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High-resolution imaging and inversion of 3D GPR data for layered media

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Ground penetrating radar is increasingly being used to provide quantitative information of layered structures. For application in civil engineering these can be roads, highway pavements, airport runways, bridges, tunnels, or buildings. Monitoring is important for the management and safety of these structures. Standard imaging uses a modeled wavefield extrapolator to image the data and the quality of the image depends heavily on the quality of the modeled extrapolator. Usually, data inversion is implemented by minimizing a cost function involving the measured data and the modeled data. The model is modified such that data computed from the model fits to the measured data. The data itself is not used, except as a measure of the model data fit.

A recently developed alternative method is to use results from inverse scattering theory to first construct an image while all multiple reflections are simultaneously eliminated from the data. This image can be constructed from surface reflection data if the data allows separating the subsurface reflection response from the down going emitted field. For 3D waves in a layered medium this requires knowledge of all horizontal electric and magnetic field components. If the data is properly sampled the solution is unique. In layered media the plane wave decomposition allows computing the image for each angle of incidence separately as a function of image time that is equal to the one-way intercept time. Once the image is constructed for all available angles of incidence a simple matrix inversion leads to the desired electric permittivity and magnetic permeability values in each layer. Finally these values provide interval velocities that can be used to convert image time to depth and the inverse problem is solved. The theory requires infinite bandwidth frequency domain data, which is equivalent to measuring the true impulse response. This is not possible in practice and numerical results show that data with finite bandwidths can be used as long as the source time function is known. The construction of the image is robust for noise in the sense that good results are obtained by using an iterative scheme for imaging and the iterative scheme is terminated when the result no longer improves.