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Intrinsic modeling of near-field ground penetrating radar and electromagnetic induction antennas for layered medium characterization

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We developed a closed-form equation for intrinsic modeling of near-field ground-penetrating radar (GPR) and electromagnetic induction (EMI) antennas for reconstructing the electrical properties of planar layered media. Resorting to plane wave decomposition, the antennas operating on the ground or in near-field conditions are modeled using a set of infinitesimal dipoles and characteristic, frequency-dependent, global reflection and transmission coefficients. Wave propagation and diffusion in the medium are described using a set of three-dimensional planar layered media Green's functions. Both GPR and EMI antennas were calibrated using measurements collected at different heights, ranging from near-field to far-field conditions, over a perfect electrical conductor. The GPR and EMI models were then validated for measurements collected over water subject to different salinity levels. The models showed a high degree of accuracy for reproducing the observed data and model inversion provided good estimates of the medium electrical properties. Yet, for EMI, discrepancies between measured and estimated electrical conductivity values were observed for the lowest salinity levels, resulting mainly from the limited sensitivity of the prototype EMI system used for this study. Technical possibilities for increasing the sensitivity of the EMI system are currently under examination. In addition, in order to further improve the model performances for EMI, we also investigate different configurations for the set of infinitesimal dipoles used to model the EMI antenna. The proposed approach is applicable to any GPR and EMI system, either prototypes or commercially available sensors and operating either in the time domain or in the frequency domain. It is in particular promising for joint analysis of GPR and EMI data in an inverse data fusion framework, especially as the modeling procedures are identical for both instruments.

Index Terms: Ground-penetrating radar, electromagnetic induction, near-field, inverse modeling, soil electrical properties

References:
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