thank my beloved family for their encouragement and never ending support. Their support and lovely companionship is another important source of strength for me. They spend all their time and effort on me. Without their devoted love and sacrifices, none of this would have been possible. My deepest appreciation goes to all my fellow friends for the companionship, fruitful suggestion, proof reading and wishes.

Lastly, I would like to acknowledge every individual who give me a helping hand in order to achieve this accomplishment.

ABSTRACT

This project presents the design of a six order microstrip hairpin resonator filter. The hairpin filter is one of the most popular microwave frequency filters because of it is compact and does not require grounding. The design is based on the edge parallel coupled regarding to the Chebyshev response. The initial procedure involves the development of a low pass prototype with cross couplings between non-adjacent resonators. The filter is designed at a center frequency of 2.44 GHz with a fractional bandwidth of 3.42%. This frequency is presenting for wireless LAN application and operates in the ISM (Industrial, Scientific and Medical) band which is covering from 2.4 GHz to 2.4835GHz. There are several steps to design this filter that are including by determine filter specifications, order of filter, low pass filter prototype elements, low pass to band pass transformation, physical dimension (width, spacing, length) and wavelength guide. The EM simulation of the filter design was completed on Microwave Office software and fabricated on FR4 substrate by using etching process. The explanation details for design procedure, simulated results, methods and techniques are discussed in this report.

ABSTRAK

Projek ini menampilkan rekabentuk mikro jalur penapis penyinar untuk 6 peringkat. Penapis Hairpin ini adalah salah satu diantara penapis gelombang mikro frekuensi rendah paling popular kerana bentuknya sangat padat dan tidak memerlukan penamatan bumi. Rekabentuk ini berdasarkan pada penapis sisi sepadan selari. Prosedur yang melibatkan pembinaan prototaip penapis lebar jalur dengan silangan pasangan antara tiada penyinar sebalahan. Penapis ini adalah direkabentuk pada frekuensi 2.44 GHz dengan jalur lebar 3.42%. Frekuensi jalur penapis ini adalah untuk aplikasi LAN tanpa wayar dan beroperasi dalam jalur ISM di mana ia merangkumi frekuensi dari 2.4GHz ke 2.4835GHz. Kaedah pengiraan mempunyai beberapa langkah-langkah untuk mereka bentuk filter ini, di antaranya adalah tentukan spesifikasi penapis, bilangan peringkat, penukaran lulus bawah ke lulus jalur, elemen penapis lulus bawah prototaip, dimensi fizikal (lebar, jarak dan panjang) dan panjang gelombang berpandu. EM (Elektromagnetik) simulasi pada rekabentuk adalah lengkap dengan menggunakan perisian Microwave Office dan di fabrikasi pada papan substratum FR4 dengan menggunakan proses goresan. Sebarang penerangan secara terperinci terhadap prosedur untuk proses rekabentuk, keputusan simulasi, kaedah dan teknik telah dibincangkan dalam bahagian laporan ini

TABLE OF CONTENT

CHAPTER	TITLE	PAGE
	TITLE	i
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENT	vii
	ABSTRACT	viii
	ABSTRAK	xi
	TABLE OF CONTENTS	x
	LIST OF TABLES	xiii
	LIST OF FIGURES	xv
	LIST OF APPENDICES	xix
	LIST OF TERM	xxi
CHAPTER	TITLE	PAGE
I	INTRODUCTION	
	1.1 INTRODUCTION	1
	1.2 PROBLEM STATEMENT	3
	1.3 OBJECTIVE	4
	1.4 SCOPE OF WORK	4
	1.5 METHODOLOGY	5

II**BACKGROUND STUDY**

2.1 WLAN (WIRELESS LOCAL AREA NETWORK)	7
2.2 DEFINITION OF MICROSTRIP	7
2.2.1 Overview of microstrip	8
2.2.2 The basic elements of microstrip filter.	10
2.2.3 Microstrip transmission line	12
2.2.4 Substrate materials.	15
2.2.5 Common substrate material	17
2.2.6 Microstrip Resonators:	18
2.2.7 Distributed Resonators:	19
2.2.8 Coupling of distributed resonators:	20
2.2.9 Coupling between two Microstrip Hairpin Resonators	20
2.2.10 Communication system using microstrip filter.	21
2.3 SOURCED AND LOADED TRANSMISSION LINES	23
2.4 SCATTERING PARAMETERS	25

III**THEORY**

3.1 BASIC LOW PASS FILTER	28
3.2 BAND PASS FILTER	30
3.3 BASIC OF CHEBYSHEV FILTER	32
3.4 BASIC THEORY HAIRPIN FILTER	32
3.5 INITIAL DESIGN	33
3.6 PRACTICAL TECHNIQUES	34

