

Standard Operating Procedure: Free-Line-Sensing (FLS) System

Area-Wide Soil Moisture Characterization via High-Voltage Power Lines

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1. Purpose & High-Voltage Safety Precautions

This SOP defines procedures for field specialists operating the Free-Line-Sensing (FLS) system, which utilizes freely suspended high-voltage transmission lines (e.g., 220 kV) as large-scale dielectric probes to measure integrated soil moisture over several kilometers.

- High-Voltage Isolation:** Direct electrical coupling to transmission lines is **STRICTLY PROHIBITED**. Signals must be injected exclusively through certified TFH carrier-frequency capacitive post coupling units.
- Grounding Verification:** Ensure vector network analyzer (VNA) chassis and signal conditioning enclosures are tied to the station master earth ground rod prior to connecting RF cables.

2. Hardware Configuration & Test Setup

The FLS measurement chain consists of a high-stability RF signal source (1 V amplitude), a Hewlett-Packard HP3588B Vector Network Analyzer, an HP35677A S-Parameter Test Set, and a impedance-matching transformer network connected to the TFH capacitive coupling post.

- Set VNA operating frequency band between **50 kHz and 500 kHz**.
- Set IF measurement bandwidth to **100 Hz** to achieve high dynamic range and narrow-band noise rejection.
- Select **S_{11} input reflection factor** ($S_{11} = b_1 / a_1$) as the primary dielectric tracking parameter to eliminate long-distance remote synchronisation errors.

3. Calibration & Inversion Procedure

- Impedance Matching:** Adjust coupling circuit variable capacitors to match line characteristic impedance under baseline dry conditions.
- Baseline Sweep:** Record S_{11} magnitude ($|S_{11}|$) and phase (ϕ) across the 50–500 kHz sweep. Save baseline trace to non-volatile memory.
- Permittivity Conversion:** As soil moisture increases, bulk soil permittivity (ϵ_b) and conductivity (σ_b) increase, slowing phase velocity and shifting complex reflection coefficients. Compute weighted mean soil moisture using line sag and land-surface coupling models.

4. Maintenance Matrix

Component	Inspection Activity	Target / Tolerance
TFH Capacitor Post	Visual crack, flashover, and oil leak check	Zero discharge / intact insulator
HP3588B VNA	100 Hz IF bandwidth & 1V output calibration	Amplitude drift < 0.05 dB
Coupling Transformer	Impedance match tuning at 165 kHz spot freq.	VSWR < 1.15