TECHNICAL PAPER

STANDARDIZED UXO DEMONSTRATION SITES

NRL MULTI-SENSOR TOWED ARRAY DETECTION SYSTEM (MTADS) GEM ARRAY - *BLIND GRID SCORING RECORD NO. 127*

The MTADS GEM Array was demonstrated by Naval Research Laboratories (NRL) of Washington, D.C.

The Multi-Sensor Towed Array Detection System (MTADS) GEM Array *was demonstrated by Naval Research Laboratories 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

The Multi-Sensor Towed Array Detection System (MTADS) GEM array is comprised of three 96-cm diameter GEM3 frequency-domain electromagnetic interference (EMI) sensors mounted in a triangular array. The array is mounted on a 3.5-meter long platform that is pulled by the MTADS tow vehicle. The sensor transmit electronics and signal analog to digitals (A/Ds) are located on the tow platform just in front of the sensor coils. The remaining sensor electronics are rack-mounted in the tow vehicle. Also mounted on the tow platform are three Global Positioning System (GPS) antennae and an International Measurement Unit (IMU).

Each of the three sensors in the array sequentially transmits a composite waveform made up of ten frequencies logarithmically spaced from 30 Hz to just over 20 kHz for one base period (1/30 s). Thus, only one complete cycle of the 30 Hz frequency is transmitted while many thousands of cycles of the highest frequency are transmitted. The transmit current drives both a transmit coil and a counterwound bucking coil. This serves to set up a “magnetic cavity” inside the bucking coil in which is placed a receive coil. The current induced in this receive coil by the induced fields in buried metal targets is detected, digitized, and frequency-resolved during the two subsequent base periods while the other array sensors are transmitting. The detected signal is compared to the transmitted current and reported relative to the transmit current (parts per million) as both an in-phase and quadrature component.

These twenty measured responses (in-phase and quadrature at ten frequencies) make up the “EMI Spectrum” of the buried targets. These spectra can be analyzed by fitting to empirical functions, comparing against known library spectra, or fitting to target response coefficients. All three of these analysis methodologies will be applied to the data collected in this demonstration and their results compared.

The MTADS GEM array consists of three, 96-cm diameter sensors arranged in a triangle. It is pulled by the MTADS tow vehicle over the site at approximately 3 miles per hour. Lane spacing is the width of the MTADS tow vehicle, approximately 1.75 meters. Data are recorded from the array at approximately 9.7 Hz. This results in a down-track sampling interval of ~15 cm and a cross track sampling interval of 50 cm. For the measurements at APG, data was recorded while traversing the test field in two orthogonal directions (roughly north-south and east-west). As part of the analysis, the extra classification performance (if any) that results from these extra data will be determined.

Individual sensors in the array are located using a three-receiver real-time kinematic (RTK) GPS system. From this set of receivers, the position of the master antenna is recorded at 20 Hz, and the vectors to the other two antennae are recorded at 10 Hz. All positions are recorded at full RTK precision, ~2-5 cm. In addition, the output of a full 6-axis IMU at 80 Hz is recorded to give complementary information on platform pitch and roll. All sensor readings are referenced to the GPS PostPostscriptum (1-PPS) output so that full advantage could be taken of the precision of the GPS measurements.

The individual data streams into the data acquisition computer, running a custom variant of the WinGEM program called WinGEMArray, are each recorded in a separate file. These individual data files, which share a root name that corresponds to the data and time the survey was initiated, include three sensor data files, four GPS files (one containing the National Maritime Electronics Association GGK sentences corresponding to the position of the master antenna and an automatic volume recognition (AVR) sentence giving one of the vectors to the secondary antennae, another containing the second AVR sentence, a third containing the universal time coordinated time tag, and the fourth containing the computer-time stamped arrival of the GPS PPS, and one file for the IMU output. The sensor and GPS files are ASCII format and the IMU file mirrors the packed binary output of the IMU.

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/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 positives was calculated assuming that the number of detections and false positives are binomially distributed random variables. All results have been rounded to protect the ground truth. However, lower confidence limits were calculated using actual results.

Blind Grid Scoring Summary

Metric	Overall	Standard	Nonstandard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	>= 1
RESPONSE STAGE									
P_d	0.85	0.90	0.85	1.00	0.75	0.80	1.00	0.95	0.00
P_d Low 90% Conf	0.81	0.80	0.73	0.91	0.61	0.55	0.95	0.88	0.00
P_{fp}	0.95	-	-	-	-	-	0.95	0.95	1.00
P_{fp} Low 90% Conf	0.90	-	-	-	-	-	0.89	0.85	0.63
P_{ba}	0.20	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	0.80	0.80	0.80	0.95	0.60	0.70	0.90	0.90	0.00
P_d Low 90% Conf	0.73	0.69	0.69	0.88	0.48	0.45	0.82	0.80	0.00
P_{fp}	0.65	-	-	-	-	-	0.55	0.75	0.80
P_{fp} Low 90% Conf	0.59	-	-	-	-	-	0.47	0.63	0.42
P_{ba}	0.15	-	-	-	-	-	-	-	-

Response Stage Noise Level: 0.40
Recommended Discrimination Stage Threshold: 100.00

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