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Proceedings of Symposium on Ultrasonic Electronics, Vol. 37 (2016)

16-18 November, 2016

Tunable rejection filters with ultra-wideband using SH_0 plate wave resonators
複数個の SH_0 板波共振子を用いた周波数可変超広帯域帯域阻止フィルタ

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1. Introduction

Currently, the wide spread of smartphones and other mobile terminals has led to the depletion of available frequencies. To address this problem, cognitive radio technology using a vacant frequency band of digital TV (DTV) channels (TV white space), which is standardized as IEEE 802.11af, is receiving a lot of attention.[1)] This technology requires tunable filters with a wide tunable frequency range from 470 to 710 MHz and a tunable bandwidth (BW) of 5, 11 or 23 MHz. However, such a tunable filter is very challenging due to a limited electromechanical coupling factor (k^2) of resonators, a limited quality factor (Q) of variable capacitors etc.

To address the above problem, we proposed a system combining a wideband filter fully covering the DTV band and tunable band rejection filters.[2)] The former was demonstrated using 0-th shear mode (SH_0) plate wave in a (0º, 117.5-120º, 0º) $LiNbO_3$ thin plate (thickness < 0.1λ), which had k^2 larger than 50%[3)4)]. The fractional bandwidth of the ladder filter reaches 51% at 6 dB BW.[5)] The latter, i.e. the band rejection filter, also needs wide rejection band and wide tunable rejection frequency range. The band rejection filter with a wider rejection band was obtained by connecting several wideband resonators with different frequencies in parallel or series. A wide tunable range was obtained by connecting Si diode variable capacitors.

2. Band rejection filter using a resonator

Band rejection filters is obtained by connecting the $LiNbO_3$ thin plate SH_0 resonator in parallel and series, as numerically simulated in **Figs. 1** and **2**, respectively.[2)] The rejection frequency of the parallel type (Fig. 1) and the series type (Fig. 2) corresponds to the resonance (f_r) and anti-resonance frequency (f_a) of the resonator, respectively, and can be controlled by changing a capacitance connected to the resonator. The observed rejection bands at 10 dB attenuation are 19 MHz (3.5%) and 23 MHz (4.4%) in width, respectively, which are too narrow for the aimed application.

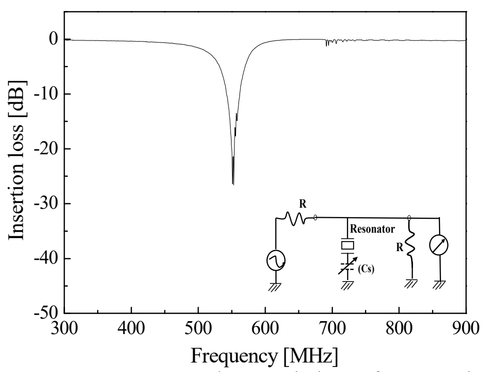

Fig. 1 Frequency characteristic of numerically-synthesized parallel type band rejection filter.

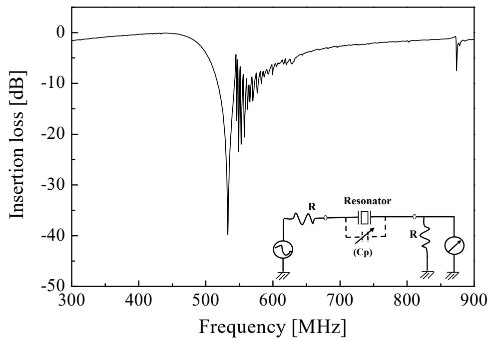

Fig. 2 Frequency characteristic of numerically-synthesized series type band rejection filter.

3. Band rejection filter with wide rejection band

A parallel type band rejection filter composed of three resonators with different frequencies (35 MHz separation each other) was fabricated. **Fig. 3** shows a sample and its frequency characteristic. The observed rejection band of 122 MHz (23.4%) is 6.4 times wider than that in Fig. 1.

A series type band rejection filter composed of two resonators with different frequencies (35MHz different) was fabricated. **Fig. 4** shows a sample and its frequency characteristic. The rejection band of 87 MHz (13.6%) is 3.8 times wider than that in Fig. 2. Thus, a wide rejection band is obtained by using several resonators with different frequencies.

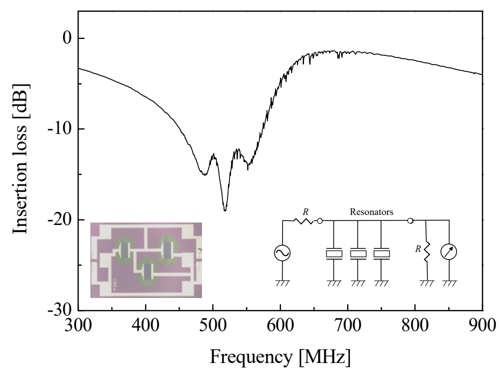

Fig. 3 Measured frequency characteristic of parallel type rejection filter composed of three resonators with different frequencies.

