Proceedings of Symposium on Ultrasonic Electronics, Vol. 32 (2011) pp. 215-216
8-10 November, 2011

Band Pass Type Tunable Filter using SAW Resonator composed of Grooved Cu Electrode on $LiNbO_3$

SAW 共振子を用いたバンドパス型チューナブルフィルタ

Michio Kadota, Yasuyuki Ida†, Tetsuya Kimura (Murata Mfg. Co., Ltd.)
門田　道雄，伊田　康之†，木村　哲也　(村田製作所)

1. Introduction

Surface Acoustic Wave (SAW) devices are key components in general use for duplexers and filters in cellular phone and Mobile communication.[1] The cellular phones in recent years have multi-band circuits corresponding to several telecommunication systems. Furthermore, a cognitive radio system to use a limited frequency source a effectively is actively researched.[2] They requires a tunable filter with a wide tunable range. An ultra wide band SAW resonator is effective to fabricate the tunable filter.

Authors fabricated SAW resonators having a ultra wide bandwidth of 17% composed of a grooved Cu-electrode/4°YX-$LiNbO_3$ structure. And, the authors proposed and simulated the application of this resonator to a tunable filter consisting of a conventional band pass filter circuit.[3] In this paper, the authors report that characteristics on the band pass type tunable filter using Si diode variable capacitors and a dependence of capacitor's Q on insertion loss of the tunable filter.

2. Ultra wide band SAW resonator

Figure 1 shows a dependence of electro-mechanical coupling factor on (a) a conventional structure of a Cu electrode on 4°YX-$LiNbO_3$ and (b) a structure of grooved Cu-electrode/4°YX-$LiNbO_3$ as a function of the Cu thickness.

The coupling factor was calculated by using FEM.[3] In the area of Love wave shown by the solid line in Fig. 1, the structure of (b) grooved Cu-electrode structure has a large coupling factor. Where λ is a wavelength. Figure 2 shows the measured frequency characteristics of one-port SAW resonators composed of the 2 kinds of structure (a) and (b) at the Cu-electrode thicknesses of 0.1λ. The bandwidth of (b) structure is very wide as 17 % than (a) structure. A resonant impedance of (b) structure is low than one of the (a) structure. An anti-resonance impedance of (b) structure has small ripples slightly. Their ripples, which are affected by slow shear bulk wave, can be fixed by increasing the metallization ratio.[4][5]

E-mail: kadota@murata.co.jp

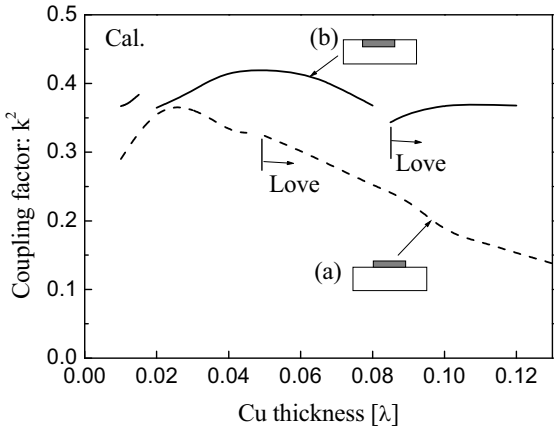


Fig.1 Electro-mechanical coupling factor on (a) conventional structure of Cu electrode on 4°YX-$LiNbO_3$ and (b) grooved Cu-electrode /4°YX-$LiNbO_3$.

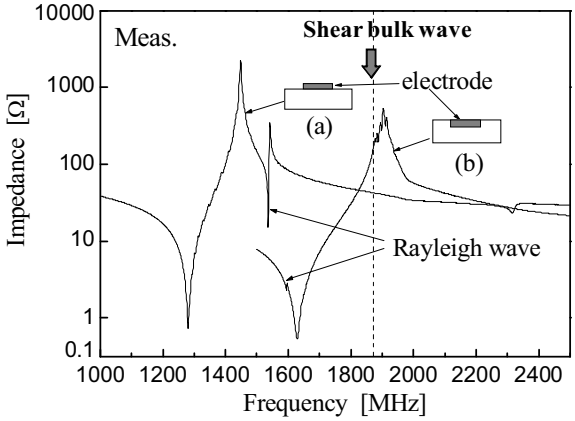
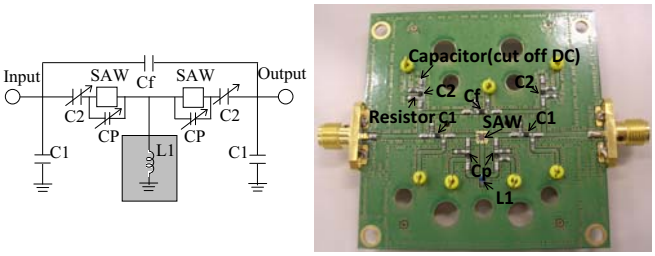


Fig.2 Frequency characteristics of SAW resonators composed of (a) and (b) structures in Fig. 1.

