Developments of the SkyTEM System

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ABSTRACT

Since 2011, activity in the mineral exploration industry has been in a state of decline and only very recently have we seen signs that this situation may be improving. One result of the continuous fall of the mining index from 2011 until January 2016 is a decrease in exploration budgets and less demand for airborne geophysical survey services. Today there is guarded optimism in the exploration and airborne sectors, but the cold winds we all endured, reduced research and development activities in the airborne geophysical industry and hence developments of one of the more important exploration technologies – helicopter-borne time domain electromagnetic instruments (HTEM).

For providers of TDEM technologies this prolonged decrease in business meant reduced funds available to pursue new developments. We have seen a few new providers enter the market and perhaps some slight improvements in traditional systems, but there have not been any breakthroughs, that have made a difference to the exploration industry. One important exception is SkyTEM Surveys that, during this period of inertia, introduced several new and important operational and technological features. These include fast flying systems, the achievement of transmission of increasingly higher moments (NIA) on smaller light weight frames, improvements in motion noise suppression and the MultiMoment pulsing of the transmitter current. The mineral exploration sector will benefit from these advancements by enjoying higher quality data at a lower price.

INTRODUCTION

Many of the important developments in AEM over the last two decades are those of helicopter time-domain EM (HTEM) systems (Fountain, 1998; Vallée et al., 2001; Allard 2007; Fountain, 2008). The traditional target for airborne HTEM has been mineralization, but since 2002 the mapping needs of other sectors has been addressed. The most outstanding of these has been for rapidly growing groundwater and geotechnical applications and these sectors globally are increasingly utilizing airborne geophysics to deliver much needed solutions.

A recent review paper: "Airborne Electromagnetic Systems-State of the Art and Future Directions" (Legault. 2015) presents in large details the state-of-art HTEM systems and their developments. Generally the mineral exploration market has focused on increasingly deeper targets and hence high resolution of late time decay data at the expense of near surface resolution.

This paper outlines how satisfying the mapping challenges of the groundwater and geotechnical sectors has led to the development of breakthroughs in HTEM and how the mineral exploration sector can now take advantage of this latest generation of HTEM systems designed to deliver high quality data economically.

These achievements perhaps pave the way to new directions for future developments in HTEM as they, to a large extent, also focus on providing high quality data to a lower price.

The long period up to 2010 was a "bull" market for the industry and generally speaking any provider that could field a system and produce data could earn money.

It was however a rude "wake up call" during the period of declining exploration budgets that followed this boom. This created fierce competition amongst geophysical survey companies as they chased fewer dollars resulting in dramatic decreases in survey prices and revenues. Some suppliers disappeared altogether. Service providers have been forced to meet this situation by searching for ways develop instrumentation that differentiates them and makes them more competitive.

It can be said that conventional and traditional HTEM systems have now reached a level of outmoded maturity as the ability to achieve ever higher transmitting moments has led to larger and heavier systems while overlooking near surface resolution. This path is not sustainable in today's exploration world. Today's HTEM systems need to be more "holistic" and be able to offer high S/N ratios with sufficient penetration concurrently with early time data, at a lower price as well as satisfy mapping needs across several market sectors.

RECENT DEVELOPMENTS

Of good news to geophysical professionals is that opportunities in the water, environmental and geotechnical sectors have grown and continue to grow notably providing an increase in available exploration dollars. HTEM development over the last few years has benefited from innovative thinking by focusing on satisfying the needs of sectors other than mineral exploration. Groundwater mapping programs with airborne platforms in particular have increased significantly due to the global awareness to consume and protect water sustainably. Government agencies usually commission water resource mapping programs but budgets are typically small compared to government sponsored mineral exploration programs. Water mapping projects however tend to cover large areas and resolving subtle contrasts throughout these vast areas is important. Another important distinction when exploring for water is that near surface resolution is as essential as mapping to depth. These factors point to the need for faster data collection speeds that serve to reduce helicopter and field costs. They also underline the need for airborne systems designed with more robust instrumentation that is able to quickly deliver accurate high quality data. These market forces have led to new, interesting and beneficial achievements in the airborne geophysical survey sector.

