AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

Electronics Engineering and Electrical Communications

Metamaterial-Inspired Microwave Passive Devices

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

Master of Science in Electrical Engineering

(Electronics Engineering and Electrical Communications)

by

Mohamed Adel GalalEldin Ibrahim Elsheikh

Bachelor of Science in Electrical Engineering

(Electronics Engineering and Electrical Communications)

Faculty of Engineering, Ain Shams University, 2016

Supervised By

Prof. Hadia Mohamed Said Elhennawy

Prof. Amr Mohamed Ezzat Safwat

Cairo - (2019)

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Statement

This thesis is submitted as a partial fulfillment of Master of Science 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.

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Thesis Summary

This thesis aims to provide the geometrical-based equivalent circuit models for different resonator-coupled transmission lines (TL). These models are derived from the general multi-mode cross-junction by applying the appropriate boundary conditions. This methodology successfully produced the models of several structures such as strip-loaded slotline, strip and Split Ring Resonator (SRR) -loaded Coplanar Waveguide (CPW), in addition to the investigation of the CPW odd mode strip-loading. These models have led to the development of a range of applications spanning low-pass filters, slow-wave structures, wideband Composite Right Left Handed (CRLH) TL and compact planar air-bridge free CPW Wilkinson Power Dividers (WPD). For the complementary structures, the investigated models are the Defected Ground Structure (DGS), Complementary Split-Ring Resonator (CSRR) loaded microstrip (MS), and DGS coupled lines, and their applications to directional couplers. The thesis then branches out to two-dimensional periodic structures and provides a low frequency experimental verification for the high efficiency double-layer Artificial Magnetic Conductor (AMC) -backed dipole based on the lossy FR4 platform.

The thesis is divided into seven chapters as listed below:

Chapter 1:

This chapter introduces the background, motivation, objectives, major contributions and organization of the thesis.

Chapter 2:

This chapter reviews the theory of CRLH TLs and includes a literature survey on the different unit cells configurations, while placing emphasis on the implementations employing SRR and CSRR -loadings. It also provides a brief summary regarding two-dimensions implementations of metamaterials, particularly the AMC.

Chapter 3:

This chapter develops the methodology of deriving the geometrical-based equivalent circuit models of resonator-coupled CPW from the slotted-MS multi-mode cross junctions. It successfully models the strip-loaded slotline, and strip and SRR -loaded CPW. It provides new implementations for CPW low-pass filters, slow-wave structures, and ultra-wideband CRLH TL.

Chapter 4:

This chapter investigates a strip-loaded CPW supporting both the even and odd modes. Then it presents the analysis of a small-footprint all-CPW WPD. The proposed circuit-models enable two air-bridge free realizations for this WPD. The first is based on the selective slow-wave effect present for the odd-CPW mode, and the second deploys the floating strips as an electrical air-bridges.

Chapter 5:

The scope of this chapter is extending the developed geometric equivalent circuit models to cover the complementary structures, including the DGS and the likes. It provides the models for the slot-loaded MS, and CSRR-loaded MS. It also provides an accurate four-port circuit model for slot-loaded coupled MS lines. The circuits

models are exploited in the development of two directional couplers; a 0-dB forward coupler and a 3-dB backward one.

Chapter 6:

This chapter aims to provide a practical implementation of a double layer AMC-backed dipole on FR4 platform. The substrate stack is developed, and a wideband balun is designed to accommodate the bandwidth of the antenna. The antenna provides high gain and efficiency while being low-profile in comparison to similar structures in the literature.

Chapter 7:

This chapter provides a conclusion to the executed work and suggests future research directions.

Key words:

Split-ring resonator (SRR), Coplanar waveguide (CPW), Microstrip, Slotline, Cross-junction, Shielded-Coplanar waveguide (S-CPW), Air-bridges, Equivalent circuit model, Wilkinson power divider, Directional couplers, Artificial Magnetic Conductor (AMC), FR4.

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