Recommendations for Main.Net

- Don't operate overhead units above power level 4

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Conclusions Regarding Access BPL

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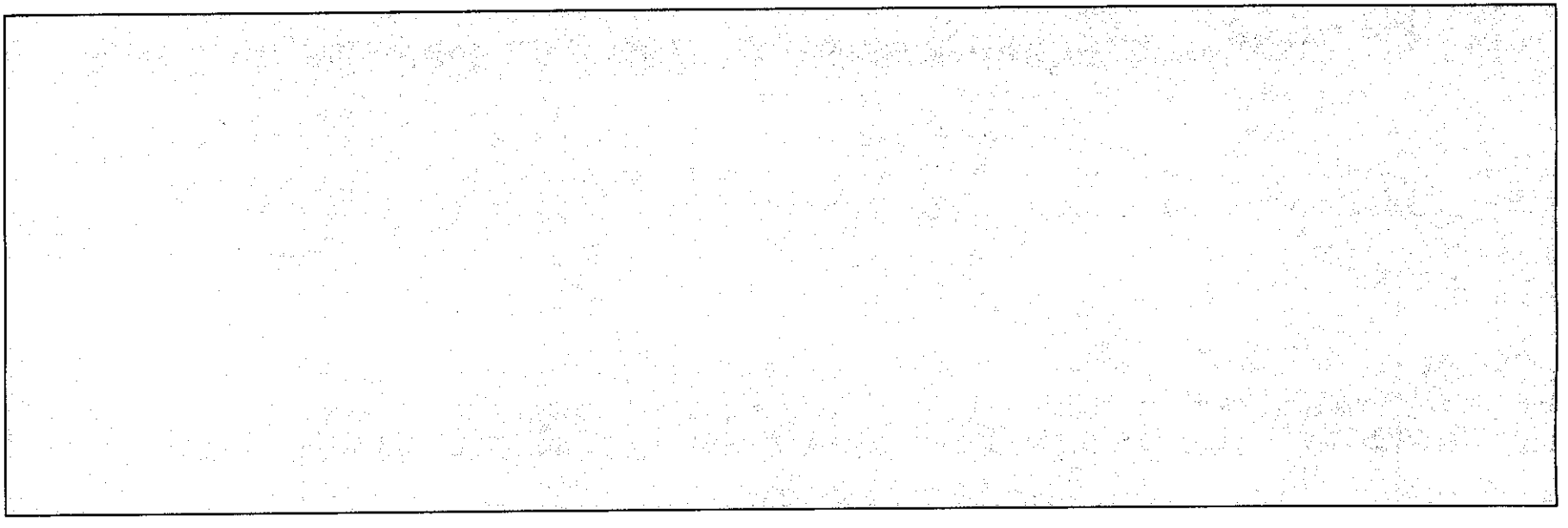

Conclusions Regarding Testing

- **Test Issues**
  - Underground systems
    - Buried power cable influences emission measurements in its vicinity. Should testing in its immediate vicinity be avoided?
  - Overhead systems
    - Pole ground wire appears to be a source of radiation for an overhead system that couples to neutral, but we don't believe that it should be a considered part of the system for distance scaling purposes
  - Ambients that exceed limits will be present & must be excluded based on bandwidth
- **Future Test Considerations**
  - Need notch or high-pass filter to attenuate AM radio signals
  - Average spectra work well for finding peak emission locations
  - Achieving high duty factor is important but time consuming.
    It can take several hours to get the right signal with cooperation from system developer
    - Control computer needs rebooting & no one is in facility
    - Control computer facility is being moved by the power company to another room.
      Need to wait for lineman to access system through another transformer.
  - Testing in a cold rain is not fun

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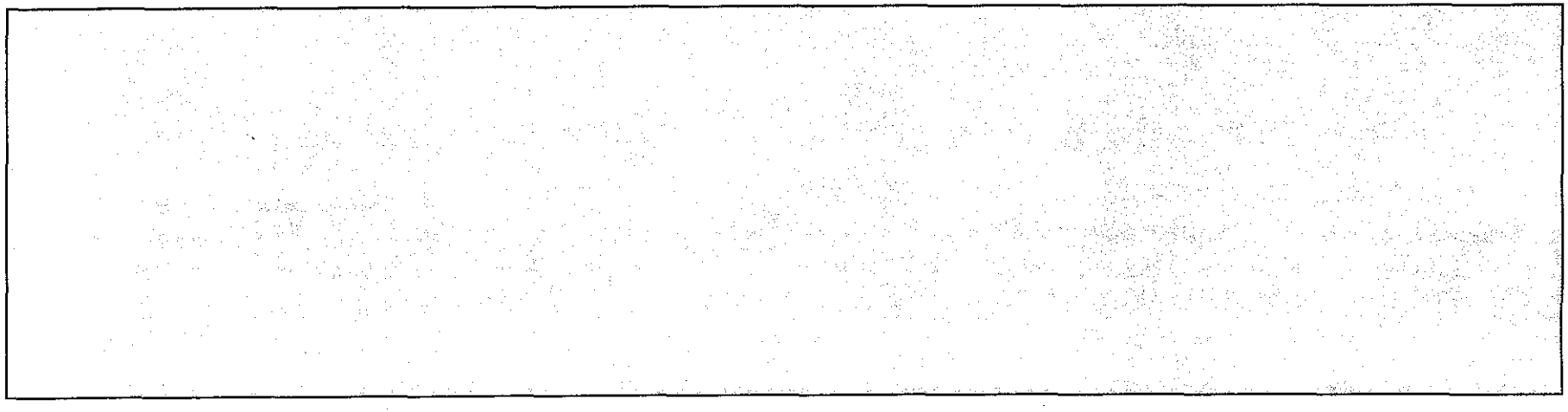
Other Issues



Emission Measurements on Current Technologies Medium Voltage BPL System

22 April 2003

Steve Martin
Technical Research Branch
FCC Laboratory

We thank Current Technologies for the excellent support they provided for these tests

FCC Lab Objectives for Access Systems

- **Overarching Objectives**
  - Support FCC in decisions regarding emission limits
  - Develop a measurement procedure for access BPL systems
- **Specific Test Objectives**
  - Provide an understanding of
    - Access BPL radiated emission characteristics
      - Average, quasi-peak, and peak levels
      - Temporal characteristics
      - Variation in field strength with receive antenna height
      - Field strength down line (point radiator versus distributed radiator)
    - Measurement issues
      - Ambient signals
      - Use of pre-filters
      - Other

