AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
CAIRO-EGYPT

Reconfigurable Compact Filter Using Modern Techniques

A Thesis
Submitted in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in the Electrical Engineering

Submitted by
Eng. Eman Gamal El sayed Ouf
M.Sc. of Electrical Engineering

Supervised by
Prof. Esmat Abdel-Fattah Abdallah
Prof. Hadia Mohamed Said El Hennawy
Prof. Ashraf Shouki Seliem Mohra

Cairo, Egypt

2019

AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
CAIRO-EGYPT

Examiners Committee

Name: Eman Gamal El Sayed Ouf
Thesis: Reconfigurable Compact Filter Using Modern Techniques
Degree: Doctor of Philosophy in Department of Electronics and Communication Engineering.

	Title, Name and Affiliation	Signature
1	**Prof. Dr. Hala Abdel Monem Elsadek** Professor and Microstrip Dep. Head Electronics Research Institute.	…….
2	**Prof. Dr. Abdelhalim A. Zekry** Professor in Electrical and Communication Engineering, Ain Shams University.	…….
3	**Prof. Dr. Esmat Abdel-Fattah Abdallah** Former President of Electronics Research Institute and Professor in Microstrip Dep.	…….
4	**Prof. Dr. Hadia Mohamed Said El Hennawy** Former Dean of Faculty of Engineering, Ain Shams University and Professor in Electronics and Communication Dep.	…….

Date: 21 / 3 / 2019

ACKNOWLEDGEMENTS

All gratitude is due to "ALLAH" who guides me to bring forth to light this thesis.

Pursuing Ph.D in Reconfigurable compact filter using modern techniques is one of the most valuable and exciting experiences in my education. The knowledge I learned and confidence I gained during the studying years will be beneficial to my whole life.

I owe my deepest gratitude to my supervisor, Prof. Dr. Esmat A. Abdallah, Former President of Electronics Research Institute, whose encouragement, guidance and support from the initial to the final level enabled me to develop an understanding of the subject. Prof. Dr. Esmat teaches me how to be a researcher, how to be patient and how to deal with research problems quietly. Prof. Dr. Esmat exerts extreme efforts in revising thesis and papers, never forgetting any details. As a matter of fact, this thesis would not have been possible without her deeply insight, opinions and her widely knowledge.

I also want to thank Prof. Dr. Hadia M. S. Elhennawy, Former Dean of Ain Shams University, Egypt for her interest in microwave components and her guidance in Ph.D qualification courses.

Also my deepest gratitude and sincerest thanks to Prof. Ashraf shouki seliem Mohra for his supervision, fruitful guidance through the course of the work, encouragement, endless help and many illuminating discussions.

Thanks for my colleagues and friends in Microstrip Department and the Electronics Research Institute staff for being around me helping and caring.

Also, I would like to thank my family. I am very grateful to my mother and father who encouraged and supported me. I owe all my achievement to my husband Eng. Maher, who always encourages me for further progress, and my kids, Sarah, Mariam and Sama, who shares all my joy and bitterness every day and night.

Curriculum Vitae

Name of the Researcher	Eman Gamal El sayed Ouf
Date of Birth	1st of January 1982
Place of Birth	Menofia, Egypt
Last University Degree	M.Sc in Electrical Engineering, Electronics and Communication Department, Ain-Shams University
Date of Degree	May, 2011.

STATEMENT

This Thesis is submitted for the degree of Doctor of Philosophy to the Department of Electronics and Communication Engineering, Faculty of Engineering of Ain Shams University, 2019.

The work included in this thesis was carried out by the author in the Department of Electronics and Communication Engineering, Ain Shams University and Electronics Research Institute, Microstrip Department.

No part of this Thesis has been submitted for a degree or a qualification at any other university or institute.

Name: Eman Gamal El sayed Ouf

Signature:

Date:

Published Papers

1. Eman G. Ouf, Ashraf S. Mohra, Esmat A. Abdallah, and Hadia Elhennawy, "Ultra-Wideband Bandpass Filter with Sharp Tuned Notched Band Rejection Based on CRLH Transmission-Line Unit Cell", Progress In Electromagnetics Research Letters, Vol. 69, PP. 9–14, 2017.
2. Eman G. Ouf, Ashraf S. Mohra, Esmat A. Abdallah, and Hadia Elhennawy, " A Reconfigurable UWB Bandpass Filters with Embedded Multi-Mode Resonators", Open Journal of Antennas and Propagation, Vol. 6, No. 3, PP. 43-59, 2018.
3. Eman G. Ouf, Esmat A. Abdallah, Ashraf S. Mohra, and Hadia M. S. Elhennawy, “Electronically Switchable Ultra-Wide Band /Dual-band Bandpass Filter Using Defected Ground Structures", Progress In Electromagnetics Research C, Vol. 91, PP. 83–96, 2019.

AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
CAIRO-EGYPT

Electronics and Communication Department

Supervised by

Prof. Dr. Esmat A. Abdallah, Prof. Dr. Hadia M. Elhennawy, and Prof. Dr. Ashraf S. Mohra.

SUMMARY

The objective of this thesis is to design and analyze RF reconfigurable compact filters using modern techniques such as meta-materials and electromagnetic band gap structures to meet the most of the requirements of wireless communication applications as in ultra wide band wireless applications, wireless fidelity (Wi-Fi) applications, Worldwide Interoperability for Microwave Access (Wi-Max) applications, WLAN applications, wireless laptops and mobile applications.

