Configurations of natural field airborne MobileMT system – technical features, differences, and applications

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Summary

The AFMAG airborne system, MobileMT, introduced in 2018, exhibits a diverse range of configurations, each tailored to meet the demands of specific exploration tasks, varied terrain, geoelectrical conditions, and in support of time-domain data. Presently, three distinct systems have been fully developed, rigorously tested, and are commercially available. The original MobileMT, MobileMTm and the innovative hybrid TargetEM+AFMAG collectively represent the result of the precision engineering and adaptability of the technology. However, ongoing developmental efforts are focused on a cutting-edge fourth option—MobileMTd—a drone-based system undergoing testing. This technical abstract provides an analysis of each system's technical features. By examining how these airborne systems differ, understanding their inherent strengths, and identifying optimal usage conditions, valuable insights into their applications under different conditions across various exploration tasks are revealed. We aim to provide some insights for practitioners and researchers, facilitating informed decision-making in selecting the most suitable configuration for specific airborne geophysical exploration programs. Ultimately, this review of the MobileMT airborne system's diverse configurations contributes to advancing the understanding of their nuanced applications and paves the way for future innovations in airborne electromagnetic technologies.

Introduction

The MobileMT system, a passive airborne electromagnetic technology, was introduced to the airborne geophysics market in 2018 (Bagrianski et al., 2019; Sattel et al., 2019). This airborne electromagnetic system, which exploits natural electromagnetic (EM) fields, is an efficient tool for mineral exploration in various geological and geoelectrical terrains and across a wide depth range, from near-surface to depths between 1 and 2 km and even deeper, depending on the overall conductance of the environment. The described 'passive' field electromagnetic system measures magnetic and electric field variations across an expanded frequency range spanning three decades of frequency, using up to 30 comparatively narrow frequency windows. The technology demonstrates its capability to identify geoelectrical boundaries of various geometries and detect resistivity differentiations across a wide range of resistivities (Prikhodko et al., 2024). Despite the versatility of the technology and its wide range of applicability, there are some conditions and requirements that necessitate different system configurations. These include high altitudes requiring lightweight systems, precise positioning for detailed surveys, addressing time-domain data insufficiencies, and meeting the requirements to explore deeper under conductive overburden.

Theory and the system configurations

The operating principle of the airborne natural-field MobileMT EM technology is a combination of magnetotelluric (MT) and magnetovariational (MV) concepts (Prikhodko et. al., 2022). The measuring system for all configurations includes two main parts (Figure 1):

- Three orthogonal dB/dT inductive coils (Figure 1b) in a teardrop-shaped shell towed below the helicopter. Variations of the measured magnetic field (H-field) are recorded digitally in an acquisition system placed inside a helicopter. It is unnecessary to monitor or control the tilt precisely because the measurement system provides rotationally invariant total-field data.
- Two pairs of independent grounded orthogonal electric lines positioned a few meters apart (Figure 1a) for measuring ‘main’ and ‘reference’ variations of the electric field (E-field). The data from the stationary measurement system are recorded similarly to the mobile H-field acquisition system.

The denoised and corrected E-field data represent the primary natural electromagnetic field variations. They facilitate the separation of the time-variance from the space-variance of the measured fields (like in MV). The combination of magnetic (H) and electric (E) fields variations are used for admittance tensor calculation introduced by Thomas Cantwell in 1960 as Y = H/E (Cantwell, 1960; Jones, 2017) and, ultimately, the calculation of apparent conductivities corresponding to different frequency bands:

$$\sigma(\omega)=\mu\omega|Y^2|,$$

where μ is the magnetic permeability of free space, and ω is the angular frequency.

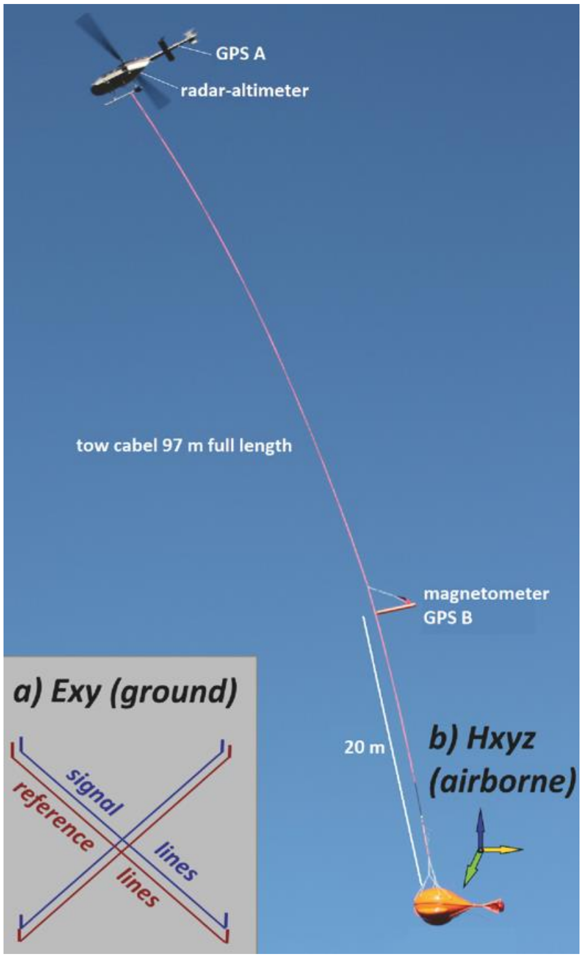

Figure 1 *MobileMT system in survey configuration. a) schematic of a base station that includes two pairs of independent grounded orthogonal electric lines in the same position, b) shows a schematic of three orthogonal dB/dT inductive coils*

Having magnetic and electric field data variations measured in different relative orientations and in different relative directions, magnitudes of total H and E vectors independent of the sensors' spatial attitudes are calculated at the same frequency and time (Prikhodko et. al., 2024).

