T877 Tensor Gradiometer

TRISTAN TECHNOLOGIES

The Tristan model T877 SQUID tensor gradiometer is designed to measure magnetic fields and gradients for geophysical measurements.

It is a valuable tool for:

- Magnetotellurics
- Controlled Source Measurements
- Borehole Measurements
- Transient Electromagnetic Measurements (TEM)
- Unexploded Ordinance (UXO)
- Magnetic Anomaly Detection
- Environmental Waste Detection
- Airborne Measurements
- Site Survey Measurements

Superconducting magnetometers and gradiometers offer several advantages over other detectors commonly used for Magnetic Anomaly Detection, MagnetoTellurics, magnetic detection of induced polarization, and other geophysical measurements. Superconducting detectors offer constant sensitivity from dc to tens of kHz (or higher), and magnetic field resolution up to 10^{-5} nT√Hz. with magnetic gradient resolution up to 10^{-5} nT/ft√Hz and a dynamic range of 140 dB. These systems are well suited to field use, being lightweight, reliable, fast to set up, and easy to use.

The T877 magnetometer/gradiometer offers several important advantages over other magnetometers. It is a vector magnetometer, in contrast to the proton precession device which responds only to the magnitude of the field. With a three-axis vector magnetometer, both the magnitude and direction of the field can be determined. With eight sensing elements in a tensor configuration, the complete magnetic field gradient can be determined. Its performance is not impaired by the presence of large gradients and — unlike fluxgate devices — SQUID magnetometers do not saturate. In comparison to large induction coils, the T877 is not awkward or cumbersome in deployment and use. The T877's dc response avoids giving undue emphasis to high frequency phenomena such as the ubiquitous lightening induced sferics.

Because of the superconducting nature of SQUID magnetometers, they offer not only dc response, but also flat frequency response well past 10 kHz. Their flat phase response allows for seamless data integration, unlike conventional magnetometers which suffer from 90° (or higher) phase shifts.

The Tristan Model T877 is a field-proven rugged, highly sensitive superconducting SQUID magnetometer/gradiometer designed for geophysical exploration and measurement. With the full tensor configuration, it is possible to obtain complete characterization of magnetic dipole sources at long range, obtaining localization and classification information. This has been shown theoretically by Wynn[1] and demonstrated in the field. All that is necessary is knowledge of the magnetic field components (H_x, H_y, H_z) and the five unique field gradients ($\partial B_x/\partial x$, $\partial H_y/\partial x$, $\partial H_x/\partial z$, $\partial H_y/\partial z$, $\partial H_z/\partial z$). The T877 combines eight individual magnetometers into an array that yields all necessary field and gradient components.

T877 sensor housing showing cold electronics

For airborne operation, Tristan can supply custom dewars including horizontal or other customer specified configurations.

[1] Wynn, *et al.*, "Advanced Superconducting Gradiometer/Magnetometer Arrays and a Novel Signal Processing Technique", *IEEE Trans on Magnetics*, **11**,701-707 (1975)

TENSOR CONFIGURATION

- The magnetic field vector, *H*, can be expressed in terms of Cartesian components $H = (H_x, Hy, H_z)$. For each component, there are three spatial derivatives along orthogonal directions, generating nine components of the second rank magnetic field gradient tensor. This tensor can be represented by the matrix:

$$\begin{pmatrix} \frac{\partial H_x}{\partial x} & \frac{\partial H_x}{\partial y} & \frac{\partial H_x}{\partial z} \\ \frac{\partial H_y}{\partial x} & \frac{\partial H_y}{\partial y} & \frac{\partial H_y}{\partial z} \\ \frac{\partial H_z}{\partial x} & \frac{\partial H_z}{\partial y} & \frac{\partial H_z}{\partial z} \end{pmatrix} \rightarrow \begin{pmatrix} \frac{\partial H_x}{\partial x} & & \\ \frac{\partial H_y}{\partial x} & \frac{\partial H_y}{\partial y} & \\ \frac{\partial H_z}{\partial x} & \frac{\partial H_z}{\partial y} & \end{pmatrix}$$

