



# Assessing The Underworld

## An Integrated Performance Model of City Infrastructures



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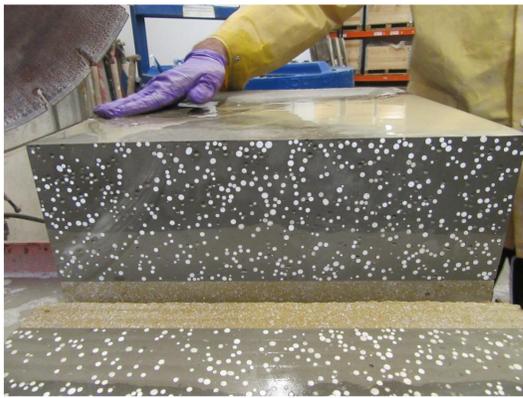
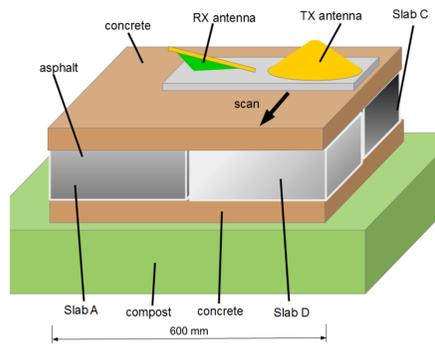
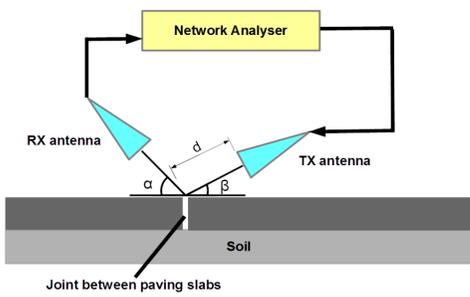
### WS3b – High Frequency Electromagnetic and GPR Techniques

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#### Crack and Void Detection in Pavement Structure

- Most scattering when antennas at 90° and 10° away from angles of incidence = reflection.
- Voids introduce a significant cross polarised signal. Cross polarised antennas are mutually 'isolated'.
- Little influence at traditional GPR frequencies below 1GHz, but observable scattering above 3 GHz. High frequencies limit depth of detection due to higher attenuation in the ground.
- Dielectric wedge antenna investigated - sensitive to laterally propagating cross polarised waves caused by voids in the ground.

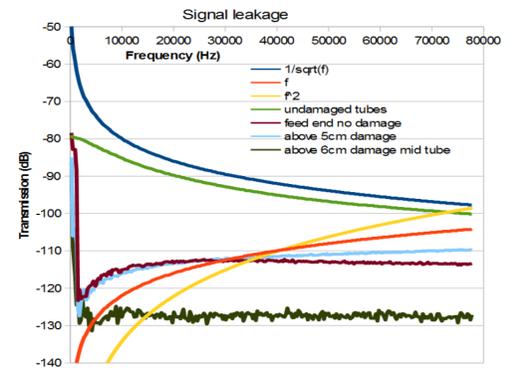
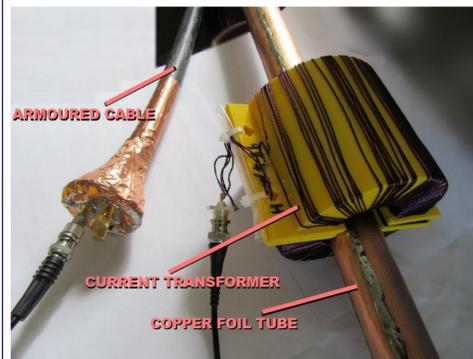
APPARATUS FOR DETECTING CRACKS IN PAVED SURFACE



