

**MICROWAVE PLANAR BANDPASS FILTER WITH
IMPROVED UPPER STOPBAND**

MOHD SHAHAR BIN ABDULLAH

UNIVERSITI TEKNOLOGI MALAYSIA

MICROWAVE PLANAR BANDPASS FILTER WITH
IMPROVED UPPER STOPBAND

MOHD SHAHAR BIN ABDULLAH

A project report submitted in partial fulfilment of the
requirement for the award of the degree of
Master of Engineering (Electrical – Electronics and Telecommunications)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

JUNE 2013

*To my beloved late Mak and Ayah, my family and my wife - idayati
for your love and support*

ACKNOWLEDGEMENT

In the name of ALLAH, the Compassionate, the Merciful, Praise be to ALLAH, Lord of the Universe, and Peace and Prayers be upon His Final Prophet and Messenger. This project dissertation is finally completed with help from numerous individuals. Therefore, first and foremost, I would like to take this opportunity to express my sincere gratitude and appreciation to my supervisor, Professor Dr. Mazlina binti Haji Esa for her invaluable guidance, suggestions and full support in all aspects during my research.

I would also like to express my appreciation to my colleagues for their endless support and to all the staff of Perpustakaan Sultanah Zanariah UTM International Campus Kuala Lumpur for their assistance in getting relevant information. I know that it is not possible to list all of them who have contributed assistance and encouragement to my work. Nevertheless, thank you very much.

Not forgetting, my fellow postgraduate students, my superior Hon. Datuk Dr Adham Baba, Mr. Shipun Anuar Hamzah, and Mr Aminuddin Adam. In addition, sincere gratitude goes to my staffs Mr. Nek Abdullah Nek Man, Mr. Faizal Alek and Mr. Mohd Hanif Abdul Rahim who have provided their valuable time and effort and also made some wonderful suggestions on various occasions so that the dissertation is a success.

Finally, I would like to express my gratitude especially to my wife and my family for their moral support, encouragement, loving and sacrifices made especially during holiday and weekends while working on my project and attending classes.

Thank you.

ABSTRACT

Ultra wide-band (UWB) is gained by achieving microwaves bandwidth with equal or more than 500 MHz values. Recent studies focus more on the application of this UWB to fulfill user demand especially in telecommunications nowadays who's concerned about size of tools and the amount of energy usage. These aspects must put into consideration when purchasing tools for various activities in the field. The use of this ultra-high bandwidth could easily expose to harmonic existence at high frequency which could lead to degradation of systems performance. Thus this project would emphasis on the effort of designing and improving existing microwave bandpass filter based on previous works that could overcome the issue in its first harmonic. Technique chooses include a various flaws form at the back of microstrip planar. All filters have been simulated and the results have been reviewed. In conclusion, frequency at the first harmonic can be reduced in order to improve interference dismissal at high frequency.

ABSTRAK

Lebar jalur ultra (UWB) kian terkenal disebabkan kejayaan memperoleh sekurang-kurangnya 500 MHz lebarjalur. Penyelidikan hari ini banyak tertumpu kepada aplikasi UWB ini kerana ia memenuhi kehendak pengguna terutamanya dalam bidang telekomunikasi yang mementingkan saiz perkakasan dan jumlah penggunaan tenaga. Aspek ini perlu diberi pertimbangan wajar apabila merancang pembelian peralatan untuk pelbagai kegunaan terutamanya aktiviti di lapangan. Penggunaan aplikasi UWB mudah terdedah kepada kewujudan harmonik frekuensi tinggi yang akan menyebabkan kemerosotan prestasi sesebuah perkakasan. Oleh itu, projek ini memberikan tumpuan kepada usaha merekabentuk dan menambahbaik penapis mikrojalur yang sedia ada berdasarkan kerja terdahulu yang berupaya mengatasi masalah tersebut terutama pada harmonik pertama. Teknik yang dipilih melibatkan pelbagai bentuk kecacatan pada bahagian belakang penapis satah mikrojalur. Kesemua penapis telah berjaya direkabentuk, disimulasi dan dianalisis. Kesimpulannya, harmonik tak dikehendaki pertama dapat dihapuskan untuk penambahbaikan kepada penyingkiran hingar pada frekuensi tinggi.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENT	iv
	ABSTRACT	v
	ABSTRAK	vi
	TABLE OF CONTENTS	vii
	LIST OF TABLES	xii
	LIST OF FIGURES	xiv
	LIST OF ABBREVIATIONS	xxv
	LIST OF APPENDICES	xxvii
1	INTRODUCTION	
	1.1 Project Background	1
	1.2 Problem Statement	5
	1.3 Objectives	6
	1.4 Scope of Project	6
	1.5 Thesis Layout	7
2	BRIEF THEORY AND LITERATURE REVIEW	
	2.1 Microwave Filters	8
	2.2 Filter Characteristic	11

