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Ultra Wide Band Resonators using SH Type Plate Wave and their Application

SH 型板波を用いた超広帯域共振子とその応用

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1. Introduction

Currently, a mobile or smart phone with multi-bands and a cognitive radio system require a tunable filter with a wide tunable range to simplify their circuits (1). An ultra wide band resonator is an important device to realize the tunable filter. Though SAW resonators with a relative bandwidth (BW) of 12 to 17 % were reported, their BWs are not sufficient to apply the tunable filter (2)(3).

There are two kinds of plate waves such as Lamb wave and shear horizontal (SH) wave. The Lamb wave is suitable for high frequency devices, but is not for wide band devices (4)(5). This time, authors tried to fabricate SH mode plate wave resonators in $LiNbO_3$ thin plates to obtain a wider BW. As a result, the resonators with an ultra wide BW of 29% and a large impedance ratio of 98dB between resonance (fr) and anti-resonance (fa) frequencies were obtained for the first time. Applying their resonators to a band pass type tunable filter, a wide tunable range of 15 % was obtained.

2. Plate waves

Figure1 shows the electromechanical coupling factor of an SH_0 mode on Euler angle (0º, θ, 0º) $LiNbO_3$ at the thickness 0.05 to 0.35λ as the function of θ. A large electromechanical coupling factor k^2 than 0.53 is obtained at around θ=120º (rotated angle = 30º) at the thin plate. The thinner $LiNbO_3$ thickness is, the larger the electromechanical coupling factor of SH_0 mode becomes.

Next, a piezoelectricity in the structure of an intergidital transducer (IDT) on the plate is considered. Frequencies of fr and fa and relative BW are obtained from stopband frequencies calculated by finite element method (FEM) (3). BW is defined (fa-fr)/fr.

Three kinds of structures of (a) Al-IDT/$LiNbO_3$ thin plate (b) Al-IDT/$LiNbO_3$ thin plate/short plane and (c) Al-IDT/$LiNbO_3$ thin plate/Al-IDT are considered. Figure 2 shows their BWs on the 28ºYX-$LiNbO_3$ plate thickness at the Al IDT of thickness of 0.0001λ and the IDT metallization ratio (MR) =0.3. The (b) structure doesn't have a wide BW. The (a) and (c) structures have wider BW than 30% at thin plate. Figure 3 shows the BW of the (a)

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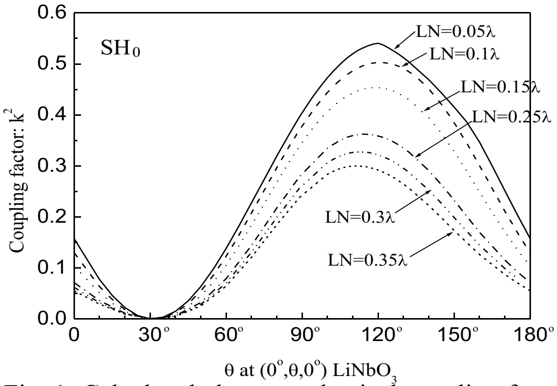

Fig. 1. Calculated electromechanical coupling factors on various Euler angle (θ) in $LiNbO_3$ plate (0º,θ,0º) at $LiNbO_3$ thickness of 0.05λ to 0.35λ.

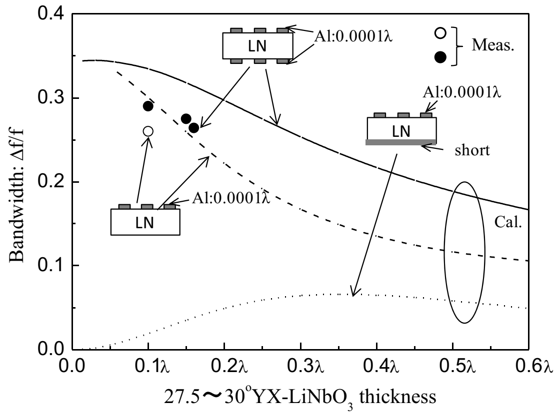

Fig. 2 Calculated and measured relative BWs of SH_0 mode plate wave in (a) Al IDT/$LiNbO_3$, (b) Al IDT /$LiNbO_3$/short plane and (c) Al IDT/$LiNbO_3$/Al IDT at MR of IDT=0.3 and Al thickness=0.0001λ as function of plate thickness. (●and○: meas.)

