Finite element modeling of mechanical cross-coupling in 1D ultrasound array

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Introduction

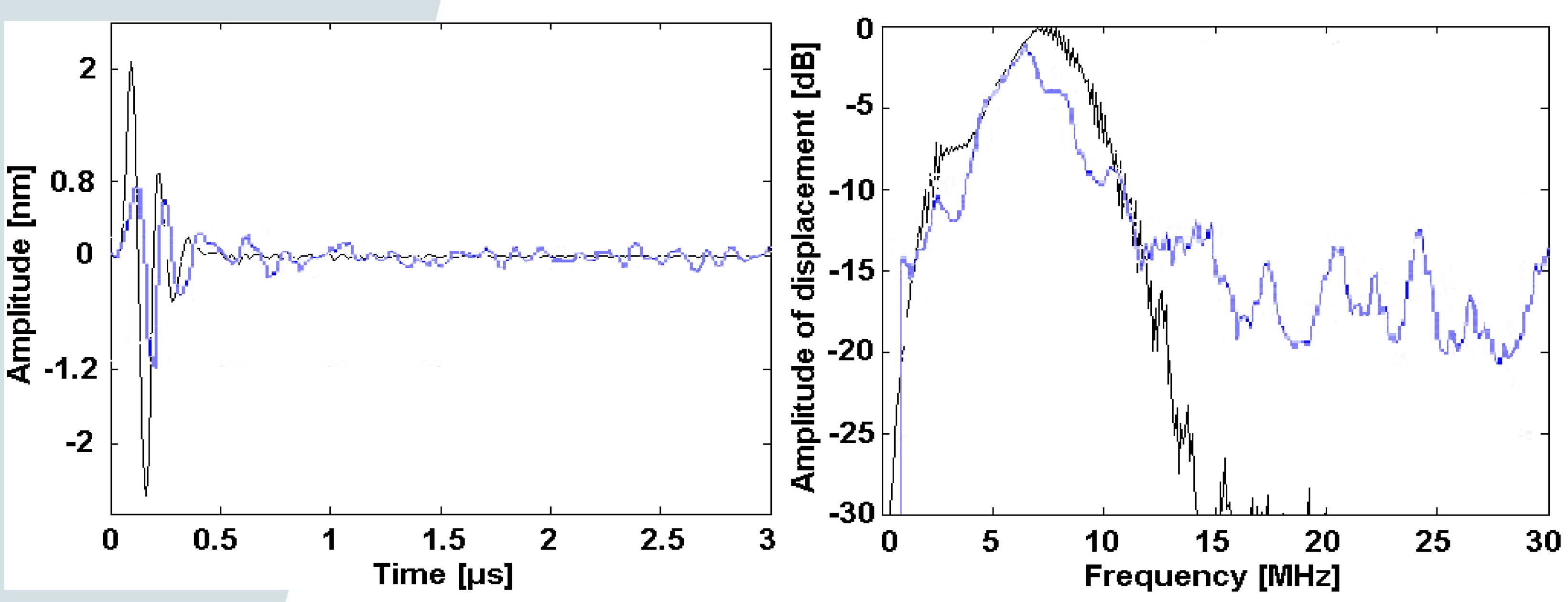
Electro-mechanical cross-coupling is responsible for undesired behavior in radiation field patterns and electroacoustic response of the ultrasound transducers for medical imaging. This undesired behavior is ultimately impairing the end echographic image quality [1,2]. The aim of our research is to study the influence of the dicing depth, for given kerf material properties, on the cross-coupling dB level. Mechanical cross-coupling was analyzed in the case of a 1-D ultrasound transducer using finite element modeling (FEM). The results were compared with experiments that were based on impedance analysis, laser interferometry and hydrophone measurements.

