Tunable Dual-band Bandpass Filter Using Piezoelectric Transducer (PET)

Dongjin Jung
Advanced Mobile Solutions
Skyworks Solutions, Inc
Newbury Park, CA, USA
david.jung@skyworksinc.com

Kai Chang
Electrical & Computer Engineering
Texas A&M University
College Station, TX, USA
kaichang@tamu.edu

Abstract— **A piezoelectric transducer (PET)-controlled tunable dual-band bandpass filter (DBBPF) is introduced. A dielectric perturber is attached to the end of a PET cantilever beam and suspended above the designed DBBPF. By applying a DC bias voltage, the PET actuator vertically lifts up or pulls down the attached dielectric perturber. The height of the dielectric perturber from the DBBPF determines the effective dielectric constant, causing a variation of the filter's center frequency. The proposed DBBPF provides concurrent dual passband tuning operation for multiband wireless systems.**

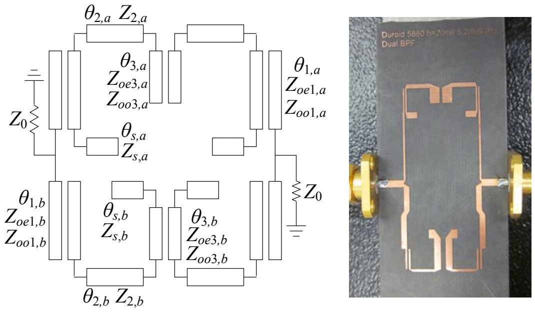
Keywords—piezoelectric transducer (PET); bandpass filter (DBBPF); dielectric perturber

I. INTRODUCTION

Recently, wireless systems using RF/microwave frequency bands are challenged due to limited bandwidth. As a result, systems are requiring frequency sharing operations or actively scanning less congested frequency spectrum to link unoccupied channels. These systems require tunable bandpass filters (BPFs) for multi-band operations. Tunable BPFs were introduced in [1-2]. These designs utilize solid-state devices including varactor diodes and PIN diodes, and also require other circuit elements such as RF coupling capacitors, RF chokes, and DC block capacitors. As a result, fabrication cost increases. Since a tunable BPF based on a single BPF is not enough to cover a broad tuning range, the tunable dual-band bandpass filter (DBBPF) has been presented in [3]. However, as presented in [3], only the upper band can be tuned. A switching function is also necessitated in the tunable BPFs to block undesired frequency channels. In this paper, a low cost tunable DBBPF with a switching function is introduced.

II. DESIGN AND FABRICATION

A DBBPF is designed at 5.2/5.8 GHz for a wireless system that can provide wireless local area network (WLAN) and unlicensed industrial-scientific-medical (ISM) band services. Fig. 1 shows the proposed DBBPF consisting of two BPFs. Each BPF employs coupled step impedance resonators (SIRs) on RT/Duroid 5880 substrate with a thickness of 0.508 mm. The SIR is well described in [4], where the resonant frequency is determined by the SIR's impedance ratio and length. Figs 1a and b present the proposed DBBPF and the fabricated model, respectively. In Fig. 1a, stubs, $Z_{s,a}$ ($\theta_{s,a}$) and $Z_{s,b}$ ($\theta_{s,b}$) are connected to a coupled line in order to tune the amount of coupling. These stubs also allow a simple frequency tuning by changing the line impedance and length. For the 5.2 GHz BPF, the electrical parameters in Fig. 1a are set to: $Z_{oe1,a}$=154, $Z_{oo1,a}$=80, $Z_{2,a}$=68, $Z_{oe3,a}$=44, $Z_{oo3,a}$=38, $Z_{s,a}$=55 Ω, $\theta_{1,a}$=53, $\theta_{2,a}$=37, $\theta_{3,a}$=41, and $\theta_{s,a}$=16 º at 5.2 GHz. For the 5.8 GHz BPF, the electrical parameters in Fig. 1a are found to be: $Z_{oe1,b}$=89, $Z_{oo1,b}$=55, $Z_{2,b}$=91, $Z_{oe3,b}$=85, $Z_{oo3,b}$=55, $Z_{s,b}$=43 Ω, $\theta_{1,b}$=49, $\theta_{2,b}$=38, $\theta_{3,b}$=66, and $\theta_{s,b}$=10 º at 5.8 GHz. Fig. 2 presents EM simulated and measured results, where a transmission zero (TZ) improves a frequency selectivity.



(a) (b)

Fig. 1. Proposed dual-band bandpass filter: (a) equivalent circuit and (b) fabricated DBBPF

