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Spectral analysis of the volume-integral-operator of electromagnetic scattering

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We study the spectrum of the volume-integral-operator in electromagnetic scattering theoretically as well as numerically. The knowledge of the spectrum helps us to develop more robust and accurate volume-integral-equation solvers for the analysis of electromagnetic scattering by arbitrarily-shaped three-dimensional objects.

The low-frequency spectrum of the integral-operator can be found mathematically, for example, by employing the Helmholtz decomposition. The spectrum of the discretized operator, i.e. the distribution of eigenvalues on the complex plane, can be obtained by numerical computations. The discrete spectrum acts as an indicator of how well the discrete-operator represents the original continuous
integral-operator. In the ideal case, the spectrum of the discretized system should approach the spectrum of the original operator as the element size decreases.

We study the volume-integral-equation formulations for flux densities, fields, polarization currents, and potentials. These formulation are discretized with basis and testing functions whose differential properties differ from each other. We show that the discrete-spectrum depends on the basis and testing functions applied. The spectrum of the discrete operator effects on the convergence of the iterative solution, which in turn, affects computational time. We also discuss preconditioning strategies based on the spectral properties to improve the convergence of the iterative solution.