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Ground-Penetrating Radar Applications for the Assessment of Pavements

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Ground-Penetrating Radar (GPR)

Capabilities of GPR

- Layer thicknesses
- Void location
- Stripping in asphalt layers
- Presence of moisture
- Detection/locate subsurface anomalies

GPR contributes to the structural assessment of pavements

- Predict pavement performance
- Determine upgrade requirements
- Prevent unforeseen pavement failures

GPR is nondestructive

- Quicker results
- Fewer delays and interference

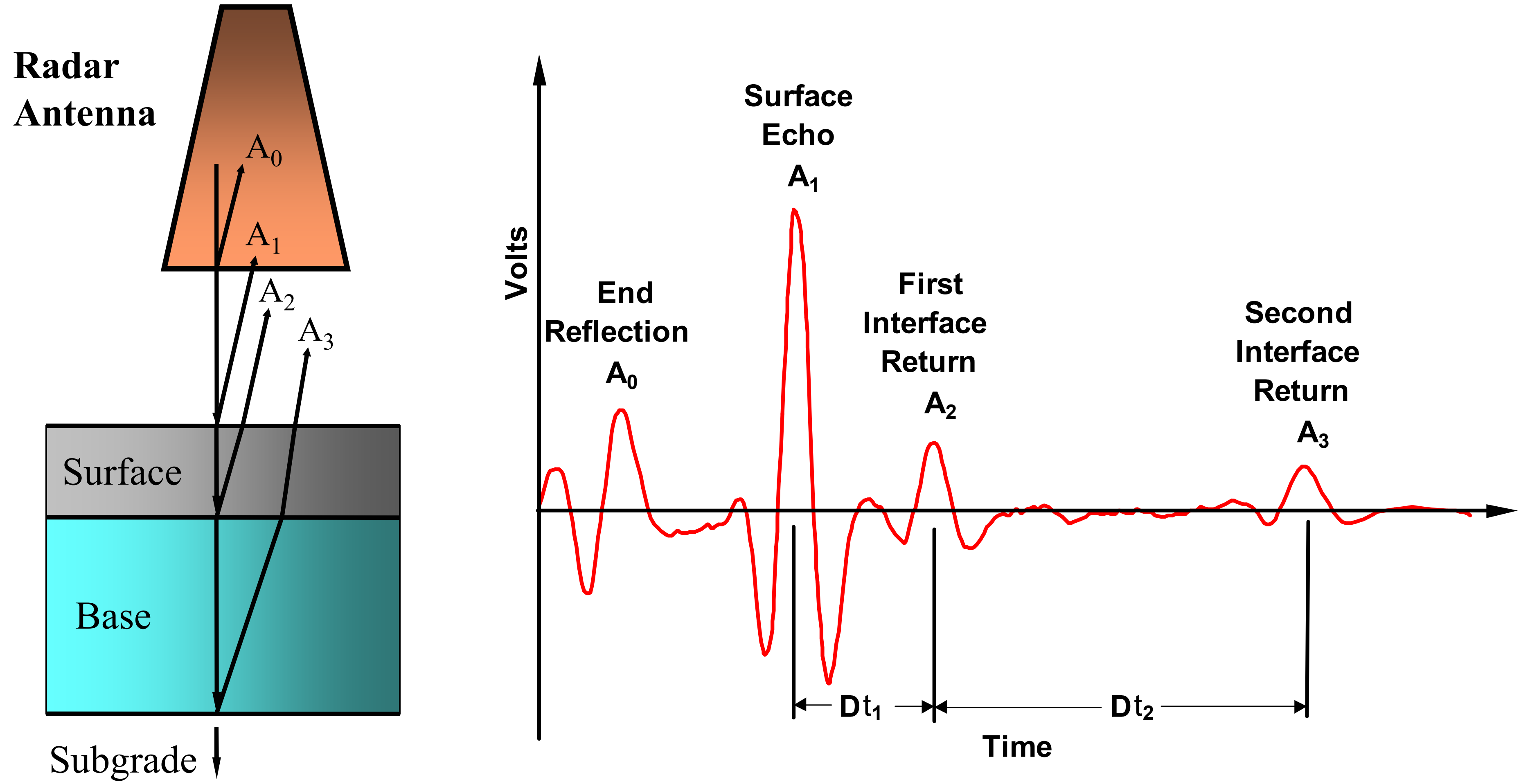
ERDC GPR Applications

- **Airfield evaluations**
  - Current pavement condition
  - Layer thicknesses can be used with falling weight deflectometer (FWD) data to backcalculate layer moduli
- **Road structures**
  - Maintenance and repair
  - Future design
- **Test sections at ERDC**
  - Quality assurance tool

Pulse Radar System

- Developed under Small Business Innovative Research (SBIR) with Pulse Radar (Houston, TX)
- Multi-Antenna
  - 1 GHz (1 meter)
  - 500 MHz (2 meters)
  - 250 MHz (3 meters)
  - 100 MHz (5-10 meters)
- Operates at highway speeds

