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## Parametric pipe detection on the urban site Sense-City using Ground-Penetrating Radar (GPR)

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### Objectives

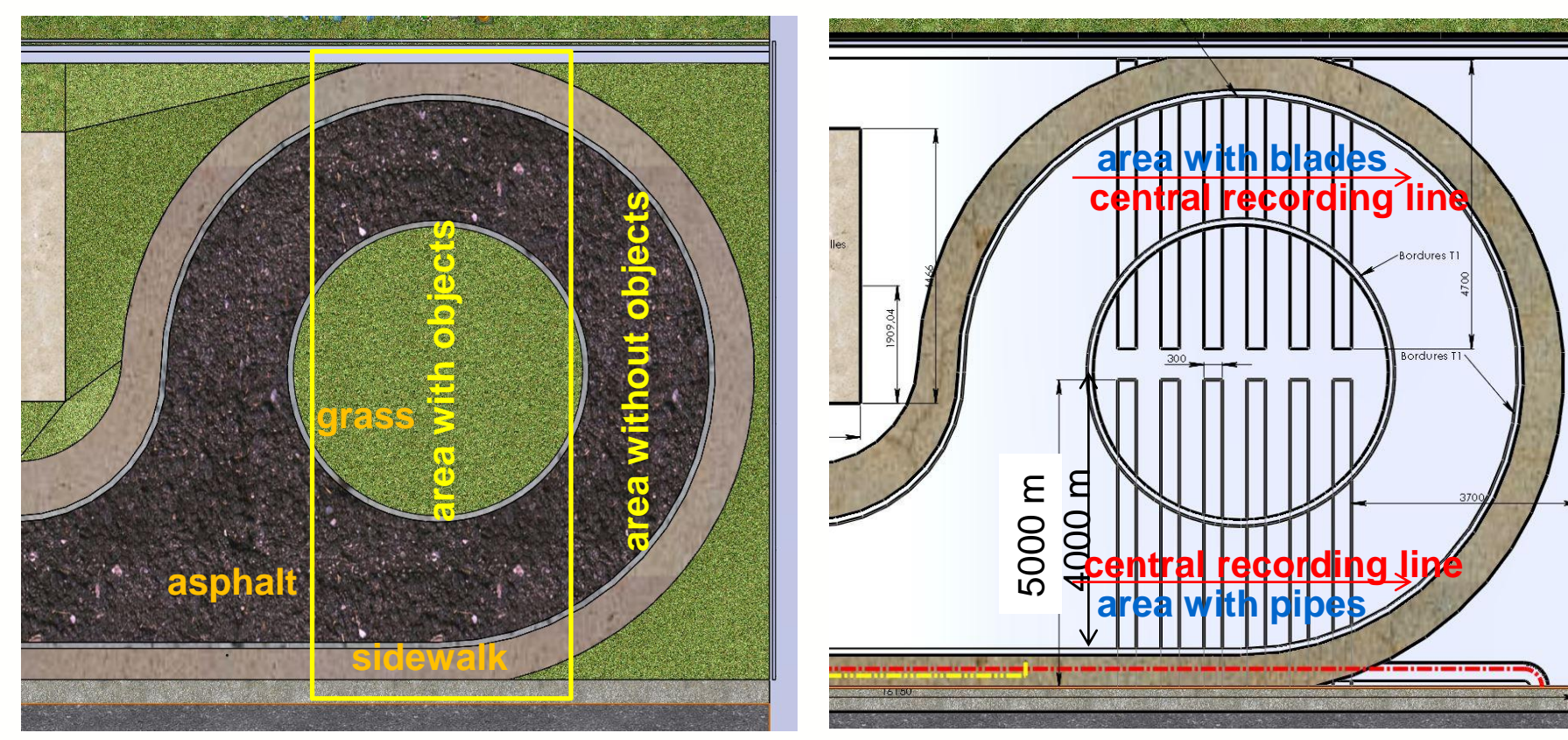
- Mapping the underground in a urban landscape with a non-destructive technique using electromagnetic waves to detect dielectric discontinuities
- Parametric detection of dielectric and conductive utilities with relative small diameters buried in different types of soils (nature, composition, moisture content) using ground-coupled georadars at several frequencies in the band [0.3;4] GHz
- Development of signal and image processing techniques for clutter removal, hyperbola detection and fitting, object and soil characterization

