Sparse-aperture qualitative inverse scattering using a multipole formulation

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The Linear Sampling Method (LSM) is a qualitative inverse scattering technique for reconstructing target shape from scattered electric fields. It has several advantages relative to various quantitative inverse scattering techniques. Notably, it does not require solving a nonlinear system, is relatively computationally efficient, and does not rely on the Born approximation. However, the LSM requires spatially dense, multi-static, multi-view data, which limits its application in many practical imaging scenarios that exhibit sparsity in either transmit or receive locations.

The lack of spatial data may in principle be mitigated by leveraging data diversity in other dimensions. Previous work has demonstrated the promise of this approach by incorporating multiple frequency data into the inverse problem (H. Alqadah, IEEE Trans. Im. Proc., vol. 5, no. 26, 2016). Faithful images may be created in scenarios with sparse spatial samples by adding a frequency variation constraint into the LSM optimization.

In this study, we investigate a strategy for enhancing the diversity in the received data using a multipole formulation of the LSM. Conventional LSM involves solving a linear system of the form **Eg** = **f** for each sample point in the imaging volume, where **E** is the matrix of multistatic data, **f** is a known radiation pattern for an elementary (i.e., monopole) source centered at the sample point of interest, and **g** is the weighting vector to be solved that that relates **E** to **f**. Recent studies have shown that LSM images can be formed with a higher degree of spatial information by modifying the LSM formulation to include higher-order multipole terms in **f** (e.g., L. Crocco *et al*, IEEE TAP, vol. 61, no. 2, 2013). The multipole formulation allows the LSM inversion to take into account various radiation modes that are related to the geometry of the target. These studies have used relatively dense transmit-receive data. We hypothesize that the additional spatial information embedded in a multipolar formulation of LSM may be used to partially overcome the limitations of a spatially sparse data collection.

In this presentation, we first describe our mathematical formulation for taking advantage of multipolar radiation patterns for sparse-data LSM. We then generate simulated scattered field data from a target of interest and apply the enhanced LSM formulation to the data. We then characterize imaging performance as a function of spatial data sparsity and make suggestions for next steps.