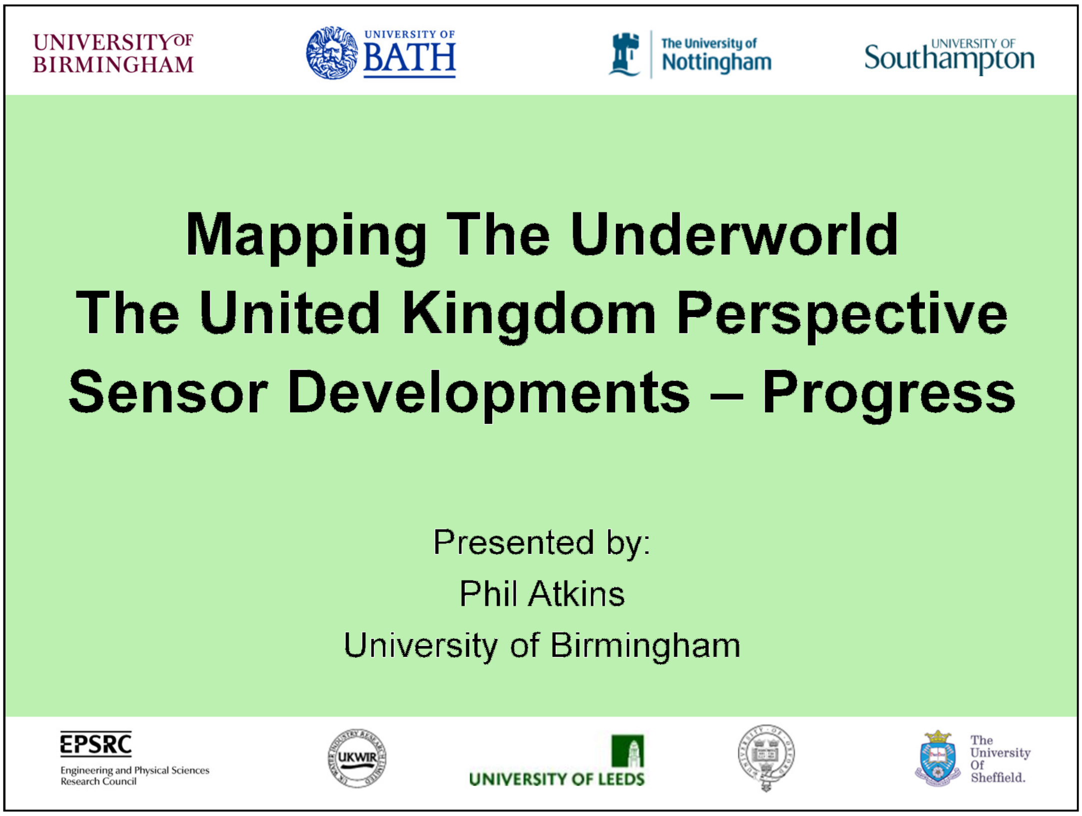


This presentation reports on the progress made during the first year of the Mapping the Underworld project. As multiple Universities and Departments are involved with the project, a single speaker will attempt to report for all parties. Only progress on a selected number of work packages will be presented – please visit the research posters for more details and for coverage of related areas.

Reminder:

To combine the outputs of four geophysical sensors to improve the 'Probability of Detection' and location of buried utilities.

The sensor technologies are:

Ground Penetrating Radar

Acoustics

Low-Frequency Electromagnetic Fields

Passive Magnetic Fields

To remember that many have said this task is impossible.

The sensors component of the Mapping the Underworld project attempts to fuse the outputs from multiple, disparate sensors in an attempt to improve the Probability of Detection (a term used in the radar, sonar and communication fields) of a buried asset.

The University of Bath is examining bi-static and multi-static ground penetrating radar systems (where the transmitter may be located within a pipe). The University of Southampton, Institute of Sound and Vibration, is examining acoustic methods for detecting buried assets. The University of Birmingham, Electrical Engineering, is examining low-frequency electromagnetic systems – borrowed from the archaeological and earth sciences community. The University of Southampton, Electrical Engineering, is examining the fields generated by 50Hz power cables as a detection mechanism. The University of Birmingham, Civil Engineering, is examining the effects of soil properties and their impact on operating procedures. Meanwhile, the University of Leeds is fusing the data from all the different sensors.