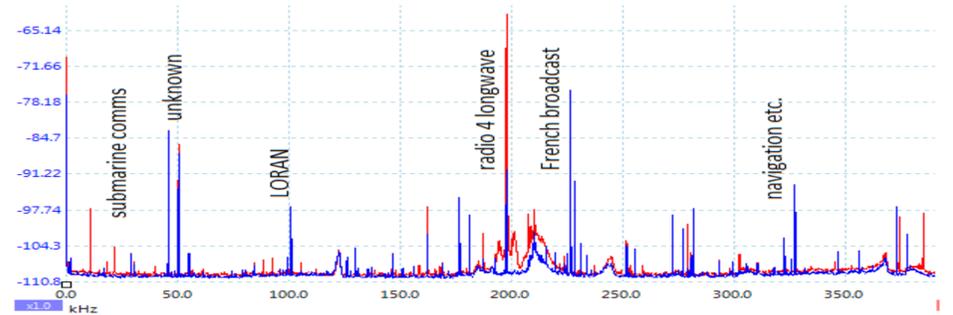
- Polystyrene balls, acting as voids, are mixed into cement, with random distribution.
- A problem was to remove unwanted air pockets.
- Air was removed from the mixture prior to pouring into the mold, by vibrating it out.
- Good results were obtained. The apparent air pockets here are where polystyrene balls have been dislodged from the surface.

#### Signals of Opportunity

- Measure the leakage of signals of opportunity through a metal shield to determine the integrity of the shield.
- A tube of thin copper foil and a coil are used to determine the transmission as a function of frequency and gap distance.
- An air-cored current transformer has been made which gives improved sensitivity compared to a simple cylindrical coil.

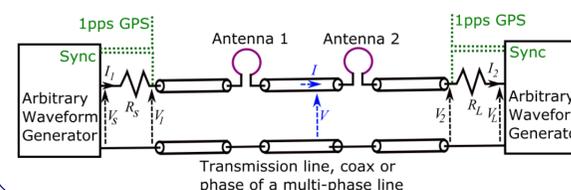
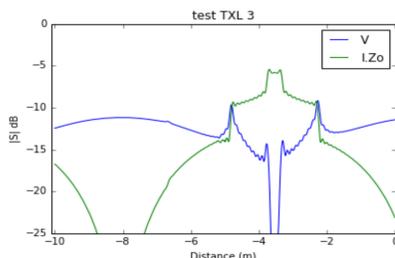
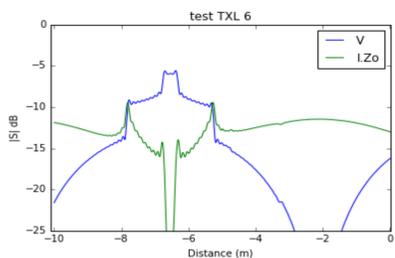
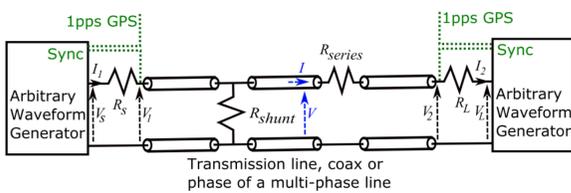


- For detecting lower frequencies (submarine, LORAN, medium wave signals) coils with high gain pre-amplifiers are used. In order to determine magnitude and direction the coils are 3-axis types. Three are used as a gradiometer.
- Sensitive from around 30 Hz to 2+ MHz (with improved amplifier).



#### Transmission Line Antenna Scanning

- Potential for rapid scanning along lengths of tens of metres of roadways and cable runs.
- Investigations have identified desired bandwidths and source signals.
- Proof of concept using cables with known resistances and leaky lines.



- Synchronised Arbitrary Waveform Generators used to produce standing wave patterns along a transmission line.
- Pulse shape along the line is controlled by the amplitudes and phases of the signals programmed into the ARB. Many sophisticated pulse shapes are possible, under software control.
- Maximising voltage across the line and minimising current flow along the line increases sensitivity to shunt resistance – for example where the cable insulation is deteriorating.
- Maximising current and minimising voltage increases sensitivity to series resistance – for example where cable conductors are deteriorating.
- Pulse shaping can selectively excite antennas mounted along the transmission line feed.

#### The Use of a Software Defined Radio as an OFDM GPR

##### SOFTWARE DEFINED RADIO (SDR)

- Commercial SDR offers ability to produce experimental platform for OFDM, Step Frequency, pulsed, and FMCW radar modes of operation.
- Proper phase coherence requires additional circuits.



##### AMPLITUDE AND PHASE MEASUREMENT

- Additional switch and attenuator path added to provide phase reference to measurements.
- Commercial Off the Shelf (COTS) components added, all under control from PC

##### RESULTS

- Measurements on SDR showed amount of internal break over encountered depends on choice of TX and RX units
- Correcting for the natural gain slope of the TX and RX units has produced measurements that compare favourably with those obtained on a commercial Network Analyser

