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FaIMS: A fast algorithm for the inverse medium problem in acoustic scattering

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We consider the inverse medium problem for the time-harmonic wave equation with broadband and multi-point illumination in the low frequency regime. Such a problem finds many applications in geosciences (e.g. ground penetrating radar), non-destructive evaluation (acoustics), and medicine (optical tomography). We use an integral-equation (Lippmann-Schwinger) formulation, which we discretize using a quadrature method. We consider only small perturbations (Born approximation). To solve this inverse problem, we use a least-squares formulation. We present a new fast algorithm for the efficient solution of this particular least-squares problem.

If N is the number of excitation frequencies, N_s the number of different source locations for the point illuminations, N_d the number of detectors, and N the parametrization for the scatterer, a dense singular value decomposition for the overall input-output map will have $[\min(N_s N N_d, N)]^2 \times \max(N_s N N_d, N)$ cost. We have developed a fast SVD-based preconditioner that brings the cost down to $O(N_s N N_d N)$ thus, providing orders of magnitude improvements over a black-box dense SVD and an unpreconditioned linear iterative solver.