GEM-3M: A Ground Imager with a Local Navigator

1. Problem Statement

Most handheld metal detectors annunciate ground response in audio for a potential contact. The sound becomes louder, or higher in pitch, as the detector approaches a target. Depending on settings on detection sensitivity and threshold, the audio can be very jumbled and chaotic in cluttered areas, a typical IED venue. This disorganized sound is one of the most significant factors that render the sensor unproductive and its operator fatigued, inefficient, and confused. Military mine detectors, like all hobby metal detectors, have used audio ever since the first detector was invented over a century ago. Audio has been the only indicator the operator could use throughout the history of the landmine detector. It is about time to change that.

2. Proposal Background: Army SBIR Phase II and CPP

In 2009, Geophex received an SBIR Phase II contract (Contract W15QKN-08-C-0518) from Picatinny Arsenal to develop a new high-speed electromagnetic induction (EMI) sensor array for route clearance. As demonstrated in the Picatinny compound, the sensor (Fig 1) can (1) display realtime subsurface image along its track, (2) generate a GPS-based "diglist" for potential targets, and (3) identify an object if its EMI spectra is included in the sensor library as a "wanted" object.

Fig 1. A prototype GEM-3 array mounted on a Hummer for a demo in Picatinny Arsenal. Shown on the right are realtime GPS-based ground image over a seeded roadway traversed on two different days. Notice the excellent data repeatability.

Upon successful Phase II completion, Picatinny recommended the project for the Army SBIR Commercialization Pilot Program (CPP). After rigorous evaluation and PM recommendations, the CPP office selected Geophex for funding in July, 2011. This 18-month contract calls for building an improved GEM-3 array sensor with following capabilities:

1. A vehicle-mounted GEM-3 array detector with high detection/low false alarm rate;
2. Realtime data display in a color format in a moving vehicle, following the sensor path;
3. Automated target picking and building a GPS-based “diglist” in real time;
4. Realtime target identification experiments using the EMIS fingerprinting algorithm;
5. Demonstration of these capabilities at a test site to be designated by the Army.

3. Ground Imager Proposed for the SBIR Enhancement Funding

As a derivative of our SBIR effort, we have developed a handheld landmine/ordnance/IED detector/imager, called the GEM-3M, that combines an EMI conductivity sensor, like metal detector (MD), and a ground-penetrating radar (GPR) along with a revolutionary built-in navigator that enables the operator to visualize ground image on a HUD or PDA (e.g., *iphone*) screen while sweeping for buried objects like IEDs. This is done by painting the screen in real time using a new local navigation method.

Figs 1-3 depict the operation of the GEM-3M with a real data example. The system has a sensor navigator that locates the sensing head at centimeter accuracy and a small computer that produces audio and, at the same time, displays a graphic image following the sensor path. The navigator, which uses the sensor itself as a beacon, is the primary enabling technology that makes the realtime screen image possible.

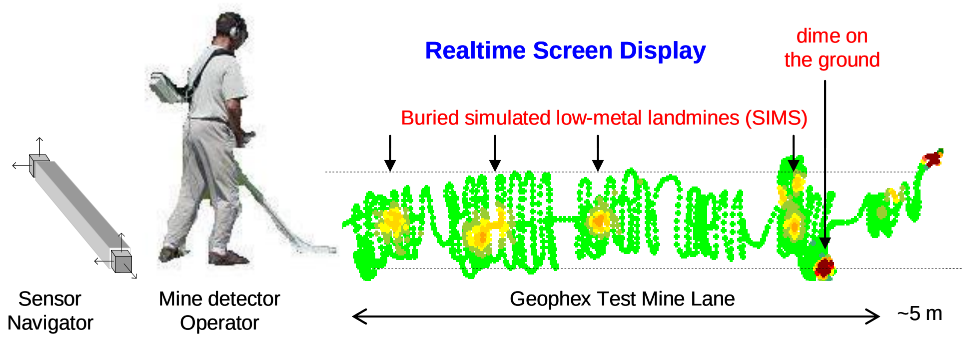


Fig 1. The Navigator, using the MD transmitter as a beacon, generates the x-y coordinates of the sensing head at a very high accuracy. As the operator sweeps the lane, the sensor output *paints the screen* using the data location as determined by the Navigator. The data shown here are obtained over a small test lane (1m x 5m) where several US Army simulated plastic mines are buried. Shown for reference to the right is a US dime dropped on the ground.

