Signal Interference-Based Bandpass Filters with Frequency Reconfigurable In-Band Rejection Bands

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***Abstract*— Wide-band bandpass filters (BPFs) with in-band frequency-agile notches are presented. They are based on series-cascaded transversal signal-interference filtering cells with embedded quasi-absorptive-type notches. Each of these cells is made up of three signal-propagation paths in which one of them is reused by both filtering functionalities. This leads to significantly-smaller size asopposed to conventional solutions based on in-series cascades of separate filtering units. Moreover, the in-band notches can be merged so that the number of active rejection bands is dynamically controlled. For validation purposes, a tunable 2-GHz filter prototype was developed and measured.**

I. Introduction

Broad-band RF front-ends are highly desirable in wide-band radar and communication systems. However, due to the large portions of the electromagnetic (EM) spectrum that their antennas need to acquire, they are vulnerable to unwanted jamming signals. A dynamic interference suppression scenario is shown in Fig. 1. It is based on wide-band bandpass filters (BPFs) with multiple frequency-controllable in-band notches. Current trends towards hardware minimization have revealed the need for co-integrating different RF-analog-processing actions into the same component. As such, this reconfigurable multi-notch filter could be co-synthesized either with the broad-band antenna or the pre-selection wide-band BPF in a dual-functionality circuit approach. Illustrative examples of wide-band antennas with tunable suppressed bands have been proposed in [1], [2]. However, they exhibit poor power-rejection levels and a rather limited number of eliminated bands. In relation to wide-band BPFs with inserted in-band notches, most of the previous contributions are static. Tunable architectures are only shown in [3], [4]. However, they exhibit poor attenuation, narrow-band tuning, and deteriorated selectivity [4].

As an attempt to overcome the aforementioned shortcomings, a class of wide-band BPFs with embedded tunable quasi-absorptive-type notches is proposed. It allows dynamically-reconfigurable notches with high attenuation levels to be realized, as well as the control of the number of rejection bands in the passband.

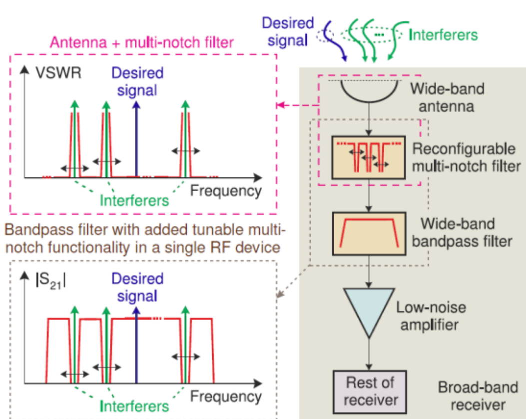

Fig. 1. Block diagram and operational principle of a broad-band receiver with reconfigurable-multi-notch interference-mitigation capabilities.

II. Theoretical Foundations

The circuit architecture and operational principles of the proposed wide-band BPF concept with spectrally-agile in-band notches are shown in Fig. 2. It consists of the in-series cascade of several transversal signal-interference filtering sections (TFSs) [5]. Each of them comprises three electrical paths that are combined and operate as follows: paths 1 and 2 contribute to a wide BPF response, and ii) path—made up of lossy coupled resonators— and path 1 introduce an in-band quasi-absorptive-type notch. Thus, path 1 is reused by both filtering sections. As such, circuit-size and insertion-loss advantages in relation to a conventional in-series cascade approach of a separate wide-passband TFS and a notch filtering unit are attained. The transfer function of each section is determined by the aggregation of the wide-band bandpass and notch filtering actions. By making tunable the notches (by inserting controllable resonators in path 3), a highly-selective broad-band

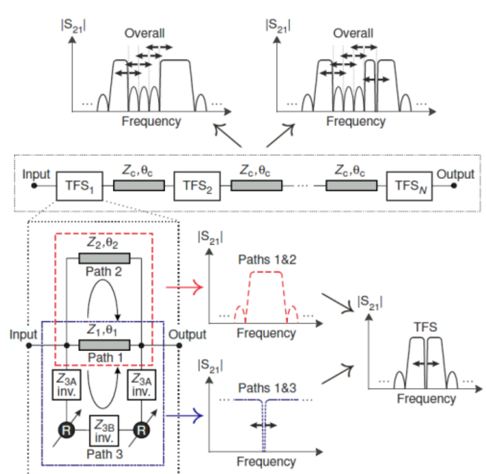

Fig. 2. Proposed filter concept ("TFS": transversal filtering section; "R": resonator; Z: characteristic impedance; θ: electrical length).

