

Imaging with waves in homogeneous and random media

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The goal of this mini-course is to introduce a general mathematical audience to sensor array imaging. This is an emerging interdisciplinary area in applied mathematics, with roots in wave propagation, statistics, optimization, and numerical analysis.

Imaging with waves is used in medical imaging, geophysical exploration, and non-destructive testing of materials for instance. The principle is to record the waves generated by active sources or ambient noise sources on a sensor array and to process the data in order to estimate relevant features of the medium (reflector locations and shapes, propagation speed).

The lectures will present the mathematical tools for the analysis of different approaches to wave imaging including migration, time reversal, and cross correlation techniques. We will see that imaging with waves can be seen as a general inverse problem and can be approached with standard techniques, such as least squares methods. However imaging with waves has also specific properties due to the physical nature of waves. In particular we will show that the energy conservation, reciprocity, and time reversal properties of the wave equation can be exploited for imaging.

The following items will be addressed during the mini-course:

- Introduction and motivations (time reversal experiment and passive imag-

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ing using ambient noise).

- Migration and least squares imaging. Basic resolution theory (in homogeneous medium).
- Time reversal in homogeneous and random medium. Statistical stability and resolution enhancement.
- Passive sensor imaging using cross correlations of ambient noise signals. Travel time estimation, background velocity estimation, and reflector imaging.