Data Quality Quantification for Time Domain IP Data Acquired along a Planned Tunnel near Oslo, Norway

Dahlin, Torleif; Dalsegg, Einar; Sandström, Torbjörn

2013

Citation for published version (APA):
Dahlin, T., Dalsegg, E., & Sandström, T. (2013). *Data Quality Quantification for Time Domain IP Data Acquired along a Planned Tunnel near Oslo, Norway*. Paper presented at Procs. Near Surface Geoscience 2013, Bochum, Germany.

Total number of authors:
3

Mo S2a 12

Data Quality Quantification for Time Domain IP Data Acquired along a Planned Tunnel near Oslo, Norway

T. Dahlin* (Lund University), E. Dalsegg (NGU) & T. Sandström (Lund University)

SUMMARY

Tests were done measuring resistivity and time domain induced polarisation using standard multi-core cable spreads and a special layout with separate cable spreads for transmitting current and measuring potentials. For both types of cables spreads both normal and reciprocal measurements were done in order to estimate the measurement errors. The tests were done along a planned tunnel stretch outside Olso in Norway. The electrode contact was variable with resistances in the range 0.6 - 25 kΩ. The results gave low median error levels for both types of cable spreads, but the single cable spread showed a significantly larger variation with more scatter in the IP data. Data for both types of spreads gave models that are consistent and appear to delineate the complex geology in a useful way. It is concluded that the single cable spread gives surprisingly good IP data considering the large layouts at this site, which is adequate for inversion of the integrated full decay. If on the other hand the data were to be used for spectral IP inversion of the decay curves for recovering the Cole-Cole parameters the extra effort of measuring with separated cable spreads would probably be well motivated.

Introduction

Combined resistivity and time-domain induced polarisation (IP) surveying can provide data that is very useful in engineering investigations (e.g. Dahlin et al 2010). Measuring IP in the time-domain with relatively compact multi-channel multi-electrode systems is attractive because of the simplicity of the procedure and thus its efficiency in the field. However the use of this technique is sometimes discouraged by the bad quality of the measurements in cases of high electrode contact resistances which can render data interpretation infeasible or at least unreliable. Electromagnetic coupling in the multi-core electrode cables can have a significant role in creating this problem (Nielsen 2006). In such cases separation of current and potential circuits by using separate multi-conductor cable spreads can yield significant improvement in data quality (Dahlin and Leroux 2012). The procedure is relatively simple and can be implemented with common resistivity and time-domain IP equipment. The results presented using this approach show improved results compared to measuring with a single cable spread. We have carried out systematic measurement tests at a number of sites in order to do such quantification, and results from one of the sites are presented here.

Method

Combined resistivity-IP data acquisition was carried out with an ABEM Terrameter LS with 12 measuring channels. A standard electrode cable set consisting of 4 cables with 21 take-outs each was used for one set of measurements. A second data set was measured using two identical cable sets placed parallel to each other and separated by around one metre and shifted one step. In the latter case one cable spread was used for transmitting current and one for measuring potentials, and after one round of measurements were finished this way the cable connections were reversed and an identical but mirrored data set recorded (Dahlin and Leroux 2011).

Measurements were taken using multiple gradient array. All measurements were repeated using reciprocal arrays in order to allow quantification of the measurement errors. The observation errors were calculated in percent for the resistivity data, but as mV/V for the IP data since a percent measure becomes meaningless for very small or zero chargeabilities.

Field Data Example

A field test was carried out along a planned tunnel line outside Oslo in Norway, as piggyback on a site investigation survey for refining the engineering geological model. The area is geologically complex with volcanic rocks including porphyry, basalt and dolerite dykes, plus faults and weathering. The electrode separation was 10 m giving a total layout of 800 m. Stainless steel electrodes were used throughout following results from Dahlin et al. (2002).