BPF with multiple in-band notches can be synthesized. Moreover, the produced adaptive notches can be further exploited to transform the overall wide-band transmission range into a multi-band BPF with/without embedded stopbands. These reconfigurable eliminated bands can also control the bandwidths of the shaped passbands by modifying their cut-off frequencies. Supporting examples of these principles are shown in Fig. 3. As can be seen, by adjusting the resonant frequencies and the quality factors of the resonators, in-band notches with theoretically-infinite attenuation are created. They can be positioned throughout the entire passband range either at separated frequencies or close to each other to shape multi-transmission-zero (TZ) stopbands. This allows the suppression of finite-bandwidth interferences and the separation of the overall passband into multiple transmission sub-bands.

III. Experimental Validation

In order to verify the proposed concept, a two-stage prototype with 2-GHz center frequency and 40% relative bandwidth was developed on a Rogers 4003. Paths 1 and 2 of the TFS were implemented as microstrip lines, whereas path 3 was realized by means of inter-coupled capacitive-loaded resonators. Tuning is achieved through mechanically-adjustable capacitors. Fig. 4 illustrates the manufactured prototype and its RF measured reconfiguration capabilities that were obtained at Purdue University. In particular, Fig. 4(a) demonstrates how the lower notch is spectrally controlled—27-to-46-dB isolation in the range 1.81-1.97 GHz—so that a two-TZ stopband is shaped when the notches are placed in a close proximity to each other.

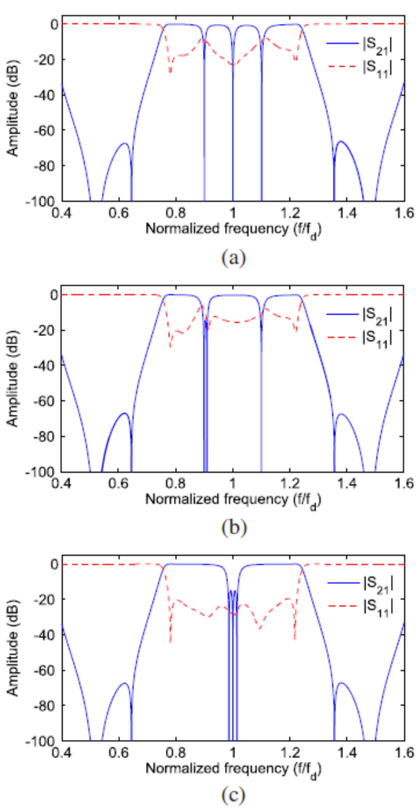

Fig. 3. Theoretical responses of a three-stage design of the filter concept in Fig. 2. (a) Spectrally-separated in-band notches. (b) The two lower in-band notches shape a two-TZ stopband. (c) The three in-band notches shape a three-TZ stopband.

Fig. 4(b) shows upper-notch tuning—44-to-17-dB isolation in the range 1.8-2.16 GHz—along with its spectral merging with the lower one. Note that such a feature enables the control of the number of notches that remain active.

IV. Conclusion

Wide-band BPFs with multiple tunable quasi-absorptive-type notches in their passband have been reported. They exhibit smaller size and lower insertion loss than conventional filter cascades. When compared to prior-art approaches (in [3] and [4]), they feature higher rejection levels (17-46 dB), lower insertion loss (< 1 dB), sharper cut-off slopes, and wider notch-tuning range (1.2:1). Furthermore, they are scalable to arbitrary number of rejection bands. Besides, they allow dynamic control of the number of active rejection bands through band merging which makes them suitable for spectrally-agile multi-interference suppression in broad-band antenna systems.

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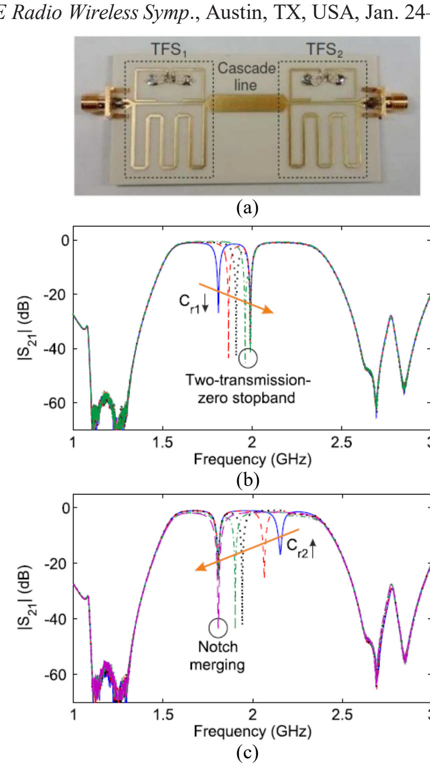

Fig. 4 Manufactured prototype and measured response. (a) Tuning of the lower notch and shaping of a two-transmission-zero stopband when it comes to a close proximity to the upper notch. (b) Tuning of the upper notch and spectral merging with the lower one.