

Metamaterial-Inspired Structures and Their Applications in Microwave, Millimeter-wave and Terahertz Planar Circuits

by

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Thesis submitted for the degree of

Doctor of Philosophy

in

Electrical and Electronic Engineering,
Faculty of Engineering, Computer and Mathematical Sciences
The University of Adelaide, Australia

2014

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*To my Mom and Dad
and also to my wife, Zahra
with all my love.*

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Abstract

Metamaterials are generally defined as periodic composite structures that are engineered to modify the electromagnetic properties of materials, especially in order to achieve new physically realizable responses that may not be readily available in nature. The key to the application of metamaterial resonators for the synthesis of such effective media is their small electrical size. This feature can be also exploited for the miniaturization of planar circuits.

Motivated by the need for miniaturized planar structures in mobile wireless systems, metamaterial-inspired structures are proposed throughout this thesis for the design of compact microwave, millimeter-wave and terahertz planar structures with improved performance. The thesis firstly proposes slow-wave and SRR-loaded coplanar strips resonators for the design of compact high quality factor balanced resonators for 60 GHz VCOs in CMOS technology. Next, the thesis is focused on the miniaturization of microwave filters either by proposing resonators with dual-band functionality or through modifying the shape of metamaterial resonators. Shape modifications of metamaterial resonators are also used for the design of high-dynamic-range one- and two-dimensional displacement sensors as well as of a rotation sensor with improved dynamic range. It is further shown that high level of miniaturization can be achieved in a single-layer S-shaped SRR (S-SRR), if the loops of the S-SRR are excited by contra-directional magnetic fluxes, which makes the S-SRR very well suited for application in coplanar waveguide (CPW) technology. The thesis also proposes the dual counterpart of the S-shaped SRR, i.e., S-shaped complementary split ring resonator (S-CSRR) for application in the design of compact differential bandpass filters with inherent common-mode suppression. Finally, the application of SRRs to the design of compact bandpass filters for terahertz surface waves on single wire waveguides—the so-called planar Goubau lines (PGLs)—is studied numerically and experimentally. The results of this research show the versatility and potential of metamaterial-inspired resonators for the realization of miniaturized structures in planar technologies in different frequency bands.

Statement of Originality

I certify that this work contains no material, which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

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Acknowledgment

First and foremost, I would like to take this opportunity and glorify this Thesis to the name of God, the beneficent, the merciful. “Every inhalation of the breath prolongs life and every expiration of it gladdens our nature; wherefore every breath confers two benefits and for every benefit gratitude is due” as Saadi said in his *Rose Garden*. Thus, our hands and tongues are not capable to fulfill the obligation of thanks to Him.

I would also like to take the opportunity to express my gratitude to all those people whose support, skills and encouragement has helped me to complete this journey successfully. First, I would like to express my deep gratitude to my principal supervisor, Prof Derek Abbott for accepting me as a PhD candidate in 2009 and introducing to me the amazing world of metamaterials. His unwavering optimism, ever-so encouraging attitude, constructive suggestions, linguistic finesse, and generous travel financial assistance have been helpful in propelling my research forward. I also wish to express my appreciation to my co-supervisor, Dr Said Al-Sarawi. His critical suggestions and constructive advice in various areas, especially in the field of millimeter-wave CMOS circuits, have been of great importance towards my research. From the second year of my PhD, I have had the pleasure to work with another great scientist, my co-supervisor, Prof Christophe Fumeaux. His theoretical understanding and experimental experience in the field of electromagnetic and microwave engineering have been of great importance towards my research. He has always welcomed scientific discussions and has given me critical feedback. I would like to gratefully acknowledge his enthusiastic supervision, encouraging attitude, and generously sharing his knowledge and experience. He provided me with direction and technical support, and taught me the alphabet of ethics in science. Dear Christophe, you became more of a mentor and friend, than a supervisor. I am also indebted to all my supervisors for tirelessly reviewing all our publications including this thesis. I appreciate all their contributions, time, ideas, strict requirements, funding, and answering quickly all questions I had about topics of their expertise to make my PhD experience productive and stimulating.

Another key person whom I am strongly indebted to is Prof Ferran Martín. He has been a great mentor to my research during my visit at GEMMA/CIMITEC, Departament d'Enginyeria Electronica, Universitat Autònoma de Barcelona, Bellaterra, Spain.

Acknowledgment

His deep theoretical knowledge and long experimental experience with metamaterial-inspired microwave structures have been of great importance towards my research. I would also like to include my gratitude to Dr Miguel Durán-Sindreu, and Jordi Naqui, who have enabled part of this research work together with Prof Ferran Martín. I would also thank Anna Cedenilla for her administrative assistance, and Dr Gerard Sisò, Dr Ferran Paredes, Paris Vélez, Gerard Zamora and other members of GEM-MA/CIMITEC, for making such a friendly research environment during my stay in the Universitat Autònoma de Barcelona.