IV	DEVELOPMENT OF PROJECT	
	4.1 INTRODUCTION	35
	4.2 HAIRPIN BAND PASS FILTER DESIGN	36
	4.2.1 Filter Specification	37
	4.2.2 Steps in designing band pass Hairpin filter	37
	4.3 DESIGN PROCEDURE	48
	4.4 ELEMENT MICROSTRIP	52
V	RESULT, ANALYSIS AND DISCUSSION	
	5.1 SIMULATION RESULT	56
	5.1.1 Preliminary result	57
	5.1.2 The optimized result during simulation	58
	5.1.3 The effect when adjust the spaces (S)	59
	5.1.4 The effect when adjust T-Point	62
	5.1.5 The effect when adjust coupling coefficient (M)	65
	5.2 EM STRUCTURE RESULT	68
	5.3 MEASUREMENT RESULT	69
	5.4 EXPECTED FABRICATION OF HAIRPIN	73
VI	CONCLUSION, RECOMMENDATION AND FUTURE WORK	74
	REFFRENCES	77
	APPENDIXES	80

LIST OF TABLES

TABLE	DESCRIPTION	PAGES
Table 4.1	The bandpass filter specifications	36
Table 4.2	FR4 substrate's properties	36
Table 4.3	Low pass prototype element	39
Tables 4.4	Hairpin filter Parameters-calculated	41
Table 4.5	Simulated external q-factor	44
Table 4.6	Space for coupling coefficient	47
Table 4.7	The parameter of MLIN element	52
Table 4.8	The parameter of MLEF	53
Table 4.9	The parameter of MBENDA element	54
Table 4.10	The W/H parameter of MBENDA element	54
Table 4.11	The parameter of MTEE element	54
Table 5.1	List and number of elements	57

Table 5.2	Comparison between reduction and Increment space	62
Table 5.3	Comparison between reduction and Increment t-point	63
Table 5.4	Comparison between Reduction and Increase Coupling Coefficient(M)	66
Table 5.5	Comparison of S-parameters between simulation and measurement	72
Table 5.6	Comparison of physical dimension after adjustment in millimeter	77

LIST OF FIGURES

FIGURES	DESCRIPTION	PAGES
Figure 2.1	Layout microstrip	8
Figure 2.2	Microstrip over stripline	9
Figure 2.3	Graph frequency. Versus filter width	11
Figure 2.4	Rectangular Resonator Microstrips	12
Figure 2.5	Graph Z_0 versus w/h	14
Figure 2.6	Graph ϵ_{eff} versus w/h	15
Figure 2.7	Block diagram communication system using microstrip	22
Figure 2.8	Lossless transmission line with source	24
Figure 3.1	Basic Low Pass Filter and its Frequency Response (a) Low Pass Filter (b) Frequency Response	29
Figure 3.2	Frequency Response of a Band Pass Filter	31
Figure 3.3	6 th order hairpin filter where θ is the slide factor	33

and $S_{j,j+1}$ is the spacing between resonators.

Figure 3.4	Tapped hairpin resonator filter dimensions	33
Figure 4.1	Attenuation versus normalize frequency for 0.2 dB ripple low pass filter prototype	38
Figure 4.2	TX line Microstrip	42
Figure 4.3	Setup for external Q-factor	43
Figure 4.4	S11 phase plot for $t = 3.175$	44
Figure 4.5	Plot of t vs. simulated Q-factor	44
Figure 4.6	Setup for coupling coefficient	45
Figure 4.7	S21 (dB) magnitude plot for space = 0.254mm	46
Figure 4.8	Space vs simulated coupling coefficient	46
Figure 4.9	Layout schematic of the filter	47
Figure 4.10	Layout EM structure	47
Figure 4.11	TXLINE Microstrip	48
Figure 4.12	Schematic Microstrip	49
Figure 4.13	Symbol of MLIN in microstrip	51
Figure 4.14	Symbol of MLEF in microstrip	52

Figure 4.15	Symbol of MBENDA in microstrip	53
Figure 4.16	Symbol of MTEE in microstrip	54
Figure 5.1	The schematic circuit design	56
Figure 5.2	The layout after convert from schematic circuit design	56
Figure 5.3	Optimized Result with actual Space (3.1mm)	58
Figure 5.4:	Spaces parameter on the hairpin resonators	58
Figure 5.5	Increase spaces 20%	60
Figure 5.6	Reduction spaces 20%	60
Figure 5.7	Layout schematic for T-point	61
Figure 5.8	20% Reduction T-point	62
Figure 5.9	20% Increment T-point	63
Figure 5.10	Layout schematic for coupling coefficient (M)	64
Figure 5.11	Space vs. simulated coupling coefficient	66
Figure 5.12	Increment 20% coupling coefficient	67
Figure 5.13	Reduction 20% coupling coefficient	68
Figure 5.14	The layout EM structure with fixes the edge ports.	69

Figure 5.15	EM Structures Result with frequency response 2.44GHz	69
Figure 5.16	Approximate Measurement Result for Insertion and Return Loss Response	70
Figure 5.17	Approximate Measurement Result for Gain Response	71
Figure 5.18	Hairpin filter designed on the microstrip board	73
Figure 6.1	Layout of topology multiple-coupled microstrip hairpin resonator filter	76
Figure 6.2	Layout of feedline multiple-coupled microstrip hairpin resonator filter	76

