Finite Element Evaluation of Surface Acoustic Wave Reflection and Scattering From Topographic Irregularities Comparable with the Wavelength

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Abstract

Introduction
Currently, the design of surface acoustic wave (SAW) devices needs the accurate study of the scattering fields, arising from the interaction of SAW with periodic topographic irregularities placed on a surface of crystal to form either interdigital transducers (IDT), or reflective structures. To solve this problem the finite element methods very perspective, because with its help one can take into account the actual geometry of the electrodes and reflectors, in contrast with analytical methods.

This work describes results of original time domain finite element calculation of two-dimensional SAW scattering fields in reflective delay line made on a 128°YX $LiNbO_3$ substrate. The properly defined reflection, transmission and scattering coefficients are numerically evaluated as functions of the reflector's thickness, from infinitively small to comparable with the SAW wavelength λ.

Use of COMSOL Multiphysics®
Model's geometry is illustrated by Figure 1. Domains d1-d6 represent 128°YX $LiNbO_3$ substrate. Domains d4-d6 are used to eliminate SAW reflections from boundaries of device and bulk reflection from the bottom of the substrate by introducing gradient of attenuation. It's also assumed that there is no propagation loss in domains d1-d3. IDT (d7) generates RF pulse with center frequency f0=2.44 GHz and duration of 25/f0. Point "A" was used to detect of incident and reflected pulses, point "B" - to detect transmitted pulse. Thereby time dependence of electric potential V was obtained at these probe points and the energy of the incident Esaw, reflected Erefl, and transmitted Etrans pulse was calculated. This allows us to evaluate reflection (cR), transmission (cT) and scattering (cB) coefficients as cR=Erefl/Esaw, cT=Etrans/Esaw and cB=1-cR-cT. It's worth to underline that using Cb, one shouldn't separately calculate energy of BAW scattering field under reflectors.

Results
Abovementioned coefficients were evaluated for the reflective structure represented by the sequence of six rectangular grounded aluminum strips with fixed width wr=0.25*λ and thickness hr, that changes in the interval (0, λ). Resulting dependences are shown on Figure 2. These dependences have quasi-oscillatory and nonmonotonic behavior. Clearly observed peaks of transmission and scattering are due to excitation of high acoustic modes in array of metal strips with big height.

Conclusion
Calculations of two-dimensional picture of SAW scattering fields clearly show that the intense SAW energy scattering into volume occurs for certain parameters of the reflectors, while for some other their configuration a SAW beam can pass through topographic irregularities practically without scattering. This method should be applied for further detailed analysis of reflective structures to synthesize properly the modern SAW tags.

Figures used in the abstract

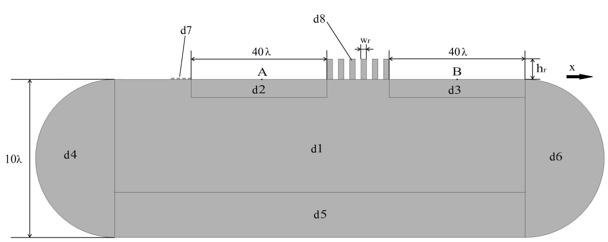

Figure 1: Geometry of the model

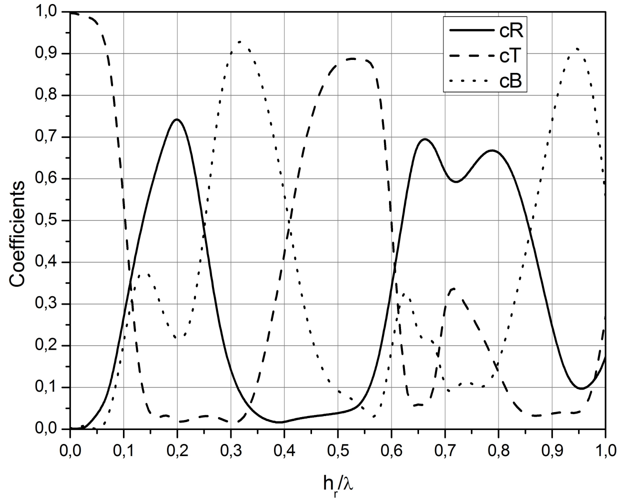

Figure 2: Reflection Cr, transmission Ct and scattering Cb coefficients for aluminum as function of normalized height