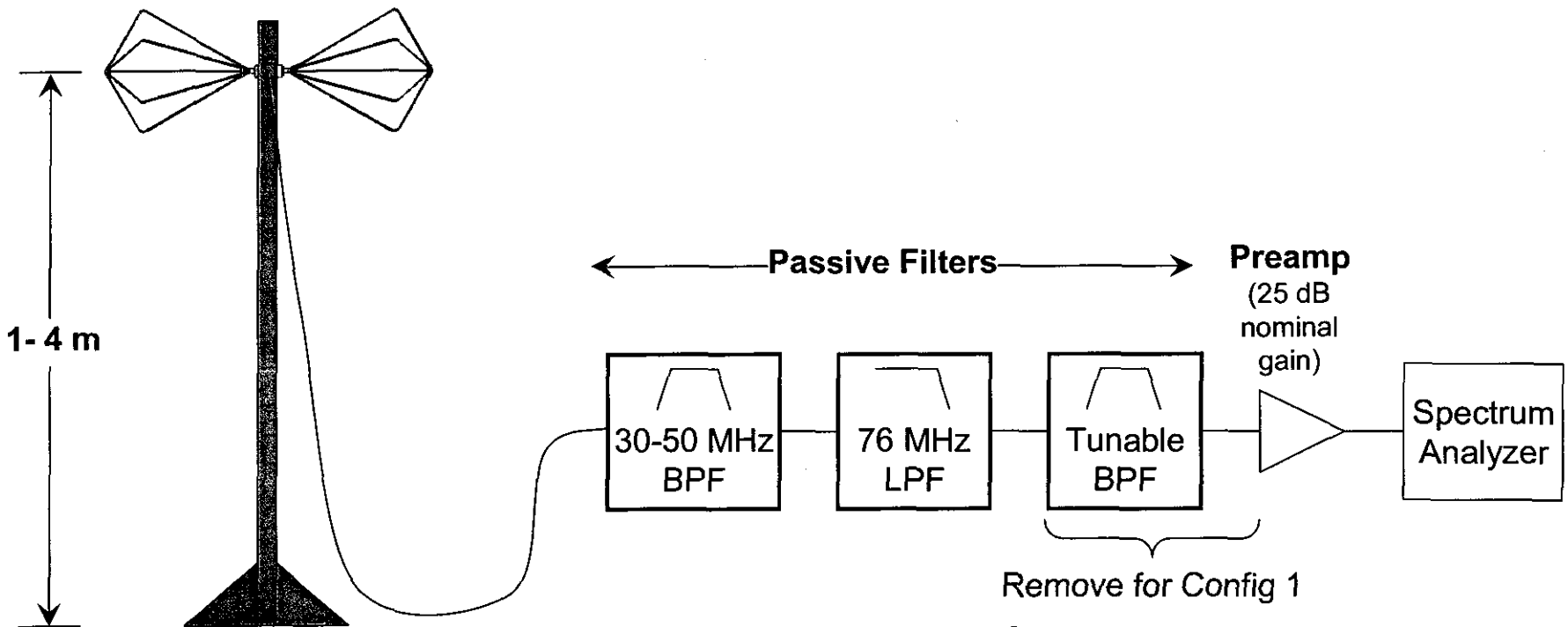
Test Limitations

- **Testing was not intended for certification or verification**
- **Testing was limited to:**
  - Two DUTs
  - 1 – 2 radials
  - One polarization for 1st DUT
  - Intended operating frequency band of the system
- **Ambient impulse noise affected results for DUT 2**

Communication Conditions

- **Objective**
  - Create data transmission representative of high rate transmissions from the DUT. For medium voltage coupler outside home, this means communication in upload direction.
  - Achieve the ≥ 20 Hz pulse rate required for CISPR quasi-peak measurements [CFR 47, 15.35(a)(note)]
- **Three communication conditions were tried**
  - Pings
  - FTP
  - 1.5 Mbps upload created with TTCPW (a software tool to measure network performance)
- **Only the latter technique met the objective, so it was used for all testing**

Test Setup

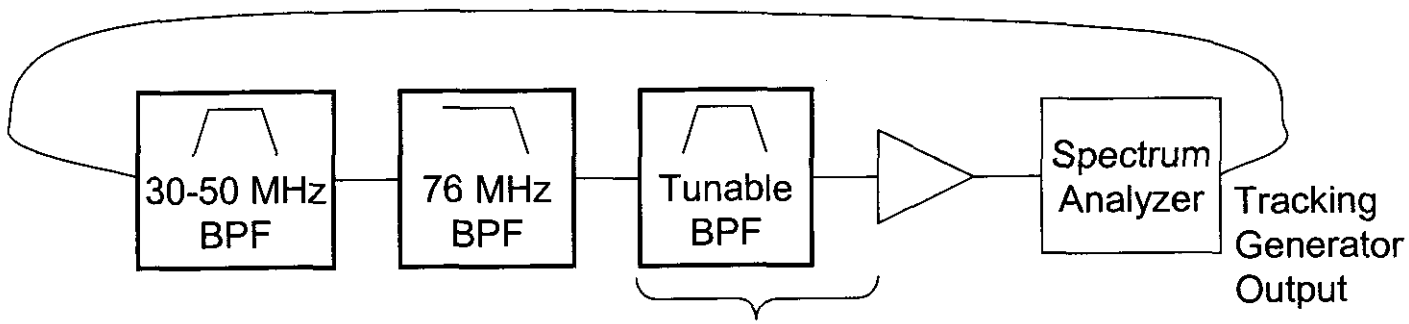


Measurement Config. 2

Notes:

- BPF = Bandpass Filter; LPF = Lowpass Filter
- Measurement Configuration 2 shown. Remove Tunable BPF and its output cable for Configuration 1.
- All filter, amplifier, and cable gains, losses, and impedance mismatch effects are calibrated out
- 30 – 50 MHz BPF was custom built and provided by Current Technologies for the test. Measured insertion loss of filter with 50-ohm source and 50-ohm load was 1.4 to 2.3 dB over the frequency range from 31 to 48 MHz.
- LPF needed to reduce UHF TV signal transmission through 30-50 MHz BPF lobe and direct pickup through unshielded 30-50 MHz BPF