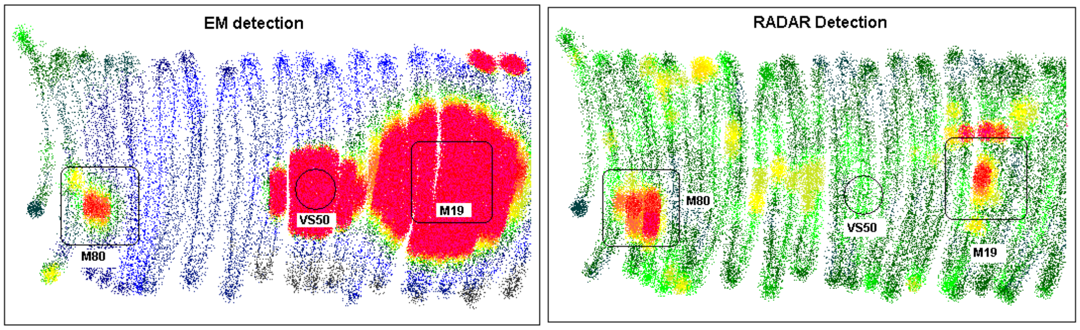


Fig 2. MD/GPR data collected over landmines M80, VS50 and M19 at the Indoor Mine Lane, Ft. Belvoir. Both data are from the same run, obvious from the identical sweep patterns.

Fig 3 shows the current experimental GUI for the GEM-3M on a Windows screen. It shows the realtime 2-D data display for the MD (left) and GPR (right), along with the signal strength as strip chart (bottom left). The touch screen also has buttons for clearing the screen (Clear), +/- audio, pause/resume, background nulling (BGND), and target identification (Identify). The color bar at the bottom has a sliding handlebar for quick adjustment.

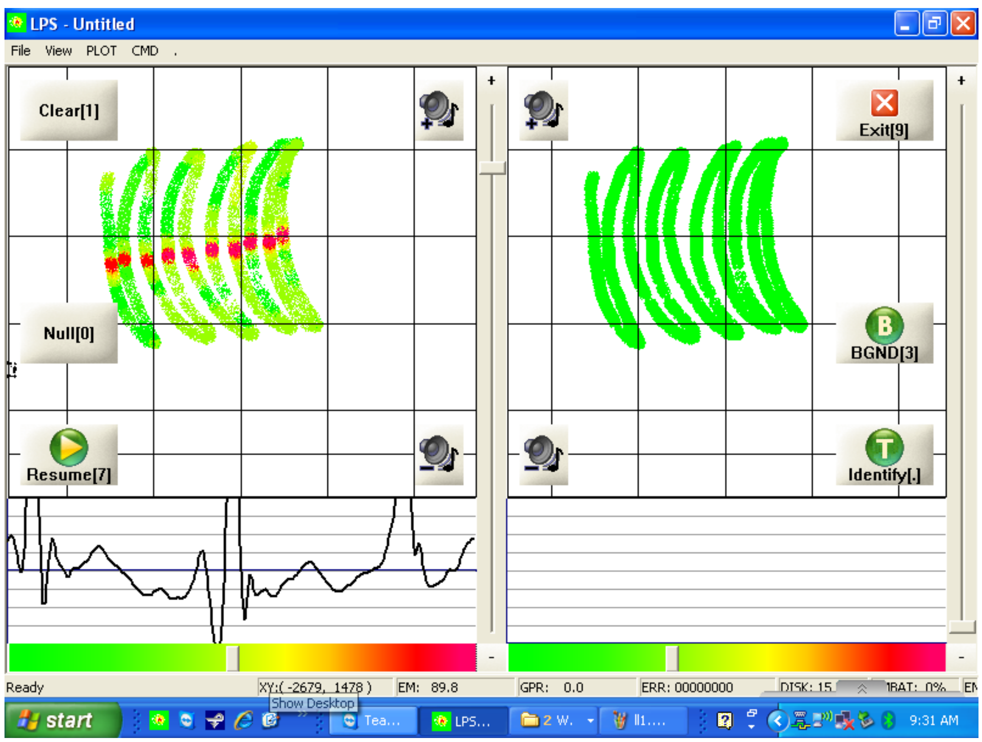


Fig 3. An experimental realtime GEM-3M GUI for MD (left) and GPR (right) on Windows.