Short Pulse GPR



Note: Requires dielectric discontinuity at layer interfaces

GPR Equations

- Layer thickness*

$$h = \frac{c \times \Delta t}{2\sqrt{\varepsilon}}$$

h = layer thickness
c = speed of light
Δt = two way travel time
ε = dielectric

- Dielectric values*
  - Use assumed value (typically 6.0 for asphalt, 8.0 for concrete)
  - Backcalculate dielectric from core
  - Use equations

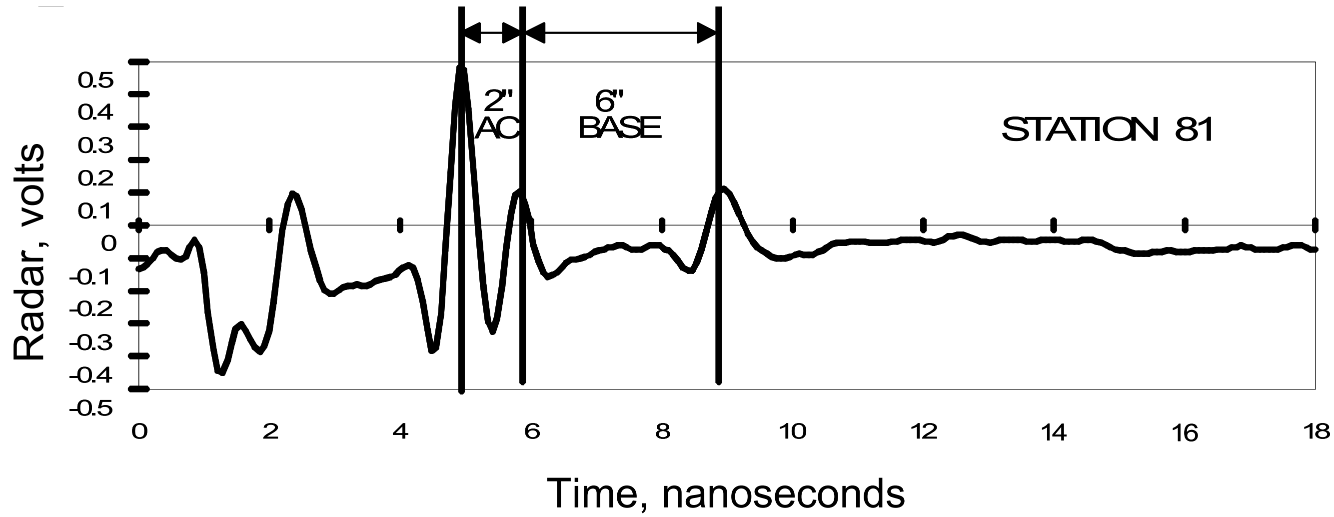
$$\varepsilon_a = \left[\frac{1 + \frac{A_0}{A_m}}{1 - \frac{A_0}{A_m}}\right]^2$$

$$\sqrt{\varepsilon_b} = \sqrt{\varepsilon_a}\left[\frac{1 - \left[\frac{A_0}{A_m}\right]^2 + \left[\frac{A_1}{A_m}\right]}{1 - \left[\frac{A_0}{A_m}\right]^2 - \left[\frac{A_1}{A_m}\right]}\right]$$

ε_a = dielectric of first layer
ε_b = dielectric of base layer
A_m = metal reflection amplitude
A_0 = surface reflection amplitude
A_1 = base reflection amplitude

