Multi-Mode Dielectric Resonator Filters and Antennas

Mustafa S. Bakr, *Student member, IEEE*, Ian C. Hunter, and Wolfgang Bosch, *Fellow members, IEEE*

***Abstract*— this report provides a brief summary of the research remarks of the project submitted for IEEE MTT-S Graduate Fellowship Award entitled "Innovative solutions for adaptive transceiver front ends/mobile commutations for internet of things". The main goal of the project was to propose innovative design solutions of miniature microwave antennas and filters for mobile communications and the Internet of things. Multi-mode resonances were investigated to design compact single/multi-band narrow/broadband planar antennas and dielectric-loaded cavity filters. The research activates resulted in many publications and four patents pending.**

***Index Terms*— compact antennas and filters, dielectric resonators, multi-mode resonators, broadband, reconfigurability, multi-band.**

I. Introduction

THE advances in modern cellular radio and satellite communication have increased the demand for improving and simplifying the architecture of a system. Microwave filters and antennas are vital components to enable communication and remove unwanted frequencies. The specification of these devices are severe and approach the theoretical limits in terms of electrical and mechanical. A major obstacle in the design of high-power and high-performance microwave filters is their bulky size and difficulty in building compact simple architecture for miniature, reconfigurable, multi-band filers. Similarly, compact and low-power consumption antennas are that can be easily integrated within the system are required for the Internet of things devices. Simple miniature architecture of microwave filters and antennas were investigated to design narrow/broadband single/multiband non-planar filters and planar patch antennas. The approach used in this project is to use multi-mode dielectric-loaded cavities for the design of new class of filters. Similarly gap-coupled multiple resonators approach is used to design compact broadband and single/multiband reconfigurable antennas with directional radiation pattern. A brief summary of the main outcomes of this project is presented in the rest of the report.

Mustafa S. Bakr Author, is with Graz University of Technology, Graz, Austria. He is also with the Pollard Institute, University of Leeds, UK and Radio Design Ltd, Shipley, UK. He is also with the University of Technology, Baghdad, Iraq (e-mail: mustafa.bakr@tugraz.at).

Ian C. Hunter Author is with the School of Electronic and Electrical Engineering, University of Leeds, UK (i.c.hunter@leeds.ac.uk).

Wolfgang Bosch Author is with Graz University of Technology, Graz, Austria (wbosch@tugraz.at).

II. Miniature Multi-Mode Dielectric Resonator Filters

New classes multi-mode dielectric resonator filters were studied to design the following:

A) *Miniature Multi-Mode dielectric Resonator Filters*

The approach used in this work is to use dielectric-loaded cavities, which supports a dual degenerate $HE_{11\delta}$ fundamental mode resonance. The geometrical dimensions of the cavity is adjusted to support dual- and triple mode resonators, i.e $HE_{11\delta}$ and $TM_{01\delta}$ mode. This enables fourfold size reduction compared with TEM filters and good spurious window. A new class of high Q-factor non-degenerate dual-mode dielectric resonator filters was investigated. The proposed structure requires no intra-cavity coupling thus simple structure (parallel-coupled resonators). Real-frequency transmission zeros can be generated on the upper or lower side of the passband. Broadband response is obtainable by proving strong

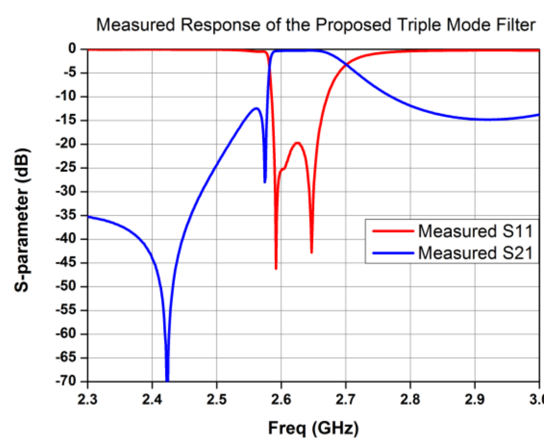

Fig. 1. Measured frequency response of three-pole bandpass filter with two real frequency transmission zeros on the lower side

input to resonators coupling. Higher order filters can be obtained by cascading the basic building block. The work was extended to design high Q-factor triple-mode dielectric resonator filters with two transmission zeros on the upper or lower side and tunable centre frequency. The measured response of three-pole filter with two real-frequency transmission zeros on the lower side is shown in Fig.1

