Miniaturized Tunable BPFs With Wide Stopband Using Two-Path Complementary Coupling Scheme and Multi-Layer Dual-Mode SIDGS Resonator

Jiacheng Xie, *Graduate Student Member, IEEE,* and Xun Luo, *Senior Member, IEEE*

***Abstract*—In this report, the two-path electric complementary coupling scheme and multi-layer folded dual-mode SIDGS resonator are proposed for tunable bandpass filters (BPFs) with flexible bandwidth control and wide stopband. Based on the multi-layer coupled structure and dual-mode resonator, the tunable BPFs with constant absolute bandwidth (ABW) and independently tunable dual-band are designed and fabricated, respectively. All the tunable BPFs are measured with less than 3.5 dB insertion loss during the tuning range with stopband up to 10 GHz with a rejection level more than 16 dB. Meanwhile, the circuit size of the BPFs is no more than 16 mm × 16 mm.**

***Index Terms*—Constant absolute bandwidth (ABW), dual-band, multi-layer structure, tunable bandpass filter (BPF), SIDGS, wide stopband.**

I. Introduction

In microwave circuit systems, bandpass filters (BPFs) play important roles to select signals within the assigned communication channels and confine out-of-band interferences [1], [2]. To utilize the spectrum efficiently, tunable BPFs are the important research topics due to their agile characteristics, such as continuous multi-passband control. Meanwhile, particular interest is devoted to tunable BPF with constant absolute bandwidth (ABW) to maintain the stable data rate [3] during the entire tuning range. However, only a few reported articles discuss the bandwidth control with stopband suppression and compact size simultaneously, which limits the application. In this report, two-path electric complementary coupling scheme [4] and multi-layer folded dual-mode SIDGS resonator [5] are proposed for the tunable BPF design. These BPFs exhibit reconfigurable passband, wide stopband, and miniaturized size.

II. Third-order Tunable BPF With Constant ABW

For the tunable BPF with constant ABW, the coupling coefficient $k_{i,j}$ is inversely proportional to the tuned center frequency, which has the convex function properties. Conventionally, the coupled line and mixed coupling are used to meet the requirement of $k_{i,j}$. However, both the coupling coefficients exhibit the properties of concave function, while the target curve is a convex function. The discrepancy introduces a large bandwidth variation. To achieve a constant ABW, the two-path electrical complementary coupling is proposed. The couplings on two paths are both electrical and have a positive superposition relationship, while the bandwidth variations are opposite. In this way, the couplings are complementary and contribute to a flat bandwidth within a wide frequency range. In order to verify the proposed two-path electric complementary coupling scheme, a third-order tunable BPF is designed and fabricated, as shown in Fig. 1. Fig. 2 exhibits the simulated and measured responses with a good agreement. The measured frequency range is from 1.26 to 2.00 GHz with the insertion loss of 2.42–3.05 dB. The 3-dB bandwidth is 278 ± 5 MHz (1.8%). The core circuit size of the BPF is 11.3 mm × 9.7 mm (i.e., 0.08 λ_g × 0.068 λ_g, where λ_g is the microstrip guided wavelength at the minimum center frequency at 1.24 GHz). Moreover, the stopband is up to 10 GHz with a rejection level more than 20 dB.

The authors are with the Center for Advanced Semiconductor and Integrated Micro-System, University of Electronic Science and Technology of China (UESTC), Chengdu 611731, China.

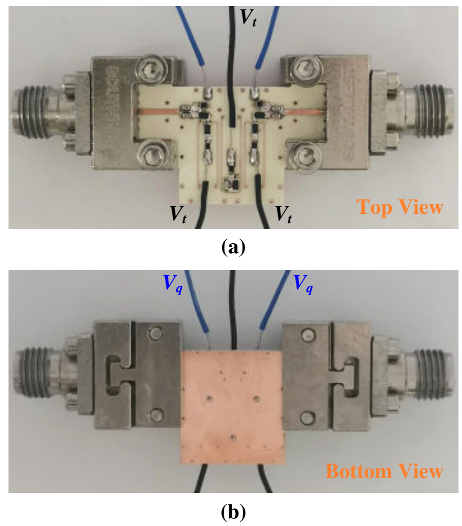

Fig. 1. Photographs of the fabricated third-order tunable BPF. (a) Top view. (b) Bottom view.

