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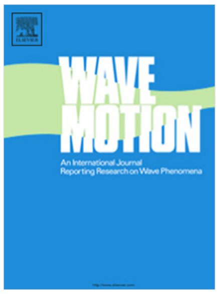

Egocentric physics: Summing up Mie

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Egocentric physics: summing up Mie

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Abstract

We consider sum rules for the electric type (TM) multipole coefficients in the Mie theory of the scattering coefficients for electromagnetic waves incident upon spherical particles. These sum rules are derived from infinite product representations for the scattering coefficients as a function of the size parameter of the sphere and involve an analytically-determined multiplying factor in addition to the resonant eigenstate values. We show that the product expansions converge rapidly to the scattering coefficients with increasing numbers of resonant state values only if the analytic multiplying factor is included in expansions, and that the use of these sum rules strongly accelerates the convergence of scattering coefficient expansions. We present analytic asymptotic estimates for the resonant state eigenvalues in the dipole, quadrupole and hexapole cases, give the corresponding sum rules, and numerically illustrate their convergence.

1. Introduction

This article builds on results in a previous paper[1], wherein it was shown that compact superpositions of the Resonant States (RSs) in Mie scattering theory [2] could be used to understand an interference effect known as the anapole phenomenon occurring in high-index dielectric spheres [3]-[5]. While purely numerical studies based on the Mie solution to the electromagnetic scattering by a sphere are readily carried out, theoretical studies based on the RS expansion can still be valuable, provided two conditions are satisfied. Firstly, it should be the case that the phenomena involved can be treated using a small number of RSs. If this is not the case, the RS expansion is not likely to yield much more insight and predictive power into studies of the phenomena than pure numerics. It should be noted however that the most striking interference phenomena in physics involve small numbers of modes in optimal bases. Secondly, as shown in our previous paper [1], the product formula involving RSs needs to include an analytic factor guaranteeing that causality is satisfied, otherwise the RS expansion will need to involve multiple terms (see also [6]).

Although the notion of a resonant state (under its myriad names) has been used for over a hundred years to phenomenologically describe damped or 'decaying' excitations, there is increasing interest in using resonant state expansions (RSEs) for systematic and quantitative descriptions of the response of physical systems. Given their long history and their utility not only in electromagnetic scattering, but in a wide variety of fields, RSs have also been referred to in various ways: Quasi-Normal Modes, (QNMs), leaky waves, transient states, Gamow states, etc.

This revival of theoretical interest in RSEs is motivated at least in part by the following considerations: RSEs promise to compactly encode the full, wide-band temporal