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Piston like design for longitudinal resonance suppression on SAWs

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1. Introduction

Longitudinal modes cause spurious resonances in high Q one-port surface acoustic wave (SAW) devices for in the passband of ladder-type filters. Konaka, et al., proposed two ways for their suppression: adjusting gap length between reflector and IDT[1)], and adjusting the periodicity of the reflector to suppress longitudinal resonance[2)].

This paper examines applicability of the piston mode design[3),4)] for the longitudinal mode suppression instead of the transverse mode suppression.

2. Piston mode design for longitudinal mode suppression

Fig. 1 shows a left half of the 'piston-like' resonator structure for the longitudinal mode suppression. In the figure, the velocity profile is also shown. The electrode period p_{ref} of the reflector is set longer than that p_{I1} of the main IDT region (Zone 1) so that the SAW field is evanescent near the main resonance. A supplemental IDT (Zone 2) with the periodicity p_{I2} is inserted between the main IDT and the reflector, and p_{I2} is set larger than p_{I1} so that this region serves as a phase shifter necessary for the piston mode.

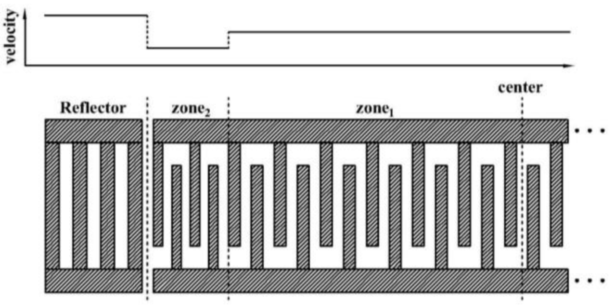

Fig. 1 'Piston-like' design and SAW velocity profile

This profile shifts the stopband of the reflector leftward as shown in Fig. 3. The transverse modes may occur in the overlap frequency region between the stopband of the reflector and that of the main IDT. Phase shift given by the supplemental IDT adjust the SAW reflection phase at the boundary between the main IDT and the reflector to zero as if mechanically free.

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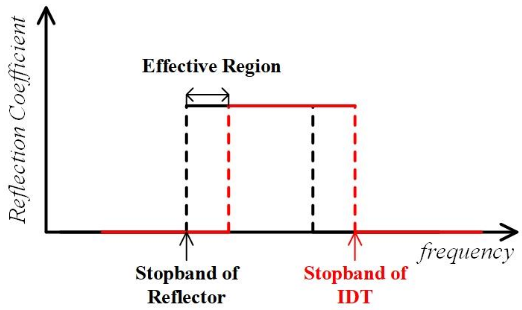

Fig. 2 Stopband of reflector and IDT

3. COM analysis

Following to the design guideline described above, the 'piston-like' resonator is designed based on the traditional coupling of modes (COM) theory[5)].

Table I shows COM parameters used for the design. in this paper. The number of electrode pairs for the IDT (main N_{IDT1} + supplemental N_{IDT2}) and reflector are 100 and 30, respectively, and p_{I1} is 1.96 μm.

Table I. COM parameters used for simulation

parameter	value
Phase Velocity, V_p	3,825 m/s
Group Velocity, V_g	V_p/1.1
Reflectivity, κp_I	0.05π
Excitation Efficiency, $4\zeta^2 p_I/\omega C$	0.0429π

Fig. 3 shows the variation of calculated admittance Y and conductance G with F_r=p_{I1}/p_{ref} when F_2=p_{I1}/p_{I2}=1.01 and N_{IDT2}=7. The dash lines represent the stopband of reflector. It is seen that F_r decrease shifts the stopband leftward. Owing to existence of the phase shifter, spurious peaks in the stopband and below the main resonance are relatively weak and well suppressed when F_r=0.98. Series of transverse modes are seen below and above the reflector stopband, they are relatively weak because they occur at frequencies relatively far from the IDT stopband edges.

The stopband width becomes wider with a decrease of F_r. This is because of the SAW velocity dispersion in the grating structure.

Note that when F_r is too small, the upper edge of the reflector stopband becomes close to the antiresonance, and the resonator performances are degraded. In addition, the separation between the antiresonance and the reflector stopband is necessary for the ladder-type filter synthesis.

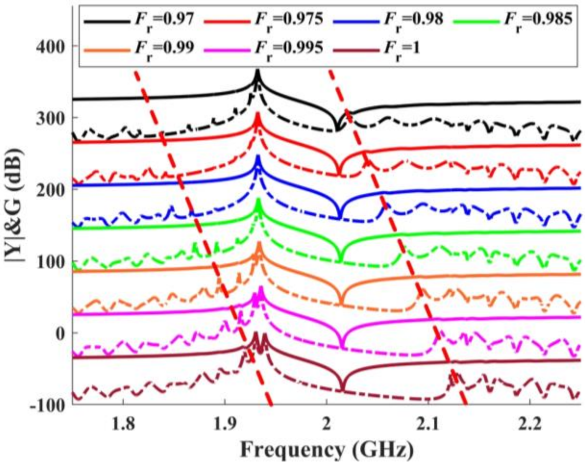

Fig. 3 Variation of $|Y|$ and G with F_r when F_2=1.01 and N_{IDT2}=7. Red broken lines: reflector stopband edges.

