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Resonance modes due to excess charges on particle surfaces: Theory vs experiment

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It has been recognized only recently, that electric charges deposited on a spherical particle can influence significantly the scattered component of electromagnetic radiation in the far-field zone. The physics of this effect can be introduced through the surface current density that is linearly proportional to a phenomenological surface conductivity and the tangential electric field at the surface of a particle. At present, the optical effects of excess charges on a small particle or on a collection of small particles are highly uncertain; however, they are of high importance for new technologies and for correct understanding of many physical processes.

The resonant amplification due to excess charges is governed by mutual relations between size parameter, refractive index, surface conductivity and Riccati-Bessel functions of n-th order (JQSRT 106, 170-183, 2007). The theoretical derivations indicate that a mode of vibration occurs only if scattering coefficient b_n reaches its maximum value, which quickly changes with mode index n. The first-order mode is not sufficient to reproduce the resonance peaks. For these reasons the Rayleigh approximation is not a correct approach for modelling the optical effects by charged particles much smaller than the wavelength of an incident radiation.

Experiments on electromagnetic scattering by charged particles are rare, but microwave measurements indicate that the attenuation of electromagnetic wave in a sandstorm can be more than one order of magnitude higher than that predicted from Rayleigh theory (Appl. Opt. 49, 6756–6761, 2010). This sufficiently unexpected result challenges present models. We have shown that the experimentally measured attenuation can be successfully reconstructed theoretically if the vibrational mode resonance arising from charged particles is included.

The net surface charges carried by a particle can be almost arbitrary except for liquids, where the Rayleigh limit is a typical constraint. For atmospheric particles the dielectric strength of the air also is a limiting factor. We have simulated the resonance that can occur between the incident EM radiation and charged water droplets much smaller than the wavelength to explain and to interpret the some experimental results (JQSRT 111, 2550–2557, 2010). It is shown that EM scattering by a charged water droplet is susceptible to an applied electric field only if resonance conditions are fulfilled which is a prerequisite for successful experiment.

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