Multi-Trace Surface Integral Equation Using Hyper-singular Kernel for Solving Electromagnetic Wave Scattering from Penetrable Targets

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This work presents the multi-trace surface integral equation domain decomposition method (SIE-DDM) with hyper-singular kernel. The SIE-DDM decomposes the composite objects into non-overlapping homogeneous sub-regions with constant material properties. For each sub-region, multiple traces on its interior and exterior domains' surfaces are introduced. The Robin transmission conditions (TCs) are used to couple the traces at the material/domain interfaces, which allows for the enforcement of both electric and magnetic field continuities. As a consequence, each sub-region can be modularly treated in terms of discretization and solution process.

The integral equation discontinuous Galerkin (IEDG) method is employed for both the interior and exterior domains. It is comprised of tangential components of both electric and magnetic fields, which ensures the removal of the resonance solutions. Furthermore, it permits discontinuous/local trial and testing functions, in square-integrable L2 space, to accommodate non-conformal discretizations, without the continuity requirements across element boudaries. Various types and shapes of elements, non-conformal discretization and non-uniform orders of approximation can be applied in the same solution process.

To evaluate the hyper-singular integrals in the dyadic Green's function, the reverse operation self-consitent Evaluation (ROSE) approach is applied. To keep the self-consitency in ROSE, auxiliary problems are formulated for both the interior and exterior domains, through the equivalence principle. ROSE avoids the integration by part technique to convert the hyper-singular integrations to weak-singular ones, thus removing the contour integrals across elements in non-conformal meshes.

In our implementation, the vectorial piecewise constant basis functions are employed based on mixed triangle/quadrilateral meshes. The multilevel fast multipole algorithm (MLFMA) is performed to expedite the couplings calculation. In addition, the computational experiments are performed via a hybrid MPI and OpenMP parallelismon on advanced distributed computing system. To demonstrate the capability, flexibility and scalability of the proposed method, plave wave scattering from a highly composite unmanned aerial vehicle (UAV) at X-band is presented.