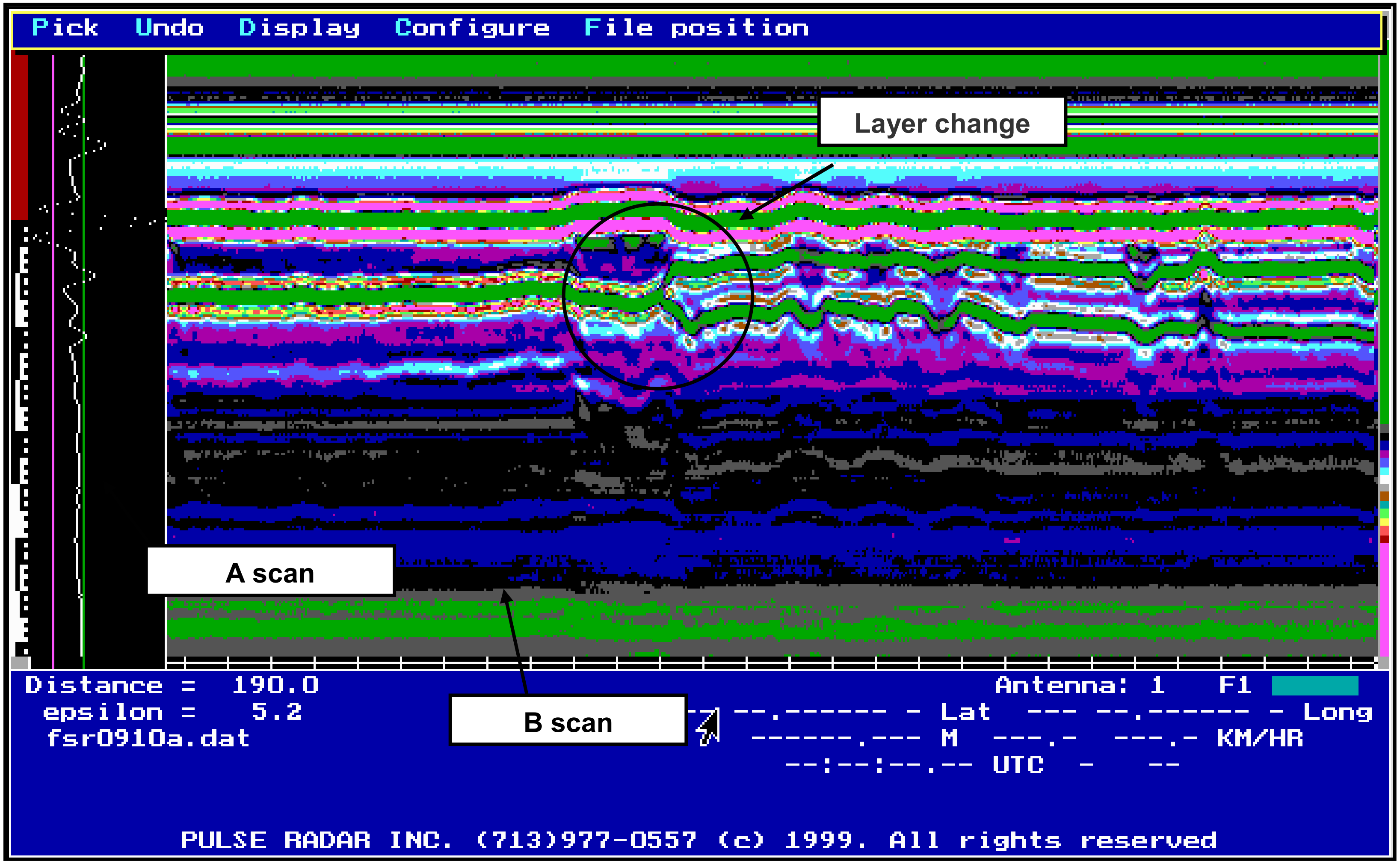
*Scullion et al, 1994

GPR Data Analysis



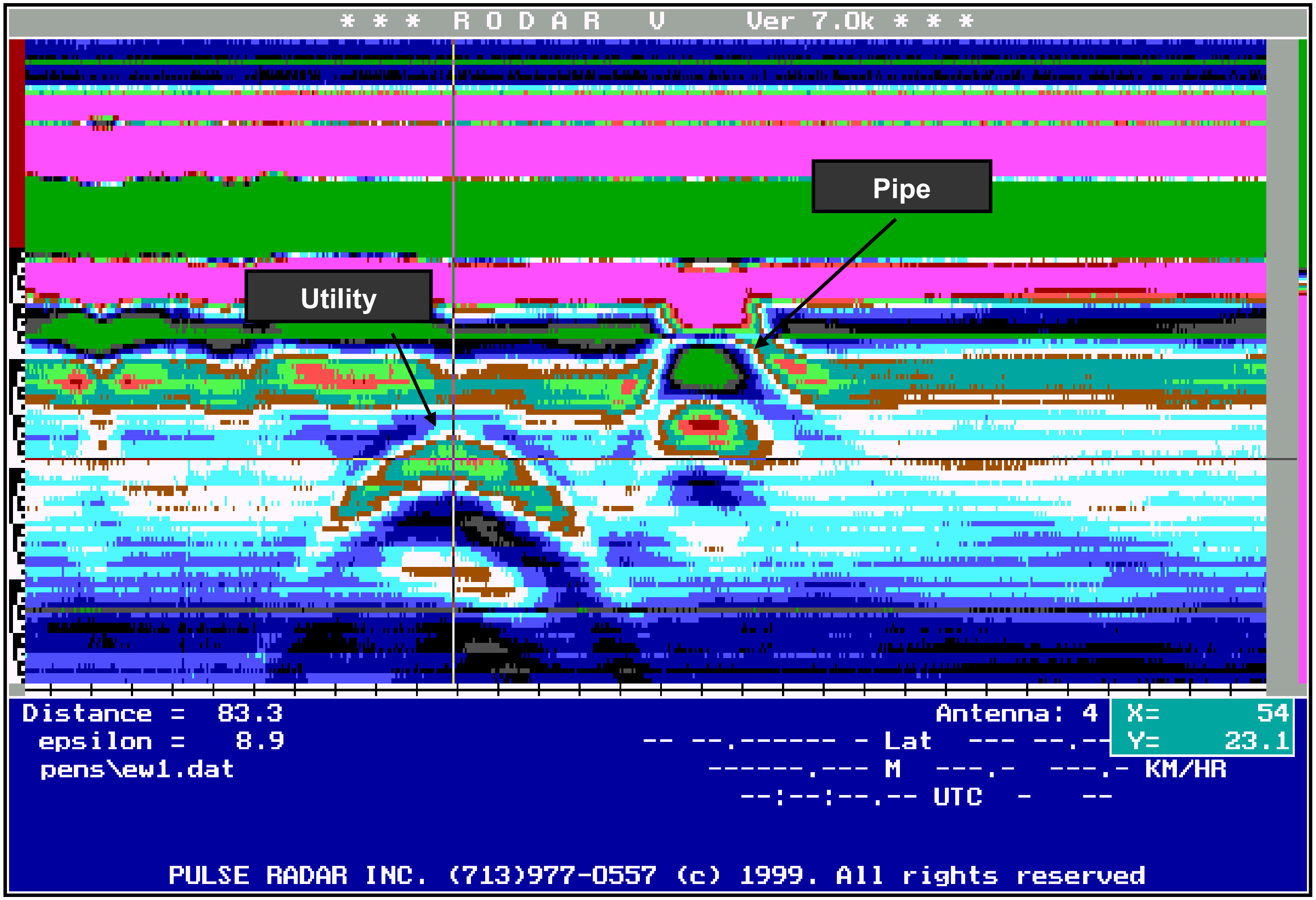
- Layer interfaces (signal peaks) are found using a cross-correlation technique
- Layer thickness are calculated using the locations of the signal peaks and the previous equations
- Layer thickness measurements improve when calibrated/corrected with a thickness value from a single core (“ground truth”)