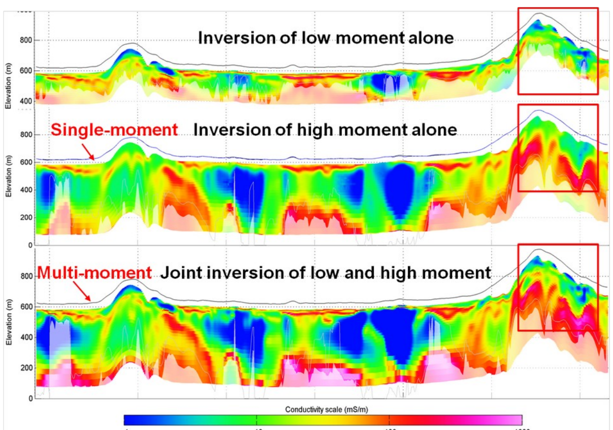

Figure1. The figure demonstrates the resolution by applying a Multi Moment data set compared to that of the respective single moments.

Near-surface and deep mapping

Mapping of groundwater resources requires accurate delineation of near-surface geology as well as the ability to map the distribution and interrelations of deeper situated aquifers. Therefore high quality datasets that include late decay times as well as early times are required.

In reaction to the needs of the National Danish Groundwater Mapping Act SkyTEM developed the sequential transmitted moment technique. Following this the MultiMoment method was developed to meet the demands of the government authorities with respect to data quality. SkyTEM's MultiMoment applies a single waveform with HM and LM combined, that are transmitted and measured simultaneously. Recently CGG introduced the MultiPulse technique based on a similar measuring procedure.

The use of HTEM in geotechnical applications has increased substantially in the last few years due to the development of very early time measuring instruments. In the past, frequency EM dominated the airborne geotechnical market as its ability to resolve very near surface features was superior to that of conventional HTEM systems. This is no longer the case as HTEM equipment, that can measure very early times – in fact, in the on-time - has been launched (see figure 1). It is considered that today's HTEM can provide resolution of the very near surface similar to that of the frequency domain.

Another important mapping issue is the quality of the interpretation of measured datasets. When interpreting early time datasets it is essential that the geometrical parameters are included in the interpretation. Therefore the altitude and orientation of the carrier frame, transmitter loop and receiver coils must be accurately measured and determined, and not estimated from videos, etc.. Small derivation of these parameters will introduce significant bias in the interpretation and hence the quality (Christiansen et al, 2011).

High survey speed

In order to meet the challenge of a very competitive HTEM market and maintain reasonable profit margins with increasing downward pressure on prices, tremendous effort has been put into increasing the survey speed and thereby lower helicopter costs – being the dominant part of the overall costs in an airborne survey. Flying fast introduces several challenging issues. The most important are the drag and weight of the carrier frames and ancillary instrumentation, and the increased significance of motion induced noise.

Many attempts have been made to overcome these obstacles. The most successful to date is the SkyTEM Fast Flying System (see figure 2) which is capable of acquiring over 1,000 line kilometers of data per day at surveys speeds of 140 - 150 km/hrs. This has been accomplished and is now available with transmitting moments up to 1.000.000 NIA concurrently with the application of the MultiMoment technique, thus assuring measurements from early times to late times.

This system has a very rigid carrier frame structure engineered with low drag aerodynamic elements to ensure stable behavior while in full flight, and constant geometrical parameters for the transmitter loop and receiver coils.

Figure 2. The Fast Flying SkyTEM System at a speed of 150 km/h.

Challenging survey areas

HTEM systems often meet extreme environments when surveying for mineral targets situated in rugged terrain and at high altitudes. The challenges can arise from strong gusty winds making the operation potentially hazardous. Acquiring quality data in rugged terrain demands carrier frames and instrumentations that the pilot can maneuver without undue stress. Flying at high altitudes requires light weight equipment in order for the helicopter to safely and sufficient lift and fly the system.

One obvious solution for these challenges is to apply a light-weighted small system with low drag, but in order to accurately and adequately resolve targets it must have a high signal-to-noise ratio.

The S/N ratio is controlled by two factors: the magnitude of the transmitted moment and the noise from the receiving unit. New developments of suspended receiver coils together with new receiver electronics have provided significant higher S/N ratio for the receiver system (see figure 3).

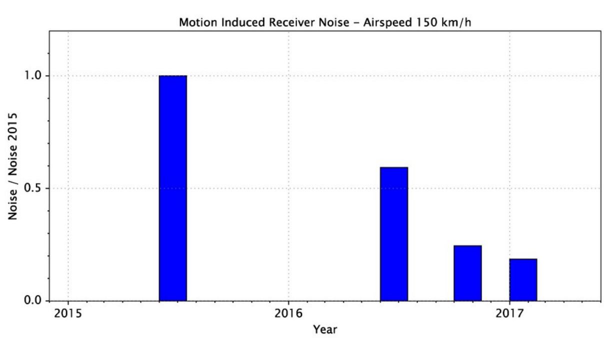

Figure 3. The progress in the development of suppression of motion induced noise in the receiver coil since 2015. Notice that the reduction is of a factor 4 to 5.

