SphericalScattering: A Julia Package for Electromagnetic Scattering from Spherical Objects

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Summary

When electromagnetic fields are impinging on objects of various kinds, determining the scattered field as a solution to Maxwell's equations is crucial for many applications. For example, when monitoring the position of an airplane by a radar, the scattering behavior of the airplane plays a pivotal role and, thus, needs to be studied. Analytical approaches, however, to characterize such scattering behavior are rarely known. Some of the few exceptions where at least semi-analytical descriptions are available are metallic or dielectric spherical objects excited by time-harmonic or static fields (Jin, 2015; Ruck et al., 1970). In some applications these canonical scattering problems are the study subject of interest. In other areas, solutions to the scattering from spherical objects rather serve as a means to verify the correctness of more involved numerical techniques, which allow to analyze the scattering from real-world objects, for instance, via finite element or integral equation methods (Adrian et al., 2021; Harrington, 1993; Jin, 2015; Rao et al., 1982). Hence, semi-analytical descriptions for the scattering from spherical objects facilitate a reproducible and comparable verification of approaches to solve electromagnetic scattering problems.

Statement of need

`SphericalScattering` is a Julia package (Bezanson et al., 2017) providing semi-analytical solutions to the scattering of time-harmonic as well as static electromagnetic fields from spherical objects (including the Mie solutions for plane wave excitations). To this end, series expansions are evaluated with special care to obtain accurate solutions down to the static limit. The series expansions are based on expressing the incident and scattered fields in terms of spherical wave functions such that the boundary conditions can be enforced at interfaces of different materials yielding the expansion coefficients of the spherical wave functions of the scattered field (Jin, 2015; Ruck et al., 1970).

Other available implementations have a different focus, that is, specific 2D scenarios are addressed (Blankrot & Heitzinger, 2018), T-matrices are employed for general shaped objects (Egel et al., 2017; Art Gower & Deakin, 2018; Parker, 2022; Schebarchov et al., 2021), ensemble averaged waves are obtained (Artur Gower, 2020), spontaneous decay rates of a dipole are studied (Rasskazov et al., 2020), light scattering is considered employing only plane waves as excitations (chillin-capybara, 2022; Ladutenko et al., 2017; Leinonen, 2016; Prahl, 2023; Schäfer, 2023; Walter, 2023; Wu, 2023), or only far-field quantities are computed.

In contrast, in `SphericalScattering` a variety of excitations is available, that is,

- plane waves,
- fields of electric/magnetic ring currents,
- fields of electric/magnetic dipoles,

- transverse electric (TE) and transverse magnetic (TM) spherical vector waves, and
- uniform static electric fields,

where several parameters including the orientation, direction, or polarization of the sources can be set by the user and are not predefined. The scattered far- and near-fields are then obtained following (Hansen, 1988; Jackson, 1999; Jin, 2015; Jones, 1995; Ruck et al., 1970; Sihvola & Lindell, 1988) for

- perfectly electrically conducting (PEC) spheres and
- dielectric spheres

all via a unified interface. In consequence, `SphericalScattering` is a useful (code-) verification tool in the area of electromagnetic scattering for a wide range of scenarios. For this purpose, it has already been employed in scientific publications (Hofmann et al., 2022a, 2023a, 2021, 2022b, 2023b, 2023c, 2023d).

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