The reconfigurable compact filters were designed and analyzed using software packages including CST Microwave Studio, HFSS, ADS and Matlab-2016. The mini circuit switching matrix was used instead of RF PIN diodes in the switching process.

These filters were made using thin film technology and photolithographic technique on Rogers RO3006 (lossy) substrate with (ε_r = 6.15, h = 1.52 mm), and Rogers RT/Duroid 5880 with (ε_r =2.2, h =0.787mm). The measured results are characterized using a N9928A FieldFox Handheld Microwave Vector Network Analyzer, 26.5GHz. The design was validated by comparing simulation results with the laboratory measurements.

Three types of filters are designed, analyzed, fabricated and measured. First, the design and implementation of microstrip filter to satisfy the Federal Communications Commission ultra-wideband (FCC-UWB) specifications and also creates and controls sharp rejection notch-bands

within the filter's passband in order to provide interference immunity from unwanted radio signals, such as wireless local area networks (WLAN) and worldwide interoperability for microwave access (WIMAX) that cohabit within the UWB spectrum. This filter is based on CRLH concept consisting of an asymmetric transmission line unit cell with a short circuited inductive stub to realize high performance in an operation band from 3.1 to 10.6 GHz with a very compact size of 16.4 mm × 5.0 mm. The main advantage of the proposed filter is that four notch frequencies are tuned in the UWB frequency band. The notch frequencies of the filter can be changed by increasing the length of the coupling stub which is controlled by using switching matrix equipment (Mini Circuit) instead of PIN diodes. To validate the design theory, a microstrip UWB BPF with four notch bands centered at frequencies 6.18, 5.9, 5.7, and 5.5GHz is designed and fabricated. Good agreement is found between simulated and measured results.

Second, the design and implementation of two microstrip filters satisfying the Federal Communications Commission Ultra-wideband (FCC-UWB) specifications and also control the center frequency and bandwidth of the filters passband are presented. These filters consist of two distinguishing parts, Electromagnetic bandgap (EBG)-embedded multiple-mode resonator (MMR) and interdigital coupled lines to realize high performance in the operation band with a compact size of 14.0 mm × 10.1 mm. The main advantage of the two proposed filters is that three different bands are tuned. The 1st tuned band is from 3.5 GHz to 11.4 GHz for the first filter and from 3.1 GHz to 11.6 GHz for the second proposed filter, respectively. The 2nd tuned band is from 3.5 GHz to 7.5 GHz for the first filter and from 3.1 GHz to 7.8 GHz for the second proposed filter, respectively. While the 3rd tuned band of the first proposed filter is from 3.5 GHz to 5.9 GHz and from 3.1 GHz to 5.8 GHz for the second proposed filter. The bandwidth of the filters can be changed by increasing the length of the outer open circuited stubs which are controlled by using switching matrix equipment (mini circuit, replacement of PIN diodes). To validate the design theory, a reconfigurable UWB bandpass filters (BPFs) with EBG Embedded MMR are designed, fabricated and measured. Good agreement is found between simulated and measured results.

Third, the design and implementation of a reconfigurable ultra wide band BPF using rectangular shape DGS to satisfy good passband selectivity by the transmission zeros and good passband under -15dB from 3.6 GHz to 10.6 GHz is carried out. The stopband characteristics of this filter

are less than -20dB up to 17GHz. The filter has compact size of 12.5 mm × 10 mm. The main advantage of the proposed filter is that reconfiguration from UWB to dual band from 3.6 GHz to 5 GHz and another from 9.5 GHz to 10.8 GHz is obtained. Therefore, it is expected that the proposed structure with its characteristics will be a strong candidate to avoid the interferences from the narrow band services such as the WLAN, WIMAX, C- band of radar from 5.85 GHz to 8.20GHz, and interference with X (Military) band of satellite from 7GHz to 8 GHz. It is suitable for modern RF and microwave satellite and mobile communication systems. To validate the design theory, electronically switchable ultra-wide band / dual band bandpass filter is fabricated and measured. Good agreement is found between simulated and measured results.

Table of Contents

List of Abbreviations

ADS	Advanced Design System
AMC	Artificial Magnetic Conductor
BPF	Band pass filter
CST	Computer Simulation Technology
CRLH	Composite Right/Left-Handed Transmission Line
DGS	Defected Ground Structure
EBG	Electromagnetic Bandgap Structure
EM	Electromagnetic
FEM	Finite Element Method
FIM	Finite Integral Method
FIT	Finite Integration Technique
HFSS	High Frequency Structure Simulator
HTS	High Temperature Superconductors
HIES	High Impedance Electromagnetic Surface (HIES)
LTE	Long Term Evolutions
LTCC	Low-temperature Co-fired Ceramics
LPF	Low Pass Filter
MTMs	Metamaterials

MMIC	Monolithic Microwave Integrated Circuits
MEMS	Micro-electromechanical System
PBA	Perfect Boundary Approximation
PBG	Photonic Band Gap
PIN	P Junction Isolator N Junction
PCS	Personal communication systems
RF	Radio Frequency
RFIC	Radio Frequency Integrated Circuits
SAW	Surface Acoustic Wave
SRR	Split-ring Resonator
SDR	Software-defined Radio
TV	Television
UMTS	Universal Mobile Telecommunications System
UWB	Ultra-Wide-Bandwidth
VNA	Vector Network Analyzer
Wi-Fi	Wireless Fidelity
Wi-MAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network