FEM Simulation for 'pulse-echo' Performances of an Ultrasound Imaging Linear Probe

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Abstract

Pulse-echo response FEM simulation is seldom found in literature for ultrasound imaging array probes. Indeed the complete modeling of such device is extremely complicated for several reasons [1],[2] :
1) A complete knowledge of acoustical material properties is requested and it's not often available from technical specification and literature
2) Multiple vibration modes of the array elements complicate the analysis of principal 'thickness' mode response
3) Acoustic/structural domain interface need to be handled, for both pressure field and pulse-echo simulations
4) Array dimension must be generally limited and symmetry and far field integral simplification are to be employed, in order to avoid huge number of nodes/calculations
5) Pulse-echo needs two consecutive simulation to limit the model dimensions
6) IFFT algorithm must be performed separately (Matlab) on FEM output data, since simulations should run in the frequency domain

Nevertheless, the 2D FEM described in the present work was successful, thanks to the following design procedure (see figure):
Two piezoacoustic models were employed, one for transmission of the pressure wave into the acoustic domain, one for reception. The far field pressure data output from the transmit FEM was exported and input as amplitude of an incident plane wave (back-travelling) on the acoustic boundary of the 'receive' model, in order to get the final echo-voltage on the array piezoelement. Finally, IFFT algorithm (Matlab) is used to recover the pulse-echo voltage waveform and compare it to the measured one.

The final agreement between measurement and simulation results can be considered good and the model is validated for further applications and probe performance prediction.
Indeed, many different design can be simulated, varying the material parameters or geometrical design, to study the change in probe pulse-echo performances. The latter is essential to limit the cost of development for a new design ultrasound imaging probe.

Reference

[1] : L.Spicci, M.Cati, “Ultrasound Piezodisk Transducer Model for Material Parameter Optimization”, Comsol Conference 2010, Paris (best paper award)
[2] : L.Spicci, M.Cati, “Design and Optimization of a high performance ultrasound imaging probe through FEM and KLM models”, Comsol Conference 2011, Stuttgart

Figures used in the abstract

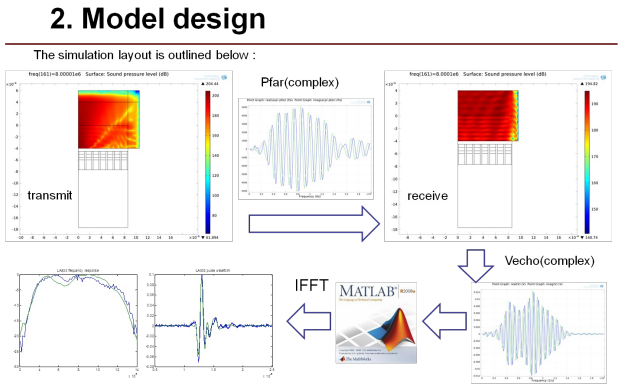

Figure 1: FEM system diagram

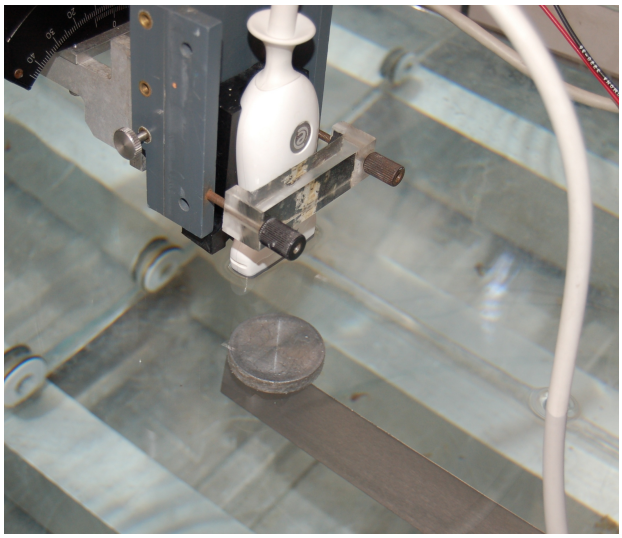

Figure 2: pulse-echo measurement