Calibration and Data Scaling



- All results converted to field strength units using two frequency-dependent calibration curves:
  - **Antenna factor curve**
  - **Electronics calibration curve measured as shown above**
    - Includes losses, gains, and impedance mismatch effects of all filters, amplifier, and cables, measured as shown above
    - Any mismatch effects between antenna and filter input are not included. (Control of this effect by addition of an attenuator or preamp between the antenna and 1st filter was not implemented due to concerns of increasing the noise floor or overdriving the preamp.)
    - Tracking generator was calibrated by connecting a short cable between tracking generator output and analyzer input.
- **Distance scaling: 20 dB/decade of range based on slant range to coupler**

Calibration Measurements

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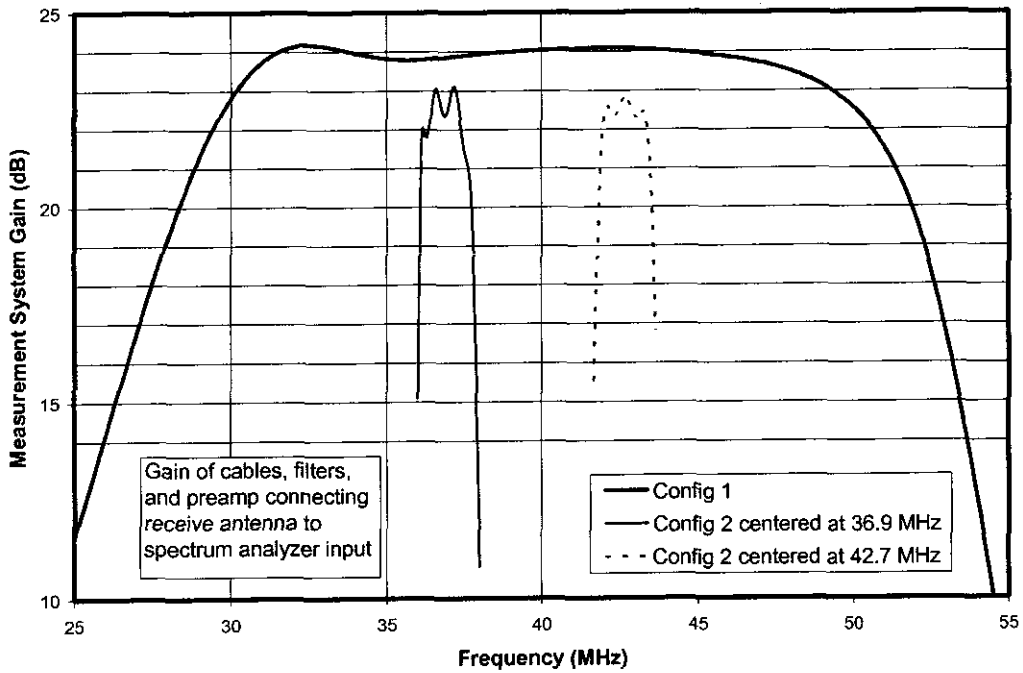

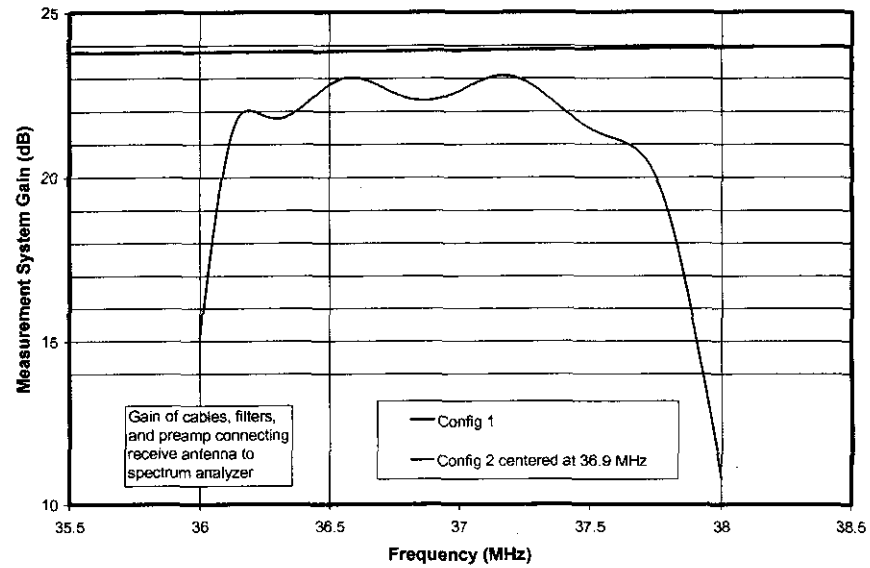

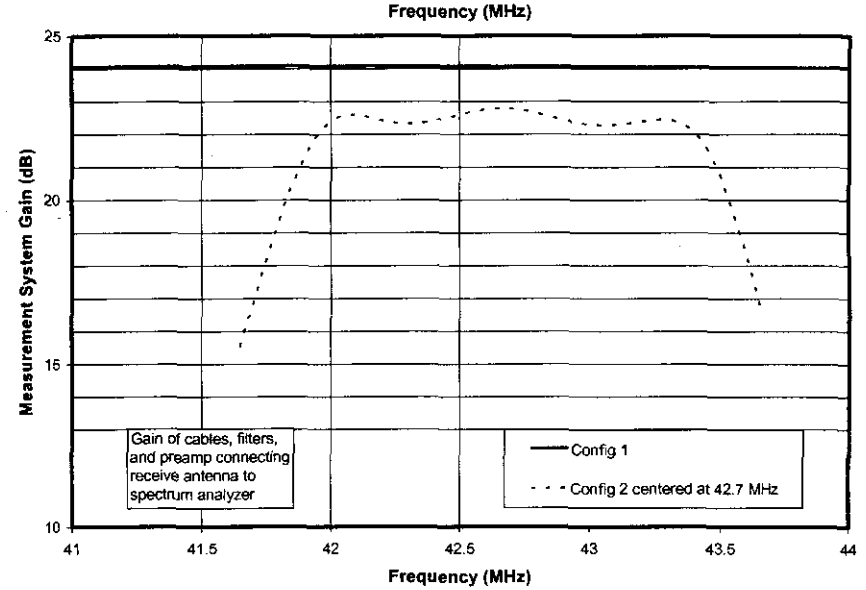

DUTs

- **DUTs**
  - **DUT 1**: Active coupler with fiber optic connection to bridge
  - **DUT 2**: Passive coupler with transformer coupling to bridge (newer design)

