Adam Baddeley examines the latest developments in buried explosive-detection technology, and asks whether GPR has replaced traditional metal detection as the detector of choice

The earth exhales

GPR has uses in everything from detection of explosive devices to body remains ©DoD

Beginning in the 1970s, mines changed. Most significantly, the range of materials used by manufacturers changed in order to reduce their susceptibility to detection from the default technology at the time – metallic detection. The materials used ranged from plastics to protective rubber to protective fiberglass and combinations thereof, each having the common core of minimal metallic consistency. This posed self-evident challenges to the mine detection community. In the absence of immediate alternatives, manufacturers addressed the problem by increasing the efficiency and sensitivity of their detectors and using additional approaches such as the induction technique. As with any technology, there is only so far that a solution designed for combat situations can replicate laboratory performance. Consequently, other technologies were examined. The most promising, and now increasingly fielded, is Ground Penetrating/ Penetration Radar (GPR). This operates by sending radar pulses of electromagnetic radiation in the microwave VHF/UHF band beneath the surface and then processing the returns to detect anomalies associated with mines.

GPR dynamics

The biggest limitation on GPR's effectiveness has nothing to do with the quality or power of the system's instrumentation; rather it lies in the material being surveyed, which limits the depth of penetration and the quality of perception. All radar is RF energy, and the same rules that apply for radio communications also affect GPR. A simple rule of thumb is that those factors that affect mobile phone performance also affect GPR. For example, the thicker the material the device seeks to penetrate, the more difficulties are posed for the system. In clay, rock and concrete – denser materials with poorer electrical conductivity – attenuation is increased. Sodden ground also increases attenuation, as it adds ions and thus becomes a stronger energy absorber. There are exceptions. Granite, for example, can be penetrated quite well, although few mines are likely to be found buried in this material. Dry sand offers the best conductivity and GPR performance, a self-evident boon to current operations.

Reducing the frequency of the pulses increases the depth of penetration but, somewhat unsurprisingly, the complex problems of penetration don't go away simply by lowering frequency. Just as high frequency (HF) radios operate on a lower frequency than VHF radios to go further, but carry much less data, lower frequency GPS lose their resolution as penetrative depth increases, and beyond a certain point the all-important waves become diffuse and cease to provide usable feedback.

Increasing the power of the signal would, like any other RF, require an exponential increase in power; thus man-portable and vehicle systems are dependent upon the weight of batteries and the amount of power available from on-board platform power.

Pack leader

GPRs for mine detection are now entering the field. The leader is without doubt the L-3 Cyterra AN/PSS-14 – the Handheld Standoff Mine Detection System (HSTAMIDS) programme. This project was a response to the failure of the US Army's AN/PRS-7, designed to provide metallic and non-metallic detection but which failed to meet the requirement for a 92 per cent success rate. This prompted the acquisition of the AN/PSS-12 from Austrian firm Schiebel.

In parallel to these off-the-shelf buys, the Defense Advanced Research Projects Agency (DARPA) took the reins of driving forward new technology and, in 1992, kicked off the research project that would lead to the AN/PSS-14. It reviewed the technologies available and after discarding approaches such as chemical, metal or thermal neutron activation, it settled on GPR as the way forward. Contracting the then Cyterra for the work, the firm was able to deploy the system ready for 2001 and the beginning of Operation Enduring Freedom – fielding systems while still in the midst of its engineering and manufacturing development (EMD) phase after being given the go-ahead to do so by the Army Requirements Oversight Council. A total of 210 systems were acquired as the system continued its formal acquisition

The earth exhales

and testing process, with the systems achieving a detection rate of over 95 per cent. In July 2006, the Army awarded a production contract to L-3 Communications to proceed with full-rate production, and by 2010-13 as many as 18,000 systems are to be delivered.

The AN/PSS-14 is distinguished from its predecessors by the use of GPR, but a metal detection capability is retained with both sensors operating together synergistically. This allows a soldier who hitherto might have had to excavate each positive reading for metal to quickly distinguish between scrap metal, shrapnel and actual mines by using the GPR. When a threat is located, the metal detection capability would audibly alert the operator and provide a detailed position and data about the mass of metal. The GPR then kicks in, providing further position and depth information, and can also provide an accurate cross-section of the target. This provides the operator with a high level of confidence about the identity of the target. Another boon from the AN/PSS-14 is that in Afghanistan, as in countries such as Bosnia and Cambodia, there is a high metal content in the ground which serves as a mask for man-made metallic objects such as mines. With GPR, this is no longer the factor it was.

