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On physical bounds on absorption, scattering, and extinction in lossy media

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This contribution gives a report on ongoing research on physical bounds on absorption, scattering, and extinction for passive linear scatterers embedded in lossy media. Fundamental bounds on absorption, scattering, and extinction have been considered in various formulations. The bounds recently obtained in [1, 2, 3] are based on the equivalent (polarization) current formulation, which is incorporated with analytical [1] and numerical [2, 3] optimization techniques. However, all these bounds do not take into account losses in the medium surrounding the scattering object, and thus, they are valid only for lossless backgrounds or backgrounds with sufficiently small losses. In this contribution, we present two versions of an optical theorem that are formulated in terms of internal and external fields, respectively, and express the same power balance at the external surface of the scatterer: $P_{\rm a} = -P_{\rm s} + P_{\rm t} + P_{\rm i}$, where $P_{\rm a}$, $P_{\rm s}$, $P_{\rm t}$, and $P_{\rm i}$ are the absorbed, scattered, extinct (total), and the absorbed incident powers, respectively, which are defined from the Poynting's theorem; see e.g., [4]. Furthermore, the total electromagnetic fields at the external surface of the scatterer are given as a sum of incident and scattered fields.

The first version of the optical theorem is based on equivalent (polarization) current formulation and generalizes the results obtained in [5] to the case when the surrounding isotropic medium is lossy. The associated bounds on absorption, scattering, and extinction are obtained by employing elementary optimization techniques and the calculus of variations as in [5], and depend on the geometrical and material properties of the corresponding scatterer. From the new optical theorem, it follows that the extinct power has to be expressed as an affine form in the equivalent currents, which provides subtle changes in the resulting bounds on absorption, scattering, and extinction.

The second version of the optical theorem is based on the T-matrix parameters of the scatterer and is valid for any linear scatterers of an arbitrary geometry, which can be circumscribed by a given spherical volume. It is also assumed that the scatterer can be made of an arbitrary passive material, and the spherical volume is surrounded by an isotropic lossy medium. Here, the corresponding physical bound on absorption, previously derived in [4], is generalized to the case, when the surrounding lossy medium can be magnetic as well. The corresponding fundamental bounds on scattering and extinction are derived by employing the method of Lagrange multipliers and the method introduced in [4] for the determination of the bounds on absorption in lossy media. The obtained bounds include all the multipole fields and are valid for scatterers, which can be made of general heterogeneous materials.

The two versions of the optical theorems are fundamentally different, and thus in numerical examples, we consider cases with homogeneous and core-shell spheres embedded in electric and magnetic lossy backgrounds. The obtained results demonstrate that the physical bounds on absorption, scattering, and extinction obtained from two different formulations provide complementary information.

References

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