2.2.1	Reflection Coefficient (Γ)	12
2.2.2	Return Loss (RL)	12
2.2.3	Insertion Loss (IL)	13
2.2.4	Voltage Standing Wave Ratio (VSWR)	13
2.2.5	Passband	14
2.2.6	Stopband	14
2.2.7	Cut-off frequency	15
2.2.8	Center frequency	15
2.2.9	Group delay	15
2.3	Related Research Work	18
2.3.1	Design of a Compact UWB Bandpass Filter with Notched Band	18
2.3.2	A Compact UWB Bandpass Filter with Improved Upper-Stopband Performance	19
2.3.3	A Compact UWB Bandpass Filter with Improved Out-of-Band performance using Modified Coupling Structure	21
2.3.4	Ultra-Wideband Bandpass Filter with Improved Upper Stopband Performance Using Defected Ground Structure	23
2.3.5	Ultra-Wideband Bandpass Filter with Dual Notched Bands Using Hybrid Microstrip/CPW Structure	26

3	DESIGN METHODOLOGY	
3.1	Introduction	28
3.2	Design Specification	29
3.3	Design of Ultra Wide-band Bandpass Filter	30
3.3.1	Chosen Configuration	30
3.3.2	Even-mode and Odd-mode Characteristic Impedance	31
3.3.3	Approximate Synthesis Technique	34
3.3.4	Length of Coupled Microstrip Lines	36
3.3.5	Width and Length for the Input and Output Sections	38
3.4	Design of Defected Ground Structure (DGS)	39
3.5	Chosen Configuration of DFG	43
3.5.1	Rectangular DFG, RD	43
3.5.2	Square DFG, SD	44
3.5.3	Dumbbell DFG, DD	45
3.5.3.1	Movement Gap of DD	46
3.5.3.2	Length of DD	46
3.5.4	Open Close Loop DFG, OCLD	47
3.6	Simulation Settings	48
4	RESULTS AND DISCUSSION	
4.1	Geometries of Filter Designed using Roger's Board	50
4.2	Chosen Filter, CF	52

4.2.1	UWB BPF without Defected, ND	52
4.2.2	RD ($W_4 = 2.0$)	54
4.2.3	RD ($W_4 = 3.0$)	56
4.2.4	RD ($W_4 = 3.5$)	58
4.2.5	RD ($W_4 = 4.0$)	60
4.2.6	Overall Discussion of RD	62
4.3	Configuration of SD	65
4.3.1	SD (2.0 mm)	65
4.3.2	SD (3.0 mm)	67
4.3.3	SD (4.0 mm)	68
4.3.4	SD (5.0 mm)	70
4.3.5	SD (6.9 mm)	72
4.3.6	Overall Discussion of SD	74
4.4	Configuration of DD	76
4.4.1	DD with different Number of Dumbbell	77
4.4.1.1	DD (1 unit)	77
4.4.1.2	DD (2 unit)	79
4.4.1.3	DD (3 unit)	81
4.4.1.4	Overall Discussion of DD in Different Number of Dumbbell	83
4.4.2	DD with Different Movement of Dumbbell	85
4.4.2.1	DD (Left: 1.0 mm)	86
4.4.2.2	DD (Left: 0.5 mm)	88
4.4.2.3	DD (Right: 1.0 mm)	89
4.4.2.4	DD (Right: 0.5 mm)	91
4.4.2.5	Overall Discussion of DD in Different Movement of Dumbbell	93

4.4.3	DD with different Length of Dumbbell	96
4.4.3.1	DD (wdb=1.0 mm)	96
4.4.3.2	DD (wdb=2.0 mm)	98
4.4.3.3	Overall Discussion of DD with Different length of Dumbbell	100
4.5	Configuration of N, R, S and D with OCLD	102
4.5.1	N with OCLD, N-OCLD	102
4.5.2	R with OCLD, R-OCLD	104
4.5.3	S with OCLD, S-OCLD	105
4.5.4	D with OCLD, D-OCLD	107
4.5.4.1	D (1 unit) with OCLD, D-OCLD (1 unit)	108
4.5.4.2	D (Left: 0.5) with OCLD, D-OCLD (Left: 0.5)	109
4.5.4.3	D (1.0 mm) with O CLD, D-OCLD (1.0 mm)	111
4.5.5	Overall Discussion of N, R, S, D with OCLD	113
5	CONCLUSION	
5.1	Conclusion	117
5.2	Recommendation of Future Work	117
	REFERENCES	119
	APPENDIX A – B	122-131

LIST OF TABLES

TABLE NO.	TITLE	PAGE
2.1	Electrical and thermal parameters of several PCB dielectric Materials	17
2.2	Dielectric properties of MPC substrate materials	17
3.1	Bandpass filter specification	29
3.2	Microwave board characteristics	29
3.3	Dimension of DD based on dimension of the proposed UWB BPF	45
4.1	Geometries of CF	50
4.2	Geometries of RD	51
4.3	Geometries of SD	51
4.4	Geometries of DD	51
4.5	Geometries of Movement Gap of DD	51
4.6	Geometries of Length of DD	52
4.7	Simulation Results of RD	64
4.8	Simulation Results of SD	76
4.9	Simulation Results of DD with Different Numbers of Dumbbell	85
4.10	Simulation Results of DD in Different Movement of Dumbbell	95

4.11	Simulation Results of DD in Different Length of Dumbbell	101
4.12	Simulation Results of N-OCLD	114
4.13	Simulation Results of R-OCLD	115
4.14	Simulation Results of S-OCLD	115
4.15	Simulation Results of D-OCLD	116

