COST Action TU1208

Civil Engineering Applications of Ground Penetrating Radar

This presentation is part of the TU1208 Education Pack

GPR assessment of roads

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Lecture Layout (1/2)

Introduction

- GPR antennas used on roads
- The structure of a road
- GPR assessment of roads – Basic concepts
- GPR assessment of roads – An example

GPR assessment of roads – guidelines

- 1. Most frequently asked questions of road operators about existing roads
- 2. Input from the client
- 3. Road survey levels and general road evaluation framework
- 4. Check the applicability of the GPR technique
- 5. Choice of the equipment
- 6. Choice of data density
- …

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Lecture Layout (2/2)

- …
- 7. Drafting the survey plan
- 8. Drafting the ordered list of actions to be undertaken in the field
- 9. Check the equipment before leaving the office
- 10. Data acquisition on the road
- 11. Pre-operational measurements
- 12. Execution of the measurements

Case studies and planning of a practical session

- Case studies (examples from BRRC experiences)
- Planning a practical session (GPR measurements on a road)

Biography and contact details of the Author

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Introduction

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GPR antennas used on roads

- Air-coupled antennas
  - 1 GHz
  - 2 GHz

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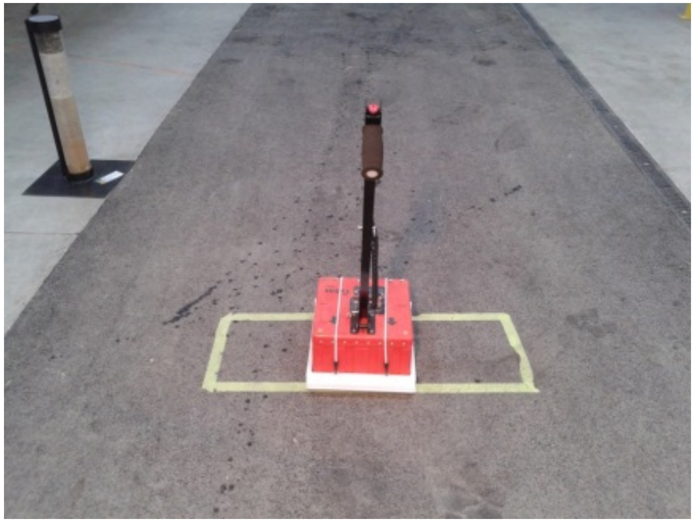
GPR antennas used on roads

- Contact antennas
  - 400 MHz
  - 900 MHz
  - 2.6 GHz



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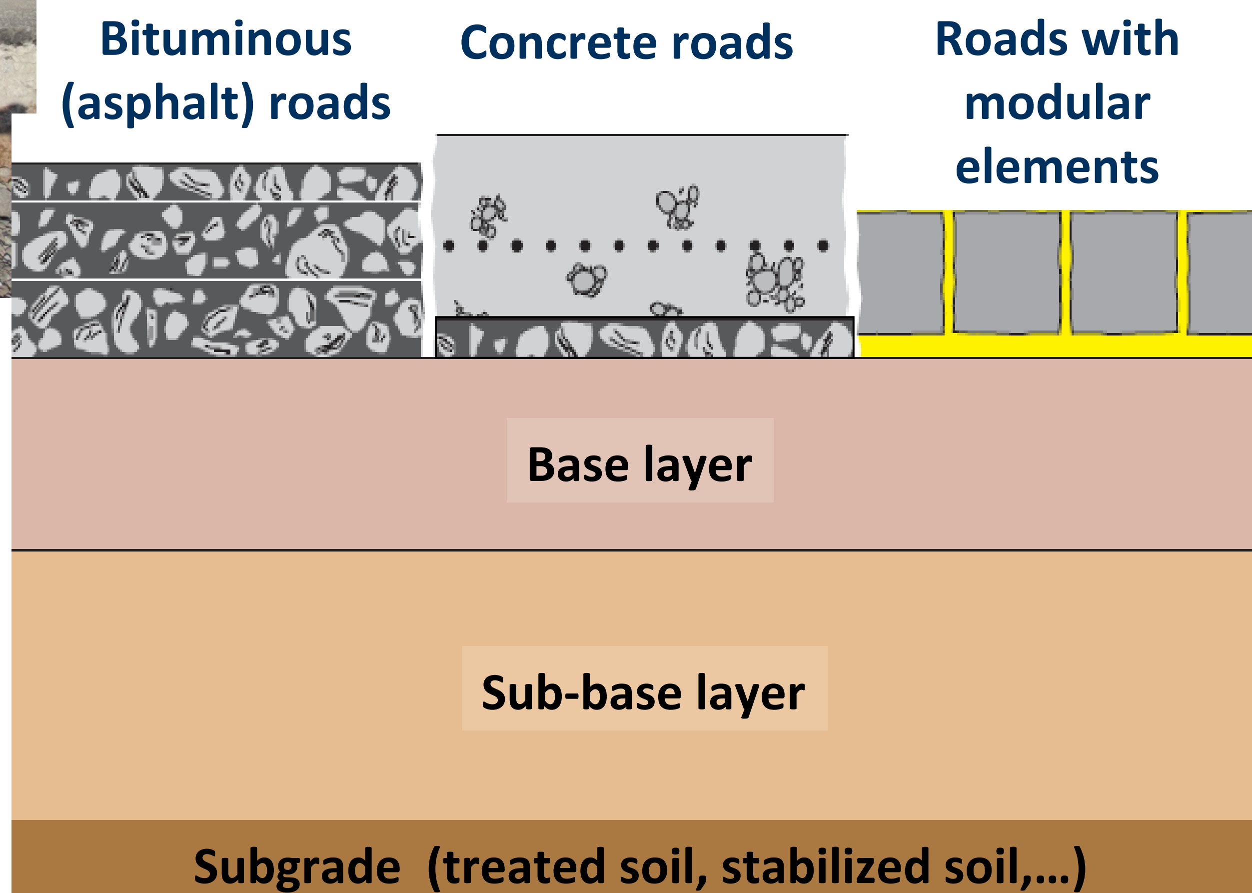
GPR antennas used on roads