3. Application to band pass type tunable filter using Si diode variable capacitors

A Q of the inductance (L) component of the SAW resonator is higher than one of a conventional inductor. A tunable filter with tunable range of 7 % was simulated by using the L component of the SAW resonator in a circuit shown in Fig. 3(a) instead of conventional inductors by the authors.[3][4] This time, the authors tried to fabricate a band pass type tunable filter shown in Fig. 3(a) using Si diode variable capacitors (JDV2S71E: Toshiba). Figure 3(b)

shows a PCB mounting the tunable filter composed of the Si diode variable capacitors and the SAW resonators. The parts of Cp, Cf, and C2 are Si diode variable capacitors. By applying voltage from 1.2V to 10V to the variable capacitors, the frequency is continuously shifted as shown by solid lines in Fig. 4. This tunable frequency range is 6.1 %. On the other hand, dashed lines in Fig. 4 are calculated characteristics where Q of the variable capacitor is infinite (∞). The Si diode variable capacitor has very small Q as 1 in high frequency of 1.8GHz. Therefore, insertion loss has been significantly degraded from 10 to 12dB than results calculated using capacitors with Q=∞. The insertion loss of the tunable filters measured using interdigital capacitors (IDCs) with Q=5 were larger 2 to 3dB than ones calculated using the capacitors with Q=∞. The Q of the variable capacitors is an important parameter in order to fabricate a tunable filter with low loss. Figure 5 shows calculated insertion losses on various Q of the variable capacitor; (a) Q=∞, (b) 50, (c) 30, (d) 5, and (e) 1. As shown in Fig. 5, Q = 50 is no degraded. However, The Q less than 20 degrades largely the insertion loss.



(a) circuit (b) tunable filter composed of Si diode variable capacitors

Fig.3 (a)Circuit and (b)PCB of tunable filter composed of Si diode variable capacitors and SAW resonators.

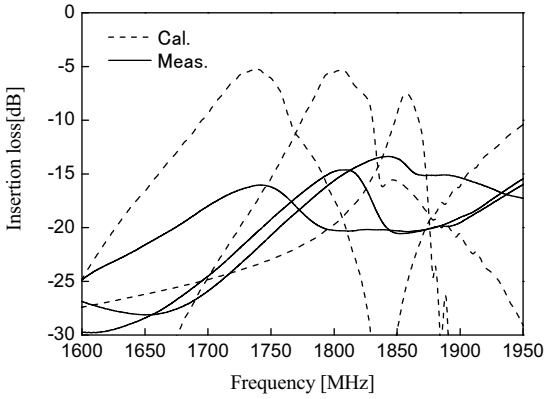


Fig.4 Frequency characteristics of band pass type tunable filter using Si diode variable capacitors.

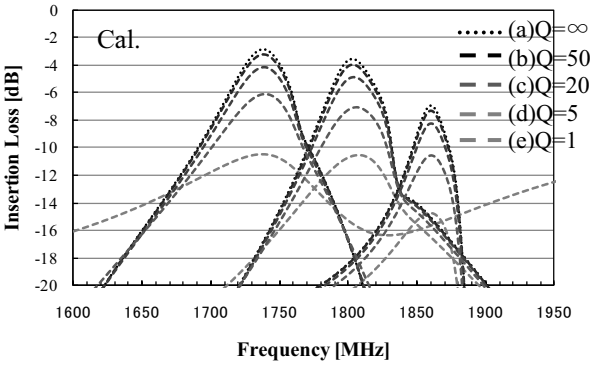


Fig.5 Calculated frequency characteristics on various Q value of variable capacitor

4. Conclusion

SAW Resonator composed of the structure of grooved Cu-electrode/4°YX-$LiNbO_3$ has a ultra wide band of 17 %. The authors fabricated a band pass type tunable filter using the SAW resonators and the Si deiode variable capacitors. The tunable frequency range of 6.1 % was continuously measured by appling the voltage to the variable capacitors. However, Q of the capacitors is low as 1 , so insertion loss is very large. In order to realize a low-loss tunable filters, capacitors with high Q are very important components.

Acknowledgment

This research is granted by the Japan Society for the Promotion of Science (JSPS) through the "Funding Program for World-Leading Innovative R&D on Science and Technology (FIRST Program)," initiated by the Council for Science and Technology Policy (CSTP).

References.

[1] M. Kadota: Jpn. J. Appl. Phys. **44**, 6B (2005) 4285.

[2] H. Harada: IEICE vol.J91-B, No.11, (2008-11) 1320.

[3] M. Kadota, T. Kimura and Y. Ida: Proc. IEEE Ultrason. Symp., (2009) pp. 2668-2671.

[4] M. Kadota, T. Kimura and Y. Ida: Jpn. J. Appl. Phys. **49** (2010) 07HD26-1-4.

[5] M. Kadota, T. Kimura and Y. Ida: IEEJ Trans, Electronics Information and Systems, vol131, No.6, pp.1108-1114 (2011).