Mapping The Underworld (MTU) – Development of a Multi-Sensor Device

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The MTU Multi-Sensor Mobile Laboratory

The MTU multi-sensor project investigates the use of several sensors to improve target detection and potentially target identification. In fusing the data outputs from the individual sensors it is important that the positions of the sensor heads are known, and in particular their mutual co-location. Only with this information can the outputs of the sensors be co-located. In order to reduce co-location uncertainty a multi-sensor Mobile Laboratory has been created where three of the sensors are physically mounted on the same frame at positions that can be measured to within a few millimetres. The Mobile Laboratory also holds all the computers and other instrumentation for the 'scientific' tests undertaken to prove and assess ideas.

The only significant mutual interference problem encountered was with the magnetic detection. The coils needed to be more than 0.7m from the rest of the Mobile Laboratory.

External sources in the vicinity of the sensors will create interference. Hence care needed be taken to ensure that current carrying cables, high amplitude acoustic or RF sources were excluded by 1m-2m.

The position of the Mobile Laboratory is established with respect to a fixed target board using laser rangefinders.

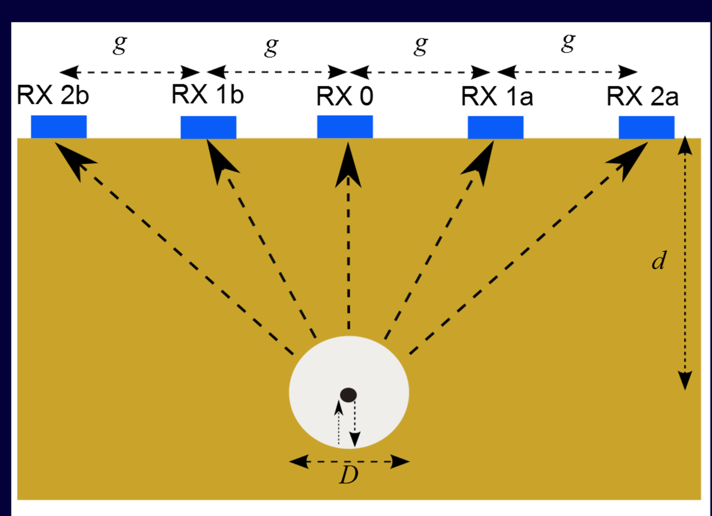
The position of the target boards are determined using a Total Station

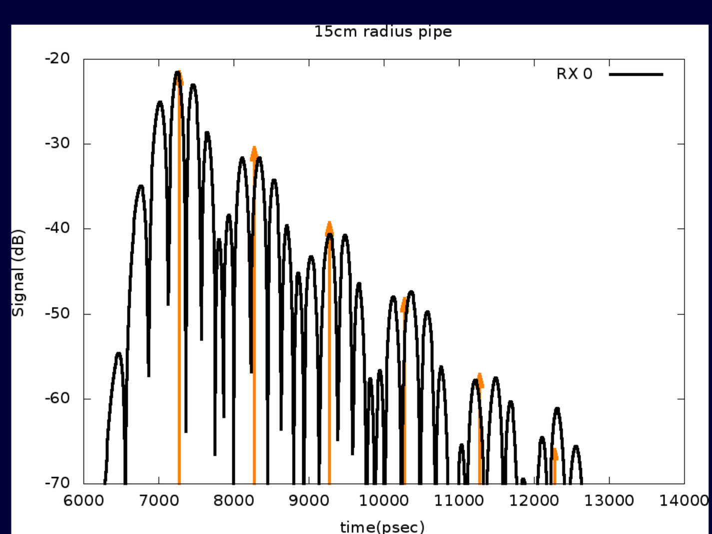
In pipe investigations

Tests using the SFCW experimental radar have been carried out at Bath and Wigan test sites where access to buried pipes has been made available.

Dielectrically loaded bicone antennas were used, with a 10cm diameter and 25cm length to fit inside standard drain/sewer pipes.

Finite Difference Time Domain analysis revealed that the multiple echos set up by having an antenna in a pipe could be very easily modelled assuming that the effective dielectric constant within the pipe is the average of the air filling the pipe and the ground surrounding it. An example from the analysis is shown to the right where the simulated radar waveform in black is compared to the orange impulse response which coincides very well with the peaks in the simulated radar responses. Knowing the impulse response allows for dimple deconvolution of the signals into single responses at clearly identifiable time delays.



