Digitalising the subsurface:

the way to a (under-the) Street view for underground utilities

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Subsurface Utility Engineering

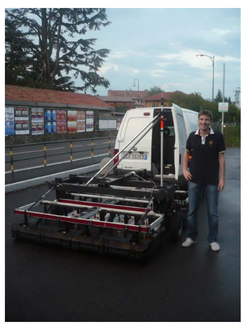
Subsurface Utility Engineering is an engineering discipline that manages **the risks of utility mapping**, which primarily includes activities such as the assessment, relocation and design of utilities.

Utilities are mostly located within the first layer of the subsurface and they represent a relevant **physical assets existing underground**. Including the underground in urban planning to address urbanisations and cities growth represents an obvious, though fundamental, development opportunity.




The role of technology: Ground Penetrating Radar

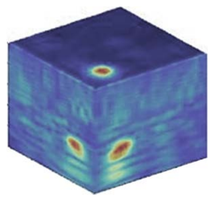
Among all the available technologies, **Ground Penetrating Radar** can be safely considered as the **principal method of choice**, as it provides a number of advantage over alternative technologies.

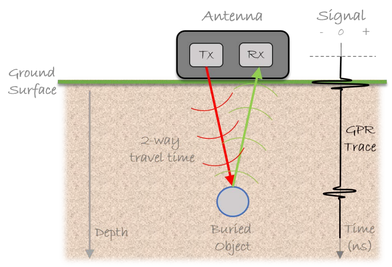


It is based on recording the delay and energy of electromagnetic signals scattered and reflected at **underground disturbance**, which are associated to differences in **materials** or differences in material properties, thus allowing to identify where the utility is located and a number of **additional features**.

The primary benefits of GPR are:

- Highly **accurate**.
- It can locate both metallic and **non-metallic** utilities.
- Non invasive, **rapid** and flexible.
- Economically viable
- High-resolution, **3D imagery**



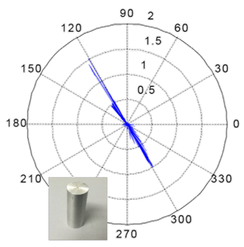


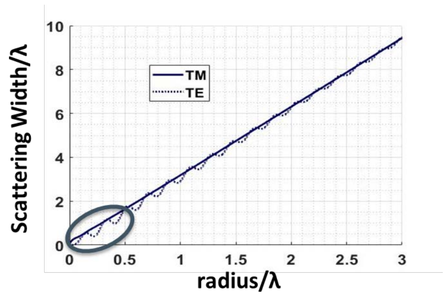
Polarisation as the enabler for visibility

Full 3D reconstruction performance can be corrupted when acquiring across **directional features** and hence the detection or missing of a specific target can be managed through its polarimetric response.

Polarisation is a parameter describing the magnitude and direction of electromagnetic field as a function of time and space.
It represents a **unique feature** of the technology intrinsic in the vectorial nature of the EM wavefield, affects how a radar system **perceives the objects in the scene**.

This provides the GPR technique an opportunity for producing improved images of objects in the subsurface, together with the possibility of planning an effective survey.





Thus, **polarisation-dependent scattering properties** have important implications for target detection, survey design, and data interpretation

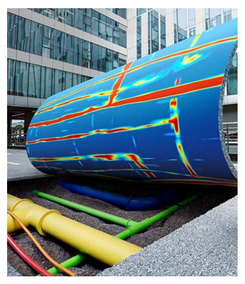
Benefits from underground awareness

Protect underground utilities.

Ensure workers safety.

Ensure services continuation.

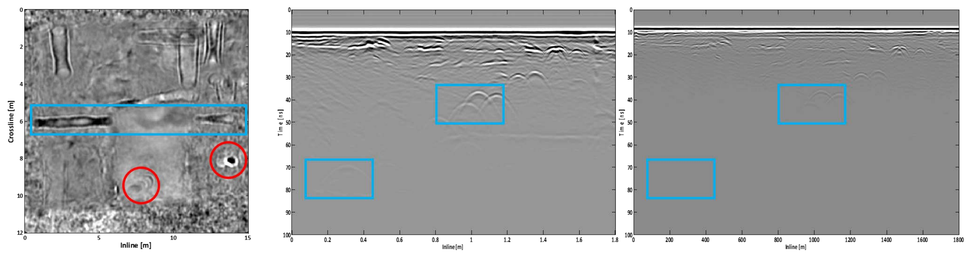
Save time and avoid delay.