- Array antennas

The structure of a road



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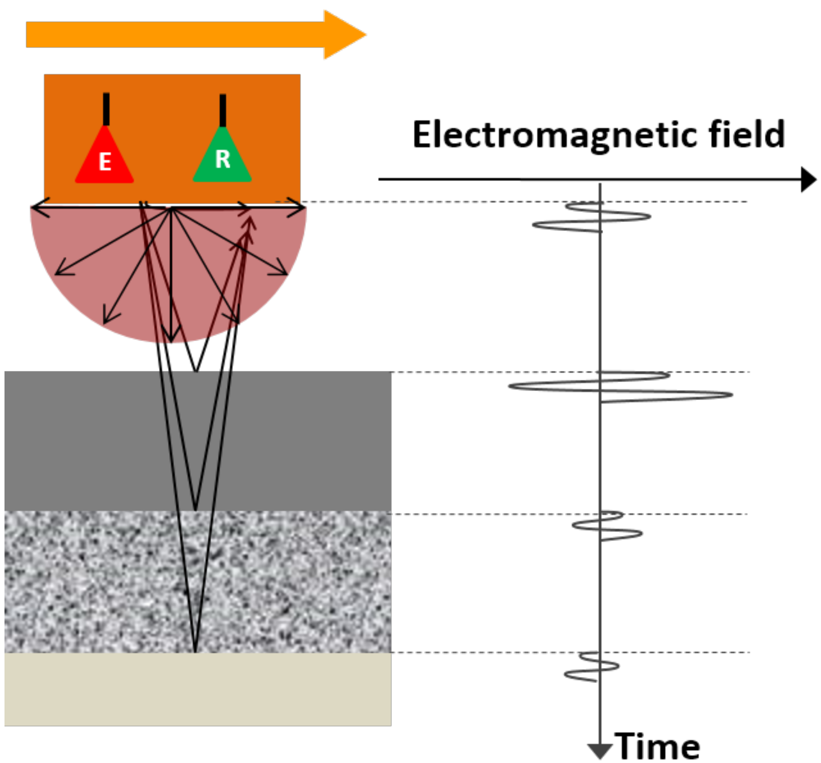
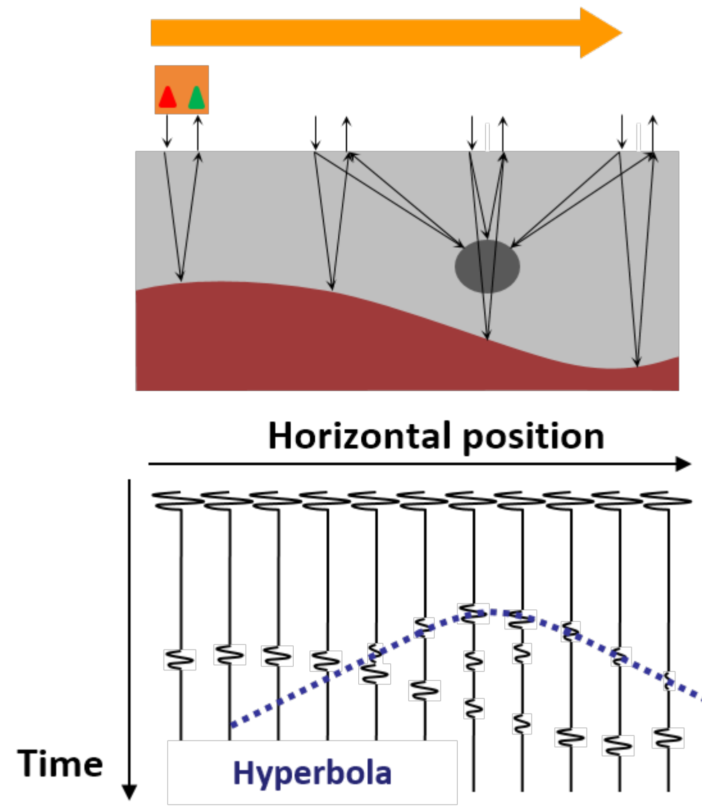
GPR assessment of roads – basic concepts

- Moving the antenna over the surface
- Usually we are most interested in the “B-scan”
- Usually we are looking for “layers” and “local objects”





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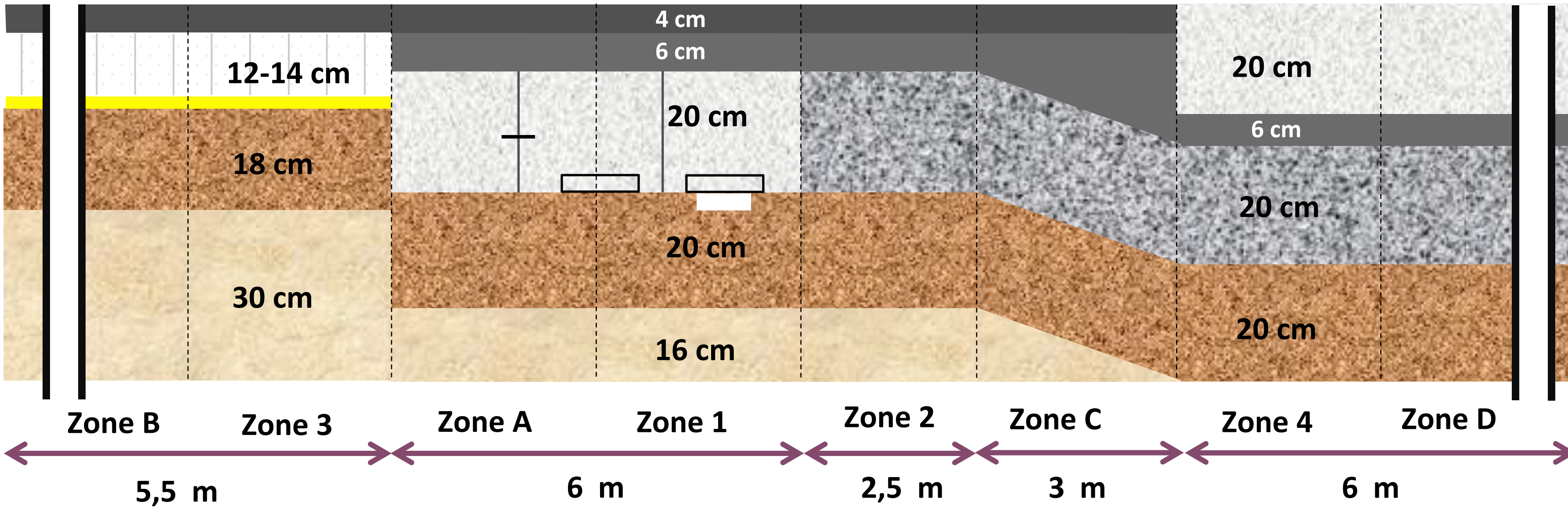
Example: A trench at BRRC containing 4 different road structures