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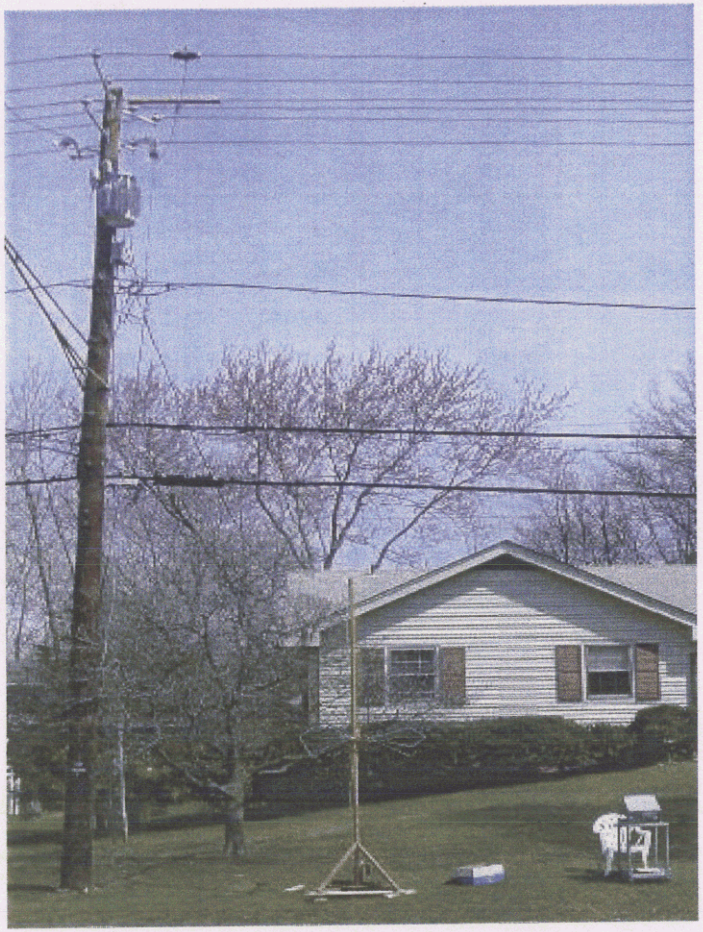
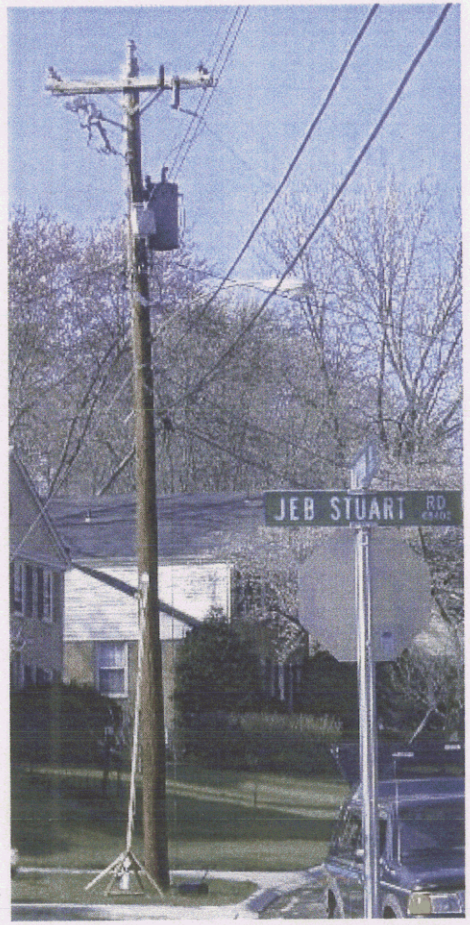
DUT Coupler Heights



DUT 1: Height ≈ 11.1 m



DUT 2: Height ≈ 10.9 m

DUT heights measured by comparison on photos to 4.34 m test mast

Measurement Sites

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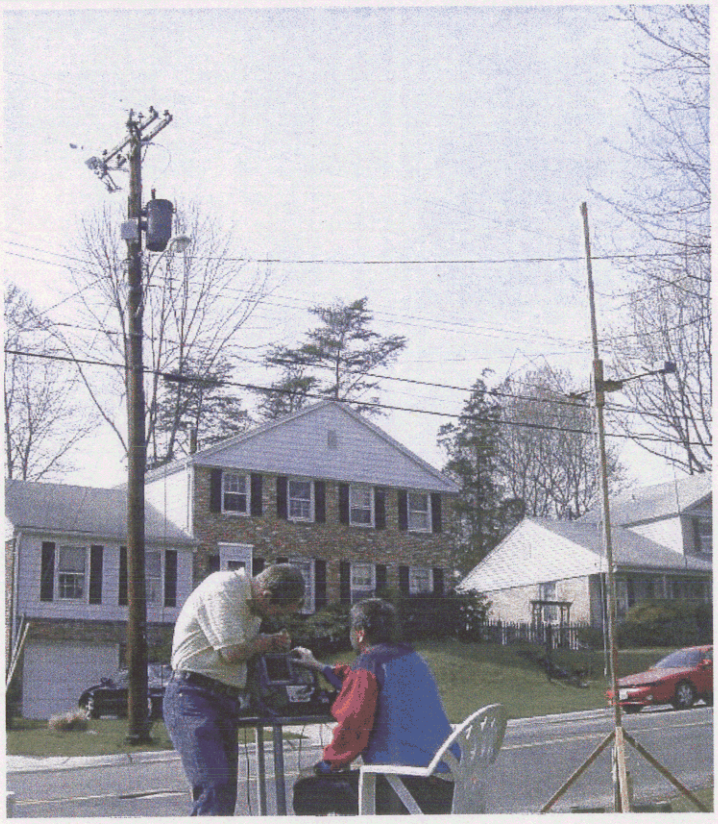
Site 1

- Chosen to **maximize SNR**
- Directly under power line, ~2 m down line from DUT 1 coupler
- **AL siding & 2nd coupler** prevented selection of representative compliance location



Site 2a

- Chosen as **representative compliance measurement location**
- Directly across street from DUT 2 coupler; 14.1 m horizontal distance from power line and coupler

Site 2b not shown. Antenna mast was located on same side of street as shown for 2a, but to the left by ~25 m.

