


Introduction to GPR *Ground Penetrating Radar*

PHYTOSEQUESTRATION WORKSHOP

JULY 23RD & 24TH, 2015

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ORGAINZED BY arpa·e CHANGING WHAT'S POSSIBLE

Purpose of Presentation

- Introduce those unfamiliar with GPR to its basic functionality and how it could be used for Phytosequestration
  - What is GPR, What does it measure and Why use it.
  - Overview of a GPR System
  - Operating Frequency, Spatial Resolution, Penetration Depth
    - Effects of Soil, Clutter
  - Example Data / Simulation 2-3 slides
    - Imaging vs. Non-Imaging

What is GPR

- A method for non-invasively probing below ground surface using back-scattered electromagnetic radiation.
- Measures variations in the electromagnetic properties of materials.
  - Changes in dielectric and conductivity properties.
- Rapidly measure large areas.
- Provides detailed localized data (3D-images) of subsurface features.

Conclusions

- GPR can be used to produce 3D images of root structures
- GPR can be used to monitor and estimate root growth/biomass
  - Direct measurements & change detection
- cm to cub-cm voxel resolution may be possible under right soil conditions.
- Soil characteristics will determine overall performance/limitation of GPR
- Upper operating frequency <10GHz (needs further investigation)
- Penetration depth in good soils @ 10GHz ~0.5m (needs further investigation)Hetero
- Non-Homogenous conductive soils are bad for GPR performance
- Uniform non-conductive soils are good for GPR performance