The overall aim is to be able to detect 100% of all buried assets. This aim is considered to be 'overly optimistic' by many practitioners.

A realistic scenario:

Initial reaction = No Chance (when looking down)

Unless looking for train tunnels

Or

Excavate

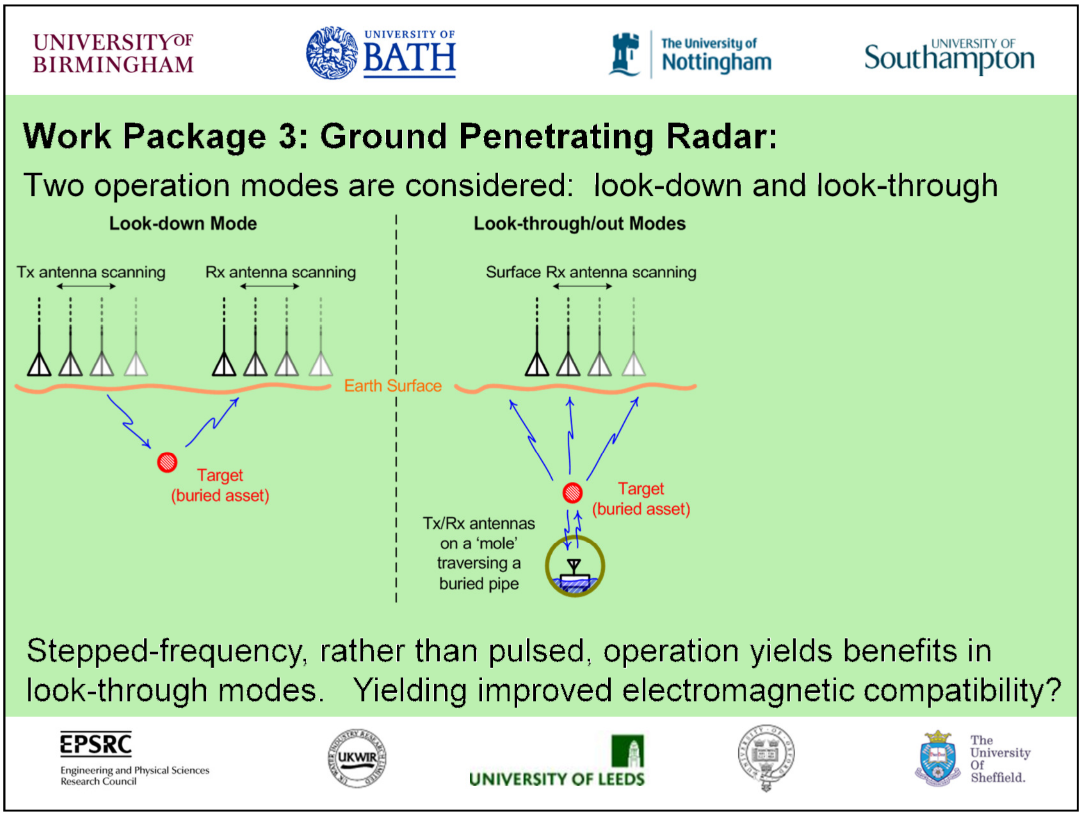
Guaranteed to be expensive

But: Expense leads to creativity …………

Any photograph taken in a United Kingdom urban environment will show a mass of shallow-buried telecommunications and road-furniture cables near the surface. Looking through these cable and their associated trunking systems will obviously be difficult, or even impossible. However, large targets such as train tunnels and large sewers may be visible through this type of 'clutter'.

Other methods of detecting assets buried beneath the telecommunications cables include excavation. Whatever method is used, it is likely to be time consuming and expensive.

However, once the true level of expense is understood, there may be other approaches.



The University of Bath is examining alternative ground penetrating radar configurations. These include bi-static and multi-static systems (where the transmitter may be located within a pipe).