Site 2b

- Chosen to measure **emission reduction down line**
- Across street from DUT 2 and 25.4 m down line; 12 m horizontal distance from power line

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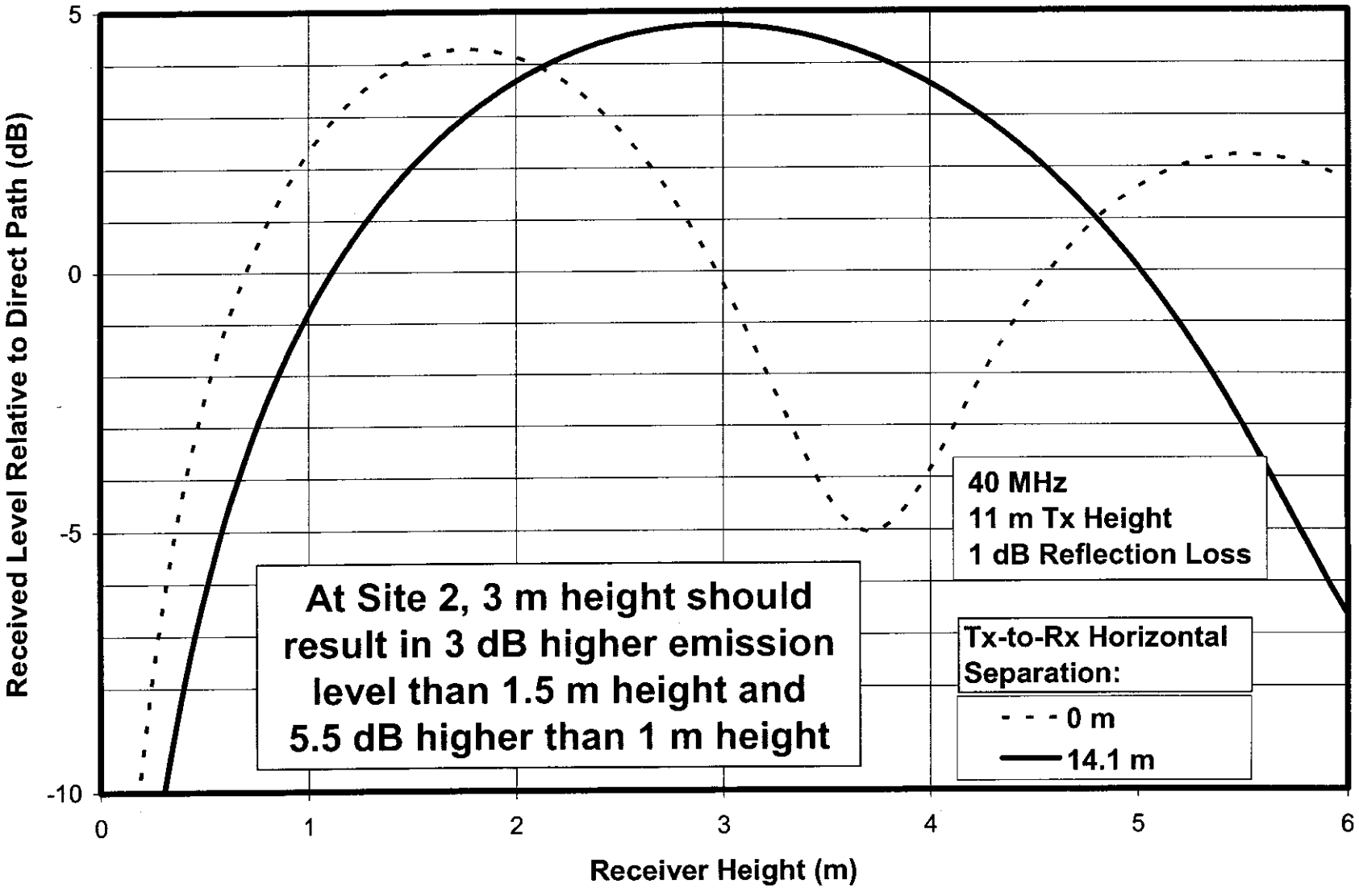
Rx Antenna Height Selection

Rx Antenna Height: Rules and Procedures

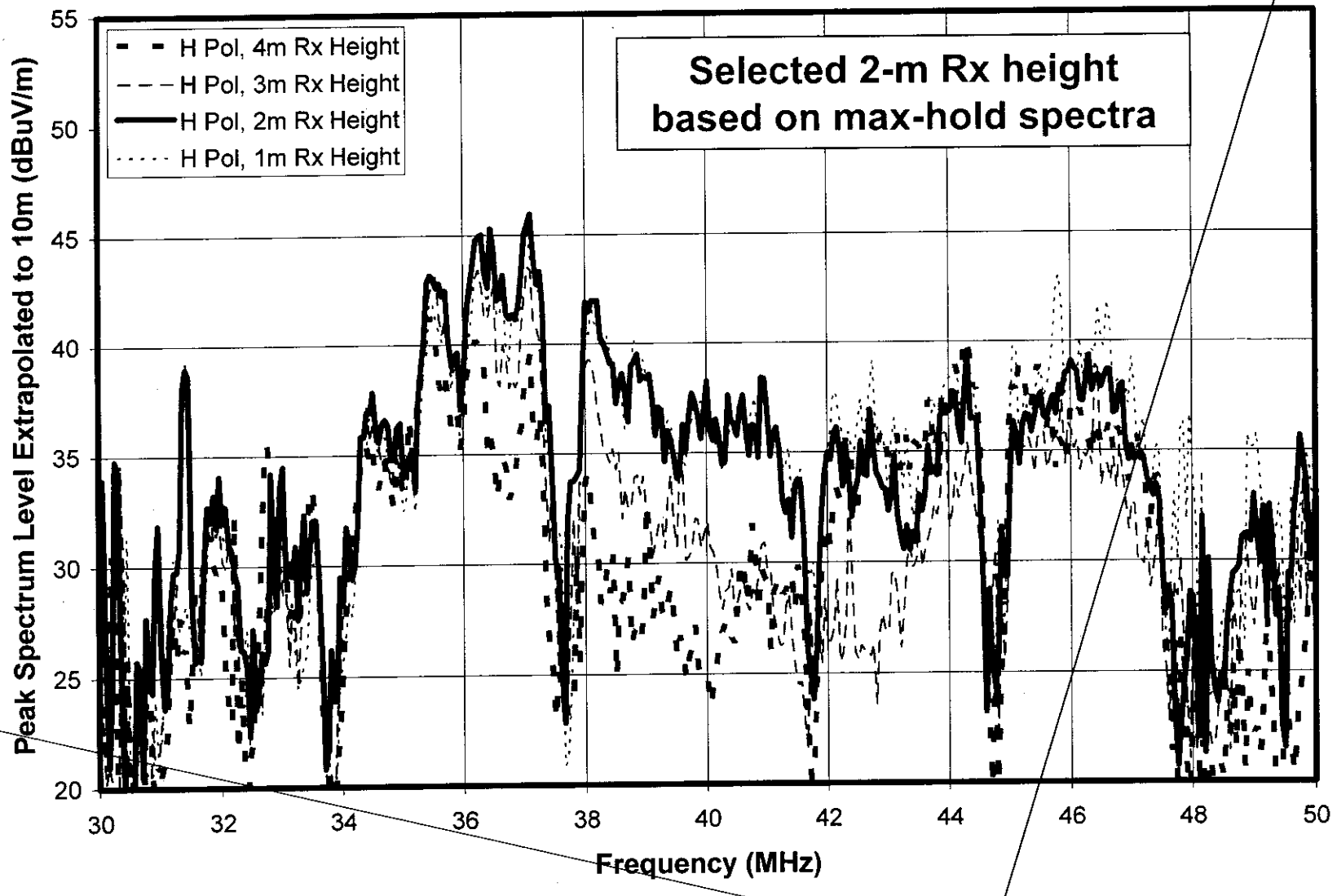
Current rules and procedures don't address DUT mounted 11 m off ground

