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

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Wavefield methods provide qualitative and can provide quantitative information of layered structures. Non-destructive testing for engineering and geosciences applications is of growing interest. Monitoring is important for the management and safety of engineering structures. Almost all imaging full waveform inversion techniques use a modeled wavefield to image the data or obtain wavefield parameters. The quality of the image or the inverted parameters depends heavily on the quality of the model. Usually, data inversion is implemented by minimizing a cost function involving the measured data and the modeled data. Model updates are found such that the computed data better fits the measured data. The data is used as a measure of the model data fit.

We provide an alternative approach by first eliminating all multiple reflections from the data. This can be performed as an automated unsupervised process. The resulting primary reflections only data is suitable for velocity estimation, imaging and inversion. 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 values of the medium parameters in each layer. These values provide interval velocities that can be used to convert image time to depth and the inverse problem is solved. In the case losses are present, these can be taken into account and estimated. The theory accommodates the finite frequency bandwidth of practical data and numerical results show that the method works on seismic and GPR data without the need to know the source time function. The construction of the image is robust for noise in the sense that good results are obtained by using an iterative scheme for multiple removal, imaging and inversion. The iterative scheme is terminated when the result no longer improves.