A new UWB Handheld Vector EMI Sensor System that Exploits Precise 3-D Positioning

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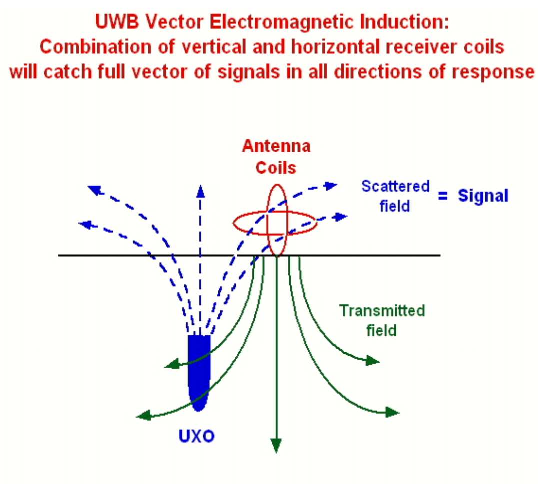
Vector Electromagnetic Induction (EMI) Data

- To identify UXO vs clutter reliably, (high detection, low false alarms) we need physically complete UXO signatures, including all complexities of composite composition, in any orientation, near field and far field, for realistic transmitted ("primary") fields.
- Vector EMI data consists of all three vector components of the response produced by the target, here over an ultra-wide frequency band (UWB).
- Complete vector response data in 3-D should allow both better signature definition and also better localization of target position (examples below).
- Up to the present, arrays of measurements had to be taken laboriously over horizontal grids around a presumed target location. Laser positioning will allow arbitrary, adaptive sensor head sweeps, at different elevations and tilts, as needed, with extremely precise locations determined relative to local reference points and output co-registered with the EM data.

Vector (multi-axis), UWB Electromagnetic Induction (EMI) Receivers for UXO Discrimination

Background

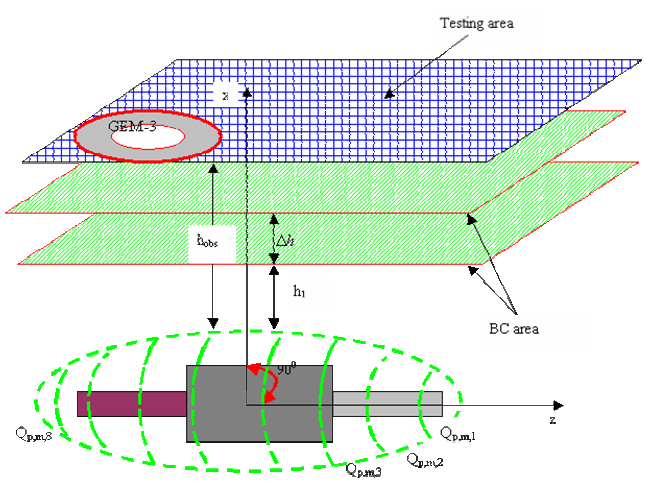
1. An EMI radiator produces a magnetic field response in the form of a spreading fan of field lines. Available frequency domain devices only receive one scattered field field (signal) component, usually the vertical.
2. Additional, orthogonal sets of coils have been added to the Geophex Ltd GEM-3 device. Being parallel to the transmitted field, these receive only the signal produced by the target.
3. The combination of all three receiver coils records full vector response by the target. Because the hand held sensor can be tilted in any direction, it can record the vector response due to excitation fields in any direction.
4. The resulting UWB frequency domain data can also be used to infer the full time domain response over a greater duration than is possible via direct time domain measurement.



Detailed, physically complete UXO signatures can be derived directly from data, representing the UXO's response to any sensor, both in near and far field, in any orientation, no matter how complex the target. These new "reduced" forward models are also fast enough to use in inversion routines. In practice data are typically obtained only over a limited area above an object. In this case the signature definition benefits greatly from data with all three vector components in the signal.

A test:

A rigorous, detailed numerical model generates data at two measurement levels ("BC areas") and this is used to derive a reduced model, the validity of which is tested over the "testing area." Forward models based on both 1-D and 3-D received data are evaluated.