GPR System

Typical Center Frequencies

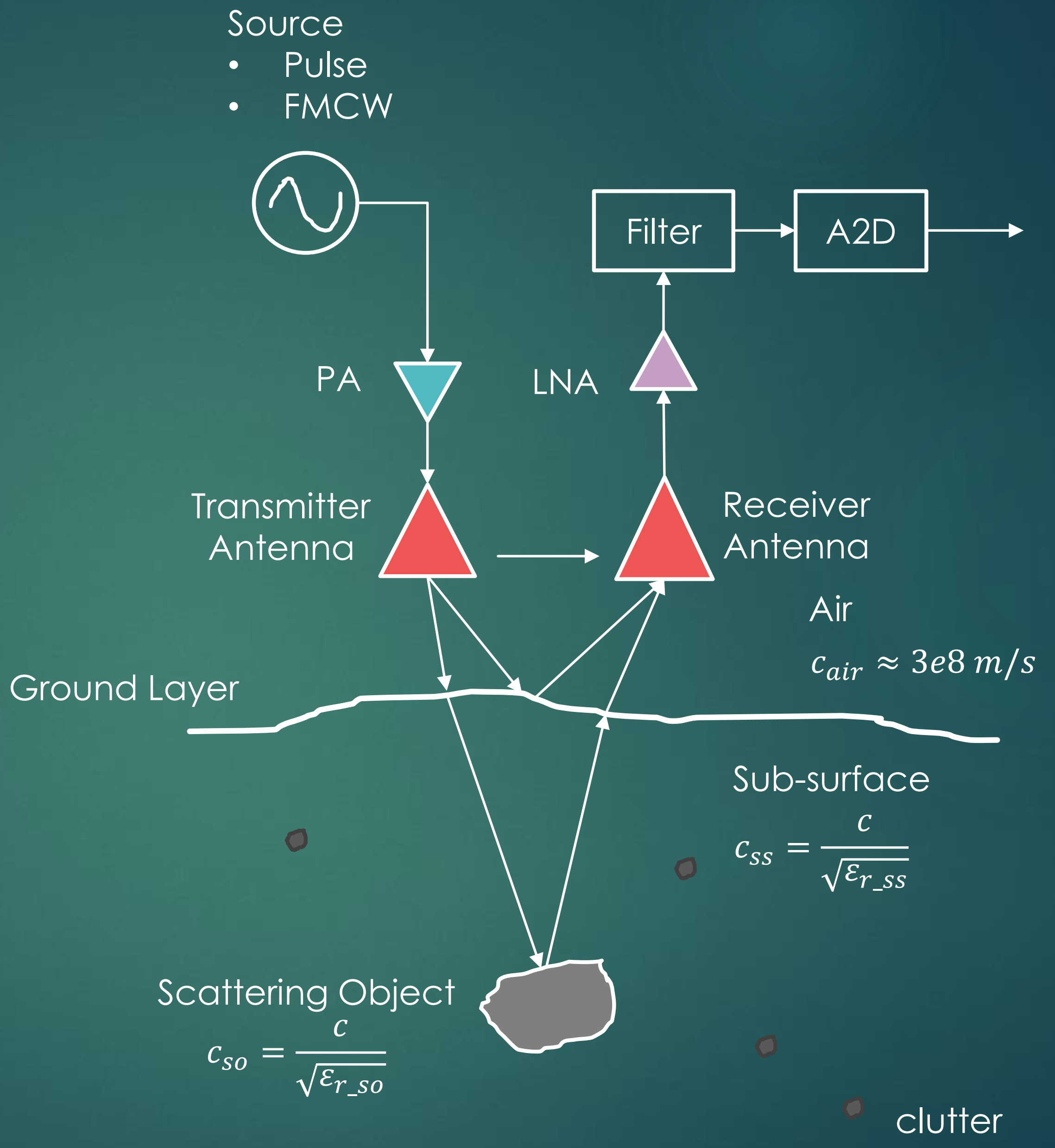
100 MHz – 2GHz

Typical Bandwidth

100MHz – 1GHz

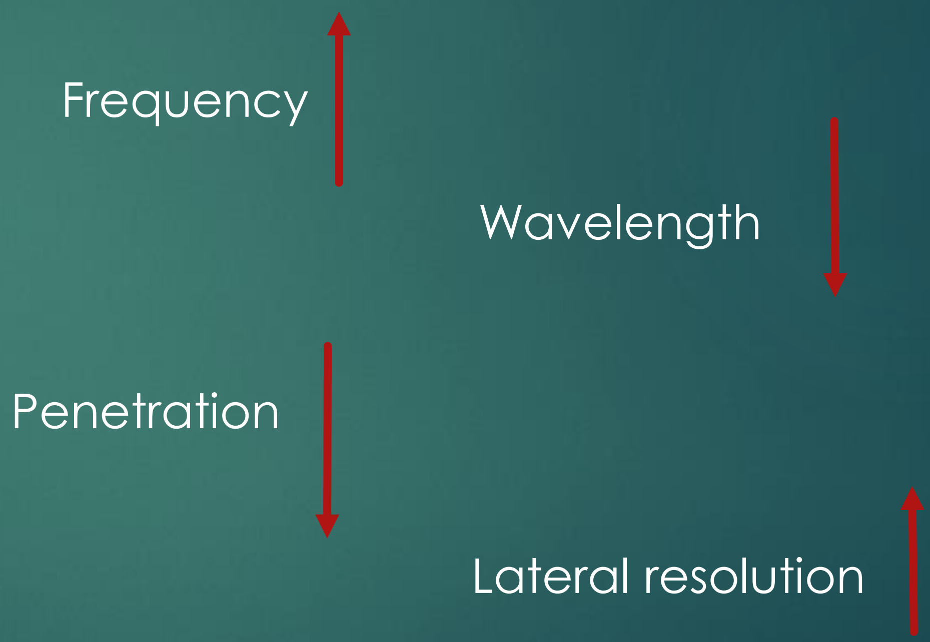
Typical Penetration Depth

Good Soil	Bad Soil
(Dry Sand)	(Wet Clay)
1-10m	0.01 – 2 m



General Factors That Effect GPR Performance

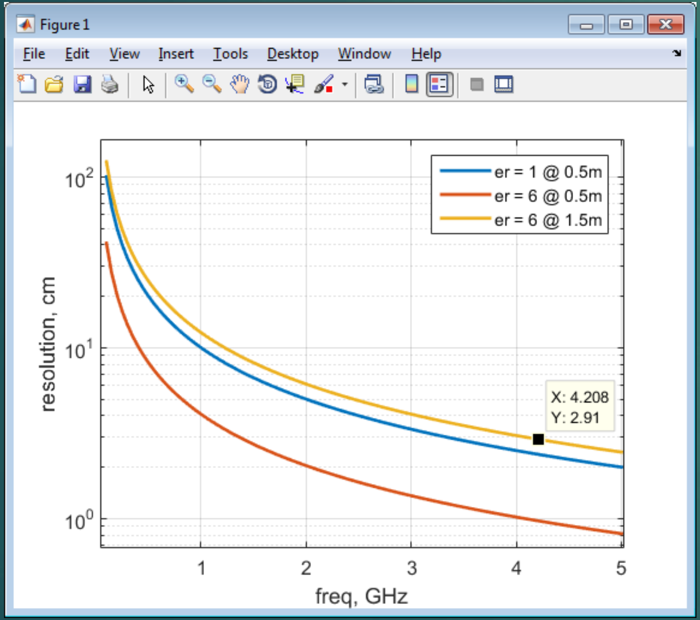
- Higher frequency = shorter wavelength
- Shorter wave length = better cross range resolution
- Higher frequency = decreases penetration
- Increased Bandwidth = better depth resolution



Resolution

Lateral Resolution

$$\Delta x = \frac{\lambda_r}{D} R \qquad \Delta x_{sar} = \frac{\lambda_r}{2D_{sar}} R$$