Material and methods

In the present study a linear 1-D array was analyzed. Its structure comprises a diced piezoceramic core (Stettner), a backing layer (customly produced epoxy resin/Al2O3 composite), and two matching layers: epoxy resin based composite and polystyrene. The pitch was 315 μm. In order to assess the mechanical cross-coupling, a finite element frequency and time domain structural analysis was performed using ANSYS Multiphysics 10.0. The results were postprocessed in Matlab. Experimental validation was performed by the means of laser interferometry and hydrophone measurements.

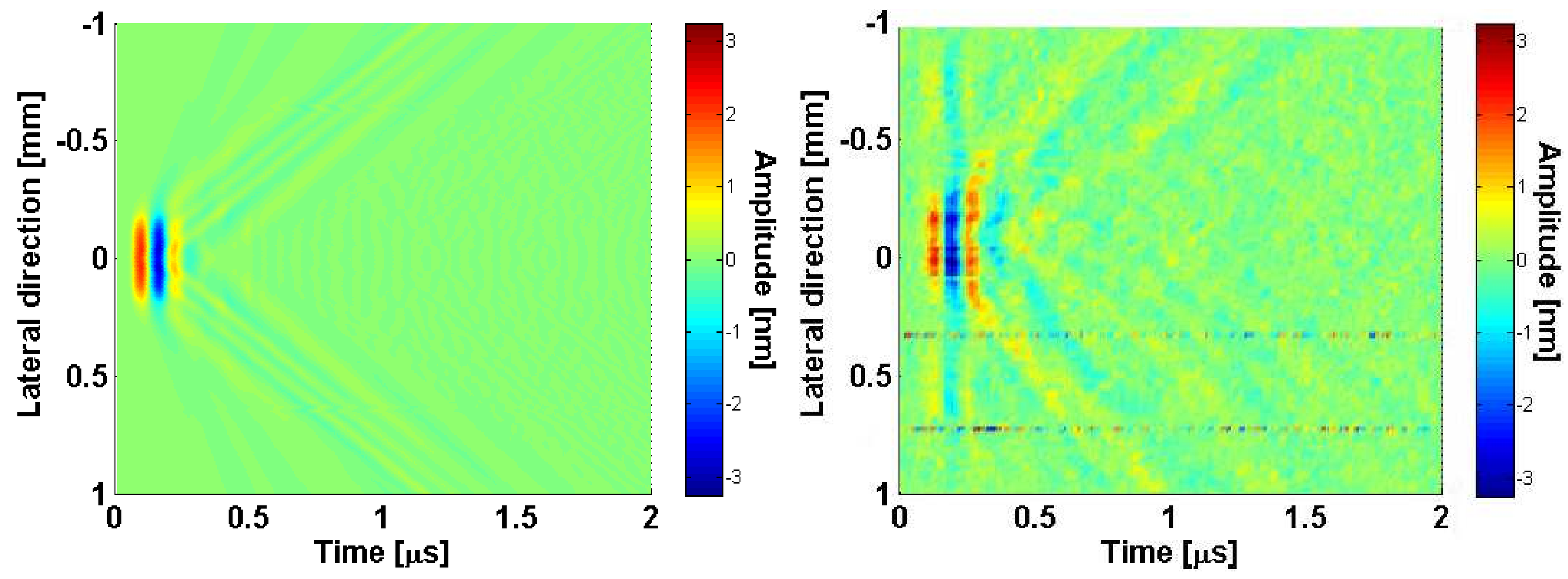
Results

The impulse response to a pulsed excitation was computed and further postprocessed (1D and 2D Fourier transformant) in order to assess the displacement on the transducer top surface. Laser interferometry results showed a good resemblance with the simulated ones in terms of wave morphology and ringing down. Furthermore, the frequency content and bandwidth were well predicted by the FE model in the 0 – 14 MHz frequency range.

