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Modified Watson's Transformation for Asymptotic Analysis of Backscattering from Electrically Large Low-absorption Spheres

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Electromagnetic scattering from electrically large low-absorption spheres is rich in spectacular scattering phenomena, including solar rainbows and glories, seemingly irregular ruffling in scattering cross sections (ripple) and anomalously strong backscattering from silica glass balls. The underlaying physical mechanisms include multiply reflected rays, interior resonances, creeping and whispering-gallery modes. Physical explanation of these phenomena and their mathematical description require a high-frequency asymptotic approach which could be applied to the available exact multipole solutions (Mie series) in the case of an electrically large sphere [1,2]. The multipole expansions provide numerically exact values for the scattered fields but include many terms with unapparent physical meaning (high-order electric and magnetic multipole contributions), being therefore unsuitable for physical interpretation.

A classical method of asymptotic analysis of the electromagnetic scattering from large spheres has been proposed more than a century ago [3]. The method, referred to as Watson's transformation, consists in replacing the multipole series by a contour integral on the complex plane of the multipole order ν. The integral can be evaluated as a sum of either stationary-point contributions or residues at the poles in the complex plane, which extracts the contributions of the various scattering mechanisms in a physically pure form. A problem with the classical form of the Watson transformation is however that instead of Legendre polynomials as in the multipole expansions, the integrand of the contour integral includes the Legendre function $P_{\nu-1/2}[\cos(\pi-\theta)]$ which is infinite when the bistatic angle θ vanishes, i.e. at the direction of backscattering. The backscattering case requires therefore a modification of the Watson method. The modification proposed in [4] uses the Legendre function of the form $P_{\nu-1/2}(\cos\theta)$ which is *finite* when $\theta=0$, and makes the backscattering case amenable to the asymptotic analysis. The approach has been applied to various backscattering phenomena, and the specific results have been reported in [5-8]. The goal of this work is to provide an overview of the achieved results. The paper will briefly address the derivation of the modified Watson transformation, the asymptotic evaluation of the solutions for spheres and the physical interpretation of the asymptotic contributions. Furthermore, application of the theory to the phenomena of solar glories, of the ripple and of the anomalous backscattering from silica glass spheres will be outlined and supplemented with illustrative examples.

1. H. C. van de Hulst, *Light Scattering by Small Particles*, New York, Dover Publications, 1981.

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3. G. N. Watson, "The Diffraction of Electric Waves by the Earth," *Proc. R. Soc. Lond. A*, **95**, 1918, pp. 83-99, doi:10.1098/rspa.1918.0050.

4. A.V. Osipov, "A Rigorous Theory of Backscattering from an Electrically Large Dielectric Sphere," *URSI EMTS 2019*, San Diego, USA.

5. A.V. Osipov, "Towards a Rigorous Electromagnetic Theory of the Solar Glory," *URSI EMTS 2019*, San Diego, USA.

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7. A.V. Osipov, "A Theory of Ripple in Electromagnetic Scattering from Low-absorption Spheres," *URSI EMTS 2023*, Vancouver, BC, Canada.

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