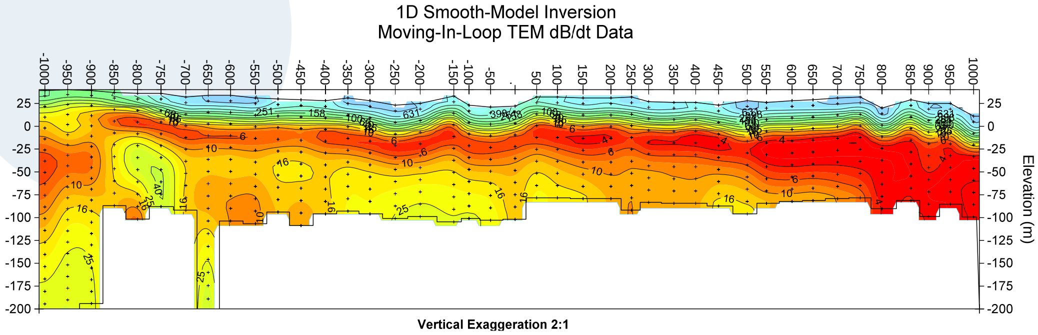
Introduction to TEM

NOVEMBER 2009

Zonge GDP-32[II] multichannel receiver.

Overview of TEM



The transient electromagnetic or TEM technique is a commonly used surface based geophysical method which provides resistivity information about the subsurface.

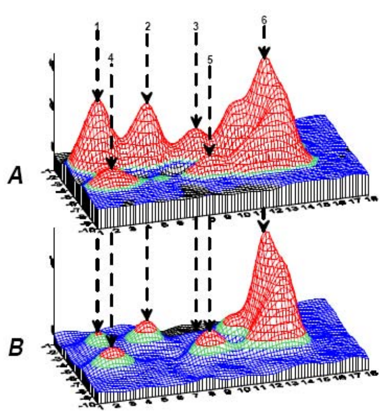
A transmitter (usually a loop of wire on the ground) is driven by a time varying current. The change in current, and resulting EM field, establishes an image current within the earth equal in magnitude, but opposite in sign to that of the transmitter. This image current then interacts with conductive materials, setting up secondary magnetic fields that are measured at the receiver site.

The depth of exploration attained can vary from 10's of meters to over 1000 meters, depending upon transmitter loop size, available power from the transmitter, and ambient noise levels.

TEM systems have been used in exploration for geothermal sources, mapping structure and lithology, searching for sources of groundwater and groundwater contamination, and for engineering applications.

TEM systems have also been used to identify buried metallic objects such as buried utilities, abandoned wells, UST, and UXOs.

The transient electromagnetic or TEM technique can be used for vertical depth sounding or profiling as well as metal detection.



1. **Wood Boxes; one with ferrous metals.**
2. **Wood Box; mixed metals.**
3. **Wood Box; non-ferrous metals.**
4. **55 gal. Drum; concrete.**
5. **55 gal. Drum; foam.**
6. **Combined Anomaly from dense pack metal and two filing cabinets.**

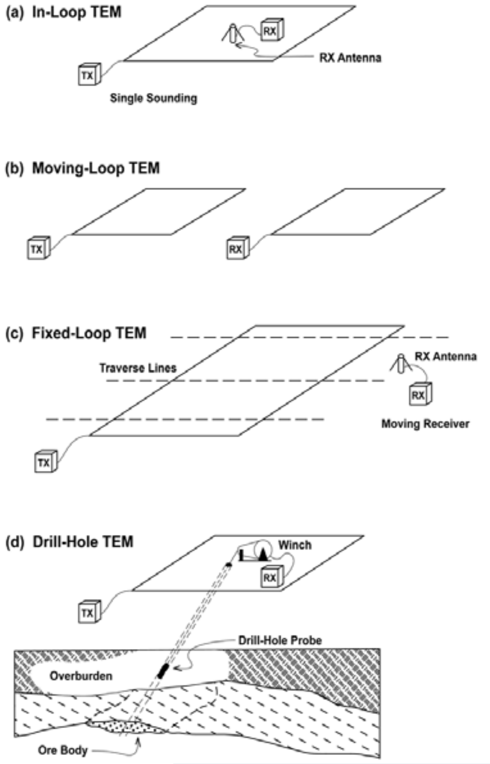
Field Logistics

Field logistic vary depending upon the target, but all configurations are non-intrusive and low-impact. For large (deep sounding) scale TEM surveys a typical field crew consists of 3 or 4 people, with one pick-up truck at the transmitter site and one at the receiver site. At the receiver site, the equipment can be carried by backpack, and no off-road driving is necessary. Shallow surveys utilizing a fast-turn off system requires 1-3 people and all the equipment is backpack portable.

Depending upon the target, the set-up of the system varies greatly from large loops on the ground, to cart mounted systems, to boat towed arrays. For loops that are not self contained in a cart mount system or towed array, the transmitter consists of a thin, insulated surface wire laid out by walking along the ground, (vehicle access along the length of the transmitter is not necessary).

The equipment consists of a transmitter and receiver which can be contained in a single box (with an external power source for the transmitter) or used with separate transmitter and receiver enclosures.