Fig. 4 shows variation of calculated admittance Y and conductance G with N_{IDT2} when F_r=0.975 and F_2=1.025. It is seen that longitudinal modes in the reflector stopband can be suppressed well when N_{IDT2}=2, and further increase of N_{IDT2} causes split of the main resonances. This is due to excess phase shift in the region 2.

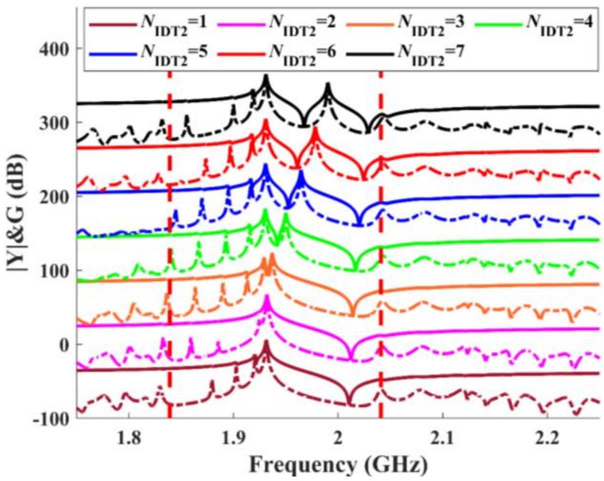

Fig. 4 Variation of $|Y|$ and G with N_{IDT2} when F_2=1.025 and F_r=0.975. Red broken lines: reflector stopband edges.

Fig. 5 shows variation of Y and G with F_2 when N_{IDT2} and F_r=0.975. Similar to Fig. 4, longitudinal modes in the reflector stopband can be suppressed well when F_2=1.015, and further increase of N_{IDT2} causes split of the main resonances. Comparison of these two figures indicates that setting smaller F_2 and larger N_{IDT2} are preferable for the longitudinal mode suppression for a wide frequency range. This may be because small F_2 may give smaller variation of the phase shift with the frequency.

Fig. 6 shows the amplitude distribution at 1.9GHz, while the F_2=1.015, F_r=0.975 and N_{IDT2}=5. The vertical dash lines represent the region 2. The amplitude distribution indicates that the slow region effectively suppresses the generation of longitudinal modes. Furthermore, the energy is effectively confined to the IDT region.

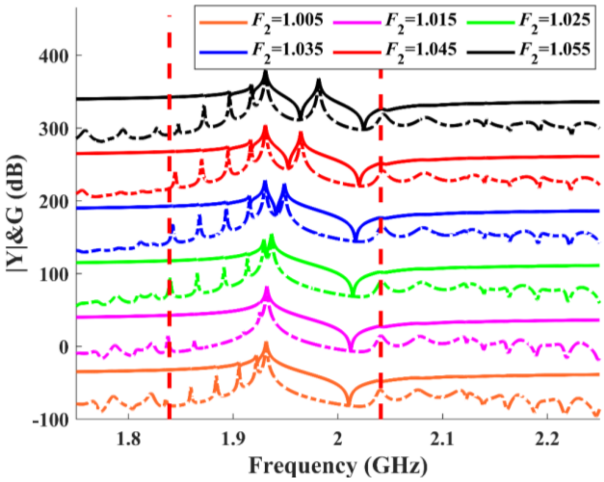

Fig. 5 Variation of $|Y|$ and G with F_2 when N_{IDT2}=5 and F_r=0.975. Red broken lines: reflector stopband edges.

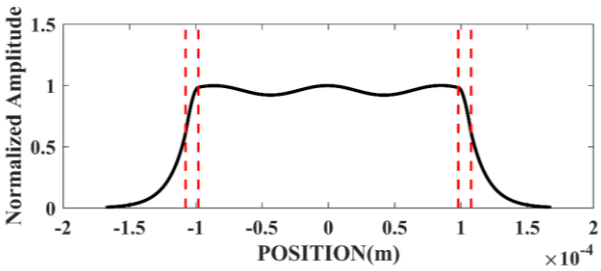

Fig. 6 Example of amplitude distribution

4. Conclusion

In this paper, we designed a 'piston-like' structure by adding an additional electrode region at the end of IDT, and its operation was confirmed.

As a next step, we will check possibility to expand the reflector stopband width by adjusting the metallization ratio for the reflector.

Acknowledgment

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References

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