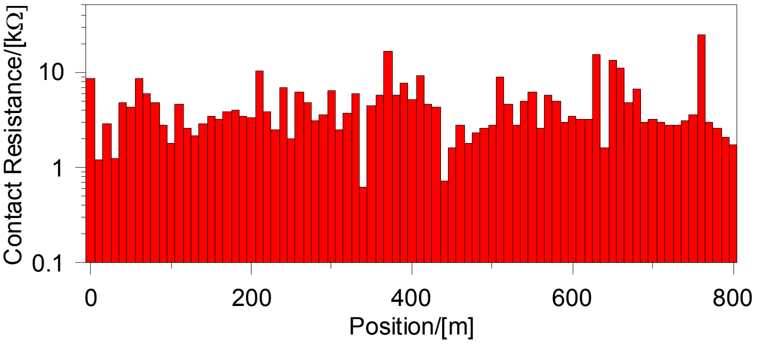


Figure 1 *Electrode contact resistance along E16 test line.*

The mean electrode contact resistance was ranging from 0.6 to 25 kΩ, with a mean of 4.7 kΩ. Although the contact resistance is quite high for a number of electrodes, the grounding conditions were favourable for the site thanks to moist ground conditions at the time of surveying. The distribution along the line is shown in Figure 1. Data were measured using 2 stacks per data value.

The apparent resistivity mean observation error is 1.4 % and 0.8 % for the single cable spread and separated cables spreads data respectively, and the median error is 0.3 % for both (Table 1). The standard deviation is higher for the single cable spread. The chargeability observation errors have a mean of 7.0 mV/V and 1.9 mV/V for the single and separated spreads data respectively, whereas the median error is 0.8 mV/V for both. The standard deviation is 18 times higher for the single cable spread data. These IP data errors were calculated for the total integrated IP decay (10 – 1950 ms). The error distribution is shown in pseudosection form in Figure 2.

Table 1 *Observation errors for resistivity and chargeability (IP decay time 10-1950 ms) for measurements with single cable spread and separate cables spread.*

Statistical Parameter	Single cable spread		Separate cable spreads	
	Resistivity error [%]	Chargeability error [mV/V]	Resistivity error [%]	Chargeability error [mV/V]
Mean	1.4	7.0	0.8	1.9
Median	0.3	0.8	0.3	0.8
Standard deviation	8.5	82.1	2.6	4.6

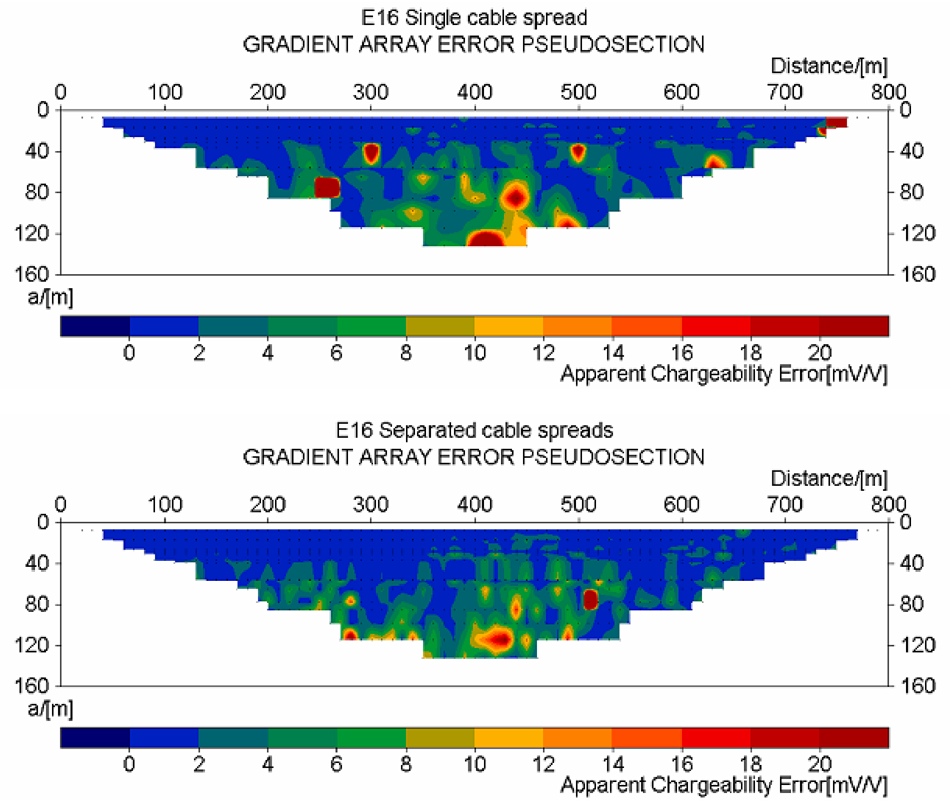


Figure 2 *Chargeability observation errors for integrated full IP decay (10-1950 ms); a) single cable spread, b) separated cables spread.*

Also when looking at individual IP time windows the median errors are similar throughout the decay process, whereas the mean values are much lower for the separated cables spreads data (Figure 3). This means the variability is larger with more outliers in the single cable spread data set.

