CGG'S NEW HELITEM-C AEM SYSTEMS

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SUMMARY

Recent development and re-design of the Helitem helicopter time domain system have resulted in the release of the Helitem$_{30C}$ and Helitem$_{35C}$ systems, both of which employ MultiPulse™. We describe the Helitem$_{30C}$ system, which was designed for efficient operation and is applicable to the majority of TEM surveys. The Helitem$_{35C}$ was designed to increase sensitivity to both resistive and conductive targets (increased geologic bandwidth) while achieving maximum power (and depth). A redesigned receiver suspension system significantly reduces coil motion at low frequencies, allowing for 12.5/15 Hz operation with no increase in coil motion noise, important for exploring under cover. We show case histories using both systems to illustrate their performance.

Key words: airborne electromagnetics, low-base frequency, MultiPulse, system innovation, geologic bandwidth

INTRODUCTION

Airborne electromagnetic (AEM) surveying has existed for more than 60 years. Available technology and market conditions have led to tremendous system development. Fixed-wing time systems were able to provide depth for mineral exploration while helicopter frequency domain systems provided high-resolution near-surface mapping and exploration, but neither technology could perform both functions. As deposits have become more difficult to discover, direct detection of targets has become more difficult and more information about geologic structure has been sought by explorers. Today, the exploration community demands sensitivity to a wide range of targets simultaneously; for most applications a system must be able to detect structures at depth while resolving near-surface/subtle features. Achieving this performance requires increasing system bandwidth.

There are various system characteristics important to achieving near-surface resolution. A transmitter pulse with sharp turn-off maximises the high-frequency response from the ground, important for resolving thin/subtle features. A receiver coil capable of measuring early time channels and high resonant frequency is necessary to measure this response. To achieve depth of exploration and energisation of conductors, the opposite characteristics are desired; a long, slow transmitter pulse is required to energise conductors (Liu, 1998) while a receiver's noise levels are more important than a high frequency response.

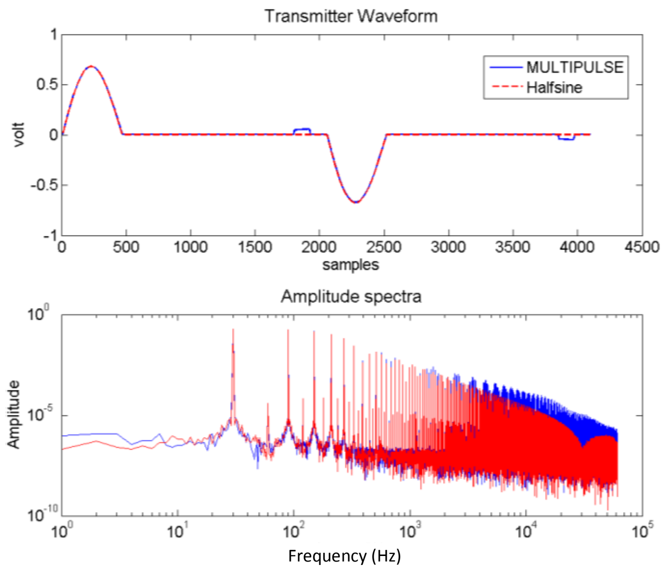

Figure 1: Current waveform for a halfsine-only pulse (red) and MultiPulse (top panel) and their calculated power spectra (bottom). At low frequencies, the power spectra are the same but at high frequencies (> 2 kHz) the MultiPulse waveform has significantly more power.

SYSTEM DESCRIPTION AND RESULTS

The past decade of development on airborne electromagnetic (AEM) systems by CGG has focused on extending the bandwidth of measurements and increasing the range of geologic targets that can be detected. About 10 years ago, CGG introduced HELITEM, a helicopter EM system where the receiver was offset vertically (and laterally) from the transmitter. In an effort to increase sensitivity to small, near-surface features, CGG's Helitem$_{30C}$ and Helitem$_{35C}$ were developed with the receiver in plane with the transmitter, substantially decreasing distance to near-surface targets and increasing signal. At the same time, a multi-pulse transmitter excitation, appropriately named MultiPulse™ was developed to inject more high-frequency signal and better excite weaker/smaller/near surface features (Chen et al, 2014). With MultiPulse, each transmitter cycle contains a long halfsine pulse and a sharp square pulse. A halfsine only current waveform is compared with a MultiPulse waveform in Figure 1, where the transmitter power spectra have also been calculated. The blue trace in the bottom panel shows that the MultiPulse waveform has significantly more power at high frequency (> 2kHz). The halfsine pulse efficiently energises strong conductors while the square pulse generates high frequencies for thin/resistive features. Because of this, the off-time of the square pulse has been made shorter. These changes result in the data having more high-frequency content and helps increase the "geological bandwidth" (Hodges and Chen, 2015).

