# Fast Computation of Double Bounce Contributions to Physical Optics Integrals in the Near Field

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A multilevel algorithm for the fast computation of double bounce (DB) contributions to near field (NF) scattering physical optics (PO) integrals is presented. The algorithm aims at accelerating the computation of the mono-static DB contribution for multiple excitations, i.e., for sources set within a wide range of locations with respect to the scatterer, and over a range of frequencies. The DB-NF fast PO algorithm is an extension of its far field predecessor (A. Boag and E. Michielssen, IEEE Trans. Antennas Propag., 52, 205-212, 2004) and it complements our fast NF algorithm for computing the single bounce PO contribution (A. Gendelman, Y. Brick, and A. Boag, IEEE Trans. Antennas Propag., 62, 4325-4335, 2014).

The algorithm relies on the optimal sampling of phase- and amplitude-compensated partial contributions to the integral, by pairs of finite size subdomains, and their interpolation in a hierarchical fashion. For each pair, the phase- and amplitude-compensation is performed by using a multiplicative compensation factor that is specifically tailored to the case of DB-NF back-scattering. This multiplication approximately removes the rapid oscillations and radial decay common to all pairs of elemental scatterers residing on the two subdomains, such that the pair's partial contribution is down-converted to spatial base-band. This allows for its coarse sampling on a spherical grid which is uniform in both angular coordinates and the frequency, and is non-uniform with respect to the distance to the scatterer's center, with sampling rates which are dictated by the subdomains' size.

The algorithm directly evaluates the partial contributions at a fixed number of points only for paris of the smallest sized subdomains. It then gradually interpolates and aggregates the contributions until the entire DB integral is computed. For the most complicated scenarios, where the scattered field is of interest for sources located within ranges of both azimuth and elevation angles, distances from the scatterer, and frequencies, the multilevel interpolations allows for the reduction of the computational complexity (CC) from $O(N^9)$ to $O(N^5)$ ($N = kR$ where $k$ is the wavenumber and $R$ is the scatterer's linear dimension). For reduced scenarios, i.e., when the scattering is of interest only for a certain geometrical cut or a single frequency, further reduction of the CC to $O(N^4 \log N)$ and even $O(N^4)$ is obtained, depending on the scenario.