- Aggregates
- Concrete
- Lean concrete
- Asphalt
- Sand
- Cobblestones
- Soil

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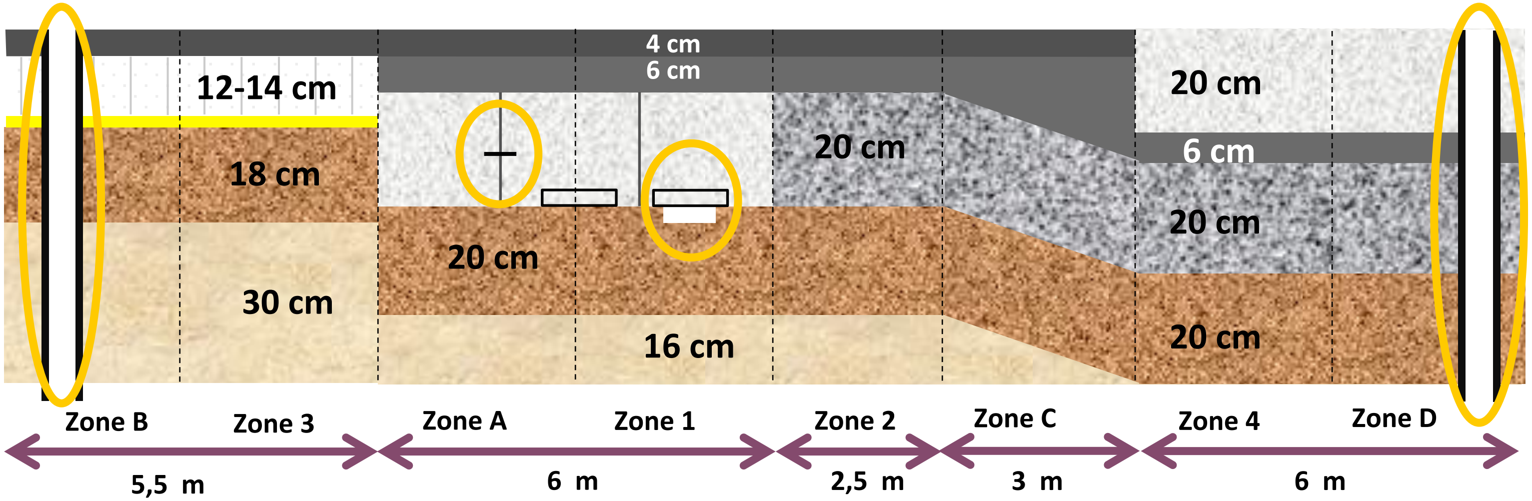
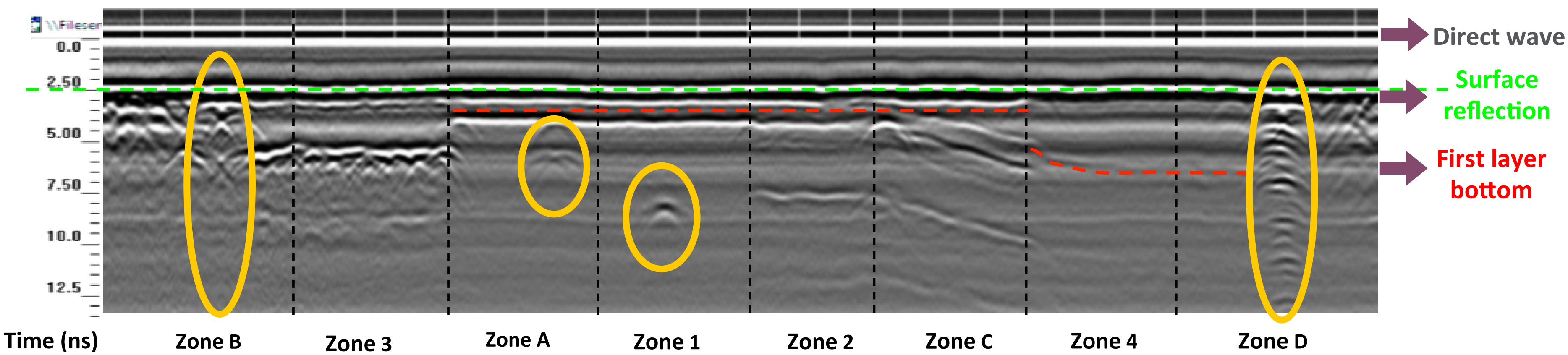
In the B-scan we detect layers and “objects”





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GPR assessment of roads - guidelines

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Typical questions of road operators about existing roads

- What is the road structure made of?
  - Materials, layer thicknesses, homogeneity?
- Do we need to replace the base course?
- What is the remaining life of the road?
- Are there cavities under the road?
  - Under the concrete slabs?
  - Between sewer pipe and road structure?
  - Under the rail structure of the tramway?
- Is there delamination and presence of water between asphalt layers?
- Concrete roads:
  - Where are the dowels (location and depth)?
  - Where are the reinforcing bars of a mesh (location and depth)?