### Experiments in the test site Sense-city

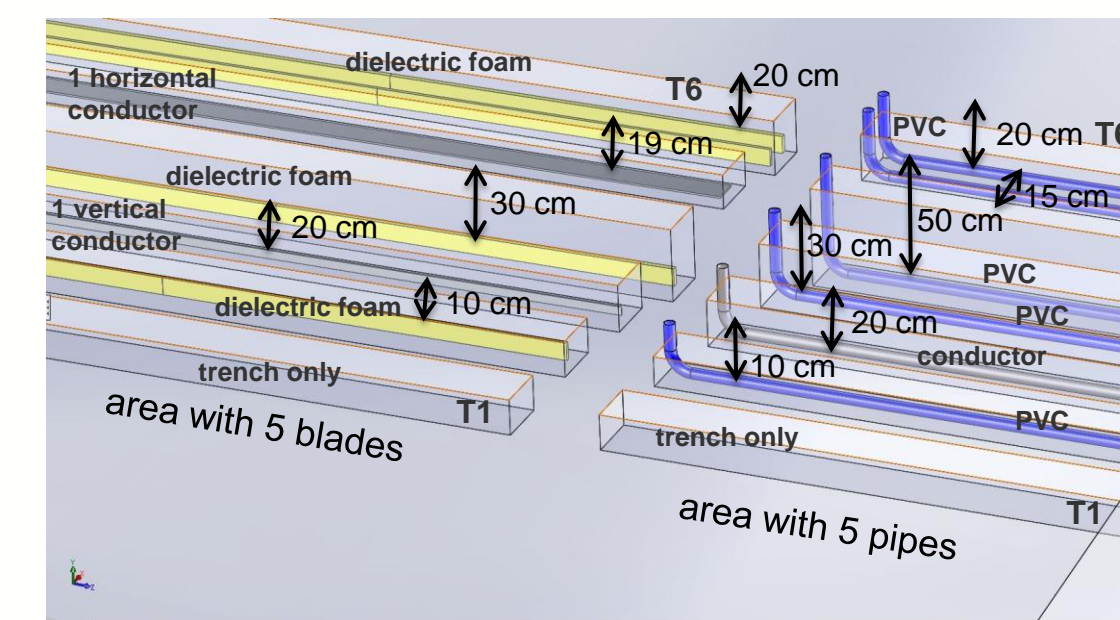
General view of the mini-city test bed



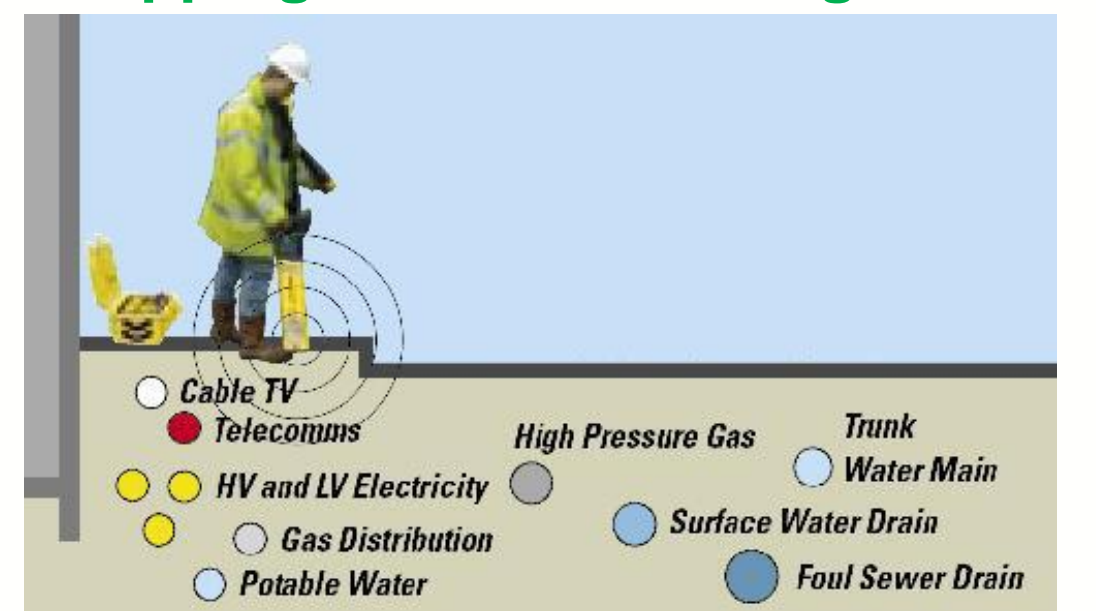
Top views



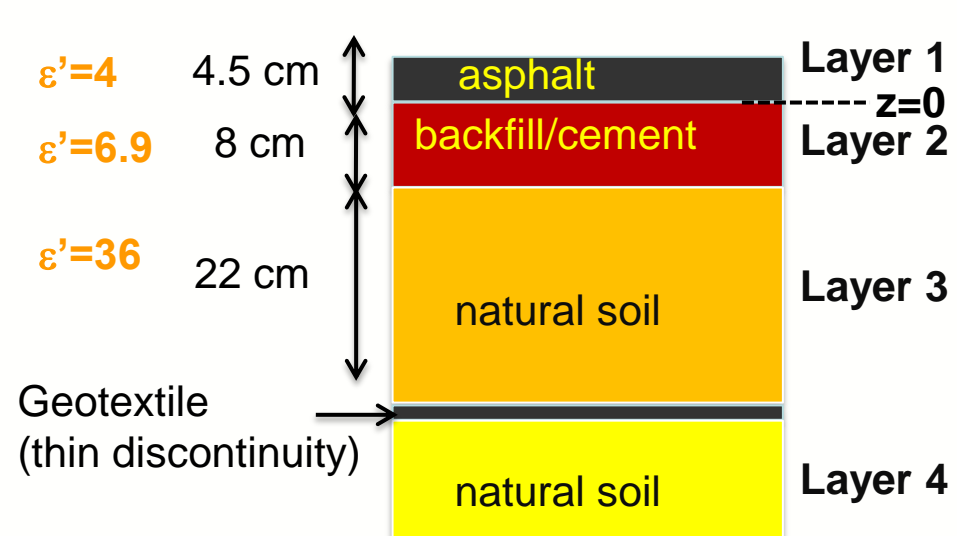
Distribution of the buried pipes/blades



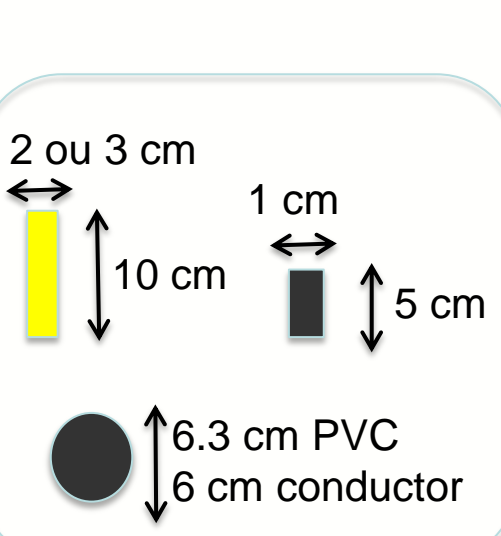
