Action TU1208
Civil Engineering Applications of Ground Penetrating Radar

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Development and testing of a new lightweight radar system for tomographical reconstruction of circular structures

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Talk Layout

- **Introduction and motivation**
- **System design:**
  - Description of the radar system
  - Antenna design and modeling
- **Experimental results:**
  - Sand box measurements
  - Circular cylinder with inclusion
- **Conclusions**

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Introduction and motivation

- New applications of GPR need small and efficient **measurement systems**
- An **accurate modeling** of the physical effects between GPR antenna and soil interface is fundamental
- Growing interest for advanced **data processing** techniques for GPR
- **Non-invasive** investigation of cylindrical structures (e.g., tree trunks)

UCL Université catholique de Louvain

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AEM Applied Electromagnetics Group

cost EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

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Radar system design and antenna modeling

Description of the developed radar system and antenna

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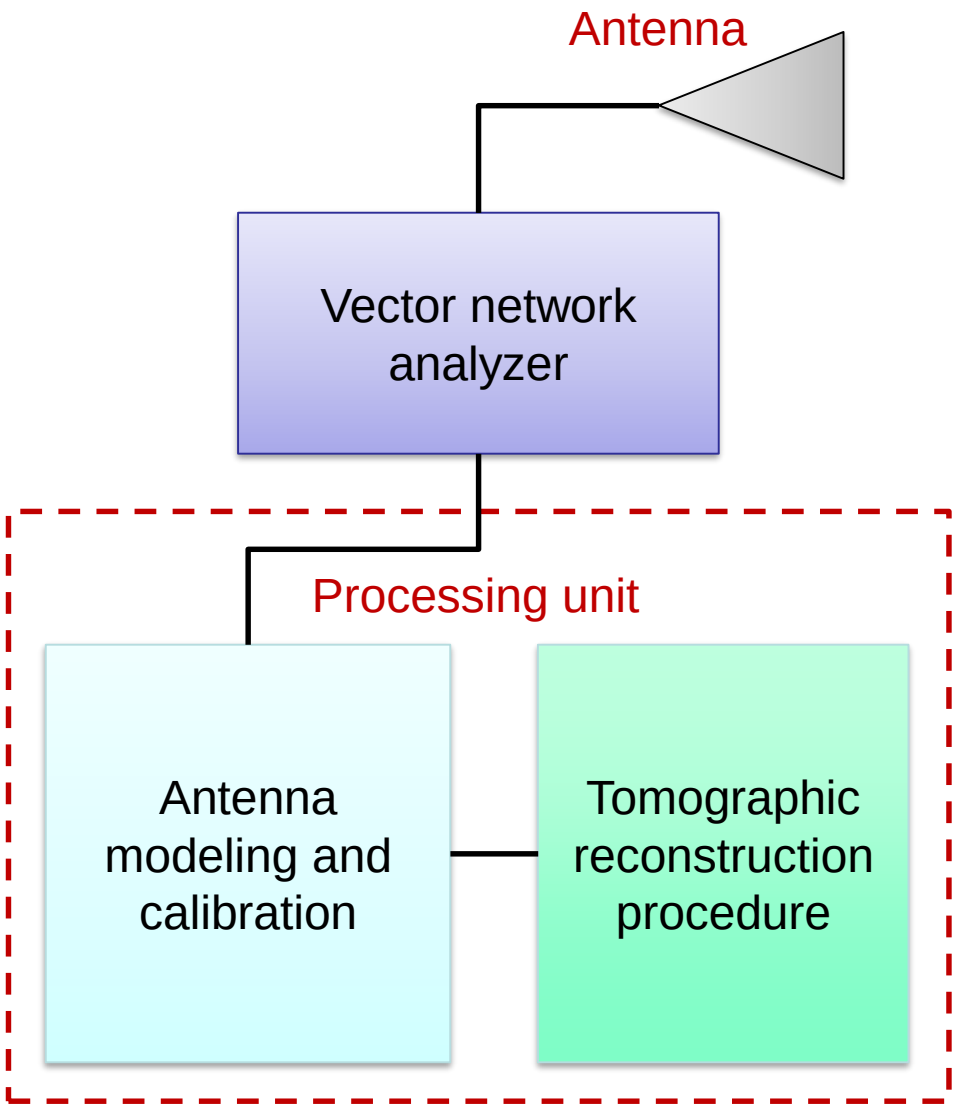
Tomographic radar system design

