The Building Tomography Inverse Problem

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We consider the use of microwaves for inference of building interiors. The building tomography problem presents a number of challenges due to model representation, model order, data sensitivity, and feasible/practical experiment aperture. *Model representation* is non-trivial due to (i) the complexity and potentially high dimensionality of the model space, (ii) the need for a model encoding suitable for use in high-fidelity forward computation codes and yet adjustable within an optimization framework and (iii) the trade-off between fidelity of representation versus model compactness. The *model order* issue is difficult, since the model configuration (or model basis) is unknown; that is, the number and geometric arrangement of walls, doors, clutter objects, and so forth is not necessarily known *a priori*. In addition, the wall types, and hence the associated number and identity of the corresponding model parameters, may also vary. Even for topologically similar configurations, the parameters must still be determined e.g., wall locations, dielectric values, and others. Microwaves are sensitive to the geometry and dielectric properties of building structures, but there are ultimate limitations due to attenuation, dynamic range of instrumentation, and ability to resolve parameters as a function of the experiment aperture and available frequency range. For realistic inverse problems only a very limited experiment aperture may be available with respect to the building under study; clearly, the quality and quantity of data available has a strong bearing on the ultimate inversion success.

Each of the above issues are illustrated with a combination of synthetic and real-data inversions. We present real-data inversion results for a multi-wall structure using a global optimization method based on simulated annealing, in which we simultaneously estimate all model components. This is feasible due to the small model order. We also present the results of a blind-test inversion for a two-story building structure (using synthetic data), in which a hierarchical estimation approach is applied.