Mapping The Underworld (MTU): Vibro-acoustics

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Engineering and Physical Sciences Research Council

Mapping the Underworld

Background

Two novel acoustic techniques for locating buried service, in particular pipes, were proposed & examined experimentally in Mapping the Underworld phase 1.

Both techniques have been taken forward in the current phase

Technique 1: Direct excitation of the pipe

- Excite pipe directly at surface
  - Measure ground vibration as a result of energy radiated from pipe
  - Technique effective & pipe run can be found
    - Emphasis on the measurement of phase

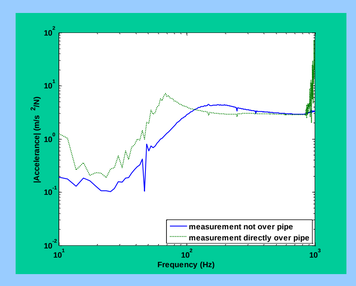
Technique 2: Excitation of the ground

- Excite ground above or in vicinity of pipe
  - Measure ground vibration as a result of energy scattered from pipe
  - Two configurations tested
    - Point vibration measurements, using vertical excitation (for shallow-buried infrastructure)
    - Array-based vibration measurements, using shear excitation (for deeper structures)

Adam Hart-Davis with Jen Muggleton and Chris Rogers at Blagdon, Feb 2012

Point vibration technique

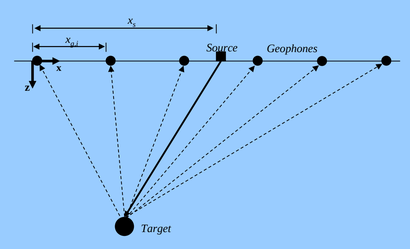
- Applicable when no direct access to the pipe is available
- At low frequencies, ground exhibits classic mass-spring behaviour with a well-defined resonance
- Changes in resonance frequency can be used to detect the presence of a buried object close to the surface
- Vertical excitation is applied at the ground surface at several points along a line and accelerance (acceleration/force) is measured at each point
- Potentially extremely quick to implement
- Has been used successfully to detect a number of shallow-buried services



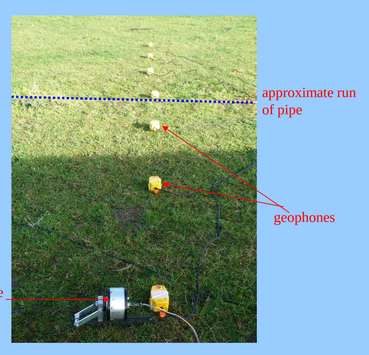
Two point accelerance measurements

Shear wave excitation technique

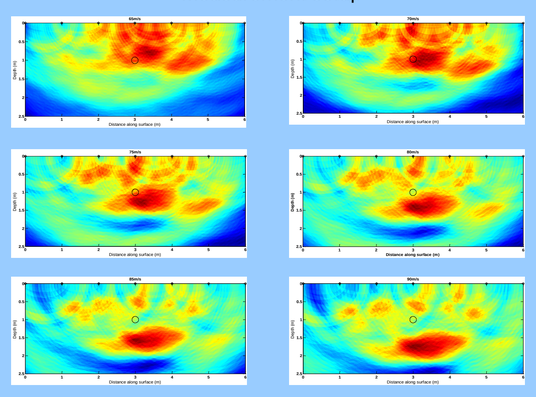
- Again applicable when no direct access to the pipe is available
- Directional shear waves generated at ground surface using exciter attached to rake (excitation direction is perpendicular to measurement line)
- Line of geophones used to measure ground surface vibration
- Generalized cross correlation functions used to extract time delay information
- Time domain stacking technique employed to generate cross-sectional images of the ground
- Method has been successful at detecting both plastic and metal water pipes and empty metal pipes



Measurement configuration

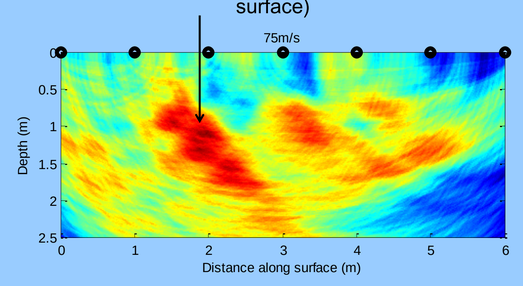


Measurement setup



Results for MDPE water pipe at Blithfield using six different wavespeed estimates
(the black circle indicates the location of the pipe)

Test site at Blagdon
(here the run of the main pipe and those of three service pipes can be seen on the ground surface)



Example result for empty cast iron pipe at Blithfield
(the arrow indicates the location of the pipe)

Pipe Excitation method

- Applicable when a buried pipe can be accessed from the surface (e.g. a fire hydrant)
- Exposed pipe is mechanically excited at low frequencies (<1kHz) resulting in waves that propagate along the pipe and in any fluid contained within the pipe
- The energy of these waves then radiates to the ground surface where it is measured, using geophones, and from which the location of the remainder of the pipe can be inferred
- Very successful for locating both plastic and metal water pipes, laid under grass and under tarmac.

