AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

Electronics and Electrical Communication Engineering Department

Integrated Metamaterial Subsystem Components for Microwave Applications

A Thesis submitted in partial fulfillment of the requirements of the degree of

Doctor of Philosophy in Electrical Engineering

(Electronics and Communications Engineering)

By

Eng. Ahmed Fawzy Ezzat Aly Abd-El Azim Daw

Supervised By

Prof. Dr. Hadia Mohamed El Hennawy

Assoc. Prof. Dr. Mahmoud Abd El Rahman Abdalla

Cairo - (2017)

Statement

This thesis is submitted as a partial fulfilment of Degree of Doctor of Philosophy in Electrical Engineering, Faculty of Engineering, Ain shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

Ahmed Fawzy Ezzat Aly Abd-El Azim Daw

Signature

……..…….

Date: 2017

Researcher Data

Name	: Ahmed Fawzy Ezzat Aly Abdelazim Daw
Date of birth	: 20 - 10 - 1983
Place of birth	: Egypt
Last academic degree	: Master of Science
Field of specialization	: Electronics and Electrical Communication Engineering
University issued the degree	: Ain Shams University
Date of issued degree	: June 2009
Current job	: Assistant Lecturer - MSA University

Thesis Abstract

The rapid development of microwave systems requires a new generation of compact passive components. Metamaterials have the potential for novel types of components because of their new opportunities to realize physical phenomena that were previously only theoretical predictions. The response of metamaterials had a huge effect on physics, optics, guided wave, and radiated wave applications. Recently, the benefits of metamaterials structure got the attention for new systems with compact size and multiband operations with very simple structure.

This thesis aims to use metamaterial in the design of compact, low loss, and efficient microwave passive components. The thesis is concerned with the design, analytical study, simulation, and fabrication of microwave components based on new configurations of metamaterials.

Novel multiband and compact size resonators based on dual composite right left handed (D-CRLH) are presented. A dual band sharp-skirt resonator is introduced with high quality factors of 194.3 and 180.6 and insertion losses of 0.44 dB and 0.07 dB at frequencies 5.8 GHz and 7.7 GHz, respectively, with total compact size of 16.7×12 mm^2. Another quad band resonator is introduced with high selectivity at frequencies 4 GHz, 5.8 GHz, 6.6 GHz, and 7.7 GHz with insertion losses of 0.69 dB, 1.9 dB, 3.9 dB, and 3.6 dB, respectively, and a total size of 11.55×12 mm^2. The resonator quality factors are 151.28, 75, 125, and 82.7 at the four bands, respectively. Furthermore, a triple band resonator with the same compact size of the dual resonator is presented. The resonances frequencies are 7.4 GHz, 9.2 GHz, and 13 GHz with insertion losses 0.02 dB, 0.05 dB and 0.5 dB, respectively.

New designs for compact power dividers based on D-CRLH are introduced. The first power divider is a two-way dual wide bands with the first band extended from 1 GHz to 4.8 GHz, and the second band extended from 6.2 GHz to 9 GHz. The power divider has a stop band extended from 4.8 GHz to 6.2 GHz with very sharp immunity characteristics. The insertion losses for the both bands are 4 dB with total compact size of 21.4×16.6 mm^2. Moreover, a three-way dual bands power divider is introduced. The dual frequencies band are extended from 1 GHz to 4.6 GHz for the first one and from 5.7 GHz to 11.1 GHz for the second band with insertion loss of 5 dB for both bands and a total size of 22.5×39 mm^2.

A new efficient version of metamaterial (Loaded inductor composite right left handed "L-CRLH") is also proposed for the first time. Based on this new configuration, a novel ultra-wide band impedance transformer is introduced with operating bandwidth extended from 2 GHz to 11 GHz, insertion loss of 0.2 dB and ultra-compact size of 2.7×8.6 mm^2. Furthermore, new power divider based L-CRLH is introduced with ultra-wide band (UWB) characteristic extended from 3.1 GHz to 10.6 GHz with insertion loss of 3.3 dB for both outputs and total compact size of 12.14×19.63 mm^2. Finally, a new configuration named HS-L-CRLH, a new transformer based on HS-L-CRLH are introduced. In addition, a new ultra-compact power divider based HS-L-CRLH is proposed with total ultra-compact area 14×16 mm^2 and insertion loss equal 3.1 dB within pass band extended from 3.1 GHz to 10.6 GHz.

Published papers:

1-Ahmed F. Daw, Mahmoud A. Abdalla, and Hadya M. Elhennawy:"Dual Band High Selective Compact Transmission Line Gap Resonator ", 2014 Loughborough Antennas & Propagation Conference, UK, pp. 91-94.

2-Ahmed Fawzy Daw, Mahmoud Abd EL Rahman Abdalla, Hadia Mohamed EL Hennawy, “Multiband Sharp-Skirt Compact Gap Resonator Based D-CRLH”, 2015 32th National Radio Science Conference (NRSC), Egypt, pp. 43-50.

3- Ahmed F. Daw, Mahmoud A. Abdalla, and Hadia M. Elhennawy:" New Configuration for Multiband Ultra Compact Gap Resonator Based D-CRLH",2016 3rd Middle East Conferences on Antennas and Propagation (MECAP 2016), September 2016, Bairut, Lebanon.

4- Ahmed F. Daw, Mahmoud A. Abdalla, and Hadia M. Elhennawy "Dual-Band Divider Has Rejection Band at 5 GHz", Microwave& RF Magazine, Nov. 2016.

5- Ahmed F. Daw, Mahmoud A. Abdalla, and Hadia M. Elhennawy:" Compact Dual Wide Band D-CRLH Three Way Power Divider",2016 3rd Middle East Conferences on Antennas and Propagation (MECAP 2016), September 2016, Bairut, Lebanon.

6-Ahmed F. Daw, Mahmoud A. Abdalla, and Hadia M. Elhennawy:"New inductor loaded composite right left hand impedance transformer for UWB wireless applications", 2015 9th International Congress on Advanced Materials in Microwaves and Optical (METAMATERIALS), September 2015,Oxford, UK, pp. 355-357.

Key words:

Microwave passive component, Sharp resonators, Multiband resonators, DCTLH resonators, Metamaterial resonator, D-CRLH power divider, Dual band power divider, Compact power dividers, L-CRLH transformer, L-CRLH power divider, Hub shape L-CRLH power divider, Ultra-compact power divider. UWB power divider, metamaterial power divider.

Acknowledgment

First, all praise be to Allah for all his great and continuous guidance, generosity, and help.

I would like also to express my thanks to Prof. Dr. Hadia El-Hennawy for her help, care, interest, and valuable advice.

Also, I would like to express my deep gratitude to Assoc. Prof. Dr. Mahmoud Abderhaman Abdalla for his great effort, guidance, and assistance even before beginning my work in this research point and throughout the research period. He also helped me by his continuous reviews and suggestions during research work and thesis development.

Last but not least, I must express my thanks and appreciation to my family for their love, support and sincere for success.

Table of Contents

Chapter (III)

Chapter (IV)

Chapter (V)

Chapter (VI)

List of Figures