

Towards The Design Of Vector Potential Only Integral Equations For PEC Scattering

Paul Olyslager, Hendrik Rogier, and Kristof Cools

Dept. of Information Technology, Ghent University, Ghent, Belgium

The scalar and vector potential are commonly used as physical quantities in multi-physics applications. Therefore, we propose a stabilized, vector-potential-only method to compute free-space scattering by a perfect electrical conducting (PEC) object.

The vector potential integral equations do not suffer from low-frequency breakdown. However, when these integral equations are discretized, additional numerical stabilization may be required to ensure accurate low-frequency results for quantities such as the charge, the scalar potential (computed through the Lorenz gauge), the far field among others. The near field and the radar cross-section for the electric field are often computed accurately without further stabilization.

Two formulations to compute the scattering at a PEC can be written down for the vector potential, similar to the classical field formulations, where this leads to the first-kind electric field integral equation and the second-kind magnetic field integral equation. We will focus on the first-kind integral equation for the vector potential.

The boundary conditions for the vector potential are not uniquely defined, since there is still gauge freedom after applying the Lorenz gauge. Therefore, we can choose to introduce a constant unknown scalar potential V on the PEC object, but then we have to enforce the charge neutrality condition more strictly by setting both the contribution of the scalar potential and the vector potential to zero:

$$\rho = \rho_s + \rho_v = - \int_{\Gamma} \partial_{\mathbf{n}} \phi - i\omega \int_{\Gamma} \mathbf{n} \cdot \mathbf{A} = 0, \quad \rho_s = \rho_v = 0. \quad (1)$$

in which the boundary of the PEC domain is denoted by Γ , the scalar potential by ϕ and the vector potential by $\mathbf{A}$. The $e^{i\omega t}$ dependence is omitted. The normal vector $\mathbf{n}$ is pointing outwards.

This sharper condition for the charge is not used in the second formulation, in which the potential V is set explicitly to zero. Both formulations have a similar set of unknowns, given by $\mathbf{n} \times \nabla \times \mathbf{A}$ and $\mathbf{n} \cdot \mathbf{A}$. The stabilization of the vector unknown $\mathbf{n} \times \nabla \times \mathbf{A}$ with a loop-star basis has already been discussed in previous work (R. Chen, et al., IEEE Trans. Antennas Propagat., vol. 70, no. 12, pp. 12411-12416, Dec. 2022).

This work focuses on the stabilization of the scalar unknown for both formulations and on the applicability of the Lorenz gauge to compute the scalar potential in the post-processing step, leading to a vector potential only formulation. We compare our method to non-stabilized methods, and we will show at the conference for which physical quantities of interest further stabilization is required and for which existing methods are sufficient.

This project was funded by the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (Grant agreement No. 101001847).