In Situ Monitoring of Soil Water Content: An Assessment of Current Instrumentation & Technology

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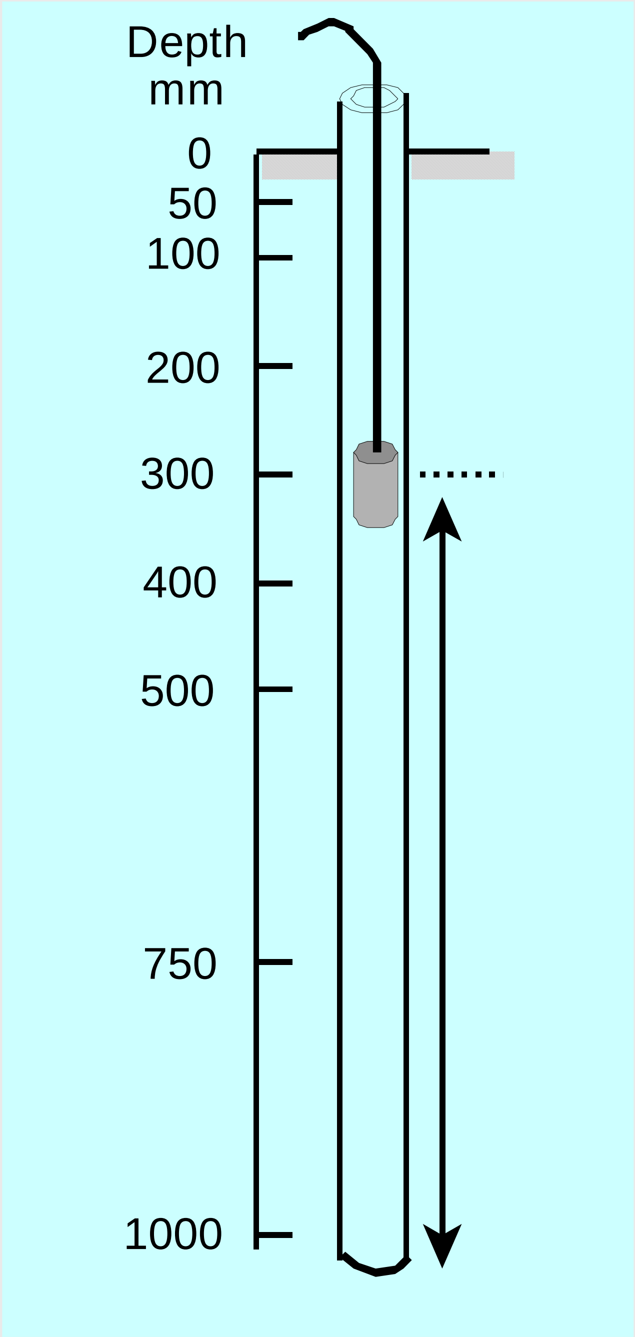
Presented at CGEO Workshop on Soil Moisture Monitoring Analysis and Prediction in Agricultural Landscapes
June 19 – 20, 2007, Saskatoon

Where I will go today

- Introduction
- Review of principles of operation of EM methods
- Measuring water content by EM devices
- Classes of EM devices
- Advantages & limitations of EM devices
- Making the choice?
- Concluding remarks

Introduction

- 20 years ago
- Conductive blocks, neutron, gravimetric
- Recent developments
- Electromagnetic (EM) methods – optimal choice