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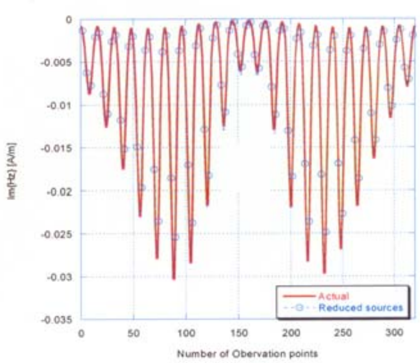
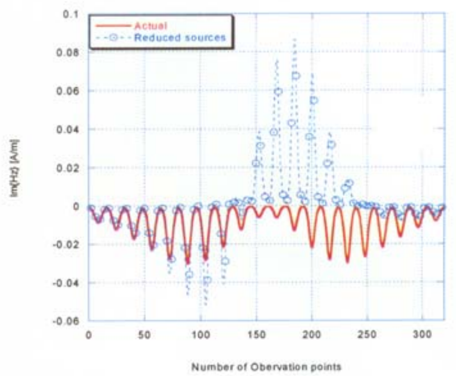
The model based on complete, 3-D data performs much better over the Testing Surface.

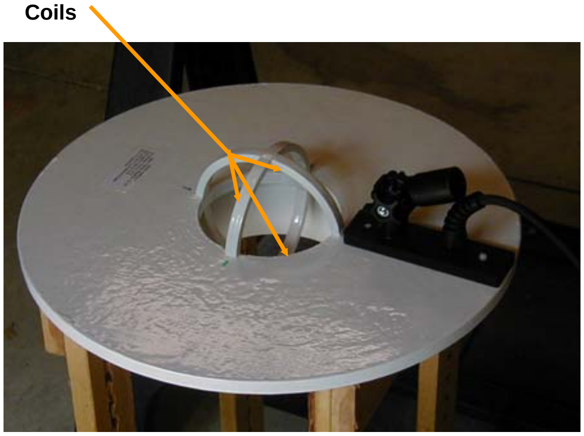
Values produced by the model ("reduced sources") based on 3-D data agree closely with actual numerical values, over horizontal scan lines on the Testing Surface.

Same comparison between model and actual values along scan lines, but with "reduced source" values obtained from the model based only on 1-D received data – worse performance.





Receiving Coils

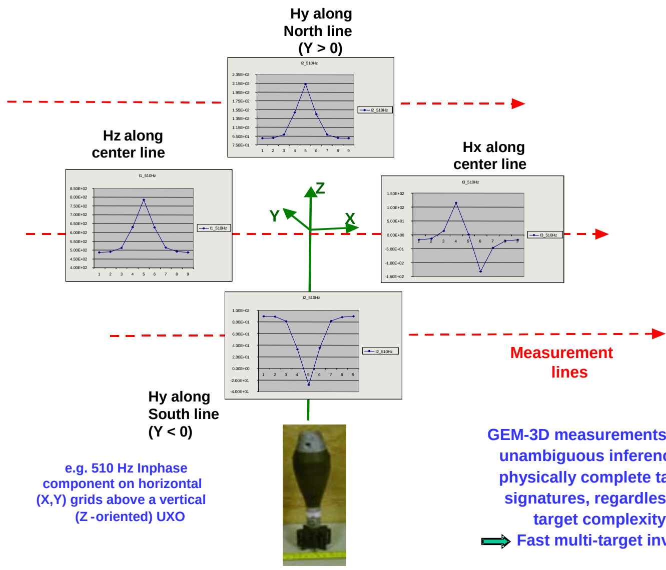


The new GEM-3D Sensor Head

- Three receiver coils on EMI sensor head measure all three vector components of target response over ultra-wideband.
- Precise laser positioning being added, so head can be swept horizontally, elevated, and tilted arbitrarily (see below)

GEM-3D data along measurement lines in a plane over a vertical UXO.

Note telling sign reversals in horizontal components, when the sensor moves from one side of the UXO to the other ⟹ more accurate location of the target and superior signature definition

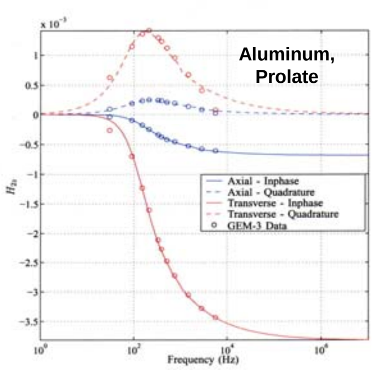


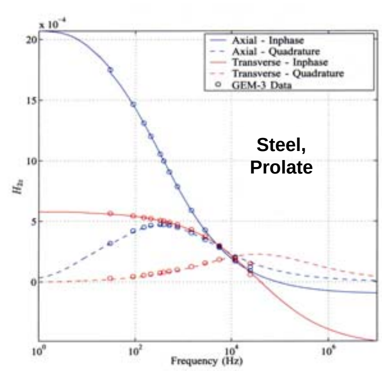
e.g. 510 Hz Inphase component on horizontal (X,Y) grids above a vertical (Z -oriented) UXO

