2P3-1

Modelling of in-plane diffraction in SAW resonator based on COM model

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1. Introduction

It is well known that the side leakage occurs when the SAW velocity V_B in the busbar region is slower than that V_I in the aperture region. [1),2)] Recently, the authors showed that this side leakage always occurs due to finite aperture width W and/or IDT length N_I and limits achievable Q factors of current high-performance SAW resonators[3),4)], namely, TC-SAW using bulk LN wafer and I.H.P. SAW using an LT thin plate bonded with a support substrate[5),6)].

Fig. 1 shows the Fourier transform in the wavenumber (β_x) domain of displacement field near the main resonance in a SAW resonator toward the main propagation direction. Owing to the resonance, the two peaks appear in the spectrum at $\pm\pi/p$ where p is the grating period. Since the peak widths are finite, the spectrum is nonzero even when $|\beta_x|$ is small, and those with $|\beta_x|<\omega/V_B$ contributes to the lateral leakage. Larger aperture length results in narrower peak width and weaker side leakage.

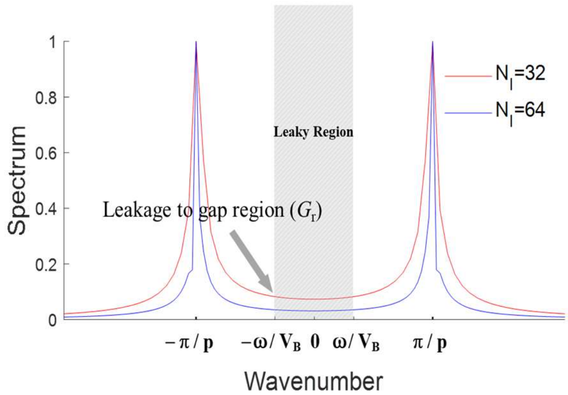

Fig. 1 Spectrum in the wavenumber (β_x) domain of the displacement field in IDT region.

This work proposes a simple model for this side leakage. Its outline is as follows:

1. The conventional coupling-of-modes (COM) model is used for the field estimation in the aperture region, and its result is used to estimate SAW field in the busbar region.
2. The Fourier spectra with $|\beta_x|<\omega/V_B$ are integrated and leaked power is estimated.

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2. Analysis

In this paper, the TC-SAW using the SiO_2/128-LN structure is employed for the discussion.

Fig. 2 shows the structure used for the following analysis. It is seen that copper stripes are applied for transverse mode suppression. The structural parameters are taken from Ref. [3].

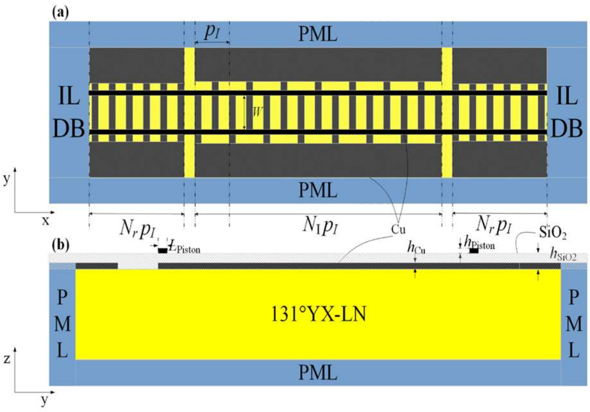

Fig. 2 TC-SAW resonator: (a) top view; (b) cross section (IDT).

Note that no additional loss is not included in the simulation.

First, parameters used in traditional 1D COM model for admittance characterization of the structure in Fig. 2 are extracted by fitting full-2D FEM simulation of the aperture region. The results are shown in Fig. 3, where results calculated by full-2D FEM, full-3D FEM and traditional COM theory are compared when N_I=128, W=12.8p_I.

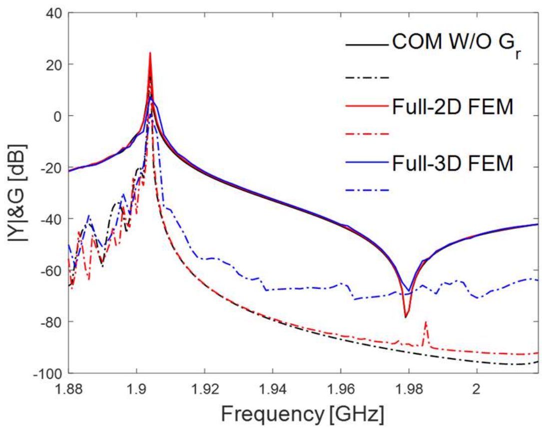

Fig. 3 Admittance curves calculated by traditional COM model and FEM model.