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Input from the client: 3 types of clients with a question

- Type 1: Thinks that GPR will solve the question, so this client just asks for a GPR survey
  - Needs to be interrogated about the questions
  - Must be convinced that GPR surveys have their limitations
- Type 2: Never heard about GPR, comes with a question, asks for an answer to the question
  - When analyzing the question, it is found that GPR can help
  - If so, then client must be convinced that a GPR survey is useful
- Type 3: Knows about GPR, thinks that GPR will contribute to the search for the answer to the question
  - Discussion about the question and careful planning of the survey

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Input from the client: discussion about the "question"

- What are the objectives of the client?
- Can we expect that the objectives could be matched by using the GPR technology?
- Get as much information as possible from the client:
  - Infrastructure design: geometries, material characteristics
  - Existing embedded "stuff"
  - Previous maintenance actions, repairs, interventions
  - Previous investigations
  - Situation plans, maps
  - Traffic information
  - Work allowance, safety requirements, insurance,..

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Survey levels

- Network level
  - For road network management
  - Evaluation and classification
  - Usually only “homogeneity” of layers and their thickness
  - Limited number of scans per meter, at high speed, only 1 profile with air-coupled antenna
- General project level
  - For preparation of road works on a particular road section
  - Local evaluation on overlay or rehabilitation design
  - More scans per meter, several profiles, air- and ground-coupled antennas
- Detailed project level
  - Detailed investigations
  - Material properties, bonding/delamination, presence of voids and water, detection of targets (canalizations, cables,…),…
  - Grid of surveys, making a C-scan, ground-couples and/or array antennas

General road evaluation framework

- What is the best procedure (given the technical capacity of the service provider) for meeting the objectives of the client?
- Note: This is preparatory work, before the GPR leaves the office.

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General road evaluation framework

- Questions to be answered:
  - Is a GPR survey sufficient? Or do we need other inspection or measurement techniques (non-destructive or destructive)?
  - In which order the different devices have to be deployed?
  - What GPR data interpretation techniques will have to be used?
  - Does the interpretation need additional information?
  - Is the location accessible?
  - What are the safety measures to be taken?
- It may be necessary to do a visual inspection of the site in order to collect all answers to these questions.

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Check the applicability of the GPR technique

- Electromagnetic environment
  - Are there disturbances: radio transmitter, walkie-talkie, cell phone, metallic structures, confined environments?

- Climate conditions
  - Presence of water inside the road? (usually to be avoided)
  - Freezing/thawing? (probably not the best moment)
  - Frost? (special attention is needed)

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Check the applicability of the GPR technique

- Conductivity of the present materials
  - Clay ground, clayey unbound materials? (attenuation of the signal)
  - Mixing of materials between layers... (unclear border)
  - Deicing salts inside the road? (other velocity, signal attenuation)
- Geometry of the road
  - Accessibility of the survey area and safety measures

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Choice of the equipment

- For the particular application asked for by the client:
  - Which type of antenna(s) to be used?
  - Which frequency of antenna(s)?

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Choice of required data density

- Step distance (= time interval between 2 consecutive traces)
- Sampling interval (= time between 2 points on 1 trace)
- Time range (= how long we store data on 1 trace)
- Number of samples per trace (= time range / sampling interval)
- Collected data must match the requirements for data interpretation

Remark:

- BRRC document ME91/16 (method of measurement) gives some numbers for these parameters, for different antennas… and of course you can also check out the TU1208 guidelines.

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Draft of the survey plan

- Along how many lines is there going to be measured?
- In longitudinal and/or transversal directions?
- Detailed coverage of a small area (measures along a grid)?
- Draw a plan on a map for the operator…
  (If possible: also indicate on that map where other measurement devices will be applied.)
- Suggestions:
  - Try to find out if there are reference points on site (kilometre markers, light poles,…)
  - Ask road manager for a detailed plan of the site

Drafting a script for the surveys

Script = ordered list of actions to be taken on the field

- Is there a place to park the car, warm the antennas, prepare the equipment, meet with the other persons that have to intervene on the site on the same moment,… near the survey site?
- Describe how to proceed for referencing of the locations on site
- Describe in which order the different measurements have to take place
- In particular: note the order w.r.t. other measurement devices (visual inspection, deflections, coring,…)
- Also: describe to what extend the operator is asked to decide for performing other (or additional) measurements (at other places, with another antenna,…), maybe based on his/her first rough interpretation of the results while on site

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Check the equipment

Before leaving from the office on site…

- Antennas, cables, fixation systems, cart, laptop, acquisition equipment, battery, GNSS/GPS equipment and cable, safety signs, metal calibration plate, logbook and pencil, safety vests, work shoes, hard hat, safety (sun) glasses, sun cream, bottled water, first aid kit, power tape, photo camera, video camera, tool box, measuring tape, spirit level, pocket torch, paint spray, …

- Suggestion: make a checklist…

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Check if odometer needs to be calibrated

- Compare a known distance to number of “ticks” of the odometer
- Do this at least every 3 months! Do this when something has changed to vehicle or cart!
- Important parameters that affect the calibration of the odometer: vehicle loading, tyre pressure, tyre wear, …
- Minimum distance (recommended in TU1208 guidelines):
  - 1 km straight line (for a vehicle)
  - 20 m straight line (for a cart)