Geologic bandwidth is a method of quantifying how system specifications affect the range of targets that can be detected. First, a geologic model is assumed, such as a wire loop target. The system response to the target can be computed incorporating system waveform, power, altitude, transmitter-receiver separation, filtering, etc. Calculation can be performed for various target properties and the "bandwidth" of geologic target properties can be determined by comparing with the noise level. An example for the wire loop case is shown in Figure 2.

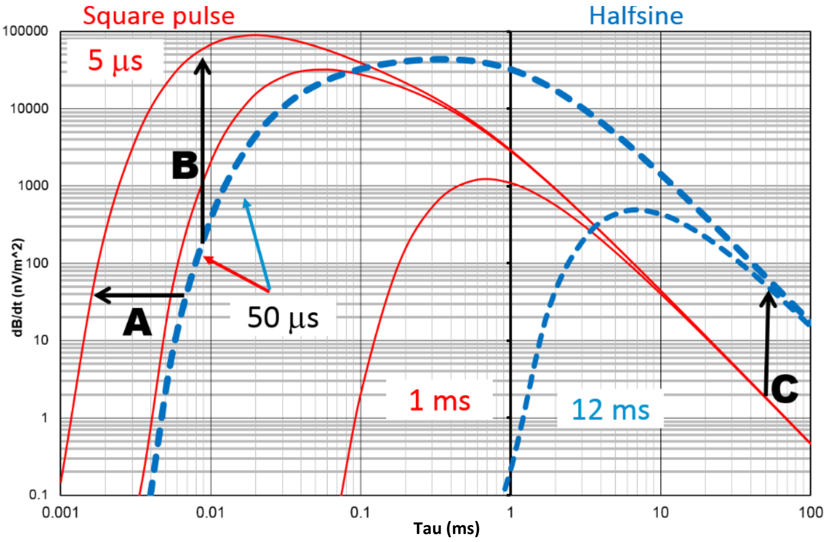

Figure 2: An example of the geologic bandwidth calculation for MultiPulse on the 30_C system for a wire loop target. The red lines show the response of the 1st, 3rd and last square pulse channels. The blue curve shows the response of the first and last channels from the halfsine pulse. The response has been calculated for a range of wire-loop time constants τ. "A" shows that wire loops with smaller τ (resistive targets) can be detected with the first channel from the square pulse. "B" shows that for this particular time constant, the response amplitude is 2.5 orders of magnitude greater for channel 1 of the square pulse and 5x higher for channel 3 than channel 1 of the halfsine pulse. "C" shows that for large time constants (very conductive/large targets) the response from the halfsine is more than an order of magnitude higher than from the square pulse.

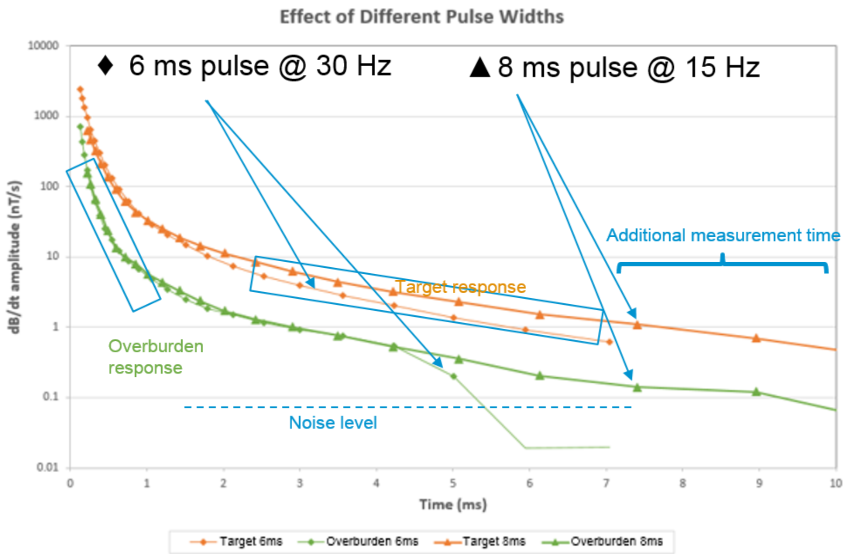

Figure 3: Measured response of the HelitemA (offset transmitter-receiver) at 30 Hz with a 6 ms waveform compared to Helitem35C at 15 Hz with 8 ms waveform. The target response for the wider pulse is significantly larger than for the shorter pulse while overburden response is largely identical. The concentric receiver and re-designed suspension result in the Helitem35C system having lower noise level and being able to measure the decay curve to longer times after the pulse.