Figure 1 shows an example result at a single frequency for an 18m MDPE water pipe. When using magnitude information alone, only the excitation point (at (0,0)) and the pipe end (at (0,18)) can be seen; the unwrapped phase clearly reveals the entire run of the pipe.

Figure 2 shows an example result for a cast iron pipe laid under a combination of grass and tarmac. Here too, the run of the pipe is clearly evident. Furthermore, in this plot, the waves radiating cylindrically out from the excitation point are also apparent.

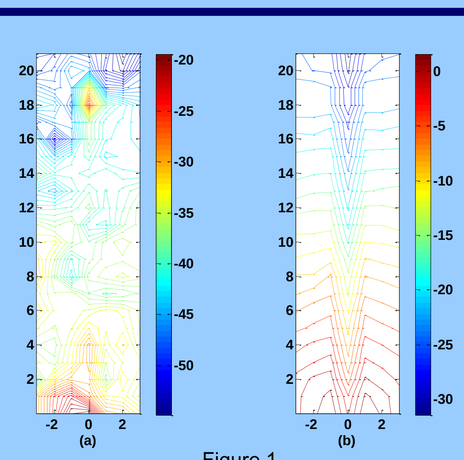


Figure 1
Contour plots of magnitude and phase of frequency response at 62Hz. (a) dB relative to velocity measured by geophone adjacent to excitation point, scaled by the square root of the distance from excitation point to measurement point; (b) spatially-unwrapped phase in radians. The x- and y-axes are in metres relative to the excitation location; the pipe runs up the centre-line in each plot

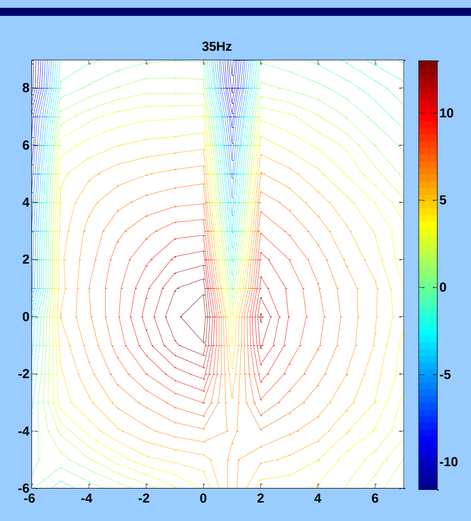


Figure 2
Contour plot of unwrapped phase of frequency response at 35Hz. The x- and y-axes are in metres relative to the excitation location

Summary and Future Work

- Results for all three techniques are extremely promising
- Together the three techniques constitute an innovative and powerful tool and a substantial step change in the way buried pipes can be detected using vibro-acoustic methods
- Assessing the Underworld aims to develop techniques to assess pipe condition remotely, without requiring sensors to be mounted on a pipe
- Potential avenues to explore will include extension of the techniques developed to date along with entirely new vibro-acoustic methods

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Website

Mapping the Underworld has a new website which was launched at the end of 2009, including a News feed and Blog to furnish you with regular web-based updates. This can be found at

www.mappingtheunderworld.ac.uk

Selected Publications:

J M Muggleton, M J Brennan and Y Gao, Determining the location of underground plastic water pipes from measurements of ground vibration, *Journal of Applied Geophysics,* 75 (2011), 54-61

J M Muggleton, M J Brennan and C D F Rogers, Point Vibration Measurements for the Detection of Shallow-Buried Objects. *Tunnelling & Underground Space Technology*, Special Issue 2012

J M Muggleton, B D Papandreou and M J Brennan, The detection of buried pipes using a shear wave technique, *Proceedings of the19th International Congress on Sound and Vibration*, 8-12 July 2012 , Vilnius, Lithuania.

J M Muggleton and J Yan, Wavenumber prediction and measurement for buried fluid-filled pipes: inclusion of shear coupling at a lubricated pipe/soil interface, *Journal of Sound & Vibration*, in press 2012

J M Muggleton and M J Brennan, the use of acoustics in the water industry, *Water and Sewerage Journal ,* Winter Edition *(*4), 35-36, November 2012

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