Analysis of XBAR main resonance and its higher order spurious modes

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Background, Motivation and Objective

A laterally eXcited Bulk Acoustic Resonator (XBAR) based on suspended thin film monocrystalline ZY cut Lithium Niobate platelet was presented in [1]. This resonator consists of a suspended LN platelet (400nm thick) with Aluminum IDTs (100nm thick) on top that create an alternating lateral electric field parallel to the Y-crystallographic axis to excite vertical shear A1 mode within the platelet. This is the main mode of resonance at 4.8GHz with large electromechanical coupling (25%) and potentially high Q (currently 300-400). Clearly it shows good promise in design of ultra wideband 5G filters.
This work aims to study behavior of the A1 XBAR mode and its higher order harmonics as a function of thickness, pitch and material properties. This enables to create rules for XBAR filter design.

Statement of Contribution/Methods

2D periodic and finite structure simulations were performed in Comsol. The model has been validated by using our 2Dand 3D software [2] Layers, and comparison with experimental results. We found at least three types of parasitic modes in the structure: horizonal harmonics of the main A1 mode (A1_n), propagating modes, such as S0 and SH0, transverse oscillations in aperture direction. Here we mainly concentrate on A1-3, A1-5,… modes as potentially most damaging for filter design.

Results/Discussion

Although, A1 shear mode is expected to be solely thickness defined, we observe both by simulations and experimentally - a secondary dependence on pitch p. There are also appearances of higher order harmonics in the horizontal direction (A1-3, A1-5..), despite being a λ/2 thickness mode. The horizontal A1-3 harmonic is close to the right of Anti-Resonance for larger pitches and poses a problem for filter design. Therefore, it is essential to quantify the parameters that influence relative position of A1-3 to A1 mode to eliminate or push the A1-3 mode out of filter pass band. Analysis of dispersion curves show that resonance frequency with respect to pitch dependent wavenumber (π/p) do not follow a parabolic relation for very large p. This can be attributed to the non-parabolic behavior of slowness curves of ZY cut LN. Another reason can be increasing non-uniformity of electric field for very large pitch. Figure 1(b) shows comparison of the resonance frequency of A1 mode for the cases of 1) mechanical loading of the platelet by Al electrodes 2) Resonances in a free platelet with electrodes situated nearby without mechanical contact to the platelet.

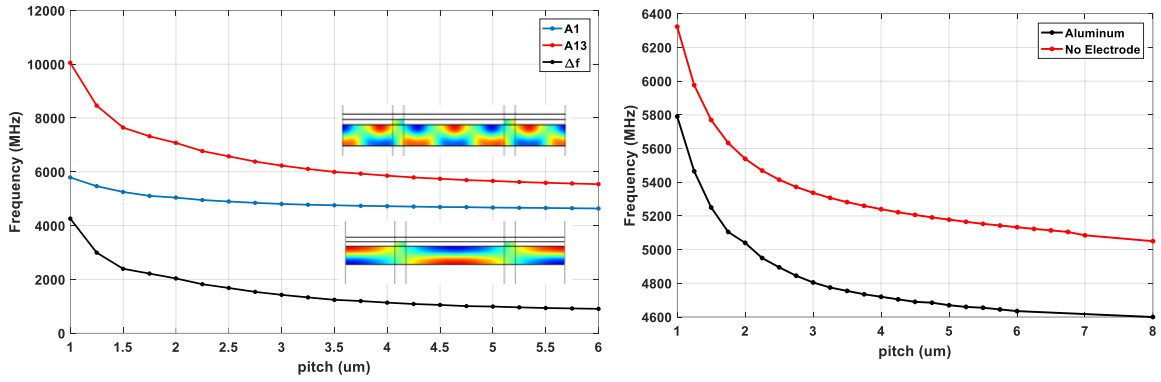

Figure 1: (a) Resonance frequency vs pitch of A1 and A1-3 XBAR mode, indicating mode shapes in the inset (b) Al mode for the electrodes on the platelet and nearby (no mechanical contact).

[1] V. Plessky, et al, Electronics Letters 55.2 (2018), pp. 98-100.
[2] J. Koskela, et al, "Hierarchical Cascading Algorithm for 2-D FEM Simulation of Finite SAW Devices," in *IEEE TUFFC*, vol. 65, no. 10, pp. 1933-1942, Oct. 2018.