Multiplicity of Optical Theorems

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The optical theorem is a fundamental result in scattering theory, which provides a framework to characterize the extinction cross section of a scatterer from scattered field data corresponding to well-defined limited views; e.g., in the classical plane wave excitation case, in free space, the extinction is defined by the value of the scattering amplitude in the forward direction only. The sensor employed for measurement of the extinction is not unique, however. This has been demonstrated in [1] in several scalar-wave frameworks, e.g., 1) Kirchhoff-Helmholtz and Rayleigh-Sommerfeld-based diffraction, 2) backpropagation-based imaging, 3) lens-based imaging, 4) boundary-value problems, as well as 5) the canonical multipole expansion.

Recently, we have generalized the scalar theory in [1] to the full vector, electromagnetic case. This has led (as in [1]) to a multiplicity of optical theorem realizations, in several contexts: 1) Love's equivalence principle, in both time and frequency domains, 2) backpropagation-based imaging, 3) planar aperture realizations, and 4) electromagnetic multipole expansions, where in the latter approach we have derived two alternative theories, a restricted version that is the multipole form of backpropagation-based imaging and a more general one that applies in the near field. These generalizations shed insight into alternative methods for sensing the extincted power associated to the scattering phenomenon and, importantly, apply for arbitrary probing fields. This is an important generalization, e.g., for radar and remote sensing applications in multipath environments; in such environments the targets are interrogated both by the aimed probing beams as well as by additional medium's reflections, and this impacts, accordingly, the perceived cross section.

This talk will summarize these theoretical developments alongside representative numerical illustrations in both two-dimensional (2D) and three-dimensional (3D) geometries. Applications to the detection and tracking of targets through full vector, electromagnetic field data will also be discussed.

References

[1] E. A. Marengo, "Nonuniqueness of Optical Theorem Detectors," *JOSA A*, **32**, 11, November 2015, pp. 1936–1942.