This paper presents an accurate method to calculate the P-matrix of an arbitrary transducer on an arbitrary substrate material. The approach is based on the COM model, and COM-parameters (transduction, reflectivity, capacitance and velocity) are calculated for each individual cell of the transducer in a manner such that the influence of the neighboring cells is taken into account. This method is particularly well suited for the analysis of the RSPUDT. Since in RSPUDT both reflectivity and transduction are weighted, there are transducer areas with different types of basic cells (reverse or forward SPUDT, non-SPUDT) as well as areas transitional from one cell type to another. The common approach to calculate the COM parameters for the cells is to use the same set of COM parameters (usually evaluated for the case of an infinite periodic SPUDT structure) throughout the transducer with transduction and reflectivity multiplied by corresponding weighting coefficients. As a result, the mutual influence of the cells is ignored. In this paper a model is developed which provides a more accurate analysis approach. An IDT is subdivided into a sequence of cells starting and ending in the middle of electrodes gaps; each cell containing only one electrode for which the COM parameters are evaluated. The transduction coefficient and capacitance are calculated based on the charge distribution on all electrodes of the transducer. The reflectivity of a cell is calculated as a sum of piezoelectric and mechanical terms [1]. The velocity perturbation within a cell is also presented as a sum of piezoelectric and mechanical terms. The piezoelectric term for both velocity perturbation and reflectivity, is calculated based on charge distribution induced on the transducer electrodes by an incident wave. As in [1], basic material parameters are extracted from FEM/BEM analysis for a single electrode structure. In the paper the theoretical approach and model will be discussed. Experimental results for several RSPUDT filters on quartz and langasite are presented. Excellent agreement between modeled and measured data is shown which verifies the approach.

THE ELECTRIC ADMITTANCE OF A COMPLEX PERIODIC ELECTRODE CELL

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A new method for calculating the electrical admittance matrix of a periodic cell consisting of an arbitrary number of different elastic electrodes placed on piezoelectric substrate is developed. The method starts from the relation between distributions of surface charges and electric fields. It is derived in [1] with the aid of the impedance method, where the effective permittivity matrix has been introduced to characterize the piezoelectric substrate surface loaded by arbitrarily shaped elastic strips. Due to this approach the known complex electromechanical boundary-value problem for calculation of SAW interdigital transducers (IDT) is reduced to a pure electrical boundary-value problem. Here this problem is solved by methods of electrostatics developed in [2] as applied to arbitrary IDT placed in an external electric field. Analyzing the polarization of electrodes in the electric field of periodic structure spatial harmonics, the natural representation of charges and fields in IDT, for the first time in the case of arbitrary number of electrodes per cell, is proposed. Such approach was named recently the natural boundary element method (NBEM). As a result, the electrical admittance matrix elements, relating electrode currents with voltages, are obtained. These elements are represented as ratios of dispersion equation left-hand sides corresponding to various electrode connections. As examples, the frequency dependence of electrical admittances for some unidirectional multi-electrode periodic cells are calculated.


A NOVEL PSEUDO-SPECTRAL ANALYSIS OF THE MASSLOADING PROBLEM IN SAW- AND BAW DEVICES WITH ARBITRARILY-COMPLEX ELECTRODE PROFILES AND MATERIAL CONSTITUTION

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We consider singly and doubly periodic corrugated structures as models for the calculation of the massloading problem in SAW and BAW structures. We permit arbitrarily complex electrode profiles and inhomogenous material constitution. In previous works we have solved this and similar problems using the finite element method, or, alternatively, the boundary element method. Thereby, our efforts culminated to the development of the concept of universal functions for accelerating computations. The developed techniques are extraordinarily robust and provide results with unprecedent accuracy. However, they are, admittedly, rather difficult to implement. The main focus in this contribution is to combine rigour with simplicity when modeling the massloading problem. To achieve this objective we propose a pseudo-spectral analysis which combines a sophisticated spectral decomposition in planes parallel to the propagation direction of waves with a discretization of the diagonalized form of acoustic equations in the direction normal to the surface. The involved system matrices for three dimensional problems may become prohibitively large. To combat this problem we use iterative solvers. Our choice for the iterative solver has been the transpose free quasi minimal residual method (TFQMR), which is efficient, can handle non-symmetric and non-Hermitian matrices well, and even manages to solve nearly singular matrices. However, iterative solvers converge poorly for non-preconditioned systems, and very often they even completely fail to converge. To overcome this problem, and at the same to guarantee high speed and high accuracy of the computations we discuss the implementation of powerful preconditioners. Test device structures involving electrodes with complex geometries and inhomogenous material will serve to exemplify the flexibility and simplicity of our method.

P2I-4

ACCURATE FEM/BEM-SIMULATION OF SURFACE ACOUSTIC WAVE FILTERS
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The accurate analysis of surface acoustic wave (SAW) filters is still a very challenging task for SAW designers. Especially the prediction of losses in RF-filters employing leaky surface acoustic waves (LSAWs) with aperiodically arranged metallic electrodes such as DMS-filters is not possible with conventional COM-, P-matrix or equivalent-circuit models, since these approaches ignore relevant second-order effects: neither the weak guiding of the LSAWs near the upper stop-band edge nor radiation into bulk-waves are accounted for correctly. However, bulk-wave radiation causes increased insertion loss (in particular near the upper pass-band edge) and deteriorates the steepness of the upper skirt. Therefore, it is a matter of special importance. We have developed and implemented an accurate model for acoustic tracks with the 2D approximation only: to describe the electro-acoustical properties of the piezoelectric substrate a Boundary Element formulation is used, which is
based on a semi-infinite dyadic Green’s function, avoiding any compromises in
the characterization of the physics of bulk-wave interactions. The mechanical
behavior of the electrodes is described with Finite Elements since this approach
provides high flexibility with respect to the geometry and material composi-
tion. Due to the fact that the FEM/BEM model does not make any a priori
assumptions concerning crystal cuts and/or wave types employed in the sim-
ulated device, it is widely applicable. Since well-adapted shape functions are
used for the BEM-part of the model, the size of the discretized system is kept
to a minimum, thereby enabling the simulation of acoustic tracks with up to
400 electrodes in reasonable CPU times on a PC. To guarantee an accurate
description of real SAW-devices, a model for finite finger resistance as well as
a tool for the description of the electromagnetic effects on the chip and in the
package are attached to the FEM/BEM-model.
Comparison between simulations and measurements on real SAW-devices show
(i) very good agreement and (ii) proof the effectiveness of the developed simu-
lation tool.

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A COMPARISON OF EXPERIMENTAL AND
THEORETICAL RESULTS FOR THE INSERTION LOSS
OF PAIRED IDTS FOR HIGH FREQUENCY HARMONICS
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There are several theoretical models which describe the harmonic response of
surface acoustic wave (SAW) interdigital transducers (IDTs) of different topolo-
gies. The experimental results for the insertion loss of IDTs, obtained for sev-
eral tens of frequency harmonics, are compared with theoretical predictions of
the well-known model, based on the “quasi-static approximation”. The paired
transducer insertion loss of LiTaO3 (Y-112deg) and ST-X Quartz were measured
using a harmonic rich split finger IDT (metallization ratio is 0.6 and the elec-
trode thickness is approximately 0.1um) over a frequency range from 30 MHz
to above 2.4 GHz (LiTaO3) and to above 1.6 GHz (Quartz). It is shown that
the measured conversion loss of the IDT is in good agreement (within about
1dB) with the theoretical results up to the 55th IDT harmonic for LiTaO3 and
up to the 43th IDT harmonic for Quartz.

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