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
1.1	Type of transmission lines (a) Waveguide (b) Planar (microstrip)(c) Coaxial line (d) Two-wire lines	1
1.2	The diagram of coupled lines (a) Coupled microstrip or three-wire coupled (b) Equivalent circuit network	2
1.3	The modes of propagation (a) Even mode (b) Odd mode	3
1.4	Circuit Diagram for a Bandpass Filter	3
1.5	Frequency responses of a Bandpass filter	4
1.6	The diagram of UWB Technology	4
2.1	The standard configuration of a two port	9
2.2	Amplitude response of different filter types	9
2.3	Frequency scaling for low-pass filters and transformation to a high-pass response. (a) Low-pass filter prototype response. (b) Frequency scaling for low-pass response. (c) Transformation to high-pass response	11
2.4	(a) and (b) Frequency response of filter characteristic	14
2.5	Frequency response group delay (ns) versus Gain (dB)	15
2.6	Type of filter responses	16

2.7	(a). The propose configuration of UWB BPF with notchedband. (b). Simulated response of the proposed notched structure with varied coupling gaps (d). (c). Simulated and measured response of the proposed UWB BPF with notched band	19
2.8	(a). Schematics of the proposed UWB BPF on microstrip line topology. (b). Frequency-dependent frequency responses of aperture-backed interdigital parallel-coupled lines. (c). Frequency-dependent responses of the interdigital coupled-lines and stub-loaded FSIR with backside-apertures under weak coupling. (d). Simulated and measured frequency responses of the optimized UWB BPF in (a)	21
2.9	(a). Configuration of the proposed UWB BPF. (b). Frequency responses of the traditional parallel-coupled lines and the modified coupling structure. (c). Simulated and measured results of the proposed UWB BPF	22
2.10	Geometry of the CDSIR and the OLDGS: (a) CDSIR (b) OLDGS. (c). Simulated S-parameters of the CSIR without OLDGS. (d) Simulated S-parameters of the CDSIR with the OLDGS for various loop length	23
2.11	Geometry of LPF. (a). Top view. (b). Bottom view. (c). Simulated S-parameters of the LPF for various DGS numbers	24

2.12	Geometry of the proposed UWB BPF. (a). Top view. (b). Bottom view (c). Measured and simulated S-parameters of the proposed UWB BPF	25
2.13	Proposed UWB bandpass filter with dual notched bands. (a) Top view. (b) Back view. (c). Notch I (d) Notch II (e). Simulated frequency responses of the proposed UWB BPF S ₁₁ - and S ₂₁ - magnitudes.	27
3.1	(a) Configuration of the proposed UWB BPF. (b) Odd-mode equivalent circuit of the SISLR. (c) Even-mode equivalent circuit of the SISLR	31
3.2	The equivalent capacitance network. (a) Even-mode excitation. (b) Odd-mode excitation.	31
3.3	Normalized even- and odd-mode characteristic impedance design data for edge-coupled strip lines	33
3.4	Normalized ratios of the first and second even-mode resonant frequencies to the fundamental odd-mode frequency (f_1/f_0 , f_2/f_0) under different admittance ratios k and stub length θ_3	34
3.5	Various DGSs: (a) spiral head, (b) arrowhead-slot, (c) “H”shape slots, (d) a square open-loop with a slot in middle section, (e) open-loop dumbbell and (f) inter-digital DGS	40
3.6	(a) Dumbbell DGS unit. (b) Simulated S-Parameter for dumbbell DGS unit.	40
3.7	Conventional design and analysis method of dumbbell DGS	41

3.8	The equivalent circuit: (a) LC equivalent circuit of the Dumbbell DGS circuit. (b) RLC equivalent circuit for unit DGS	42
3.9	The proposed of RD	... 44
3.10	The proposed of SD	44
3.11	The proposed of DD	45
3.12	The proposed movement gap of DD with left and right side	46
3.13	The proposed length of DD	47
3.14	The proposed of OCLD	47
3.15	Simulated response S11 and S21 of DD (3 unit). (a) The Correct Response. (b) The Wrong Response	48
3.16	Simulated response S11 and S21 of the DD ($w_{db}=2.0$). (a) The Correct Response.(b) The Wrong Response	49
4.1	Configuration of ND (a).top view. (b). bottom view. All in mm	53
4.2	Current Distribution of ND (a). top view. (b). bottom view	53
4.3	Simulated response (a) Magnitude of S11 and S21 of the chosen ND. (b) VSWR1	54
4.4	Configuration of RD ($W4 = 2.0$) (a).top view. (b). bottom view. All in mm	55
4.5	Current Distribution of RD ($W4 = 2.0$) (a).top view. (b).bottom view	55

4.6	Simulated response (a) Magnitude of S11 and S21 of RD ($W_4 = 2.0$). (b) VSWR1	56
4.7	Configuration of RD ($W_4 = 3.0$) (a).top view. (b). bottom view. All in mm	57
4.8	Current Distribution of RD ($W_4 = 3.0$) (a). top view. (b). bottom view	57
4.9	Simulated response (a) Magnitude of S11 and S21 of RD ($W_4 = 3.0$) (b) VSWR1	58
4.10	Configuration of RD ($W_4 = 3.5$)(a).top view. (b). bottom view. All in mm	59
4.11	Current Distribution of RD ($W_4 = 3.5$) (a). Top view (b). bottom view	59
4.12	Simulated response (a) Magnitude of S11 and S21 of RD ($W_4 = 3.5$) (b) VSWR1	60
4.13	Configuration of UWB BPF with RD ($W_4 = 4.0$) (a).top view. (b). bottom view. All in mm	61
4.14	Current Distribution of UWB BPF with RD ($W_4 = 4.0$) (a).top view. (b). bottom view	61
4.15	Simulated response (a) Magnitude of S11 and S21 of RD ($W_4 = 4.0$) (b) VSWR1	62
4.16	Simulated response. (a) Magnitude of S11 RD with vary size of W_4 (b) Magnitude of S21 RD with vary size of W_4	63
4.17	Simulated response of RD with vary size of W_4	64

