Spectral Inversion of SIP field data using pyGIMLi/BERT

Thomas Günther[1], Tina Martin[2], Carsten Rücker[3]

[1]Leibniz Institute for Applied Geophysics (LIAG), Hannover, Germany; [2]Federal Institute for Geosciences and Natural Resources (BGR), Berlin, Germany; [3]University of Technology Berlin, Germany

Leibniz Institute for Applied Geophysics

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Motivation

No freely available tools for handling SIP data

- (laboratory) spectra: fitting, EM removal
- processing large amounts of field data
- testing out different approaches
- reproducible scientific workflows
- producing publication-ready figures

Example: slag heap lab and field measurements

Framework pyGIMLi

Geophysical Inversion and Modelling Library

- free and easy-to-learn language Python
- fast C++ linear algebra kernel
- flexible inversion and regularization
- data manager classes for easy scripting
- submodule for SIP spectra (frequency domain)

`http://www.pygimli.org`

pyBERT

Boundless Electrical Resistivity Tomography

- efficient triple-grid approach (Günther et al., 2006)
- based on finite element calculation
- inversion on triangle mesh (Martin&Günther, 2013)
- customizable inversion and regularization
- submodule for SIP field data (so far only FD)

`https://gitlab.com/resistivity-net/bert`

Example of spectra handling

```
from pygimli.physics import SIP
sip = SIP('example.txt')
sip.showData(norm=True, KramersKronig=True)
sip.removeEM(epsilon=True)
sip.fitColeCole()
sip.showAll(savePDF=True)
```

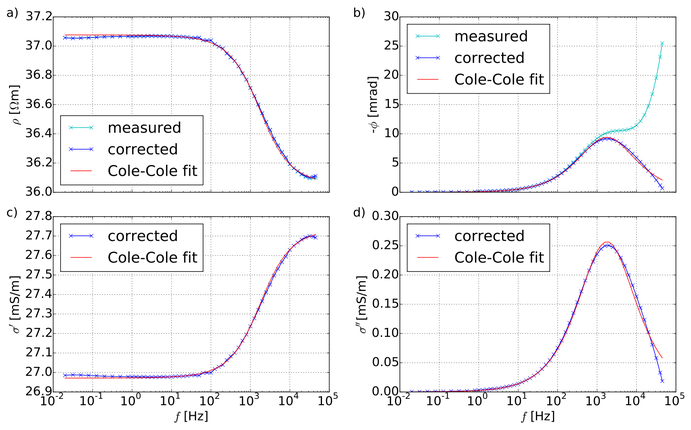
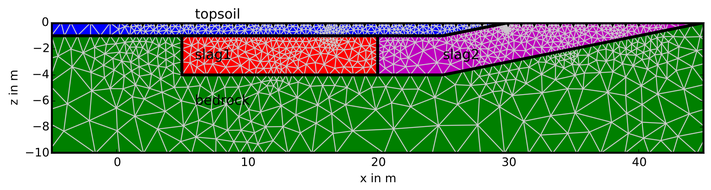


Fig. 1: Example slag-sand mix (Hupfer et al., 2015).

Spectral field data inversion

- no assumption of specific model (e.g.Cole-Cole)
- fully-spectral approach: simultaneous inversion of all frequency data (Günther & Martin, 2016)
- constraints along space and frequency axes

Synthetic slag heap model (Günther & Martin, 2016)



Region	ρ [Ωm]	m [mV/V]	τ [s]	c [-]
topsoil	100	0.001	0.001	0.25
bedrock	500	0.001	0.001	0.25
slag 1	200	0.8	0.1	0.5
slag 2	200	0.7	1.0	0.5

Cole-Cole model:

$$\rho^* = \rho\left[1 - m\left(1 - \frac{1}{1+(\iota\omega\tau)^c}\right)\right]$$

Fig. 2: Synthetic slag heap model with properties: resistivity ρ, chargeability m, time constant τ and relaxation exponent c.

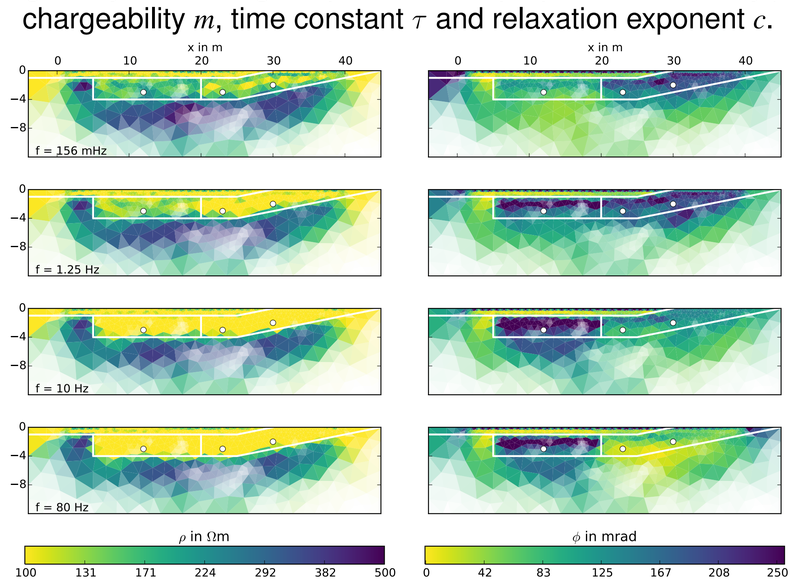


Fig. 3: Resistivity (left) and phase (right) inversion results.

