Coalesced Single-Input Single-Output Dual-Band Filter

Chi-Ho Chang, Hsien-Shun Wu, Houng Jay Yang, and Ching-Kuang C. Tzuang

Institute of Electrical Communication Engineering,

National Chiao Tung University, Hsinchu, Taiwan,

e-mail:cktzuang@mail.nctu.edu.tw

Abstract — **An experimental proof-of-concept two-terminal single-input and single-output (SISO) 1.7GHz/4.1GHz dual-band filter is presented. It incorporates the so-call frequency-selective resonators that are composite in structure, cascading a microstrip and microstrip on a two-dimensional periodical surface or the so-called PBG(photonic bandgap) ground plane. The composite resonators add additional degrees of freedom for controlling the relative positions of the passband center frequencies, Thus making the dual-band filters, which essential share one common layout. Measured and theoretical filter characteristics for such coalesced dual-band filter agree excellently, validating the proposed concepts.**

I. Introduction

Growing interests in wireless broadband internet access and high-performance cellular phones demand comparable quality of service (QoS) for similar cost as competing wired technologies [1]. Such demand leads toward the development of MIMO (multiple-input and multiple-output) transceiver system, resulting in the improvement of high spectrum efficiency, reliable transmission and high peak data rates. The MIMO RF front-end, therefore, becomes much more complex than conventional SISO (single-input and single-output) transceiver architecture that was widely employed in the past. A. Hajimiri et al reported the concept of concurrent multi-band low-noise amplifier (LNA), capable of simultaneous operation at two-different bands without dissipating twice as much power or a significant increase in cost and footprint [2]. Such concurrent LNA, when incorporated into the MIMO system, can significantly reduce the complexity of the MIMO RF front-end. On the other hand, multi-band antenna has been under extensive investigations recently [3], and integrated into the wireless products such as WLAN (wireless local area network).

In the above-mentioned advanced RF front-end architectures, filtering of the received and transmitted signals into the LNA and out of the power amplifier, respectively, is necessary to improve the system performance. Miyake et al reported a two-terminal SISO dual-band filter, which combined a 900MHz filter and a 1.9GHz filter by passive LC matching circuits at both input and output ports [4]. The size of such stacked filters increases with the increasing number of bands. This paper presents a dual-band filter which coalesces the resonators at the various bands into one, thus making two filter sharing the same layout and consequently reducing the filter size significantly. To authors' best knowledge, such coalesced SISO dual-band filter is the first of its kind, showing good filter performance.

Section II describes the operational principle of the dual-band filter using the frequency-selective resonators. Section III reports the constructor and simulations of the dual-band filter design. Section IV shows the measured filter performance in good agreement with predictions. Section V concludes the paper.

II. Qualitative Descriptions of the Proposed Dual-Band Filter

The proposed coalesced dual-band filter employs the concept of frequency-selective resonators. Fig.1 illustrates an example of such filter, showing three quarter-wavelength short-circuited stubs resonating

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approximately at 1.7 GHz. The design procedure for such filter is well documented in [5]. The resonators employed in Fig.1, however, are composite in a sense that they are formed by a series connection of a microstrip and a microstrip on two-dimensional periodical array or the so-called PBG (photonic bandgap) surface [6]. The two-dimensional periodical array employed in the filter design had been reported in literature [7].

The first stopband of the PBG surface has been carefully designed to be at 5.0 GHz, which is intended for adding a transmission zero above the second pass band. By properly adjusting the lengths of the microstrip and the microstrip on the PBG surface, respectively, the composite resonators show an effective 1/4£f short-circuited stub at 1.7 GHz (near the open circuit to the right of the Smith chart as shown in Fig.2) and a second open circuit at 4.1 GHz (also shown in Fig.2), rendering a dual-band filter design. Notice that the application of the PBG loading on the resonator moves the next periodical band from 3 f_o to approximately 2.2 f_o (4.1/1.7) in the particular design. As operating frequency increases to 5.0 GHz, the corresponding input impedance of the composite resonator is indeed close to a short circuit as shown in Fig.2, thus introducing a high-side transmission zero above the second passband centered at 4.1 GHz.