- Custom antenna design
- Vector network analyzer measuring the complex reflection coefficient
- Acquired data are preprocessed by using **calibration techniques** developed at UCL
- **Tomographic inversion** methods developed at UNIGE are applied



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Antenna modeling and calibration

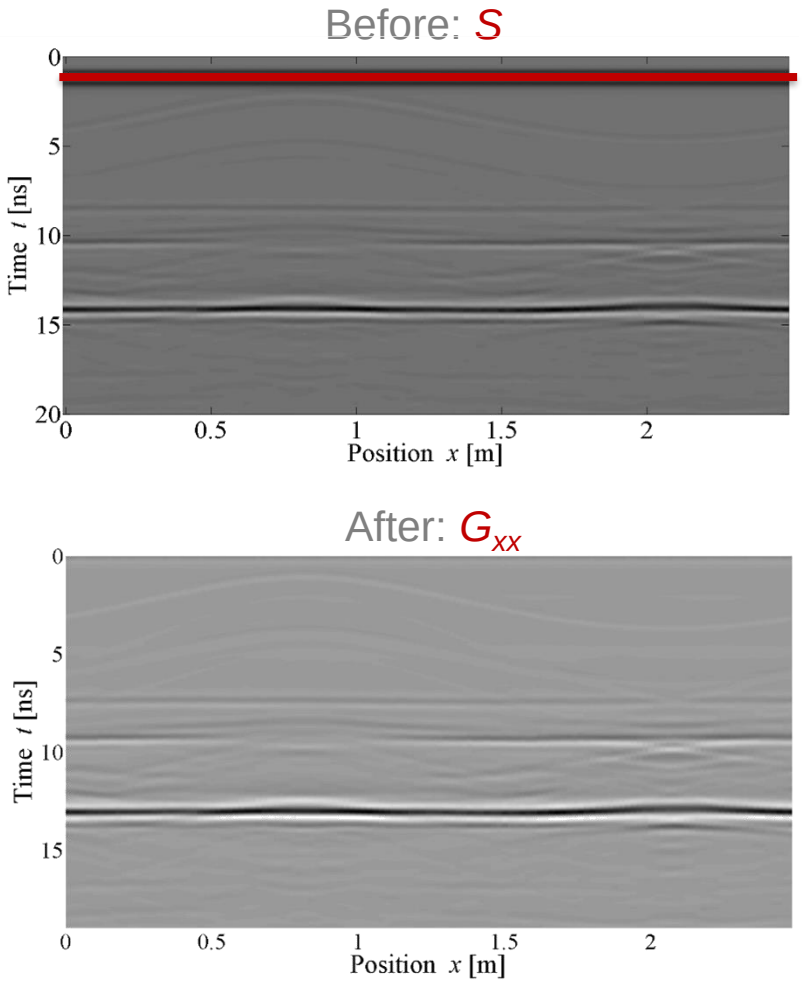
- The **antenna modeling** and **calibration** technique proposed by Lambot *et al.* [1] is used

Signal — Medium Green's function

$$S = H_i(\omega) + H(\omega) \cdot G_{xx}(\omega)$$

Source and direct coupling — Source wavelet and transmission

- **Example: removal of source effects and direct TX-RX coupling in gprMax simulated data**



[1] S. Lambot, E. C. Slob, I. van den Bosch, B. Stockbroeckx, and M. Vanclooster, "Modeling of ground-penetrating Radar for accurate characterization of subsurface electric properties," **IEEE Transactions on Geoscience and Remote Sensing**, vol. 42, no. 11, pp. 2555–2568, Nov. 2004.