GPR Display



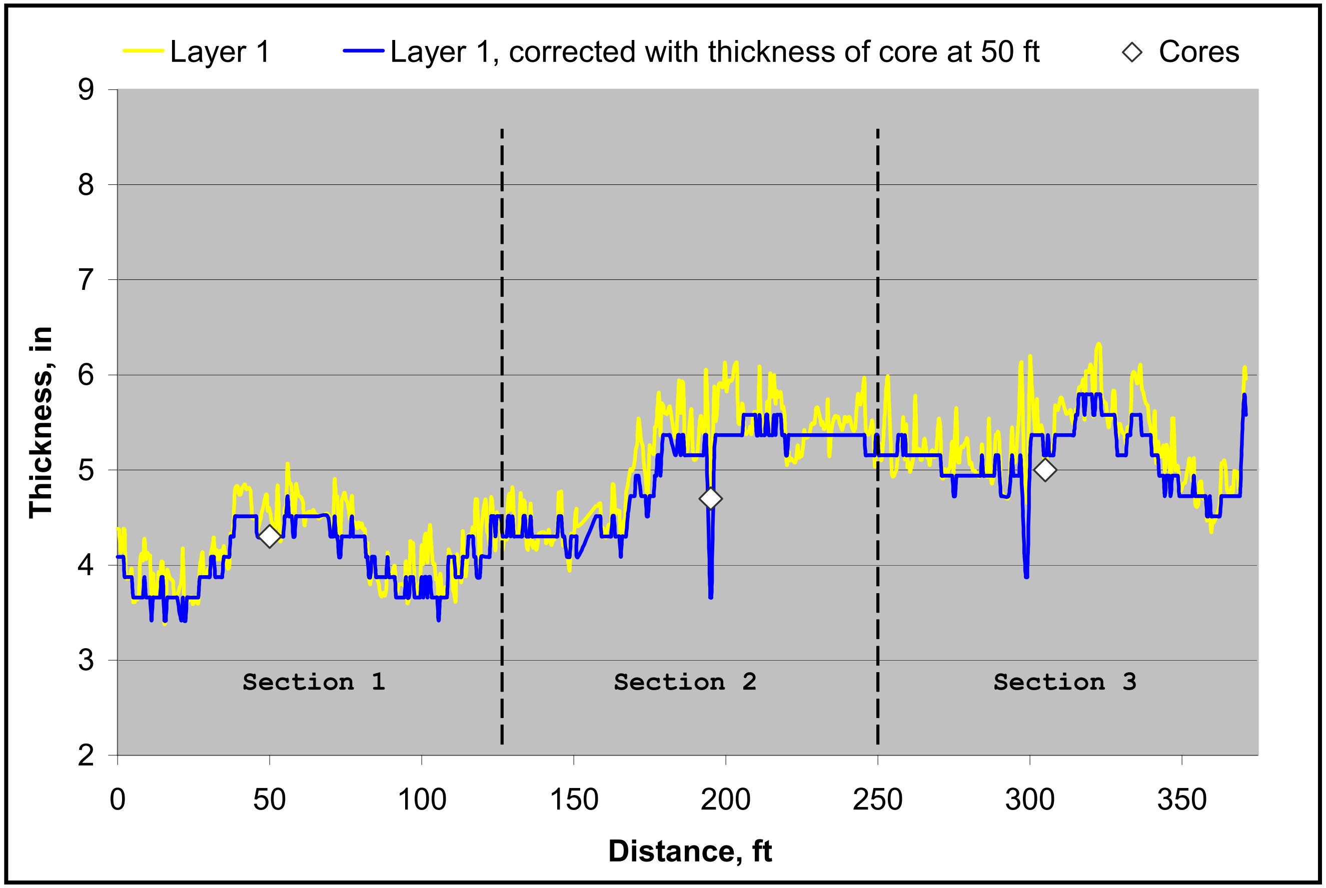
Pick Undo Display Configure File position
Layer change
A scan
B scan
Distance = 190.0
epsilon = 5.2
fsr0910a.dat
Antenna: 1 F1
--.------ - Lat --- --.------ - Long
------.--- M ---.- ---.- KM/HR
--:--:--.-- UTC - --
PULSE RADAR INC. (713)977-0557 (c) 1999. All rights reserved

