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Ultra-wideband T-type Ladder Filters using 0th Shear Horizontal Mode Plate Wave in $LiNbO_3$ Plate

LiNbO3 薄板上の SH0 モード板波を用いた広帯域 T 型ラダーフィルタ

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1. Introduction

In recent years, surface acoustic wave (SAW) and bulk wave thin film devices have been key devices in smart phone and mobile phone systems. Meanwhile, plate waves are receiving a lot of attention, because of properties such as a high phase velocity or a large electro-mechanical coupling factor k^2 (referred as coupling factor hereafter), which is different from above-mentioned SAW and bulk wave.[1,2)]

The first anti-symmetric (A_1) mode of Lamb wave has a phase velocity higher than 15,000 m/s when the plate is very thin.[1)] On the other hand, 0th mode SH (SH_0) plate wave in a thin (0º, 117.5-120º, 0º) $LiNbO_3$ plate has an electro-mechanical coupling factor k^2 larger than 50%.[2)]

Authors reported resonators with an ultra-wide bandwidth (BW) of 22% using a plate of 0.065λ to 0.081λ thickness, which was self-suspended on a Si substrate.[3)] Where λ is a pitch of interdigital transducer (IDT) and BW of the resonator is defined as (anti-resonance frequency (f_a) – resonance one (f_r)) / f_r.

The authors also reported resonators π-type ladder filters with apodized IDT. However, insertion losses, bandwidths at 3 dB attenuation, and shape factors of the filters were not reported in detail.[4)]

This time, the authors fabricated ultra-wideband T-type ladder filters with various different IDT pitch ratios (PR= IDT_p/IDT_s) between parallel and series arm resonators composed of three resonators using the SH_0 mode plate wave resonators. Insertion losses from 0.8 to 1.6 dB, 3 dB BWs from 39% to 49%, which fully cover Japan and USA digital TV bands (470 to 710 MHz), and shape factors (20 dB BW/3 dB BW) from 1.15 to 1,27 by changing IDT PR. All of them depend on the PRs.

2. Fabrication of T-type ladder filters

Based on a simulation, T-type ladder filters composed of three SH_0 resonators were fabricated using a (0º, 120º, 0º) $LiNbO_3$ plate of 0.61 and 0.62 μm thickness. The $LiNbO_3$ plate was bonded with a Si substrate, and polished down to the designed thickness. The IDT was fabricated on the plate and the Si under the IDT was etched.

Table I shows the specifications of the T-type ladder filters. The pitch ratios (PRs) of IDTs of the parallel/series resonators are 1.32 to 1.47. The parallel and series resonators have the same number of IDT finger pairs and apertures. The IDT is not apodized.

Fig. 1 shows the measured frequency characteristics of the T-type ladder filters with PRs of 1.32, 1.39 and 1.47. Figs. 2, 3, and 4 show the peak insertion losses, 3 dB BWs, and the shape factors (20 dB BW/3 dB BW) as a function of PR, respectively. They depend on the PRs.

The lowest peak insertion loss is as low as 0.8 dB. However, the peak insertion loss is slightly larger when the PR is large.

3 dB BWs from 39% to 49%, which is larger than previously reported, are obtained. The BWs fully cover for Japanese digital TV (DTV) band (41%) with a margin. Therefore, it is useful to replace the low pass filter with less than 710 MHz

	Parallel arm	Series arm
Center frequency (MHz)	590	
Plate thickness (μm)	0.61	
Normalized thickness	0.07 to 0.08λ	0.103 to 0.08λ
Al IDT thickness (μm)	0.21	
Normalized thickness	0.025 to 0.027λ	0.036 to 0.037λ
Pitch of IDT : λ (μm)	7.81, 8.05, 8.31	5.91, 5.59, 5.65
IDT pairs	60	
Apodized ratio of IDT	0%	
Aperture (λ)	40 to 60	
Metallization ratio of IDT	0.34 (design)	
Grating reflector	30 to 40 fingers each	
Pitch ratio of IDTs (PR)	1.32, 1.39, 1.47	
Euler angle	(0º, 120º, 0º)	

Table I Design specifications of ladder filters.

used in the up-conversion system reported in Ref. 5 with this filter.

The shape factor is obtained from 1.15 to 1.27. The shape factor is close to 1.0, which is its ideal value, when the PR is large.

