

Summary

Electromagnetic simulations are essential across various applications, from antenna design and radar to biomedical imaging and wireless communications, where accurate and fast handling of complex geometries, materials, and wide frequency ranges is often needed. Among the methods developed in computational electromagnetics (CEM), the Boundary Element Method (BEM) offers distinct advantages, especially in reducing unknowns through surface discretization and inherently satisfying radiation conditions at infinity, which is ideal for modelling the scattering from piecewise homogeneous and isotropic media. High-order discretizations further enhance BEM's accuracy, making it suitable for large-scale and complex models. However, BEM faces challenges such as high computational costs, the need for precise singular integral evaluations, and issues with ill-conditioning in complex scenarios. Acceleration techniques, including the fast multipole method (FMM) and low-rank block matrix compression within the framework of hierarchical matrices, have mitigated some of these obstacles by reducing computational and storage costs of matrix assembly and algebraic operations. Moreover, preconditioning strategies, such as quasi-Helmholtz decompositions and Calderón preconditioners, have been developed to address stability and conditioning of the numerical systems, allowing to significantly reduce the number of iterations when resorting to iterative solvers. Limitations remain however, in particular for high-order discretizations and complex material interfaces, for which the extension of these techniques were not fully investigated. This work aims to address these gaps by introducing new quasi-Helmholtz and Calderón preconditioning techniques tailored to high-order elements as well as structures with junctions, providing new advances in BEM's applicability to practical and large-scale problems.