Most IEDs are made of multiple parts and components often wired together to a control point. Therefore, it would be very useful if a sensor can show the image of interconnecting wires and their distribution. Fig 4 show two different sweep images over a phone wire loosely placed on the ground.

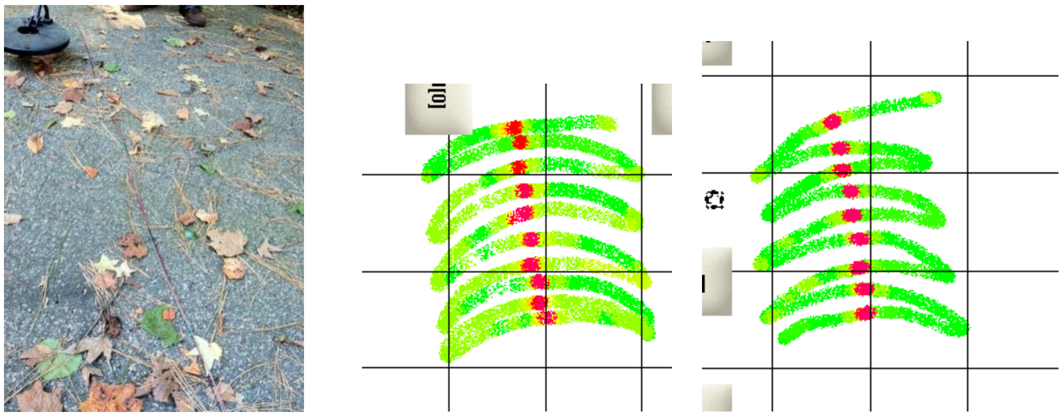


Fig 4. Two GEM-3M MD ground images for a wire laid on the ground.

Wires used for IED emplacement may come in many different shapes and geometries. Fig 4 shows four repeat images over an S-shaped insulated copper wire placed on the ground. Each sweep was made in different approach/direction and sweep patterns. The last image is made by more or less in a jumbled set of sweep paths.

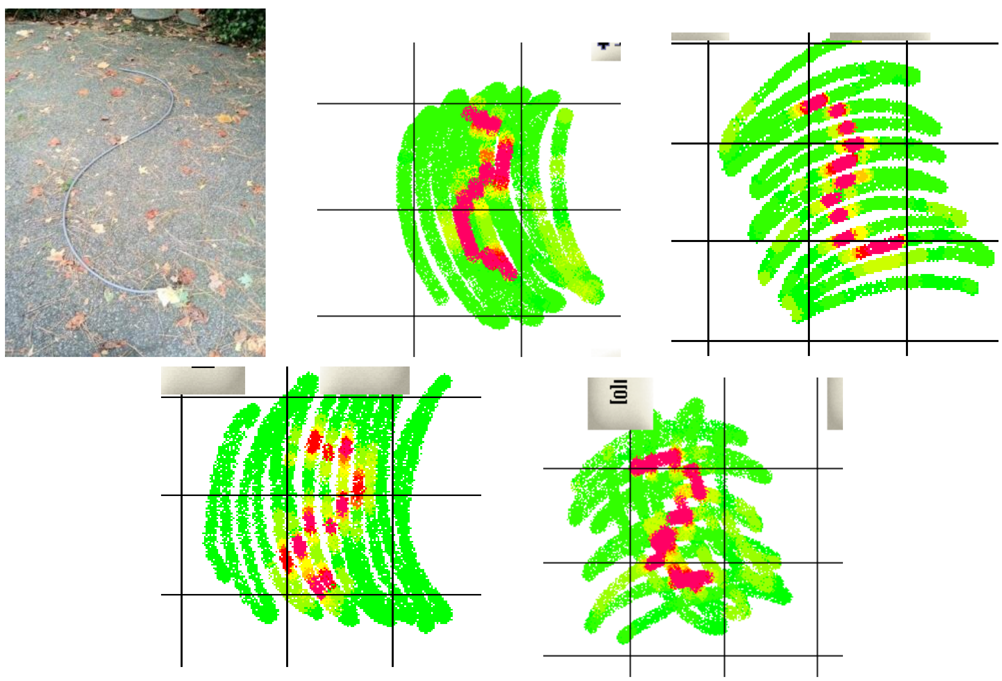
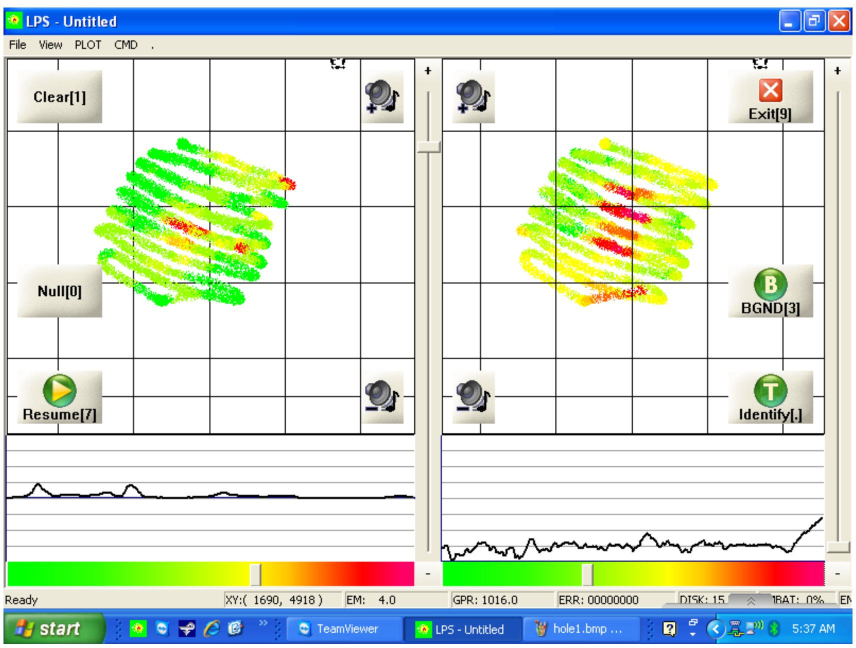