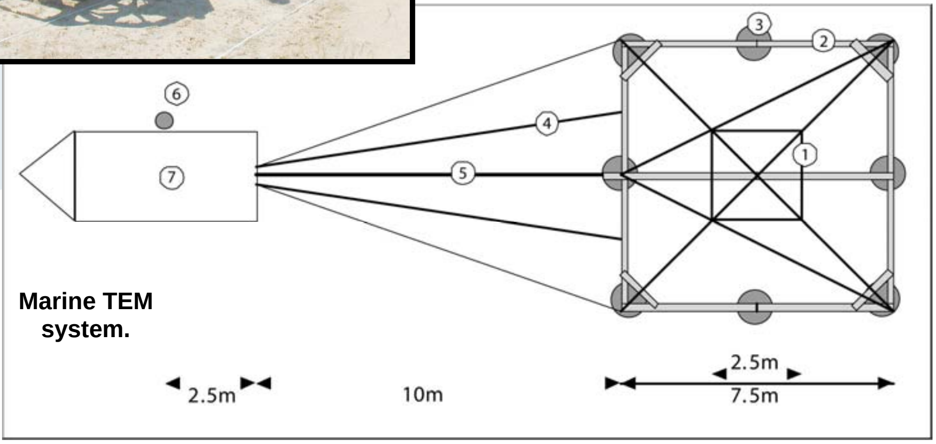
Four basic TEM configurations: a) the vertical sounding mode, in this case an in-loop configuration; b) the moving-loop or slingram profiling configuration; c) the profiling mode using a fixed loop configuration; and d) down hole measurements using a surface transmitter loop and a drill-hole receiver probe.



Many different configurations could be conceived for special conditions.

Cart mounted dynamic (continuous) NanoTEM (fast turn-off)

Marine TEM survey.



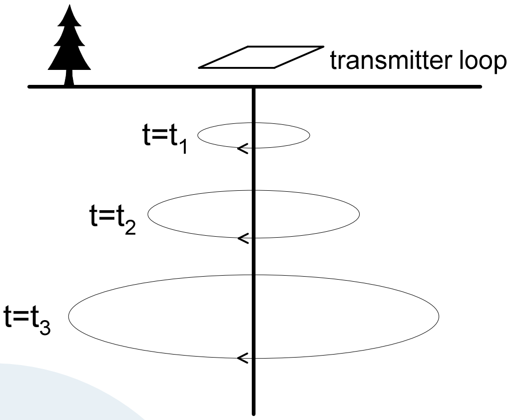
Marine TEM system.

Zonge Trusted Geophysics

Measured Fields

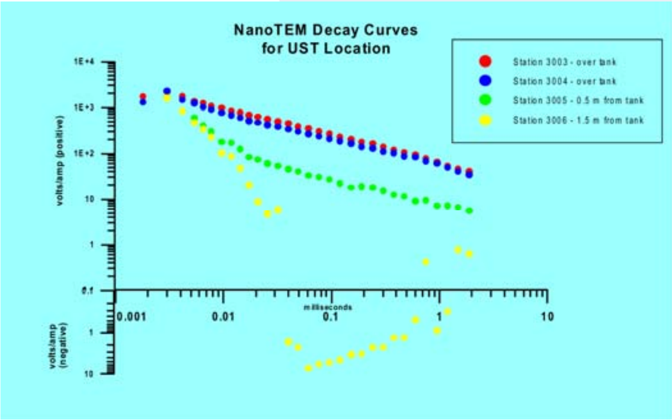
The TEM method is based on transmitting a time domain, square-wave signal into a large ungrounded loop. At some point in time, the loop current is interrupted as fast as possible thereby causing a rapid change in the magnetic field generated by the transmitter. The rapidly changing magnetic field induces eddy-currents to flow in nearby conductors producing small secondary magnetic fields that are generally measured by observing induced voltages in receiver loops.

Induced currents in poor conductors (moderate resistivity) decay quickly, currents in good conductors (very low resistivity) decay slowly, and very poor conductors (highly resistive silicified dikes, for example), will not sustain any measurable induced currents.



The response from the transmitted signal after turn off time can be represented as current filaments propagating outward and downward with time (after Nabighian 1979).

TEM receiver coils.



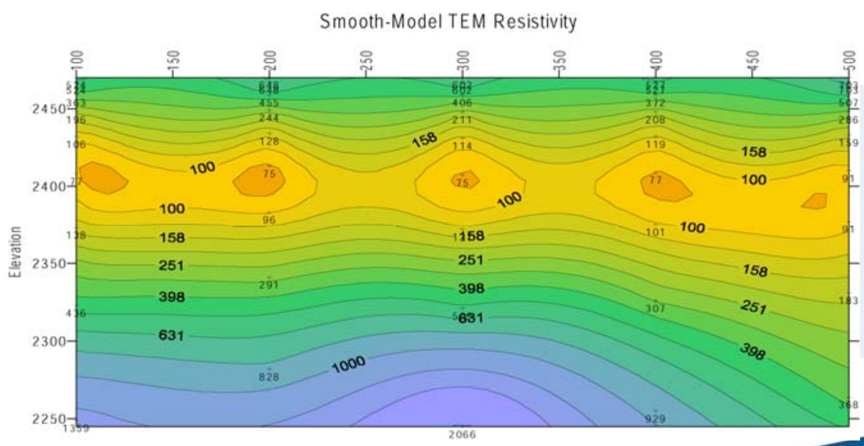
Four decay curves are shown collected over a UST (red and blue), 0.5m from tank (green) and 1.5m from tank (yellow). Over the tank the induced currents decay slowly (red and blue). Away from the tank the decay is much quicker.

