Program for Analysis of SAWs Obliquely Propagating on Metallic Grating with Finite Thickness

OBLIQ Version 2.0

G.Endoh and K.Hashimoto, Dept. EEE, Chiba University

tel:++81-43-290-3318, fax:++81-43-290-3320

k.hashimoto@ieee.org

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1 Outline

This computer program calculates the complex velocities and electromechanical coupling factor K^2 of Rayleigh and/or Leaky-SAWs obliquely propagating on fully periodic metallic grating structures with finite thickness as a function of frequency. The numerical techniques employed for these programs software are completely the same with those employed in our software "FEMSDA". In the calculations, electrode cross section is assumed to be rectangular for simplicity. Supported substrate materials are $LiNbO_3$, $LiTaO_3$, GaAs, quartz, $Li_2B_7O_4$, $La_3Ga_5SIO_{14}$ and $KNbO_3$ with either Al or Au as the grating metal. Note this software can not be applicable for the cases where one of strain components decouples with the electric field. Although the situation may occur frequently for the normal incidence case, the situation can be solved by the use of FEMSDA instead of OBLIQ.

2 Usage

Type "obliqf" for execution.

1. "Enter File Name" where the output data will be stored. Note that, if the file already exists, the file will be overwritten and the former data will be erased.
2. "Enter 1-11 for LNOW(arner), LNON(akagawa), LNOK(ovacs), LTOW(arner), LTOS(mith), LTOK(ovacs), LBO, GaAs, quartz, LGS and KNO" for spec-

ifying the substrate materials. If you enter other value, the program will be terminated.

3. "Enter Axis & Angle" for specifying the rotation of the substrate and "To proceed next step, enter 0 for axis". For example, if desired substrate cut and SAW propagation direction is specified by the Euler angles $(45, 30, -20)$ in degree, type

   3,45 <CR>
   1,30 <CR>
   3,-20 <CR>
   0,0 <CR>

   Then the program prints the bulk wave velocities whose wavenumbers are parallel to the surface and the effective permittivity $\epsilon(\infty)/\epsilon_0$ of the substrate. If the piezoelectricity is decoupled with some displacement components u_i inproperly, the program displays its situation and returns to step 2.

4. " Enter 1 for Al or 2 for Au" to specify the film material "& Enter 0 for OG (Open-Circuit Grating) or 1 for SG (Short-Circuited Grating" to specify the electrical condition. Then the program prints three bulk wave velocities in the film.

5. "Enter theta, Nmax, Nxd, Nyd, fs, vnorm, w/p, and h/p" where w, p, h are the strip line-width, periodicity and height (see Fig. 1). θ is the SAW propagation angle respect to the grating aperture. The integer N_{max} represents the number of Floquet expansions to be included for the calculation. The integers N_{xd} and N_{yd} represent numbers of FEM subdivions for $w/2$ and h, respectively. The value V_{norm} represents arbitrary value used for the frequency normalization. Hereafter the operation frequency is normalized by V_{norm}/p. The value f_s is the relative frequency used only for finding initial value of the SAW velocity in the next step. For returning to step 2, enter "0 0 0 0 0 0 0".

6. "Enter vrs, vre and vrint" where V_{rs}, V_{re}, and V_{rint} are the start, end and interval, respectively, of velocities for searching initial values of the SAW velocity manually. Then "Enter als, ale and alint" where α_s, α_e, and α_{int} are the start, end and interval, respectively, of attenuation in dB for the search. After typing, the program tabulates velocities, attenuation and calculated determinants (complex value). The velocity giving zero determinant corresponds to the SAW velocity for specified f_s. Location of the solution can be found easily by searching velocity where the sign of real and/or imaginary parts of the determinant change. Once the zero of the determinant is estimated to within an accuracy adequate for an initial guess, "0 0 0" must be entered to proceed to the next step.

7. "Enter fs, fe, fint and vstart" where f_s, f_e, f_{int} are the start, end and interval, respectively, of frequencies where the SAW properties are to be estimated. V_{start} is the approximate value of the SAW velocity for $f = f_s$, and is estimated in the previous step. After typing, the program tabulates relative frequency, determined velocity (m/sec), attenuation (dB/λ) and K^2. These values are displayed and stored simultaneously into the file specified in the first step. Preceding the tabulated data, specified values and $\epsilon(\infty)/\epsilon_0$ are also listed. When all of the iteration complete, the program reexecutes this step. For returning to step 2, enter "0 0 0 0".

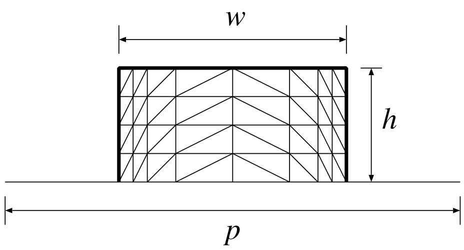

Figure 1: FEM mesh. In this case, $w/p = 0.5$, $h/p = -0.125$, $N_{xd} = 4$ and $N_{yd} = 4$.

2.1 Note

1. "obliqt" calculates SAW properties, in the final step, as a function of θ instead of f.

2. Although the software allows to specify $\theta = 0$ (normal incidence), some displacement component may decouple from the SAW due to the crystal symmetry. In the case, the software may miss the exact solution. In the case, solutions for $\theta = 0$ should be searched separately by the use of FEMSD2 or FEMSD3.

3. When V_{start} is far from the exact value, the program may fail to find a solution, and will return to the previous step. This situation may occur when the frequency is too close to the stopband edge.

4. Since piezoelectricity disappears at the frequency corresponding to the upper and lower edges of the stopband for the OC and SC gratings, respectively, it is actually impossible to determine SAW properties at the frequency. Since negative V_{int} is allowed, behaviour near the frequency can be determined by calculating SAW properties from frequencies higher than the stopband.

5. Although the reason is uncertain, even "Nmax" and "Nxd" should be used for fast convergence.

6. Maximum values of "Nxd", and "Nyd" are limited by available memory size of user's computer. That is, they must satisfy following relations:

$$(4 \times \mathrm{Nxd} + 2) \times (\mathrm{Nyd} + 1) \leq \mathrm{npm}$$

and

$$2 \times \mathrm{Nxd} + 1 \leq \mathrm{npa}$$

where "npm" and "npa" are the parameters defined in the software source-code. Note that their default values are 300 and 100, respectively.

7. In the software, the temperature is assumed to be 25°C. It can be adjusted by specifying the parameter "temp" in the main routines in "obliq?.f".

8. In the software, the electrode cross section is assumed to be rectangular. The software is also able to analyze the trapezoid case by specifying the parameter "aspect" in the main routines in "obliq?.f". Note that "aspect" is defined by $(b - a)/h$ where a and b are the upper and lower lengths, respectively, and h is the electrode height.