D = 0.75m

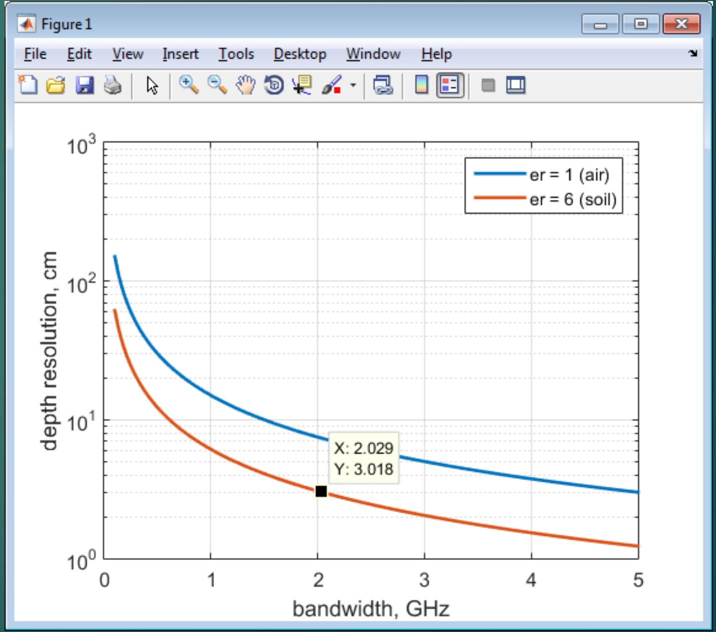
$$\lambda_r = \frac{c_r}{f}$$

$$c_r = \frac{c}{\sqrt{\varepsilon_r}}$$

$$\varepsilon_r = 1\ (air)$$
$$\varepsilon_r = 3 - 10\ (soils)$$

Depth Resolution

$$\Delta z = \frac{c_r}{2 \times Bandwidth}$$



Attenuation

$$L_a = 2 \times R \times 2\pi f \sqrt{\frac{\mu_0 \mu_r \varepsilon_0 \varepsilon_r}{2}\left(\sqrt{1 + tan^2\delta}\right) - 1}$$

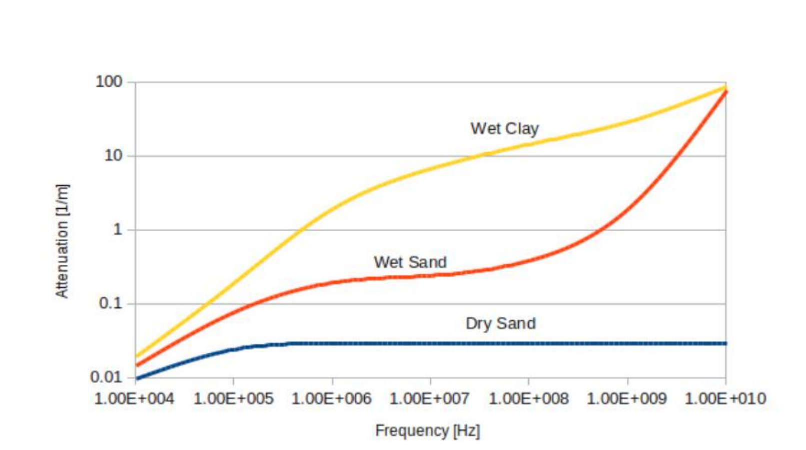
$$tan\delta = \frac{\sigma_{dc}}{\omega \varepsilon_0 \varepsilon_r} + \frac{\varepsilon''}{\varepsilon_0 \varepsilon_r}$$