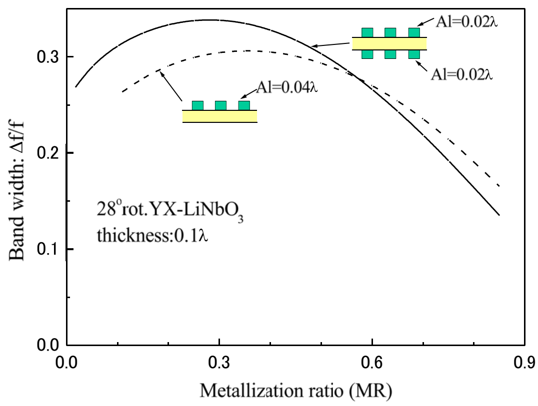

Fig.3 Calculated relative BWs of SH_0 mode plate wave in (a) Al IDT/28°YX-$LiNbO_3$ and (c) Al IDT/28°YX-$LiNbO_3$/Al IDT at plate thickness of 0.1λ and Al total thickness 0.04λ as function of MR.

and (c) structures of the SH_0 mode on the Al IDT of 0.04λ total thickness on the plate of 0.1λ thickness as the function of MR. Ultra wide BWs of 31 and 33 % are obtained at MR of around 0.35 and 0.25, respectively, and their BW are about twice as wide as the widest BW reported up to now (3).

3. Fabrication and measurement of resonators

The resonators composed of the (a) and (c) structures are fabricated. The SH_0 mode resonators composed of Al IDT on a 27.5 to 30ºYX-$LiNbO_3$ plate of 0.1λ, 0.15λ, and 0.16λ thickness were fabricated. The IDT is composed of the λ of 2 and 1.9mm, MR of 0.3, aperture of 20λ and 10λ, and Al thickness of 0.0001λ. Two kinds of IDT pairs of 23 and 40 were fabricated in (a) structure and 40 pairs in (c) structure. The resonators were used a reflection of SH_0 mode on edges of the plate instead of grating reflectors. Black ((c)structure) and white ((a)structure) circles in Fig. 2 show measured results. Figure 4 shows their measured frequency characteristics. The dot and broken lines show ones with 23 and 40 pairs of IDT in (a) structure at 0.1λ plate thickness, respectively. The solid line shows one with 40 pairs of IDT in (c) structure. The characteristics in Fig. 4 are normalized and the two characteristics are slightly shifted right and left to observe easily. They have ultra wide bandwidths of 25 to 29% and large impedance ratio of 83 to 98 dB.

4. Application to BP type tunable filter

The above-mentioned two SH_0 plate wave resonators of (a) structure with ultra wide band composed of 23 and 40 IDT pairs are applied to a band pass (BP) type tunable filter using a circuit shown in Fig.5. Selecting several kinds of fixed capacitors, the tunable range of 15 % was obtained as shown in Fig.6. This tunable range is 2.5 times of the previous BP type tunable filters reported by the authors (3). An application of their SH_0 mode resonators to a ladder type tunable filter is one of future works.

5. Conclusion

The SH_0 mode plate wave resonators having an ultra wide band of 29 % and large impedance ratios of 98 dB were realized, which is widest and largest, respectively, compared with resonators reported up to now. Applying the two resonators to the tunable filter, the very wide tunable range of 15 %, which is 2.5 time compared with previous reports[3], was realized.

Acknowledgment

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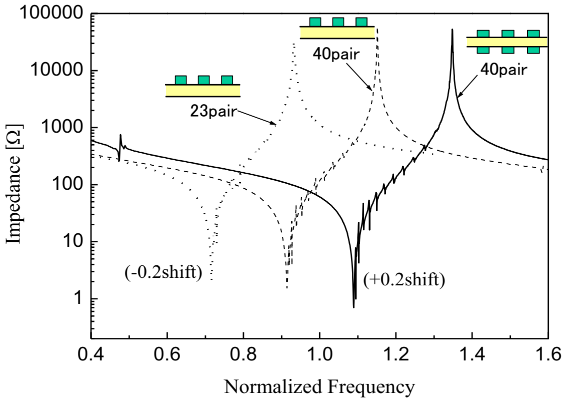

Fig. 4 Measured frequency characteristics of SH_0 mode in (a) Al IDT /$LiNbO_3$ with IDT of 23 and 40 pairs and (c) Al IDT/$LiNbO_3$/Al IDT with 40 pairs at MR of IDT=0.3.

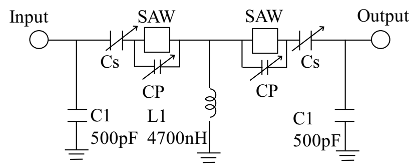

Fig.5 BP type circuit of tunable filter.

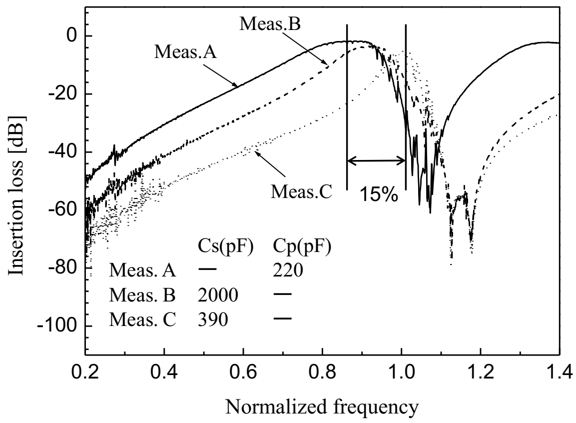

Fig.6 Measured frequency characteristics of tunable filters.

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