Detection of Pipelines using Sub-Audio Magnetics (SAM)

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- Sub-Audio Magnetics is a patented technique developed by Gap Geophysics.
- The technique uses a fast sampling magnetometer to monitor magnetic and electromagnetic signals simultaneously.
- The technique has been under development for over 15 years and has various applications including mineral exploration, unexploded ordnance detection and utility mapping.
- For the mapping of pipes, it is necessary to transmit electrical current through a conductor in the pipe at a known alternating frequency and with a regulated current using a geophysical transmitter which in turn is synchronized to a fast sampling magnetometer.
- Synchronization is usually achieved by synchronizing both instruments with GPS timing pulses.
- Positioning and navigation is achieved with GPS.
- The alternating current transmitted through the pipe produces an alternating electromagnetic field which is detected by the magnetometer as it traverses across the pipe.
- The data recorded by the magnetometer is processed and the magnetic and electromagnetic signals are separated. The position of the pipe can then be determined by the amplitude and polarity of the electromagnetic field.
- In low latitude areas such as near the Equator, total field magnetometers are not suitable for this application. Our recommendation would be to use the vertical component of the magnetic field as may be measured by a fluxgate magnetometer.
- In this situation, the anomaly produced would indicate a dipolar shaped anomaly on the survey profile across the pipe with a point of inflection immediately over the pipe.
- The amplitude of the anomaly decreases proportionally with distance from the pipe (1/r) and is therefore a direct indication of the depth to the conductor in the pipe (assuming constant current).
- This technique is dependent on an ability to transmit current through the pipe ie it is necessary to gain access to a conductor in the pipe and also to achieve an earth return.
- The following pages provide some background information on the SAM technology.

Sub-Audio Magnetics (SAM)

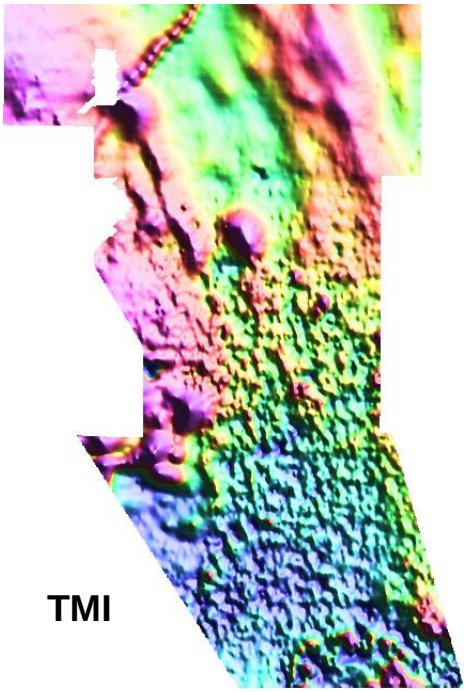
Sub-Audio Magnetics (SAM) is a "high definition" patented technique which measures both magnetic and electrical properties of the earth from a single survey.

Field Methodology:

- SAM has two main modes of operation – Galvanic and Electromagnetic. Both modes employ a geophysical transmitter to produce an energising field.
- SAM Galvanic surveys are similar to the MMR technique where current is transmitted through a pair of grounded electrodes. The electrical current will "channel" along relative conductors in the ground.
- SAM EM surveys use a transmit loop and rely on electromagnetic induction to produce secondary fields in buried conductors.
- The transmitter produces a time domain waveform typically in the sub-audio frequency range of 1-20 Hz.
- A rapid sampling total field magnetometer acquires both the spatial and induced temporal fields whilst continuously traversing the ground.
- The signals are separated by digital filtering. Low pass filtering of the recorded data yields the spatially varying magnetic field. High pass filtering extracts the artificially induced modulation.
- Signal processing extracts parameters of interest including, Total Magnetic Intensity (TMI), Total Field Magnetometric Resistivity (TFMMR), Total Field Magnetometric Induced Polarisation (TFMMIP) and Total Field Electromagnetic Induction (TFEMI).

Benefits of SAM include:

- Simultaneous acquisition of physically independent data sets
- Continuous sampling enables cost-effective, high spatial resolution surveys
- Use of a magnetic sensor allows a "point" measurement as opposed to a volume measurement permitting higher definition than conventional resistivity and IP techniques.
- B-field measurement is superior to dB/dt for late time EM decays.