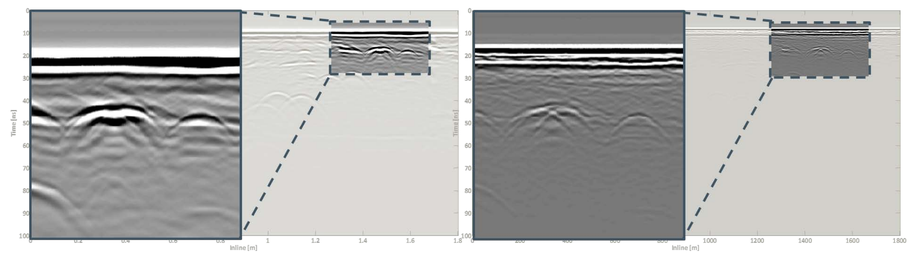


Mapping the underground maze

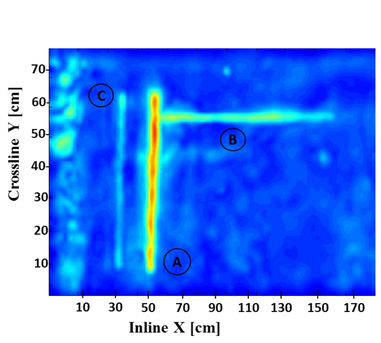
Absorption: recording the deepest pipe

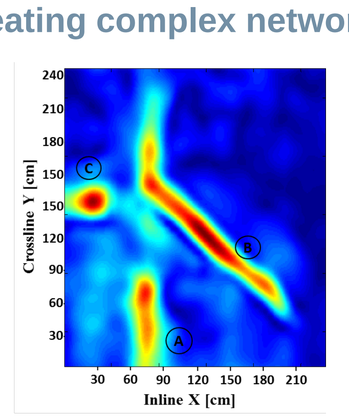


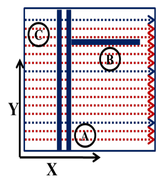
Resolution: differentiating the smallest pipe

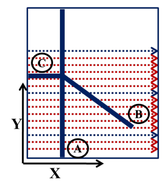


Spatial Sampling: delineating complex network



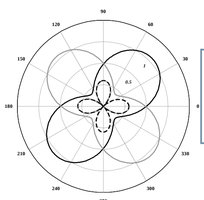






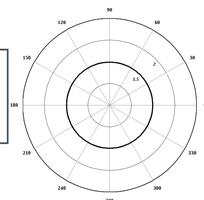
Taking advantage of a polarisation mismatch

Combination of mutually orthogonal data

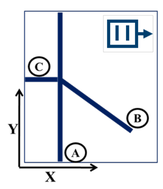
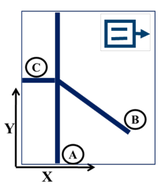
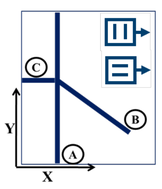


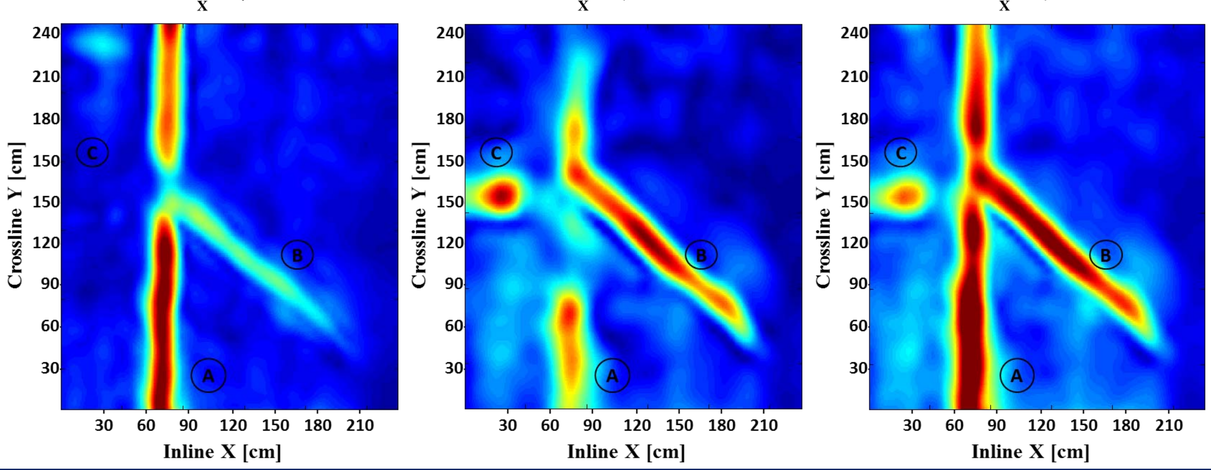
$$S = \begin{bmatrix} S_{xx} & S_{xy} \\ S_{yx} & S_{yy} \end{bmatrix}$$

$$S^{C}(t) = \begin{bmatrix} S_{xx} + S_{yy} & 0 \\ 0 & S_{xx} + S_{yy} \end{bmatrix}$$



Network geometry



Target material