Soil water content – EM methods operation and the wave equation

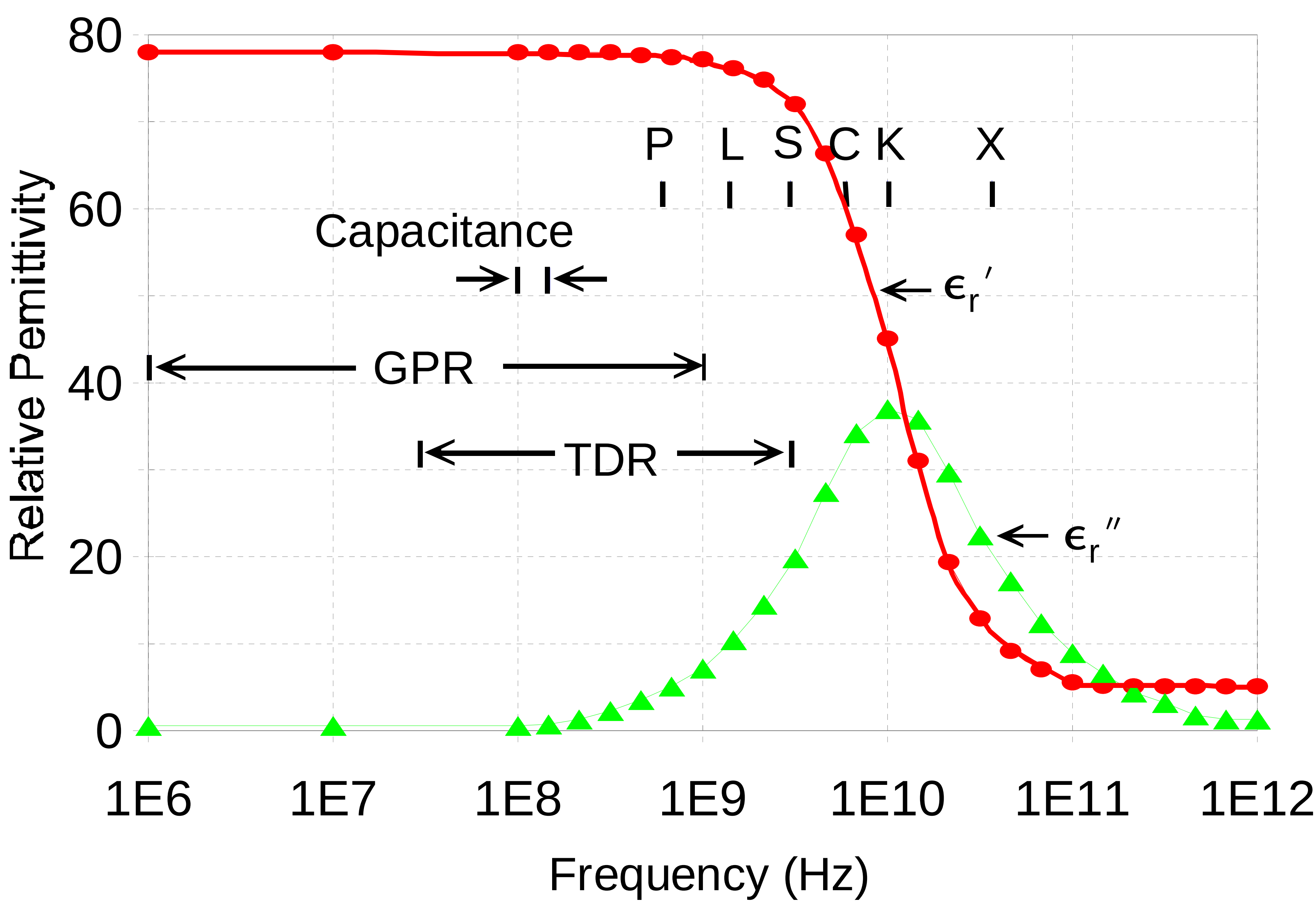
$$V(z) = V_1 e^{\alpha z} e^{j(\omega t + \beta z)} + V_2 e^{-\alpha z} e^{j(\omega t - \beta z)}$$

$$v = \frac{\omega}{\beta} = \frac{c}{\sqrt{\frac{\varepsilon_r'}{2}\left[1 + \sqrt{1 + \left(\frac{\varepsilon_r'' + \sigma_0 / \omega\varepsilon_0}{\varepsilon_r'}\right)^2}\right]}} \approx \frac{c}{\sqrt{\varepsilon_{ra}}}$$

$$Z_0 = 120\pi\sqrt{\frac{1}{\varepsilon_r' - j\left(\varepsilon_r'' + \sigma_0 / \omega\varepsilon_0\right)}} \approx \frac{120\pi}{\sqrt{\varepsilon_{ra}}}$$

$$\rho = \frac{Z_L - Z_0}{Z_L + Z_0}$$

EM Properties of water



Measuring water content

- Permittivity (dielectric constant) of H_2O is high
- Air and soil solids have low permittivity
- Measuring permittivity is a good measure of water content
- What is the relationship of permittivity to water content?
- Factors affecting measurements

