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Widely Tunable Surface Acoustic Wave Filters
帯域幅を広く調整できる SAW フィルタ

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1. Introduction

Tunable RF filters are strongly demanded for developing a reconfigurable RF front-end supporting multi-band and multi-standard operation in a transceiver[1)2)]. For their realization, a configuration using surface acoustic wave (SAW) resonators and variable capacitors (VCs) has been investigated[3)].

In this paper, we propose a new configuration of the widely tunable RF filter using SAW resonators and variable capacitors.

2. Widely tunable SAW filters

Fig. 1 shows the circuit topology of newly proposed widely tunable SAW filter. In this configuration, both the series and parallel arms are composed of two pairs of SAW resonators and VCs, respectively. The circuit is designed so that the resonance frequency of the series arm coincides with the anti-resonance frequency of the parallel arm, similar to conventional ladder-type filters.

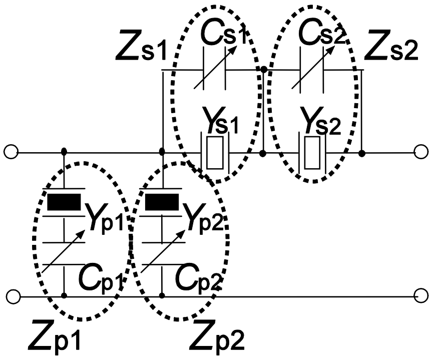

Fig. 1 Circuit topology of proposed tunable filter

Fig. 2 shows a typical transmission response of this circuit. Location of transmission zeros is determined by the condition of Z_{p1}, Z_{p2} = ∞ or Z_{s1}, Z_{s2} = 0. and are given by[3)]

$$f_{Z=\infty} = f_a \sqrt{1 - \frac{1}{\gamma+1} \cdot \frac{C_P}{C_0^P + C_P}}\ , \tag{1}$$

$$f_{Z=0} = f_r \sqrt{1 + \frac{1}{\gamma} \cdot \frac{C_0^S}{C_0^S + C_S}}\ , \tag{2}$$

where f_r, f_a, γ (= $((f_a/f_r)^2-1)^{-1}$) and C_0 are the resonance and anti-resonance frequencies, the capacitance ratio and the clamped capacitance of the resonators, respectively. Thus location of transmission zero is adjustable using VCs (C_P, C_S).

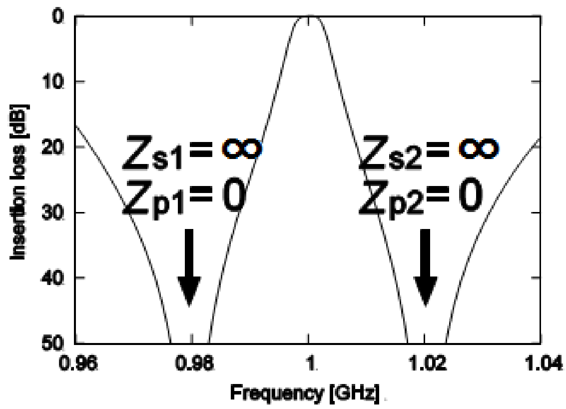

Fig. 2 Typical frequency response of filter

In general, wide tuning range is not incompatible with good out-of-band rejection. A solution for this problem is to combined with fixed bandpass filter with good out-of-band rejection for frequencies out of tunable passband range.

Fig. 3 shows a frequency response of the tunable filter cascaded with a fixed frequency BPF. Comparison of this figure with Fig. 2 indicates that the out-of-band rejection is improved significantly without deteriorating the passband characteristic.

