Advances in FEM modelling of nonlinearities in surface acoustic wave devices

Andreas Mayer[1], Elena Mayer[1], Werner Ruile[2], Michael Smirnow[2], Markus Mayer[2], Vikrant Chauhan[2,3], Ingo Bleyl[2], and Karl Wagner[2],
[1]Hochschule Offenburg – University of Applied Sciences, Gengenbach, Germany,
[2]RF360 Europe GmbH, a Qualcomm-TDK Joint Venture, Munich, Germany,
[3]Friedrich-Alexander University, Erlangen-Nürnberg, Germany

Background, Motivation and Objective

Nonlinearities in SAW signal processing devices can give rise to disruptive effects like inter-modulational distortions. In view of increasingly tight requirements in new-generation mobile communication devices using multiple channels, countermeasures are urgently called for. This requires an in-depth understanding of nonlinear effects, combined with a detailed and realistic modelling on the device level.

Statement of Contribution/Methods

The main source of inter-modulations is believed to be the nonlinear relationship between stress and charges on the one hand and strain and electric field on the other in the materials involved. Since nonlinear terms in the stress-strain relation are small, they may be accounted for in the framework of perturbation theory. Our main focus here is on third-order inter-modulations (IMD3) and third-harmonic generation (H3). In both cases, perturbation theory yields a direct contribution to the wave-fields and the currents in the electrodes, resulting from third-order nonlinearity, and a cascaded contribution via second-order nonlinearity, involving the second harmonic. In the case of IMD3, an additional cascaded term occurs, generating a low-frequency field component. The wave-fields and currents corresponding to these contributions are computed with the help of the finite element method. Their relative importance will be assessed and their dependence on nonlinear material constants and geometry parameters will be discussed.

Results/Discussion

The systems considered are SAW-cuts of $LiNbO_3$ with a temperature-compensating SiO_2 film and Cu electrodes, and also LSAW cuts (42°YX-$LiTaO_3$). Since only few of the nonlinear material constants of $LiTaO_3$ are known, assumptions have to be made for the substrate nonlinearity in the latter case. A detailed analysis is presented of the bulk-wave radiation generated by nonlinearity at the second- and third-harmonic frequency. The FEM calculations yield the nonlinear wave-fields as well as the distribution of nonlinearly generated electrical currents in systems with a finite number of electrodes in various configurations.