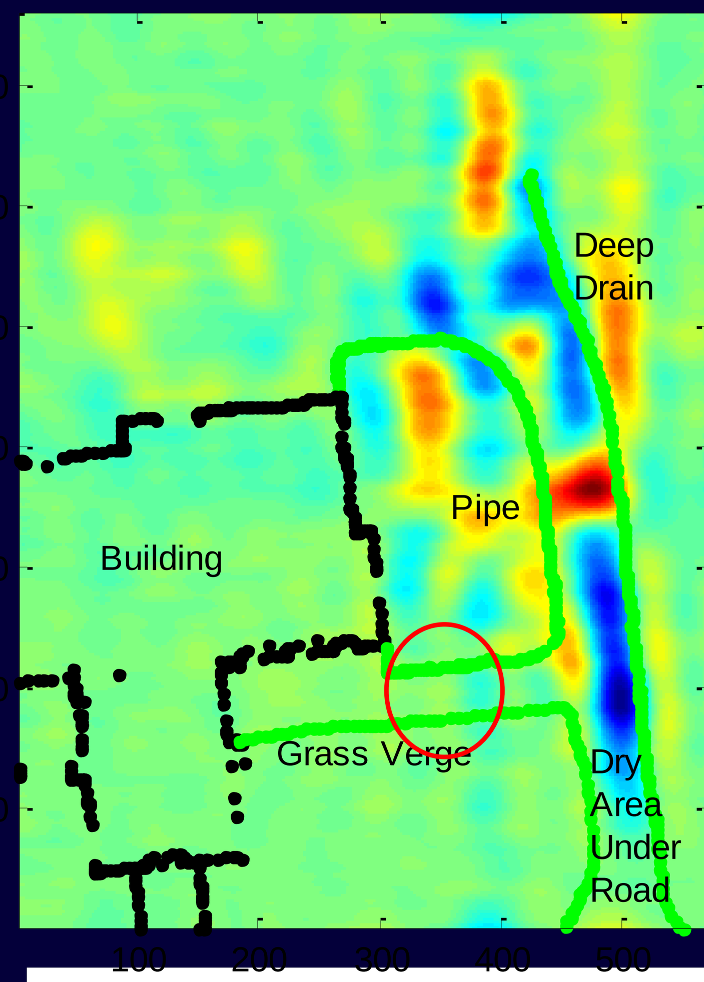


Results from the Bath sandpit with the SFCW radar indicated a relative permittivity of 6.2, while examination of b-scans from a commercial GPR suggested a relative permittivity of about 6. Similarly tests at Wigan produced a relative permittivity of 7.4 with the SFCW radar and 8 from the commercial GPR.

The determination of relative permittivity of the ground from the through ground measures facilitates the focussing of all GPR images. In addition it provides a real measure of the permittivity at positions in the street to compliment the data available from the Knowledge Based System.

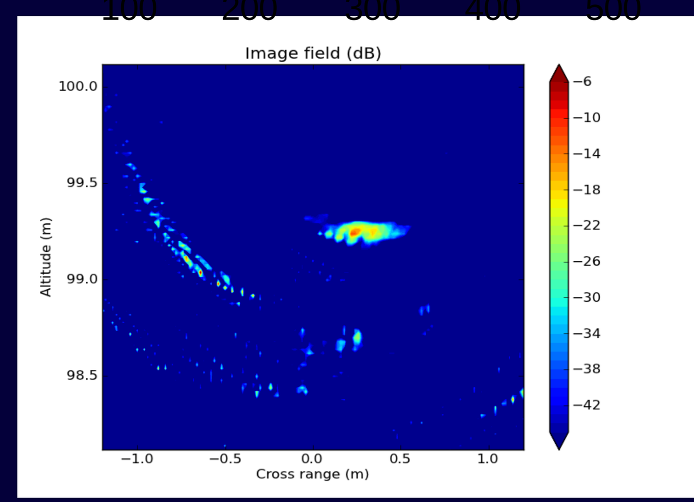
Example measurement with the MTU Multi-Sensor Mobile Laboratory

Measurements were taken at Blagdon, using the MTU sensor packages: Low Frequency EM, SFCW-GPR, Magnetic and Acoustic. Their individual outputs are shown in that order to the right.