GEM-3D measurements allow unambiguous inference of physically complete target signatures, regardless of target complexity.
⟹ Fast multi-target inversion

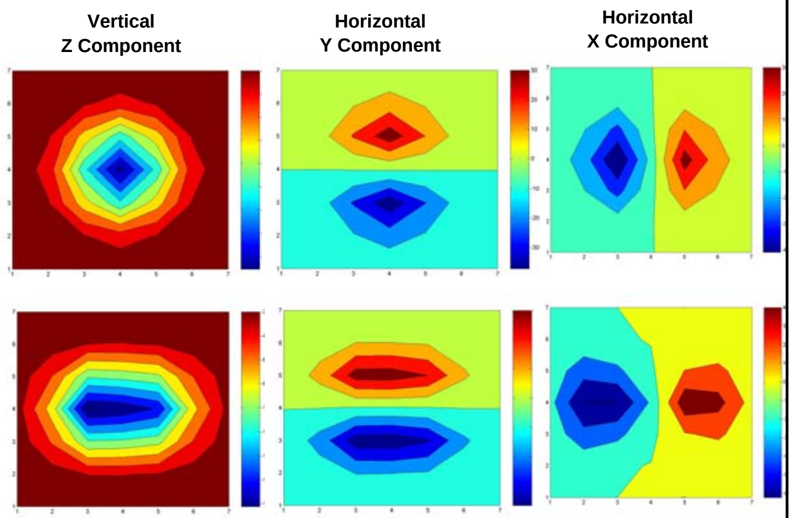
Modeling of the GEM-3D, and tests of its data against exact solutions

Data from the GEM-3D is compared to new analytical solutions for each item in a collection of machined canonical spheroid shapes. Detailed description of the primary field is treated by the solution – Agreement is good, showing that both the instrument and new solution are sound





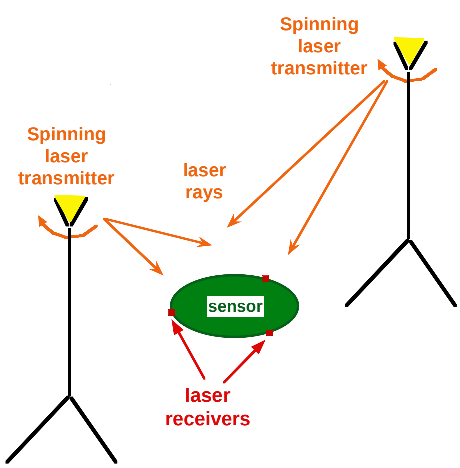
Examination of all magnetic field components, from different views of the target, shows details of symmetry, asymmetry, and a distribution of signal reflecting the UXO's shape



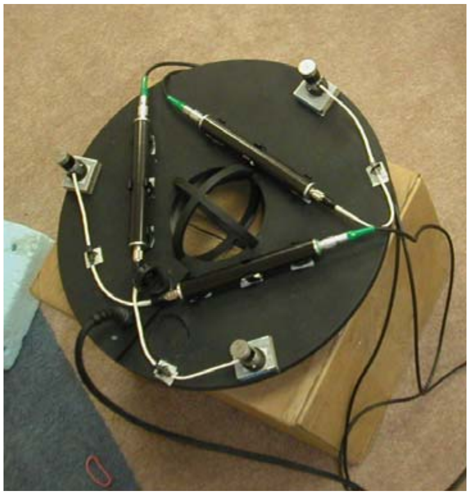
Example: GEM-3D response over a horizontal grid above the UXO, Quadrature component shown at 510 Hz

New Arcsecond laser Positioning adds locally precise positioning

Signals from spinning transmitters are picked up by three receivers with known locations on the sensor. These may be set on a frame off the head itself, to minimize interference. This allows precise local positioning, i.e. within a millimeter, relative to the transmitters which are set at reference locations near a signal anomaly. X,Y,Z, and all tilt angles are readily obtained and output together with the EM data so there are no co-registration problems.



Operational GEM-3D Sensor Head with Laser Positioning



ALTOGETHER:

With precise local positioning, entirely complete signature definitions can be obtained from grids of EMI measurements, using an UWB sensor that registers all three vector components of the scattered EMI field.

The new forward models fit arbitrarily complex UXO's, in any orientation and for any sensor, near field and far field. Derivation of the models benefits from 3-D data and from measurement at a number of sensor elevations.

The new, complete models are fast enough to use in inversion routines.

Precise local positioning of the handheld sensor, including elevation and tilt, can be obtained from laser systems. Positions are defined relative to reference locations of transmitter towers near a point of interest.