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Backscattering from Electrically Large Low-absorption Spheres: an Explanation of Solar Glories

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1. Introduction

Geometrical Optics (GO) cannot fully explain backscattering from electrically large low-absorption spheres [1]. In [2,3] it is shown that the waves that are excited by the incident plane wave in a small region around the equator and circumventing the sphere in its interior dominate the backscatter. These waves explain the irregular frequency patterns of the backscatter from such spheres (the ripple). This paper shows that these contributions are also responsible for the formation of solar glories.

A glory consists of colored rings that are seen around the shadow of an observer placed in front of a cloud, a scientific explanation of which is still a topic of debates. According to [4], the phenomenon is caused by interference between two rays entering the water droplets at diametrically opposite points and ejected back upon one internal reflection. Because of the properties of water in the visible range of electromagnetic spectrum, one of these rays must however make about 14° of its path as a creeping wave, which imply a too strong attenuation to quantitatively explain the phenomenon. Another explanation [5,6] employs a lateral excitation of multiply reflected waves by the portions of the wavefront of the incident wave that miss the sphere (similar to wave tunneling in quantum mechanics). Association of the glory with a specific order of the internal reflections is however difficult.

2. Summary of Main Results

The following scattering problem is considered. A plane electromagnetic wave with the wavenumber k illuminates a dielectric sphere of the radius a, which is electrically large ($ka \gg 1$) and lossless (or possesses some negligibly small absorption). The wavenumber in the material of the sphere k_1 is such that $k_1 > k$. Application of Watson's transform to the exact multipole solution of the problem shows that in addition to GO rays (specular reflection, multiple reflections in the interior of the sphere) and creeping waves propagating along the convex side of the spherical boundary, there are also diffraction rays of a different kind that propagate on the *concave* side of the spherical boundary, being similar to whispering-gallery modes in spherical resonators. In electrically large low-absorption spheres the attenuation rate of these contributions is $O(1)$ and therefore much smaller than that for creeping waves, which is proportional to the large parameter $(ka)^{1/3}$. Diffraction rays of this kind with particularly low attenuation rates are excited by the portions of the wavefront of the incident wave closest to the equator of the sphere, including lateral excitation. These waves circumvent the sphere along the concave side of the spherical boundary before leaving the sphere toward the observer. In the case of water in the visible, superposition of the waves of this type propagating in the opposite directions around the sphere results in the maxima of the scattered field, the position of which depends on the wavelength and agrees with the position of the colored rings observed in the solar glories.

3. References

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