B) Broadband Dielectric Resonator Filters

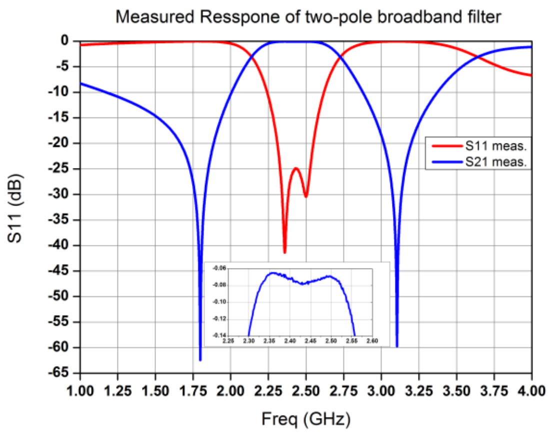

Fig. 2. Measured Response of two-pole broadband filter with a pair of real-frequency transmission zeros

Broadband filters are widely used in cellular base station and satellite communications (e.g. combiner and input filters). However, most of the proposed solutions are based on bulky cavity filters (Waveguide and TEM). Compact dielectric resonator filters were investigated to achieve broadband response.

Simple input to resonators coupling configurations were proposed to achieve a fractional bandwidth of 70%. The measured response of two-pole broadband bandpass filter with fractional ripple bandwidth of 11% and pair of real-frequency transmission zeros is shown in Fig.2. In addition, the appearance of real-frequency transmission zeros in any type of dual-mode resonator in planar layout were investigated supported by a circuit model and design examples.

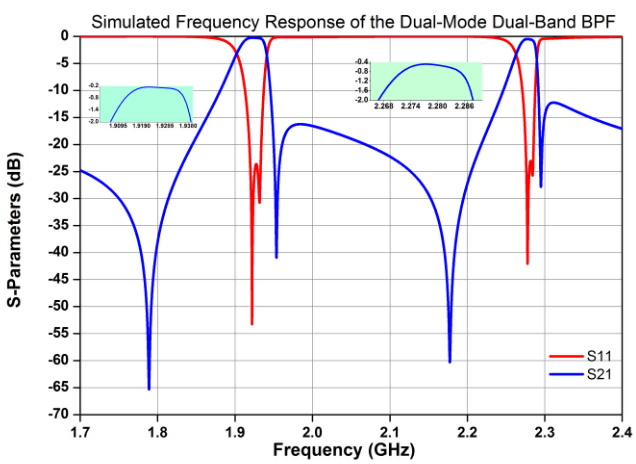

Fig. 3. Simulated Response of the proposed dual-mode dual-band filter [1]

C) Multi-Mode Multi-Band Dielectric Resonator Filters

New class of compact moderate Q factor dual-mode multi-band filters was proposed. The approach used in this work is to use multiple resonances within the same cavity vicinity. The centre frequency of each band can be controlled independently. The simulated frequency response of dual-mode dual-band bandpass filter is shown in Fig.3.

III. Gap-Coupled Multiple Resonances Patch Antennas

Compact directional broadband gap-coupled multiple resonances patch antennas were designed for the Internet of things application, e.g. high resolution positioning. The proposed antennas were linearly polarised with nearly constant gain over the band of operation and high efficiency (>75%). A fractional impedance bandwidth of 62% was achieved in compact size. Approximate equivalent circuits were obtained to study the couplings between multiple resonances. Multi-band response can be achieved by controlling the couplings between resonators. Reconfigurability is attainable by altering the current path using tuning elements [2].

IV. Future Work and Career Plans

My short term goals are to finish PhD in 2018 as well as write several good journal papers. My long term goals concern continuing my learning journey in the domain of science, mainly the field of microwave engineering. I am very interested in doing research related to the big questions in the field, where the art of circuit theory and synthesis wonder side by side with practical applications. I am also interested in developing a good industrial experience. I believe that the ability to break a problem to its abstract form is a powerful tool in both domains, academic and industry.

V. Conclusion

A brief summary of this project main remarks have been presented. Solutions of compact broadband dielectric resonator filters were proposed. In addition, miniature dielectric resonators filters with single and mulit-band operation were attainable with simple architecture. Research on compact broadband patch antennas were carried out using gap-coupled resonators.

VI. Acknowledgment

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