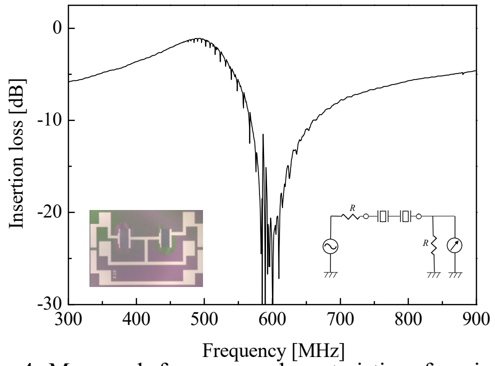

Fig. 4 Measured frequency characteristic of series type rejection filter composed of two resonators with different frequencies.

4. Tunable rejection filter with Si diodes

A wide rejection band is obtained by using several resonators with different frequencies, and a large tunable frequency range is realized by connecting Si diodes to the resonators. A tunable rejection filter was fabricated by using radio frequency Si diodes, JDV2S71E (Toshiba Semiconductor).

Fig. 5 shows the measured frequency characteristics of a parallel type rejection filter using three resonators and three Si diodes. The rejection frequency was controlled in a range of 66 MHz (12.6%).

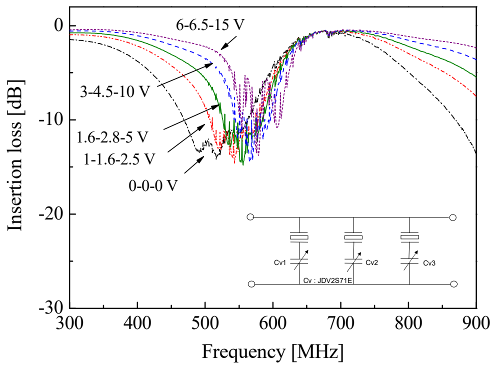

Fig. 5 Measured frequency characteristics of parallel type rejection filter when different voltages are applied to each Si diode. For example, "1-1.6-2.5V" means that 1, 1.6 and 2.5 V were applied to C_{v1}, C_{v2} and C_{v3}, respectively.

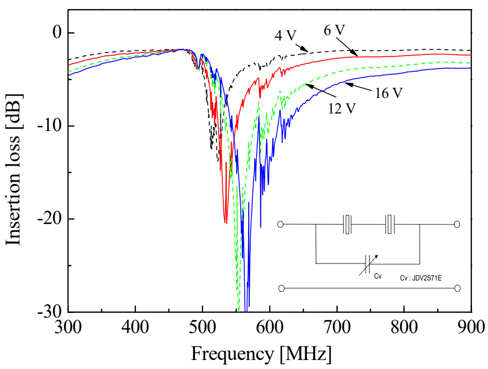

Fig. 6 Measured frequency characteristics of series type rejection filter at different voltage application to Si diodes.

Fig. 6 shows the measured frequency characteristics of a series type rejection filter using two resonators and one diode. The rejection frequency was also largely controlled in a range of 58 MHz (9.4%). **Fig. 7** shows the frequency characteristics of another type band rejection filter composed of three resonators and two diodes connected in parallel. A larger tunable rejection frequency range of 163 MHz (31%) was obtained.

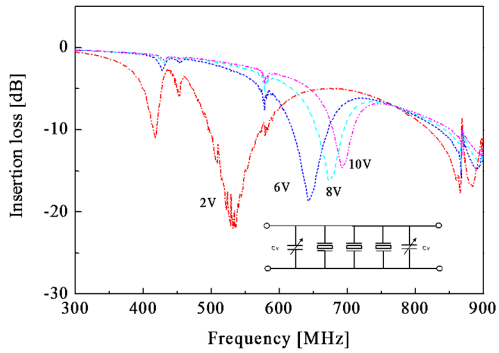

Fig. 7 Frequency characteristics of band rejection filter composed of three resonators and two Si diodes connected in parallel.

5. Conclusion

An ultra-wideband resonator using SH_0 plate wave on $LiNbO_3$ was applied to wide band rejection filters and tunable rejection filters. Wide rejection bands were obtained using the several resonators with different frequencies. Tunable rejection filters were constructed using Si diodes connected to the resonators. Wide tunable ranges up to 31% were measured by applying DC voltage to the Si diodes. Such rejection filters can be applied to cognitive radio systems.

Acknowledgment

This research was supported by Strategic Information and Communications R&D Promotion Program (SCOPE). We would like to thank Dr. Y. Hori and Mr. T. Tai at NGK Insulators Company and Dr. H. Takagi at Advanced Industrial Science and Technology (AIST), who helped us with the fabrication of the devices. A part of this work was supported by "Nanotechnology Platform" of the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan, at the Center for Integrated Nanotechnology Support, Tohoku University.

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