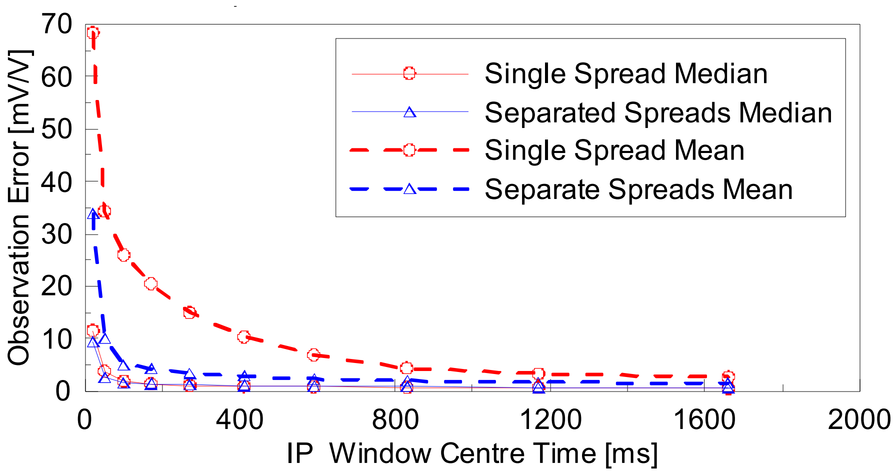
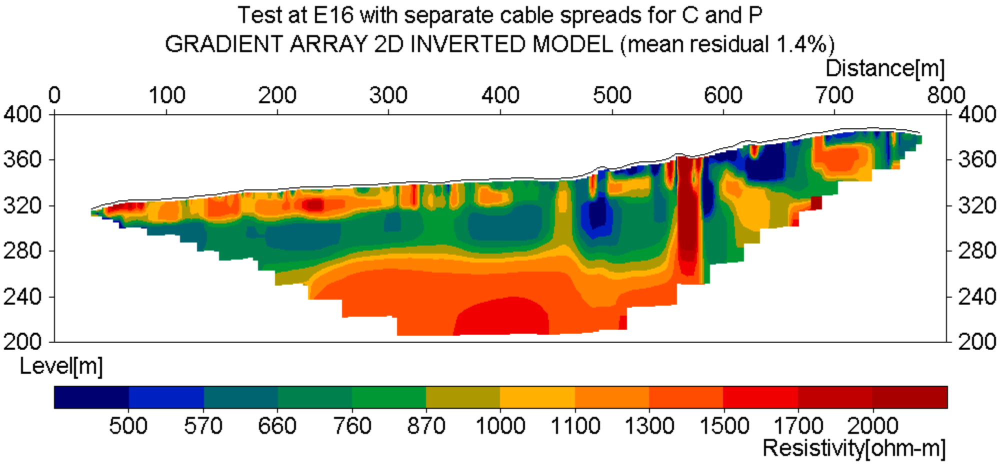


Figure 3 *Mean and median chargeability observation error for individual measured IP time windows as function of decay time.*

a)



b)

