Acoustic multiple scattering using recursive and iterative techniques

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Abstract:

Multiple scattering (MS) by a system of obstacles is an important topic, of great practical and theoretical interest in a wide variety of physical contexts. A computation of the wave field scattered by multiple objects that takes into account the interaction between the obstacles is required in numerous wave propagation problems. These problems include modeling acoustic devices that precisely control and guide propagating waves in a defined manner for specific applications, i.e.: the implementation of ``invisibility" cloaks; the fabrication of phononic crystals (PC) and dynamically tunable structures such as the gradient index lenses and waveguides; and the characterization of effective parameters of heterogeneous media. Recent improvements in design and manufacturing have significantly improved our ability to manage PC. We study acoustic wave scattering in 2D PC by means of MS theory, by taking advantage of the PC structure and using specific recursive algorithms for block Toeplitz (BT) matrices. This problem requires to solve a large complex valued linear system that has a special multilevel BT structure. The expensive costs of direct matrix inversion of a linear system motivates the development of numerically efficient iterative and recursive algorithms. New efficient and accurate algorithms will be presented for solving acoustic MS problem by the cluster of closely spaced cylinders to design acoustic negative refraction imaging in a PC. The unit cell of the PC consists, in general, of a solid cylinder in an acoustic medium. The dispersion curves of PC have a negative refraction dispersion branch producing the focusing effect. We explore the effect of focal point on structural parameters, and employ a parallelization technique that allows efficient application of the proposed recursive algorithms for solving BT systems on high performance computer clusters. Numerical comparisons of CPU time and total elapsed time taken to solve the linear system using the direct LAPACK and TOEPLITZ libraries on Intel FORTRAN, show the advantage of high performance recursive algorithms over the Gaussian elimination. Additionally, an iteratively computable Neumann expansion technique applicable to arbitrary distributions of cylinders will be shown; the method works if the spectral radius of the interaction matrix is less than one. The spectral radius properties of the interaction matrix and convergence characteristics will be displayed to demonstrate the strength and validity of the Neumann expansion method for MS problems.

About the Speaker:

Dr. Feruza Amirkulova is the Postdoctoral Fellow in Physics and Astronomy Department at Vassar College. She received her B.Sc. and M.Sc. in Mathematics, and Ph.D. in Techniques (Civil Engineering) from Samarkand State University in 1995 and 2000 correspondingly, and M.Sc. and Ph.D. degrees in Mechanical and Aerospace Engineering from Rutgers University in 2010 and 2014 respectively. Her area of research includes acoustic-structure interaction, wave propagation, multiple scattering, “invisibility” cloak, phononic crystals, metamaterials, negative refraction, superlenses, fractals, sound diffuser, anisotropy, heterogeneity, composites, BEM, high performance computing, block Toeplitz structures, recursive and iterative techniques, etc.

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