Modelling of infrastructure effects in semi-airborne EM data

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The infrastructure problem

Infrastructure in survey areas is unavoidable and can cause characteristic distortion of semi-airborne electromagnetic (sAEM) data leading to artefacts in inversion models. Metal-bearing infrastructure is characterized by high conductivities, a small-scale geometry and complicated coupling to the EM field (inductively, galvanically, capacitively). We aim at investigating the effects of infrastructure and implementation of infrastructure into 3D models, using the open-source python toolbox custEM [1].

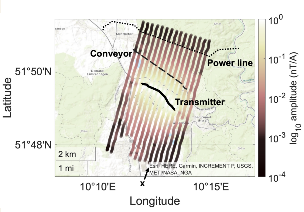

Fig. 1 sAEM survey near Bad Grund, Germany. The map illustrates the flight area superimposed by the amplitude distribution of the vertical magnetic field transfer function at 512 Hz. Transmitter, pipeline and quarry material transport route (conveyor) are indicated. Small-scale amplitude alterations indicate the infrastructure effect.

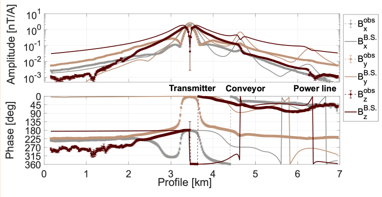

Fig. 2 Amplitude and phase of the complex transfer functions along flight line x are plotted for 512 Hz. Calculated B-fields based on Biot-Savart's law are added as solid lines.

Approach

As **boundary condition** on mesh element edges, implying **infinite conductivity**, infrastructure can be included into 3D models. This approach is not only efficient in terms of computation time but is known to reproduce characteristic infrastructure effects evident in forward modeling approaches that integrate infrastructure as 3D objects [2] and in real data observations. We test this boundary condition approach to **compensate for artefacts** in inversion models from synthetic and field data.
Furthermore, we explore the concept of infrastructure objects as secondary source by **inversion for the induced current**, modelling of the resulting secondary field distribution and subsequent inclusion of this impact in inversion for the resistivity distribution.

Conclusion

Infrastructure artefacts in synthetic data afflicted by the influence of a pipeline-like object are successfully compensated for by application of the boundary condition approach. Inversion of a field dataset reveals limitations of assuming infrastructure to be a perfect electric 1D conductor. Magnetic transfer functions corrected for the secondary field contribution of the infrastructure, which is found by current inversion, yields promising improvements in inversion models for the field dataset as well as synthetic data (not shown here).

Synthetic data inversion

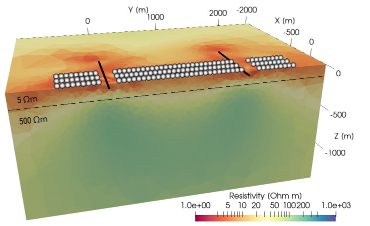

Fig. 3 Reference inversion model. Forward calculation model consists of a 500 Ωm half-space with conductive surface layer of 5 Ωm and 100 m thickness. The survey geometry contains two transmitters and three flight-lines. No infrastructure object is included.

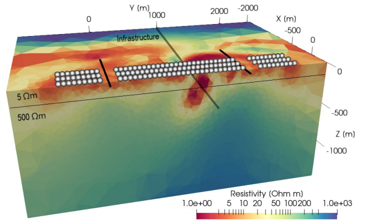

Fig. 4 Inversion result of data afflicted with the influence of a 3D pipeline-like conductor modelled at 10m depth, parallel to the transmitter at y = 1000m. Conductive near-surface as well as subsurface anomalies reaching deeper than 400 m indicate infrastructure artefacts.

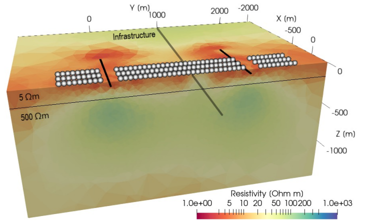

Fig. 5 Inversion of the same data as in Figure 4 treating the infrastructure as 1D object applying homogeneous zero Dirichlet boundary conditions on surface mesh edges. Note successful compensation for conductive infrastructure artefacts and the small-scale, resistive surface anomaly arising from infrastructure treatment as perfect electric conductor.

Field data inversion

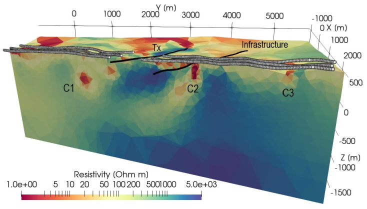

Fig. 6 Bad Grund inversion result from data of the flight-line shown in Figure 2 and two neighboring flight-lines. Inversion model indicates conductive surface-near anomalies, C2 and C3, in the vicinity of known infrastructure objects. The conveyor belt from Figure 1 is indicated as infrastructure close to conductor C2.

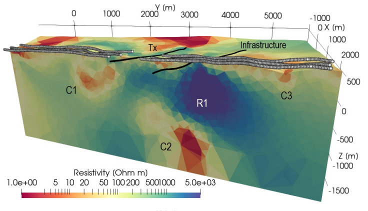

Fig. 7 Inversion result of the same data as in Figure 6, treating the conveyor belt as perfect electric conductor at the surface by usage of boundary conditions. Employing this approach yields a large resistive artefact below the infrastructure and a deeper conductive body, indicating this approach not to be applicable for this dataset.

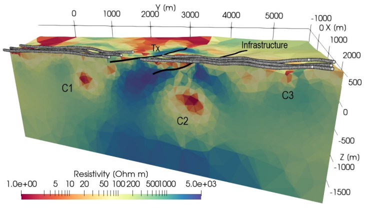

Fig. 8 Inversion of the same dataset as in Figure 6, treating the conveyor belt as current carrying. After inversion for the induced current in this infrastructure object, magnetic field responses are corrected for its secondary field contribution. Subsequent inversion for resistivity distribution yields better convergence and more physical inversion results.

References
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2) E. S. Um et al. "3D borehole-to-surface and surface electromagnetic modeling and inversion in the presence of steel infrastructure". In: *Geophysics* 85.5 (2020), E139-E152.

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