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The Principles and Practice of FLAIRTEM

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ABSTRACT

FLAIRTEM (Fixed Loop AIRborne Transient Electromagnetics) is a hybrid ground-air system that combines the use of a very large ground based transmitter loop with an airborne receiver. The method was developed in Australia during the period 1991-93. Preliminary FLAIRTEM test surveys were completed in Australia and Papua New Guinea (PNG) over a number of mineral deposits. Results are presented over a 40-mt copper sulphide ore deposit in the Freida River area of PNG. Results from modelling suggests that the FLAIRTEM method could have greater sensitivity to buried conductors at depths of over 100 m than conventional airborne systems.

INTRODUCTION

Airborne Electromagnetic (AEM) methods have been applied extensively over the last four decades to exploration for base metals, precious metals, salinity studies, and general geological mapping. They are becoming more favoured as a rapid reconnaissance search method to cover large tracts of land, particularly in areas of soil cover. Traditional AEM systems have improved greatly over the last decade, in that lower frequency and more precise measurements can be made, thereby increasing their effective depth of investigation. However, further improvements are likely to be incremental and will depend greatly on new innovations in data collection and processing.

Existing AEM systems still have a limited search depth, particularly in arid and mountainous terrains. In the arid outback areas of Australia where the surface cover is generally conductive (e.g., overburden conductance greater than 4 S) the maximum search depth is often less than 50 m. Similarly, in mountainous terrain, where ground clearance is often greater due to vegetation or narrow valleys, the effective search depth of moving source AEM systems is restricted.

FLAIRTEM is a relatively new geophysical development. It was developed over a period of three years with the support of major mining companies, through AMIRA (Australian Minerals Industry Research Association). The method was initially conceived as a way of "seeing" through conductive overburden in the arid parts of Australia, and as a means of investigating to greater depths than was achievable by moving source AEM systems. Since its inception it has also found use in the rugged parts of south-east Asia and the South Pacific where it suffers less than other AEM methods from problems associated with excessive ground clearance.

THE FLAIRTEM METHOD

System Configuration

The FLAIRTEM survey configuration is presented in Figure 1. It uses a high powered (up to 25 kW) ground-based Zonge transmitter with a basic time domain square

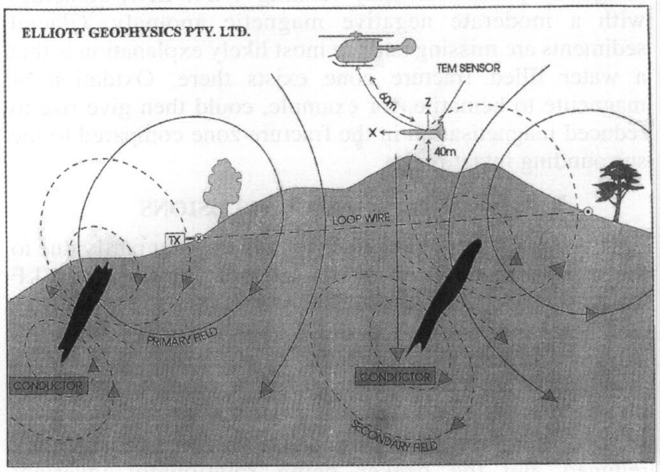

Figure 1. FLAIRTEM Survey Configuration.

pulse frequency range of 1 to 32 Hz. The transmitter loops employed are typically kilometres in size, e.g., 6 km x 2 km. The frequency range enables data to be collected at a much larger bandwidth than existing airborne electromagnetic systems; the TEM response decay curve is measured over a period of 25 ms after current turn off for the basic 8-Hz transmitter frequency most commonly used in surveys, and can be measured for longer periods at lower frequencies. A very large magnetic moment is achievable using a large fixed transmitter loop compared to that achieved using a moving loop airborne system.

The receiver system is a modified Zonge GDP32 coupled with ferrite-core sensors which measure the transient electromagnetic field. The GDP32 has been specially programmed with proprietary software and has supplementary mass data storage. The receiver system therefore has the full capabilities of the GDP32, as well as the extra facility for airborne survey work. The receiver configuration currently measures three channels: H_z and H_x components, and a third channel that records radar altimeter data. However, up to 16 channels can be installed in the receiver for the connection of other components or instruments, such as a third sensor for measuring H_y. The effective sensor areas are 10 000 m^2. Each independent transmitter cycle response can be stored, giving a minimum achievable sample interval in the order of 1 to 2 m on the ground, depending on flight speed and base transmitter frequency. This allows for a large redundancy of data for various filtering techniques.

The currently favoured airborne platform is a helicopter with a towed receiver bird. However, other platforms, such as light aircraft, can be easily adapted. The preferred method of navigation is by RTDGPS (Real Time Differential Global Positioning System). A pair of Garmin SvyII interchangeable GPS units with radio link are currently being used. The TEM and radar altimeter data acquired are married to the RTDGPS data to provide a located data set. However, it is also possible to connect the GDP32 and GPS system to a common laptop computer for data recording.

The use of large ground-based transmitter loops enables the effective penetration of the source field to be in the order of kilometres. The source field is relatively uniform over a large area thus allowing many square km to be surveyed off each loop. To complement the extra large transmitter loops, very low transmitter frequencies are used for excitation. The low frequencies result in a smaller response from conductive overburden compared to higher frequency systems.

Data Processing

The raw located data are filtered using a weighted average temporal filter, followed by a half-cosine spatial Fourier filter. The processed data may be presented as profiles, contours, perspective plots, parametric plots, or any other form of presentation. Because the data is in digital form many different parameters can be calculated automatically from the located data set. These include decay constants, gradients, cross correlation parameters, and band ratios.

