Design of an Evanescent-Mode Tunable Dual-band Filter

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***Abstract*— This paper presents the design of a tunable dual-band bandpass filter based on evanescent-mode cavity resonators with two capacitive loadings, which results in two independently tunable resonant frequencies. High unloaded quality factor, for both resonant modes, and small filter size is achieved since the two modes share the same physical volume of a single cavity. In addition, the internal and external couplings of the filter can be controlled independently at the two passbands to create flexible frequency responses. An example design of the proposed filter demonstrates: 1) a first tunable passband of 0.875–1.583 GHz with 3-dB bandwidth (BW) of 52–148 MHz and insertion loss (IL) of 3.04–1.07dB, and 2) a second passband of 2.273–3.637 GHz with 3-dB BW of 221–552 MHz and IL of 3.83–0.98 dB.**

***Index Terms*—dual-band filters, tunable filters, evanescent-mode filters**

I. Introduction

Interference mitigation is a critical concern for future multi-band multi-frequency high-frequency communication and sensing systems. Compared to a bank of fixed frequency filters, electronic tunable/reconfigurable bandpass and band-stop filters provide more flexible frequency responses and potentially reduced complexity/loss in signal routing. Dual-and triple-band tunable bandpass filters offer selectivity for multiple signal frequencies concurrently.

Several tunable dual-band bandpass filter designs have been reported in recent years [1]–[4]. Conventionally, dual-band filters are designed by parallel integration of two band-pass filters using duplexing elements, cascading a band-stop filter with a band-pass filter, direct synthesis, and utilization of the even and odd modes of transmission line resonators. The reported dual-band filters are predominantly based on various forms of microstrip line resonators. Although compact in size, such dual-band filters suffer from relatively low unloaded quality factor.

In this paper, we present a novel tunable dual-band filter design methodology based on evanescent-mode cavity resonators with two capacitive loadings. Fig. 1 shows an illustration of a 2-pole tunable dual-band filter consisting of two of such resonators. Each resonator consists of a cavity and two conductive posts, both connected to the resonator on one end. On the other end, the posts are connected to the cavity through varactors whose capacitance can be electronically changed by the reverse bias voltage. Similar to a capacitively loaded coaxial resonator, the first two resonant frequencies of the proposed cavity resonator can be tuned by the loading capacitance and are relatively independent of each other, thus making it possible to design dual-band filters with flexible passband frequencies. Input/output coupling is provided by coplanar waveguides shorted to the cavity by vias. The inter-resonator and external coupling coefficients of the two passbands can be controlled relatively independently by the placement of the loading posts and the input/output coupling structures.

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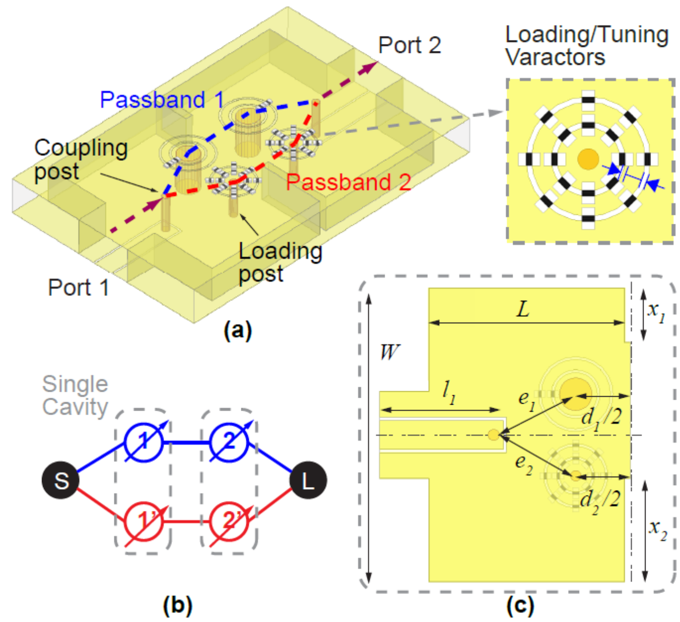

Fig. 1. (a) Concept of the proposed tunable dual-band filter. The inset shows the capacitive loading and tuning scheme using reversed connected varactors. (b) Signal routing diagram of the filter. (c) Top view of one of the resonators with critical dimensions labeled.

II. Design

A. *Resonator Design*

Fig. 2 presents the simulated electric field patterns and the resonant frequencies f_1 and f_2 of the proposed resonator. It is clear from the field distribution plot (Fig. 2-a&b) when one loading post is at resonance, the adjacent post does not introduce significant perturbation to the field pattern. This is confirmed by the resonant frequency plot in Fig. 2-c&d which shows that the tuning of one resonance has negligible effect on the other.