- **ANSI C63.4-2001 ...Measurement of...Emissions from Low-Voltage...Equipment...**
  - 8.1 Radiated Emission Measurement Requirements:
    - "...***height such that the maximum radiated emissions level shall be detected***."
  - 8.2 Antenna Selection, Location, And Measuring Distance
    - 8.2.1 Magnetic Field Radiated Emissions (9 kHz to 30 MHz): "center of the ***loop ...1 m*** above the ground"
    - 8.2.3 ***Electric Field*** Radiated Emissions (30 MHz to 1 GHz): "varied from ***1 m to 4 m***"
  - 8.3 Radiated Emission Measurement Procedures:
    - 8.3.1 Measurements ***On A Test Site***: "scanned between ***1 m and 4 m***" (8.3.1.2)
    - 8.3.2 ***On-site*** measurements: "...heights ***as normally required***... For further guidance, ***see IEEE Std 139-1988***."
- **IEEE Std 139-1988—IEEE Recommended Practice for the Measurement of RF Emission from ISM Equipment Installed on User's Premises**
  - 2.6 Determine the RF Spectrum: "measurements ... around, and, if possible, above the EUT. ...if possible, determine if there is significant emission directed upward from the EUT on, or near, frequencies used locally for aircraft beacons or aircraft communications."
  - 2.8 Measure Radiated Emission: "... moving the antenna ... Vertically from ***1 m*** above the ground up ***to 4 m***, ***(preferably even higher)*** if practical, (for measurements at frequencies above 30 MHz).
  - 2.8.2 Overhead Measurements. "If ... possibility of aircraft communications or navigation interference, measure the emission in a line extending up from the EUT, vertically and at several points near ***vertically above the EUT***.... This measurement can be made ... on the roof over the equipment."
- **FCC/OET MP-5 (1986)—FCC Methods of Measurements of Radio Noise Emissions from ISM Equipment**
  - 2.2.5 Antenna height variation
    - ***Loop*** antenna: "height ... ***around 2 meters***" but not in a null.
    - For a ***dipole*** or equivalent antenna: ***1-4 m at distances ≤10 m; 2-6 m at distances*** > 10 m

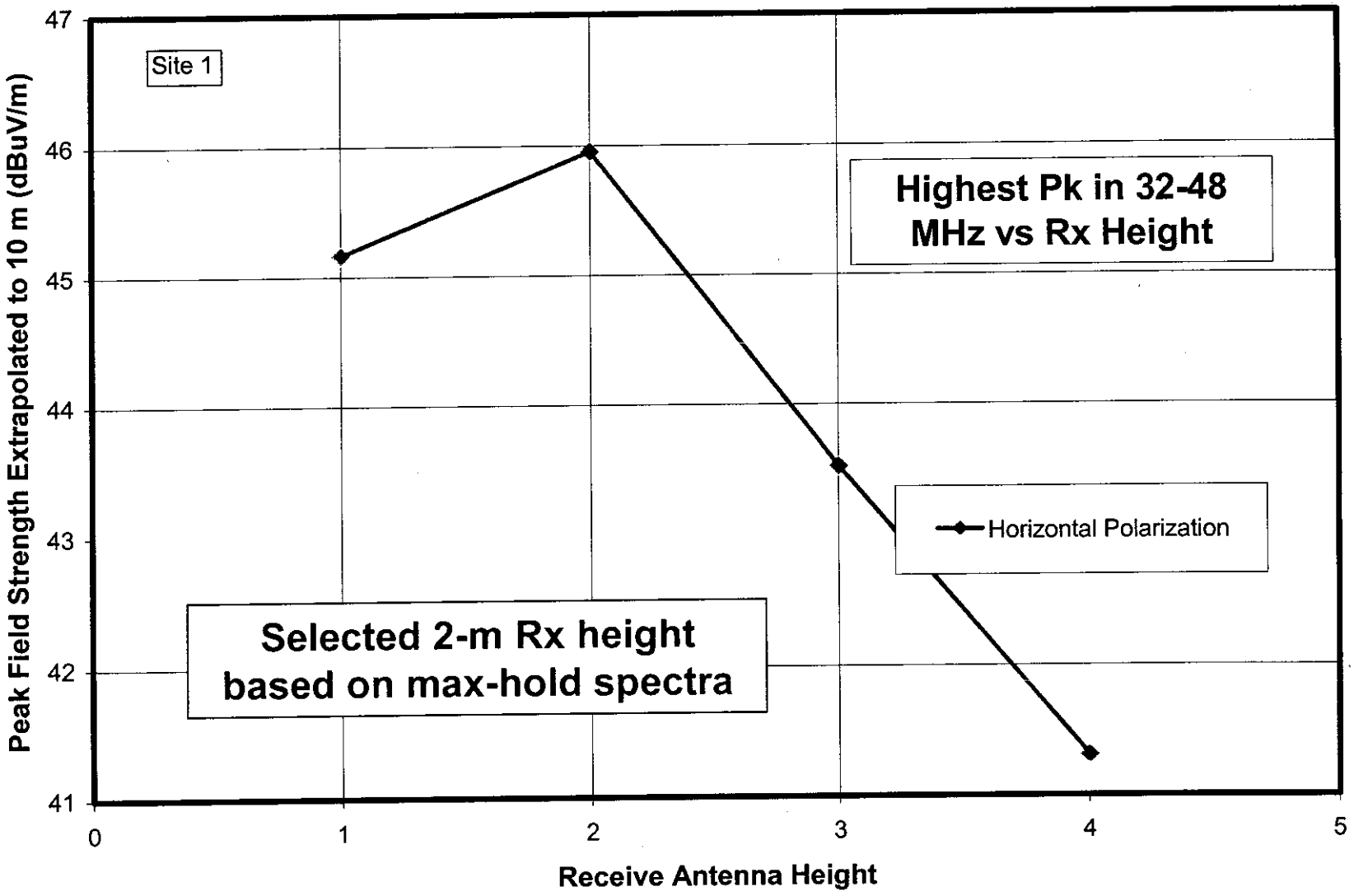
Rx Antenna Height: Theoretical Effect at Center Frequency



