A comprehensive model of the electrical response of SAW devices submitted to thermal perturbation

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Temperature sensitivity of surface acoustic wave (SAW) devices has been studied by numerous research groups for improving the thermal control of resonators, filters and sensors for analog signal processing. Two principal approaches have been followed based on perturbation models using either effective or fundamental thermoelastic material coefficients. However, most works are focused on the theoretical estimation of the temperature coefficient of the frequency of waves propagating either on free/metalized surfaces or under infinite periodic gratings. However, the analysis of the evolution of the electrical response of even very simple devices (single-port resonators) along temperature shows that several parameters may dramatically change, depending on the evolution of the temperature-dependent wave parameters.

Previous works were dedicated to introduce thermoelastic properties of piezoelectric crystals in the analysis of infinite-periodic acoustic wave-guide using harmonic admittance approaches, yielding several advances in the understanding of advanced device operation versus temperature. In the present work, the possibility to derive the thermal evolution of all the wave parameters used to design and optimize SAW devices is exploited to develop a simulation tool based on the mixed-matrix formalism capable to provide a comprehensive representation of the temperature dependence of the electrical response of SAW devices. In that purpose, the temperature dependences of the wave velocity of course but also of the reflexion coefficient, directivity conductance and capacitance are established using polynomial development allowing to compute the wave parameters for any temperature. These parameters are used to simulate the device response at the corresponding temperature, accounting of course for the thermal expansion of the device along the propagation direction. The interest of this approach is illustrated for SAW devices on directive crystal cuts for which dramatic changes of the SAW parameters versus temperature may occur, such as NSPUDT quartz orientation and the (YX*lt*)/48.5°/26.7° LGS cut. For this later cut, theory/experiment assessment shows that the origin of the temperature-induced modification of the device response is strongly related to directivity and reflection changes when increasing the temperature. Further work will concern the evolution of guiding capabilities of bus bars to propose a 2D analysis of the SAW device response versus temperature.

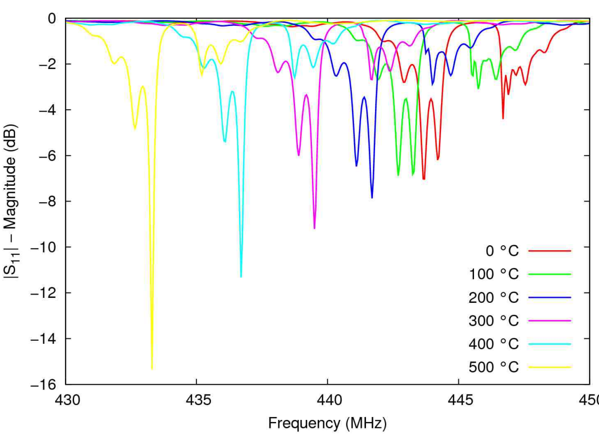

Fig. 1: Simulation of the evolution of the S_{11} response of a single-port resonator on (YX*lt*)/48.5°/26.7° LGS cut for various temperature