Noise reduction in a mobile, continuous operation TEM system - Loupe

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SUMMARY

Loupe is a new generation of time-domain electromagnetic (TEM) instrument designed for profiling and mapping in the near surface. It employs a two man backpack-mounted transmitter-receiver combination for rapid continuous data acquisition. In addition, a trailer-mounted version is under construction.

Interference from a range of sources is a significant problem for TEM systems. Problems are exacerbated when surveys are undertaken in urban areas.

This paper will present case histories from a range of applications including mapping buried rubbish, saline incursion, shallow sulphide exploration, graphite exploration and tailings dam assessment.

Key words: TEM, near-surface, noise, mineral exploration

INTRODUCTION

Loupe is a portable backpack-mounted TEM system that has been under development since 2015. A transmitter loop is suspended from an ergonomically designed backpack and a receiver is mounted on a similar backpack. The system is designed for continuous operation but can be used in a stop/start mode if desired. Features of the Loupe TEM system include:

- Time-domain, with a range of transmitter base frequencies and geometries possible, including fixed-loop and hybrid dynamic/stationary surveys.
- Completely-integrated RTK GPS for precise timing and navigation.
- A transmitter switching a moment of 170 Am^2 in 10 microseconds. Likely to be operated at base frequencies between 25 Hz and 150 Hz.
- A 3-component receiver coil with 100 kHz bandwidth, 24-bit sampling at up to 500k samples per second with several gain options, depending on transmitter-receiver spacing.
- Real-time signal processing and storage that can deal with approximately 6 Mbytes of raw data per second. Signal processing performance is an important consideration for noise reduction.
- Operator health and safety have been addressed extensively in the design. Manual handling and magnetic field exposure are important considerations for the operator.

Since presentation of the initial results using the prototype Loupe TEM system (Duncan and Street, 2018) there have been significant redesign and software upgrades. Further field tests have confirmed the applicability of the system to a wide range of applications in near surface investigations.

A range of applications are currently being tested and some of these will be addressed in our presentation. The range of applications includes:

1. Shallow rubbish mapping
2. Saline incursion along coast
3. Clays in iron ore deposits
4. Shallow sulphides and graphite mapping
5. Salt in regolith
6. Tailings dam investigations
7. Archaeology investigations
8. Pollution plume mapping
9. Groundwater exploration

Loupe was first presented in prototype form at the 2018 AEGC conference (Duncan and Street, 2018). There has been considerable development since then, with various deficiencies overcome and improvements made.

Broadband TEM receivers such as used in the Loupe system are open to a wide variety of noise sources. Loupe's coil sensors have a bandwidth of 100 kHz in order that very-early-time TEM signals of high-fidelity can be measured.

The biggest noise sources for Loupe are:

- VLF station fields
- Noise caused by motion of the receiver sensors in the geomagnetic field
- Power transmission line magnetic fields
- Sferics and other transient events
- Errors in estimation of system response

Three improved Loupe systems have been constructed. Improvements include a reduction in weight of the transmitter, an increase bandwidth of the receiver and the ability to address the effects of motion noise and other interference in the measured results. Most of the past 18 months have been spent on these improvements that were recognised from the field trial presented by Duncan and Street (2018).

At the time of writing of this abstract, one new field trial has been completed and others are underway. These trials will incorporate new processing to reduce noise.

METHOD AND RESULTS

Swanbourne Oval near the coast in Perth has been used for three trials of the Loupe system starting with a rudimentary test of components fixed to a wooden frame and moving on to a test of the current version. The oval was built by the Australian Army in a community service project. Considerable building waste was used to fill swales in the dune system and it appears from previous survey results, and some trenching, that the fill included metallic objects as a well as some putrescible waste.

New Loupe survey data collected at Swanbourne will be used to illustrate improvements in system performance and to demonstrate a range of noise sources (urban, global and system-related) that are addressed.

NOISE

Loupe's receiver is open to a wide variety of noise sources. Loupe's coil sensors have a bandwidth of 100 kHz and can be sampled at up to 500,000 samples per second. As a result, especially in urban areas, raw Loupe data can be quite noisy.

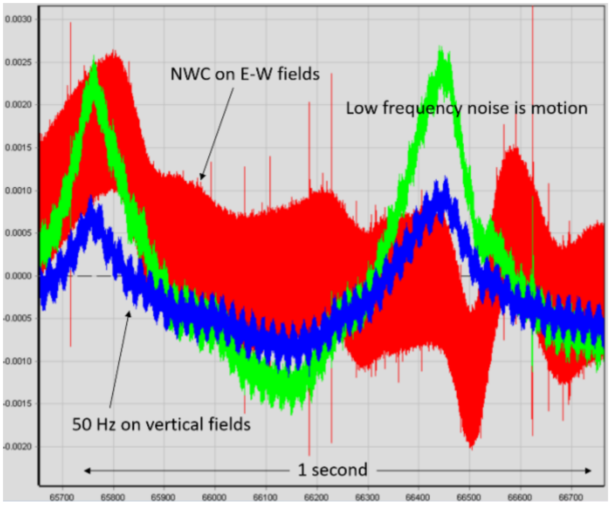

Figure 1. A one second recording by the Loupe receiver in an urban area (Swanbourne), with transmitter turned off, shows the various noise contributions that need to be removed from final data.

