LOUPE - A PORTABLE EM PROFILING SYSTEM

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SUMMARY

Loupe is a new, portable, time-domain electromagnetic system specifically designed for rapid reconnaissance and near-surface conductivity measurements. The receiver and transmitter are each carried by one person on a backpack. Loupe incorporates a 3-component coil sensor with 100 kHz bandwidth, a fast-switching transmitter loop, a simple user-interface and the ability to navigate and recover position using RTK GPS. By virtue of intelligent signal processing, carried out in real-time and in post-acquisition processing, Loupe will operate effectively in the presence of interference from power transmission lines and other sources of noise that traditionally degrade the performance of EM systems in urban areas.

A completely portable time-domain EM system of this nature is unique. This paper will discuss the design and features of Loupe and likely applications for it.

Here, we present an example of data from a geotechnical investigation. By the time of the conference, we expect to be able to present results from other work done with Loupe in exploration and mine projects. This system, and its results, will be compared against other techniques to illustrate the increase in near-surface resolution and speed of broadband data collection.

Key words: TEM, near-surface, conductivity, geotechnical, mineral

INTRODUCTION

The Loupe electromagnetic profiling system is a two-operator, portable, time-domain electromagnetic (EM) system designed to measure electrical conductivity in the near-surface at high spatial and vertical resolution.

The aim of Loupe development was to develop a modern, easy-to-use, time-domain EM system that could be used in rapid profiling by two operators separated by a chosen distance. A time-domain architecture was chosen to give the system the ability to make measurements simultaneously over a broad part of the EM spectrum useful for a range of applications in near-surface EM. This modern instrument has considerable processing power and can deal with a range of noise sources as a result of its signal processing prowess.

It is anticipated that this instrument will be used for a wide range of applications such as:

1. Mapping water content and seepage in tailings dam walls
2. Mapping clay pods and shear zones in iron-ore mining operations
3. Detecting sub-surface voids
4. Mapping of disseminated or massive sulphide ores in underground mines
5. Mapping underground infrastructure
6. Geological mapping and shallow exploration for base metals, graphite, manganese and gold
7. Groundwater exploration
8. Mapping of dryland salinity and seawater incursion

DEVELOPMENT OF LOUPE

Over a time-frame of several years, Loupe has been designed and prototyped. A three-component set of receiver coils, with 100 kHz bandwidth, is mounted on an adjustable, ergonomic backpack. A multi-turn transmitter coil (640mm diameter, maximum moment 170 Am^2) and transmitter electronics is mounted on another similar backpack. Figure 1 illustrates layout of the commercial version of Loupe, being assembled at time of writing.

The transmitter has been designed to transmit bi-polar square waveforms of current, switching off in 10 microseconds, but this is adjustable. Loupe is designed to be used in continuous profiling mode with transmitter-receiver separations between 5 and 50 metres or more. No physical connection between transmitter and receiver systems is required. Like all electromagnetic systems, depth of penetration is dependent upon ground conductivity, system geometry and measurement frequencies. The fast-switching transmitter current, high bandwidth receiver coils, rapid sampling of the received signal and small separation of transmitter and receiver are designed to measure conductivity in the top 50 metres.

Comfort and safety of the operator are issues that have guided the design of this instrument. The transmitter loop is positioned behind the operator, rather than around the operator, in order to minimise exposure of the operator to excessive magnetic fields (IEEE and other international bodies have standards and guidelines discussing acceptable exposure). Weight has been kept as low as possible - the entire transmitter system weighs approximately 15 kg (including battery and backpack) and the receiver system weighs approximately 10 kg. The transmitter loop itself weighs only 2.5 kg. The backpacks used for Loupe are designed for military applications in which much heavier loads than this are worn comfortably for long periods. The transmitter battery is designed to be swapped for a fresh battery after 2 hours of continuous usage.

Loupe can be used while walking continuously, or, for higher precision measurements, operators can stop for a short time to make a longer, stationary recording. Receiver and transmitter systems carry RTK-capable GPS receivers which will enable navigation accuracies of sub-metre in real-time or during subsequent processing. Real-time communication between transmitter and receiver systems (via integrated Wi-Fi and/or UHF radio band) facilitates maintaining a fairly constant spacing of transmitter and receiver and recording of the spacing. The integrated GPS systems also give the transmitter and receiver absolute timing references and synchronisation between transmitter and receiver. Integrated quartz crystal oscillators allow timing synchronisation in the absence of GPS, such as in underground TEM surveys with Loupe.

Loupe records full time-series TEM data to memory and processes it in real-time. This means a range of processing options are available. Signal processing methodologies developed for SMARTem receiver systems are implemented here (Duncan et al, 1988). These are designed to attenuate noise sources such as interference from power transmission lines, VLF stations and vehicles moving nearby. As a result, Loupe can successfully collect good quality TEM data in urban environments. Naturally, the transmitter frequency can be selected to suit the aims of the survey and the conductivity of the environment. VLF transmissions are of particular interest because they can be one of the largest sources of interference in broadband TEM measurements and can also be used to create an independent set of frequency-domain EM data at VLF frequency.