Mapping the urban underground



Structure of the subsurface



Buried objects



Commercial GPR systems operating in the time domain

500 MHz (SIR 3000)

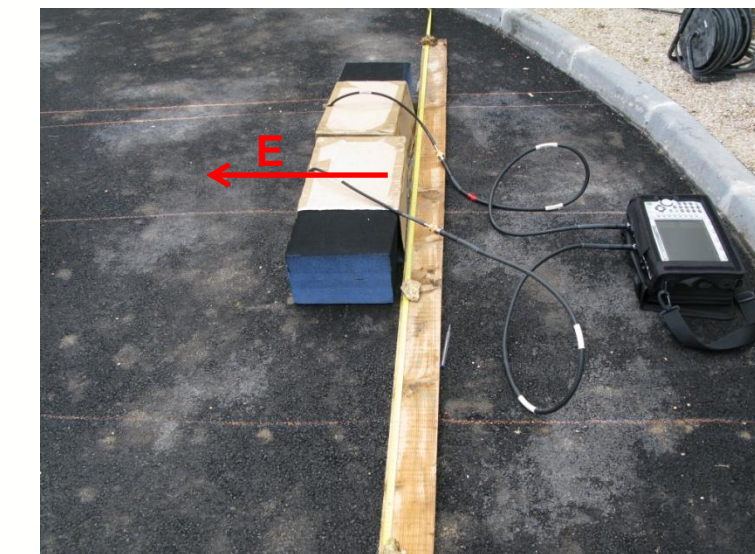


Double frequency 300-800 MHz (UtilityScan DF)



Laboratory-made GPR system operating in the frequency domain (FMCW)