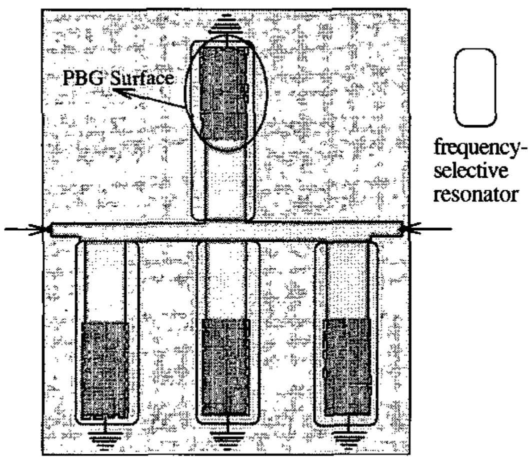

Fig.1 Coalesced SISO dual-band filter structure

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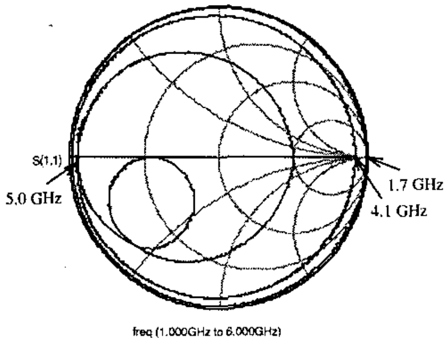


Fig. 2. The simulated input impedance of the frequency-selective resonator as shown in Fig.1

III. DUAL- BAND FILTER DESIGN

To incorporate the PBG surface into the dual band filter design, we apply the multi-layered RO4003™ substrates to realize the filter. The dual-band filter consists of four layers of RO4003™ with thickness of 0.203mm and relative permittivity (£`r) 3.38.

Structure, as seen in Fig.3, consists of the top signal lines in the form of microstrips; the second metal layer is etched away; the third metal layer is used to design the upper PBG surface; the fourth or the bottom metal layer is for making the lower PBG surface and/or the ground plane. Notice also that we connect the short-circuited stubs of the top metal layer to the ground plane (bottom layer) by the plated through holes.

In Fig.3 a pre-preg dielectric layer is sandwiched between the upper and lower dielectric substrates for adhesion. The structural parameters and material constants used in the filter design are listed in Fig.3.

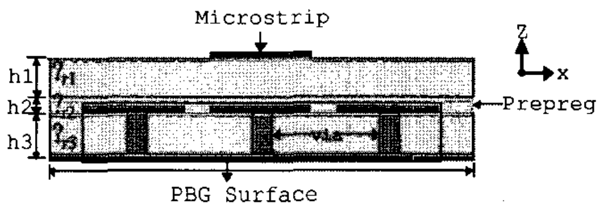


Fig. 3 The microstrip line on the PBG ground plane, cross-sectional view of the complete structure. Cross-sectional view of the coalesced dual-band filter; $h_1 = h_3 = 0.2$ mm, $h_2 = 0.05$ mm, $?_{r1} = ?_{r3} = 3.38$, $?_{r2} = 4.4$.

The circuit simulations of the dual-band filter are based on the ADS^{TM} of Agilent Co. and the full wave simulation therein.

Since the slow-wave propagations are inherent in the PBG surface, we initially offset the center frequencies in the two pass-bands to higher frequencies before adding the PBG ground plane. We tuned the width and the lengths of each microstrip in the series and shunt branches of the filter until obtaining the desired filter responses.