Interpretation

The interpretation FLAIRTEM data is similar to fixed-loop ground data. Thus, a large range of modelling software is available.

FIELD RESULTS

Preliminary tests of the use of large 5 km x 2 km loops in conductive terrain were carried out over known deposits in Western Australia during 1991-92. These tests were encouraging enough to warrant progression to the construction of the airborne system. Airborne tests of the method were achieved in 1993 over known deposits in South Australia, Queensland, and Papua New Guinea. These were successful in detecting the deposits over which they were flown and providing additional information on dip and depth of each conductor. A recent survey in Indonesia successfully located an anomalous conductive zone, which was then detailed on the ground and found to be a sulphide stockwork with associated clay alteration.

Frieda River

A FLAIRTEM survey was flown over the 40-mt massive copper sulphide Frieda River deposit in 1993. A Dighem survey flown over this deposit in 1985 failed to detect the deposit. The FLAIRTEM survey outlined the deposit successfully. Hz-component contours for time window 24 (24ms delay) are presented in Figure 2.

Comparison with other AEM systems

Various AEM systems have been compared through model studies with the Multiloop II program: a fixed-wing, towed bird TEM system with base frequencies of 75 Hz and

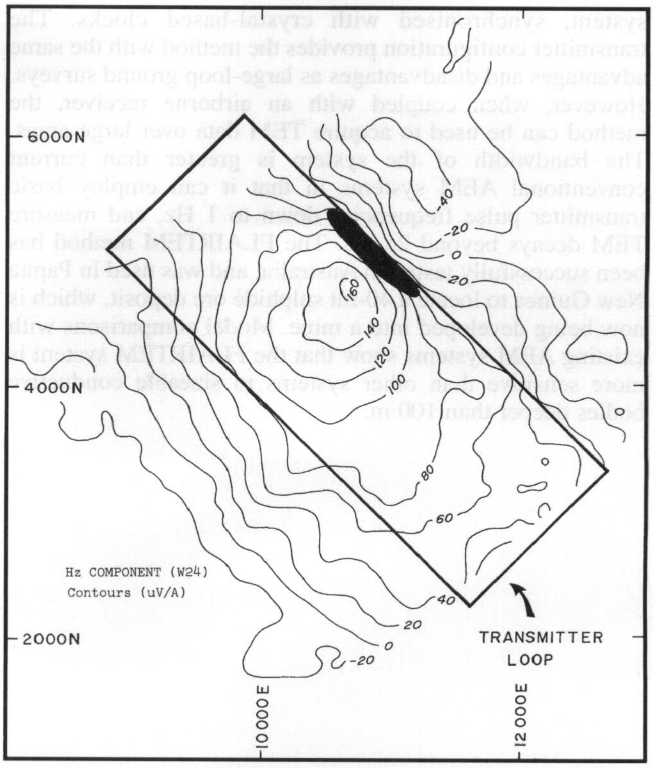

Figure 2. Vertical (Hz) component voltage contour plots (mV/A) for the 24-ms window, over the Nena massive sulphide deposit, Freida River, Papua New Guinea.

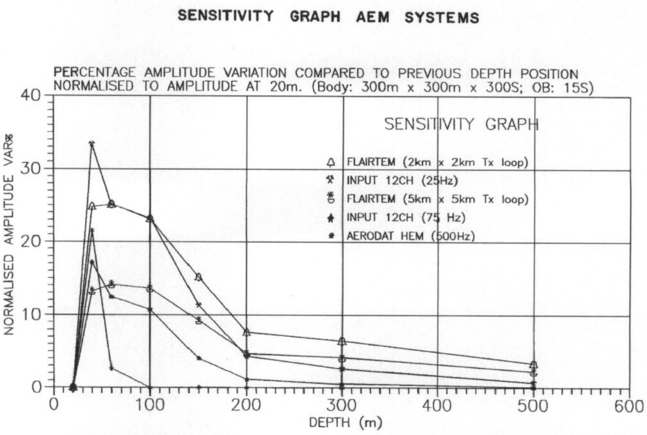

Figure 3. Sensitivity graph for various AEM systems to a 300 m x 300 m conductor (300 S) buried at different depths beneath a 15-S conductive overburden.

25 Hz, a frequency-domain HEM system, with a base frequency of 500 Hz , and FLAIRTEM with 5 x 5 km, and 2 x 2 km loops and a base frequency of 16 Hz.

The sensitivity graph in Figure 3 shows the different sensitivities of each configuration to a 300 x 300 m horizontal plate with conductance 300 S buried at various depths beneath a 15 S overburden. The sensitivity of the 25 Hz fixed-wing system and the 2 x 2 km FLAIRTEM configuration are very similar down to about 100 m, below which the FLAIRTEM arrangement retains a higher sensitivity to variations in body depth.

CONCLUSIONS

FLAIRTEM, or fixed-loop airborne transient electromagnetics, combines the facility of a large fixed ground based transmitter loop with a lightweight airborne receiver system, synchronised with crystal-based clocks. The *transmitter configuration* provides the method with the same advantages and disadvantages as large-loop ground surveys. However, when coupled with an airborne receiver, the method can be used to acquire TEM data over large areas. The bandwidth of the system is greater than current conventional AEM systems in that it can employ basic transmitter pulse frequencies down to 1 Hz, and measure TEM decays beyond 25 ms. The FLAIRTEM method has been successfully tested in Australia, and was used in Papua New Guinea to locate a 40-mt sulphide ore deposit, which is now being developed into a mine. Model comparisons with existing AEM systems show that the FLAIRTEM system is more sensitive than other systems to sizeable conductive bodies deeper than 100 m.

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