Full Wave-form Time-domain IP Data Acquisition

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SUMMARY

We present and discuss some examples of full wave form resistivity-IP data recorded at one site in Sweden and one in Malaysia. The examples show that highly detailed recordings can be made, and that various types of noise can be clearly distinguished. With such detailed information about the character of the signal and noise it is relatively easy to develop algorithms that can remove the noise without biasing the extracted data. Tests using a pure square wave as measuring signal show that information relating to the chargeability of the ground are as clearly visible as in traditional time-domain IP-data, and it should thus lend itself well to extraction of the spectral IP information. An advantage of using square wave for time-domain SIP over frequency domain SIP is that data acquisition can be much faster, furthermore it would be more time efficient than a traditional time-domain IP signal. The results also show that the transmitted current wave form is almost ideal, whereas recorded output voltage varies to a significant extent. This may be due to, for example electro-chemical processes, and a constant voltage transmitter would not have produced current wave forms with such regular shape.

Introduction

Instruments that measure resistivity and time-domain induced polarisation generally integrate the measured potentials over a number of time intervals, and the output data consists of averaged quantities based on these integrated signals. For most instruments it is not possible to record and view the actual recorded waveform, which may be very useful for analysis in order to understand the mechanisms behind different types of noise that may contaminate the data. Full waveform data opens possibilities for developing advanced signal processing algorithms, which in real time or post processing might extract meaningful data from data sets that are otherwise too contaminated to be used in a meaningful way. Furthermore, it might make it possible to extract spectral IP (SIP) data from time-domain IP data.

The extraction of information on the frequency-dependent complex resistivity – or SIP - could potentially open up for detailed interpretation in terms of material identification, mapping of contamination and permeability estimation for example, as indicated by numerous laboratory measurements and a few field studies (e.g. Börner et al, 1996; Hördt et al, 2007). However the method must be economically feasible to be really useful and the prospects of simplified and faster time-domain procedures are attractive (see e.g. Hönig and Tezkan 2007; Tarasov and Titov, 2007) In that case the recording of the full signal is a requirement for enabling a control over the quality of the measurements and reliable extraction of the frequency information.

The measurement / estimation of normalised chargeability (Slater and Lesmes, 2002) has also shown useful in many studies (e.g. Johansson et al., 2007). It is apparently much simpler to measure since only the apparent chargeability value is required. However, our experience has shown that data are easily contaminated by noise, due notably to the small potential involved, and that the noise and its origin are not always easily identified. Here too the recording of the full signal waveform could be useful.

Some current transmitters available on the market are of constant current type, whereas many are of voltage type. The latter measures the transmitted current over a shunt resistor, to deliver an integrated average current for the measurement. This should work well for pure resistive targets, but there may be concerns in the case of IP measurements over ground with significant chargeability or electro-chemical effects at the interface between the electrodes and the ground.

Method

In this paper we present and discuss some examples of full wave form resistivity-IP data recorded with an ABEM Terrameter LS. This resistivity-IP instrument is a fully integrated data acquisition platform with built-in relay matrix switch. The instrument is equipped with a constant current transmitter that can deliver maximum 600V, 2.5A or 250W. A special feature of the transmitter is that it can switch polarity instantaneously without switching off the current, thus allowing transmission of a near perfect square wave. The transmitted current and voltage are recorded and can be saved with 1 millisecond intervals. The input channels are based on 24 bit sigma-delta AD-converters, with input ranges ±2.5V, ±15V and ±1000V (selected by auto-ranging), and the measured full waveform data can be saved with 1 millisecond resolution. The two individuals of the instrument that were used for the examples presented here have 4 input channels each.

The data was recorded with a standard setup of electrode cables, stainless steel electrodes, etc. of the type commonly used for DC resistivity imaging. A layout of 41 electrodes with 2 metre spacing was used for a test layout along a car parking area next to the university campus in Lund, Sweden. The ground consists of clayey till and coarse grained fill material overlying shale. The other test line had 81 electrodes at 5 metre intervals and was measured in an oil palm plantation at Bikam Estate in Malaysia. The site is characterised by sedimentary rock (schist, phyllite, slate, limestone, etc.) under a soil cover.

Example 1

An example of recorded raw data from the Bikam Estate site is show in Figure1a. The figure shows the transmitted current and the received signals for one of the measuring channels, where it is clear that the measurement has captures a relatively small but clearly discernable IP-effect. There are small but distinct spikes in the received data when the transmitter switches on and off, probably due to coupling in the electrode cables. Since the duration of the spikes is very short it does not affect the measured resistivity and IP data adversely.

A close-up on a part of the received signal (Figure 1b) shows a regular noise pattern with 50 Hz frequency, obviously power-net noise which is effectively removed by signal averaging over multiples of 20 ms.