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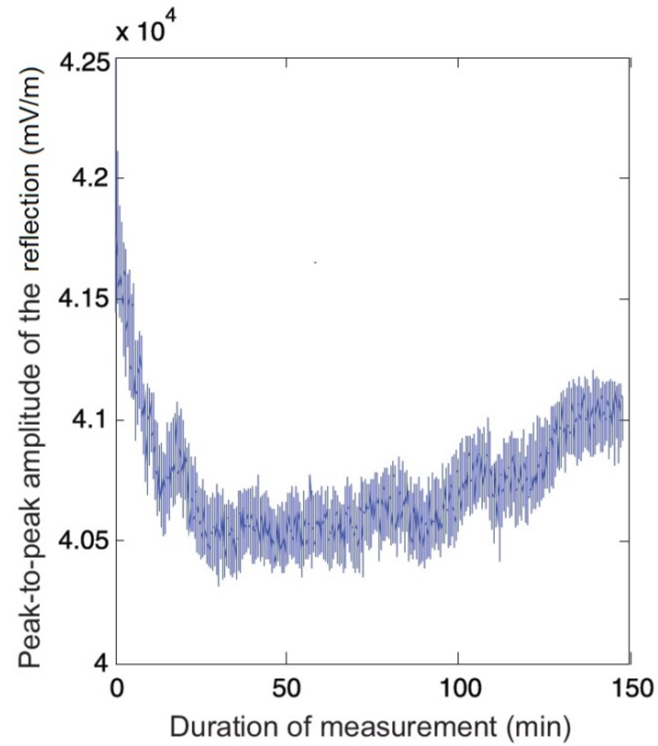
Data acquisition in the field
(on the road or on a bridge)

- Warming up the GPR equipment
  - In order to get (almost) stabilized amplitudes and arrival times of the signal
  - Warm up of 20 to 30 minutes (or seek advice of manufacturer)
  - Do again after long interruptions of the measurements

- Distance calibration (if not done before)

- GPR parameter setting:
  - Time range (time window)
  - Spatial sampling (scans/m)
  - Scan sampling (frequency)
  - Frequency filtering
  - Gain



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Pre-operational measurements

- Free-space signal
  - Collect 100 waveforms in absence of material
  - Can be used for clutter removal

- Flat metal plate
  - Mainly for air-coupled antennas
  - Repeat each time when configuration changes
  - Collect 100 waveforms, oriented to the plate
  - Used for removal of strong surface echo and in some procedures for layer thickness estimation

- Depth calibration / velocity estimation
  - Flat metal plate – usually for air-coupled antennas
  - Common-Middle Point (CMP) – usually for ground-coupled antennas
  - Coring… - destructive technique but "ground truth"
  - Other techniques – EM in lab, from hyperbola on local reflectors,…

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Execution of the measurements

- Safety measures in place?
- Follow the script
- Make notes in a logbook (a booklet, taken on the field)
- Make photos
- Record videos
- Make markings in the GPR data with the acquisition software
- Check before withdrawal that all files are stored correctly…

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Case Studies
(examples from BRRC experiences) and planning of a practical session

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Examples of applications on roads

- What is the road structure made of:
  - Materials, layer thicknesses, homogeneity?
- Do we need to replace the base course?
- What is the remaining life of the road?

  - Thickness of a road structure: 40 to 60cm…
  - Thickness of a layer: more than 3cm, up to more than 25 cm

Hence

  - Use 1 GHz or 2 GHz air-coupled antenna
  - Use 900 MHz contact antenna (if safety measures allow to)

  however, we most probably need additional survey techniques

  - Coring
  - Deflection measurements
  - Traffic loads (past and future)

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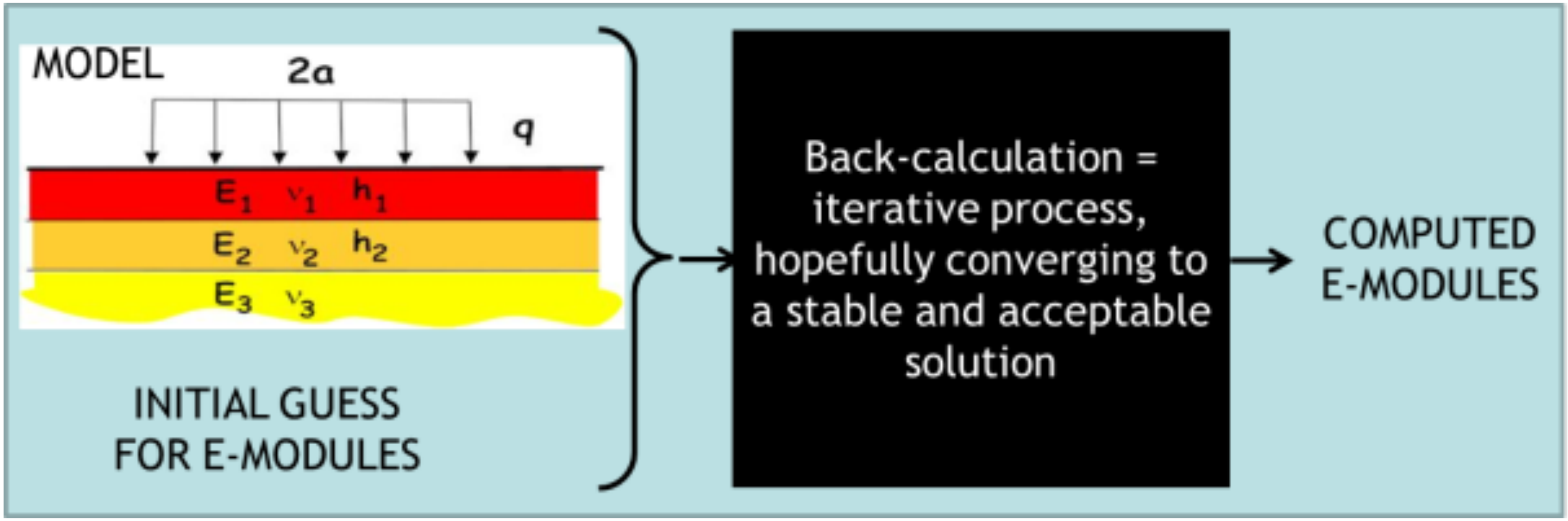
Back-calculation: GPR can help



Point	Year	E1	E2	E3	E4	E5
nbr.	built	asphalt	Lean concrete	sand	Virtual soil	soil
1	1982	6746	998	382	173	275