The Helitem30C system has been designed for versatility and efficiency. The transmitter is a 30 m loop generating a MultiPulse waveform (up to 5.5 ms halfsine, 1 ms square pulse with 50 µs ramps) and dipole moment from 0.5 MAm^2 to 1 MAm^2. The redesigned receiver coil is concentric to the transmitter loop, resulting in a decrease in noise levels by a factor of 4 compared to the original Helitem "A" system with receiver in front of and above the transmitter. System weight has been purposely kept low to assist in high elevation flying and maximise survey efficiency.

The Helitem35C has been designed to deliver optimum performance. The transmitter diameter is 35 m generating a MultiPulse waveform (4 ms to 10 ms, 1ms square pulse with turn-off time as low as 35 µs) with dipole moment from 0.6 MAm^2 to 1.3 MAm^2. To improve the low-frequency bandwidth, CGG has developed a new receiver architecture for the Helitem35C to dramatically reduce coil motion noise and allow operation at lower base frequencies (Konieczny et al, 2016). Electronically, low base frequency operation on an AEM platform is not difficult; receiver coil motion at the lower base frequency is the limiting factor, resulting in significantly higher noise levels. For the Helitem35C system, the amplitude and resonant frequency of coil motion has decreased such that 12.5 or 15 Hz base frequencies can be used, with a noise level only marginally above the expected increase due to reduced stacking. This development allows operation at lower base frequencies; now, longer transmitter pulses can be employed, better energizing stronger conductors (low base frequency necessary to maintain adequate off-time with larger duty cycle) and measurements can occur at a longer time after the end of the pulse (for better discrimination of strong conductors) thereby improving the low-frequency end of the "geologic bandwidth".

Figure 3 shows an example of decays measured by the Helitem35C from a test survey flown in Canada. The diamond symbol shows the measured decays for the original HelitemA system (offset transmitter-receiver) at 30 Hz while the triangles show Helitem35C concentric with re-designed suspension operated at 15 Hz. The survey area has a conductive overburden but a resistive host so base frequency is not a limiting factor for detecting the target. The figure still illustrates two important points: (1) pulse width is important in energising the target. The target response is larger for the 8ms pulse than for the 6ms pulse, but overburden response is largely the same. The wider pulse has a larger target to overburden ratio (increased signal to noise) important for exploring under conductive cover; and (2) the overburden decay curves show that the 35C 15 Hz base frequency has a lower noise level with coherent data 10 ms after the pulse whereas the 30 Hz_A system is in noise around 6ms. In conductive environments, this is extremely beneficial since the 15 Hz base frequency provides longer measurement time. As the conductive host delays the measurement time where the target response becomes significant, it is important to be able to measure at longer times after the pulse.

Figure 4 shows amplitude grids for 3 different channels from the survey. The top panel shows the original offset transmitter-receiver system result while bottom panel shows the $Helitem_{35C}$ result. The early time channels show the overburden response, obscuring the targets. Arguably, the grids for the 0.5 ms channel show 1 of the targets but the others are hidden. The 2.34 ms grids show the targets; $Helitem_{35C}$ operated at 15 Hz with 8 ms halfsine pulse is able to detect 4 distinct targets (verified by client) while the original "A" system (30 Hz, 6 ms) only sees 2 targets. This is a result of both pulse width and system noise level. As the host resistivity is quite high, late time channels are not necessary to image the target so in this example there is no benefit to the extended measurement time afforded by the 15 Hz base frequency on $Helitem_{35C}$.