Polarization TM

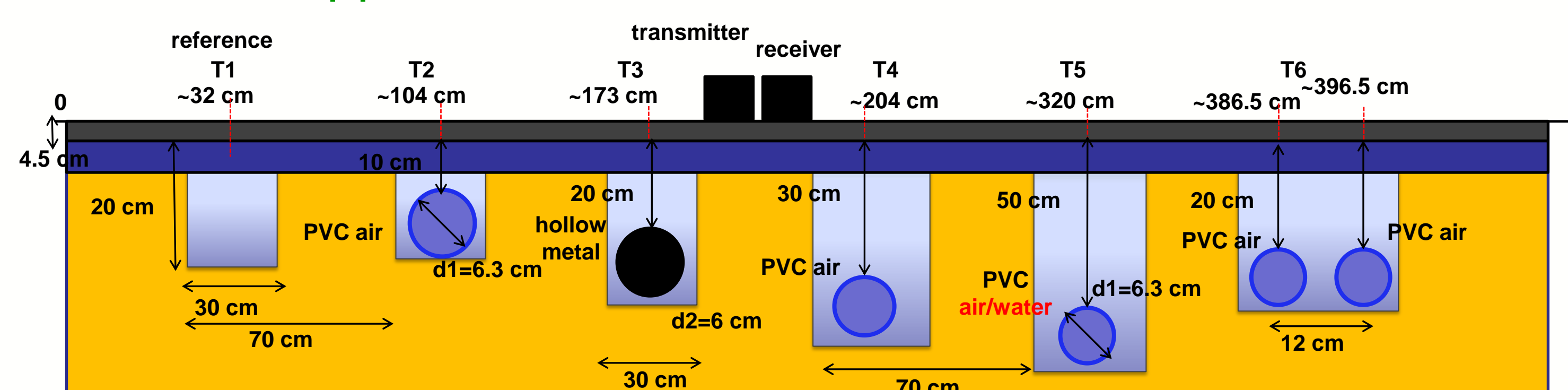


Polarization TE



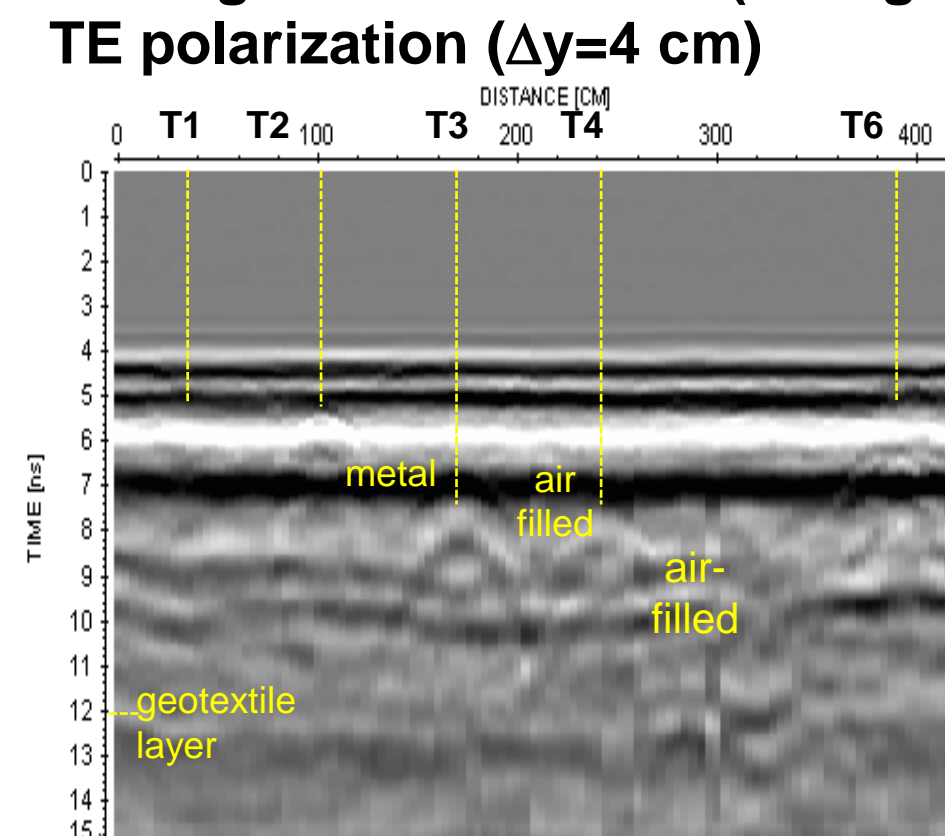
### Measurements in the pipe area

A cut view of the pipe zone

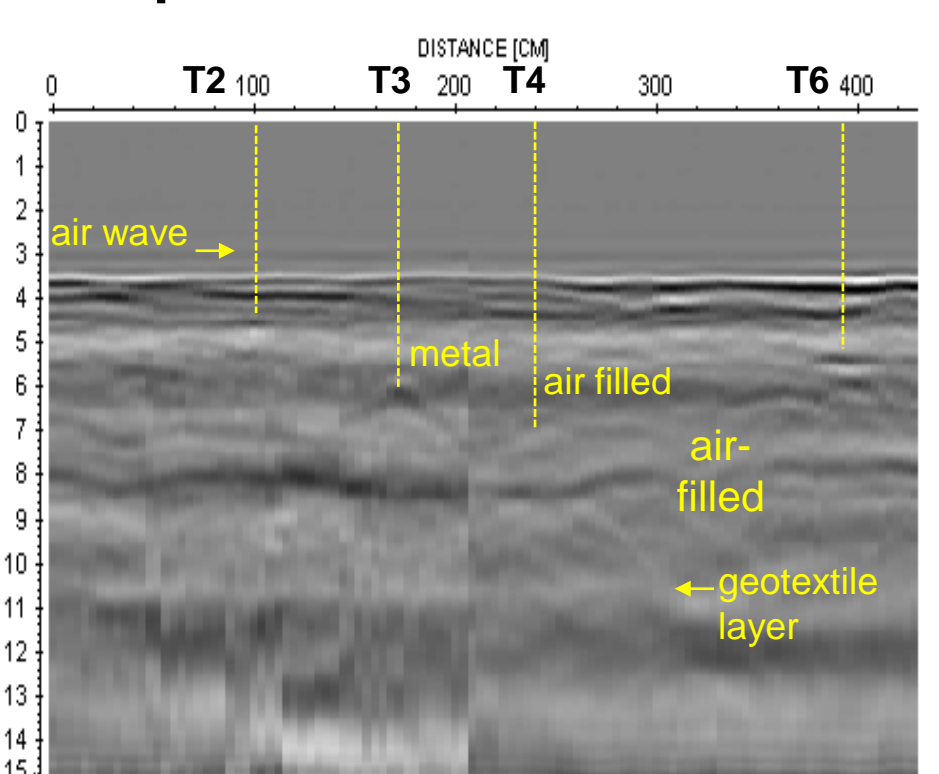


Measurements in the frequency domain

Radargrams at 900 MHz (with gain)

