

Standard Operating Procedure: Ground Penetrating Radar (GPR)

Subsurface Dielectric Stratigraphy and Reflection Time-Domain Spectroscopy

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1. System Overview & Dielectric Principle

Ground Penetrating Radar (GPR) is a field-portable electromagnetic reflection technique operating in the 250 MHz to 1 GHz frequency band. It measures subsurface dielectric contrast ($\Delta \epsilon_r$) between soil layers, moisture fronts, or buried structural targets.

- EM Wave Velocity Formula:** Pulse propagation velocity v in soil is governed by the real dielectric permittivity ϵ_r :

$$v = \frac{c}{\sqrt{\epsilon_r}} \implies d = \frac{v \cdot t}{2}$$

where $c = 0.3 \text{ m/ns}$ (speed of light in vacuum), t is two-way travel time, and d is target depth.

2. Time-Zero (T_0) & Metal Plate Calibration

- Time-Zero (T_0) Calibration:** Align the air-ground direct wave arrival peak to $t = 0 \text{ ns}$ in the radar control unit.
- Metal Plate Reflection Test:** Place a $1 \text{ m} \times 1 \text{ m}$ aluminum reference plate beneath the antenna skid. Verify 100% reflection amplitude ($|S_{11}| = 1.0$) and a 180° phase inversion.
- Odometer Wheel Calibration:** Calibrate the survey distance wheel over a measured 10-meter baseline course to ensure spatial sampling accuracy ($\leq 1.0 \text{ cm}$ step spacing).

3. Field Survey Execution & Inversion

- Antenna Ground Coupling:** Keep the skid-mounted shielded antenna in direct contact with the ground surface to maximize power transmission and reduce air-interface scattering.
- Hyperbolic Fitting for ϵ_r :** Fit diffracted hyperbola tails from point reflectors to directly extract localized soil propagation velocity v and calculate relative permittivity ϵ_r .

4. Operating Parameters & Tolerances

Parameter	Field Setting / Target	Acceptance Criteria
Antenna Frequency	500 MHz shielded center frequency	Bandwidth 250–800 MHz
Time Window (T_w)	50 ns to 100 ns record length	Captures target depth range
Odometer Accuracy	Distance calibration over 10 m line	Error < 0.5% ($\pm 5 \text{ cm}$)
Permittivity Range	Dry sand ($\epsilon_r \approx 4$) to saturated clay ($\epsilon_r \approx 25$)	Monotonic depth inversion