In accordance with specific survey requirements or terrain conditions, currently, there are three modifications to the MobileMT system:

1) Basic model (Figure 1, 1.4 m diameter coils, 97 m tow cable), capable of providing data in the full range of frequencies (26-21,000 Hz). The historical lowest frequency data is 22 Hz. The system has the lowest mechanical noise, noise from a helicopter, and is free of nearby noise sources. A GPS antenna with a Cs magnetic sensor is located 20 m above the magnetic variations receiver. The system weighs 250 kg.

2) MobileMTm (Sirohey et. al., 2022) (0.7 m diameter coils, 55 m tow cable length), Figure 2. Currently, the recorded frequency range is 50-21,000 Hz. Two Cs magnetic sensors, in the horizontal gradiometer configuration (4 m apart), gyro inclinometer for the magnetic sensors tilt corrections, and GPS antenna are located on the same bird with the magnetic variations receiver. The system weighs 150 kg.

Figure 2 *MobileMTm lightweight system with precise positioning*

3) AFMAG component in the time-domain (TEM) system TargetEM (Prikhodko, et. al., 2023). In the TEM combination case, the natural field frequency range with informative data depends on the controlled primary field source base frequency and the current waveform duty cycle. For this reason, apparent conductivities are derived from streaming EM data in the high-frequency range - 5000-21,000 Hz.

The basic model of MobileMT is used when the maximum possible depth of investigation is required, including in conductive conditions. In regions with high altitudes (higher 3,500-4,000 m ASL) or in surveys with line spacing <100 m, the MobileMTm system is used because it is a lighter version and with more precise positioning, with the GPS antenna on the bird. Natural field AFMAG data during surveys with the time-domain system, TargetEM, is valuable in filling the gaps when the time-domain method is limited: at mapping highly resistive geological terrains, in detecting superconductors, during surveys in rugged relief conditions, and at parasitic effects appearance (IP and SPM).

Starting in 2023, Expert Geophysics Limited has been in the process of developing a drone version of the

MobileMT system, known as MobileMTd (Figure 3). The following advantages are expected from the drone system:

- Reducing mechanical noise and getting data at lower frequencies (10-20 Hz), which is crucial in exploring conductive areas or areas covered by thick conductive overburden;
- Flexibility in selecting the optimal survey timeframe amid peak natural electromagnetic activity, including after sunset.

Figure 4 *MobileMTd (drone) system during a test flight*

How the depth of investigation is expected to be increased, primarily in a conducive environment, is shown in Figure 5. Thus, a depth of 600 m will be reached at 5 ohm-m of unlimited half space.

Figure 6 demonstrates a dynamic change in the natural EM signal intensity during the evening.

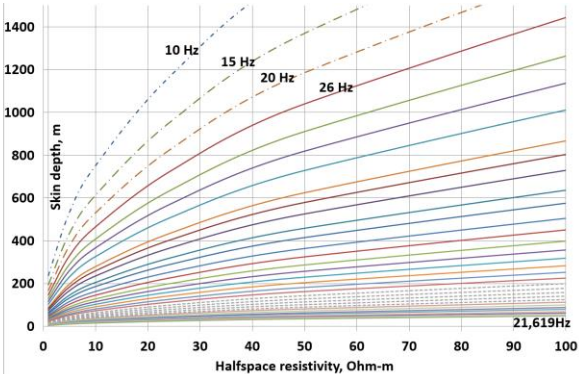

Figure 5 *Diagram of 1.5xskin depth with MobileMTd additional frequencies (10-20 Hz) calculated for conductive half space 1-100 ohm-m*

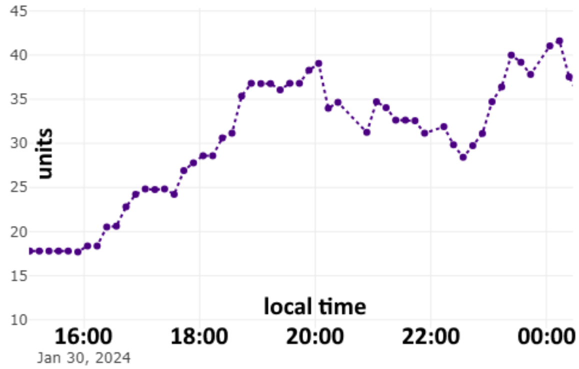

Figure 6 *Monitor signal levels on the electrical base station for 69 Hz between 15:30 and 0:00 local time (Saskatchewan, Jan.30, 2024)*

Conclusion

Advancements in the natural field airborne electromagnetic technique have resulted in improved exploration abilities. However, it is imperative to emphasize the ongoing necessity for developing and adapting various configurations of this technique to ensure its efficiency across diverse geoelectrical and terrain conditions. Moreover, integrating the AFMAG technique with the time-domain EM principle (TEM) holds several advantages. They include the capability of covering or compensating for insufficiency of the TEM data in cases of superconductive targets, lack of response in resistive terrain or at comparatively high flight clearance above the ground, or the discrimination of SPM anomalies, and recovering scenarios involving the interference of the IP effect with induction within TEM data. Using a drone configuration is crucial in exploring territories covered by thick and conductive overburden.

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