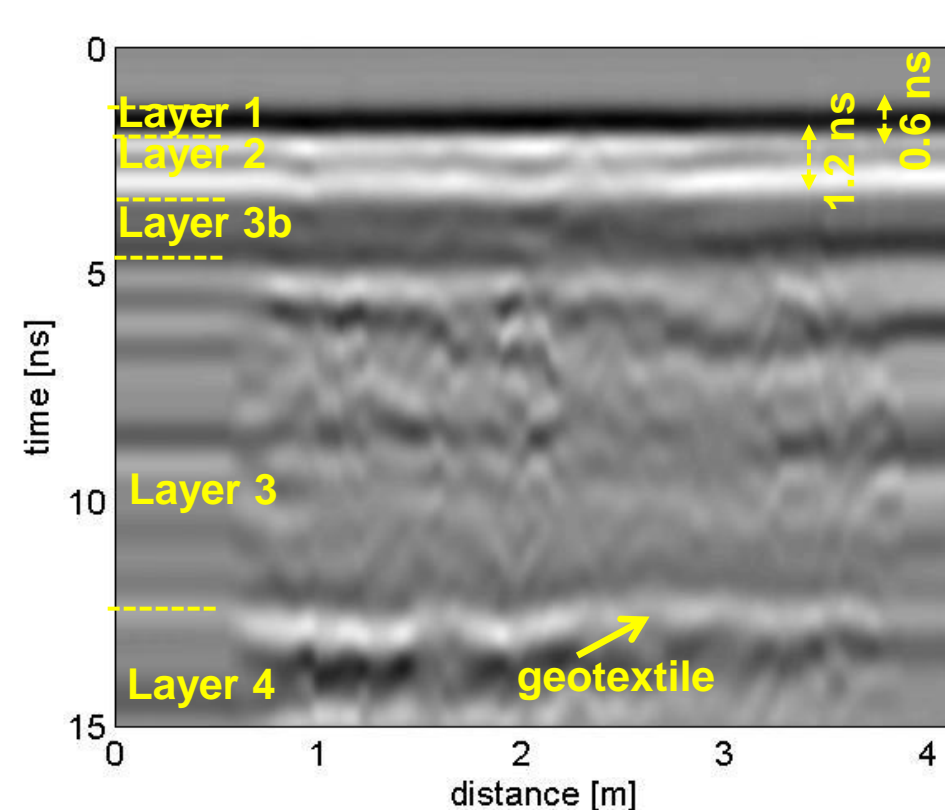


TM polarization

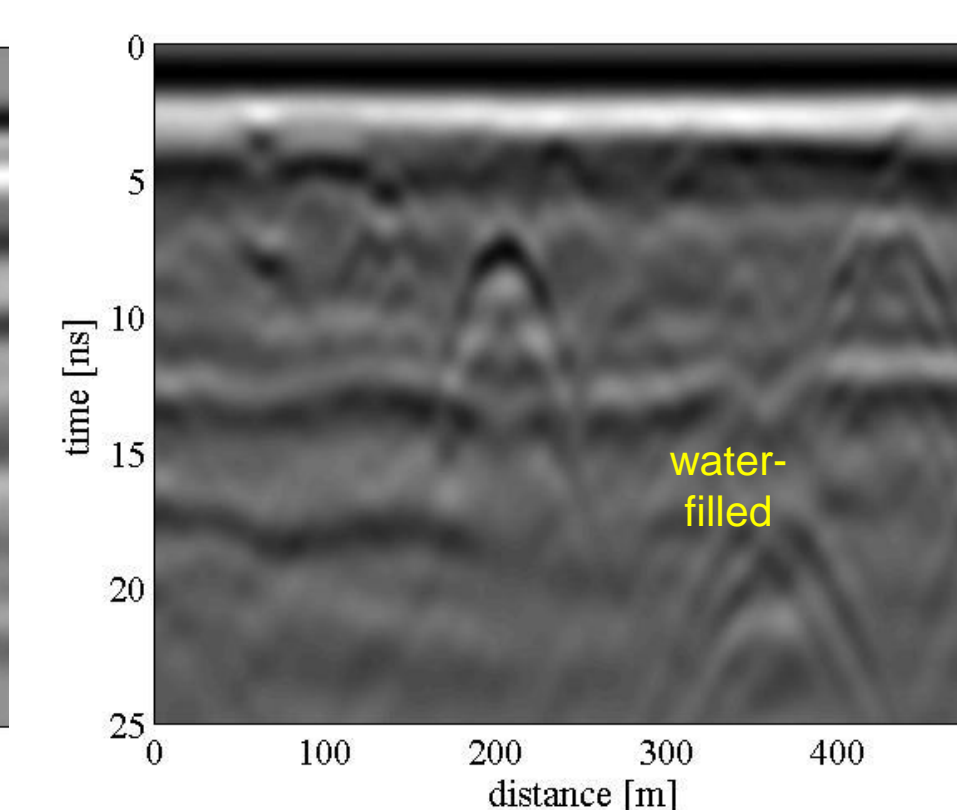


Measurements in the time domain

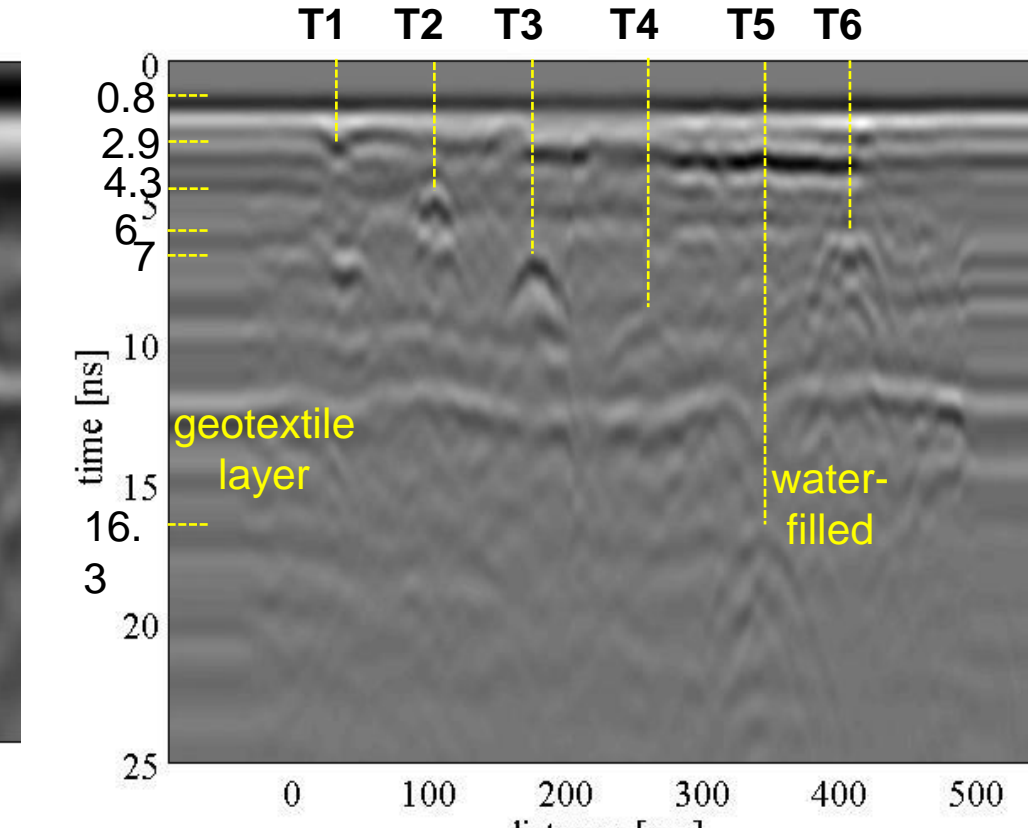
Soil characterization at 900 MHz (with linear gain, Δy=1 cm)



Pipe radargram (with linear gain) 500 MHz (Δy=1 cm)