The resultant filter characteristics obtained by the ADS simulations are plotted in Fig.4, showing two pass-band centering at 1.7 GHz and 4.1 GHz as expected. Poorer insertion-losses (shown by S_{21}) are observed for the second passband at 4.1 GHz. The effect of the transmission zero as introduced by the PBG loading in the composite resonator is significant as seen on the high side of the second passband, resulting in more than 55 dB rejections at approximately 1 GHz above the upper corner of the second band.

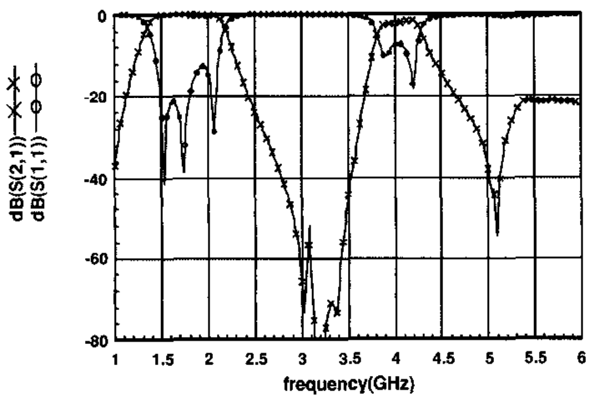
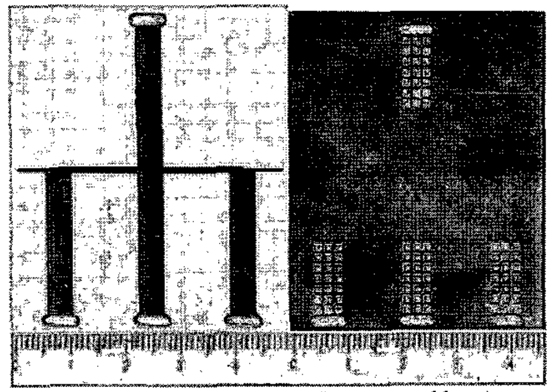


Fig.4 Simulated filter characteristics obtained by ADS^{TM} and its field solver MOMENTUM^{TM}; transmission coefficient S_{21} and reflection coefficient S_{11}

IV. Measurement

Fig.5 shows the photograph of the prototype. It occupies real estate of 50 mm by 50 mm for the proof-of-the-concept design. Fig.6 shows the measured data of the prototype. Excellent agreements between the theoretical data and the measured results are obtained.



(top metal layer) (bottom metal layer)

Fig.5. Prototype photograph of the dual-band filter

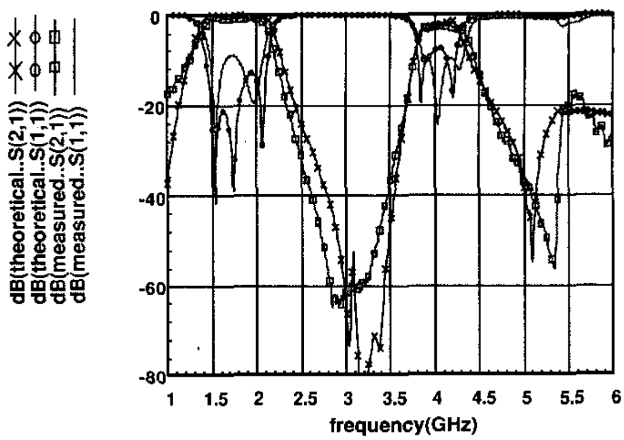


Fig.6 Measured and theoretical filter characteristics; blue (measured) and red (theoretical)

V. Conclusion

A new approach for designing a dual-band filter without resorting the adoption of two filters is presented. The use of the proposed composite resonators for the particular dual-band filter design demonstrates the applicability of such frequency-selective resonance behavior that can control the locations of the center frequencies of two passbands. Measured filter responses agree very well with the theoretical data, validating the proposed approach.

ACKNOWLEDGEMENT

This work was supported by the Ministry of Education of Taiwan under Grant 89-E-FA06-2-4, and by the National Science Council under Grant NSC 91-2219-E-009-025.

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