  -Size and shape of sample

  -Intended use of data

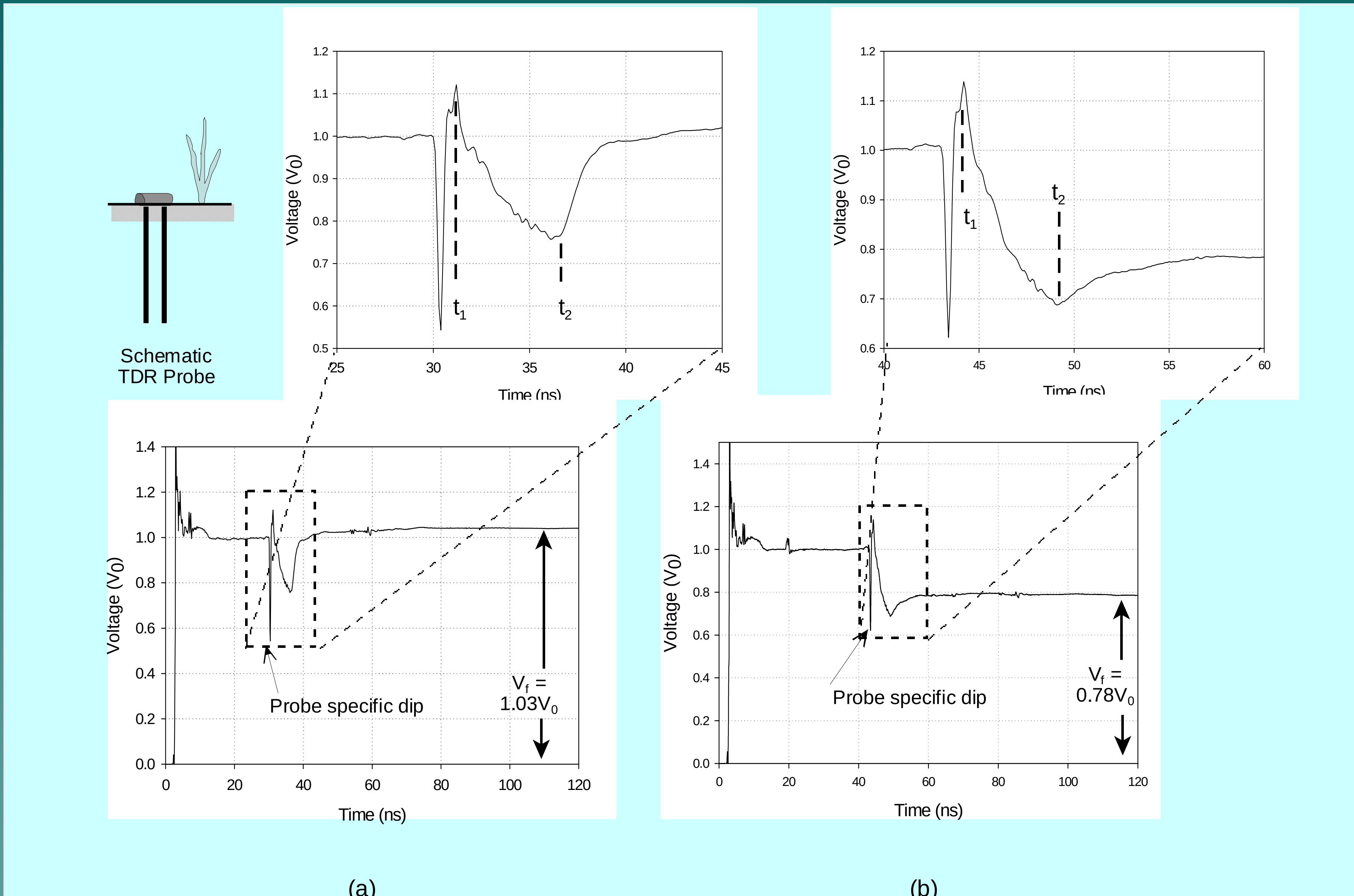
$$\theta_v = M_1\sqrt{\varepsilon_{ra}} + M_0$$

$$\theta_v = 0.115\sqrt{\varepsilon_{ra}} - 0.176$$

Types of EM Methods

- Time Domain Reflectometry (TDR) & TDT
- Capacitance
- Impedance
- Ground Penetrating Radar (GPR)
- Synthetic Aperture Radar (SAR)
- Passive Microwave Radar