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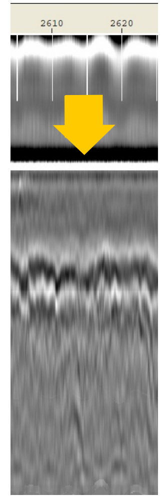
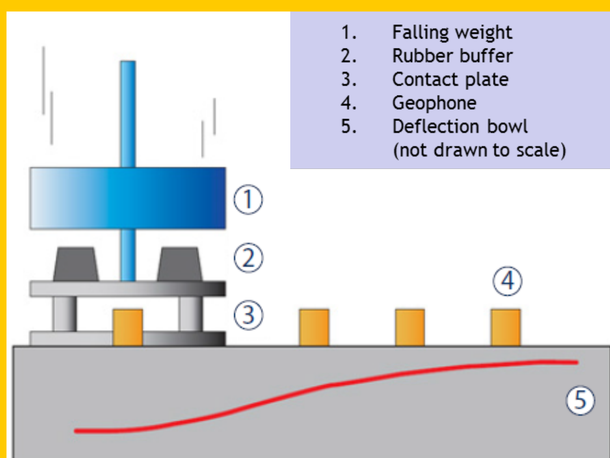
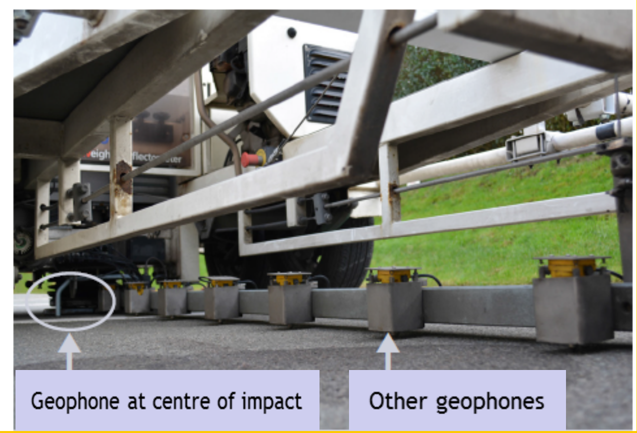
Back-calculation: GPR can help







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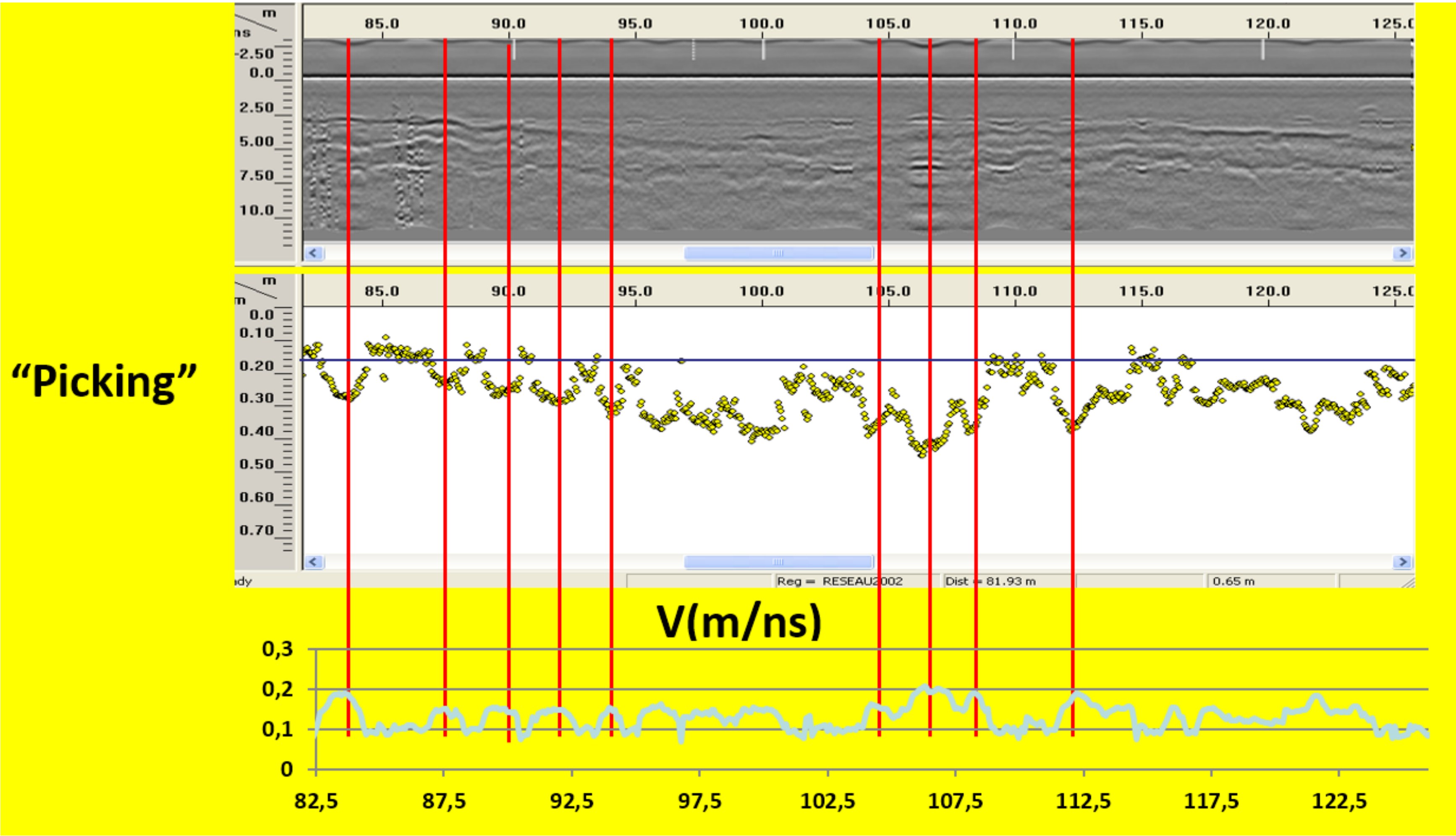
GPR can help with continuous layer thickness evaluation