Detection of Subsurface Utilities



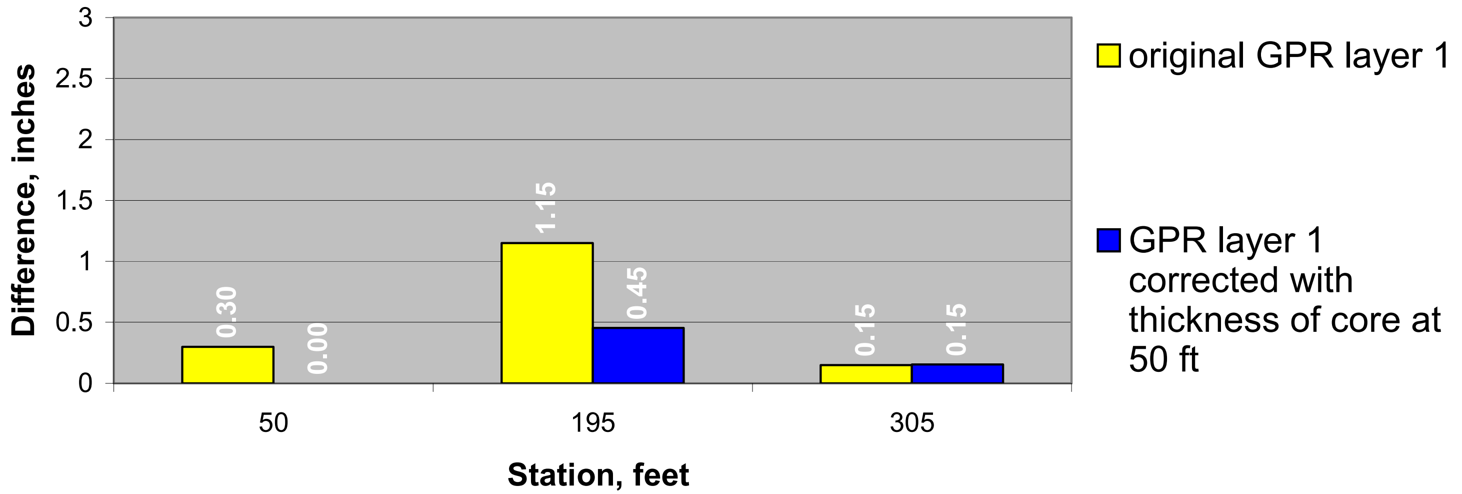
Verification – Flexible Pavements

Layer 1 original and corrected thicknesses as determined from the 1 GHz antenna on the ERDC asphalt test pavement