Fig 4. GEM-3M MD ground images of an S-shape wire placed on the ground.

Fig 5 shows how the GEM-3M may be eventually deployed and used for path clearance missions. In this example, the soldier sees the ground image through a heads-up display that displays accumulated ground image following his sweep paths.



GEM 3M MD detecting Ground Disbursement and Fertilizer

Fig 5. The GEM-3M displays visual ground image following the sweep paths

We expect that the GEM-3M would assist dismounted soldiers with a robust and efficient subsurface threat detection capability. By sweeping the sensor head back and forth over the ground, the operator can literally "paint" an image of sensor response – indicative of buried threats – over an x-y grid. This is a unique capability in a hand-held unit where historically an operator has had to rely only on audible tones. The sensor will respond to both metallic and non-metallic buried hazards, including IEDs and landmines.

The visual display allows the operator to quickly localize targets and also easily keep track of ground that has already been scanned. The visual display device is a peripheral device that is attached via a standard connection; it can be selected from many display devices, including heads-up displays, tablet PCs, PDAs, and even remote displays, to tailor the system to various mission requirements. This visual display, in concert with audible alarms or stand-alone, offers an intuitive approach to detection that minimizes training time.

The ground-imaging technique demonstrated here should be the game-changer in the countermine and IED technology. The screen that shows both the target image and the sweep paths is visually intrinsic in coverage and easily understandable and, thus, can tremendously reduce the need of operator training. The scheme will also eliminate the need for remembering audio histories following the sweep paths. This will significantly cut the stress and fatigue the operator experiences during a mine sweep mission.

Again, the ground image itself provides an intuitive target recognition function by simply being able to view the size, shape, and extent of a target. Such a holistic ground image is particularly important for understanding the makeup of an IED that may consist of several hidden components (e.g., command wires, trigger mechanisms, detonators, etc.), all intricately connected as a single IED unit. A whole image showing interconnections of several parts would be a powerful means of detecting, understanding, identifying, and neutralizing an IED.

To recap, the GEM-3M ground image examples shown here clearly demonstrate the following advantages, in comparison with the traditional audio-based mine detectors:

- The screen image represents *accumulated* history of data, relieving the operator from memorizing audio beeps related to potential contacts (thus, reducing fatigue);
- Wire-like targets, used for many IEDs, are much easier to recognize on a 2-D image than by the conventional audio output alone;
- The image shows the *sweep paths* ensuring proper ground coverage;
- The operator can visualize the spatial extent of a target, as well as its center;
- The operator can arbitrarily improve image by adding sweeps over interested spots;
- A cursor on the screen, centered at the sensing head, allows the operator to return to any spot of interest to improve the image resolution.

Geophex

605 Mercury St, Raleigh NC 27603
Phone: 919 8398515
Email: oren@geophex.com