TMI

EQMMR

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Sub-Audio Magnetics (SAM)
Applications to utility mapping

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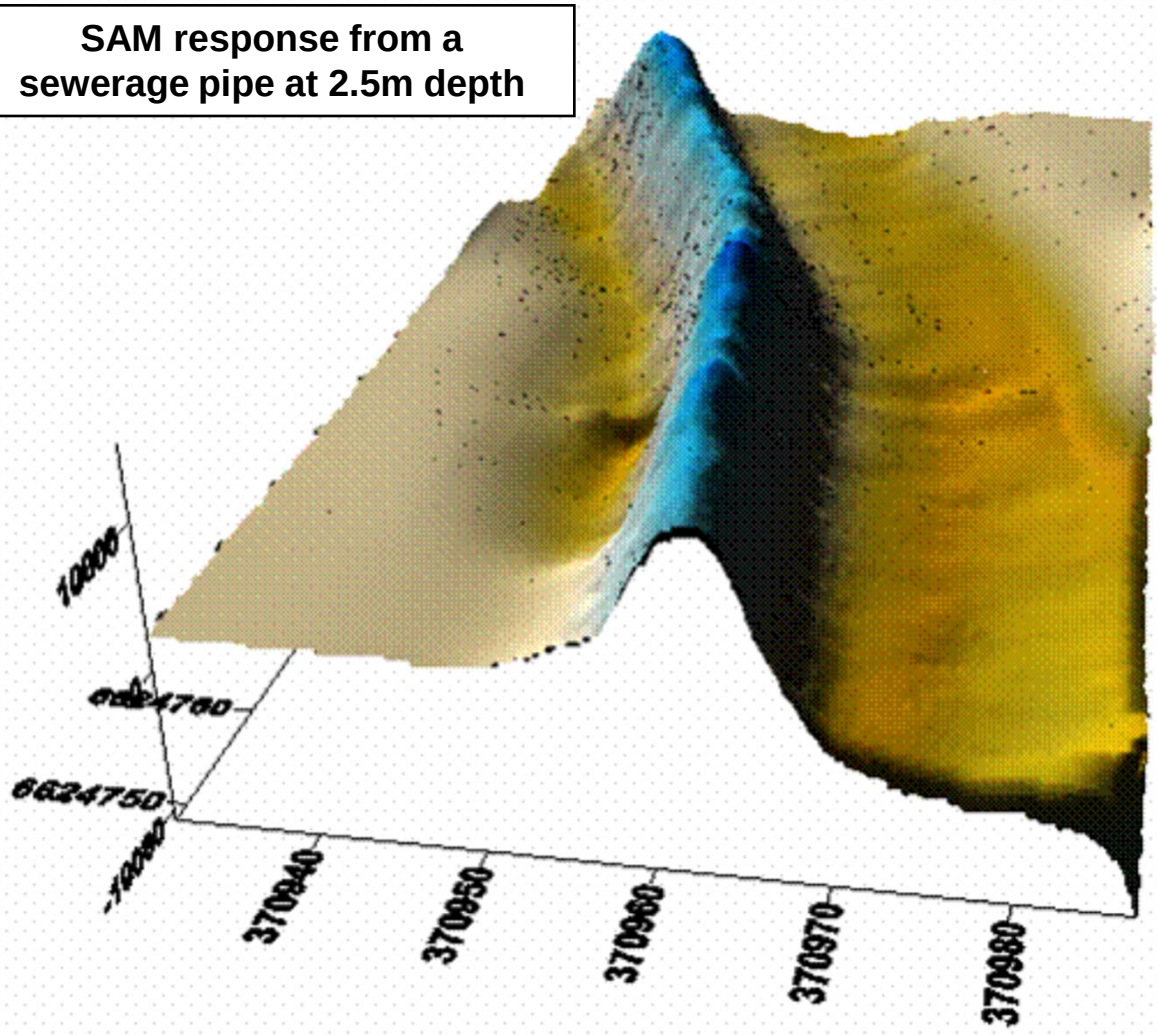
SAM response from a sewerage pipe at 2.5m depth