4.18	Configuration of SD (2.0) (a).top view. (b). bottom view. All in mm	66
4.19	Current Distribution of SD (2.0)(a).top view. (b). bottom view	66
4.20	Simulated response (a) Magnitude of S11 and S21 of SD (2.0) (b) VSWR1	66
4.21	Configuration of UWB BPF with SD (3.0) (a).top views. (b). bottom view. All in mm	67
4.22	Current Distribution of UWB BPF with SD (3.0) (a).top view. (b). bottom view	68
4.23	Simulated response (a) Magnitude of S11 and S21 of SD (3.0) (b) VSWR1	68
4.24	Configuration of SD (4.0) (a).top view. (b). bottom view. All in mm	69
4.25	Current Distribution of SD (4.0) (a).top view. (b). bottom view	69
4.26	Simulated response (a) Magnitude of S11 and S21 of SD (4.0) (b) VSWR1	70
4.27	Configuration of SD (5.0) (a).top view. (b). bottom view. All in mm	71
4.28	Current Distribution of SD (5.0)(a).top view. (b). bottom view	71
4.29	Simulated response (a) Magnitude of S11 and S21 of SD (5.0) (b) VSWR1	72

4.30	Configuration of SD (6.9)(a).top view. (b). bottom view. All in mm	73
4.31	Current Distribution of SD (6.9)(a).top view. (b). bottom view	73
4.32	Simulated response (a) Magnitude of S_{11} and S_{21} of UWB BPF with Square DFG (6.9) (b) VSWR1	74
4.33	Simulated response. (a) Magnitude of S_{11} SD with vary size of W_4 and L_4 (b) Magnitude of S_{21} SD with vary size of W_4 and L_4	75
4.34	Simulated response of VSWR1 SD with vary size of W_4 and L_4	75
4.35	Configuration of DD (1 unit)(a).top view. (b). bottom view. All in mm	78
4.36	Current Distribution of DD (1 unit)(a).top view. (b). bottom view	78
4.37	Simulated response (a) Magnitude of S_{11} and S_{21} of DD (1 unit) (b) VSWR1	79
4.38	Configuration DD (2 unit)(a).top view. (b). bottom view. All in mm	80
4.39	Current Distribution of DD (2 unit)(a).top view. (b). bottom view	80
4.40	Simulated response (a) Magnitude of S_{11} and S_{21} of DD (2 unit) (b) VSWR1	81
4.41	Configuration of DD (3 unit)(a).top view. (b). bottom view. All in mm	82

4.42	Current Distribution of DD (3 unit) (a).top view. (b). bottom view	82
4.43	Simulated response (a) Magnitude of S_{11} and S_{21} of DD (3 unit) (b) VSWR1	83
4.44	Simulated response Magnitude of S_{11} and S_{21} DD with 1, 2 and 3 units of Dumbbell	84
4.45	Simulated response of <i>VSWR1</i> DD with 1, 2 and 3 units of Dumbbell	84
4.46	Configuration of DD (Left:1.0)(a).top view. (b). bottom view. All in mm	87
4.47	Current Distribution of DD (Left:1.0) (a).top view. (b). bottom view	87
4.48	Simulated response (a) Magnitude of S_{11} and S_{21} of DD (Left:1.0) (b) VSWR1	87
4.49	Configuration of DD (Left:0.5) (a).top view. (b). bottom view. All in mm	88
4.50	Current Distribution of DD(Left:0.5) (a).top view. (b). bottom view	89
4.51	Simulated response (a) Magnitude of S_{11} and S_{21} of DD (Left: 0.5) (b) VSWR1	89
4.52	Configuration of DD (Right:1.0)(a).top view. (b). bottom view. All in mm	90
4.53	Current Distribution of DD (Right:1.0) (a).top view. (b). bottom view	91

4.54	Simulated response (a) Magnitude of S_{11} and S_{21} of DD (Right:1.0) (b) VSWR1	91
4.55	Configuration of DD (Right:0.5)(a).top view. (b). bottom view. All in mm	92
4.56	Current Distribution of DD (Right:0.5) (a).top view. (b). bottom view	93
4.57	Simulated response (a) Magnitude of S_{11} and S_{21} of DD (Right:0.5) (b) VSWR1	93
4.58	Simulated response Magnitude of S_{11} and S_{21} DD in Different Movement of Dumbbell	94
4.59	Simulated response of VSWR1 DD in Different Movement of Dumbbell	95
4.60	Configuration of DD ($w_{db}=1.0$). (a).top view. (b). bottom view. All in mm	97
4.61	Current Distribution of DD ($w_{db}=1.0$). (a).top view. (b). bottom view	97
4.62	Simulated response (a) Magnitude of S_{11} and S_{21} of DD ($w_{db}=1.0$). (b) VSWR1	97
4.63	Configuration of DD ($w_{db}=2.0$) (a).top view. (b). bottom view. All in mm	98
4.64	Current Distribution of DD. (a).top view. (b). bottom view	99
4.65	Simulated response (a) Magnitude of S_{11} and S_{21} of DD ($w_{db}=2.0$) (b) VSWR1	99
4.66	Simulated response Magnitude of S_{11} and S_{21} DD with different length of Dumbbell	100