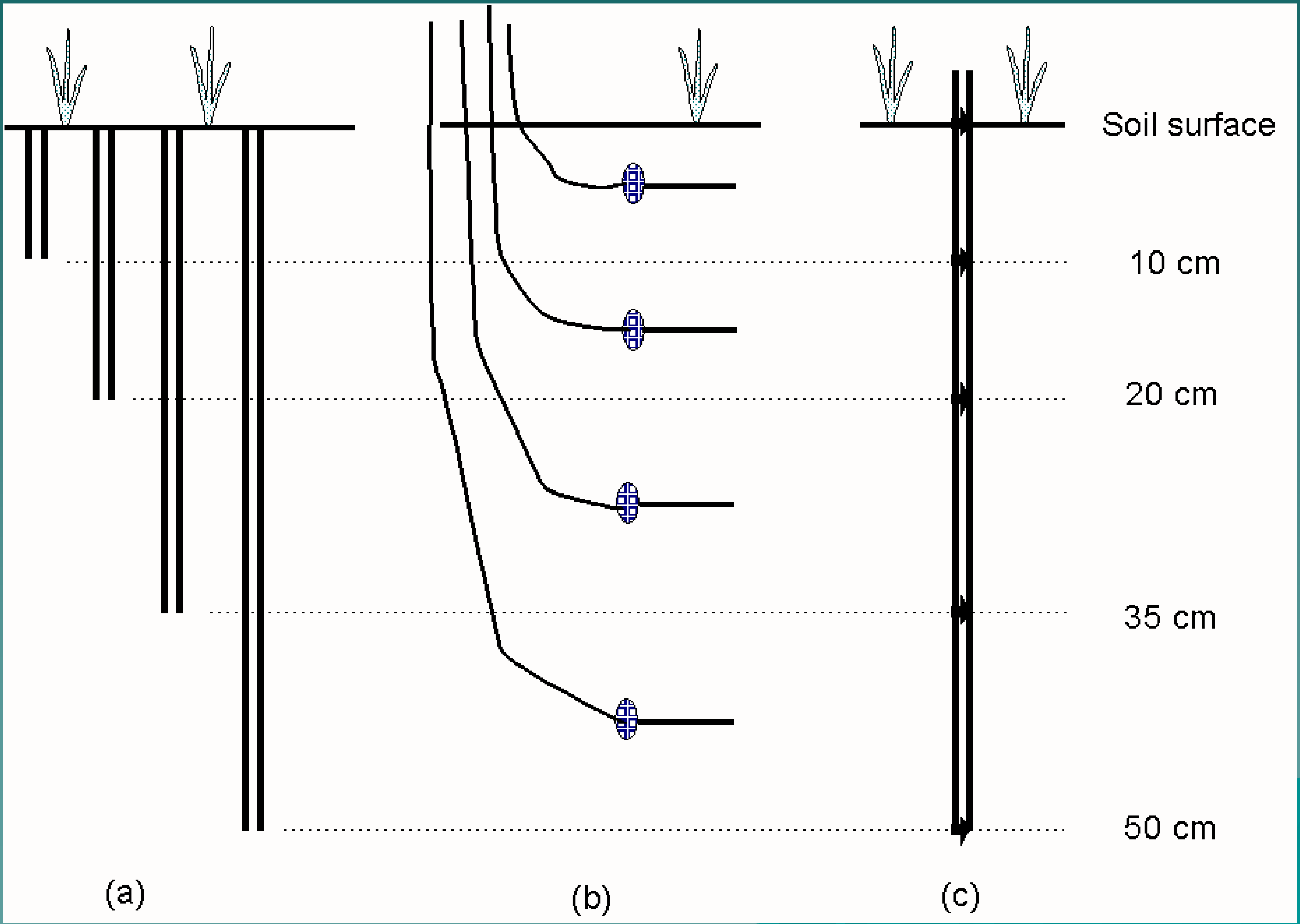
Principles of TDR



