Standardized UXO Demonstration Sites

Geophex GEM-3 Handheld Electromagnetic Induction Sensor - *Blind Grid Scoring Record No. 50*

The GEM-3 Handheld Electromagnetic Induction Sensor was demonstrated by Geophex, LTD.

Geophex GEM-3 Handheld Electromagnetic Induction Sensor

The GEM-3 is an electromagnetic induction sensor that was demonstrated as handheld, pushcart and towed array platforms. Geophex, LTD demonstrated the sensor in Aberdeen Proving Ground's Blind Grid Area. This technical sheet contains the results of that demonstration. This technical sheet 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 Demonstration Sites Program.

Background

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 diversity in geology, climate, terrain, weather, 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 pre-processed in units of 30-Hz intervals (base periods) and averaged over a selectable number of base periods, typically six for handheld operation (net output rate of 5 Hz).

The handheld configuration, with a 40-cm diameter coil disk mounted on a composite material, is used in environments where a large sensor on a

wheeled cart is not practical such as dense brush, woods or rugged terrain. In a previous demonstration the mogul area was surveyed with handheld sensors. In this demonstration, the calibration grid, blind grid, and wooded area will be surveyed. A detailed description of the system is provided in the Demonstration Test Plan.

The front-end data processing is performed in real-time by the system DSP. This processing consists of performing a partial Digital Fourier Transform (DFT) 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 user interface.

Further processing, performed in real-time by the user interface, consisting of a palm top computer with special software (WinceGEM). 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, which drives audio (earphones are optional) and/or graphical signals to the operator. A manual audio gain setting is augmented with an auto gain ranging function to allow high sensitivity for weak targets and high dynamic range for precise location or strongly responding targets. 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 determining if a possible UXO (i.e., metallic object) is present based on audio/graphical response. If a potential UXO is detected, the operator initiates sampling for two seconds followed by execution of the discrimination (library matching) algorithm. The raw data as well as the matching results are recorded in the palm top with a manually entered target number.

In the wooded area, lanes 1 to 2 meters wide will be marked off with cord; the operator will survey these lanes in a sweeping search fashion, using the audio/graphical detection to locate potential targets. These will be marked with a numbered flag and the matching algorithm will be initiated by the operator as above; recorded results will be manually tagged with the flag number. Subsequent to surveying with the GEM, a DGPS rover with a pole-mounted antenna will be used to locate the flags (recorded by the DGPS receiver with manual input of flag number). The GEM and GPS data will be post-processed to provide geo-referenced dig lists. If DGPS is not attainable because of tree interference with satellite signals, the location will be measured off from a point at which DGPS is available.

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 closest point of 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	0.80	0.85	0.75	0.90	0.65	0.80	1.00	0.65	0.40
P_d Low 90% Conf	0.73	0.74	0.62	0.82	0.51	0.55	0.95	0.51	0.19
P_fp	0.85	-	-	-	-	-	0.85	0.80	1.00
P_fp Low 90% Conf	0.77	-	-	-	-	-	0.76	0.68	0.63
P_{hn}	0.30	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	0.60	0.55	0.65	0.70	0.55	0.30	0.85	0.45	0.10
P_d Low 90% Conf	0.53	0.46	0.54	0.61	0.42	0.12	0.74	0.33	0.01
P_fp	0.50	-	-	-	-	-	0.50	0.50	0.60
P_fp Low 90% Conf	0.43	-	-	-	-	-	0.39	0.39	0.25
P_{hn}	0.15	-	-	-	-	-	-	-	-

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.*