Unveiling TargetEM: Pioneering a Hybrid Airborne Electromagnetic System with Expanded Exploration Capabilities

Expert Geophysics Limited

During the 8th International Airborne Electromagnetics Workshop (https://aem2023.org.au) held on September 5, 2023, the groundbreaking airborne electromagnetic system, **TargetEM**, was introduced. This workshop serves as an international platform for showcasing achievements and advancements in applied geophysics every five years.

The comprehensive abstract detailing TargetEM's capabilities can be accessed via the following link: https://zenodo.org/records/10060418. As of December 2023, this abstract stands out as the most viewed and downloaded presentation from the workshop.

For those interested, the presentation is available on ResearchGate.NET, where it can be requested under the title "Passive and active airborne electromagnetics -separate and combined technical solutions and applicability | Request PDF (researchgate.net)", or by contacting info@expertgeophysics.com via email.

To elucidate the distinctiveness of TargetEM and the rationale behind its development, construction, and market introduction by Expert Geophysics Limited (EGL), we commence with a comprehensive review of airborne electromagnetic methods.

All airborne electromagnetic (EM) methods are inherently inductive, utilizing a primary (transmitting) field and measuring a secondary field as a subsurface response. The 'typical' depth of investigation (DOI) for airborne EM methods is depicted in the table below, recognizing its conditional nature. Frequency-domain electromagnetic (FDEM) and time-domain electromagnetic (TDEM) techniques utilize controlled sources for the primary field, with the penetration depth highly dependent upon the system's terrain clearance during flights. The natural field method, represented by AFMAG, exhibits lower dependency on terrain clearance as its primary field consistently resides underground. Additionally, subsurface conductivity plays a pivotal role in influencing DOI, with more conductive environments significantly reducing the depth of investigation, particularly for methods employing a controlled-source primary field.

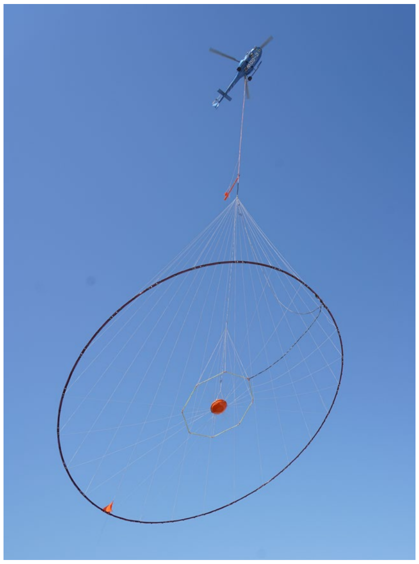

Fig 1 - TargetEM system (towed part)

Typical depth of investigation of airborne EM methods

method	Depth, m
VLF	20-30
Frequency-domain (FDEM)	100-150
Time-domain (TDEM)	500-600
Natural field (AFMAG with the lowest frequency of 25-30 Hz)	1500-2000

Another crucial factor influencing exploration capabilities is the range of resistivity within which a method or system can detect and differentiate resistivity variations.

Illustrated in Figure 2 below, both the frequency-domain and natural field (MobileMT) methods exhibit the ability to detect and differentiate across a significantly broader spectrum of potential resistivity variations. As an example, in some geological terrains, such as the Canadian greenstone belts, where the resistivities of the subsurface geology span the range of thousands to tens of thousands of ohm-m, the time-domain method demonstrates limited efficacy. A direct comparative analysis between airborne time-domain and natural field (MobileMT) methods (Fig 3) reveals that time-domain data primarily identify conductive near-surface alluvium sediments. In contrast, the resistivity profile derived from natural field data showcases distinctions across the entire resistivity spectrum.