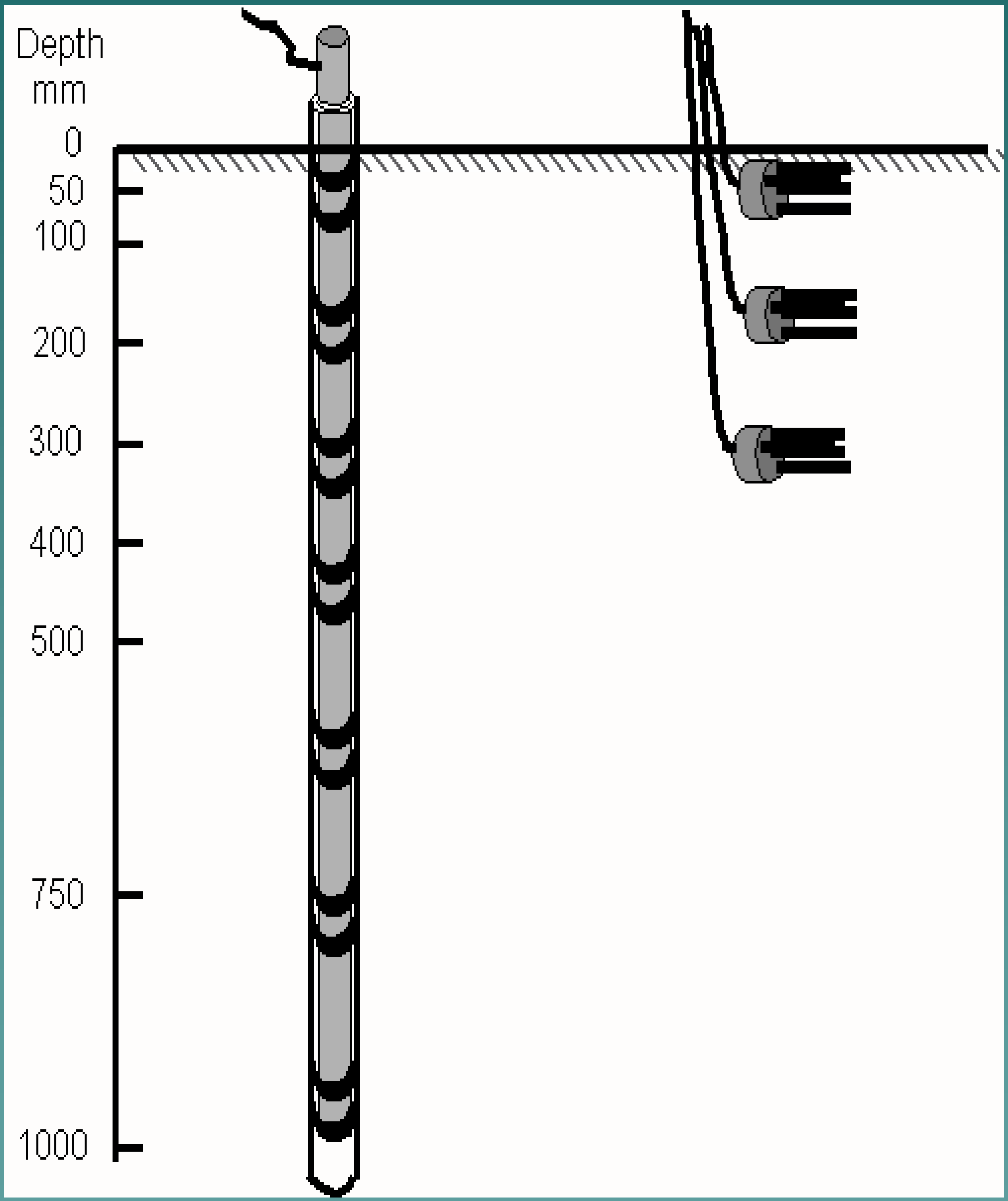
$$\sqrt{\varepsilon_{ra}} = \frac{c(t_2 - t_1)}{2L}$$