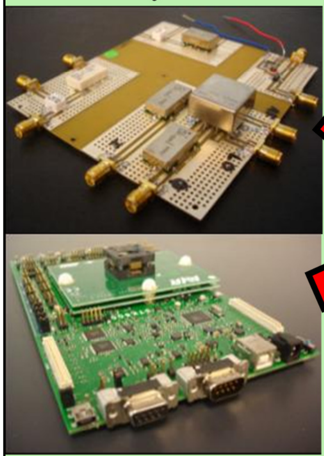
A conventional ground penetrating radar system is operated in a mono-static mode (where the transmitting and receiving antennas are located at the same position and are moved together). As a nominal operating depth is often of the order of one metre, a potential increase in range might be obtained by placing the transmitter in a sewer pipe (at a depth of perhaps 2m) and looking through the ground to a receiver placed at the surface. This scenario is called a bi-static geometry. Obviously, a receiver could also be placed in the pipe – yielding a look-out mode of operation.

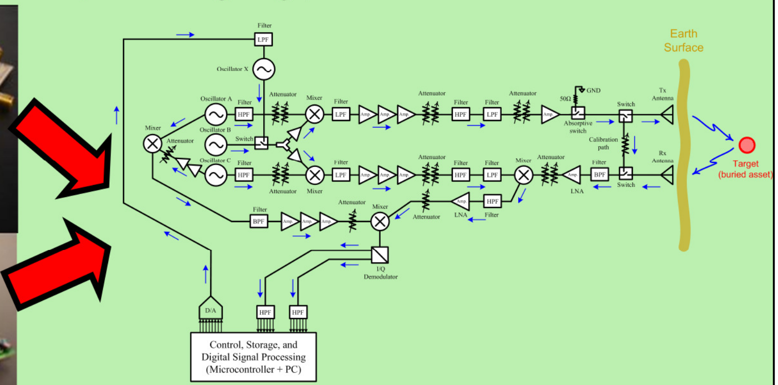
The majority of conventional ground penetrating radar systems use short, high-energy transmission pulses. Particularly in the look—through case, there are considerable gains to be obtained from using long, low-power transmissions that are stepped in frequency. Such systems may be required in future in order to meet emerging electromagnetic compatibility requirements.

UNIVERSITY OF BIRMINGHAM · UNIVERSITY OF BATH · The University of Nottingham · UNIVERSITY OF Southampton

Ground Penetrating Radar - Progress

The first year has been spent designing printed circuit boards.





Laboratory testing and evaluation is currently underway.

EPSRC Engineering and Physical Sciences Research Council · UKWIR · UNIVERSITY OF LEEDS · The University Of Sheffield.

The University of Bath has been developing a generic, broad-band transmit-receive system for use within a ground penetrating radar. Prototype printed circuit boards have been constructed and tested. The usual engineering design flow involving multiple re-working of all stages is currently underway.

Work Package 4: Acoustics:

Two operation modes are considered: directly exciting the pipe and exciting the surrounding ground.

Inertial shaker

Geophones

Rayleigh (surface waves) waves are good for detecting shallow buried assets; shear waves are preferred for deeper objects. New exciters and receivers are being developed.

The University of Southampton, Institute of Sound and Vibration, is examining the feasibility of detecting pipes using acoustic methods. Two approaches are being considered.

The first method directly excites the pipe at a convenient access point (valve, etc) and detects the vibration radiated from the pipe to the surface. This techniques has been found to be effective in detecting pipe runs. Improved location accuracy has been obtained by making use of the phase of the received signal, as opposed to considering only the amplitude.

The second method excites the ground in the vicinity of the pipe and aims to detect reflection and scattering from the pipe. The presence of multiple wave-types and propagation paths makes this technique more challenging to implement in practice.

Encouraging progress has been achieved on many fronts.

A small test rig has been buried that allows pipe excitation either at the surface, or by means of a new generation of in-pipe exciter.

A variety of non-contact laser receiving systems are being compared against the traditional geophone receiver. Should such systems prove to be a viable alternative to geophones over a wide range of surface cover materials, the survey speeds may be increased dramatically.

