TECHNICAL PAPER

STANDARDIZED UXO DEMONSTRATION SITES

GEOPHEX GEM-3 CART-MOUNTED ELECTROMAGNETIC INDUCTION SENSOR - *BLIND GRID SCORING RECORD NO. 49*

The GEM-3 CART-Mounted Electromagnetic Induction Sensor was demonstrated by Geophex, LTD. at Aberdeen Proving Ground, Maryland.

The GEM-3 CART-Mounted Electromagnetic Induction Sensor was demonstrated as handheld, pushcart, and towed array platforms by Geophex, LTD. at the Aberdeen Proving Ground Blind Grid Area. This technical paper contains the results of that demonstration. This is a reference document only and does not serve as an endorsement of the demonstrator's product by the US Army or the Standardized UXO Technology Sites Program.

Technologies under development for the detection and discrimination of unexploded ordnance (UXO) require testing so that their performance can be characterized. To that end, Standardized Test Sites have been developed at Aberdeen Proving Ground, Maryland and Yuma Proving Ground, Arizona. These test sites provide a diversity of geology, climate, terrain, and weather as well as diversity in ordnance and clutter. Testing at these sites is independently administered and analyzed by the government for the purposes of characterizing technologies, tracking performance with system development, comparing performance of different systems, and comparing performance in different environments.

The Standardized UXO Technology Demonstration Site Program is a multi-agency program spearheaded by the US Army Environmental Center. The US Army Aberdeen Test Center and the US Army Corps of Engineers Engineering Research and Development Center provide programmatic support. The program is being funded and supported by the Environmental Security Technology Certification Program, the Strategic Environmental Research and Development Program, and the Army Environmental Quality Technology Program.

DEMONSTRATOR'S SYSTEM AND DATA PROCESSING DESCRIPTION

GEM-3 Electromagnetic Induction (EMI) sensors are multi-frequency (up to 10 frequencies logarithmically spaced in the 30 Hz - 47930 Hz range) sensors consisting of three concentric coils and digital electronics. The outer coil is the primary transmitter, the inner coil the receiver, and the annular coil is a secondary (bucking) transmitter that creates a primary field cavity around the transmitter. The electronics includes a digitally controlled switching H-bridge transmitter current-source, a 24 bit A/D, and a Digital Signal Processor (DSP) with RAM and flash memory and serial data ports (RS-232). A user interface consists of a palm pack computer with Geophex software; commercial DGPS is fully integrated.

The system is a continuous wave frequency domain system in which data are recorded while the transmitter is on; the transmitter waveform consists of a continuous mix of superposed sine waves at the specified frequencies. The measured raw time-series data are voltages (pre-amplified) measured by the receiver coil and by a small reference coil located in the transmitter primary/bucking coil annular space (proportional to primary field and phase referenced to primary field), and sampled by the A/D. Data are preprocessed in units of 30-Hz intervals (base periods) and averaged over a selectable number of base periods, typically two for cart-survey operation (net output rate of 15 Hz).

The cart-mounted configuration, with a 96-cm diameter coil disk mounted on either a manually pushed composite material wheeled cart or an ATV towed

wooden wheeled cart, is used in environments where a large sensor on a wheeled cart is practical and wide-area coverage required, such as flat, open terrain.

The ATV towed system is augmented with a navigation system that provides the driver with steering indicators in order to maintain pre-planned survey lines, but it requires greater room for turning than the hand pushed cart. The actual sensors are identical and can be interchanged. A DGPS system is integrated with the GEM console, and the antenna mounted directly above the sensor, provides geo-referenced data, which are recorded in the GEM console flash memory and/or the system (laptop PC) computer. Data are post-processed for target detection/classification.

The front-end data processing is performed in real-time by the system DSP. This processing consists of performing a partial Digital Fourier Transform on the receiver and reference time series provided by the A/D at 96 kHz. The DFT frequency samples correspond to the logarithmically spaced transmitted frequencies characterizing the hybrid current waveform. Complex division of the receiver and reference DFT outputs are performed, and system transfer function (calibration) corrections are applied, to generate inphase and quadrature measurements at each frequency. These data are recorded in the console flash memory and/or output to the system computer.

Further processing, performed during post-processing, consists of color-contour map generation using commercial software such as Geosoft©. Target detection utilizes either a composite measurement such as the sum of the quadratures over all frequencies, or a weighted average apparent conductivity over all frequencies. Anomalies identified from the maps may be further scrutinized in profile format. For target discrimination, a spectral matching algorithm compares the measurement with a library of known possible target spectra; this algorithm allows for a linear combination of the intrinsic longitudinal and transverse target response. The quality of the best fit (i.e., rms or mean absolute error) is compared with a threshold for clutter declaration and used as a confidence measure.

The survey method in the calibration and blind grids will be applied by occupying the potential target location points, preceded by a nearby background reading or (optionally) utilizing a continuous filtered background reading, and operator-initiated data sampling/storing for two seconds. Target locations will be identified in the data files via line numbers. The raw data will be postprocessed as described above.

In the open area, the cart will be towed with an ATV at walking speed along half-meter spaced lines; these lines will be maintained using the onboard navigation system based on DGPS. The console and downloading software, as well as the system computer logging the data, perform geo-referencing of the GEM data automatically. The GEM and GPS data will be post-processed to provide geo-referenced dig lists as described above. The cart will be manually pushed, as needed, where maneuvering the ATV is difficult and in small patches that extend outside the main area.

Performance Summary

Results for the Blind Grid test broken out by size, depth and nonstandard ordnance are presented in the table below. Results by size and depth include both standard and nonstandard ordnance. The results by size show how well the demonstrator did at detecting or discriminating ordnance of a certain caliber range. The results are relative to the number of ordnances emplaced. Depth is measured from the geometric center of the anomaly to the ground surface.

The response stage results are derived from the list of anomalies above the demonstrator-provided noise level. The results for the discrimination stage are derived from the demonstrator's recommended threshold for optimizing UXO field cleanup by minimizing false digs and maximizing ordnance recovery. The lower 90-percent confidence limit on probability of detection and probability of false positive was calculated assuming that the number of detections and false positives are binomially distributed random variables. All results in the table have been rounded to protect the ground truth. However, lower confidence limits were calculated using actual results.

Blind Grid Scoring Summary

				By Size			By Depth, m		
Metric	Overall	Standard	Non-Standard	Small	Medium	Large	< 0.3	0.3 to <1	>= 1
RESPONSE STAGE									
P_d	0.85	0.90	0.85	0.95	0.80	0.80	1.00	0.85	0.50
P_d Low 90% Conf	0.81	0.82	0.72	0.85	0.68	0.55	0.91	0.72	0.27
P_{fp}	0.85	-	-	-	-	-	0.85	0.85	0.80
P_{fp} Low 90% Conf	0.80	-	-	-	-	-	0.79	0.76	0.42
P_{ba}	0.40	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	0.70	0.65	0.75	0.75	0.70	0.60	0.80	0.75	0.20
P_d Low 90% Conf	0.64	0.56	0.66	0.63	0.58	0.35	0.71	0.61	0.05
P_{fp}	0.70	-	-	-	-	-	0.70	0.65	0.80
P_{fp} Low 90% Conf	0.63	-	-	-	-	-	0.62	0.56	0.42
P_{ba}	0.35	-	-	-	-	-	-	-	-

Response Stage Noise Level: 10.00
Recommended Discrimination Stage Threshold: 5.00

Note: *The response stage noise level and recommended discrimination stage threshold values are provided by the demonstrator.*