Inversion Models

Smooth-model inversion is a robust method for converting TEM measurements to profiles of resistivity versus depth.

The result of the TEM smooth-model inversion is a set of estimated resistivities which vary smoothly with depth. Lateral variation is determined by inverting successive stations along a survey line. Results for a complete line are presented in cross section form by contouring model resistivities.

Modeling programs can be used to convert the measured results to profiles of resistivity versus depth.



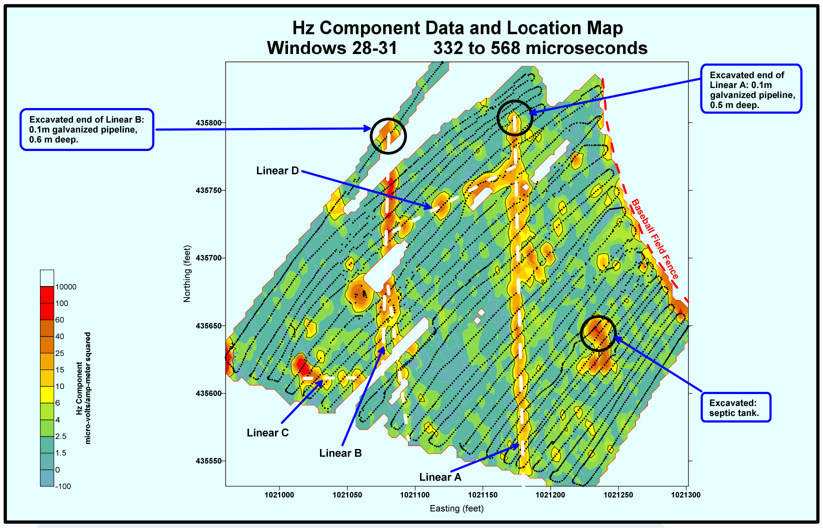
An employee-owned small business, Zonge provides:

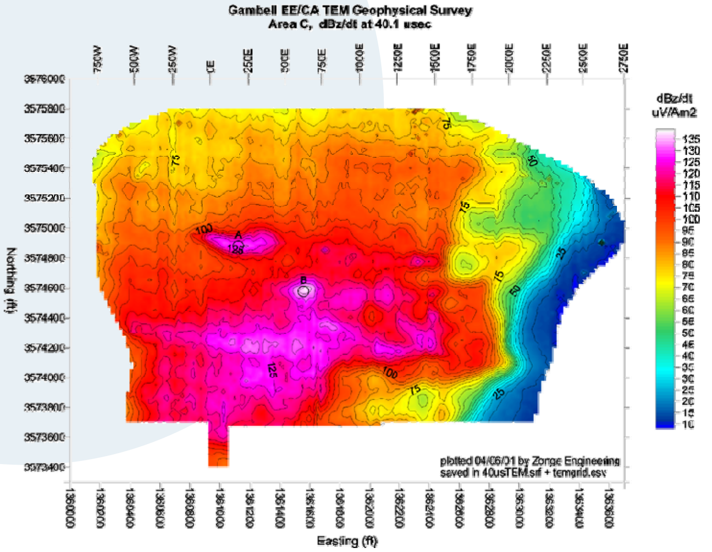
- Research and development programs,
- Equipment manufacturing, and
- A wide range of field services.

The integration of these roles allows Zonge to provide their clients complete and innovative solutions to their geophysical problems.

Zonge is a world-renown expert in the development and application of broadband electrical and electromagnetic

Final Product





TEM Reference Material

Grant, F.S., and West, G.F. 1965. Interpretation theory in applied geophysics. New York: McGraw-Hill.

Keller, G.V., and Frischknecht, F.C. 1966 Electrical methods in geophysical prospecting. London: Pergamon Press.

Nabighian, M.N., 1979, Quasi-static transient response of a conducting half-space – An approximate representation: Geophysics, 44, 1700-1705.

Zonge, K. L., 1992, "Broad Band Electromagnetic Systems", ***in*** Practical Geophysics II for the Exploration Geologist", ed. Richard Van Blaricom, Northwest Mining Association, pp. 439-523.

(Some parts of this document have been extracted from Practical Geophysics II, Northwest Mining association, 1992)

ZONGE Offices:

Tucson, Arizona
520-327-5501

Reno, Nevada
775-355-7707

Denver, Colorado
720-962-4444

Soldotna, Alaska
907-262-5072

Minneapolis, Minnesota
952-832-2616

Zonge Trusted Geophysics