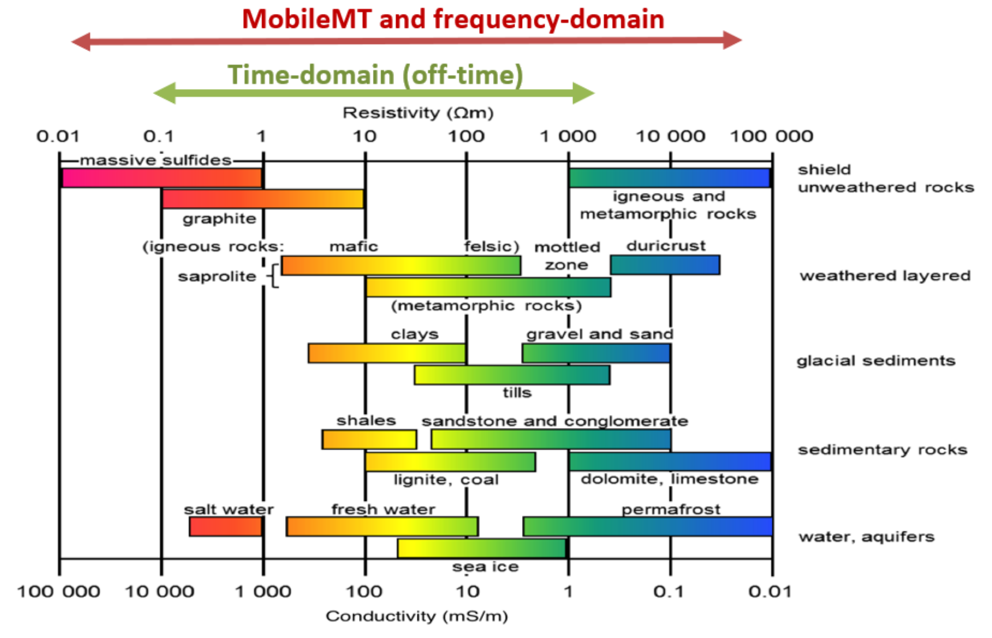

Fig 2 -RANGE OF RESISTIVITY DETECTION AND DIFFERENTIATION

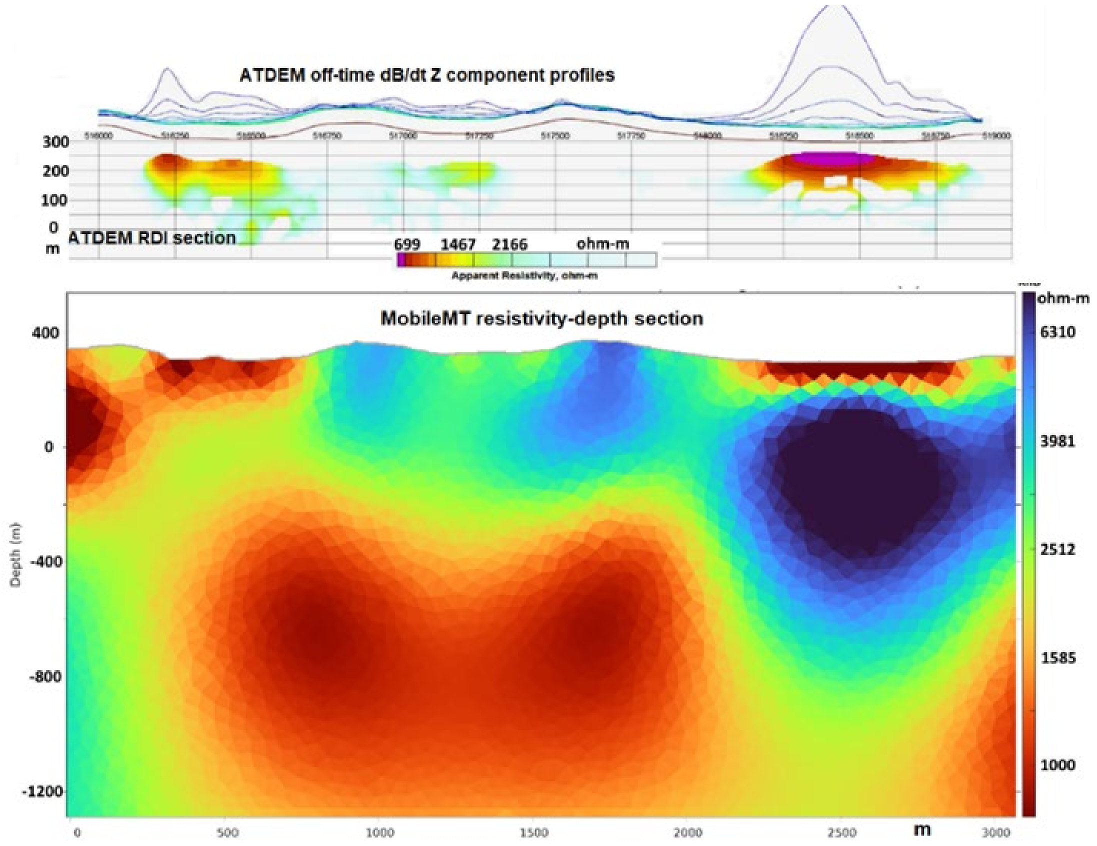

Fig 3 - Airborne TDEM z dB/dT profiles and corresponding resistivity depth image (top); MobileMT resistivity section (bottom) over the same survey line. Northern Ontario

Another disadvantage of the airborne time-domain method is its inability to penetrate a conductive media. Typically, the depth of investigation (DOI) is constrained by the presence of a near-surface conductor or its uppermost section, as depicted in the illustration below (see Fig 4). In both instances, as illustrated in Figures 3 and 4, the natural field MobileMT data presents geologically meaningful resistivity images across an extensive spectrum of resistivity differentiations and a wide depth range, beginning from the near-surface.

