ACOUSTICS2008/1382
Modeling of different transducer configurations with combined pseudospectral and finite-difference time-domain methods

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The numerical simulation of acoustic waves propagating in inhomogeneous media is often achieved using pseudospectral (PS) algorithms, which require few nodes per wavelength to converge, while complex piezoelectric structures are simulated with finite-difference (FD) or finite-element (FE) methods. A combination of the PS and FD algorithms, retaining their advantages, is presented in order to simulate the behavior of various piezoelectric transducers used in ultrasonic imaging with one single model. The theory is exposed and the algorithm is applied to simulate PZT resonators flooded into water. Perfectly matched layers are developed to absorb the mechanical waves at the borders of the computational domain, and space-shifted grids are used to reduce Gibbs phenomenon. The electrical impedance and various physical parameters (displacements, electric potentials) are calculated. Different high frequency transducer configurations have been modeled. In the case of a simple two-dimensionnal plate, described in Cartesian coordinates, the results are satisfactorily compared to those obtained with a commercial FE software. Then, simulations of an axisymmetrical single-element transducer are favorably compared to FE simulations and experimental measurements. The hybrid algorithm is also used to calculate the large radiation pattern of an annular array with little time-processing, which illustrates the efficiency of the method.