A new processing system for very early time SkyTEM101 data

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SUMMARY

Early times are of interest for near-surface surveys and are object of developments during the last decade both in the electronics and the processing domains. The new SkyTEM system, called SkyTEM101, has a very short turn-off of 3 µs which authorizes the use of gates between 3 and 10 µs, and to increase the vertical resolution of the near-surface. However, a reliable monitoring of the Coil Response (CR) is necessary to get these very early time gates usable. For this, a new Coil Response Correction (CRC) has been developed which allows removing the CR in the first early gates before the inversion process. Application of this CRC correction to high altitude and production measurements has shown its efficiency to reduce the CR to the noise level. A new adaptive data filtering has also been developed to maintain the best lateral resolution above different areas like open fields or forests above which the signal to noise ratio varies due to the change of the helicopter altitude. This improvement of the lateral resolution has a great value for environmental surveys where definition of local and shallow heterogeneities is a critical issue.

Key words: Airborne EM, early times, near-surface

INTRODUCTION

The development in transient electromagnetic airborne electromagnetic methods (AEM) has over the last decay focused on developing systems with very high transmitter moment. The high transmitter moment is necessary to resolve deep laying mining targets or groundwater resources. Resolution of the near surface geology on the scale applicable for AEM surveys is reserved to helicopter borne frequency domain systems.

A recent development has lead to a new version of the SkyTEM system (Sørensen and Auken, 2004), the SkyTEM101 system. The system is small compared to the normal system but even more importantly in this context a new coil response correction technique makes it possible to measure the first time gate in 3 – 5 µs from begin of the turn off ramp. The data processing system (Auken et al, 2009) has been changed accordingly to facilitate the new data and obtain the full potential of the data in terms of resolution of near-surface geological structures.

THE SKYTEM101 SYSTEM

The transmitter frame of the SkyTEM101 system is made of a new composite material and the total area is approx. 130 m^2. The systems cycles between two moments, a super low moment (SLM) moment transmitting approx. 7.5 Amp in one turn with a turn-off time of about 3 µs and a high moment (HM) with a current of approx. 55 Amp and a turn-off time of 20 µS. The repetition frequency of the system is variable and can be adjusted to the desired length of the off-time. Typically it is designed so the on-time period is 1 ms and the off-time period is 1.50 ms given logarithmic samples gates from begin of ramp until 1.50 ms. The system is shown in Figure 1.
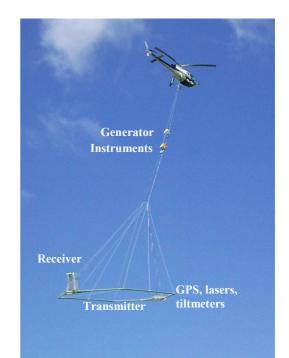

Figure 1. The SkyTEM101 system in the air. The receiver coil is integrated into the tail of the system. The altitude is measured by two duplicated lasers and the pitch and roll by duplicated tiltmeters.

The typical operation speed of the system is 120 – 140 km/hour (33 – 39 m/s) at a nominal altitude of 30 m. The altitude is for safety reasons higher when flying in steep terrains or in forested areas.

COIL RESPONSE CORRECTION

Once the primary electric current is completely turned off, there is still residual current due to electromagnetic induction in the transmitter loop, and to the coupling between the transmitter and the receiver loops. This effect is larger or at least in the same order than the earth response in the first gates following immediately the end of the turn-off. High-altitude (HA) measurements (above 1000 meters) allow to estimate the shape of the Coil Response (CR) where no earth response is measured. In previous works (Auken et al, 2010) CR was removed during the inversion by estimating a scalar factor multiplied by the shape of the CR response determined from the HA measurements (bias inversion).

Recent technical developments allow continuous Coil Response Correction (CRC) measurements acquired in the very data acquisition process. These CRC measurements are subsequently applied in the inversion scheme in order to reduce the CR distortion of the very early data sets significantly.

The CRC correction is applied on a HA measurement in Figure 2. At this altitude there is no response of the earth, and one can see that the curve reach the noise level (which has typically a slope of $t^{-\frac{1}{2}}$) for time gates that follow immediately the turn-off of the source. Application of this correction on soundings at production altitude (30 m) will be shown during the presentation.
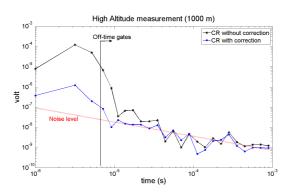
Figure 2. Removing of the Coil Response at High Altitude. The black curve is the measured data while the blue curve is the CR corrected curve.

ADAPTIVE DATA FILTERING

Trapezoid filters are applied on SkyTEM data to obtain average curves (Auken et al, 2009). A sketch of these filters is displayed in Figure 3. The principle is to apply different stack widths in function of the time gates. The later the gate, the wider the stack window is. This follows the evolution of the signal to noise ratio which decreases as long as we are far from the turn-off of the source. With these filters we can keep a good lateral resolution at the earliest time gates which contains information of the near-surface.
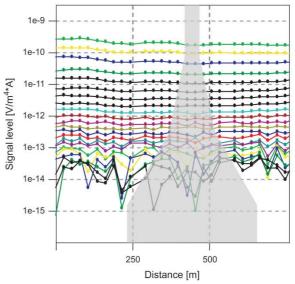
Figure 3. Trapezoid filters for the stacking from the raw to the average data

Until now, the different widths of the trapezoid filters are set and fixed for a survey once for all. This scheme is not optimal when one deals with surveys where there are variations of the production altitude due to the succession of open fields and forest areas for example. When the helicopter has to go up to avoid obstacles, the signal to noise ratio decreases, then large stack windows have to be used for the entire survey, including for open-field areas. This results in a loss of lateral resolution where the noise level is low.

We developed an adaptive version of the trapezoid filters by analysing neighbour sounding curves which are normalized by the altitude and the pitch/roll. From these normalised curves, a standard deviation is estimated along the flight lines to change dynamically the width of the stack windows. This new processing allows us to get the best lateral resolution above every area of a same survey. It has been applied on data acquired in Denmark in 2011 for the NICA project (Nitrate reduction in a geologically heterogeneous Catchment) where lateral resolution of the very near-surface is a critical issue.

CONCLUSIONS

The scope of this research has been to develop a processing and inversion system for airborne transient electromagnetic data from the SkyTEM101 system. The new algorithms are developed in close accordance with the hardware developments.

The research has involved the development of a new processing system based on:

1) Coil Response Correction of the raw data to remove the Coil Response and use the very early times

2) data filtering using new noise adaptive filters on altitude normalised data for getting the best lateral resolution above different type of survey area.

With the new processing algorithms we are able to model very early transient EM data giving the opportunity to accurately resolve geological structures in the very shallow geology. The

adaptive lateral averaging scheme ensures that geological structures are only smeared out to an absolute minimum.

The SkyTEM101 system yields data which can accurate resolve the near surface geology from the surface to a depth of 50 – 100 m. The data does not need calibration and can be processed and inverted right from the measurement platform.

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