$$\theta_v = 0.115\sqrt{\varepsilon_{ra}} - 0.176$$

Water content profiles using TDR



Capacitance / Impedance

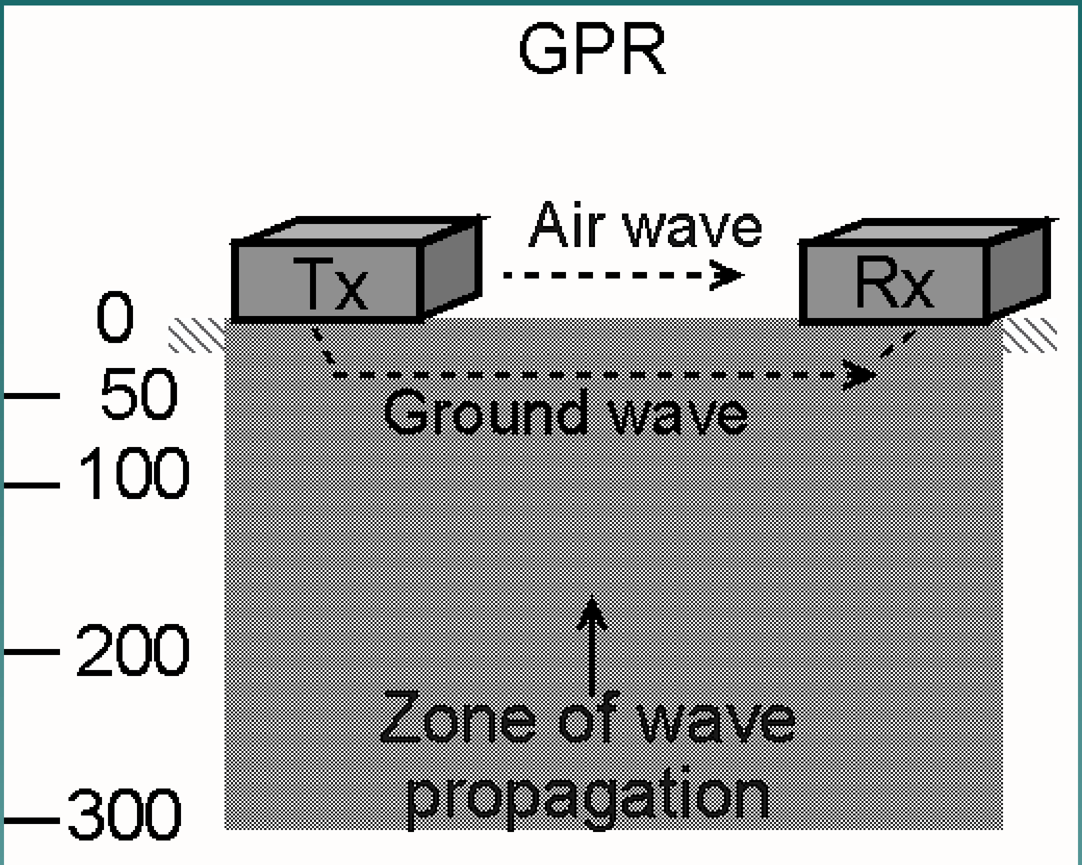


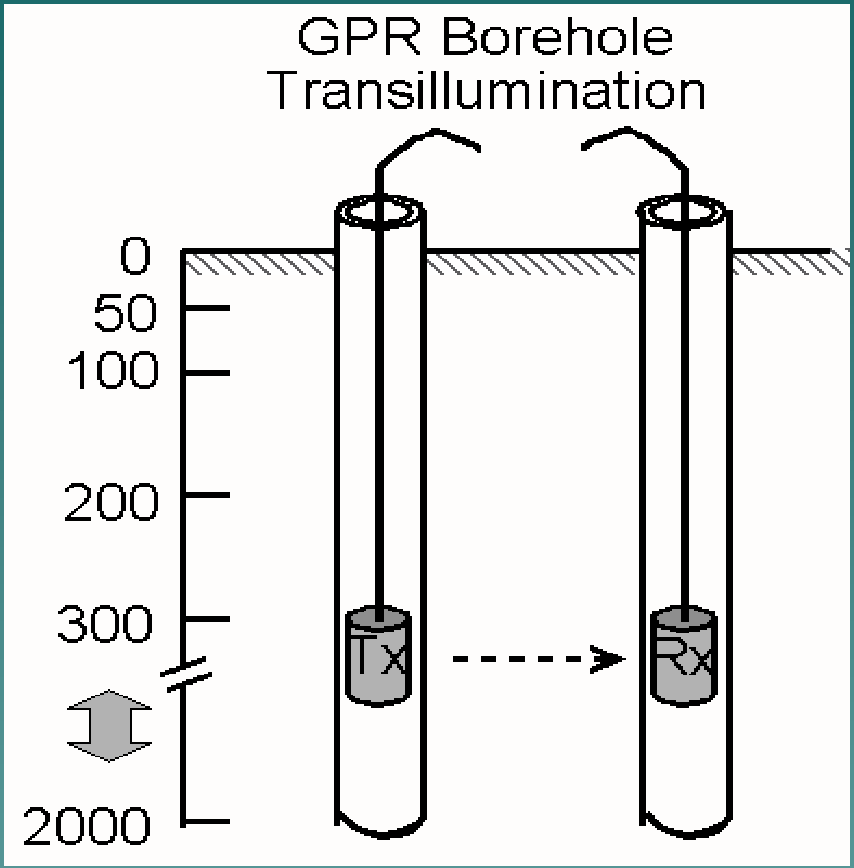
$$Z = \frac{g_1}{\sqrt{\varepsilon_{ra}}}$$

$$C = g_2 \varepsilon_{ra}$$

$$F = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{L g_2 \varepsilon_{ra}}}$$