900 MHz

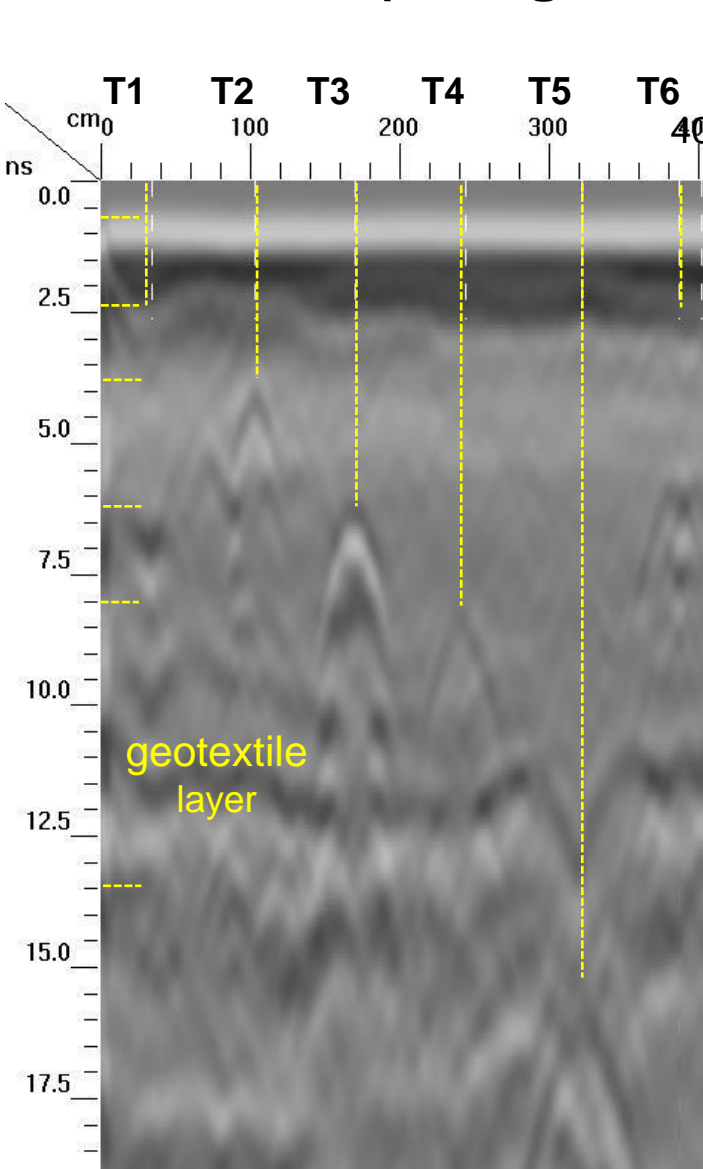


- Images of the pipe zone using 3 different GPR systems (SIR 3000, Utility scan with 2 frequencies, radar FMCW) at the following nominal frequencies :
  - 500 MHz, 900 MHz, 1600 MHz
  - 300 et 800 MHz (double frequencies)
  - [50 MHz; 4 GHz] (FMCW, 2 polarizations)

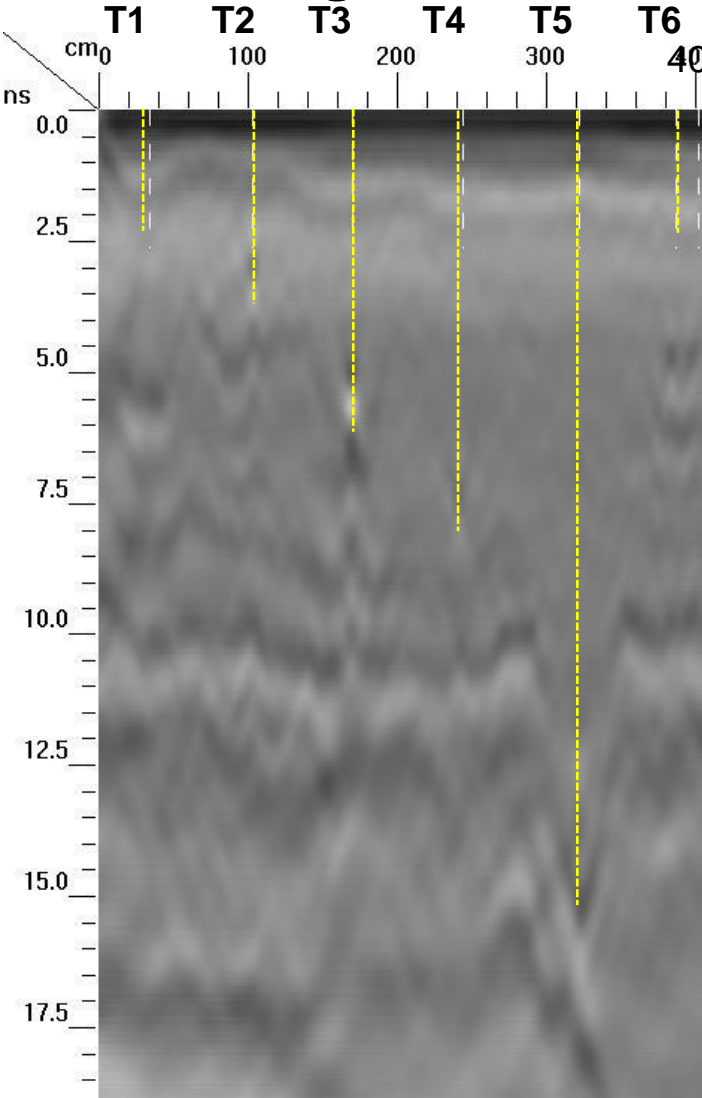
- T5 at depth 54.5 cm : air-filled not detected in the polarization TM, water-filled better detected in the polarization
- 900 MHz appears the best frequency in the compromise between resolution and penetration

