Metamaterial-Inspired Structures for Microwave and Terahertz Applications

by

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Prof Derek Abbott, School of Electrical & Electronic Engineering
To my dearest wife, Aida
and to my Mum, Dad, and Sister
with all my love.
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Statement of Originality

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Signed

Date

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Amir Ebrahimi,
January 2016,
Adelaide
Thesis Conventions

The following conventions have been adopted in this Thesis:

**Typesetting**

This document was compiled using \LaTeX2e. Texmaker and TeXstudio were used as text editor interfaced to \LaTeX2e. Inkscape and Xcircuit were 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**

Australian English spelling conventions have been used, as defined in the Macquarie English Dictionary (A. Delbridge (Ed.), Macquarie Library, North Ryde, NSW, Australia, 2001).
Awards and Scholarships

2015
- Yarman-Carlin Best Paper Award, Mediterranean Microwave Symposium
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Abstract

Electromagnetic metamaterials are engineered materials that exhibit controllable electromagnetic properties within a desired frequency range. They are usually made of periodic metallic resonant inclusions with dimensions much smaller than the operational wavelength. Since their introduction, they have found many applications from the microwave frequency range up to the terahertz and optical ranges. One key advantage of metamaterial lies in their sub-wavelength resonators making them suitable for miniaturisation of RF circuits and components.

This thesis investigates applications of metamaterial-inspired resonators and structures to design improved devices and components operating at either the microwave or terahertz frequency range. The first part of the dissertation is on the design of miniaturised microwave filters for integrated portable RF systems. Dual-mode metamaterial resonators are proposed as alternatives to conventional resonators for size reduction of the RF filters. In the second part, the focus is on the design of compact metamaterial sensors with improved functionalities. Complementary metamaterial resonators are proposed for designing microfluidic sensors with improved sensitivity and linearity. The designed microfluidic sensors have been tested and verified for dielectric characterisation of chemical and biological solutions. A wide dynamic-range displacement sensor has been designed based on a microstrip-line-coupled complementary electric-LC (ELC) resonator. Furthermore, a rotation sensor is designed with coupled U-shaped resonator with a dynamic range of 180°, where the sensor linearity is improved by asymmetrically tapering the resonators shape. The third part focuses on the design of microwave and terahertz frequency selective surfaces (FSS) based on metamaterial miniaturised elements. Tunable and dual-band FSSs are proposed for reconfigurable and multi-standard microwave communications. Eventually, miniaturised-elements are used to design second-order FSSs at the terahertz frequency range. The simulation and measurement results confirm a harmonic-free and stable frequency response of the designed FSSs under oblique incidence angles.

Overall, the research outcomes in this thesis suggest the efficiency of metamaterial resonators for the design of sensing and communications devices with improved performance over a wide frequency range from the microwave up to terahertz.
Publications

Journal Articles


Publications


Conference Articles


**Note:** Articles with an asterisk (*) are directly relevant to this thesis.
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