2. Metal Detectors

(electromagnetic induction devices)

Introduction

Metal Detectors (MDs) are a mature technology and are the primary means of detection used in mine action programmes today. Much has been written about the operating principles, characteristics and limitations of the technology and will not be repeated in this publication. A brief summary description of metal detectors is provided below. Readers wishing a more detailed discussion on metal detectors are referred to the related publications listed below, in particular, *The Metal Detector Handbook for Humanitarian Demining* and *Metal Detectors and PPE Catalogue 2005*.

Operating principle

A metal detector's search head is usually composed of a primary coil (transmitter) and one or more secondary coils (receiver), although in some arrangements one coil is actually sufficient. A time-varying current in the transmitter coil generates a low frequency electromagnetic field (kHz to MHz frequency range), which induces electric ("eddy") currents in nearby metallic objects, an effect which can be enhanced in the case of magnetic objects. These eddy currents in turn induce a time-varying current in the receiver coil(s), which is amplified and processed to provide an acoustic signal or other form of warning or signal strength indication as the detector is swept over the ground, typically very close to the soil. A metal detector's search head "illuminates" an area which is roughly as large as the sensor head ("footprint"). Larger sensor heads can therefore be used to search for deeper objects, although they will be less sensitive to small targets close to the surface (this can represent an advantage or disadvantage depending on the operating scenario). The rejection of signals generated by the soil itself is very important in a number of operating scenarios, and in this respect significant advances have been achieved by the manufacturers during the past years.

Application type

Close-in detection: hand-held, vehicle-based (arrays) .

Strengths

- Well-established technology (hand-held; vehicle-based arrays are more recent developments).
- The vast majority of all deployed mines do contain some amount of metal, albeit in some cases only at the level of the detonator capsule or striker pin (minimum-metal mines).
- Indicative detection limits (can also depend on ground conditions): shallow (about 10-15cm for minimum-metal mines, 20-30cm for mines with an

appreciable metallic content, and 50-70cm for UXO and metallic mines). Greater depths are reachable with large loop systems.

Limitations

- Magnetic (e.g. laterite rich) or strongly conductive soils (e.g. sea beaches).
- Ground compensation techniques can reduce detector sensitivity.
- Very small (minimum-metal mines) and/or deep targets, low conductivity metals (e.g. stainless steel).
- Footprint size decreases with depth (conical footprint).
- Electromagnetic interference (e.g. power lines). High false alarm rate caused by metal fragments, etc.

Potential for humanitarian demining

- Well-established technology.
- Metal detectors (MDs) are present in nearly every multi-sensor system being researched.
- Efficiency limited by metallic debris (MDs detect any metal and not just the metal components found in mines).
- Recent improvements in soil signal suppression (fielded systems).
- Appealing but challenging innovations: target identification and parameter estimation (e.g. target depth/size), imaging applications, and sensors other than coils.
- Complemented in humanitarian demining, when a real need exists (UXO only, or deeply buried UXO), by magnetometers, which measure the distortion of the Earth's magnetic field caused by nearby ferromagnetic objects.

Estimated technology readiness (enhanced MDs)

Medium-High.

Related publications

1. Guelle, D., A. Smith, A. Lewis, T. Bloodworth (2003)
Metal Detector Handbook for Humanitarian Demining, European Communities, Publication EUR 20837, 172 pp., ISBN 92-894-6236-1.

2. GICHD (2005)
Metal Detectors and PPE Catalogue 2005, Geneva International Centre for Humanitarian Demining, GICHD, Geneva, 166 pp., ISBN 2-88487-024-5, *www.gichd.ch.*

3. Das Y., J.T. Dean, D. Lewis, J.H.J. Roosenboom, G. Zahaczewsky (Eds) (2001)
A multi-national technical evaluation of performances of commercial off the shelf metal detectors in the context of humanitarian demining, International Pilot Project for Technology Co-operation, Final report, European Commission, Joint Research Centre, Ispra, Italy.

4. Gaudin C., C. Sigrist, C. Bruschini (2003)
Metal Detectors for Humanitarian Demining: a Patent Search and Analysis. EUDEM2 Technology Survey Report, November, v2.0, *www.eudem.info.*

2.1 Other low-frequency electromagnetic systems: Electrical Impedance Tomography Mine Detection System

Project identification

Project name	EIT Confirmatory Detector	**Start date**	April 2005
Acronym	EIT	**End date**	September 2006
Participation level	National (Canada)	**Technology type**	Low frequency electrical currents
Financed by	DRDC Suffield	**Readiness level**	●●●●●⑥●●●
Budget	CAD400,000	**Development status**	Ongoing
Project type	Technology development, Technology demonstration	**Company/institution**	Neptec Design Group

Project description

An evaluation prototype was built and tested in the late 1990s in realistic conditions to assess the potential use of **Electrical Impedance Tomography** (EIT) technology as a confirmatory detection modality. The early evaluations revealed that the EIT technology is particularly efficient in wet, shallow environments such as those found in ocean littorals, marshes and agricultural fields. A second project phase was started to improve the instrument and algorithms, and also extend its field evaluation to wet environments.