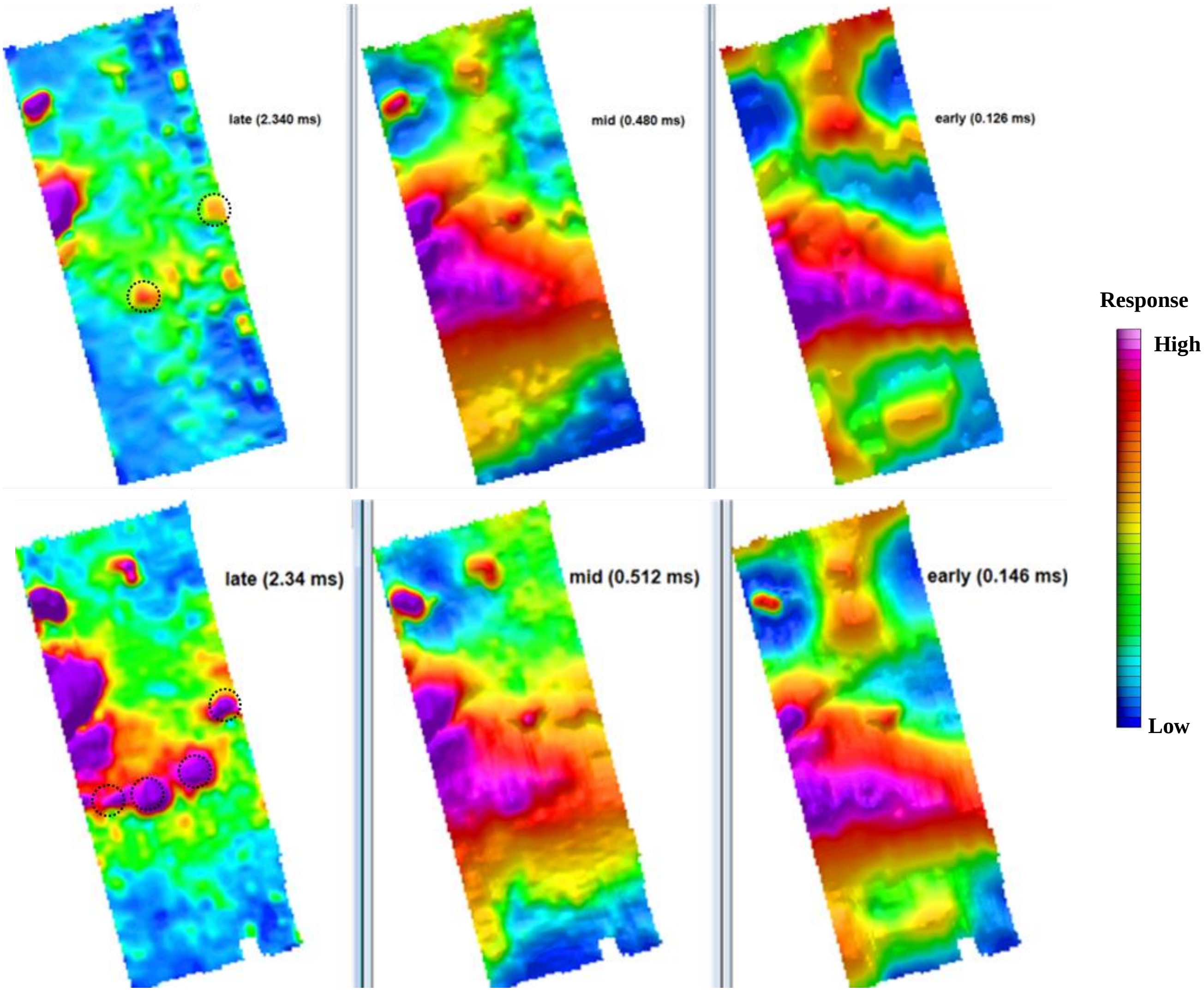

Figure 4: Measured response of the Helitem "A" (offset transmitter-receiver) at 30 Hz with a 6 ms waveform compared to $Helitem_{35C}$ at 15 Hz with 8 ms waveform. The target response for the wider pulse is significantly larger than for the shorter pulse while overburden response is largely identical. The concentric receiver and re-designed suspension result in the $Helitem_{35C}$ system having lower noise level and being able to measure the decay curve to longer times after the pulse. Grids for the early time are shown at the right and for later times on the left; the dashed circles highlight the EM anomalies which correspond to conductive targets at depth.

CONCLUSIONS

We have provided a summary of the Helitem_{30C} and Helitem_{35C} systems, describing evolutionary changes and detailed two significant innovations: operation with two distinct pulse shapes (MultiPulse) and the capability of operating at base frequencies below 25/30 Hz without significantly increasing noise due to receiver coil motion, an industry first. Two distinct pulses in one waveform allows for transmitter power spectra to be broader band; the square pulse generates high frequency power (important for resistive/thin/near-surface features) while the halfsine portion of MultiPulse has high moment and energises strong conductors well while limiting the response of conductive overburden, important for exploration of mineral deposits under cover. The reduced noise of Helitem_{35C} and the effect of increasing pulse width is shown by examining the measured decay curve and amplitude grids for a test survey conducted over ground with a conductive overburden and resistive host. The 15 Hz base frequency data from Helitem_{35C} has significantly lower noise levels than 30 Hz data from the original offset transmitter-receiver Helitem system. In this geologic terrain, the increased measurement time of a 15 Hz base frequency is not beneficial but absolutely is for conductive hosts.

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