Further developments of the Fast Flying carriers and a new transmitter system have enabled SkyTEM to produce a small transmitter/carrier system with low weight and drag, together with a high transmitting moment (1.000.000 NIA) suitable for these operations.

Taken together, a system with low weight, low drag and high S/N ratio is well suited for operations in high altitudes and areas with gusty weather conditions and rugged terrains (see figure 4).

All SkyTEM systems are now available on a single 341m^2 rigid and light weight frame platform. This basic building block is truly versatile and fully customizable for dipole moment and survey speed to suit specific exploration targets or manage safety risks such as hot climates or steep terrain. Within a day or less all SkyTEM systems can be changed. For example, the system can be reconfigured from a Multi Moment to Single Moment system with a focus on late time gates to achieve greater depth of investigation for exploring for deeper targets.

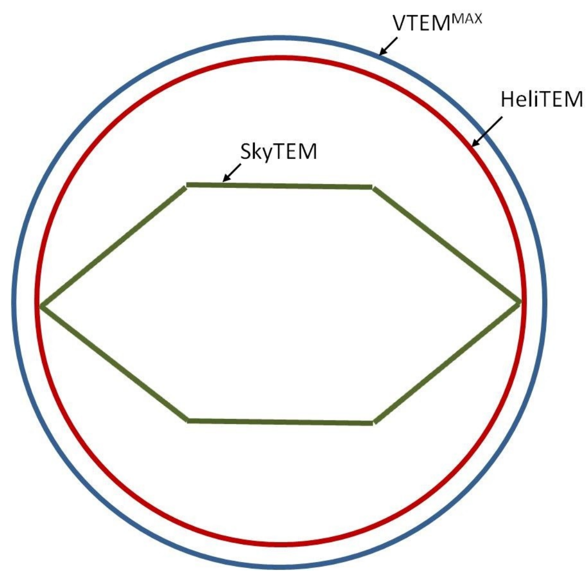

Figure 4. Comparison of size between VTEM^{MAX} (1.500.000 NIA), HeliTEM (2.000.000 NIA) and SkyTEM (1.000.000 NIA). Notice the shape of the SkyTEM carrier frame which has a more aerodynamic design for high speeds and better maneuverability.

Other Developments

Another recent development the mineral exploration sector can benefit from is the ability to deliver 1D inversion within 24 hours of acquiring the data. The ability to acquire over 1,000 line kilometres of data per day combined with fast data delivery allows exploration managers to consider flying an area regionally, with wide flight line spacing and greatly reduced helicopter hours. Results from each day's flying can be reviewed and geological trends and anomalies identified. Areas of interest can be strategically targeted for infill lines or extended flight lines, thereby reducing time in the field while maximizing exploration objectives. This is all done in one mobilization with crew and helicopter still on site as data is delivered. The combination of speed of acquisition combined with tactical selection of flight lines contributes not only to efficiency and economic benefits but also to providing exploration management with near real-time data to make appropriate management decisions.

FUTURE DEVELOPMENTS

The demand for faster data collection that can deliver high quality and reliable HTEM datasets is increasing as is the need for more powerful systems and improved resolution. Exploration projects are increasingly being carried out in more rugged terrain that is difficult to access and survey areas will grow in size especially for groundwater targets.

To satisfy these demands development of HTEM system will most likely be focused on delivery of high quality datasets measured from very early times to late decay times. Furthermore, light-weight instrumentation is needed to conduct surveys in rugged and high altitude locations. Finally, a faster operation speed will increase the number of applications as the costs are reduced.

Future developments will be directed towards smaller, light-weight yet rigid systems capable of flying faster. The data quality will increase due to improved receiver electronics and further developments in suppression of motion induced noise. The bandwidth of the induction coil receivers will be significantly improved in order to measure early and late times in one run. The transmitted moment may not increase significantly on small carrier frames but will be tested to maintain high magnitude to obtain a high S/N ratio.

A major variable is the receiver system. Do we get a new B or dB/dt field detector that is based on new principles other than the induction coil?

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