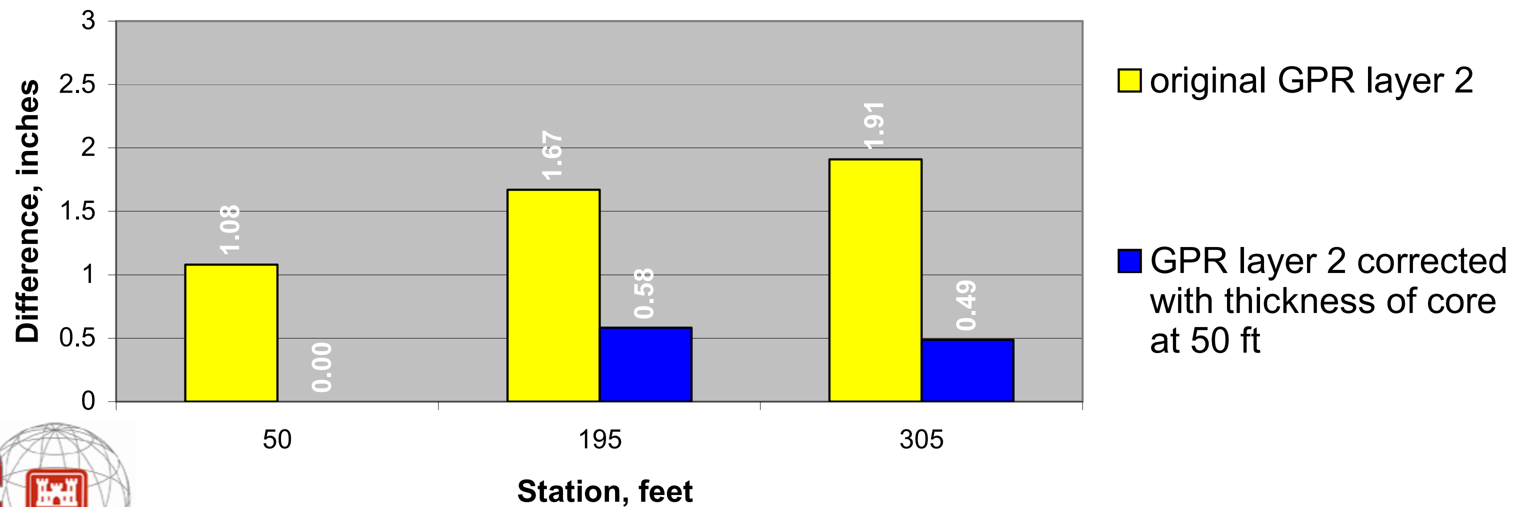


Differences/Errors

Asphalt test pavement – Asphalt, layer 1 (1 GHz)

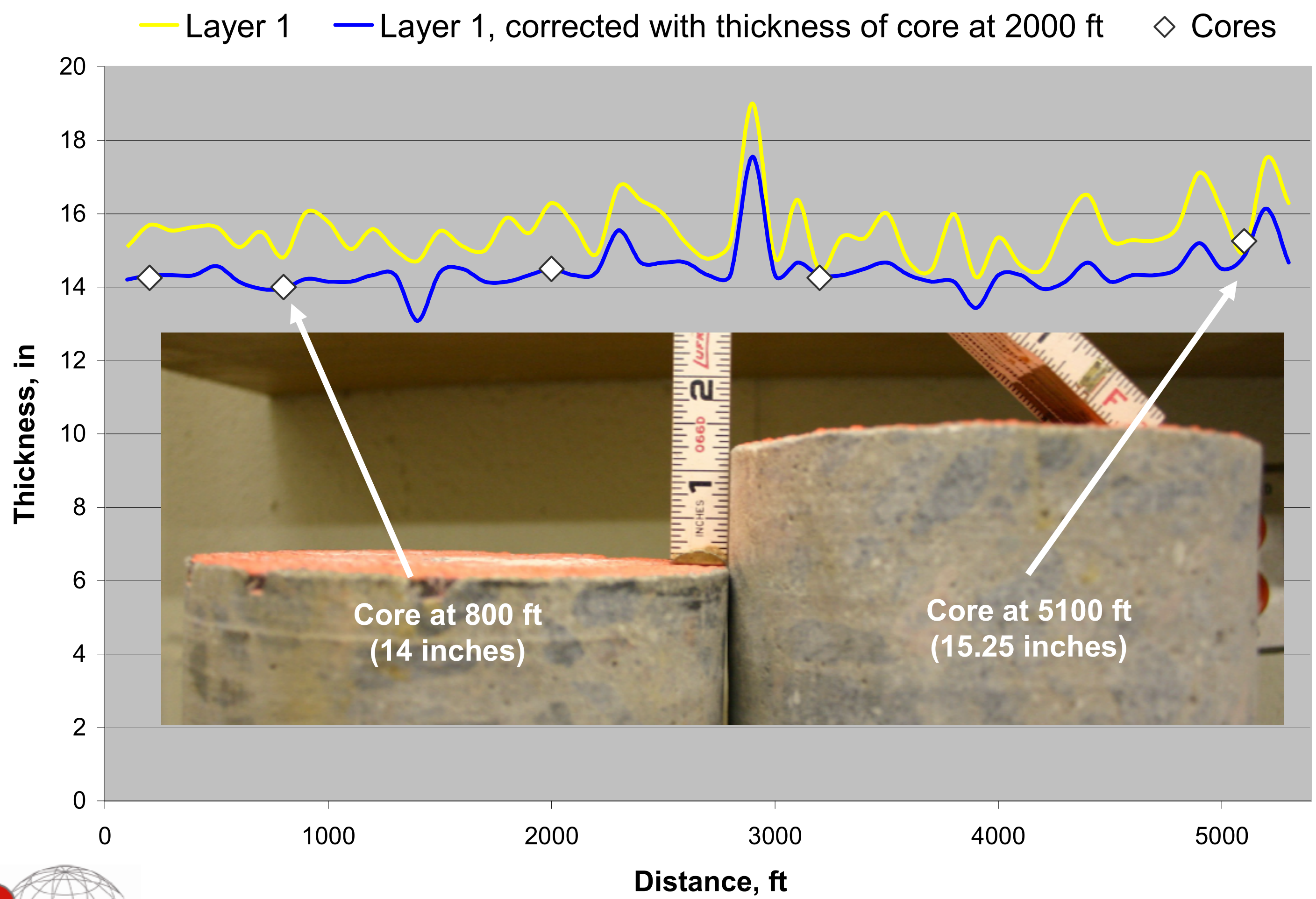


Asphalt test pavement – Base, layer 2 (1 GHz)



