WS14-A02

Multipulse Airborne TEM Technology and Test Results Over Oil-sands

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SUMMARY

The MULTIPULSE™ technology enables a time-domain electromagnetic (TEM) system to transmit a high power pulse and one or multiple low power pulse(s) within a half-cycle. The high power pulse ensures good depth of exploration and the low power pulse allows a fast turn off and earlier off-time measurement as well to provide higher frequency information, thus allowing higher near surface resolution and better sensitivity to weak conductors. The MULTIPULSE technology can be applied to current airborne TEM systems such as the HELITEM® and GEOTEM® systems to increase their geobandwidth. The addition of the small pulse extends the range of the sensitivity tenfold toward the weak conductors and therefore expands the scope of applications of the TEM systems.
We have field tested the HELITEM and GEOTEM MULTIPULSE systems in Fort McMurray, Alberta, Canada, over a typical oil sands geologic setting. The results demonstrate the effectiveness of the MULTIPULSE technology, showing comparable shallow geological resolution of the MULTIPULSE to that of the frequency-domain RESOLVE® system while maintaining superior depth of exploration.

Introduction

In airborne electromagnetic mapping or sounding, a broader bandwidth is always desirable, as it provides information of both the shallow and the deep geology, whether resistive or conductive. For deeply buried targets higher transmitter power is required. For shallow or resistive areas early time or high-frequency data is required (Spies and Frischknecht, 1991).

The high frequency information obtained by an airborne TEM system is a function of the system transmitter waveform as well the earliest off-time data that the system can reliably provide (Hodges and Chen, 2013). A transmitter waveform with fast turn-off contains higher frequencies than a transmitter waveform with a slower turn-off.

The MULTIPULSE technology, developed by CGG Airborne Surveys, can be applied to current airborne TEM systems such as HELITEM and GEOTEM to increase their sensitivity and resolution for near surface conductivities while maintaining a great depth of exploration. Here we present the MULTIPULSE technology and field examples in an oil sand geologic setting to demonstrate the effectiveness of this technology.

The MULTIPULSE technology

Typically an airborne TEM system transmits a single pulse waveform, such as the HELITEM or the GEOTEM system that transmits a halfsine waveform. The halfsine waveform can be generated to achieve high power (more than 2,000,000 Am^2 for the current HELITEM) providing great depth of exploration. However it lacks the higher frequency content that a square or a sharply-terminated trapezoid possesses. A square or trapezoid waveform, though, contains higher frequency content, but is usually difficult to generate with very high power, which limits the depth of exploration. The MULTIPULSE technology allows a TEM system to transmit multiple pulses within one half-cycle.

Figure 1 shows the whole cycle of a halfsine and a typical MULTIPULSE waveform and their amplitude spectra. At lower frequencies the spectrum is dominated by the half-sine pulse and there is no distinction between the halfsine and the MULTIPULSE. At higher frequencies (> ~2.3 kHz), the MULTIPULSE possesses much higher power than the single halfsine, confirming the effectiveness of the addition of the small square or trapezoid pulse.

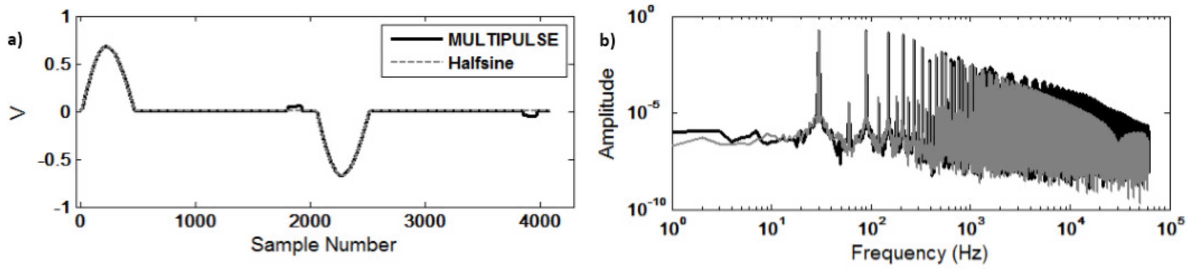

Figure 1 *(a) MULTIPULSE and halfsine waveforms and (b) their amplitude spectra. The halfsine pulse is 4 ms wide and has a peak dipole moment of 770 k Am* ^{2}**.**

