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Diaphram wall integrity inspection based on probabilistic inversion of crosshole GPR data

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Diaphragm wall is widely employed as retaining structure to provide structural support and water tightness of deep excavations in urban areas. Imperfections such as cracks and voids occurred inside or in-between diaphragm wall panels may compromise structural integrity and lead to damage of surrounding environment. We hereby provide a crosshole GPR method to evaluate diaphragm wall integrity by mapping the relative permittivity of the structure using transmitted electromagnetic waves. To enable a detailed characterization of the subsurface, we present a probabilistic inversion method that merges the strengths of Bayesian inference and crosshole GPR waveform data. Our method, coined FDTD-DCT-DREAM$_{(ZS)}$ framework, uses as main building blocks the finite-difference time-domain (FDTD) simulator, the discrete cosine transform (DCT), and Markov chain Monte Carlo (MCMC) simulation with the DREAM$_{(ZS)}$ algorithm. The FDTD simulator serves as a forward model to simulate crosshole GPR waveforms by solving Maxwell's equations iteratively. The DCT algorithm transforms model parameters to the frequency domain and reduces the dimensionality of the search space by discarding higher-frequency DCT-coefficients. MCMC simulation with the DREAM$_{(ZS)}$ algorithm automatically tune the scale and orientation of the proposal distribution and lead to a convergence to the target distribution of the DCT-coefficients. This approach allows for the treatment of different sources of error, results in a posterior parameter distribution and quantifies the uncertainty, and returns to the user an ensemble of solutions deemed statistically acceptable. We evaluate the practical usefulness of the FDTD-DCT-DREAM$_{(ZS)}$ framework by applications to both synthetic and real-world data, and demonstrate its applicability to diaphragm wall integrity inspection.