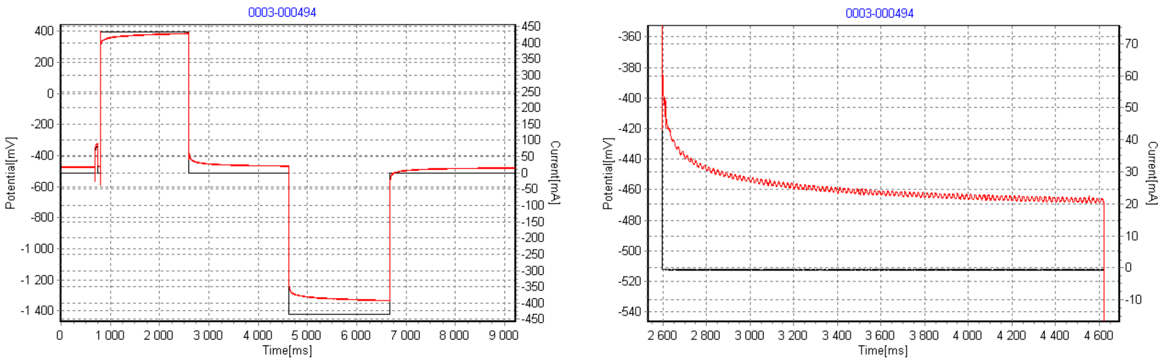

Figure 1 *Example of raw data sweep from Bikam Estate site; a) received voltage (red) and transmitted current (black), b) detail of received voltage.*

Example 2

An example of transmitted signal for a measuring cycle from the Lund site is shown in Figure 2a, and the corresponding received signal for channel 1 is shown in Figure 2b. It is evident that the transmitted current exhibits an almost ideal square shape, but it is interesting to note that the output voltage varies considerably during each current-on phase. This is phenomenon is seen to a smaller or larger extent for a great number of the so far recorded raw data sweeps. It is easy to imagine that if the transmitter would simply put out a constant voltage it would not produce constant current within a transmitted pulse.

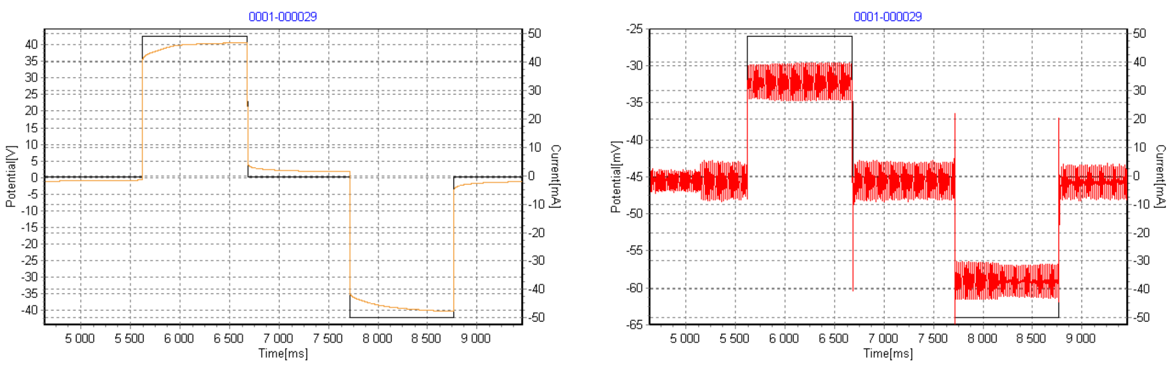

Figure 2 *Example of raw data sweep from Lund site; a) transmitted current (black) and output voltage (orange), b) transmitted current (grey) and received voltage (red).*

The received signal shows no IP response, whereas power-net noise with 20 ms period of relatively large amplitude is present. It is also evident that the level of the noise varies during the measurement interval. Furthermore data spikes occur here as well when the transmitter switches on and off. The power-net noise can easily be averaged out with a suitable integration interval, whereas the spikes caused by the transmitter on-off are short enough not to be any problem.

Example 3

An example of received signals with a combination of noise with a regular pattern and sudden stronger noise events is shown in Figure 3. As for the previous examples distinct spikes occur in immediate connection with the current turn-on and turn-off (Figure 3a). A close-up of a part of the received curve clearly shows that there is a regular noise pattern of power-net origin (Figure 3b) plus sudden spikes of irregular character that may be of magneto-telluric origin or due to an approaching thunderstorm. The power-net noise can easily be averaged out with a suitable integration interval, whereas a de-spiking filter would be recommendable for the irregular noise.