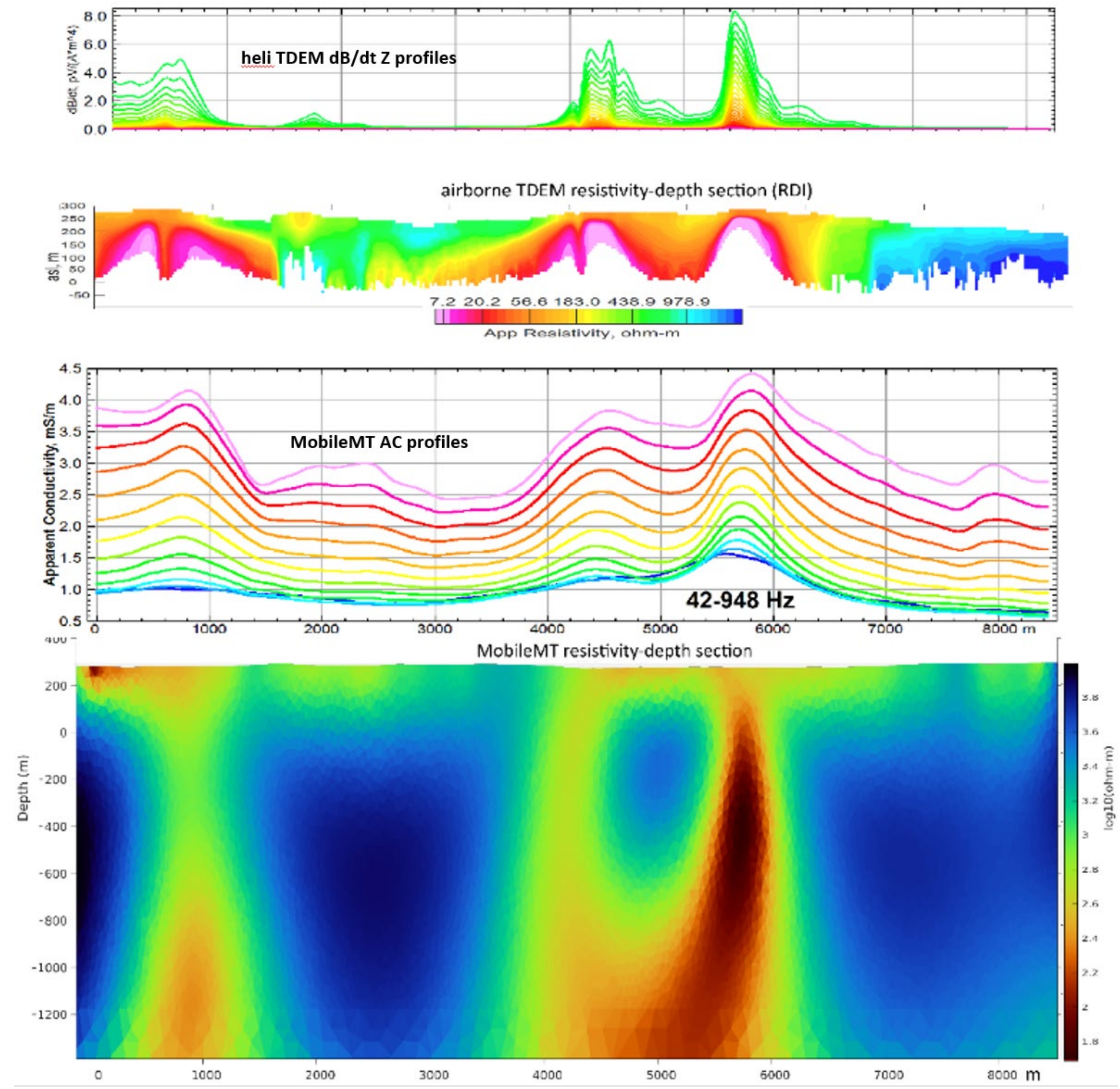

Fig 4 - Airborne TDEM z dB/dT profiles and corresponding resistivity depth image (top); MobileMT apparent conductivity profiles and corresponding resistivity section (bottom) over the same survey line. Reaume Township, Porcupine Mining Division, Northern Ontario.

One remarkable characteristic or capability of the time-domain method proves challenging to overemphasize. This pertains to its focused footprint and its capacity to identify relatively small, discreet conductors—frequently falling beyond the detectability range of methods employing broader footprints for the transmitted primary field, particularly when the targets have a limited depth extent. An illustration of such an anomaly is presented in the time-domain data depicted below (see Fig 5).