4.67	Simulated response of <i>VSWR</i> DD with different length of Dumbbell	101
4.68	Configuration of N-OCLD. (a).top view. (b). bottom view. All in mm	103
4.69	Current Distribution of N-OCLD.(a).top view. (b). bottom view	103
4.70	Simulated response (a) Magnitude of S_{11} and S_{21} of N-OCLD. (b) <i>VSWR</i> 1	103
4.71	Configuration of R-OCLD. (a).top view (b). bottom view. All in mm	104
4.72	Current Distribution of R-OCLD.(a).top view. (b). bottom view	105
4.73	Simulated response (a) Magnitude of S_{11} and S_{21} of S-OCLD (b) <i>VSWR</i> 1	105
4.74	Configuration of S-OCLD (a).top view. (b). bottom view. All in mm	106
4.75	Current Distribution of S-OCLD.(a).top view (b). bottom view	107
4.76	Simulated response (a) Magnitude of S_{11} and S_{21} of S-OCLD. (b) <i>VSWR</i> 1	107
4.77	Configuration of D-OCLD (1 unit). (a).top view. (b). bottom view. All in mm	108
4.78	Current Distribution of D-OCLD (1 unit). (a).top view. (b). bottom view	109

4.79	Simulated response (a) Magnitude of S_{11} and S_{21} of D-OCLD (1 unit). (b) VSWR1	109
4.80	Configuration of D-OCLD (Left:0.5). (a).top view. (b). bottom view. All in mm	110
4.81	Current Distribution of D-OCLD (Left:0.5). (a).top view. (b). bottom view	111
4.82	Simulated response (a) Magnitude of S_{11} and S_{21} of D-OCLD (Left:0.5). (b) VSWR1	111
4.83	Configuration of D-OCLD (1.0 mm). (a).top view. (b). bottom view. All in mm	112
4.84	Current Distribution of D-OCLD (1.0 mm). (a).top view. (b). bottom view	113
4.85	Simulated response (a) Magnitude of S_{11} and S_{21} of D-OCLD (1.0 mm). (b) VSWR1	113

LIST OF ABBREVIATIONS

BW	-	Bandwidth
RL	-	Return Loss
IL	-	Insertion Loss
SWR	-	Standing Wave Ratio
VSWR	-	Voltage Standing Wave Ratio
VSWR1	-	Voltage Standing Wave Ratio in Port 1
UWB	-	Ultra Wide Band
CPW	-	Couple Planar Waveguide
BPF	-	Band Pass Filter
LPF	-	Low Pass Filter
HPF	-	High Pass Filter
DFG	-	Defected Ground Structure
ND	-	No Defected Ground Structure
RD	-	Rectangular Defected Ground Structure
SD	-	Square Defected Ground Structure
DD	-	Dumbbell Defected Ground Structure
OCLD	-	Open Close Loop Defected Ground Structure
N-OCLD	-	Open Close Loop No Defected Ground Structure
R-OLCD	-	Open Close Loop Rectangular Defected Ground Structure
S-OCLD	-	Open Close Loop Square Defected Ground Structure

D-OCLD	-	Open Close Loop Dumbbell Defected Ground Structure
PCB	-	Printed Circuit Board
MPC	-	Microstrip Planar Circuit
CDSIR	-	Coupled Double Step Impedance Resonator
OLDGS	-	Open Loop Defected Structure
SISLR	-	Stepped Impedance Stub Load Resonator
FCC	-	Federal Communication Commission
MMR	-	Multi Modes Resonator
PI-SIRs	-	Pseudo-Interdigital Stepped Impedance Resonator
CDGS	-	Conventional Defected Structure
CSIR	-	Conventional Stepped Impedance Resonator
IMPED	-	Impedance
Max	-	Maximum
Min	-	Minimum

LIST OF SYMBOLS

Γ	-	Reflection Coefficient
S_{11}	-	S-Parameter at Port 1
S_{21}	-	S-Parameter at Port 2 to 1
C_{11}	-	Effective Capacitance at Port 1
C_{22}	-	Effective Capacitance at Port 2
f_L	-	Lower Cut-Off Frequency
f_H	-	High Cut-Off Frequency
f_o	-	Resonant Frequency
P_L	-	Power Load
P_{in}	-	Power Input
V_{max}	-	Voltage Maximum
V_{min}	-	Voltage Minimum
Z_0	-	Characteristic Impedance
Z_{0o}	-	Odd-mode Characteristic Impedance
Z_{0e}	-	Even-mode Characteristic Impedance
$Y_{in,ood}$	-	Odd-mode Characteristic admittance
$Y_{in,even}$	-	Even-mode Characteristic admittance
c_o	-	Odd-mode Resulting Capacitance
c_e	-	Even-mode Resulting Capacitance
λ_{gm}	-	Guided wavelength
eff_e	-	Even-mode Dielectric Constant
eff_o	-	Odd-mode Dielectric Constant

