Three-dimensional imaging of multi-component ground-penetrating radar data

J. van der Kruk
Institute of Geophysics,
Swiss Federal Institute of Technology
Zurich CH-8093, Switzerland

C.P.A. Wapenaar, J.T. Fokkema, P.M. van den Berg
Delft University of Technology
Delft 2628 RX , The Netherlands

Scalar imaging algorithms originally developed for the processing of remote sensing measurements (e.g., synthetic-aperture radar (SAR) method) or seismic reflection data (e.g., Gazdag phase-shift method) are commonly used for the processing of ground-penetrating radar (GPR) data. Unfortunately, these algorithms do not account for the radiation characteristics of GPR source and receiver antennas and the vectorial nature of radar waves. We present a new vector (multicomponent) imaging algorithm designed specifically for electromagnetic wave propagation.

The multi-component three-dimensional imaging procedure is based on the expression for the scattered field using the Born approximation. Taking into account that the orientation of the source and receiver is parallel to the interface, four different source-receiver combinations are possible, which is written as a two-by-two tensor formulation for the scattered field due to a contrasting domain. The vectorial Greens functions, which describe the propagation of the electric field from the source to the contrasting domain and the propagation from the contrasting domain to the receiver, for the four different source-receiver combinations are combined in the tensorial wavefield extrapolator. A bounded inverse wavefield extrapolator is obtained by inverting the forward wavefield extrapolator in the spatial Fourier domain (Van der Kruk et al. [1]). When this approach would be carried out for a single-component measurement, a non-stable inverse would be obtained. To assess the performance of the multicomponent, SAR and Gazdag algorithms, we compute their spatial resolution function, which is defined as the image of a point scatterer at a fixed depth using a single frequency. Application of the new multicomponent imaging algorithm results in a circularly symmetric resolution function, demonstrating that the radiation characteristics of the source and receiver antennas do not influence the derived image. In contrast, the two tested scalar imaging algorithms return distinctly asymmetric resolution functions, which could result in erroneous images of the subsurface when these algorithms are applied to GPR data.

The multicomponent and the two scalar imaging algorithms are tested on data acquired across numerous buried objects with various dielectric properties and different strike directions. Images of oblique and spherical objects produced by the multicomponent algorithm have noticeably higher amplitudes than those produced by the two scalar algorithms. Phase differences between the different images are similar to those observed in the synthetic examples. Of the tested algorithms, we conclude that the multicomponent approach produces the most reliable results.

REFERENCES

1. J. van der Kruk, C.P.A Wapenaar, and J.T. Fokkema. Multi-component 3-D imaging of ground penetrating radar data using matrix inversion in the spatial fourier domain. In *Proceedings Eight international conference on Ground-Penetrating Radar, Queensland, Australia*, pages 508–513, 2000.

Presenting author:	:	J. van der Kruk
Corresponding author:	:	J. van der Kruk
Suggested topic:	:	Recent Advances on Microwave Inverse Scattering Techniques for Buried Object Detection, Reconstruction and Imaging
Session chaired by:	:	Christian Pichot, Salvatore Caorsi and Andrea Massa
Preferred presentation:	:	Oral

Title of the paper:

Three-dimensional imaging of multi-component ground-penetrating radar data

Name	:	J. van der Kruk (Dr.)
Affiliation	:	Institute of Geophysics, Swiss Federal Institute of Technology
Address	:	ETH-Hoenggerberg Zurich CH-8093, Switzerland
Phone	:	+41 (0) 1 6332659
Fax	:	+41 (0) 1 6331065
E-mail	:	jvdkruk@aug.ig.erdw.ethz.ch
Misc.	:	URL: http://wwwtg.mp.tudelft.nl/~jvdkruk

Name	:	C.P.A. Wapenaar, J.T. Fokkema, P.M. van den Berg (Prof.)
Affiliation	:	Delft University of Technology
Address	:	Mijnbouwstraat 120 Delft 2628 RX , The Netherlands
Phone	:	0031-15-2782848
Fax	:	0031-15-2781189
E-mail	:	C.P.A.Wapenaar@CTG.TUDelft.NL
Misc.	:	URL: http://wwwtg.mp.tudelft.nl/~jvdkruk