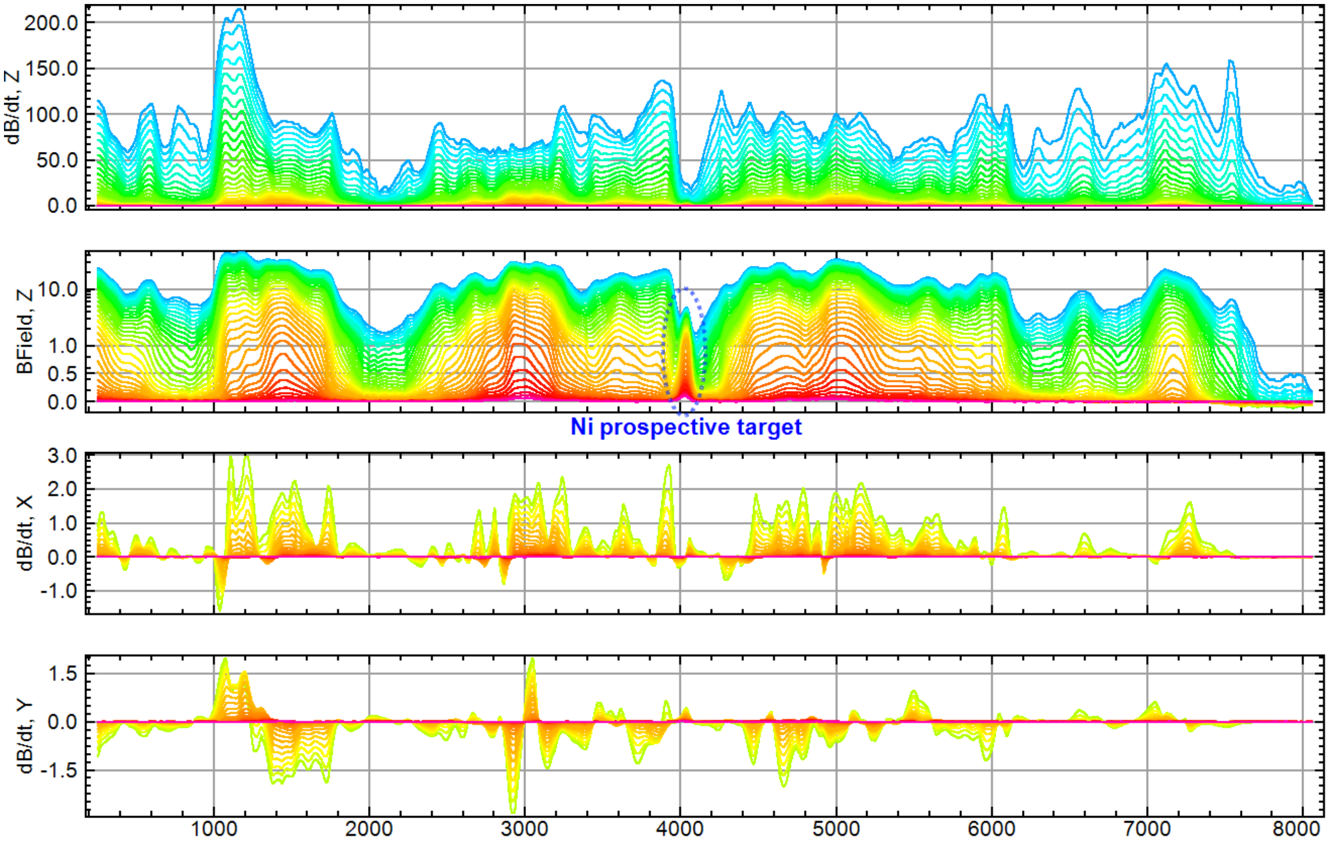

Fig 5 -TargetEM time-domain data over a line crossing a discrete conductor (Western Australia)

The table presented below provides an overview of the comparative advantages and disadvantages between two methodologies: the time-domain method (pertaining to existing time-domain systems on the market) and natural field method (in the example of the MobileMT system).

Natural field (MobileMT)	Time-domain
Variations of natural fields are susceptible to seasonal and diurnal influence and depend on weather and geographical position.	Stable, controlled, and well-described primary field
Broad primary field footprint. Limitations to detect discrete, small targets, especially limited in-depth extent	Highly focused, small primary field footprint. Ability to detect discrete comparatively small conductors, including limited in-depth extent
Depth of investigation consistently exceeds controlled source methods' capabilities by several times.	Limited depth of investigation and critically low in conducive environments
Signal detectability in a wide range of resistivity (including superconductors and in conditions of high resistivity)	Signal detectability in a limited range of resistivity in both ends (Fig 2)
Non-inductive parasitic signals are not observed.	IP and SPM effects often distort the inductive signal and create pseudo-anomalies
Negligible dependence on terrain clearance in a wide range	Highly sensitive to terrain clearance

EGL's **TargetEM** system integrates three electromagnetic (EM) methodologies: **Time-Domain**, **AFMAG (MobileMT)**, and **VLF**. Furthermore, complementary magnetic field data is acquired by a cesium sensor positioned in a separate bird suspended above the EM system.

As illustrated in Figure 6, both VLF and dB/dt data are simultaneously recorded by the identical receiver coils during a time-domain survey conducted in Western Australia.

