# Fundamental validation of the FEM based calculations concerning simulation of SAW and LSAW devices

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A famous three-dimensional finite element method (3D-FEM) is the most accurate manner to model characteristics of filters and resonators based on both pure (SAW) and leaky (LSAW) surface acoustic waves. One may obtain a very precise simulation of their features by using the wide-spread commercial FEM-based software packages (e.g., "COMSOL Multiphysics"). At this point the higher meshing density which we use is, the better simulation accuracy is. However, an extra number of meshing points may lead, generally speaking, to enormous computation time during analysis and synthesis of devices with complex architecture. Accordingly, a single criterion of the mesh quality formerly was a comparison between the results of simulations and rather costly experiments.

Now we propose another way permitting to verify the modeling correctness and to estimate the simulation precision quantitatively using only the theoretical calculations. This way is coupled with an evident necessity to satisfy **perfectly** the fundamental principle - energy balance - which should hold during any simulation procedure. In the absence of ohmic loss in electrodes it means that an electric power ($P_E=\mathrm{Re}(Y_{11})\cdot|V|^2$), consumed by arbitrary one-port acoustoelectric circuitry with input admittance $Y_{11}$ under applied voltage '$V$', is transformed totally to the power of all surface and bulk acoustic modes, excited within working piezoelectric domain - beneath both interdigital transducer (IDT) and reflecting gratings – to be radiated into a substrate.

At this point 3D-FEM package finds the frequency dependence $Y_{11}(f)$ by its own means when calculating the charges induced on electrodes with the same polarity. On the other hand it provides numerically the spatial distributions of all required values which characterize acoustic waves in a substrate, i.e., components of the elastic particle displacement vector $u_j$ and electric potential $\varphi$. By using them, under known material constants, one may find also the vector of electric displacement $D_j$ and tensor of elastic tensions $T_{ij}$ in a substrate ($j$=1, 2, 3). Then, with the help of known formula for an acoustoelectric power flow density, it is possible to calculate the total acoustic power $P_A$, going outside through some properly selected surface, enveloping the working area. Thus, the $P_E$ - & $P_A$- quantities are found with the help of absolutely different approaches, and their fractional difference ($\delta P = P_E/P_A - 1$) will be just the reliable quantitative measure of the calculation precision (achieved by 3D-FEM software under the chosen meshing type and its density). This information allows the mesh optimization, giving us a representation of simulation accuracy, on the one hand. On another hand, it is the well-grounded basis to extract properly the relevant local characteristics (COM-parameters) of distributed systems, demanded to accelerate dramatically a design of arbitrary real SAW- & LSAW- devices.

As an example, characteristics of some LSAW-resonators, made on "$LiNbO_3$ (0,-41,0)" substrate, have been calculated by means of the proposed checking algorithm which confirms the simulation validity. The measurement results agree well the simulated response of these devices over the whole frequency range of analysis.