- According to Maxwell's equations, only five of these tensor elements are independent, which is what the SQUID tensor array measures.
- The T877 can be used to create both axial and planar gradients by electronic subtraction of magnetometer signals. The figure to the right shows the relative orientation of the magnetometer coils. The five needed gradients are formed by the following relationships between the eight sensors of the Model T877:

$$H_x = \frac{1}{3}(X + X' + X''),$$

$$H_y = \frac{1}{3}(Y + Y' + Y''),$$

$$H_z = \frac{1}{2}(Z + Z''),$$

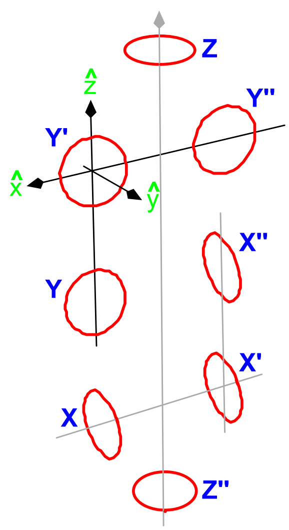
$$\frac{\partial H_x}{\partial x} = \frac{X - X'}{b},$$

$$\frac{\partial H_x}{\partial z} = \frac{X'' - X}{a},$$

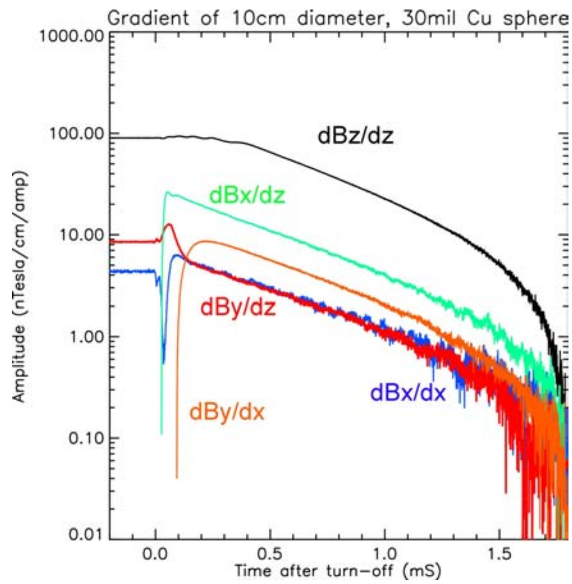
$$\frac{\partial H_y}{\partial z} = \frac{Y' - Y}{a},$$

$$\frac{\partial H_y}{\partial x} = \frac{Y' - Y''}{b}$$

$$\frac{\partial H_z}{\partial z} = \frac{Z - Z''}{c}$$



where *a*, *b*, and *c* are the coil-to-coil center spacings.



Data from Controlled Source Measurement of a 10 cm diameter hollow (30 mil thick) copper sphere showing data from the five independent tensor gradients. Data was collected at 1 μsec intervals.

SPECIFICATIONS

SENSOR:	High temperature superconducting quantum interference device (SQUIDs) operating at 77 K
OPERATING RANGE:	± 900 nT
BANDWIDTH:	dc to 10 kHz (wider bandwidths available)
SENSITIVITY:	Better than 50 fT/√Hz Better than 80 fT/cm√Hz
CRYOGEN:	Liquid Nitrogen
DEWAR VOLUME:	7 liters
HOLD TIME:	nominally 2 weeks
POWER:	120 or 240 V_{AC}, 50 Watts (12 Volt Battery Supply Optional)
OUTPUTS:	Analog ±3 Volts RS232 or IEEE-488 Visual Alphanumeric display
CONTROLLER:	321 mm wide, 121 mm high, 300 mm deep (12.6" x 4.8" x 11.8") 3.6 kg (8 lbs.)
DEWAR:	467 mm high, 250 mm diameter (18.4" high, 10" diameter) Weight: Full: 15.2 kg (33 lbs.) Empty: 9.6 kg (21 lbs.)

SYSTEM COMPONENTS

- Model HTM-8 HTS dc SQUID Magnetometer Sensors (8)
- Model NGD-1080 Liquid Nitrogen Dewar
  Horizontal and borehole dewars available on request
- Model NGI-108 cryogenic insert and cryogenic cables
- Model iMC-303 iMAG® SQUID Electronics Control Unit
- Model iFL-301-H Flux-Locked Loops (8)
- Model CC-60 six meter fiber-optic composite cables (8)
- Manual and accessory pack

for details on individual components, see their respective data sheets

Specifications subject to change without notice

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