B. *2-Pole Filter Design*

A 2-pole, tunable, dual-band filter is designed, using the above-mentioned resonators, in order to demonstrate the design concept. The inter-resonator coupling between the two resonators is achieved by magnetic coupling through an open

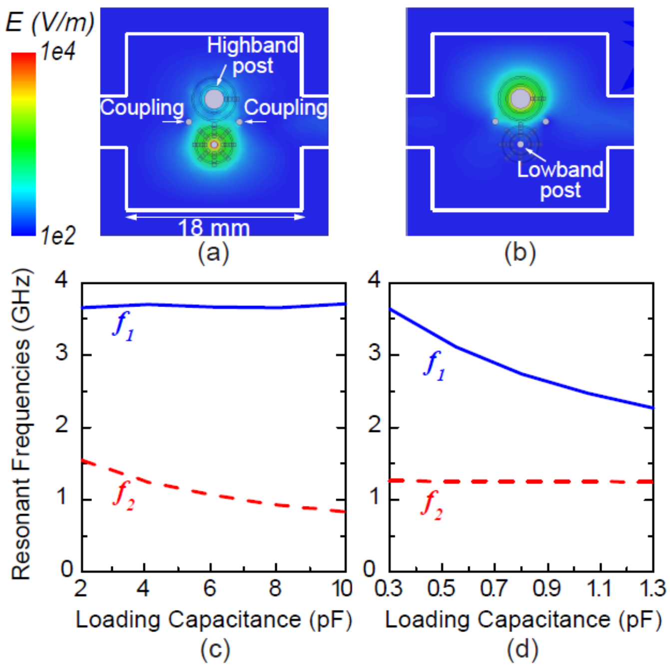

Fig. 2. Simulated field distribution of (a) the lowband resonance and (b) the highband resonance. Simulated resonant frequency change for (c) the lowband tuning and (d) the highband tuning.

window in the resonator sidewall. The coupling coefficient depends on a few parameters, such as the window width (x_1 and x_2) and the positions (d_1 and d_2) of the capacitive posts. A wider window opening generally gives higher coupling coefficients for both bands.

The external coupling is achieved by magnetic coupling between the input/output coupling posts and the capacitive posts. In general, the coupling strength is directly related to the distance (e_1 and e_2) between the coupling post and the capacitive posts. For this design, the y– coordinate of the post was kept fixed for simplicity and the x– coordinate was adjusted by varying l_1.

Using the described procedure, a 2-pole dual-band bandpass filter is designed and simulated using ANSYS HFSS and the results are shown in Fig. 3. Due to the frequency separation between the two pass- bands, two simulations with different solution frequencies are required for each tuning configuration: one for the highband, which includes the wide frequency span; and one specifically for the lowband. This ensures proper convergence of both passbands. The insets in Fig. 3 show the detailed lowband response.

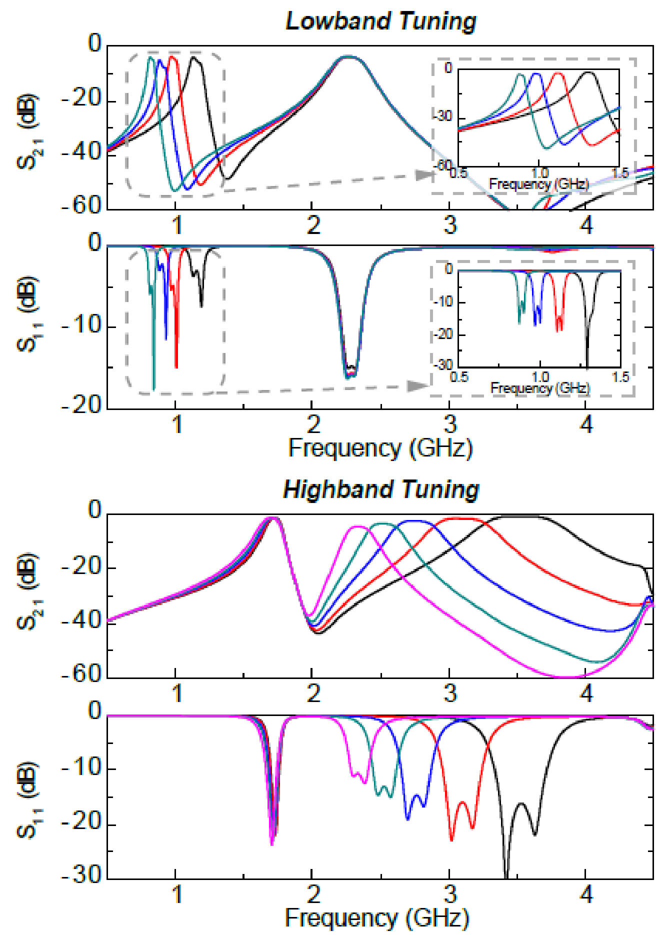

Fig. 3. Simulated tuning performance of the proposed tunable dual-band filter. The insets show the S-parameters from the narrow band simulation for the lowband passband.

III. Conclusion

A tunable, dual-band, bandpass filter with independent frequency control of each passband is presented. The filter is realized using substrate-integrated, evanescent-mode, cavity filters loaded with commercially available varactor diodes. Dual-band operation is demonstrated with tunable passbands ranging from 0.875–1.583 GHz and 2.273–3.637 GHz, for the lowband and highband, respectively. This implementation results in a compact and low-loss dual-band bandpass filter design that can be integrated in reconfigurable front-end hardware for the next generation of adaptable radios.

IV. Scholarship Impact And Career Plans

The IEEE MTT-S Undergraduate/Pre-graduate Scholarship has motivated me to pursue a graduate degree. At IMS 2015, I was able to see many of the cutting-edge research worldwide in RF and microwave. I became interested in several research topics that I would like to explore in graduate school.

Through this research project, I have learned to use the simulation software HFSS and conduct research independently. I wish to continue in the research path and become more knowledgeable and skilled as a researcher.

References

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