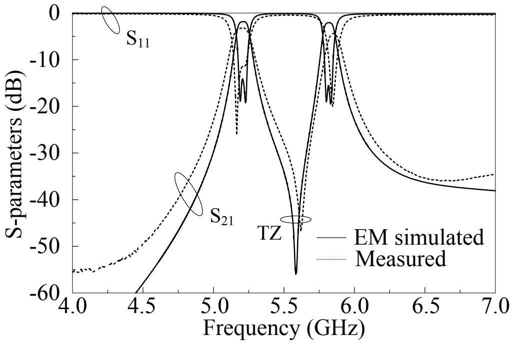


Fig. 2. EM simulated and measured results of designed DBBPF

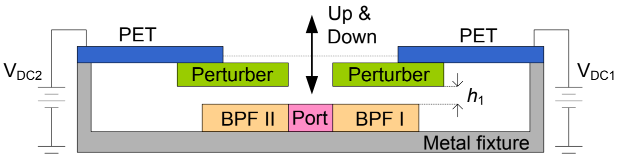


Fig. 3. Cross-section view of designed DBBPF

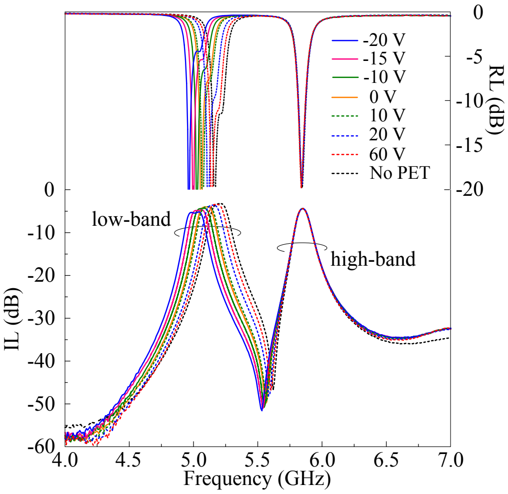


Fig. 4. Measured low-band frequency responses

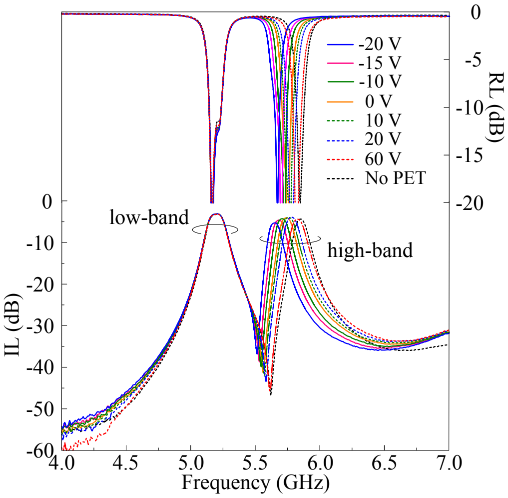


Fig. 5. Measured high-band frequency responses

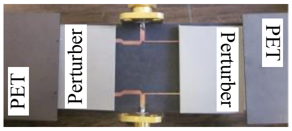


Fig. 6. Fabricated tunable DBBPF with switching function

III. PET-CONTROLLED TUNABLE DBBPF

Tunable microwave circuits utilizing a piezoelectric transducer (PET) have been reported in [5]. Using the PET, a single-band switchable BPF was illustrated in [6]. In this paper, the PET-controlled tunable DBBPF with a switching function is designed and tested. Each passband can independently be controlled by two separate PETs. Two fixed free PET cantilever beams provide mechanical movement for the attached dielectric perturber in the vertical direction as illustrated in Fig. 3. The PET actuator accommodates the dimensions of 57.2 x 31.8 x 2.2 mm^3, which ultimately affects PET response time. The PET used in this experiment has a response time of 5 ms. The PET shows a vertical movement of ±1.3 mm when applying a DC bias of ±60 V. In Fig. 3, h_1 is set to 0.7 mm, which is approximately the center of the PET's deflection range. The perturber's vertical movement creates a progressive frequency shift that can be varied by using the PET to adjust the height of the perturber above the BPF. The frequency shift can be maximized by using a higher permittivity and thicker perturber. The perturber attached to the PET has the permittivity of 10.2 with a thickness of 1.27 mm. Fig. 4 presents the measured S-parameters of the designed tunable DBBPF, where only lower-band is tuned. The average insertion loss of the on-state is smaller than 3.5 dB. For the lower-band (L-band) off-state, the insertion loss is found to be greater than 13 dB. In this off-state, the isolation to the other L-band frequency channels is greater than 25 dB. Fig. 5 shows the measured S-parameters of the tunable DBBPF, where only upper-band (U-band) is tuned. The average insertion loss of the on-state is smaller than 4 dB. For the off-state, the insertion loss is found to be greater than 16 dB. In this off-state, the isolation to the other U-band frequency channels is greater than 35 dB. The fabricated tunable DBBPF is presented in Fig. 6.

IV. CONCLUSION

A tunable DBBPF with a switching function has been presented for multiband wireless applications. The proposed tunable DBBPF provides a concurrent and independent tuning of each lower- and upper- frequency band. The designed tunable DBBPF also shows good switching operations within the frequency tuning ranges.

REFERENCES

[1] A. S. Mohra and O. F. Siddiqui, "Tunable bandpass filter based on capacitor-loaded metamaterial lines," *Electron. Lett*., vol. 45, no. 9, pp. 470-472, April 2009.

[2] J. Long, C. Li, W. Cui, J. Huangfu, and L. Ran, "A tunable microstrip bandpass filter with two independently adjustable transmission zeros," *IEEE Microw. Wirel. Compon. Lett*., vol. 21, no. 2, pp. 74-76, Feb. 2011.

[3] D. Girbau, A. Lazaro, E. Martinez, D. Masone, and L. Pradell, "Tunable dual-band bandpass filter for WLAN applications," *Microw. Opt. Technol. Lett*., vol. 51, no. 9, pp. 2025-2028, Dec. 2008.

[4] M. Makimoto, and S. Yamashita, "Bandpass filters using parallel coupled Stripline stepped impedance resonators," *IEEE Trans. Microw. Theory and Tech*., vol. 28, no. 12, pp. 1413-1417, Dec. 1980.

[5] T.-Y. Yun and K. Chang, "Piezoelectric-transducer-controlled tunable microwave circuits," *IEEE Trans. Microw. Theory and Tech*., vol. 50, no. 5, pp. 1303-1310, May 2002.

[6] W.-H. Tu and K. Chang, "Piezoelectric transducer-controlled dual-mode switchable bandpass filter," *IEEE Microw. Wirel. Compon. Lett*., vol. 17, no. 3, pp. 199-201, Feb. 2007.