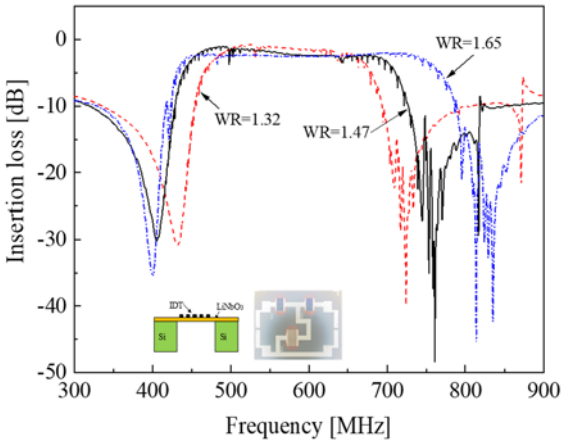

Fig. 1 Measured frequency characteristics of fabricated T-type ladder filters with PRs of 1.32.

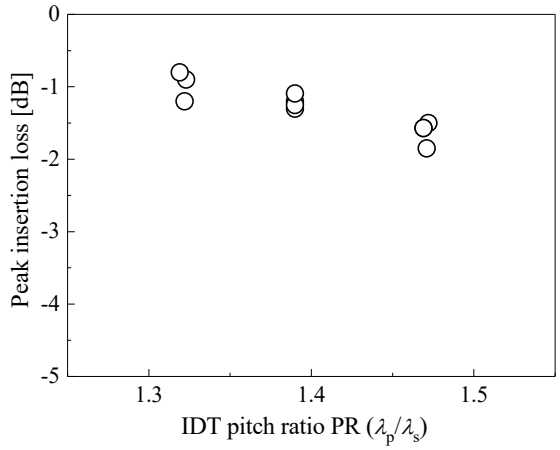

Fig. 2 Measured peak insertion loss of T-type ladder filters with PRs of 1.32, 1.39 and 1.47.

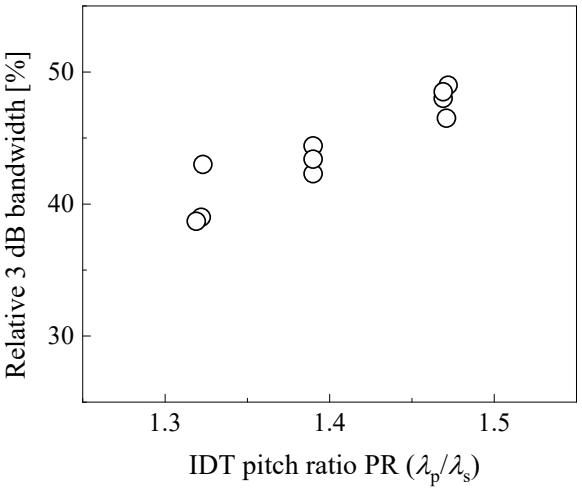

Fig. 3 Measured 3 dB BWs of T-type ladder filters with PRs of 1.32, 1.39 and 1.47.

Therefore, a filter characteristic should de designed considering BW, shape factor and insertion loss

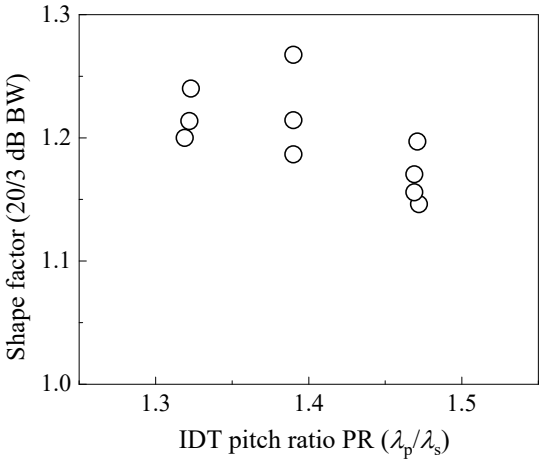

Fig. 4 Measured shape factors of T-type ladder filters with PRs of 1.32, 1.39 and 1.47.

3. Conclusion

Ultra-wideband T-type ladder filters with various different IDT pitch ratios using the SH_0 mode plate wave resonators. Ladder filters with low insertion losse 0.8 dB, ultra-wide 3 dB BW of 49%, and steep shape factor of 1.15 were obtained. All of them depend on the PRs. Desired filter characteristics could be obtained by changing PR.

Acknowledgements

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