It is seen in Fig. 3 that the conventional COM theory can explain the full-2D FEM results well on transverse modes and effective electro-mechanical coupling factor k^2_{eff}, but not the Q decrease near the anti-resonance which is experimentally observed, too. Only the full-3D FEM can express this behavior.

Next, the impact of diffraction is calculated. In the calculation, the parabolic approximation is applied for the SAW dispersion in the gap region.

Fig. 4 the relative conductance (G_r/G_{SAW}) estimated by the model, where f_B is the cutoff frequency of the lateral leakage, and G_{SAW} is the conductance calculated by the conventional COM model. It is seen that G_r/G_{SAW} increases with frequency and takes a maximum at f=f_B. The side leakage occurs when f>f_B.

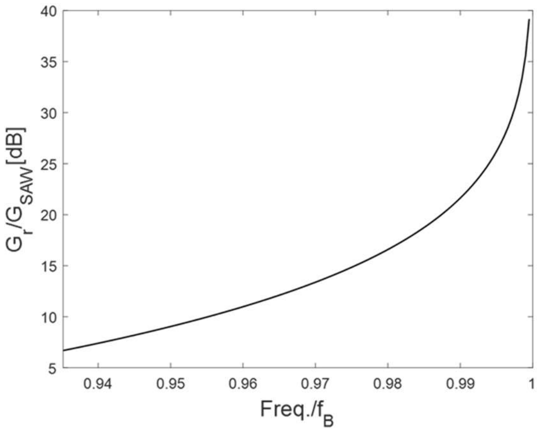

Fig. 4 Calculated radiation conductance G_r caused by side leakage based on proposed model.

3. Including of in-plane diffraction

Fig. 5 compares admittance curves obtained by this model with those obtained by the full-3D FEM. It is seen that the f dependence appearing in the full-3D FEM can be explained by G_r inclusion to the COM.

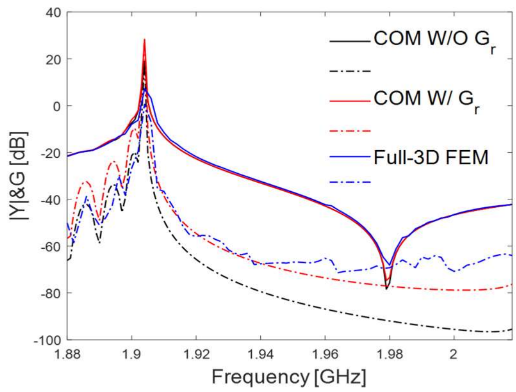

Fig. 5 Calculated Admittance Curves by COM model and FEM model.

Fig. 6 show the Bode Q [7] of these three calculations. The Q value scarcely changes with f in conventional COM result. On the other hand, the Q value decreases with f in the full 3D result due to the in-plane SAW diffraction. This Q dependence also appears in the result given by the present model. Detailed discussions may be necessary for the fact that the Full 3D result gives faster decrease in the Bode Q than the current model.

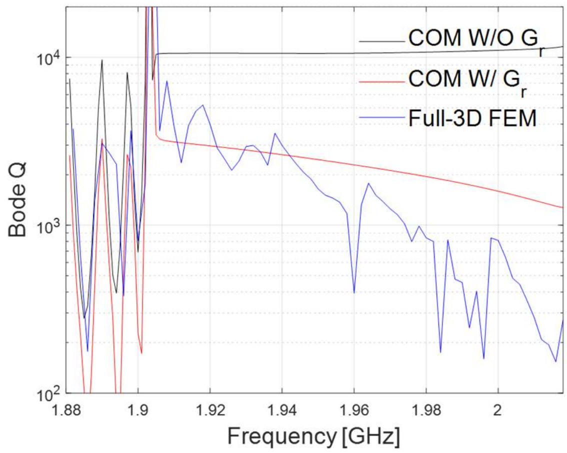

Fig. 6 1Bode Q curves calculated by proposed COM model and FEM model.

4. Conclusion

A model based on COM theory was proposed to include the impact of the side leakage and applied to the TC-SAW structure using SiO_2/128°YX-$LiNbO_3$.

First, the parameters required for analysis were determined by fitting with full 3D FEM. Then, the impact of the in-plane diffraction was estimated. The in-plane SAW diffraction could be modeled in some extent by the proposed model.

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