# Optical Theorem Method for Change Detection

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We explore the general problem of detecting unknown targets or changes to an unknown environment or scene by actively probing the region of interest with a small number of sensors or a limited view sensing aperture located far away from that region. The proposed approach is based on the optical theorem. Its practical implementation in complex media also exploits time reversal focusing and thus benefits from medium complexity and reverberations.

The optical theorem defines the rate at which energy is taken away from a probing wavefield by a scattering object, due to both scattering by the object, and absorption by the object of part of the incident energy. The acoustic, optical, and quantum-mechanical wave form of this theorem for homogeneous plane wave excitation and free space background media is well known. Recently, the electromagnetic version of this theorem has been successfully generalized to arbitrary fields and media (E.A. Marengo, IEEE Trans. Antennas Propagation, Vol. 61, pages 2164-2179, April, 2013), including both reciprocal and nonreciprocal lossless background media. This generalization not only shows that this fundamental result is far more general and broadly applicable than previously known, but also gives the explicit recipe to build scattering energy detectors in an arbitrary medium, be it physically, or synthetically - as a signal processing filter. The detector in question, which we call the optical theorem detector, measures real, reactive, or apparent power which can, in turn, be used as an effective indicator function for the detection of changes in the propagation environment.

In this presentation we will present the physical foundations for the optical theorem detector and illustrate its performance versus alternative approaches such as the conventional energy detector and the optimal matched filter. We will show that the proposed optical theorem detector can perform close to a matched filter even though –unlike the (active sensing) matched filter- it relies on no prior information about the target or medium change and the background. In addition, it defines the single projective measurement or datum carrying the sought-after energy information, which can be effectively approximated under limited data. Moreover, it exploits the local environment. These attributes makes it a form of compressive sensing, in particular, an in situ compressive detection. Thus, medium complexity leads to reverberations, which can in turn facilitate in many practical scenarios a larger density of target information at a far-positioned, and realistically sized (limited) aperture. In this framework, the local (in situ) propagation medium surrounding the target is used to carry out projective measurements, in the present case, about the energy budget of the target, through which we can infer the presence or absence of the target in the medium.