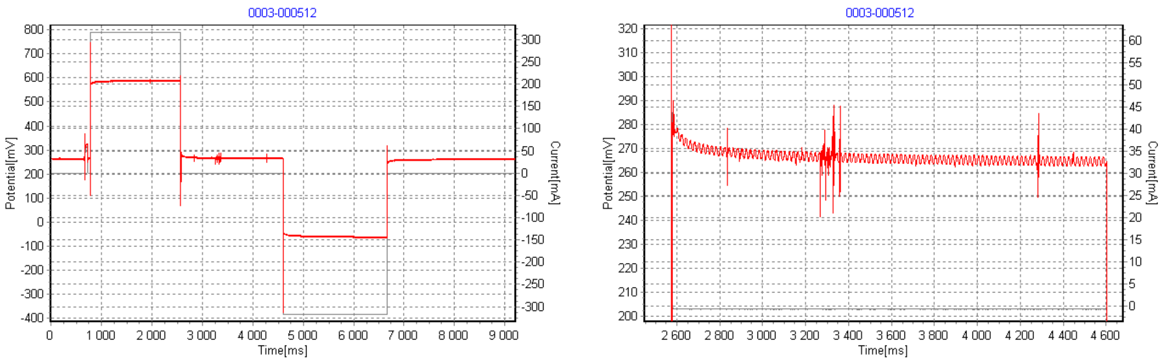

Figure 3 *Example of raw data sweeps from Bikam Estate site; a) received voltage (red) and transmitted current (grey), b) detail of received voltage.*

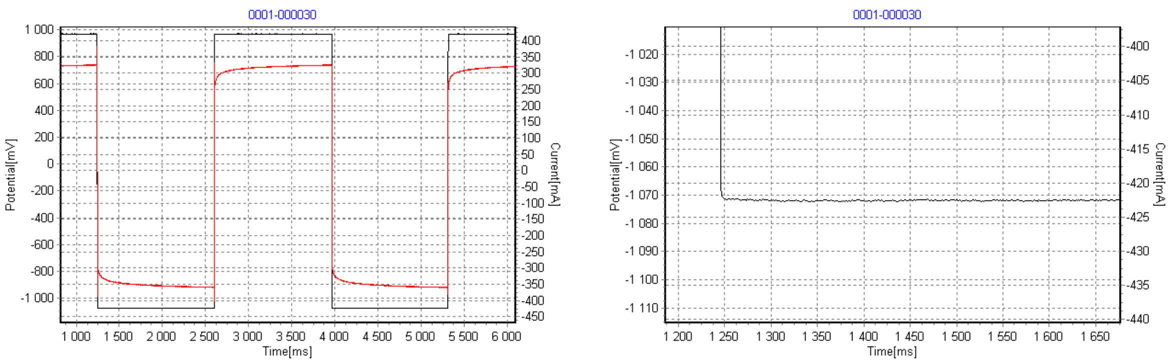

Figure 4 *Example of raw data sweeps from Bikam Estate site; a) received voltage (red) and transmitted current (black), b) detail of transmitted current wave form.*

Example 4

The transmitter can be used to generate a square wave signal, as shown by the example in Figure 4a. A close up of the transmitted current wave form is shown in Figure 4b, an it is evident that it is an almost perfect square wave. This signal was measured on the same electrode layout as the example in Figure 1, which was measured with traditional IP-signal, so that they measure the same chargeability in the ground. As can be seen the IP-effect is at least as clear in the square wave example, and it should thus be well suited for extracting information about the chargeability of the ground.

Conclusions

We have shown examples of full wave form IP-data that could form the base for inversion of the IP properties of the ground. The examples show that highly detailed recordings can be made, and that various types of noise can be clearly distinguished. With such detailed information about the character of the signal and noise it is relatively easy to develop algorithms that can remove the noise without biasing the extracted data. Cable coupling effects are clearly visible in the examples shown, but since those effects can be readily identified it may be possible to develop tools for automated data quality assessment.

The tests using a square wave as measuring signal shows that information relating to the chargeability of the ground is as clearly visible as in traditional time-domain IP-data, and it should thus lend itself well to extraction of the spectral IP information. A major advantage of using a square wave for time-domain SIP over frequency domain SIP is that the data acquisition can be made much faster. Furthermore, a square wave signal would also be more time efficient than the traditional time-domain IP signal. The robustness of the approach compared to frequency domain SIP remains to be assessed however.

The results also show that the transmitted current wave form is almost ideal, whereas the recorded output voltage varies to a significant extent. This may be due to, for example electro-chemical processes in the contact zone between the electrode and the ground apart from IP-effects. The results thus suggest that a constant voltage transmitter would not have produced current wave forms with such regular shape.

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