Equivalent Circuit Analysis of H2 Including Transverse Modes in RF BAW Resonators

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Background, Motivation and Objective (614)

Currently, nonlinearity is one of the hottest research topics in RF surface and bulk acoustic wave (SAW/BAW) devices. Yang et al., reported that transverse modes generate relatively strong second harmonics (H2) in RF BAW resonators[1], and the authors' group reported that H2 behavior including the transverse modes can be explained by a first-order 2D perturbation analysis using the *h* form constitutive relations[2]. They also derived an equivalent circuit for nonlinear behaviors based on the 1D perturbation analysis using the *h* form[3]. The circuit is equivalent to the modified BVD model for linear responses but two voltage sources V_{NT} and V_{NE} are introduced to express generated nonlinear stress and electric field.

Statement of Contribution/Methods (716)

This paper discusses extension of the equivalent circuit to include nonlinearity caused by transverse modes in RF BAW resonators. Fig. 1 shows the proposed circuit where multiple acoustic branches are added. The simulation is performed as follows: first, all the *LCR* values are determined by fitting with the measured admittance. Second, the peripheral circuit is added, and the total current I_t and acoustic current I_{mn} in the *n*-th branch are estimated. We assume that I_t and I_{mn} are proportional to the electric flux density D and stress S_n of the *n*-th mode, respectively. Then V_{NT} and V_{NE} are calculated by substituting S_n and D to the constitutive equations of the *h* form. A weighting factor necessary for the summation over n is determined from the motional capacitance C_{mn}. Finally, the peripheral circuit is added again, and H2 output is estimated.

Results/Discussion (663)

Fig. 2 compares simulated and experimental H2 in an RF BAW device with the Ru/AlN/Ru structure. It is seen that the simulation agrees well with the experiment. This indicates that H2 responses can be simulated quickly in this manner provided that the resonance frequency and field pattern are known. The latter is necessary for deriving the weighting factor described above. In the simulation, only contribution of S_1^2 to V_{NT} is considered for the main mode (n=1) while that of $2S_1S_n$ is considered for higher-order modes (n≥2). This factor of 2 makes nonlinearity of transverse modes stronger that of the main mode.

[1] T. Yang, et al., 10.1109/ULTSYM.2017.8091536

[2] K. Hashimoto, et al., abstract submitted to IUS2019.

[3] L. Qiu, et al., Jpn. J. Appl. Phys., **58**, 7 (2019) [to be published]

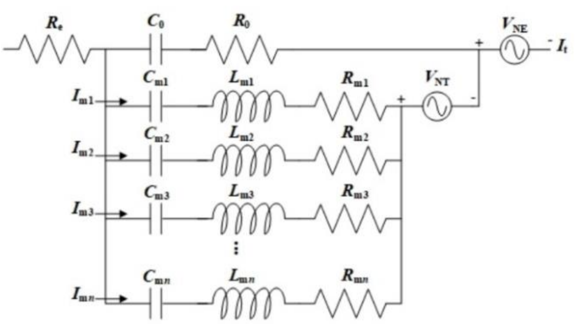

Fig. 1 Multi-resonant BVD circuit model

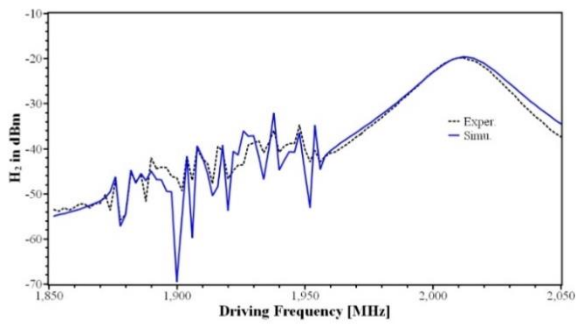

Fig. 2 Simulated and experimental H2