Figure 1 shows raw 3-component data from the Loupe receiver, recorded along a north-south traverse at Swanbourne over one second with the transmitter turned off. The noise sources at this site include:

- VLF signal from North West Cape Station, 19.8 kHz, approximately 1 mV amplitude on Y (E-W) component, coloured red
- Power line signal, 50 Hz, approximately 0.3 mV amplitude on Z (vertical) component, coloured blue
- Motion of coil sensors in the geomagnetic field while walking, low frequency, 2 mV, largest on X (N-S) component, coloured green
- Spikes, less than a few milliseconds duration and maximum 5 mV amplitude, especially on Y component (red)

Ideally, the effects of this noise should be eliminated from the final processed data.

Figure 2 shows spectra of approximately 3 minutes of Loupe vertical component data collected, with transmitter off, in an urban area while walking towards power transmission lines and more conductive ground. The image shows VLF stations, especially North-West Cape (Western Australia, 19.8 kHz), power line harmonics, sferics and transients on transmission lines plus motion noise at the lowest frequencies.

While collecting this data, the operator was walking towards power lines and walking from a resistive area to a more conductive one. The amplitude of power line interference can be seen to increase towards the bottom of the image. Additionally, the amplitude of the vertical component of the VLF station fields being seen is increasing towards the bottom of the image because VLF magnetic fields tip further towards vertical in more conductive terrain.

We require high-fidelity very-early-time TEM data for near-surface applications. System calibration becomes important in this case because we want to extract potentially small secondary fields in close proximity to a very large primary field spike. We measure the transmitter waveform, the receiver response and the sensor response in a highly-resistive location in order to correct early-time data for non-ideal performance. During a survey we measure the transmitter waveform and the ambient temperature in order to account for any thermal drift of the system response.

The system geometry can vary considerably along the line in the back-pack configuration, especially if the traverse line is not cleared and flat. It is useful to predict the attitude of the transmitter and receiver sensors in order to cancel noise induced by sensor motion and to correct processed signals to a standard series of directions.

We use the receiver's measurement of the geomagnetic field, VLF signals and power line signals to get an instantaneous measure of the receiver orientation. We use the measured primary field to calculate the transmitter geometry relative to the receiver and we use RTK GPS for accurate positioning of the transmitter and receiver.

CONCLUSIONS

Broad bandwidth TEM measurements create opportunities and challenges – a wide variety of useful information and a wide range of sources of electromagnetic interference. Noise sources for Loupe surveys were illustrated.

A good understanding of signal processing methods and a willingness to experiment are required in order to write processing software for high-fidelity TEM data, especially for TEM data collected in urban areas.

REFERENCES

Street G., Duncan A., Fullagar, P. and Tresidder R., 2018, Loupe – a Portable EM Profiling System: AEGC Conference, Sydney, February 2018.

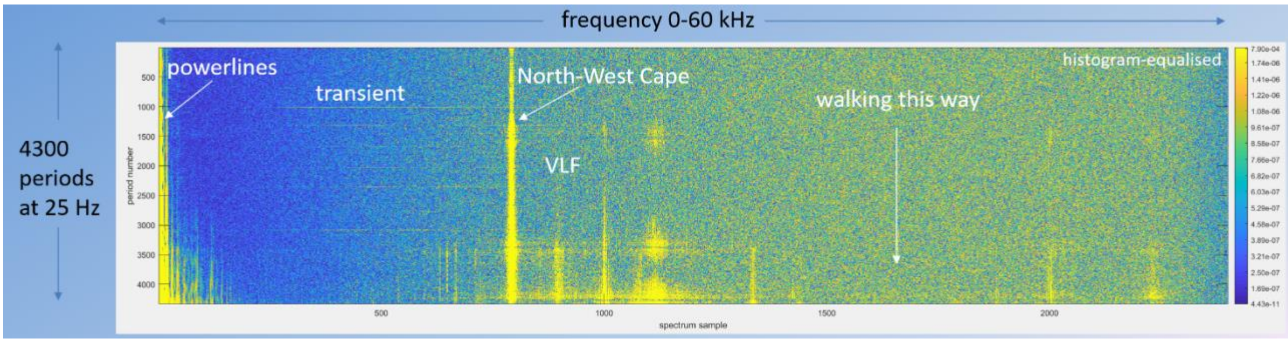

Figure 2. Spectra (DC – 60 kHz) of Loupe vertical component signals collected whilst walking, with the transmitter off, in an urban area. This is approximately 3 minutes of raw time-series (approximately 60 Mbytes in this case).