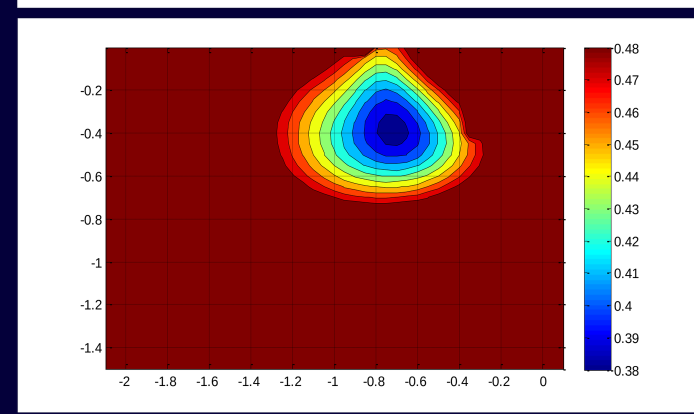


Low Frequency EM: this gives a wide area picture, with the small area of detailed observation for the other sensors circled in red. Within this area there is an indication of a target running across the road in between the grass verges.

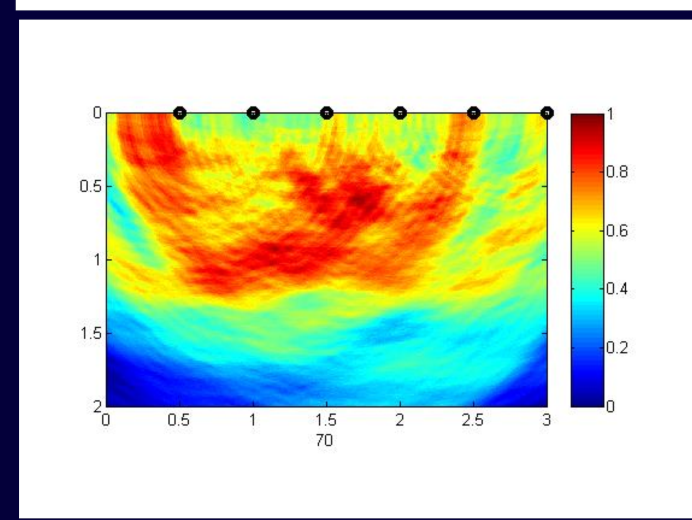
SFCW-GPR: The target focusses well here to an indicated spot that is less than 10 cm across. The indicated target depth is near 0.7m. Other potential target responses are apparent, but these are very small and may well be artefacts of the signal processing strategy being used.



Magnetic: The blue area indicates a target depth of 0.4m with a spot that is 20cm across. This provides a measure of the target, and, indicates that it is carrying a 50 Hz current.



Acoustic: The dark red area indicates a target depth of 0.7m, although there are other potential target responses. Again these may be artefacts of the signal processing strategy being used.



Note: The GPR antennas, Acoustic geophones and Magnetic coils have been relatively well spaced apart at 0.2m to 0.5m. With the signal processing strategies applied here good images of the buried targets have been obtained. This produces an output that is rather easier to interpret than traditional hyperbolic B-scan traces.

Such 'sparse' sensor positioning results in a lower density of data capture, much less than typically used in commercial GPRs for example. It is interesting to consider how, with faster data capture and careful design of the sensor arrays, much wider area mapping might be achieved at speed.

Data Fusion at Bath

The multi-sensor approach produces similar representations of targets from the different sensors. Fusing these together can enhance the identification of the location of the target.

The example in the adjacent figures shows two simulations of radar traces for measurements taken on relatively closely spaced sections over a target run. The straight target produces a consistent response while the clutter (stones, voids, etc) targets appear at irregular positions.

Fusing the upper two images produces the third image. The main target in the centre is enhanced. Much of the clutter is reduced, and the clutter at similar positions in the two original frames is resolved into individual responses.

The fusion technique should be equally effective when combining data from multiple sensors, provided they are properly co-located and provide the same sense of response at a target.