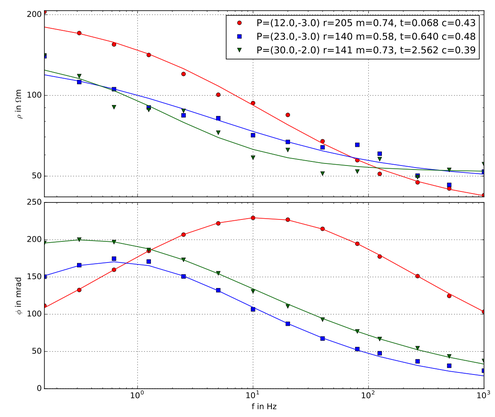


Fig. 4: Example sprectra fits (points see Fig. 3).

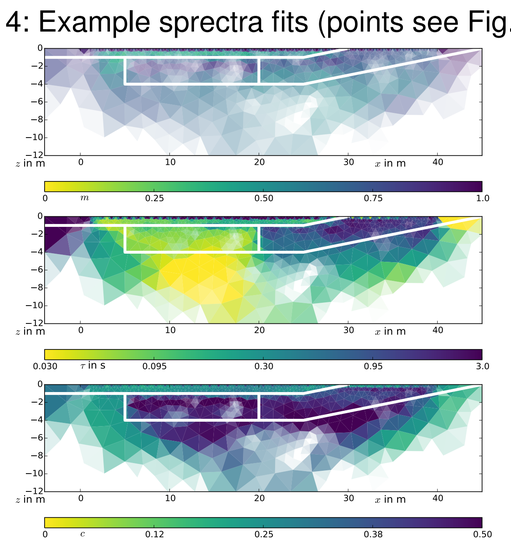


Fig. 5: Distribution of fitted Cole-Cole parameters.

SIP field data example: slag heap (Günther & Martin, 2016)

Aim: mineral content in historical slag heaps

- dipole-dipole survey with 40 electrodes and a=1 m
- SIP256C device, separated current/potential rods
- 14 frequencies f=0.2-1000 Hz ⇒ 4.5h meas. time

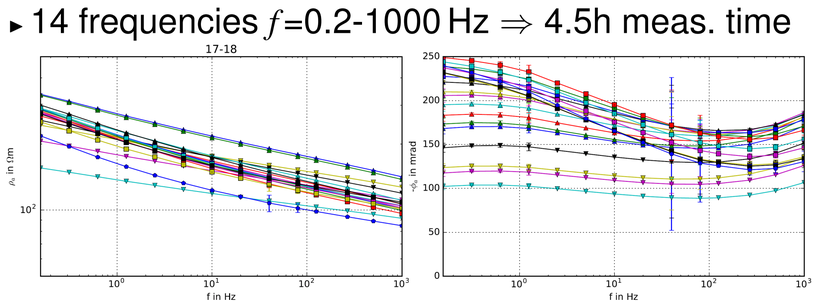


Fig. 6: Example resistivity (left) and phase (right) spectrum for a single current injection.

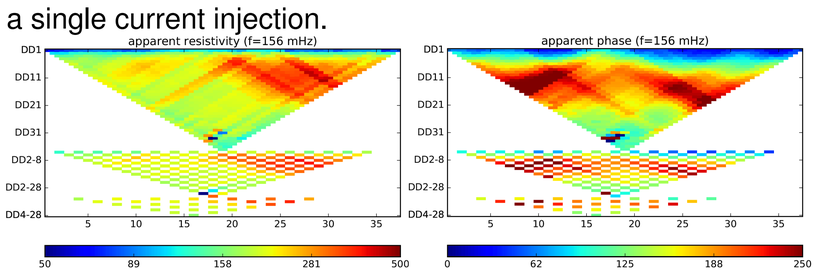


Fig. 7: Resistivity (left) and phase (right) pseudosections for the smallest frequency.