Table 2.3 Material loss at 100 MHz and 1 GHz

Material	Loss at 100 MHz	Loss at 1 GHz
Clay (moist)	5–300 dB m^{-1}	50–3000 dB m^{-1}
Loamy soil (moist)	1–60 dB m^{-1}	10–600 dB m^{-1}
Sand (dry)	0.01–2 dB m^{-1}	0.1–20 dB m^{-1}
Ice	0.1–5 dB m^{-1}	1–50 dB m^{-1}
Fresh water	0.1 dB m^{-1}	1 dB m^{-1}
Sea water	100 dB m^{-1}	1000 dB m^{-1}
Concrete (dry)	0.5–2.5 dB m^{-1}	5–25 dB m^{-1}
Brick	0.3–2.0 dB m^{-1}	3–20 dB m^{-1}

Ground Penetrating Radar, 2nd Edition. David J. Daniels

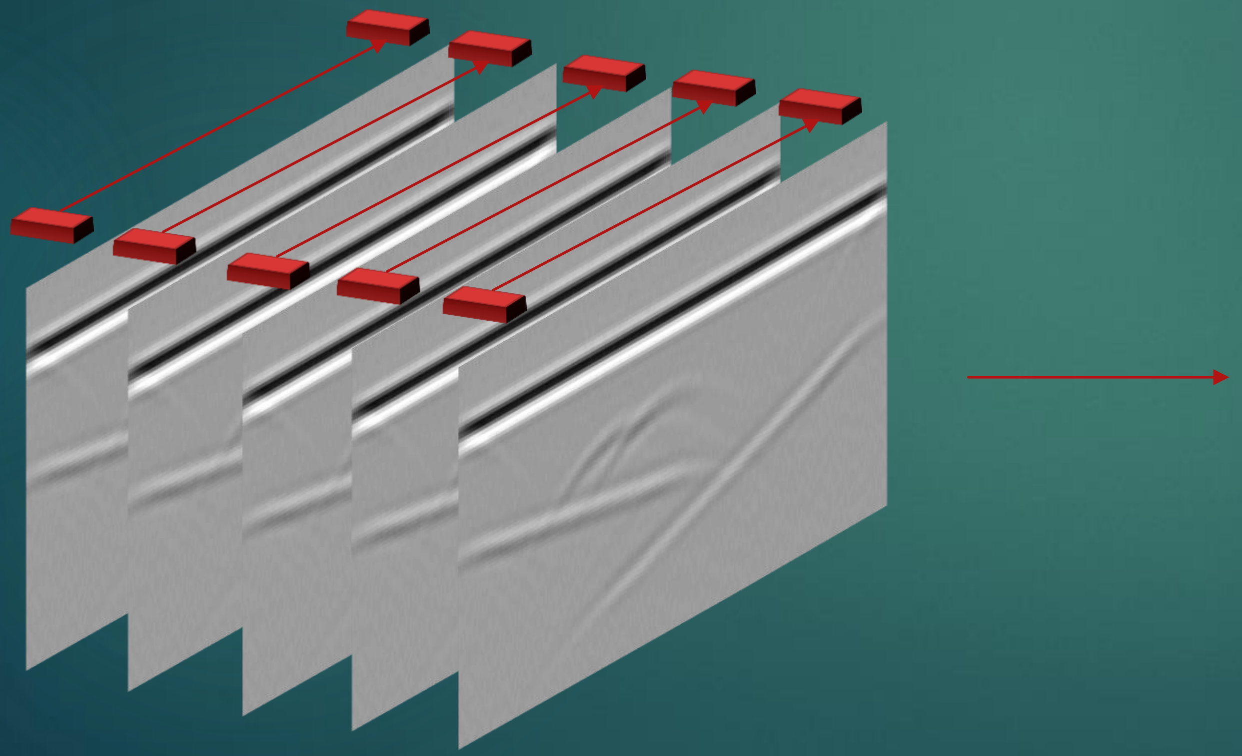
Conductive soils, such as wet clays quickly attenuate radar signals and significantly limit the penetration depth