I wish to express my warm thanks to Dr Tahsin Akalin, Abdallah Chahadih, Abbas Ghaddar, and Mokhtar Zehar at the Institut d'Electronique de Microelectronique et de Nanotechnologie IEMN, France for their fabrication and measurement support for part of this work.

I am indebted to Dr Withawat Withayachumnankul and Dr Thomas Kaufmann, outstanding scholars at the University of Adelaide, for being supportive colleagues and friends, and for their kindness, passion, and patience in discussing long hours around different research issues and also for their critical suggestions. I would also express my appreciation to my friends and colleagues in the Applied Electromagnetics Group at the University of Adelaide, Dr Akhilesh Verma, Dr Longfang Zou, Dr Shifu Zhao, Pouria Yaghmaee, Tiaoming (Echo) Niu, Amir Ebrahimi, Shengjian (Jammy) Chen, Chengjun (Charles) Zou, Nghia Nguyen, and Sree Pinapati, and to the people at the Adelaide T-ray Group, Mr Henry Ho, Dr Shaghik Atakaramians, Dr Gretel M. Png, Dr Mayank Kaushik, Dr Benjamin Ung, Dr Jega Balakrishnan, Dr Hungyen Lin, Mr Shaoming Zhu, and Mr Andrew Li. It was great to work with you all.

I would like to express my appreciation for all the fellow researchers at the University of Adelaide for creating a conducive and friendly environment. Special thanks to Dr Omid Kavehi, Ms Taraneh Arianfar, Mr Mostafa Rahimi, Ms Maryam Ebrahimpour, Dr Muammar Kabir, Mr Arash Mehdizadeh, Mr Sam Darvishi, Mr Mehdi Kasaei, Mr Mohammad Asraful Hasan, Ms Sarah Anita Immanuel. Also, to all my friends and their family in Adelaide, specially Mr Yadollah Bahrami, Mr Mehregan Ebrahimi and Mr Azim Kalantari. I also like to thank the office & support staff of The School of Electrical & Electronic Engineering at The University of Adelaide, Mr Ian Linke, and Mr Pavel Simick for their practical suggestions and fabrication of samples in the midst of tight time frames. Mr Danny Di Giacomo for his friendliness and logistical supply of

parts. To IT officers, David Bowler, Mark J. Innes, and Ryan King, and the administrative staff, Mr Stephen Guest, Ms Ivana Rebellato, Ms Rose-Marie Descalzi, Ms Deborah Koch, Ms Lenka Hill, Ms Jodie Schluter for their kindness and assistance.

I am also indebted to all my good teachers for planting love of knowledge in my heart, Mr Reza Dada, Mr Shirovi, Mr Parishani, Mr Zarei, Mr Khorami, Mr Asgari, Mr Ahmad Dibaj, Mr Mani, Mr Tabrizi among others. Special thanks to Mr Mohsen Tavasoli for his kindness and support. I learned electromagnetics and microwave engineering from three masters: A/Prof Farzad Mohajeri (Shiraz University), A/Prof Esfandiar Mehrshahi (Shahid Beheshti University), and Prof Christophe Fumeaux (The University of Adelaide), and it is appropriate to express my gratitude to them here.

This thesis was made possible by an Iranian Government Overseas Scholarship. I am grateful to the Iran Ministry of Sciences, Research and Technology for the scholarship, which enabled me to undertake a PhD program at the University of Adelaide. Also, to travel grants and awards from the School of Electrical & Electronic Engineering (the University of Adelaide), IEEE SA Section through student travel award, and the Australia's Defence Science and Technology Organisation (DSTO) through the Simon Rockliff Supplementary Scholarship.

My endless appreciation goes to my father and mother who always endow me with infinite support, wishes, continuous love, encouragement, and patience. I also thank them for being my first teachers together with my older brother. I would like to thank my sisters and younger brother for being my first students. It was amazing how much I learned through teaching them. I wish to express my warm and sincere thanks to my father- and mother-in-law for their kindness, guidance, and heartfelt wishes.

Last but not least, the warmest thanks to my dear wife, my most ardent supporter, research partner, and dearest friend, Zahra, who stood by me in the ups and downs, when I was right and when I was wrong, and never doubted my abilities. Dear, I love you.

Thesis Conventions

The following conventions have been adopted in this Thesis:

Typesetting

This document was compiled using L^AT_EX2_ε. Texmaker and TeXstudio were used as text editor interfaced to L^AT_EX2_ε. Inkscape was used to produce schematic diagrams and other drawings.

Referencing

The Harvard style has been adopted for referencing.

System of units

The units comply with the international system of units recommended in an Australian Standard: AS ISO 1000–1998 (Standards Australia Committee ME/71, Quantities, Units and Conversions 1998).

Spelling

American English spelling is adopted in this thesis.

Publications

Journal Articles

- HORESTANI-A. K., FUMEAUX-C., AL-SARAWI-S., AND ABBOTT-D. (2012b). Split ring resonators with tapered strip width for wider bandwidth and enhanced resonance, *IEEE Microwave and Wireless Components Letters*, **22**(9), pp. 450–452.
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