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Experimental results

Detection of cylindrical targets in sand box and in free space

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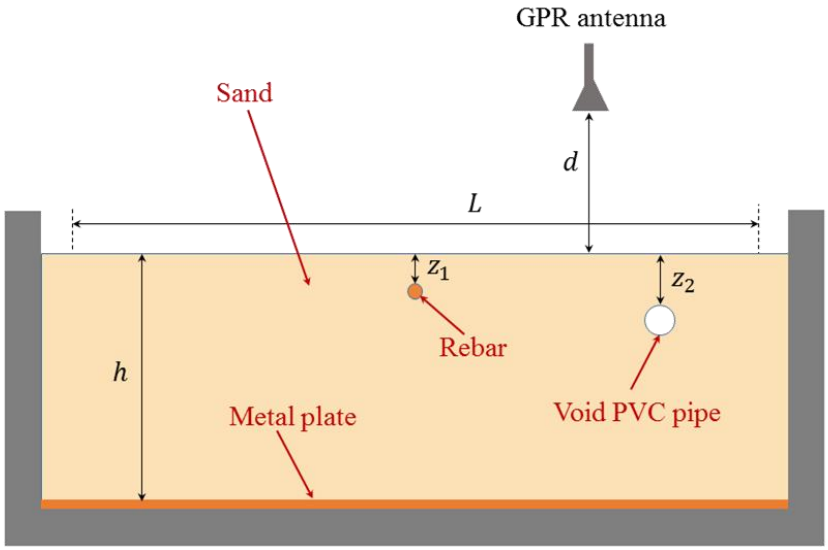
Measurements with sand box

- Sand box properties
  - Parallelepiped with side length $s = 3$ m and height $h = 1$ m
  - Filled with dry sand
  - $3\ \text{m} \times 3\ \text{m}$ metal plate at the bottom of the box
- First test set
  - Circular metallic rebar of length $l_1 = 2.5$ m and diameter $d_1 = 0.03$ m, $z_1 = 0.1$ m deep
  - Empty PVC tube $l_2 = 0.9$ m long, characterized by a diameter $d_2 = 0.08$ m, thickness $t_2 = 0.0018$ m, and depth $z_2 = 0.085$ m.
- B-scans acquired with different antennas and distances from soil



PVC tube during burial

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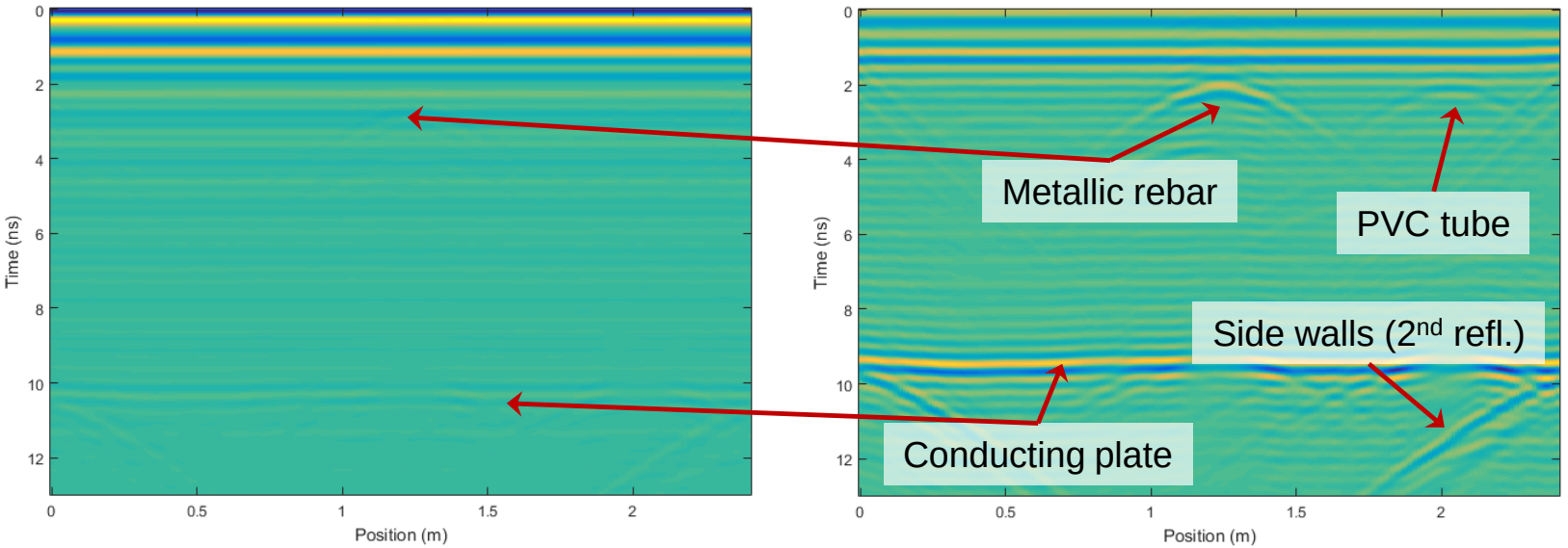
B-scans of the test set

