A Hybrid Boundary Element Method for the Simulation of Acoustic Cross-talk in Large Piezoelectric Micromachined Ultrasonic Transducer Arrays in Immersion

B. Shieh[1,*], K.G. Sabra[1], and F.L. Degertekin[1]
[1]G. W. Woodruff School of Mechanical Engineering, Georgia Institute of Technology
801 Ferst Drive, Atlanta, GA, 30332-0405
*Bernard Shieh: bshieh@gatech.edu

Piezoelectric micromachined ultrasonic transducers (PMUTs) are a promising technology for the realization of large transducer arrays for use in integrated imaging, sensing, and actuation where a broadband response is desirable. It is well-known that membrane-type arrays such as PMUTs suffer from strong acoustic cross-coupling due to surface waves at the fluid-structure interface, a phenomenon that poses a significant design and modeling challenge (Bayram et. al., IEEE Trans. UFFC, *54*, 418-429; Wilm et. al., Ultrasonics, *43*, 457-465). The simulation of large arrays--composed of hundreds and thousands of membranes—with standard tools (i.e. finite element software) is impractical due to exceeding memory and computation requirements. In this work, a hybrid boundary and finite element method is proposed for the transmit simulation of large PMUT arrays in immersion. Finite element software (COMSOL) readily handles the simulation of single membrane structures, from which static deformation (stiffness) and harmonic displacement data is extracted. A boundary element formulation based on these inputs handles the membrane-to-membrane acoustic cross-coupling through the calculation of a mutual impedance matrix. For arrays consisting of hundreds of membranes or more, the problem of quadratic storage and cubic time complexity for boundary element is avoided by employing a multi-level fast multipole algorithm (Shieh et al., IEEE Trans. UFFC, *63*, 1967-1979). We validate this hybrid method for common membrane geometries, including square and circular membranes with varying degrees of electrode coverage. Material choice and membrane design are explored in the interest of optimizing output pressure and directivity, with reference to the capabilities of comparable capacitive micromachined ultrasonic transducers (CMUTs).