Work Package 5: Low-Frequency Electromagnetics:

The aim is to replicate the successes of the archaeological community when using earth resistivity measurements.

Non-contact capacitive coupling of AC signals is used to increase survey speed.

The aim is to complement GPR by detecting small, very-shallow and large, deep assets.

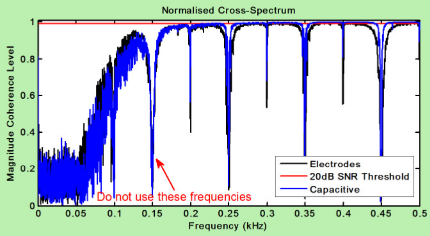
The University of Birmingham, Electrical Engineering, is developing non-contact resistivity survey techniques. This programme aims to capitalise on the successes achieved within the archaeological community with their very slow and laboriously deployed arrays of electrodes. The aim is to complement ground penetrating radar systems by detecting small, shallow-buried and large, deep-buried assets.

For shallow-buried objects, a conventional Wener array is moved with the survey cart in order to measure resitivity anomalies. For deep-buried objects, a dipole-dipole array is deployed with the transmitting dipole formed using 'leave-behind' cable-protection trunking located at either end of the street.

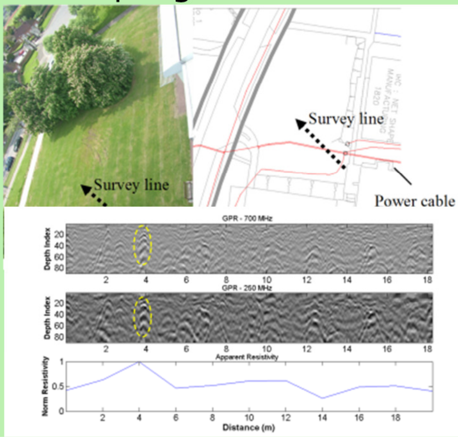
The sensing systems are also to be used to detect streaming potentials caused by geophysical self-potentials (possibly from leaking pipes).

Low-Frequency Electromagnetics - Progress

Simple field trials have revealed the difficulties of deploying such a system in practice e.g. stray fields from distant power cables and the need for dense spatial sampling.