ε_e	-	Effective Dielectric Constant
ε_r	-	Dielectric Constant
Ω	-	Ohm
Δ	-	Fractional
ns	-	Nanosecond
dB	-	Decibel

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Gantt Chart for RP1 and RP2	122
B	RO4000 Series Datasheet	124

CHAPTER 1

INTRODUCTION

1.1 Project Background

Basically, the delivery of power in an electronic system needs a connection of two wires between the source and the load. At low frequencies, power is considered being delivered to the load through wire. However, power is in electric and magnetic fields at high frequencies which is electromagnetic wave guided from place to place by a physical structure known as Transmission Line. There are several types of transmission lines available such as Two-Wire Lines, Coaxial Line, Waveguide (Rectangular, Circular) and Planar Transmission Lines as shown in Figure 1.1. The most popular is microstrip as found in the planar transmission because it is easy to design and fabricate [1].

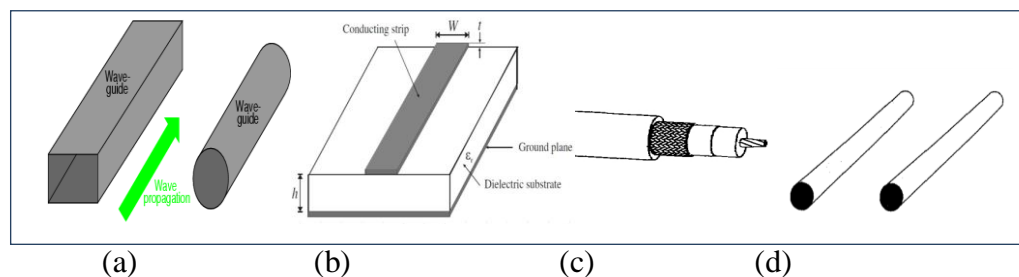


Figure 1.1: Types of transmission lines (a) Waveguide (b) Planar (microstrip) (c) Coaxial line (d) Two-wire lines [2]

A ‘coupled line’ configuration consists of two transmission lines placed parallel to each other and in close proximity as shown in Figure 1.2(a). The electrical characteristic can be completely determined from the effective capacitances between the lines and velocity of propagation on the line in the transverse electromagnetic (TEM) propagation [1]. The equivalent circuit element of Figure 1.2(b), C_{12} represents the capacitance between the two strip conductors, while C_{11} and C_{22} represent the capacitance between one strip conductor and ground. C_{11} and C_{22} are equal when the sizes of strip conductors are identical and location relative to the ground conductor [3].

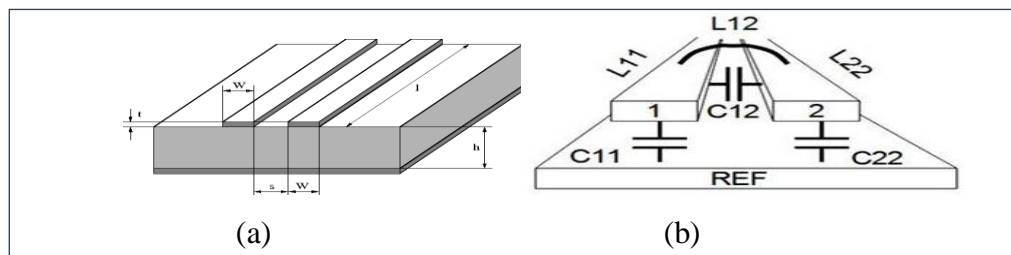


Figure 1.2: The diagram of coupled lines (a) Coupled microstrip or three-wire coupled (b) Equivalent circuit network [2]

In a coupled microstrip line, even and odd modes are two different modes of propagation excited due to coupling of electromagnetic field as shown in Figure 1.3(a) and (b). The currents in the strip conductors are equal in amplitude for both modes. Even and odd modes are differentiated by direction only where same direction in even and opposite direction in odd [1].

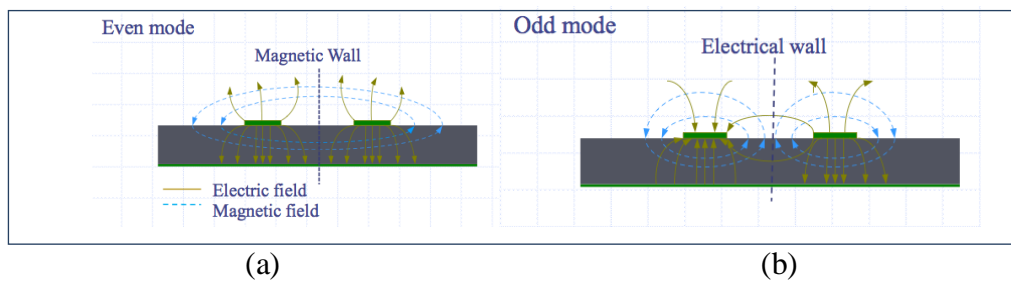


Figure 1.3: The modes of propagation (a) Even mode (b) Odd mode [4]

A bandpass filter is a combination of high and low pass filters with specific frequency range to pass, but not permitted to pass the lower and higher frequencies. The frequencies are attenuated at the edge of outside the passband region due to two cut-off frequencies f_L and f_H .