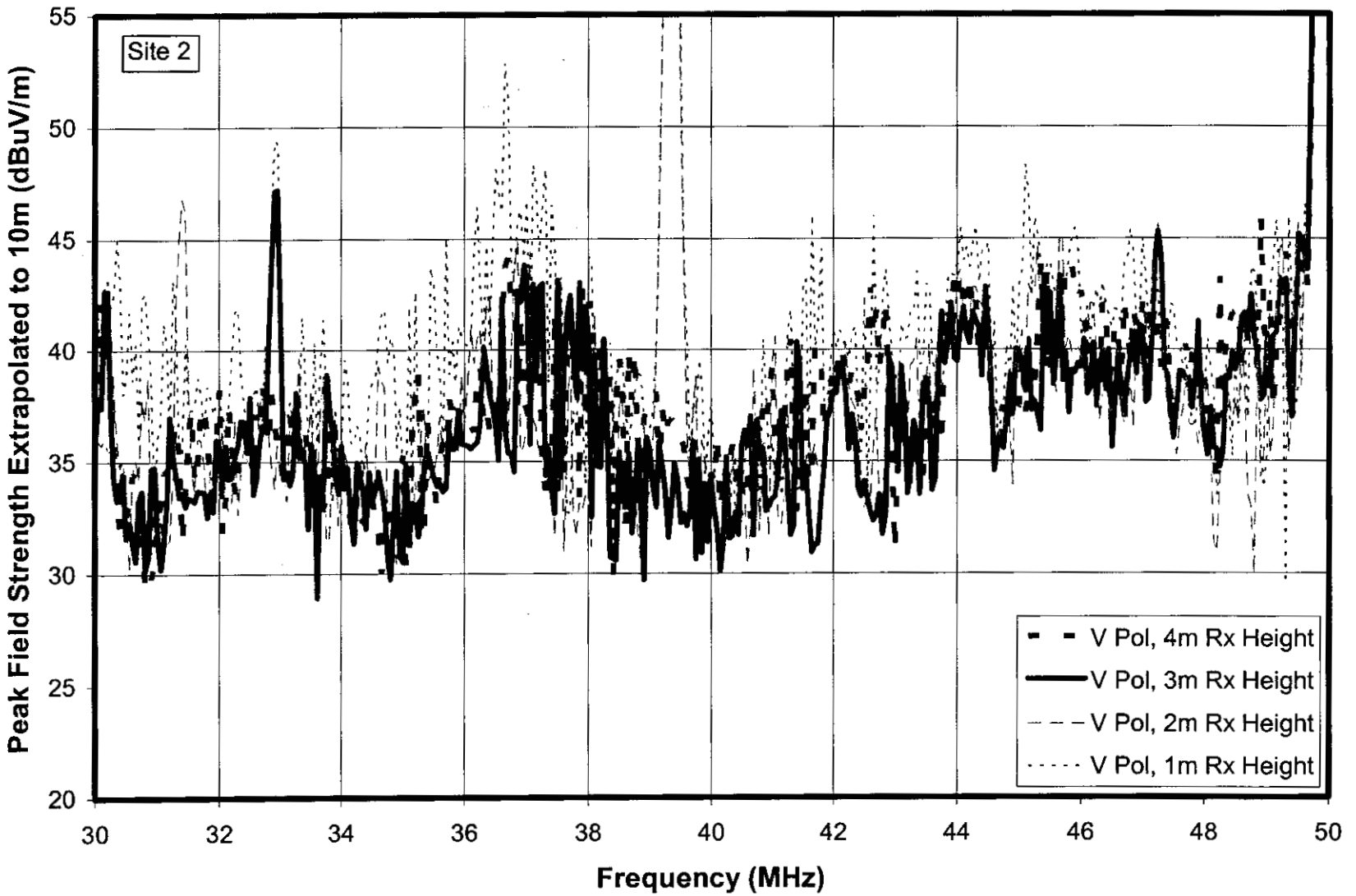
Effect of Rx Antenna Height at Site 1: Max-Hold Spectra for H Polarization