Ground Penetrating Radar

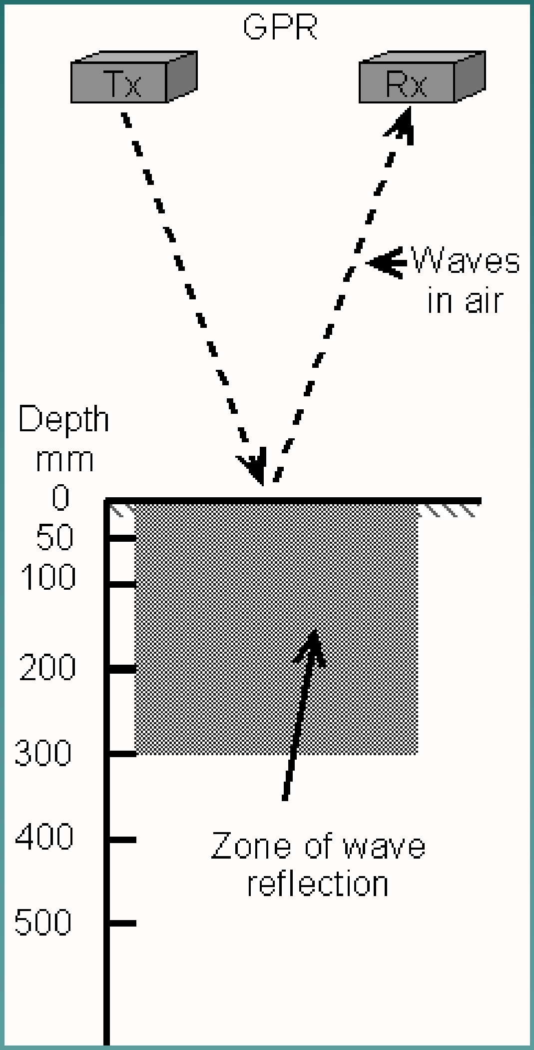




$$v \approx \frac{c}{\sqrt{\varepsilon_{ra}}}$$

$$\theta_v = 0.115\sqrt{\varepsilon_{ra}} - 0.176$$

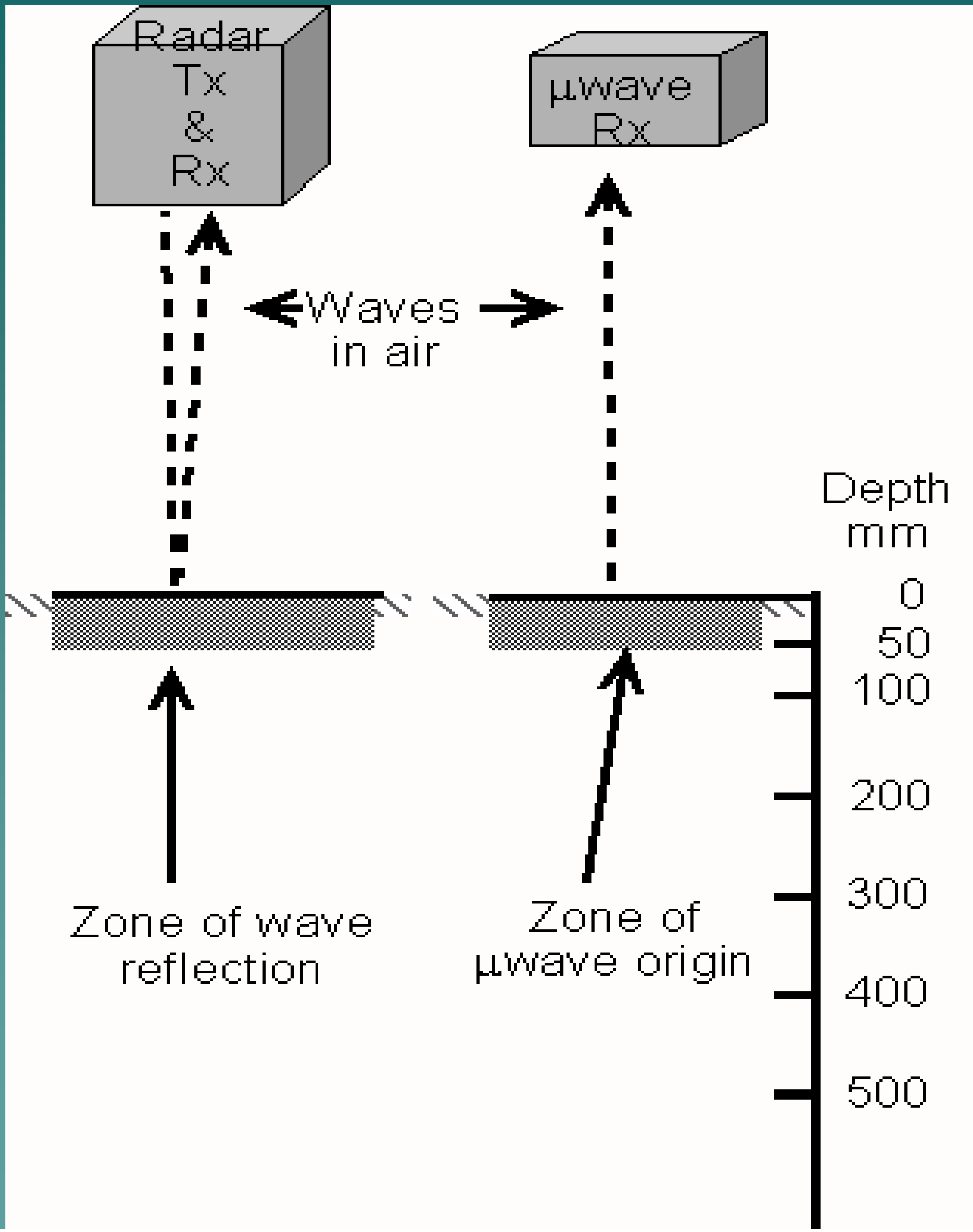
GPR Air-launched Reflection



Reflection Equation

$$\sqrt{\varepsilon_{ra}} = \frac{A_m + A_r}{A_m - A_r}$$

Active Radar & Passive Radar



EM Methods Advantages & Disadvantages

- Time Domain Reflectometry (TDR) & TDT
- Capacitance
- Impedance

Positive and Negative Attributes of **TDR & TDT**

- Robust calibration and low sensitivity to conductivity and density
- Flexibility in design of probes for TDR
- Much thorough research as support
- Several companies supply highly reliable equipment
- Equipment cost is high for TDR, not for TDT
- Probes must be embedded in soil