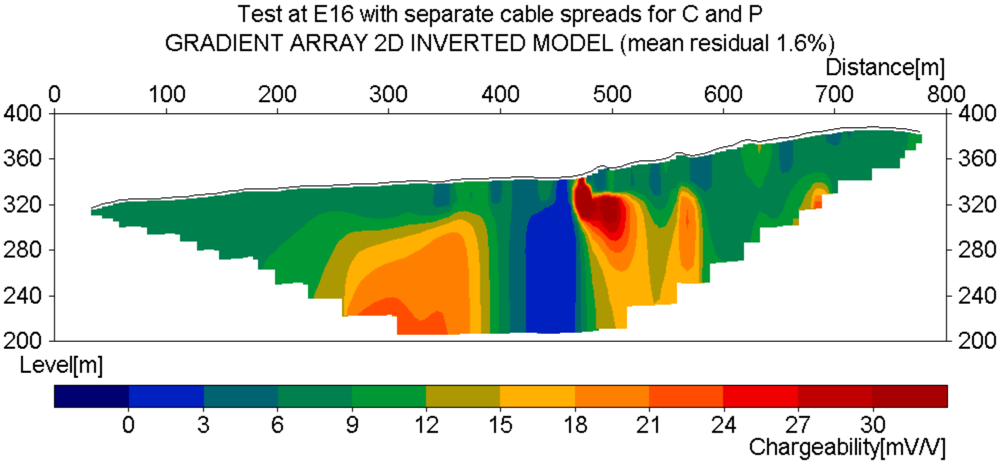


Figure 4 *Inverted models based on separated cable spreads measurement; a) resistivity, b) chargeability.*

Inversion was carried out with Res2dinv ver 3.59.106 resulting in models with a maximum depth of 152 m. The IP data was entered as integrated chargeability in the time interval 10-1950 ms. Average model residuals are small, 1.4 % and 2.2 % for resistivity and chargeability (IP effect) respectively for the single spread data set. A few data points, 1 %, were culled before inversion due to noisy appearance in the IP data. Inversion of the separated cable spreads yielded mean residuals of 1.4 % and 1.6 % for resistivity and chargeability, with 0.3 % of the data points removed. The inverted sections look quite similar but show a bit sharper contrasts for the latter (Figure 4). The inverted sections fit well with the complex geology in general terms, but a detail interpretation has not yet been made due to lack of relevant and sufficiently detailed reference data.

Discussion and Conclusions

Median observation errors as estimated from reciprocal measurements are small both for measured resistivity and chargeability. The data measured with separated cable spreads have slightly lower mean observation errors than those measured with single spread whereas the median errors are the same. This is caused by larger standard deviation and more outliers in the single cable spread data. Considering the large electrode spread and the varying and partly rather high contact resistances the data quality for the single cable spread is surprisingly good compared to previous experience (Dahlin and Leroux 2012). The data quality of the IP data could probably be further improved by additional stacking of the data, and possibly advanced noise removal techniques.

The residuals for the resulting inverted models are small, and the models from both types of spread agree well. The resulting resistivity and chargeability models provide information related to the geology at the site, and are expected to give valuable input to refining the engineering geological conceptual model.

Although the data quality is better for the separated spreads data, the single cable spread approach in this case provides data of sufficiently good quality for inversion of chargeability integrated over the full decay. This agrees with results reported by Dahlin and Leroux (2012) for sites with favourable conditions. If the data is to be used for spectral time domain IP inversion in order to recover the Cole-Cole parameters (Gianluca et al. 2012) the additional effort of measuring with separated cable spreads is likely to be well motivated for improving the quality of the models.

Acknowledgements

We thank Roger Wisén and his team from Rambøll A/S for the nice cooperation in connection with the field survey. We also wish to acknowledge financial support from NGU and Lund University in connection with the field test.

References

Dahlin, T. [1996] 2D resistivity surveying for environmental and engineering applications. *First Break*, **14**(7), 275-283.

Dahlin, T. and Leroux, V. [2012] Improvement in time-domain induced polarisation data quality with multi-electrode systems by separating current and potential cables. Accepted for publication in *Near Surface Geophysics*.

Dahlin T., Rosqvist H. and Leroux V. [2010] Resistivity-IP for landfill applications. *First Break*, **28**(8), 101-105.

Dahlin, T., Leroux, V. and Nissen, J. [2002] Measuring Techniques in Induced Polarisation Imaging. *Journal of Applied Geophysics*, **50**(3), 279-298.

Fiandaca, G., Auken, E., Gazoty, A. and Christiansen, A.V. (2012) Time-domain induced polarization: Full-decay forward modeling and 1D laterally constrained inversion of Cole-Cole parameters. *Geophysics*, **77**, E213-E225.

Loke, M.H., Acworth, I. and Dahlin, T. [2003] A comparison of smooth and blocky inversion methods in 2-D electrical imaging surveys. *Exploration Geophysics*, **34**(3), 182-187.

Nielsen, T.I. [2006] The effect of electrode contact resistance and capacitive coupling on complex resistivity measurements (2006). *SEG Expanded Abstracts,* **25**(1), 1376-1380.