Multiple-Mode Resonator Analysis and Its Applications to Microwave Waveguide Components

by Jingyu Lin

Thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy

under the supervision of
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CERTIFICATE OF ORIGINAL AUTHORSHIP

I, Jingyu Lin, declare that this thesis is submitted in fulfilment of the requirements award of the Doctoral Degree, in the School of Electrical and Data Engineering, Faculty of Engineering and Information Technology at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of the requirements for a degree at any other academic institution except as fully acknowledged within the text.

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Time flies so quickly. I was a visiting student when I first came to UTS, and now I'm about to graduate with a PhD. Everything is as good as ever, I learned a lot, met a lot of great people, gained a lot of knowledge, and I really appreciate the time I spent here.

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Published and Under Review Papers Related to This Thesis

[a1] **J.-Y. Lin**, Y. Yang, S.-W. Wong, R.-S. Chen, Y. Li, L. Zhang, Y. He, and L. Zhu, "Cavity Filtering Magic-T and Its Integrations Into Balanced-to-Unbalanced Power Divider and Duplexing Power Divider," ***IEEE Transactions on Microwave Theory and Techniques***, vol. 67, no. 12, pp. 4995-5004, Dec. 2019. **[Chapter 2]**

[a2] S.-W. Wong, **J.-Y. Lin**, Y. Yang, Z.-C. Guo, L. Zhu and Q.-X. Chu, "Waveguide Components Based on Multiple-Mode Resonators: Advances in Microwave Multiple-Mode Waveguide Components, Including Multiplexers, Three-State Diplexers, Crossovers, and Balanced/Unbalanced Elements," ***IEEE Microwave Magazine***, vol. 22, no. 2, pp. 33-45, Feb. 2021. **[Chapter 1 and 2]**

[a3] **J.-Y. Lin**, Y. Yang, S.-W. Wong and Y. Li, "High-Order Modes Analysis and Its Applications to Dual-Band Dual-Polarized Filtering Cavity Slot Arrays," ***IEEE Transactions on Microwave Theory and Techniques***, vol. 69, no. 6, pp. 3084-3092, June 2021. **[Chapter 3]**

[a4] **J.-Y. Lin**, S.-W. Wong and Y. Yang, "Filtering In-Band Full-Duplex Slot Antenna Based on TM120 and TM210 Dual-Mode Resonators," ***2021 IEEE MTT-S International Microwave Filter Workshop (IMFW)***, 2021. **[Chapter 4]**

[a5] **J.-Y. Lin**, Y. Yang, S.-W. Wong, and R.-S. Chen, “In-Band Full-Duplex Filtering Antenna Arrays Using High-Order Mode Cavity Resonators,” ***IEEE Transactions on Microwave Theory and Techniques***. **[Chapter 4]**

[a6] **J.-Y. Lin**, Y. Yang and S.-W. Wong, "Four-Way Filtering Crossover Based on Quadruple-Mode Cavity Resonator," ***2021 IEEE MTT-S International Microwave Symposium (IMS)***, 2021. **[Chapter 5]**

[a7] **J.-Y. Lin**, Y. Yang, S.-W. Wong, X. Li, L. Wang, and E. Dutkiewicz, “Two-Way

Waveguide Diplexer and Its Application to Diplexing In-Band Full-Duplex Antenna," ***IEEE Transactions on Microwave Theory and Techniques***. **[Chapter 5]**

[a8] **J.-Y. Lin**, Y. Yang, T. Zhang, S.-W. Wong and J. Du, "Inline Waveguide Bandpass Filter Using Bandstop Resonator Pairs," submitted to ***2023IEEE MTT-S International Microwave Symposium (IMS)***. **[Chapter 6]**

Abstract

Composite signals can be represented as a combination of multiple sinusoidal signals with varying frequencies, phases, and amplitudes. In general, these critical features can be manipulated by microwave components for different applications. As the indispensable part of most microwave components, microwave resonators play a significant role in functional circuit designs. Single resonance (single mode) circuit in one order or higher orders have dominated industry's usage of microwave circuits and systems. For high-power applications such as base stations, satellite communication, and aerospace communication, conventional SMR waveguide components have the advantage of achieving high performance and meeting required precision performance specifications. However, their bulky circuit volume and high fabrication cost hinder their implementation in many space-constrained scenarios. There is a need to tackle these challenges by means of a novel approach. MMRs, with more than one resonant mode in a single resonator, have been investigated by several research groups over the last decade. Compared to SMR, besides the merits of circuit miniaturization, low-loss, and low-cost, MMR has an inherent advantage of diverse topologies with better out-of-band signal attenuation, due to the generation of additional transmission zeroes (TZs). In addition, MMR provides more design freedom and flexibility in function integration, which might not be possible using single mode resonators. The main contents are as follows:

1. Cavity filtering magic-T and its integrations into balanced-to-unbalanced (B2U) power divider (PD) and diplexing power divider.
2. Single-band and dual-band filtering antenna arrays (FAAs) based on high-order mode resonators.
3. In-band full-duplex (IBFD) filtering antenna arrays based on high-order mode resonators for narrowband and wideband applications.
4. Two-way waveguide diplexer and its application to diplexing IBFD antenna using quadruple-mode resonators.
5. Inline waveguide bandpass filter using bandstop resonator pairs.

Keywords: Waveguide filter, multiple-mode resonator, transmission zero, slot antenna, in-band full-duplex, filtering antenna array, magic-T, balun, high-order mode, multi-mode resonator, millimeter-wave, terahertz.

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