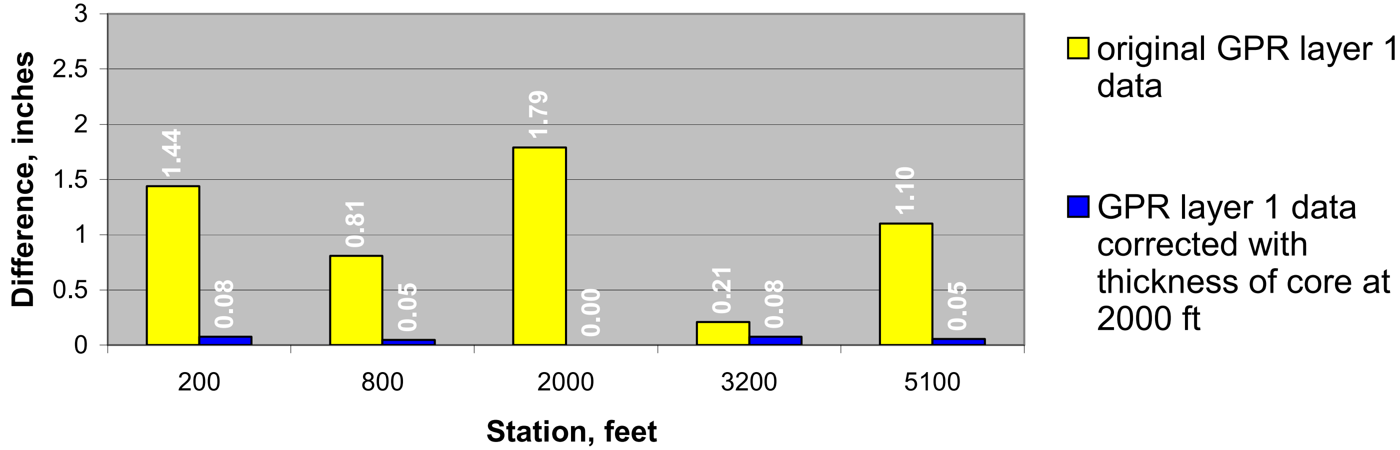
Verification – Rigid Pavement

Layer 1 original and corrected thicknesses as determined from the 1 GHz antenna on the Portland Cement Concrete (PCC) airfield pavement