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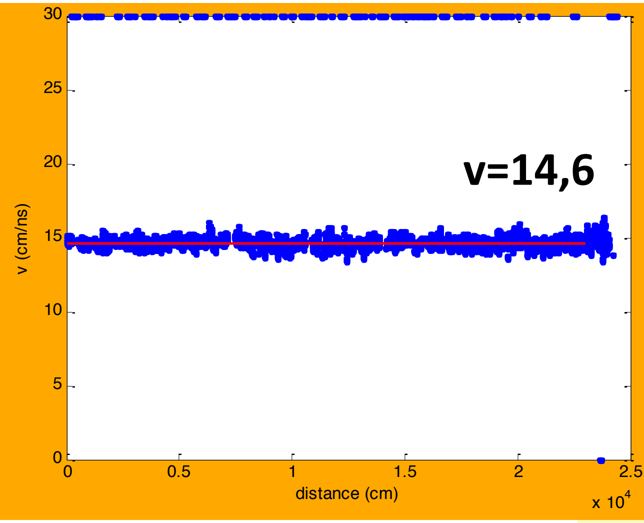
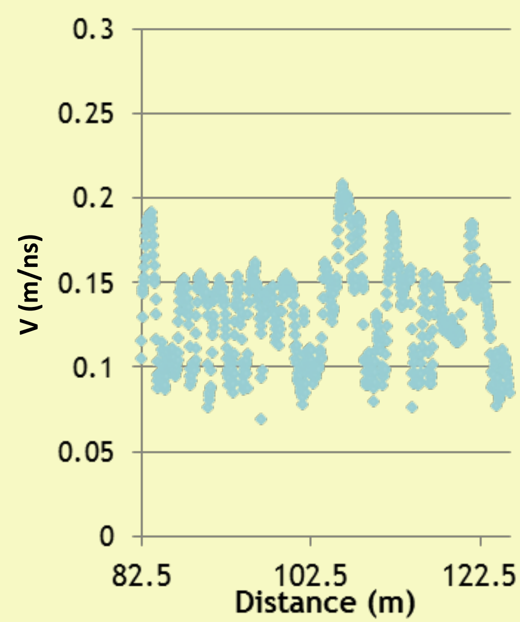
GPR can help with continuous layer thickness evaluation

Smarter way using Matlab





From "Picking" with Radan

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Examples of applications on roads

- Are there cavities under the road?
  - Under the concrete slabs?
  - Between sewer pipe and road structure?
  - Under the rail structure of the tramway?

- Thickness of a typical concrete slab: 18 to 22 cm
- Usually no or little metal integrated (sometimes: Dowels)
- Size of cavity under the slab: Less than 4 cm???

Hence

- Use high frequency contact antenna
- Depth before reaching a sewer pipe…

Hence

- Probably use a rather low frequency contact antenna
- Thickness of rail structure of tramway: +/- 50 cm

Hence

- Use 400 MHz contact antenna

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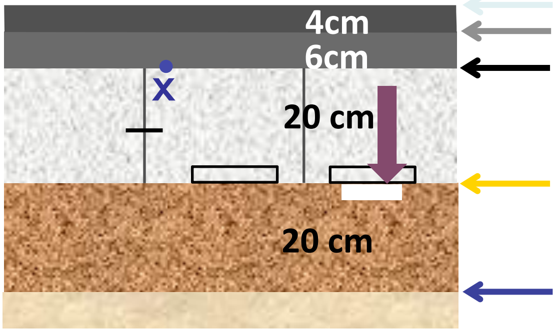
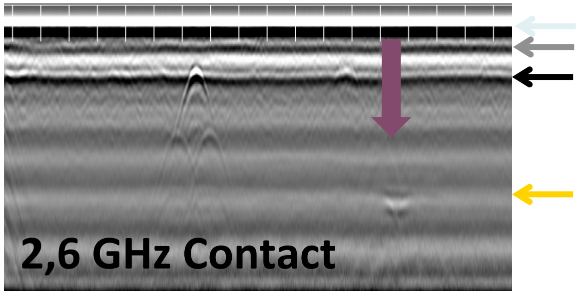
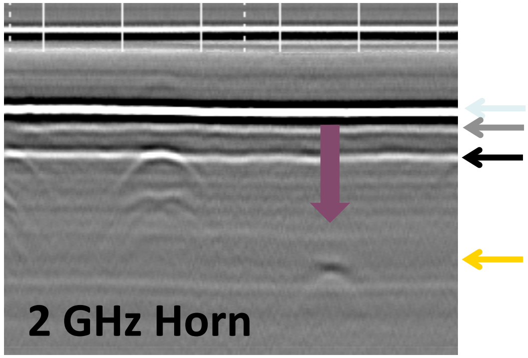
Local defects: Look for their extent under the road…

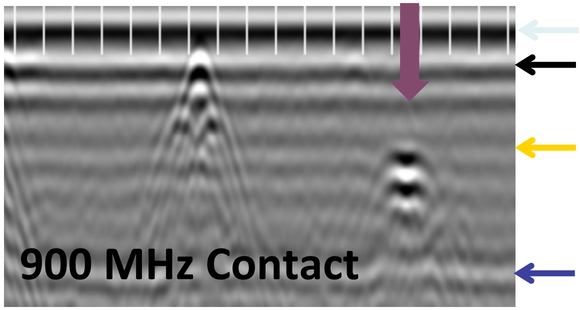
Hole detection
on BRRC test track

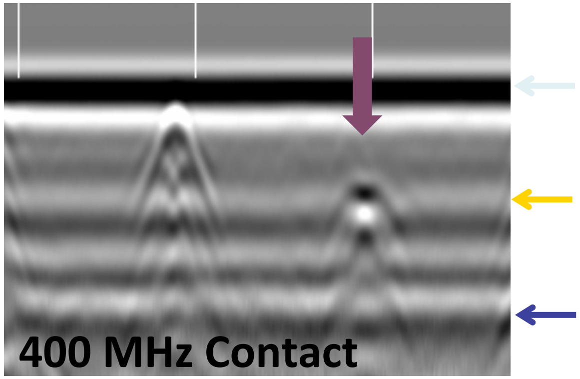
("deep" hole, air void)











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Examples of applications on roads

- Delamination and presence of water between asphalt layers?
  - Water in thin “cavity” due to delamination
  - Cavity probably too thin to be seen
  - But… air and water differ from standard road materials
  - We will look for changes in polarity…

- Probably interested in upper part of the road structure

Hence

- Use 2 GHz air-coupled antenna
- Use high frequency contact antenna (if safety measures allow to)

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Examples of applications on roads

- Concrete roads:
  - Where are the dowels (location and depth)?
  - Where are the reinforcing bars of a mesh (location and depth)?