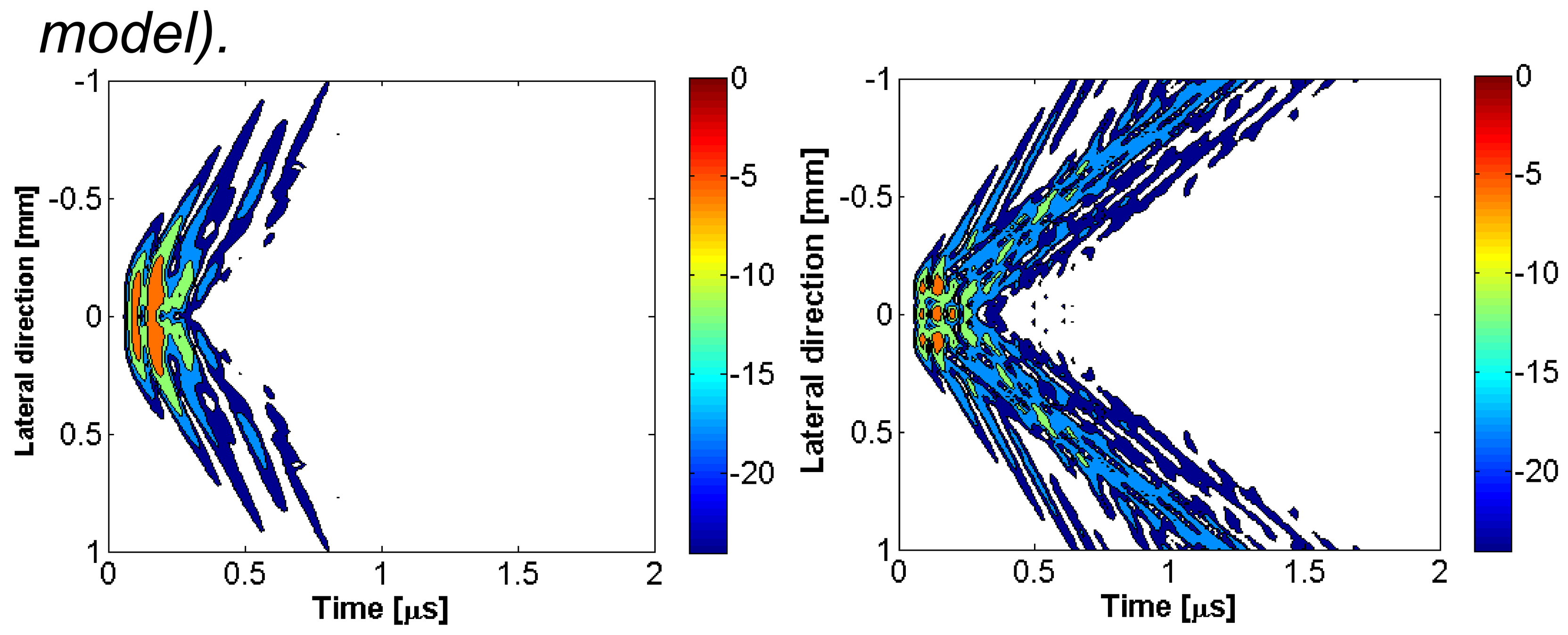


Electro-acoustical response to an electrical pulse excitation, 100 V, 7.5 MHz: left – time domain, right – frequnecy domain; black – FEM results, blue – laser interferometry.

The mechanical cross-coupling was analyzed at the neighboring elements level and the influence of different dicing depths through the first matching layer and of the kerf material properties was studied using normalized maps of modulus of displacement, plane wave decomposition, and angular directivity.



Displacement maps plotted versus time and lateral direction: left - FEM results, right – laser interferometry results (electrical cross-coupling is not present in the FE model).



6 dB contour levels mapping of the FEM predicted surface displacement: left 8% and right 100% dicing depths through the first matching layer. The kerf material is identical to the backing material.

Conclusions

Inter-element coupling was modeled using a FE model and a good correlation with laser interferometry and hydrophone measurements was found. The results emphasized a decrease of the - 6 dB cross-coupling level with the increase of the dicing depth. Future work will use the FE model for analyzing the fully diced matching layers case and kerf materials with different elastic properties.

References

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