Raw GPR data

Calibrated GPR data



- First test set configuration in sand box
- Considered frequency range: 800 MHz – 3 GHz
- Distance between antenna aperture and soil level $d = 0.15$ m
- B-scan length $L = 2.4$ m (241 measurement points spaced by 1 cm)

[1] A. Fedeli, J. Ježová, S. Lambot, M. Pastorino, A. Randazzo, and L. Pajewski, "Tomographic reconstruction of structures using a novel GPR system," in *Geophysical Research Abstracts, European Geosciences Union (EGU) General Assembly 2017*, April 23-28, 2017, Vienna, Austria, vol. 19, article ID EGU2017-18265.

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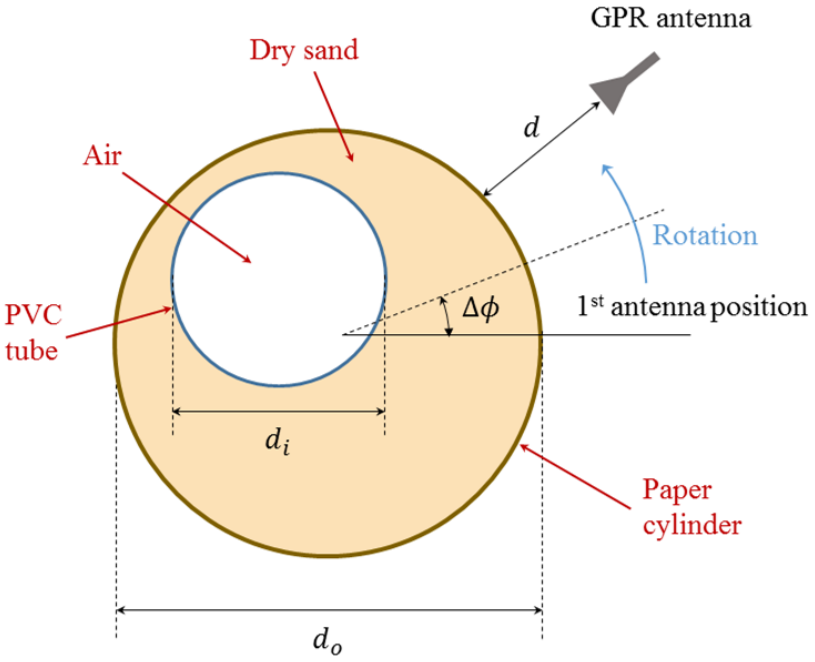
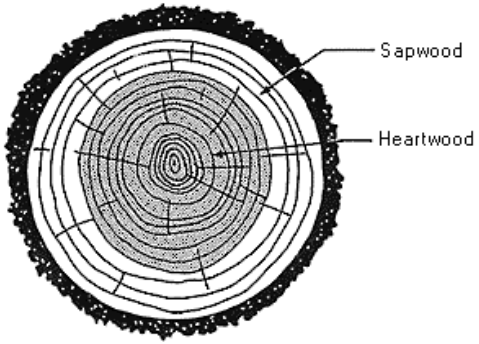
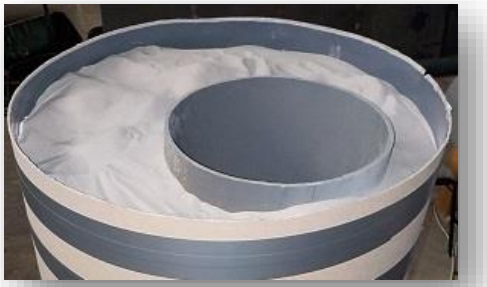
Circular cylinder with void inclusion

- Outer structure: paper cylinder with diameter $d_o = 0.82$ m
- Inner inclusion: one void PVC tube with diameter $d_i = 0.4$ m
- Internal space filled with sand
- GPR measurements acquired with counterclockwise direction
- Angular spacing between measurement points $\Delta\phi = 5.6°$
- Different antennas and distances from the outer cylinder





Top view



[1] J. Ježová, S. Lambot, A. Fedeli, and A. Randazzo, "Ground-penetrating radar for tree trunk investigation", in *9th International Workshop on Advanced Ground Penetrating Radar (IWAGPR 2017)*, Edinburgh, UK, June 28-30, 2017.