The AN/PSS-14's designers have made the complex technology underlying the GPR easier to use, though different soil conditions require recalibration of the system. The AN/PSS doesn't do this automatically; it still requires operator intervention, but the system includes an audio prompt when this is required. An unexpected use for the AN/PSS-14 is as an urban sensor. The AN/PSS-14 can see through the ground, so users wondered why not walls too? Enterprising soldiers and marines found that it could also be used to detect movement behind a wall, further boosting its value on the urban battlefield.

The AN/PSS-14 HSTAMIDS was one part of the US Army's countermine triumvirate which comprises the Airborne Surveillance, Target Acquisition and Minefield Detection System (ASTAMIDS) and Ground Standoff Minefield Detection System (GSTAMIDS). GSTAMIDS is designed to provide route clearance, automatically detecting and marking metallic and non-metallic anti-tank (AT) land mines, with threshold of 20km in 12 hours and an objective goal of 40km in six hours. In addition, an initial GSTAMIDS capability was deployed to Iraq in 2003 by EG&G Management Systems – designated GTSAMNIDS Block 0 – as part of its Engineering, Manufacturing and Development phase. This saw two systems deployed which consisted of two control vehicles and several remotely operated detection systems. The systems consisted of nine separate GPR and the same number of pulse magnetic induction (PMI) metal detectors, with two long wavelength infrared cameras. These were integrated on a protected Meerkat vehicle; when a mine is detected, the Meerkat then shoots paint onto the spot. This vehicle is "dumb"; instead of housing data fusion systems on board, a high-capacity RF link sends back telemetry to the command vehicle. For the Iraq trials a Buffalo, which received the Main Computer System (MCS), undertook this role.

Moving on from this approach, GSTAMIDS leant itself to Future Combat Systems (FCS). As part of that programme, the main thrust for GPR was the integration of the GSTAMIDS package on the Multi-function Utility/ Logistic Equipment (MULE) countermine robotic variant. The US Army selected BAE Systems in 2004 to develop the GSTAMIDS capability for the MULE.

The other element to the triumvirate is the ASTAMIDS, developed by Northrop Grumman. It has already been flown on the MQ-8B Fire Scout rotary-winged UAV, using electro-optical infrared/multi-spectral imaging payload to detect patterned surface-emplaced mines.

More research more fielding

The European Defence Agency is also getting in on the GPR act as part of its R&T Joint Investment Programme on Force Protection (JIP-FP). GPR for mine detection and other roles is being specifically explored under the Generic Urban Area Robotized Detection of CBRNE Devices – a three-year, €3.5m JIP contract that also brings in technologies such as Proton Transfer Reaction, Mass Spectrometry, chemical and biological-based solutions on handheld devices, and improving new sampling techniques. Several firms have been contracted, including France's ECA and DDSC, Austria's ION, Slovenia's IPS and Finland's ENV.

The UK had addressed the implementation of GPR on Royal Engineers' vehicles as a subset of its Mine Detection, Neutralisation and Route Proving System (MINDER) project. Originally scheduled to be in service in 2006 but subsequently cancelled, the UK pursues similar capabilities under the aegis of both the Reconnaissance Counter-Mine Capability and the Future Medium Minefield Breaching System.

Other ongoing projects include the ELTA EL/M-2190 – a GPR that has been developed into the Innovative Ground Penetration Radar (IGPR), with sales recorded to Turkey and Sweden some years ago. Similarly, US firm Geophysical Survey Systems, Inc (GSSI) produces a range of GPR solutions. The firm's SIR-20, which uses the firm's RADAN GPR software and is controlled from a Panasonic ToughBook PC, is designed to be a rugged system for the field and can be deployed on a range of platforms. The company's literature shows two 155mm rounds buried beneath the surface of a road being detected using the SIR-20 coupled with the firm's antenna.

The US continues to acquire new GPR technology to meet immediate operational needs. In April, Curtiss-Wright Controls Inc received a contract from an unspecified US Army agency to supply a GPR system over the next year, optimised for the detection of unexploded ordnance. The system consists of the firm's step frequency B3231 antenna and GeoScope GPR processing solution coupled with software algorithms developed by Exponent. A noteworthy feature of the system is that operators will be able to obtain processing information – not just data – within milliseconds of capture; a self-evident safety feature.

In Germany, Vallon's Minehound Dual Sensor Detector system takes the company's proven VMR3 detector and matches it with a bespoke 1GHz time-domain radar designed by ERA Technology, which uses 1ns duration impulses with repetition frequency of 1MHz. This has a demonstrated capability against flush-buried mines of less than 5cm diameter.