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Full-waveform inversion of crosshole georadar data: influence of source wavelet estimation

F. A. Belina (1), J. Irving (1), J. R. Ernst (2) and K. Holliger (1)

(1) Faculty of Geosciences and Environment, University of Lausanne, Switzerland, (2) Institute of Geophysics, ETH Zurich, Switzerland (florian.belina@unil.ch / Fax: +41 21 692 4405 / Phone: +41 21 692 4418)

For a wide range of environmental, hydrological, and engineering applications, tomographic imaging of the shallow subsurface is becoming increasingly important. Because of its high-resolution and sensitivity to pertinent petrophysical parameters, crosshole georadar tomography is of particular interest in near-surface investigations. Recently, a full-waveform inversion scheme was developed for crosshole georadar imaging, whose kernel is based upon a finite-difference time-domain (FDTD) solution of Maxwell's equations in 2-D Cartesian coordinates. The reconstruction properties of this inversion scheme are vastly superior to those of commonly used asymptotic ray-based inversion approaches, particularly for realistic, strongly heterogeneous media. Ray-based inversion schemes only account for a very small part of the observed wavefields and inherently suffer from limited resolution, and thus in complex environments may prove to be largely inadequate.

While the results of testing the above full-waveform inversion scheme on synthetic electrical property models have been extremely successful, and tests on a small number of field data sets have also been positive, a critical concern is being able to apply this inversion approach to a wide variety of real-world crosshole georadar problems. Here, we examine a number of features of this inversion approach with respect to their robustness under realistic conditions. First, we investigate the method used to determine the source current function, which involves deconvolving from the measured crosshole georadar data the impulse response of the subsurface for the current model iteration. Specifically, we look at whether a single estimated source current

function can adequately reproduce the pulses radiated during a crosshole georadar survey, where changes in near-field conditions and transmitter fluctuations may be significant. Secondly, we examine the assumption of infinitesimal dipole radiation in the full-waveform inversion scheme, and whether this assumption allows for successful reproduction of observed field waveforms for a wide range of transmitter-receiver angles. Finally, we look at the effects of realistic amounts of dispersion in subsurface material properties on the wavelet estimation and inversion procedures. At the present time, the full-waveform inversion scheme assumes frequency-independent material properties.