### Interpretation using migration

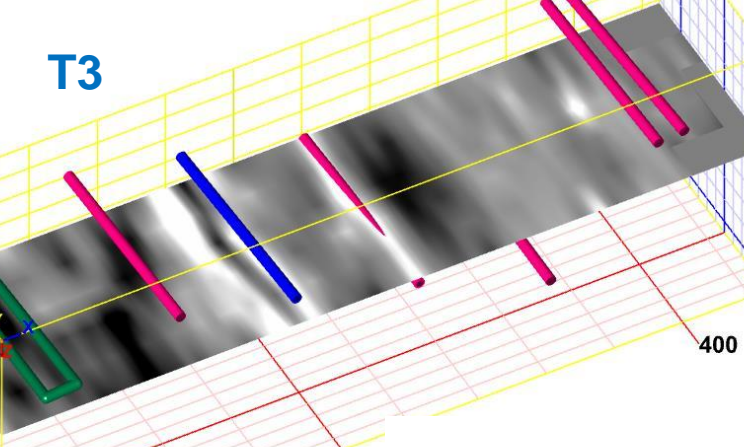
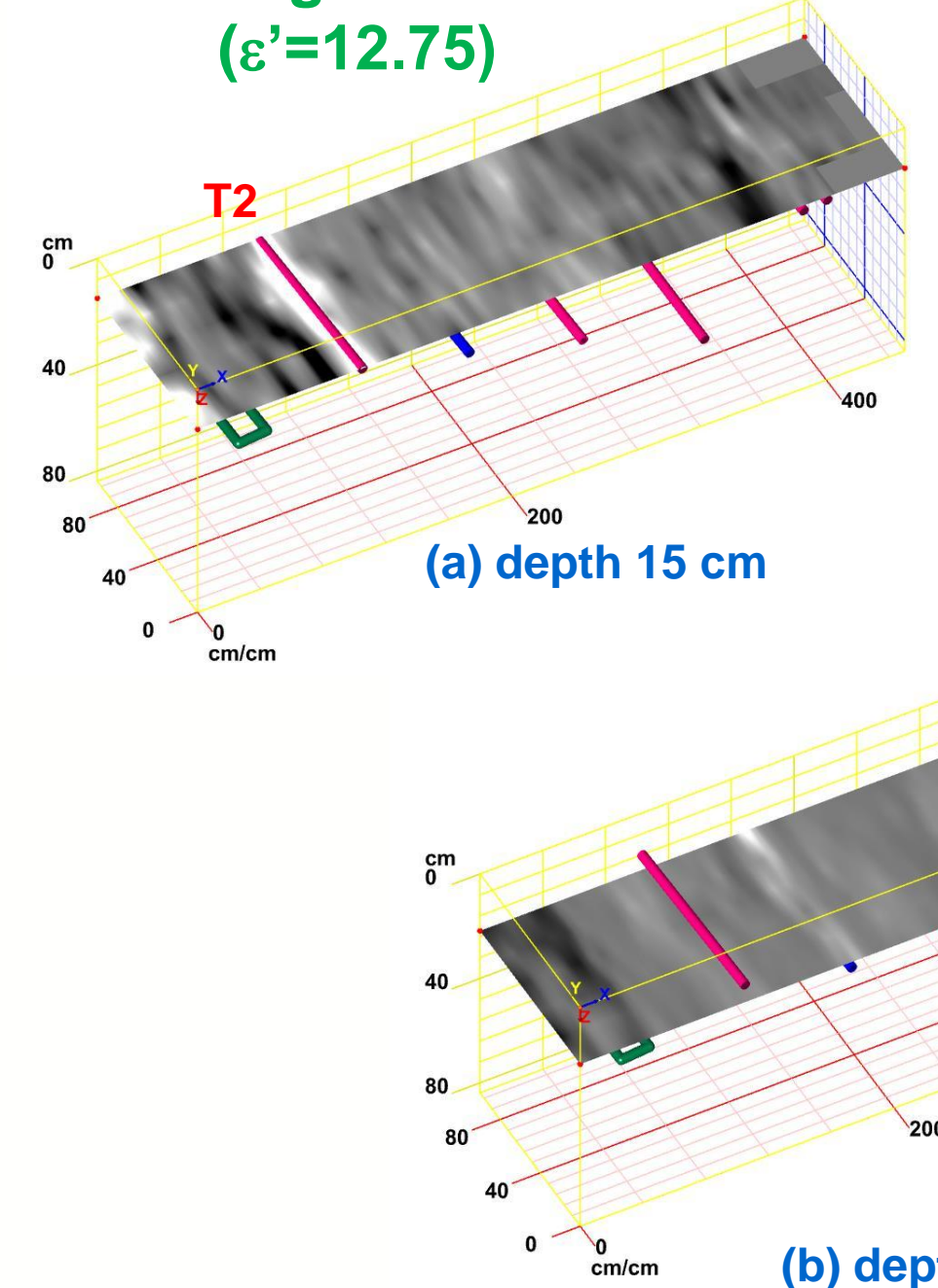
800 MHz (with gain)