http://www.3d-radar.com/wp-content/uploads/2014/02/SNR-in-3dr-GPR.pdf

iGPR
imaging Ground Penetrating Radar

iGPR = Data Collection Method + Processing



INSERT 3D IMAGE HERE

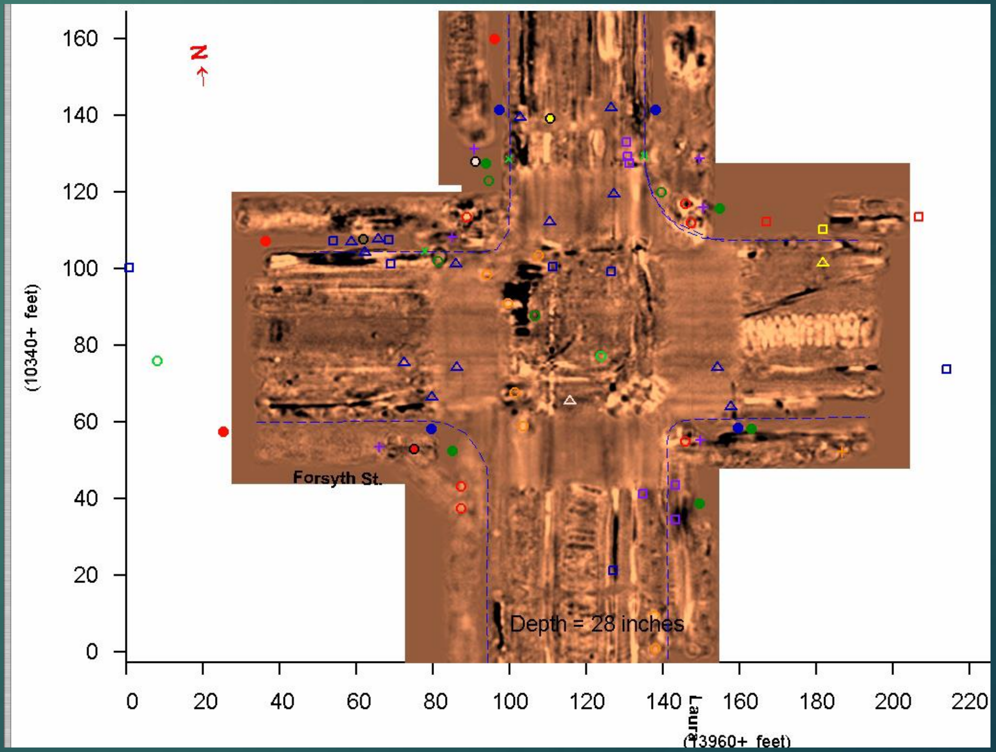
Review of Factors that Effect GPR Performance

- Environment
  - Soil – conductive (bad) vs. dielectric (good). Homogenous (good) vs. heterogeneous (bad)
- System
  - Frequency – lateral resolution (higher better), penetration depth (lower better)
  - Bandwidth – depth resolution (larger better)
  - Power – depth penetration, SNR (higher better)
  - Polarization – clutter suppression (possibly)
  - Beamwidth – lateral resolution (wider better)
- Processing
  - SNR, Spatial Resolution, Object localization

Example 3D GPR Data

Visible

GPR Depth Slice



Resources

- Literature
  - Ground Penetrating Radar, 2nd Edition. David J. Daniels
- GPR Soil Suitability Maps of US
  - http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/use/maps/?cid=nrcs142p2_053622
- GPR Equipment Manufacturers
  - IDS
  - 3D-Radar
  - Mala-Geosciences
  - GSSI
- Professional Societies
  - **Near Surface Geophysics - European Association of Geophysicists & Engineers** www.nsg-eage.org
  - **Environmental and Engineering Geophysical Society** www.eegs.org
  - **Society for Exploration Geophysics** www.seg.org