III. Independently Tunable Dual-Band BPF

The configuration of proposed dual-band tunable BPF is shown in Fig. 3. Two types of SIDGS cells are implemented at Ground I and Ground III. Such resonators can generate two independently tunable passbands, while the intrinsic harmonic suppression improves the stopband performance. The multi-layer structures are obtained by connecting two cells with buried-vias and attached components at the top layer, which leads to a miniaturized size. Fig. 4 depicts the measured results of the fabricated BPF. The lower passband is tuned from 0.94

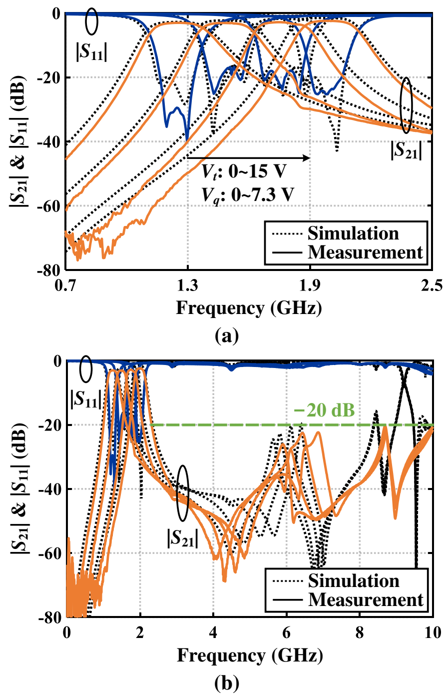

Fig. 2. Simulated and measured results of the third-order tunable BPF.

to 1.12 GHz with the insertion loss varying from 1.78 to 2.46 dB when the upper passband frequency is fixed at 2.72 GHz. The upper passband frequency range is from 2.29 to 2.92 GHz, while the insertion loss is no more than 3.31 dB with the lower passband frequency fixed at 1.12 GHz. The stopband is up to 13.9 GHz (i.e. 12.4 f_{1max}, where f_{1max} is the maximum center frequency of the first passband) with rejection of 22 dB is achieved for all tuning cases. The core size of the proposed filter is 15.4 mm × 15.6 mm (i.e. 0.081 λ_g × 0.082 λ_g, where λ_g is the guided wavelength at 0.94 GHz).

IV. Conclusion

In this report, the two-path electric complementary coupling scheme and folded dual-mode SIDGS resonator are discussed. Based on the proposed coupling scheme and resonator, a series of tunable BPFs are designed, fabricated, and measured. The design prototypes show the merits of good passband performances, wide stopband, and compact size.

V. Acknowledgment and Next Plan

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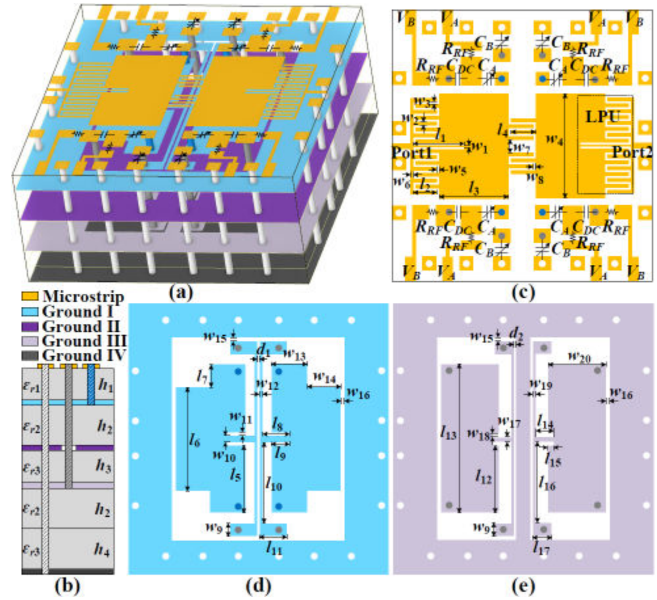

Fig. 3. (a) 3-D view of the proposed tunable BPF. (b) Layer diagram. Details of the (c) top (Microstrip) layer, (d) second (Ground I) layer, and (e) fourth (Ground III) layer.

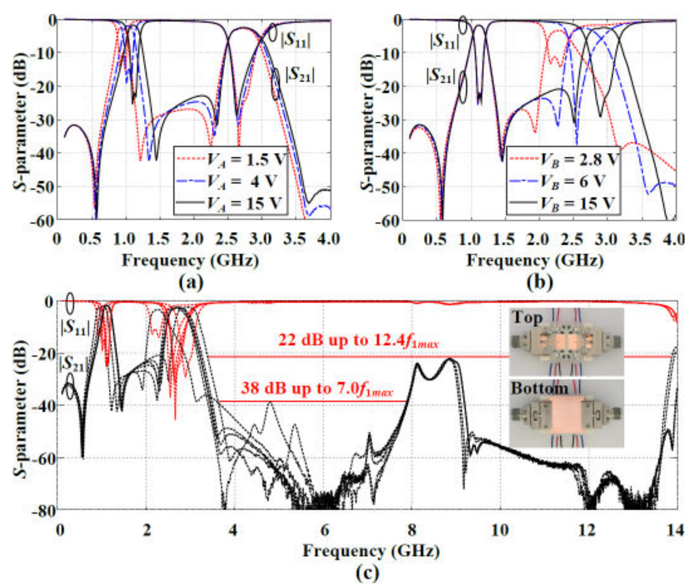

Fig. 4. Measured result of the proposed filter: (a) Lower band tuning (V_B = 6 V). (b) Higher band tuning (V_A = 15 V). (c) Wide stopband characteristics and photograph of the proposed filter (V_A: red wire, V_B: dark blue wire, GND: black wire).

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