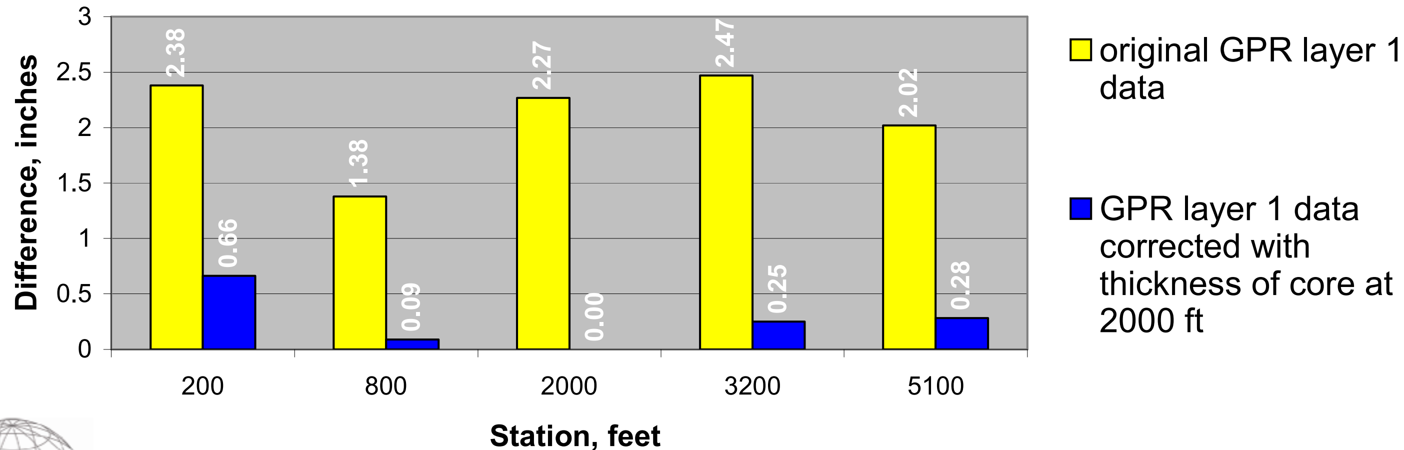


Differences/Errors

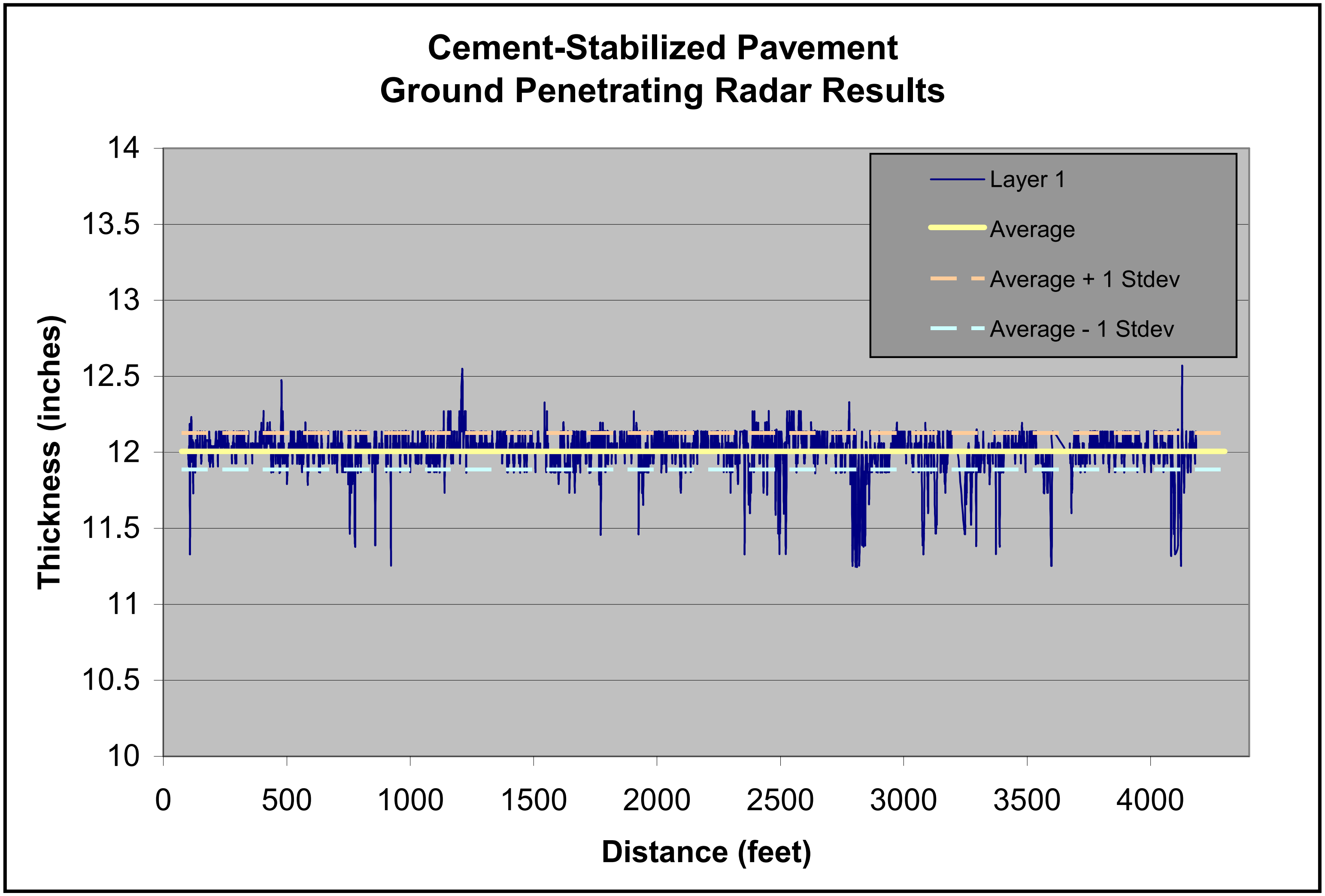
PCC airfield pavement – layer 1 (1 GHz)



PCC airfield pavement – layer 1 (500 MHz)



Cement-Stabilized Soil



Summary and Conclusions

- Continuous thickness measurements along the entire length of the pavement ensures that changes in layer structure will be detected
- Combination of the 1GHz and 500 MHz antenna appears to provide both the resolution and penetration necessary for sampling most typical pavement structures
- At least one core is required to calibrate GPR thicknesses
  - Flexible pavement - error is reduced from an average of 1.04 inches to 0.42 inches
  - Rigid pavement – error is reduced from an average of 1.59 inches to 0.19 inches

Summary and Conclusions

- Measuring layer thicknesses with GPR has the potential to minimize time required for pavement evaluations by optimizing coring and DCP testing
- GPR is useful for detecting utilities
- Using layer thicknesses from GPR along with FWD data results in more accurate backcalculated moduli, and therefore, more reliable predictions of structural capacity

Questions?

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