High Pass RL filter with a roll-off frequency f_L and a Low Pass RC filter with a roll-off frequency f_H is cascaded to realize a bandpass frequency response, with that f_L less than f_H .

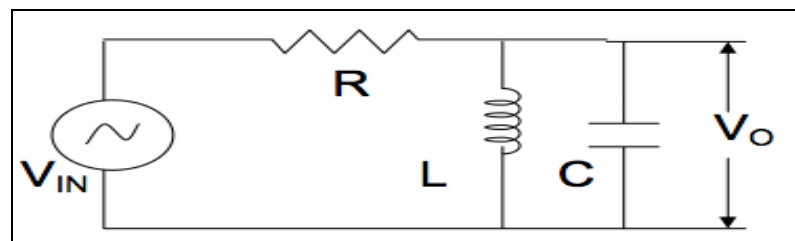


Figure 1.4: Circuit Diagram for a Bandpass Filter [2].

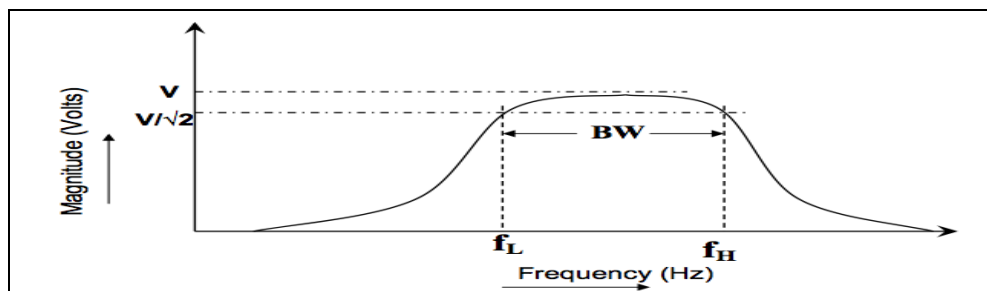


Figure 1.5: Frequency response of a Bandpass filter [2].

Ultra wide-band (UWB) is gained by achieving microwave bandwidth with equal or more than 500 MHz values. Federal Communication Commission (FCC) has allocated for unlicensed ultra wideband devices with frequency band 3.1-10.6 GHz about 7500 MHz of spectrum frequency. The UWB technology has huge opportunity in the design of modern application such as vehicular radar, through-wall imaging, medical imaging, indoor and hand-held systems [5].

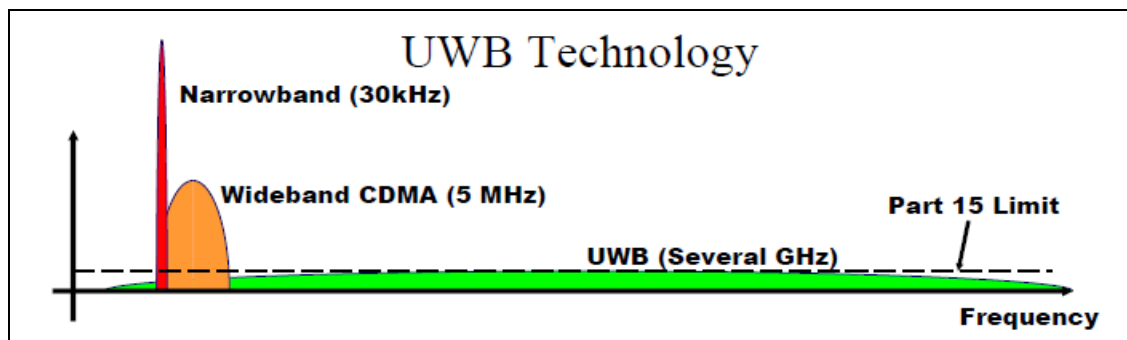


Figure 1.6: The diagram of UWB Technology [3]

Recently, different methods and structures have been used to develop new Ultra Wide-band Bandpass filter (UWB-BPF) such as multi-mode resonator (MMR), pseudo-interdigital stepped impedance resonators (PI-SIRs), combining low pass and high pass filter etc [6],[7]. However, filter design for UWB applications face many challenges. One general problem is to avoid electromagnetic interference with many other existing narrowband communication systems.

Therefore, one method to eliminate the interferences is by having defected ground structures, DFGs, which disturb the shield current distribution in the ground plane. The defect in the ground of the microstrip can give rise to increasing effective capacitance and inductance that results with higher impedance, band rejections and slow wave characteristics [8].

1.2 Problem Statement

In many applications, the presence of harmonics will degrade the overall system performance. Hence the harmonics need to be adequately suppressed. Traditionally, harmonics are filtered using separate filter circuit, hence this undesirably increase the bulkiness of the whole system circuitry. Thus, a selected microwave planar filter designed can be further modified in order to improve the upper stopband performance.

1.3 Objectives

The objective of this project is to design a microwave planar bandpass filter with emphasis on upper stopband performance and to employ modification into the bandpass filter structure for better stopband.

1.4 Scope of Project

The project is a continuation of a previous work [8]. It is further improved with different DFG structures. The designed filters are then simulated and investigated in terms of its return loss and insertion loss responses. The configuration of the ground layer is modified by integrating defected structure to improve the upper stopband region. Circuit simulations are carried out using CST Microwave Studio®. The performances of all the results are analysed to monitor the harmonic suppression in the upper region.

