On the Conditioning of Resonance-Free Integral Formulations for PEC Scattering in the High-Frequency Regime

Francesco P. Andriulli[(1)], Ignace Bogaert[(2)], and K. Cools[(3)]
(1) Telecom Bretagne / Institut Mines-Telecom, France
(3) The University of Nottingham, UK

Integral equation formulations are a primary tool in the modeling of electromagnetic scattering from perfect electrically conducting objects. Although these techniques discretize only the scatterer's surface, they require a solution of a linear system with an associated dense matrix. One of the primary strategies to tackle the computational complexity of the solution of such a system is the use of an iterative solver in conjunction with a (quasi-)linear-in-complexity fast matrix-vector multiplication algorithm.

In this scenario the overall complexity of the linear system solution will remain linear as far as the number of iterations, necessary to the iterative solver to converge, will stay constant as a function of the number of unknowns. In the majority of cases this can be achieved whenever the conditioning of the matrix is uniform in the number of unknowns.

Several preconditioning techniques have been developed to control the condition number of the linear system matrices arising from the majority of the integral formulations for electromagnetics problems. The performance of these techniques is usually assessed in two regimes that are of key importance for applications: (i) the case where the number of unknowns is kept constant and the frequency decreases (low-frequency regime) and (ii) the case where the frequency is kept constant and the number of unknowns increases (dense discretization regime).

This contribution will analyze the conditioning behavior of several integral equations in a third regime: (iii) the case where both frequency and the number of unknowns grow since the discretization size in wavelengths is kept constant and the frequency increases (high frequency regime). All the formulations (past or newly proposed) that we will analyze will be resonance-free equations. In other words the conditioning problems of interest for analysis are the ones (potentially) remaining after that all conditioning issues related to spurious resonances have been solved already.

Several standard and preconditioned integral equations will be analyzed and the appropriate strategies to obtain uniformly conditioned problems in the high frequency regime will be proposed. Theoretical developments will be complemented by numerical investigations that will corroborate the theory and that will show the practical effectiveness of the presented approaches.