Application Note: Electromagnetic Survey

Photo: Courtesy of New Resolution Geophysics, South Africa.

OVERVIEW

Electromagnetic (EM) methods have been used in mineral exploration for decades. Whilst there are multiple methods, they commonly rely on measuring either B or dB/dt to determine the underlying ground resistivity.

Fluxgate have played a role in the measurements of B field in a number of cases as an alternative to induction coil sensors. They will achieve a better sensitivity at ultra low frequencies.

Fluxgate are also typically used during airborne magnetic surveys for airframe compensation on manned flights, or direct measurements on unmanned aircrafts.

Fluxgate Sensors for B-field Measurement in Time Domain EM (TDEM)

Time domain EM is an active method where a current is injected into a coil. When the current is abruptly shut down, the laws of induction indicate that for a short period of time a small voltage is induced into the ground and with it a current loop propagate into the ground.

As this propagate into the ground, it decays and in turn induces more current into the ground which generate a secondary magnetic field.

Usually induction coils are used to measure the secondary field, which rates of decay is proportional to the ground conductivity. However, in a few cases, the ground

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Equipment

- Three-axis Fluxgate Magnetometer

Applications

- Detect the presence of magnetic anomalies to determine ground exploration strategies when looking for ores.
- Determine the ground conductivity characteristics to assess the presence of ore underground.

conductivity is high and the rate of decay very slow meaning that measuring B rather than dB/dt is more beneficial. This is where fluxgates will have an advantage over induction coils.

Noise is a critical factor here, and the availability of three-axis sensors with noise less than 4pT and bandwidth at 3kHz (-3dB) makes the Mag-13 an ideal sensor for TDEM. The availability of a small cylindrical or unpackaged version also means that integration into a borehole tool is also possible.

https://gmw.com/product/mag-03-mag-13/

The main application here will be for deeper mineral exploration, the bandwidth of the sensor not being sufficient to be able to get a response on the very early windows for shallow sources. For this, the Mag639 with an increased bandwidth to 12kHz (-3dB) may be of assistance.

https://gmw.com/product/other-probes/

Fluxgate Sensors Application to Magnetotelluric (MT)

Magnetotelluric is a passive EM method which relies on natural EM sources (e.g. lighting) to generate the signal of interest. The method relies on measuring both the 3-axis orthogonal components of the electric and magnetic field.

The depth of penetration of the signal is dependent on the frequency of the signals, with higher frequency corresponding to shallow depth. In this scenario, fluxgates are being used for deep soundings aimed at mapping changes in resistivity at crustal/upper mantle regions rather than for shallow exploration (resources).

Once again, noise is the critical parameter, with the Mag-13 being the most suitable sensor for MT.

https://gmw.com/product/mag-03-mag-13/

Fluxgate sensors in Airborne Magnetic Surveys

Whilst the standard airborne magnetic surveys are typically carried out using a manned aircraft (helicopter or plane) using a scalar magnetometer as the primary measurement sensor, the presence of the large magnetic mass of the aircraft and the change in orientation during the flight means that the readings from the scalar magnetometer are degraded. Fluxgate sensors are used to measure the field in 3 orthogonal directions during the flight and record their variations when the aircraft changes direction, tilt on inclination. Data collected are used to create a correction matrix which is then applied to the scalar readings based on the aircraft's attitude. The lower the noise of the sensor and the more accurate the compensation will be.

The Mag-03 and its successor the Mag-13 have been the main sensor used by a number of operators as their attitude monitoring sensor, with the low noise square package sensor preferred due to the ease of alignment.

https://gmw.com/product/mag-03-mag-13/

With the advances in drone technology, unmanned aircraft have made their appearance in the market as well. However, weight and power limitation from the platform have caused some users to reconsider the use of the two magnetometers and replace it instead by a sole fluxgate magnetometer. A correction routine can enable the fluxgate sensors to provide accurate scalar measurements during the survey, thus saving on power and weight on board (Gavazzi et al, 2016).

Bruno Gavazzi, Pauline Le Maire, Marc Munschy, Aline Dechamp. Fluxgate vector magnetometers: A multisensor device for ground, UAV, and airborne magnetic surveys. Leading Edge, Society of Exploration Geophysicists, 2016, 35 (9), pp.795-797