Detailed description

EIT is a technology developed to image the electrical conductivity distribution of a conductive medium. The technology is of interest because of its low cost and also because the measurement of the electrical conductivity brings direct information about the composition of the conductive medium. Since the ground is conductive to a certain extent, the technology can also be used to detect buried objects. The application of landmine detection is of particular interest because the object is usually buried at shallow depths and causes a discontinuity in the soil conductivity that can be sensed from the ground surface.

EIT uses low-level electrical currents to probe a conductive medium and produce an image of its electrical conductivity distribution. While a pair of electrodes is stimulated, the electrical voltage is measured on the remaining pairs of electrodes. After all the independent combinations of interest have been stimulated, an algorithm using the measured data reconstructs an image of the electrical conductivity distribution within the volume. In the case of ground probing, an array of electrodes is placed on the surface of the ground to provide an image of the conductivity distribution below the surface. In the case of a shallow underwater application, an electrode array is immersed in the water to probe the sediment layer. The EIT technology will detect mines buried in the ground/sediments by detecting electrical conductivity anomalies. The presence of a metallic or non-conductive mine will disturb the conductivity distribution in the soil. The signal characteristics are based on the size, shape, conductivity and depth of the buried mine.

Figure 1 below shows an EIT detector prototype optimized for the detection of anti-tank landmines. A typical EIT detector has three major components: the electrode array, the data acquisition system and a data processing unit. In this case the electrode array comprises 8 columns and 8 rows of electrodes, for a total of 64 electrodes. The electrodes are spring-loaded and can adjust with terrain variations. The data acquisition system incorporates the electronics and firmware required for the electrical stimulation of the electrodes and the recording of the resulting potentials.

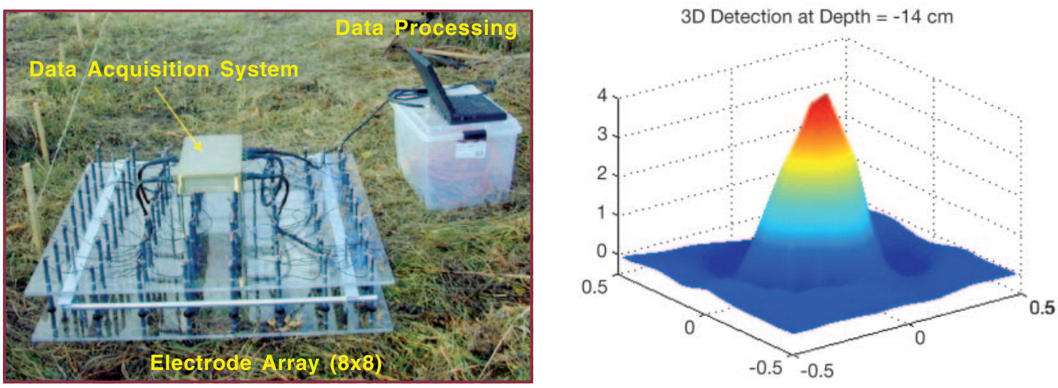

Figure 1. The EIT detector prototype and its response to an anti-tank-mine-like object buried at a depth of 14cm.

Test and evaluation

On the ground

The EIT detector prototype was evaluated at Defence R&D Canada Suffield, using anti-tank mine surrogates. Evaluations have assessed the maximum detection depth, spatial resolution and response to various anti-tank mine types.

Using the 1m^2 footprint detector, typical anti-tank-mine-like objects can be detected at depths of the order of 20cm. The detector has shown a capability to resolve the presence of more than one anti-tank-mine-like object down to depths of about 14cm.

Tests were conducted at the Defence R&D Canada (DRDC) Suffield Mine Pen facility. The first set of experiments was performed on a hard-packed gravel road containing various buried landmines. The EIT detector was used to image several inert anti-tank mines buried at depths ranging from 6 to 16cm. Examples are shown below. Tests conducted with anti-tank mine surrogates in a different part of the field were inconclusive due to factors that are not yet fully understood. There are currently not enough statistical data to define the detection and false alarm characteristics of the detector.

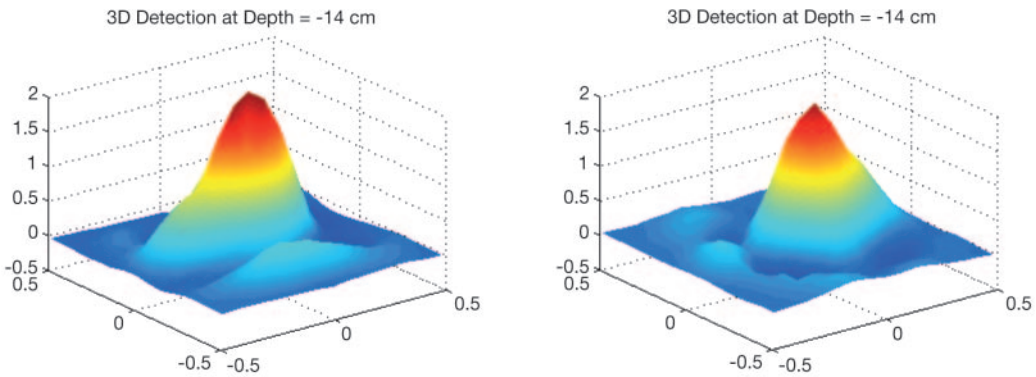

Figure 2. (Left) Detector response for a TMA3, buried at a depth of 6.4cm and (right) detector response for a M15, buried at a depth of 16.5cm.