LIST OF APPENDIX

NO	DESCRIPTION	PAGES
A	CALCULATION ORDER OF FILTER	81
B	CALCULATION OF LOW PASS PROTOTYPE	82
C	CALCULATION OF Q FACTOR (Q_{EL} AND Q_{EN})	83
D	CALCULATION OF COUPLING COEFFICIENT $M_{i,i+1}$ AND GUIDE WAVELENGTH (λ_G), $\lambda_{G/2}$, $\lambda_{G/4}$	84
E	GHANT CHART	85

LIST OF TERM

A	-	Worsening
BW	-	Bandwidth
f_0	-	Center Frequency
f_L	-	Lower Cut-off Frequency
f_H	-	Higher Cut-off Frequency
Z_{in}	-	Input Impedance
Z_0	-	Characteristics Impedance
R_{in}	-	Input Resistance
R_0	-	Characteristic Resistance
ϵ_r	-	Relative Dielectric Constants
ϵ_{eff}	-	Dielectric
ϵ_0	-	Wavelength
h	-	Substrate Height
t	-	Thickness
L	-	Length
w	-	Width
s	-	Space
Gaps	-	Internal Between
Lumped	-	Lumped of Earth
PCB	-	Printer Board Circuit

CHAPTER I

INTRODUCTION

1.1 Introduction

The hairpin resonator filter is one of the most popular microstrip filter configurations used in the lower microwave frequencies. It is easy to manufacture because it has open-circuited ends that require no grounding [1]. Step impedance hairpin resonator that proposed filter designed for 2.442 GHz operating frequency which is suitable for ISM (Industry, Scientific and Medical) band application with 0.0835 GHz operating bandwidth [2]. Actually the hairpin resonator has get an intention and interest of many researcher and scientist to discover and develop this hairpin resonator because of its unique characteristics and widely used in telecommunication systems for filtering out unwanted frequencies [3]. To appreciate the concepts behind the hairpin filter, it would be helpful to have a background about the edge-coupled filter. A detailed procedure of the design of the edge-coupled filter can be found in [10].

The hairpin filter configuration is derived from the edge-coupled filter. To improve the aspect ratio, the resonators are folded into a “U” shape [2]. To design smaller resonator size, higher frequency is used as initial design references. Consequently, a resonator that resonates at lower frequency but with overall size of shorter than its half-wavelength can be achieved. [7] The basic design of this filter is using gaps to couple the 50 ohms half wavelength resonator together.[10] The coupling from one resonator to the other is through the gap between the two adjacent open ends, and hence is capacitive.[9]

In this project, a six pole microstrip hairpin filter for wireless LAN application is presented. WLAN operates in the ISM frequency band covering 2.4 GHz to 2.4835 GHz. The design specifications of the filter include a pass band ripple of 0.2 dB and a minimum attenuation of -25dB at 2.5 GHz. The minimum attenuation of -25dB at 2.5 GHz is chosen to prevent interference from Broadband Radio Service (BRS). BRS operates in the frequency range 2.5 GHz to 2.69 GHz.

The hairpin resonator filter is one of the most popular microstrip filter configurations used in the lower microwave frequencies. It is easy to manufacture because it has open-circuited ends that require no grounding. Its form is derived from the edge-coupled resonator filter by folding back the ends of the resonators into a “U” shape. This reduces the length and improves the aspect ratio of the microstrip significantly as compared to that of the edge-coupled configuration. The most popular microstrip filter in low microwave frequencies is the hairpin resonator filter. It does not require a large real estate as the edge-coupled filter. It also does not require critical grounding thus making manufacturing easier. There is however, very little literature that discusses the design of this filter. Microstrip filters play an important role in many RF applications. As technologies advances, more stringent requirements for filters are required. One of the requirements is compactness of filters.

1.2) Problem Statements

The problem nowadays are conventional filters are the physical size problems. To overcome these problem is designed the hairpin filters that are better performance and will be compact filter when have size reduction before previous filter

The second design problem is then reduced to a two stage process. First, circuit element values are found that yield the desired response. Second, dimensions are determined for the physical realization. If the resulting structure is not practical, new circuit values are obtained by redesign or by equivalent circuit transformations. The convenient feature of the above process is that the circuit design and realization problems are not a constrained type of problem and can be carried out essentially independent of each other. In effect, each element in the equivalent circuit is related to a specific part of the physical structure. The physical dimensions obtained for a given circuit design may not be desirable or practical, but in general they are uniquely determined by the above design process.

The third problem is several possible ways to approach the design problem. The experimental design approach based on measured coupling coefficients completely eliminates any consideration of complex equivalent circuits, dispersion, mode velocities, and parasitic elements, a wide variety of resonator structures can be accommodated with excellent results. Two negative aspects of this approach area dependence on the quality and expediency of the experimental measurements and the difficulty of predicting stop band selectivity spurious responses. In addition, each new frequency range and resonator construction may require additional experimental models and measurements.