Program for Calculating Discrete Green Function for Multi-Electrode Grating with Finite Thickness

MULTI Version 3.0

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November 25, 2006

1 Outline

This computer program calculates the complex velocities and electromechanical coupling factor K^2 of Rayleigh and/or Leaky-SAWs on fully periodic metallic grating structures with finite thickness and multiple fingers per period by the use of discrete Green function theory. The finite element method (FEM) is employed for the electrode region, and distance among the FEM sampling points are weighted so as to make the convergence rapid. In the program, electrode cross section is assumed to be rectangular for simplicity. Supported substrate materials are $LiNbO_3$, $LiTaO_3$, $Li_2B_4O_7$, GaAs, quartz, $La_3Ga_5SiO_{12}$ and $KNbO_3$ with either Al, Au or Cu as the grating metal. The use of FEMSDD and FEMSDT is exactly the same. FEMSDD supports only the case where two fingers exists per period whereas FEMSDT supports the case where three fingers exists per period.

2 Usage

Type "femsdd" or "femsdt" 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 coupled and/or decoupled with some displacement components u_i unproperly, the program displays its situation and returns to step 2.

4. " Enter 1 for Al, 2 for Au or 3 for Cu" to specify the film material.

5. "Enter 0(OO), 1(OS), 2(SO), 3(SS) or 4(ii)" for FEMSDD and "Enter 0(OOO), 1(OOS), 2(OSO), 3(OSS), 4(SOO), 5(SOS), 6(SSO), 7(SSS), 8(Oii), 9(iOi), 10(iiO), 11(iii), 12(Sii), 13(iSi) or 14(iiS)" for FEMSDT. Where "O" and "S" indicate that the corresponding finger is open-circuited and short-circuited, respectively, whereas "i" indicates that the corresponding fingers are mutually interconnected but isolated from the busbars.

6. "Enter Nmax, Nxd, Nyd, fs, vnorm, d1/p, d2/p, w1/p, w2/p, h1/p and h2/p" for FEMSDD and "Enter Nmax, Nxd, Nyd, fs, vnorm, d1/p, d2/p, d3/p, w1/p, w2/p, w3/p, h1/p, h2/p and h3/p" where w_i, p_i, h_i are the line-width, periodicity and height of strip-i (see Fig. 1). The integer "nmax" represents the number of Floquet expansions to be included for the calculation. The integers "Nxd" and "Nyd" represent numbers of FEM subdivisions 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".

7. "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.

8. "Enter fs, fe, fint, vstart and alpha" 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} and α are approximate values of the SAW velocity and attenuation in dB 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".

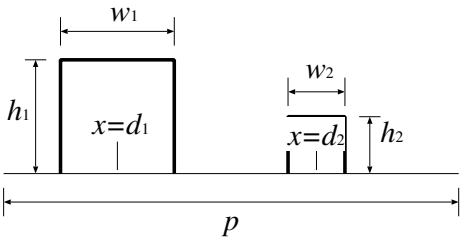

Figure 1: Electrode parameters. In this case, $w_1/p = 0.25$, $w_2/p = 0.125$, $h_1/p = 0.25$, $h_2/p = 0.125$, $d_1/p = -0.125$ and $d_2/p = 0.1875$. As for the definition of N_{xd} and N_{yd}, refer to Fig. 1 in the FEMSDA manual.

2.1 Note

1. 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.

2. 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.

3. 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 "femsd?.f".

4. 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 "femsd?.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.