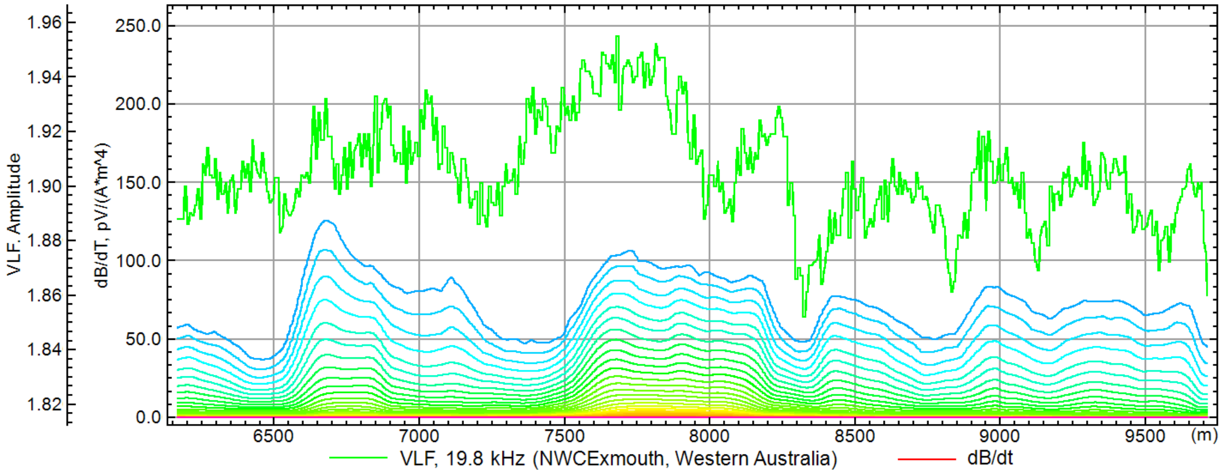

Fig 6 – TargetEM dB/dT data (bottom profiles) extracted from the same streamed data VLF amplitude (top green profile, 19.8 kHz), Kalgoorlie region in Western Australia

The image depicted below (Fig 7) shows VLF and apparent conductivity (AFMAG) anomalies in an area where time-domain data is heavily impacted by the parasitic IP effect (blue area in dB/dt color grid).

Natural field AFMAG, along with complementary VLF radio-field data, constitutes a valuable augmentation to active source time-domain electromagnetic (EM) data, particularly when recorded simultaneously.

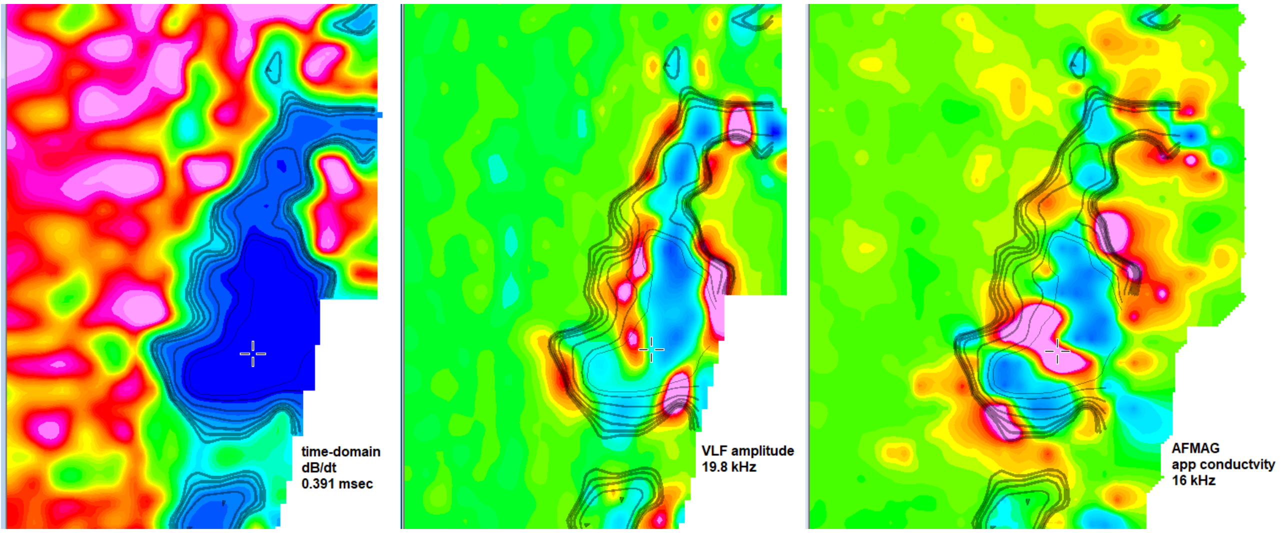

Fig 7 – TargetEM time-domain dB/dt; VLF magnitude; AFMAG apparent conductivity data recorded by the same receiver simultaneously and extracted from streamed data.

Within the TargetEM configuration, AFMAG data serves multiple purposes in conjunction with time-domain data:

1) In areas of a survey characterized by high resistivity where the off-time signal in time-domain is notably weak or absent, as depicted in Fig. 3;
2) In cases of parasitic signals like IP (Fig.7) and SPM;
3) In areas where maintaining proper terrain clearance for time-domain measurements is challenging or unattainable; and
4) In the detection of superconductors when the time-domain off-time response is exceptionally weak, often approaching system noise levels or falling below it.