Under water

The EIT technology has been evaluated under water in a laboratory environment. Figure 3 illustrates an experimental underwater electrode array detecting anti-personnel-mine-like objects buried under water in a layer of sand. The early results have shown it is possible to detect and discriminate mine-like objects buried in sediments such as sand, under a layer of water. Further research is being conducted with DRDC Suffield to develop additional algorithms, build an underwater electrode array, and perform field tests.

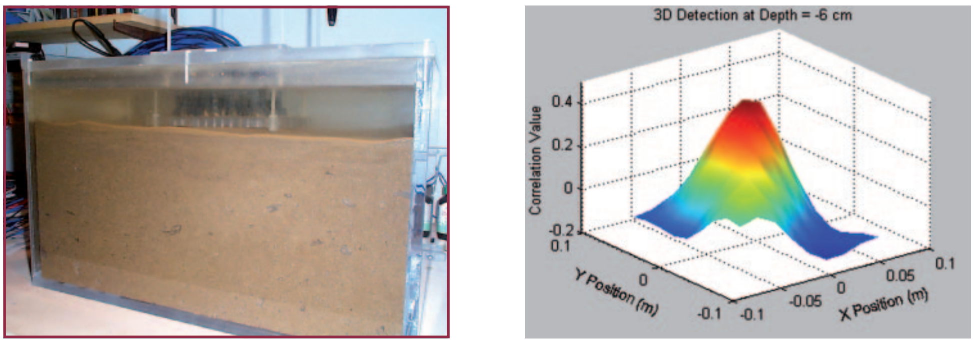

Figure 3. Laboratory evaluation of an underwater electrode array with corresponding detector response for an anti-personnel-mine-like object buried 6cm in the sand layer.

Other applications (non-demining)

EIT can be used for other geophysical-related applications, such as detection of a pollution plume seeping in the ground or detection of man-made tunnels.

Related publications

1. Church P., J. McFee (2004)
   "Laboratory Evaluation of the EIT Technology Capability to Detect Mines Buried in an Underwater Sediment Layer", *Proceedings of SPIE Conference on Detection and Remediation Technologies for Mines and Mine-like Targets IX*, Vol. 5415, pp. 342-350, Orlando, US.

2. Church P. (2003)
   "Electrical Impedance Tomography", in *Alternatives for Landmine Detection*, MacDonald et al, pp. 161-168, RAND.

3. Church P., P. Wort, S. Gagnon, J. McFee (2001)
   "Performance Assessment of an Electrical Impedance Tomography Detector for Mine-Like Objects", *Proceedings of SPIE Conference on Detection and Remediation Technologies for Mines and Mine-like Targets VI*, Vol. 4394, pp. 120-131, Orlando, US.

4. Wort P., P. Church, S. Gagnon (1999)
   "Preliminary Assessment of Electrical Impedance Tomography Technology to Detect Mine-like Objects", *Proceedings of SPIE Conference on Detection and Remediation Technologies for Mines and Mine-like Targets IV*, Vol. 3710, pp. 895-905, Orlando, US.

Technical specifications	*Neptec Design Group, Electrical Impedance Tomography Mine Detection System*
1. Used detection technology:	Low frequency electrical currents
2. Mobility:	Man portable
3. Mine property the detector responds to:	Size, shape and conductivity
4. Detectors/systems in use/tested to date:	Experimental system
5. Working length:	—
6. Search head:	
➢ size:	1m^2
➢ weight:	47kg (experimental unit)
➢ shape:	square
7. Weight, hand-held unit, carrying (operational detection set):	47kg
Total weight, vehicle-based unit:	50kg
8. Environmental limitations (temperature, humidity, shock/vibration, etc.):	Very dry soil
9. Detection sensitivity:	TBD[a)]
10. Claimed detection performance:	
➢ low-metal-content mines:	Yes
➢ anti-vehicle mines:	Yes
➢ UXO:	TBD
11. Measuring time per position (dwell time):	< 10 s
Optimal sweep speed:	—
12. Output indicator:	Laptop
13. Soil limitations and soil compensation capability:	Very dry conditions
14. Other limitations:	—
15. Power consumption:	1.5W
16. Power supply/source:	Battery
17. Projected price:	TBD
18. Active/Passive:	Active
19. Transmitter characteristics:	—
20. Receiver characteristics:	TBD
21. Safety issues:	None
22. Other sensor specifications:	—

a) To be defined.