APPLICATION NOTE

The Application of Bartington Instruments Fluxgate Magnetometers in TDEM Surveys

Instrumentation

- Mag-03MSESL three axis magnetic field sensor
- Mag639 wide bandwidth three axis magnetic field sensor
- A correction unit to compensate for the Earth's magnetic field.

Applications

This note describes an improvement to the TDEM method which will mostly concern mineral exploration, in which the main interest is highly conductive bodies, such as ore bodies. This is particularly the case for exploration for nickel or sulphides.

The Mag639 can be used for metal detection in shallow ground and would also be suitable for UXO detection.

Introduction

TDEM, or Time-Domain Electromagnetics, is a geophysical method that uses the principle of induction to determine the conductivity and geometry of sounded material. The method is based on a simple theory. Electric currents flowing in a transmitter loop generate a primary magnetic field which, when stopped, creates eddy currents in conductive material.

As a result, a secondary magnetic field is induced which decays according to the conductivity of the material. The decay of the secondary magnetic field induces a current in the receiving coil, the voltage of which will be linked to the conductivity.

This method is used in both the academic world and in private companies, mainly in mineral exploration. Its advantage is the ease of use and the good results provided at depth up to several hundreds of meters (≈ 500m up to 1.5 km in ideal conditions).

One limitation to this method is exhibited when sounding highly conductive media. The rate of decay of the secondary magnetic field is very slow, leading to a late and low signal being received by the coil antennae. This can make highly conductive materials invisible to the method. However, while the decay rate is slow, the strength of the secondary magnetic field itself is high, and can be measured using a good magnetometer.

Use of magnetometry in TDEM

Measuring the secondary magnetic field requires field-proof sensors, and research has shown that low noise fluxgate magnetometers are the most appropriate type. Furthermore, the combination of more than one magnetic sensor, and signal processing, allows for greatly improved results.

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The operation is simple: it requires adding a magnetometer to the pre-existing TDEM set-up, and connecting the magnetometer to the datalogger. Once the sensor is set up, to increase the resolution, the voltage corresponding to the Earth's magnetic field must be read and subtracted from the measurements: this means that only the secondary magnetic field is measured. Raw data shows that the noise level is in the order of nT. However, data processing (stacking) reduces this level to about 5pT, suggesting that low noise magnetometers are required so as not to increase the overall noise.

The Bartington Instruments Mag-03MSESL (70 or 100) is ideal for this application. The noise level offered is below 6pT. A square sensor allows for easy set-up in the field and offers a better axis alignment error, and the measuring range of 70µT or 100 µT allows the total Earth's magnetic field to be measured.

The only drawback to the method is the frequency limitation of the magnetometer. It is unable to measure the early time high frequency field associated with responses at shallow depths. However, this problem is overcome by the Mag639, which provides a large bandwidth (DC-12kHz) with a reasonable noise level (<15pTrms/√Hz). Due to the extended bandwidth, the sensor offers linearity in early time measurements, increasing the capacity for shallow measurements.

In comparison to other magnetometers, fluxgate magnetometers represent ease of use, thermal stability and low cost, and are much more adapted to field measurement than SQUIDs.

The setup

The magnetometer in B-field measurements can be either used as a complement to the dB/dt method or in replacement of it. As well as a Mag-03 or Mag639 and associated cables, a correction unit is also required to compensate for the Earth's magnetic field.

The setup of the emitter/receiver is relatively simple and only consists of a loop of wire. The time of set-up and investigation is usually short, but will depend on the area to survey. The emitter loop can be installed over a small area (10x10 metres), or a larger area for wider coverage and deeper exploration (2x2 km).