1.5 Thesis Layout

The content of the thesis is organized into five (5) chapters. The introduction and overview of the project are described in the first chapter. The second chapter presents relevant brief theory and literature reviews related to the behaviour of UWB Bandpass filter and DFG structure. The design methodology is presented in chapter three. Simulation results obtained are analysed and discussed. The final chapter concludes the thesis and identify some areas for recommendation and future work.

REFERENCES

1. David M. Pozar, *“Microwave Engineering Third Edition”*, John Wiley and Sons, 2005.
2. *“Microwave Filter”*, https://en.wikipedia.org/Microwave_filter
3. Jim Silverstrim *“IEEE Ultra wideband Presentation”*, IWT - Leading edge wireless solutions, October 21, 2003.
4. *“Transmission Line Basic Theory”*, Presentation paper, <http://download.intel.com/education>.
5. *“Revision of Part 15 of the Commission’s rules regarding ultra-wideband transmission system,”* Federal Communication Council, Washington, DC, Tech. Rep. ET- Docket 98-153, April 2002.
6. Lei-Zhu, Senior Member, IEEE, Sheng-Sun, Student Member, IEEE and Wolfgang Menzel, Fellow, IEEE, *“ Ultra-Wideband (UWB) Bandpass Filters Using Multiple-Mode Resonator”*, IEEE Microwave and Wireless Components Letters, Vol.15., No.11, November 2005.
7. Ming-Zhong Ji, Qing-Xin Chu, and Fu-Chang Chen, *“ A Compact UWB Bandpass Filter Using Pseudo-Interdigital Stepped Impedance Resonators”*, ICMMT2008 Proceedings, 2008.

8. L. H. Weng, Y. C. Guo, X. W. Shi, and X. Q. Chen, "An Overview On Defected Ground Structure" *Progress In Electromagnetics Research B*, Vol. 7, 173–189, 2008.
9. Inder Bahl and Prakash Bhartia, "*Microwave Solid State Circuit Design*", 2nd Edition, Wiley: New Jersey, 2003.
10. Qing-Xin Chu, Xu-Kun Tian, "*Design of a Compact UWB Bandpass Filter with Notched Band*", Proceedings of Asia-Pacific Microwave Conference 2010.
11. Shu-Toa Li, Qing-Xin Chu, "*A Compact UWB Bandpass Filter With Improved Upper-Band Performance*", ICMMT2008 Proceedings, 2008.
12. X.-K. Tian and Q.-X. Chu, "*A Compact UWB Bandpass Filter With Improved Out-of-Band Performance Using Modified Coupling Structure*", *Progress In Electromagnetics Research Letters*, Vol. 22, 191-197, 2011.
13. Jae-Kwan Lee and Young-Sik Kim, Member, IEEE, "*Ultra-Wideband Bandpass Filter With Improved Upper Stopband Performance Using Defected Ground Structure*", *IEEE Microwave and Wireless Components Letters*, Vol.20, No.6, June 2010.
14. Cong-Liu and Jun-Xu, "*Ultra-Wideband Bandpass Filter With Dual Notched Bands Using Hybrid Microstrip/CPW Structure*", *IEEE Microwave and Wireless Components Letters* 2011
15. Qing-Xin Chu, Member, IEEE, and Xu-Kun Tian, "*Design of UWB Bandpass Filter Using Stepped-Impedance Stub-Loaded Resonator*", *IEEE Microwave and Wireless Components Letter*, Vol.20, No.9, September 2010.

16. Sina Akhtarzad, Thomas R. Rowbotham, and Peter B. Johns, “ *The Design of Coupled Microstrip Lines*”, IEEE Transactions on Microwave Theory and Techniques, Vol.MTT-23, No.6, June 1975
17. Norhaslinda Hassan, “*Compact Microwave Microstrip Fractal Filter with suppressed second harmonic*”, Dissertation of Degree of Electrical-Telecommunication Engineering FKE UTM, May 2009.
18. Park, J.I., C.-S Kim, et al., “*Modeling of photonic bandgap and its application for the low-pass filter design.*” Asia Pacific Microwave Conf. APMC, Vol.2, 331-334, 1999.
19. Devendra K. Misra, “*Radio-Frequency and Microwave Communication Circuits Analysis and Design 2nd Edition*”, John Wiley and Sons, 2004.
20. Ching- Luh Hsu, Fu- Chieh and Jen-Tsai Kuo, “ *Microstrip Bandpass Filters For Ultra-Wideband (UWB) Wireless Communication*”, IEEE Transactions on Microwave Theory and Techniques, 2005.
21. Sudipta Das, Dr. S.K.Chowdhury, “*Design Simulation and Fabrication of Stepped Impedance Microstripline Low Pass Filter for S-band Application using IE3D and MATLAB*”, IJECT Vol. 3, Issue 1, Jan. - March 2012
22. Lei Zhu, Wolfgang Menze, Ke Wu, Frank Boegelsack, “ *Theoretical Characterization and Experimental Verification of a Novel Compact Broadband Microstrip Bandpass Filter*”, Proceedings of APMC2001, 2001
23. Lei Zhu, Huuheng Bu, and Ke Wu APERTURE, “ *Compensation technique for innovative design of ultra-broadband microstrip bandpass filter*”, Department of Electrical & Computer Engineering Ecole Polytechnique, University of Montreal, Quebec, Canada