Positive and Negative Attributes of **Impedance Devices**

- Principle of operation similar to TDR and same calibration
- Calibration not as robust; higher sensitivity to conductivity
- Data recording is straight forward
- Sensor design is fixed
- Delta T offers two formats
- Probe must be embedded in soil
- Instrument cost is intermediate

Positive and Negative Attributes of **Capacitance Devices**

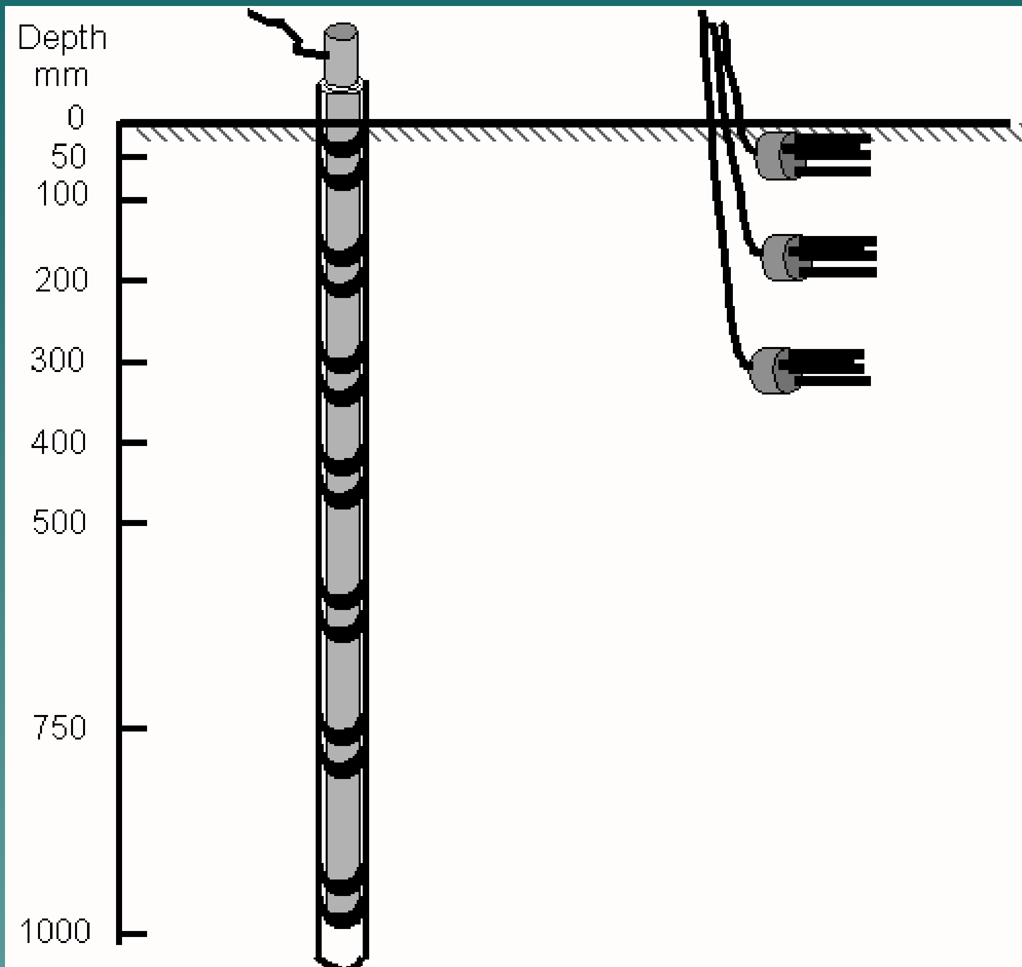
- The cost is low
- Recording data is straight forward
- Calibration is soil and instrument specific
- Sensitivity to conductivity is relatively higher
- Sensor design is predetermined
- Sensors are offered in a variety of formats
- A variety of suppliers are available

Making Choices - 1

Delta-T Devices
Theta Probe
Model ML2

Stevens Water Monitoring Systems
HydraProbe II Soil Sensor

Making Choices - 2



Sentek Sensor Technologies

Enviroscan Series

Delta-T Devices
Profile Probe - PR2

Some Questions (Criteria)?

- How will data be used?
- How many replicates are required?
- What sample size and shape?
- Reading single point or profiles?
- Reporting relative or “absolute” WC?
- Comparing different soils &/or locations?
- Single instrument or instrument comparison?
- Cropped or fallow sites? Which crop?
- Etc.?

Closing Remarks

- EM techniques appropriate choice
- Technology is now well-advanced
- Digital technology now inexpensive allowing efficient data collection
- Data collection assists modelling
- Choosing instruments – a critical step – but difficult

Discussion is now Yours

Thank You!