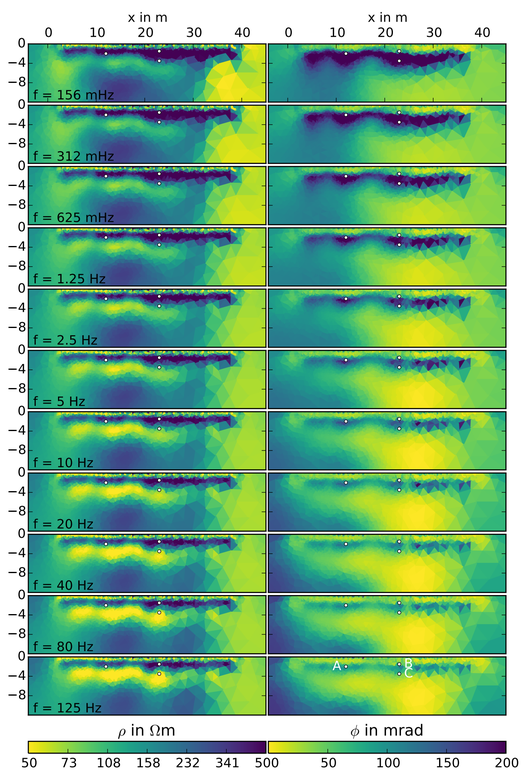


Fig. 8: Inversion result for $f \leq$125 Hz.

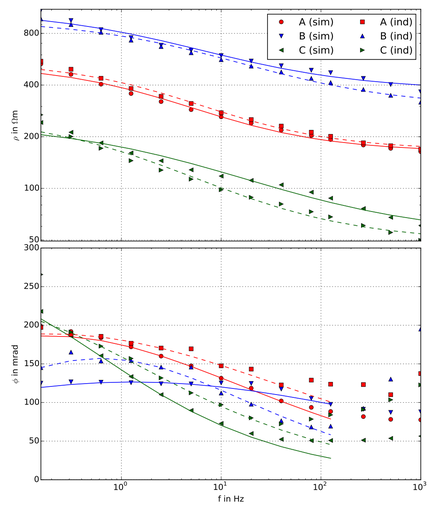


Fig. 9: Example fits of resistivity (top) & phase (bottom) spectra.

		ρ [Ωm]	m [-]	τ [s]	c [-]
A	ρ	531	0.70	0.89	0.52
B	ρ	696	0.35	0.15	0.69
C	ρ	284	0.91	0.70	0.52
A	ϕ		0.79	3.72	0.32
B	ϕ		0.75	2.35	0.24
C	ϕ		0.78	4.51	0.41

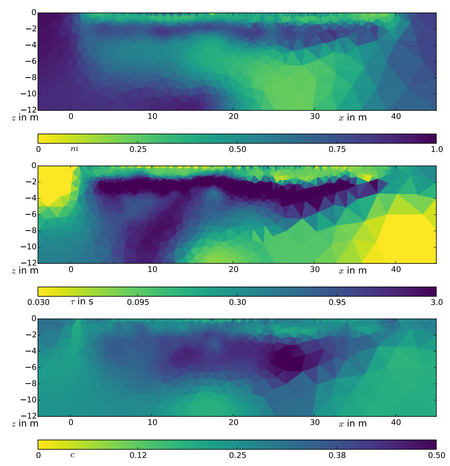


Fig. 10: Cole-Cole parameter distribution.

- resistive heap with heavily polarizable slag at the bottom
- m and τ (lower f end) from both ρ and ϕ alone, c less well resolved
- contents ≈10-20% and grain sizes of cm-dm according to results of Hupfer et al. (2015)

Example script for field data

```
from pybert.SIP import SIPdata

sip = SIPdata('example.res')
sip.generateSpectraPDF(maxdist=20)
sip.generateDataPDF(kmax=50000)
sip.removeEMTerms(Pelton=True)
sip.invertSingleFrequency(f=0.625)
sip.invertSimultaneous(maxF=200)
sip.fitColeColeModel(show=True)
```

Conclusions & Outlook

- simultaneous inversion of spectral IP data
- retrieving relevant spectral parameters m, τ
- easy-to-handle open-source tools pyGIMLi/BERT
- continuous improvement and documentation
- extension to spectral time-domain IP
- help improve and join the community!

References

Günther & Martin (2016): Spectral two-dimensional inversion of frequency-domain induced polarisation data from a mining slag heap. J. of Applied Geophysics, doi:10.1016/j.jappgeo.2016.01.008.
Hupfer et al. (2015): Polarization effects of unconsolidated sulphide-sand mixtures. J. of Applied Geophysics, doi:10.1016/j.jappgeo.2015.12.003.
Martin & Günther (2013): Complex Resistivity Tomography (CRT) for fungus detection on standing oak trees. European J. of Forest Research, 132(5), 765-776, doi:10.1007/s10342-013-0711-4.
Günther et al. (2006): 3-D modeling and inversion of DC resistivity data incorporating topography - Part II: Inversion. - Geophys. J. Int. 166, 506-517

http://www.liag-hannover.de

thomas.guenther@liag-hannover.de