HELITEM and GEOTEM MULTIPULSE test over the Fort McMurray oil sands

We flew the HELITEM and GEOTEM MULTIPULSE system at Fort McMurray in the oil sands province of Alberta, Canada. Both systems operate at 30 Hz base frequency, transmitting a higher power (780, 000 and 762,000 Am^2 for HELITEM and GEOTEM, respectively) 4 ms wide halfsine pulse with a 10.5 ms off-time and a 1ms wide trapezoid pulse with a 1 ms off-time at lower power (62,000 and 48,000 Am^2 for HELITEM and GEOTEM, respectively). The ground clearance of the transmitter for HELITEM is 35 m (receiver concentric to transmitter) and for GEOTEM, 120 m (The GEOTEM receiver is 131 m behind and 56 m below transmitter).

Detailed geology of the oil sands can be found in the report by Carrigy et al. (1973). Briefly, the test area is covered by glacial till underlain by the Grand Rapids sandstone. Beneath the sandstone is the Clearwater shale, the most prominent conductor in the test area. Underneath the shale is the Fort McMurray formation (which hosts the oil sands), itself underlain by the Devonian limestone. A salt layer exists under the limestone.

Figure 2 shows the resistivity-depth sections of one survey line, derived from the MULTIPULSE (dB/dt Z component) and one from a previous RESOLVE frequency-domain EM survey.

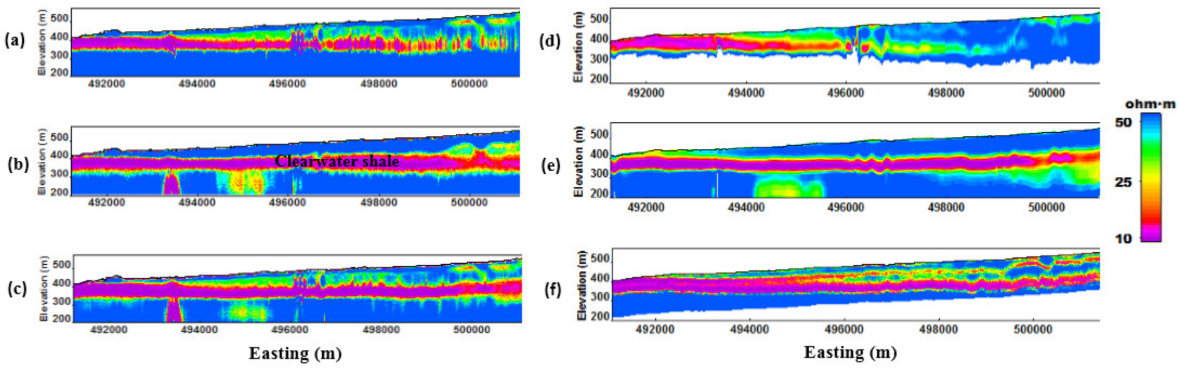

Figure 2 *Resistivity–depth-sections from MULTIPULSE and RESOLVE data. (a), (b) & (c) are from the HELTEM MULTIPULSE trapezoid, halfsine and the two pulses combined, respectively; (d) and (e) are from the GEOTEM MULTIPULSE trapezoid and halfsine pulse respectively and (f) from the RESOLVE data. Culture effects are seen west of 494000m and east of 496000m.*

The sections from the trapezoid pulse (a) and (d) reveal more details of the shallow geology, including the moderately resistive glacial till and the silt or clay rich lenses embedded in it, underlain by the also moderately resistive Grand Rapids sandstone. The section agrees well with the features depicted by the RESOLVE section (f). The halfsine pulse however, reveals more information at depth. The major conductor, the Clearwater shale, is more clearly defined as a flat-lying layer that occurs over the whole line. The less powerful trapezoid pulse renders a much fuzzier picture of the shale where it is buried deeper (east portion of the profile). Secondly, the halfsine pulse "sees" though the Clearwater shale and reveals a conductor in the oil sands formation between 494000 and 496000m but neither the trapezoid pulse nor the RESOLVE detects it. The nature of this is uncertain, but it could be saltwater rising through sinkholes in the limestone beneath the oil sands formation.

Combining the two pulses gives a more complete picture of the geology as shown in (c). The test results demonstrate the effectiveness of the MULTIPULSE technology.

Conclusions

The MULTIPULSE technology effectively increases the geobandwidth of an airborne TEM system while maintaining its depth of exploration, making it more suitable for mapping shallow and weakly conductive targets as well as for strong deep conductors in mineral exploration and near surface imaging such as mapping oils sands deposits.

References

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