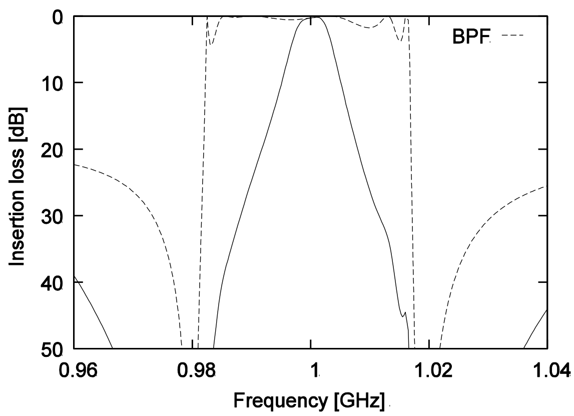

Fig. 3 A frequency response of tunable filter combined with fixed frequency BPF.

Similar to conventional ladder-type filters[4)], we

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can improve the pass-band and transition-band characteristics by cascading multiple stages in Fig. 1 with mirror inversion.

Fig. 4 shows impact of the cascade connection. It is seen that the passband becomes flat and the transition bands become narrow when the number of stages is increased to three from unity.

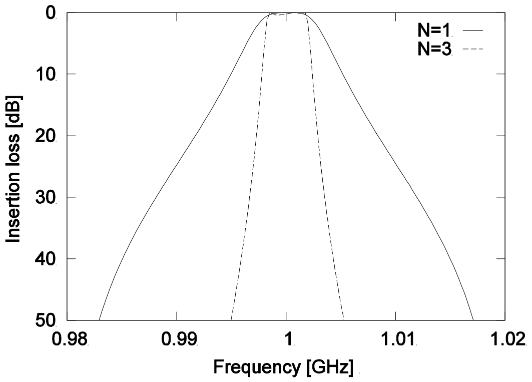

Fig. 4 Improvement of the frequency response by the cascade connection of multiple stages.

Achievable performances are further investigated for the filter with N=3. Design data for SAW resonators and VCs are shown in **Table I**. The Q factors of the SAW resonators and VCs are assumed to be 1000 and 50, respectively, and γ is set at 15.

Table I. Parameters used for the simulation

(a) SAW resonators

	Resonance frequency [GHz]	Clamped capacitance [pF]
P1	0.972	4.0
P2	1.032	1.6
S1	0.938	6.0
S2	0.996	3.0

(b) VCs

	Design A	Design B	Design C	Design D
C_{p1} [pF]	1.2	1.9	3.0	5.0
C_{p2} [pF]	5.5	2.2	1.5	1.2
C_{s1} [pF]	2.4	6.0	8.0	14.4
C_{s2} [pF]	10.8	6.4	4.2	2.2

Fig. 5 shows the simulation result. It is seen that the passband width is continuously adjustable for more than four times. Although the insertion loss increases with a decrease of the passband width, its increase is not so significant except Design A. This tendency is intrinsic. Namely the minimum insertion loss is governed by $N\gamma/Q$[4], and γ effectively increases with a decrease in the passband width. Thus use of resonators with large Q is necessary to improve the insertion loss.

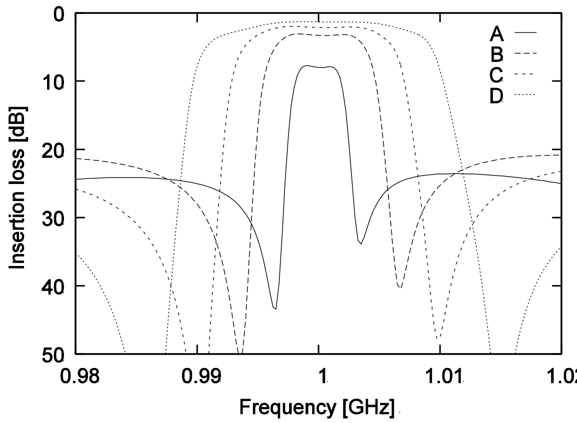

Fig. 5 Simulated frequency response of tunable filter. For Design A to D, -3 dB bandwidths are 4, 8, 12 and 18 MHz, respectively. Insertion losses of Design A to D are 8.0, 3.3, 2.1 and 1.3 dB, respectively.

3. Conclusion

This paper proposed the widely tunable RF filter using SAW resonators and VCs. Its bandwidth is adjustable to more than four times.

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