Real time control of Loupe functionality and QC of data is carried out via a small wireless tablet PC carried by the operators. Software on the tablet will be capable of navigating the operator along a pre-defined grid and plotting TEM decays and profiles for review.

Figure 1: Illustrations of the final design of the Loupe TEM system showing 3 component receiver system (left) and transmitter system (right).

FIELD TEST

At time of writing, the first Loupe field tests have been carried out at a former rubbish dump in Perth that has been covered with sand. The site, in beach-side suburban Swanbourne, has functioned as a test site for a number of near-surface geophysical techniques and a range of EM techniques have been employed there. The site is known to contain buried building rubble and general rubbish that is both electrically conductive and magnetic. The site is approximately 100 m from the ocean beach and is surrounded by houses, roads and power transmission lines. The site is roughly 1200 km from the North-West Cape VLF antenna near Exmouth, Western Australia.

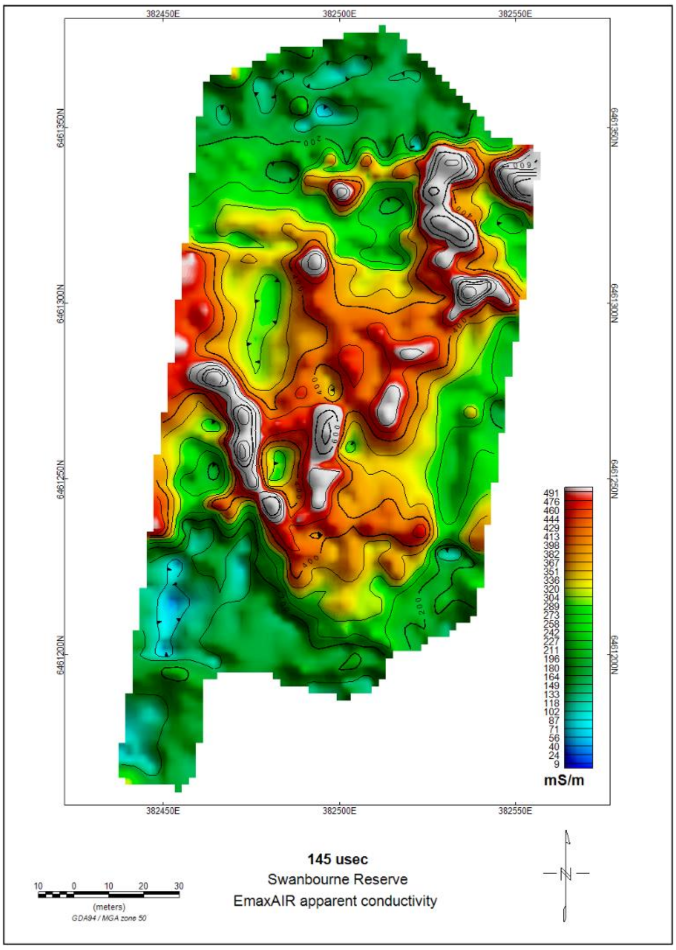

Figure 2: EmaxAIR derived apparent conductivity (145 microseconds) for Swanbourne Loupe survey.

Data was collected at the Swanbourne site using a prototype Loupe system, operating at a transmitter frequency of 25 Hz, with 50% duty cycle. Sampling of the 3-component coil signals was done at 120,000 samples per second on this prototype, roughly 2.5 times slower than will be undertaken on the final version (300,000 samples per second). Data was collected over a grid with transmitter and receiver moving continuously at a slow walking speed, separated by 5 m. The grid includes 19 lines, each approximately 200 m in length, with line separation of 5m. Transmitter current was switched off in 10 microseconds and the transmitter moment employed was 170 Am^2. The data was collected over a period of roughly 2 hours.

Data was stacked in overlapping blocks of approximately 3 seconds in duration, a stacking distance of roughly 2.5m, or half the separation. A 3-component TEM reading was generated approximately every 1.5 seconds / 1.25m. The stacked data was processed and windowed and then fed into EmaxAIR – a conductivity-depth imaging (CDI) routine developed by Fullagar Geophysics Pty Ltd (Fullagar and Reid, 2001). EmaxAIR results were used as starting models for 3D modelling in VPem3D, also by Fullagar Geophysics (Fullagar and Woods, 2016), not shown here.

A preliminary result from EmaxAIR is illustrated in Figure 2. This pseudocolour image illustrates the apparent conductivity derived for signals from a time window centred on 145 microseconds after transmitter switch-off. The conductivity is derived from both horizontal in-line and vertical components of the signal. The apparent conductivity highs outline rubbish buried at the site. The intermediate values of background apparent conductivity may reflects the fairly shallow seawater table at this site which is only a few metres above sea level.

CONCLUSIONS

A portable TEM geophysics system, operated by two persons, has been developed. The system, Loupe, can be operated in motion or with stationary measurements. It is designed to be able to make early–time TEM measurements and to work well in urban areas with associated infrastructure and interference. Though not yet complete at time of writing, this system has been tested in a geotechnical application while final designs, assembly and software are being completed. We believe that Loupe will have unique applications in near-surface conductivity measurement.

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