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Spurious-free and steep band rejection filter using $LiTaO_3$/quartz HAL SAW resonator

LT／水晶 HAL SAW 共振子を用いたスプリアス特性に優れかつ急峻な帯域阻止フィルタ

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1. Introduction

Surface and bulk acoustic wave (SAW and BAW) filters are key RF devices in mobile phone systems (1, 2). Acoustic wave filters strongly require better steepness of passband and a smaller temperature coefficient of frequency (TCF), because Tx, Rx and/or neighboring bands are very close in frequency for some bands (e.g. Band 8, 22 and 25). In addition, spurious-free characteristic at high frequency is required especially for carrier aggregation system.

To date, a lot of studies have been conducted for a better frequency characteristic and a smaller TCF of SAW devices, and several successful devices were reported (1, 3, 4, 5). Recently, we developed hetero acoustic layer (HAL) SAW resonators using a $LiTaO_3$ (LT) thin plate with a negative TCF and a quartz substrate with a positive TCF (5, 6). The HAL SAW resonator exhibits three advantages, which are a large impedance ratio (i.e. high Q factor) (82 dB at 470 MHz), a near-zero TCF (2 ppm/K at series resonance) and spurious-free characteristic up to 14 GHz.

In the past study, we prototyped a band rejection filters using a fundamental mode (0-th) shear horizontal type plate wave (SH_0) resonators on 30ºYX $LiNbO_3$ (LN) (7). Although the band rejection filters can be frequency-tunable thanks to a large bandwidth of the SH_0 resonators, the steepness is not satisfactory. In this study, band rejection filters were prototyped using LT/quartz HAL SAW resonators. If a spurious-free, steep band rejection filter is available, it is useful as a filter removing a specific frequency in a wide frequency range.

2. Experimental method

The HAL SAW resonator consisting of 0.63 μm thick 25ºYX LT and a 42º45’Y90ºX quartz substrate was used. The frequency characteristics of the HAL SAW resonator is shown in Fig. 1. The characteristics of parallel and series types of band rejection filter were measured as the two-port transmission (S21) characteristics of the HAL SAW resonator having input and output electrodes to measure a rejection filter as shown in the insets of Figs. 2 and 3. The resistance R in the figures is 50 Ω, which is the input and output impedance of a network analyzer.

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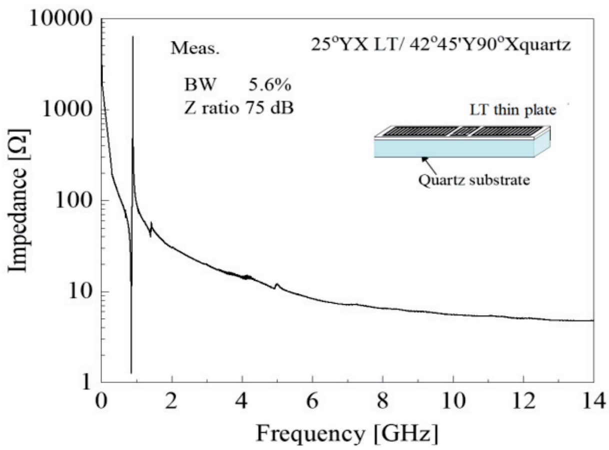

Fig. 1 Measured wide frequency characteristic of HAL SAW resonator composed of 25°YX LT plate bonded 42°45’Y90°X quartz substrate.

3. Evaluation of band rejection filters

Figs. 2 and 3 show the measured frequency characteristics of the parallel and series types of band rejection filter, respectively. As a reference, the frequency characteristic of a band rejection filter calculated from the measured result of a 30ºYX LN SH_0 resonator (8) is shown in each figure (blue dashed line). The resonance frequencies of the HAL SAW and the SH_0 resonators are 1.2 GHz and 560 MHz, respectively. For comparison, the frequency of each filter is normalized by its resonance frequency in Figs. 2 and 3. The HAL SAW band rejection filters have better steepness of attenuation than the SH_0 ones.

Figs. 4 and 5 show wider frequency characteristics of the parallel and series HAL SAW band rejection filter, respectively. No significant spurious response is observed up to 6 GHz. The parallel type has small insertion loss below the rejection frequency, while the insertion loss at high frequency is large, -8 dB at 6 GHz. On the other hand, the series type has negligible insertion loss at high frequency up to 6 GHz, while the insertion loss below the rejection frequency is large, -3 dB at 0.5 GHz.