- SAM can be used for mapping underground utilities such as pipes and cables by channeling electrical current through the item to be mapped.
- This technique uses the Gap LPTX – battery powered transmitter controlled by the GAP SAM-2 transmitter controller.
- The GAP TM-6 magnetometer is used to record the total magnetic intensity at 1200 samples per second.
- Navigation and positioning is performed by the TM-6's proprietary software in combination with DGPS.
- Use of a magnetometer in built-up areas is often difficult because of electromagnetic interference from 50/60 Hz mains power.
- The bandwidth of the Cs sensor enables the magnetometer to track the alternating electromagnetic fields.
- By using a transmit frequency which is a sub-multiple of mains frequencies, mains interference can be effectively removed by signal stacking.
- The result is a clean accurate signal which is not degraded by magnetic or electromagnetic interference.

GAP TM-6 Magnetometer Controller

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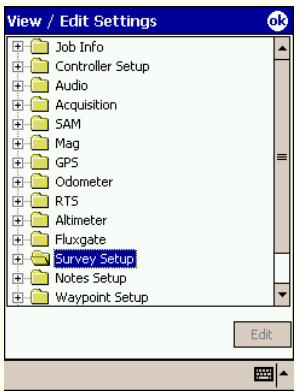
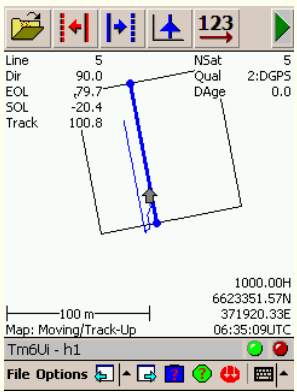
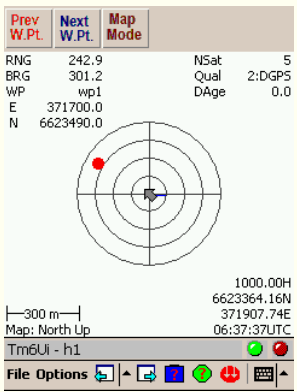
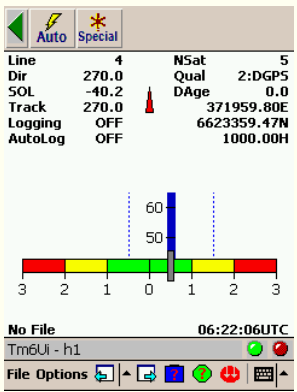
The TM-6 magnetometer controller is the culmination of over 25 years experience in high definition magnetometry and is the first magnetometer designed to meet the demanding requirements of the Sub-Audio Magnetics (SAM) technique. It is the ultimate instrument for rapid sampling magnetics from ground level multi-sensor UXO applications to airborne magnetics and EM systems.

- controls up to four Cs vapour sensors
- sample rates of 1200, 2400, 4800 and 9600 samples per second
- designed for 50/60 Hz noise rejection
- absolute measurement error 0.043 nT @50000nT
- magnetometer data range 30000-90000 nT
- RMS noise (1200, 2400, 4800, 9600 sps) 0.02, 0.04, 0.12, 0.58 nT
- 8 serial ports
- GPS data and strobe input (precise synchronisation to GPS strobe)
- fluxgate magnetometer input for compensation systems
- laser altimeter interface
- robotic total station interface
- TM-6Ui user interface has built-in navigation and positioning









GAP SAM-2 Transmitter Controller

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- Controls Zonge GGT-10, GGT-30 geophysical transmitters
- Precise synchronisation with GPS timing strobes (accurate to 1µs)
- Synchronisation updates every second – no drift unless satellite lock is lost for an extended period
- Digital display provides operator with GPS status and alarms if satellite lock is lost.
- Frequency modes
  - Binary mode 0.125 to 128 Hz
  - 50 Hz mode 3.125 to 100 Hz
  - 60 Hz mode 1.875 to 120 Hz.

  (50/60 Hz modes provide frequencies which are sub-multiples of mains power to assist in rejection of mains interference)
- Duty cycles – 12.5%, 25%, 50%, 100%
- Outputs
  - BNC analogue to monitor signal
  - RS-232 digital to monitor GPS
- Internal rechargeable battery