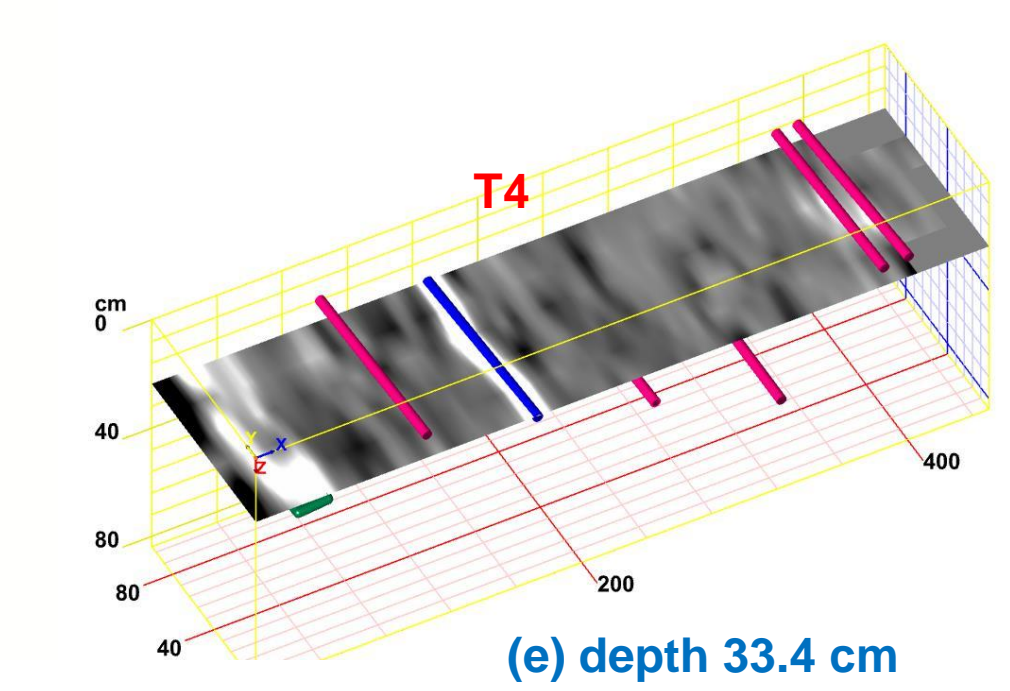
800 MHz (time zero correction and migration ε²=12.75)



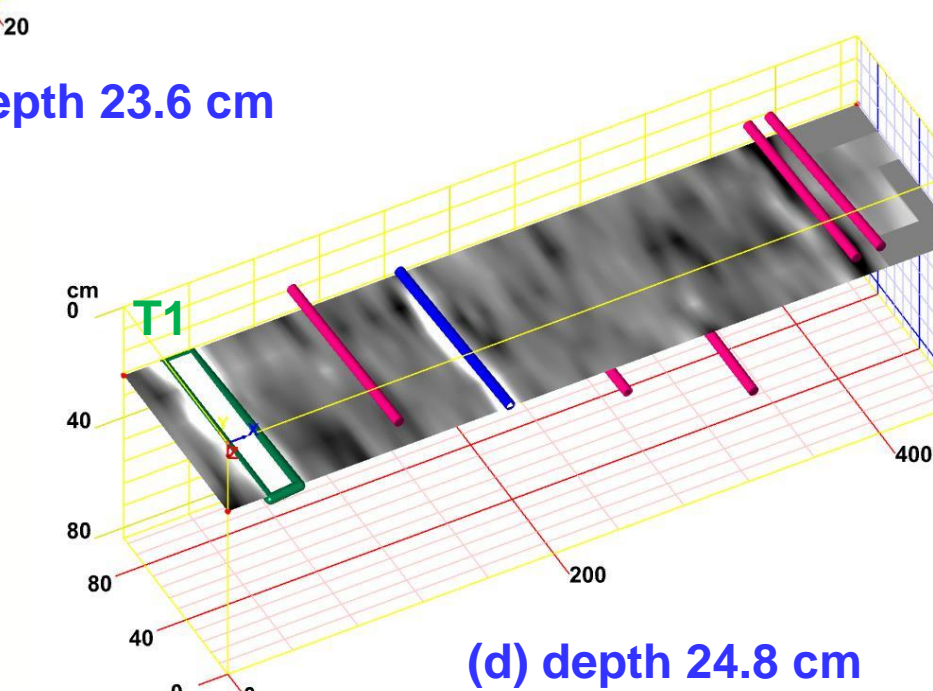
Migration 3D at 800 MHz (ε²=12.75)



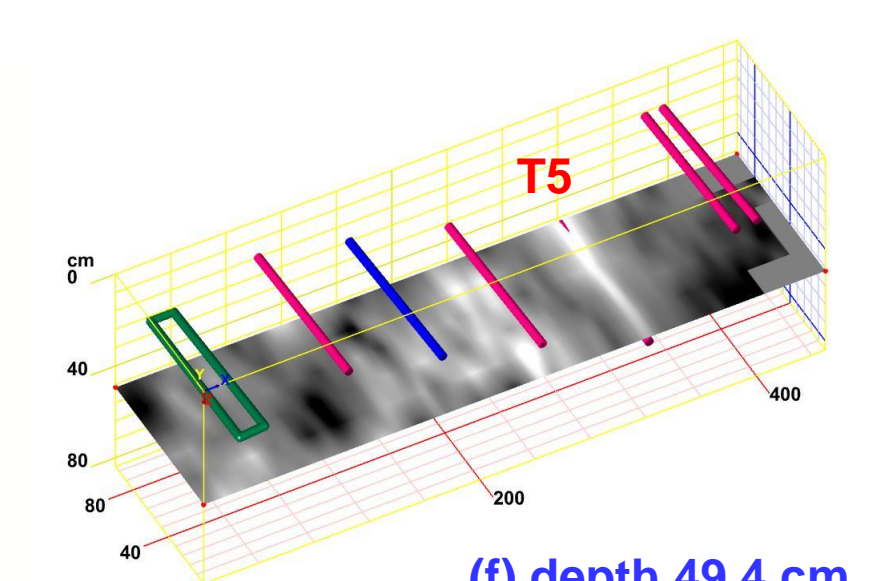
(c) depth 23.6 cm



(e) depth 33.4 cm



(d) depth 24.8 cm



(f) depth 49.4 cm