Analysis of Contributions of Nonlinear Material Constants to Temperature-induced Velocity Shifts of Quartz and Langasite Surface Acoustic Wave Resonators

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Temperature-induced surface acoustic wave (SAW) velocity shifts are analyzed for quartz and langasite SAW resonators. The analytical methodology has been verified by comparing experimental results and analytical results for quartz resonators. Sensitivity of the analytical results to different groups of nonlinear material constants (third-order elastic constants (TOE), third-order piezoelectric constants (TOP), third-order dielectric constants (TOD) and electrostrictive constants (EL)) for SAW quartz resonators is discussed; it was found that in general, the third-order elastic constants contribute most significantly to the wave velocity shift. The contribution from the third-order dielectric constants and electrostrictive constants are negligible. For some specific cases, the elimination of the third-order piezoelectric constants may cause significant errors. The sensitivity of each third-order elastic constants to the temperature-velocity effect is analyzed by applying 10% error to the third-order elastic constants separately. The analysis for SAW quartz resonators has been extended to langasite SAW resonators as well. It is worthy to mention that commonly used thermoelastic expansions provide a good but not exact description of the temperature effects on frequency in piezoelectric resonators. These commonly used expansions do not include the effects of higher order material constants. In this paper we examine the significance of the various higher order effects as regards calculating temperature behavior from a set of material constants and their temperature coefficients. Fig. 1 shows an exemplar analysis for an X-cut SAW quartz resonator.

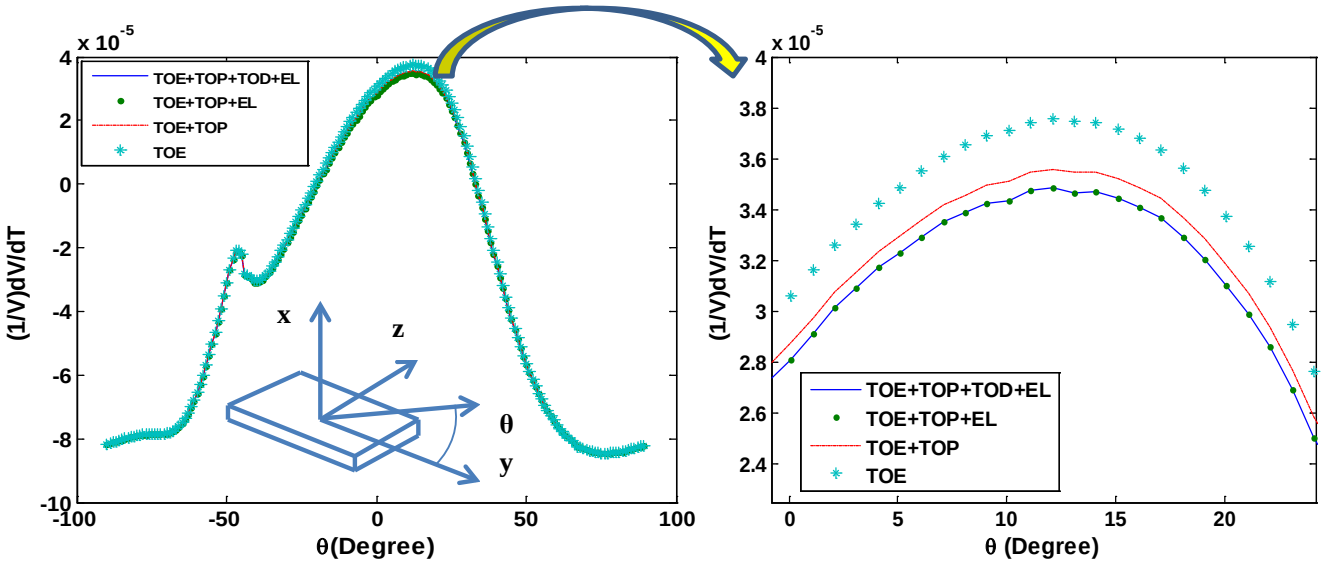

Fig. 1. The sensitivity analysis for temperature-induced velocity shifts as a function of wave propagation direction (θ) for an X-cut SAW quartz resonator. (a) The sensitivity analysis; (b) The enlarged view.