- Expected depth of dowels or mesh: +/- 10 cm to 15 cm

Hence

- Use high frequency (2.6 GHz) contact antenna
- Several scans in different directions are going to be needed

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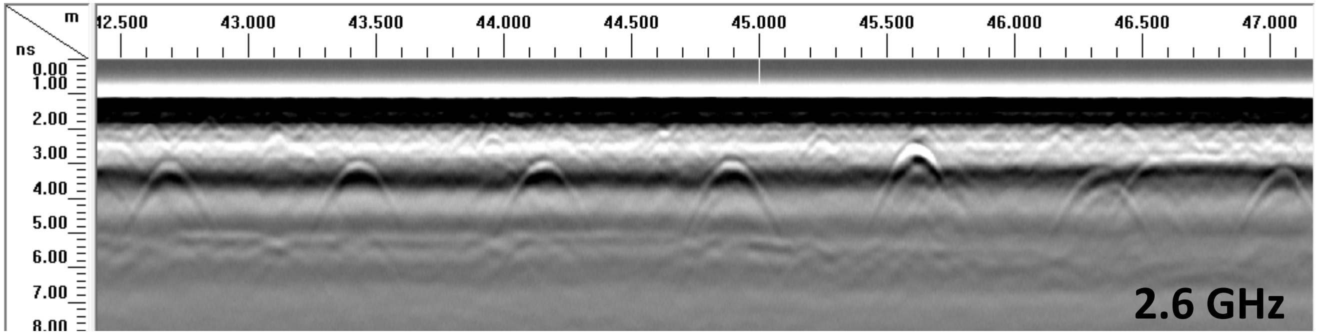
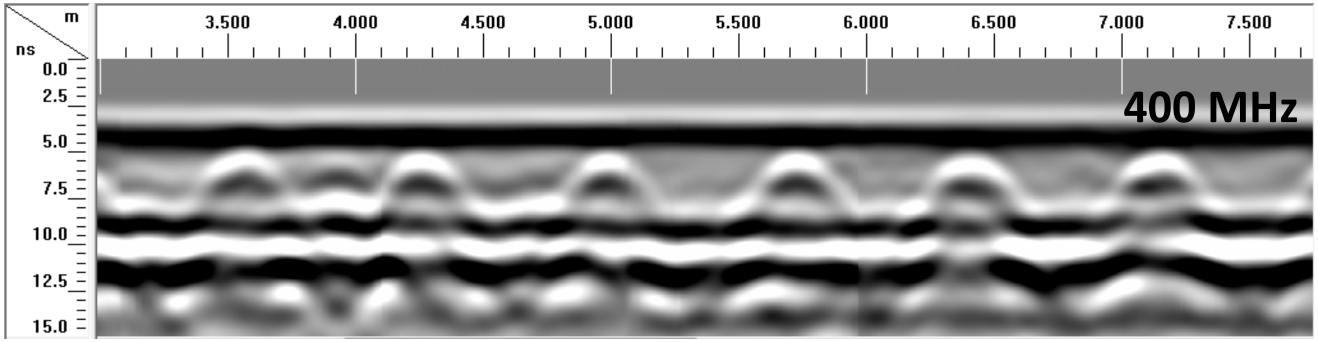
Anchor bar detection in a concrete motorway

- Anchor bar detection between two lanes marking necessary to put other bars
- Use of 2.6 GHz and 400 MHz antennas





Good detection of anchor bars with both antennas

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Planning a practical session: Real measurements on a road!

Note for the Trainer:
To be replaced with the map of the road to be measured!!

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Checking on site

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We saw…

- 2x2 lanes, bicycle path, side walk for pedestrians
- Heavy traffic: buses
- Lamp posts: they can serve as references
- Severe rutting at the traffic lights
- Transverse cracking
- Change of material + manhole covers (?) on bike path and side walk

Note for the Trainer:
To be replaced with the comments about the road to be measured!!

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Plan of action: First thoughts…

- Safety:
  - Slow lane in direction of Osijek centre will be closed for traffic

Antennas and data acquisition:

- Road structure:
  - High frequency antennas on the road, longitudinal direction
- Change in materials (top layer):
  - High frequency antennas on bike path and side walk, longitudinal direction
- Pipes underneath bike path and side walk:
  - Low frequency antennas in a mesh

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References

For this lecture, the main reference is represented by the Guidelines for flexible pavement investigation with Ground Penetrating Radar (GPR), developed and published by the COST Action TU1208. You can find them on the website of the Action.

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Author

Dr. Carl Van Geem (c.vangeem@brrc.be) is a researcher in road management and monitoring techniques, since 2004 he is working in the Mobility, security and road management (MSM) division of the Belgian Road Research Centre (BRRC), in Brussels, Belgium. He is a Working Group Member of the COST Action TU1208.

In 1996, Carl Van Geem earned the doctoral degree in technical sciences from the Research Institute on Symbolic Computation (RISC-Linz), Johannes Kepler University, Linz, Austria.

The BRRC has several devices for the evaluation of road surface properties (roughness, skid resistence), for pavement management (visual inspection device “SAND”), and for measuring the bearing capacity of roads (FWD, curviameter, GPR). The main topic of Carl’s research is the interpretation of data obtained with these monitoring devices for an optimal management of road maintenance. Carl participated in several national and international research projects, including a “national pre-normative research project on the indicators of roughness”, the COST Action 354 “Performance Indicators for Road Pavements”, the PIARC technical committee D1 “Management of Road Infrastructure Assets”, and the FP7 project “Tomorrow's Road Infrastructure Monitoring and Management (TRIMM)”.

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Thank you

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