TECHNICAL PAPER

STANDARDIZED UXO DEMONSTRATION SITES

G-TEK AUSTRALIA PTY LIMITED TM-5 EMU (DUAL SENSOR)/ MAN-PORTABLE - *BLIND GRID SCORING RECORD NO. 186*

The TM-5 EMU (Dual Sensor)/Man-Portable as demonstrated by G-TEK Australia PTY Limited.

The TM-5 EMU detector system may be configured with one or two sensors measuring the transient EM response. In the dual-sensor mode, the TM-5 EMU is operated by a single person. The TM-5 EMU (Dual Sensor)/Man-Portable sensor was demonstrated in the Aberdeen Proving Ground Blind Grid Area by G-TEK Australia PTY Limited. This technical paper contains the results of that demonstration. This technical paper 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.

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 (APG) , 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 Man-Portable TM-5 EMU consists of four major hardware subsystems:

- Magnetometer Control Module
- Multi-period, transient electromagnetic (EM) sensors
- DGPS (digital Global Positioning System)
- Odometer

The TM-5 EMU interfaces with both industry standard real-time kinematic (RTK) DGPS and proprietary cotton thread-based odometer systems providing versatile positioning adaptable to varied terrain and vegetation conditions. It has been successfully used for over five years. The odometer remains the positioning technology of choice in adverse terrains; DGPS is preferred in open environments. In both cases, where UXO detection standards of survey coverage are required, G-TEK operators use a pre-established control grid and visual sighters for straight-line navigation, and use the DGPS or odometer for data positioning only. Combined, they meet the requirements of most situations.

The TM-5 EMU user interface provides a continuous set of data quality monitors. There are audio and graphic displays and alarms monitoring sensor signal quality and position data quality. A key attribute of the TM-5 EMU is its virtual immunity to hot rocks.

Prior to performing a survey, the TM-5 EMU undergoes three procedures taking a total of five minutes to complete. (1) Sensor pulse repetition frequency is swept over about 100 Hz, centered at 1200 Hz, to select the frequency corresponding to the lowest receiver RMS noise level, in order to minimize radio frequency (RF) interference. (2) Sensors are ground-balanced to compute ground response parameters that are stored in memory so that the ground response then may be subtracted from the received signal in real time. (3) A control source known as an EMUlator is used check that sensor signal levels are within specifications

The sensors are a monocoil acting as both transmitter and receiver, operated as a vertical magnetic dipole, with 16 turns, a diameter of 18 inches, inductance of 300 mH and resistance of 0.7 W. During surveying, the sensor coil height is maintained at 100 mm, with the minimum HERO safe operating height calculated to be 10 cm above ground.

The transmitted waveform consists of two different length pulses (200 ms, 3.3 A and 50 ms, 830 mA), repeated at the rate of approximately 1200 Hz. The peak pulse amplitudes are based on an application of 5 V, and at turn off, the pulses ramp to zero in approximately 2-4 ms, (corresponding to the self-induced EMF clipped to 187 V). The theoretical bandwidth of about 500 kHz reduces to about 300 kHz after the addition of amplifiers and integrators. The detector is based on synchronous demodulation, sampling the secondary field decays over narrow integration gates. After subtracting the ground response and digitizing at approximately 60 Hz, the output is decimated to 32 samples per second that are recorded with a DGPS position at a >1 Hz rate. Amplifier gains are adjusted to provide digital output between + 4096 units such that background noise is set to + 1 to 2 units. A low pass filter is applied at periodic intervals to reset the background signal to a zero mean. During a traverse this filter is switched out so that the filter does not attenuate target responses, and the drift is removed from the digital record in post processing with a high-pass filter.

Using DGPS in the Open Area DGPS is the technology of choice in situations where satellite coverage is reliable. In this case, any of the industry standard RTK systems (with the precise 1 pulse-per-second facility) may be used, although in this program we propose using the Ashtech Z-Extreme system (with NovAtel RT-2 as a backup). The preference is to establish a Global Positioning System (GPS) base-station on a monument that is within 1 km of the survey area and to use a radio link to the roving GPS receiver. In the roving instrumentation, sensor data is merged and synchronized with the transformed DGPS positions, and recorded. In this way, sensor data is positioned with an accuracy of better than 5 cm. Prior to commencing survey, the roving GPS is located at a known reference to confirm the integrity of the system and transformations used. The real time DGPS will be used to establish a control grid using non-metallic pegs at intervals appropriate to the level of visibility. At APG, a control line interval of 25 or 50 meters is anticipated. The non-metallic polychains will then be laid as control lines, perpendicular to the proposed survey direction. Visual sighters will be located along the first survey line and used as a visual aid to navigation. As each sighter is reached, it is laterally moved 0.8 meters to the position of the return survey line.

Using the Odometer in the Wooded Area The control grid setup will combine the use of DGPS and cotton odometer survey techniques. Navigation will be done the same as described above. However, 5 meters before the commencement of each new transect, the cotton thread is tied to either vegetation or a small peg anchored to the ground. When each control line is reached, a distance mark is recorded in the TM-5 EMU prior to moving the cone. At the completion of each survey grid section the cotton is gathered and removed from the site.

In post-processing, linear error distribution delivers positional accuracy that is typically less than 0.1 percent of the distance between control lines (0.1 percent of 25 meters delivers 2.5 cm accuracy in this case.) Because the odometer is used in more adverse terrain including forests, protocols have been developed using the electronic notepad facility of the TM-5 EMU for recording the location of obstacles (e.g., trees) and the direction taken around these. If a UXO is detected close to such a tree, the validation team will know which side of the tree to search. Experience over many years surveying in forested conditions has indicated that an rms target position error of less than 30 mm can be anticipated, with the greatest errors occurring where obstacles are circumvented. These errors are not cumulative and are comparable with the interpreted target position errors achieved using DGPS.

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 closest point of anomaly to the ground surface.

The Response Sage 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	0.85	0.85	0.90	0.80	0.95	0.95	0.85	0.45
P_d Low 90% Conf	0.80	0.78	0.74	0.80	0.63	0.75	0.88	0.69	0.17
P_{fp}	1.00	-	-	-	-	-	1.00	1.00	0.00
P_{fp} Low 90% Conf	0.95	-	-	-	-	-	0.94	0.92	-
P_{ba}	0.15	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	0.70	0.65	0.75	0.85	0.50	0.55	0.70	0.70	0.45
P_d Low 90% Conf	0.61	0.54	0.63	0.73	0.37	0.37	0.61	0.56	0.17
P_{fp}	0.50	-	-	-	-	-	0.35	0.95	0.00
P_{fp} Low 90% Conf	0.44	-	-	-	-	-	0.29	0.82	-
P_{ba}	0.15	-	-	-	-	-	-	-	-

Response Stage Noise Level: 11.00

Recommended Discrimination Stage Threshold: 0.49

Note: *The Response Stage noise level and recommended Discrimination Stage threshold values are provided by the demonstrator.*