Frequencies unusable due to power cables

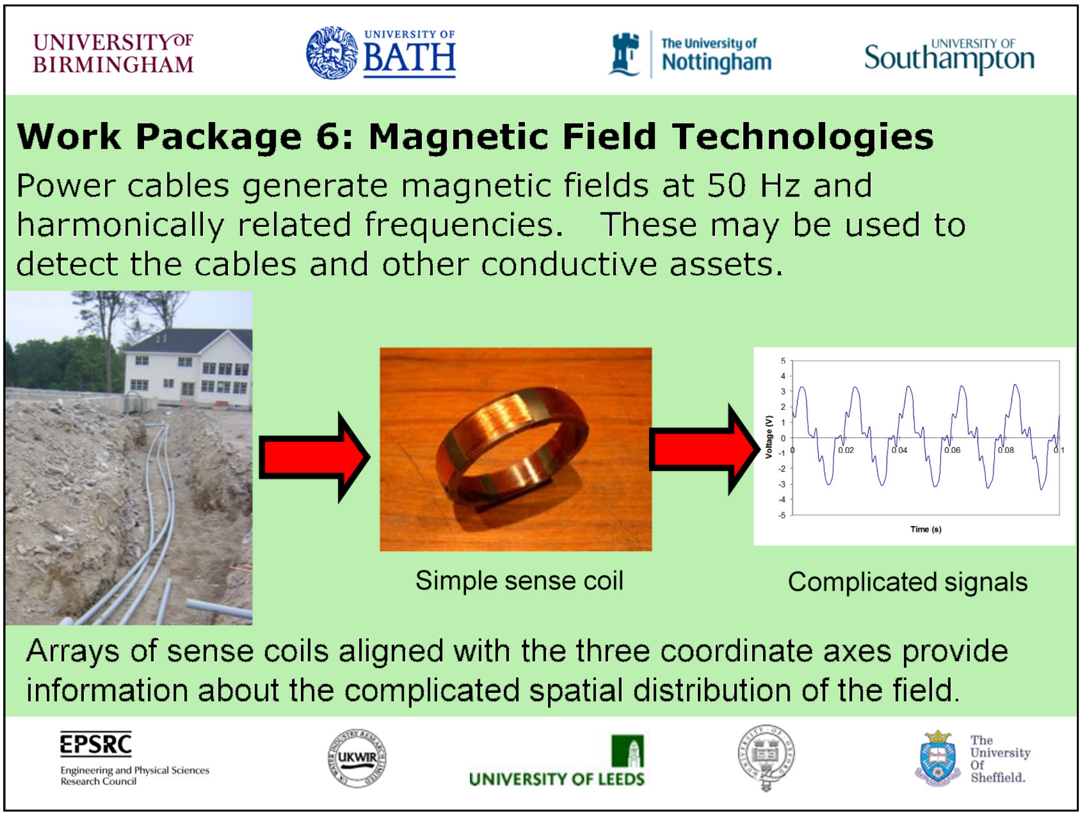


Automatic, adaptive techniques have been implemented to select appropriate signal frequencies.

The desire for rapid survey speeds implies that non-contact sensing systems are required. When low-frequency electromagnetic fields are employed, either the magnetic field (usually using sense coils) or the electric field (using capacitive plates) must be sensed. In this programme, the electric field is sensed using capacitive plates and very high input impedance signal amplifiers. Such sensors are susceptible to static electric fields and to power-line induced signals.

Automated procedures for sensing quiet regions of the electromagnetic spectrum have been developed. The transmitted signal energy is then concentrated within these quiet regions.

Initial field trials have been conducted in conjunction with a commercial GPR system, yielding encouraging results.



The University of Southampton, Electrical Engineering, is investigating the practicalities of using magnetic 'fields-of-opportunity' for detecting and locating buried assets. In this case, the fields are generated by power cables. Although the cable carries a notional 50Hz sinusoidal signal, in reality, this waveform will be contaminated by harmonics of the fundamental frequency.

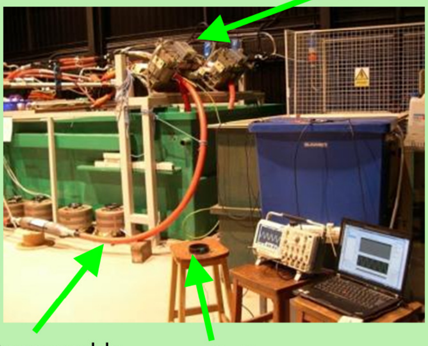
The fields may not only be used to more accurately locate a power cable, but also to detect the location of other conductive material such as pipes (normally seen as negative aspect of traditional CAT systems).

For this programme, an array of tri-axial sense coils aligned with the xyz coordinate system of the survey cart will be used to measure the spatial magnetic field.

Magnetic Field Technologies - Progress

Laboratory and field testing of the technique has been conducted.

Current transformer



Power cable

Coil

Both laboratory and field tests indicate that magnetic fields with a high signal-to-noise ratio may be sensed at large ranges from the cable.

Initial laboratory tests were based on the induction of a large current into a section of power cable using a current transformer. This was sensed using a coil and recorded using a digital storage oscilloscope.

Later field tests used a multi-turn magnetic field meter and a data acquisition system running on a laptop.

These tests indicated the need for orthogonally aligned sense coils and showed that significant signal levels were detectable from typical power cables.

Summary

- Significant progress has been demonstrated by the four geophysical sensing technology themes.
- The ground penetrating radar team have designed and substantially constructed a generic, broad-band radar system.
- The acoustics team have demonstrated the need to excite elliptical surface waves and have developed a new type of exciter. The non-contact, laser-based approach appears viable.
- The low-frequency electromagnetics team have conducted preliminary multi-sensor trials in conjunction with a commercial GPR – yielding the need for a major redesign of mechanical components.
- The magnetic field technologies team has demonstrated the detection and utilisation of fields in the street.