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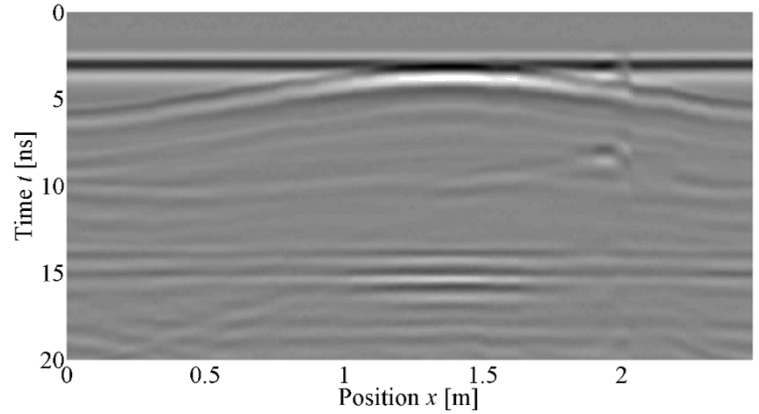
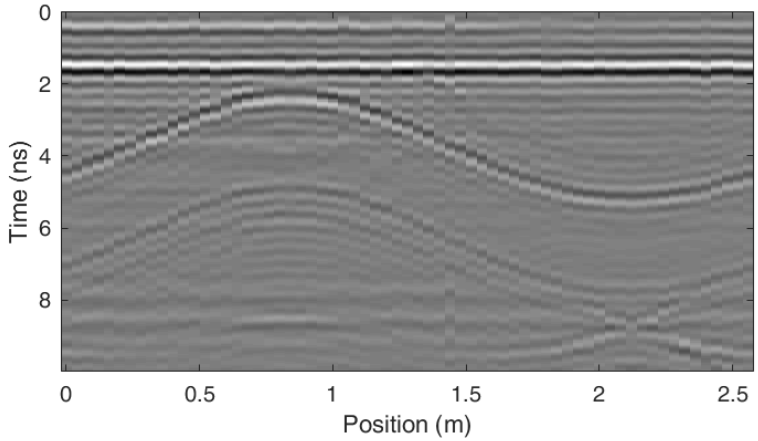
B-scan around the circular cylinder

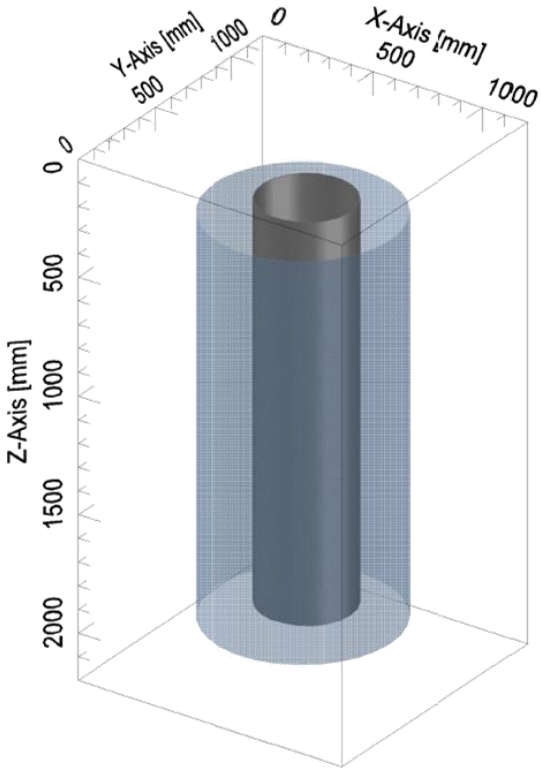
GSSI radar system with a bowtie antenna 900MHz



VNA with TEM horn antenna 0,8-4 GHz



B-scan around a trunk model
20 cm above the surface
Circumferential data acquisition



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Conclusions

- Cooperation between the **Georadar Research Centre** at the Université catholique de Louvain and the **Applied Electromagnetics Group** at the University of Genoa
- Experimental activities, testing different antennas and configurations of a **new GPR system**
  - Calibration of acquired data with an accurate model
  - Tomographic inversion
- Further activities
  - Integration of more advanced antenna models
  - Full-waveform inversion

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