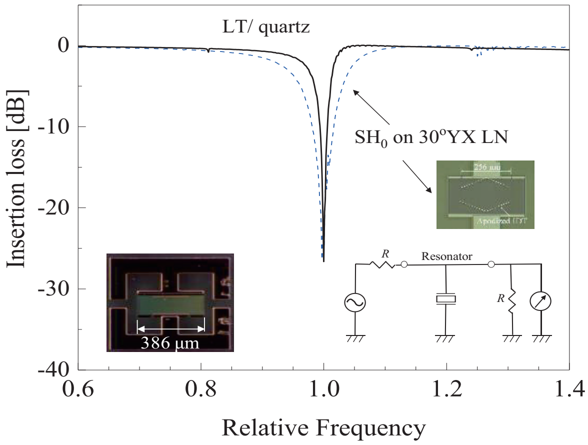

Fig. 2 Measured frequency characteristics of parallel type rejection filters. Solid line: HAL SAW based, Blue broken line: SH_0 based.

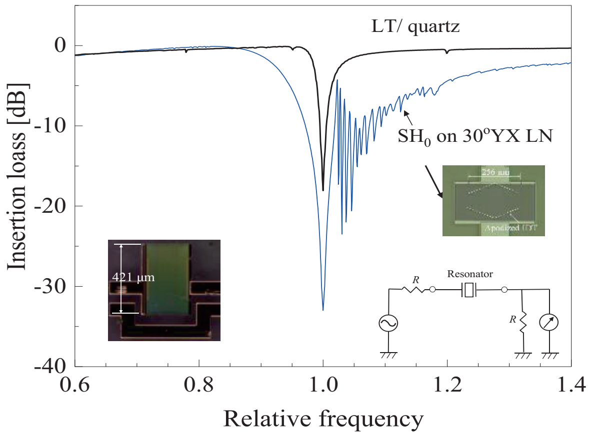

Fig. 3 Measured frequency characteristics of series type rejection filters. Solid line: HAL SAW based, Blue broken line: SH_0 based.

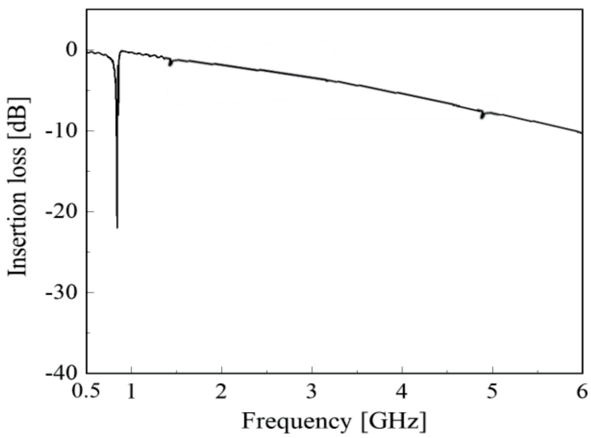

Fig. 4 Measured wide frequency characteristic of parallel type HAL SAW rejection filter.

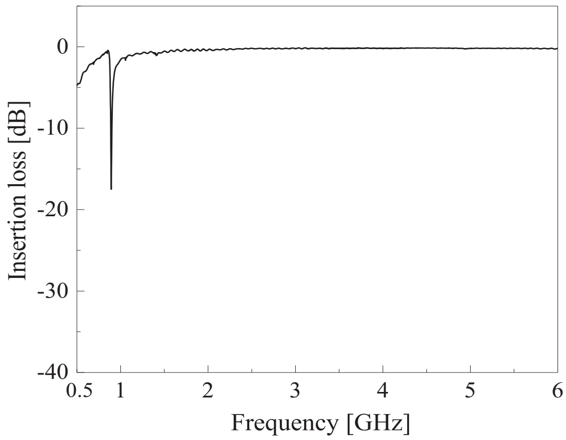

Fig. 5 Measured wide frequency characteristic of series type HAL SAW rejection filter.

4. Conclusion

Parallel and series band rejection filters at 0.9 to 1.2 GHz were prototyped using a LT/quartz HAL SAW resonator. Steep attenuation was obtained thanks to a large impedance ratio of the HAL SAW resonator. In addition, there is no obvious spurious response up to 6 GHz thank to a spurious-free characteristic of the HAL SAW resonator. The temperature characteristic was not evaluated in this study, but it is considered very stable judging from an excellent TCF of the HAL SAW resonator. The HAL SAW band rejection filter may be useful for IoT and carrier aggregation.

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