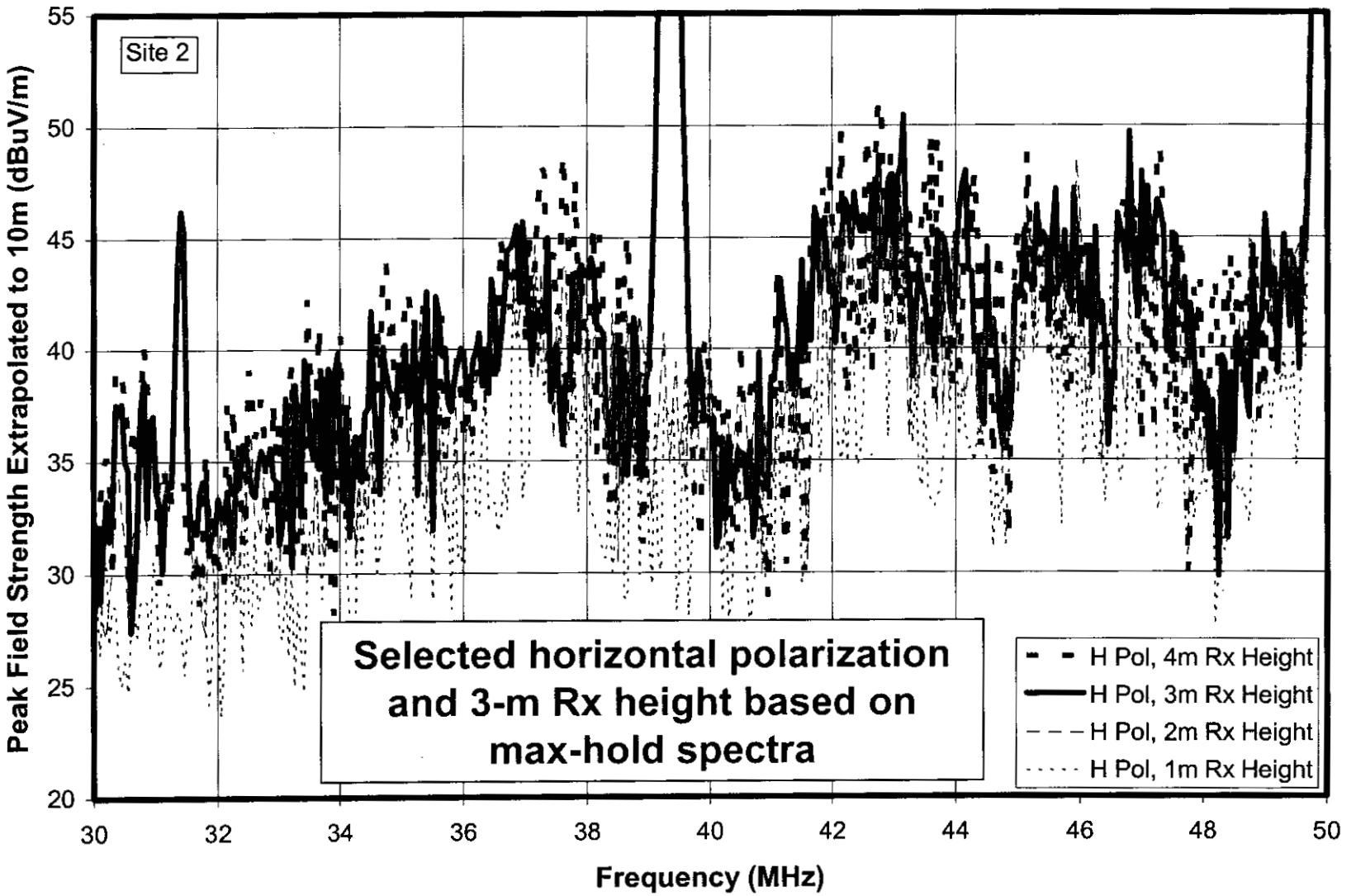
Effect of Rx Antenna Height at Site 1: Peak Spectrum Level



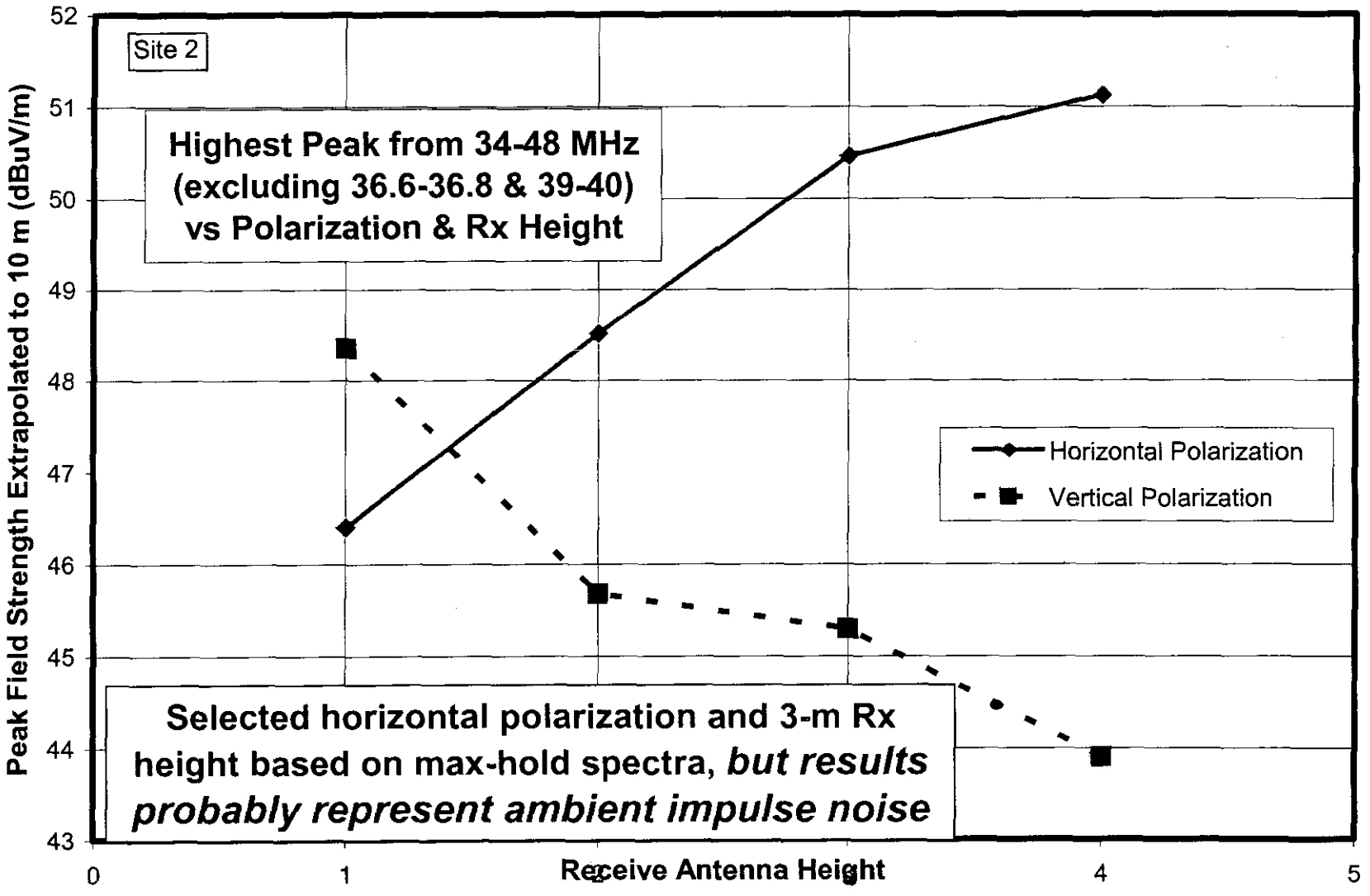
Effect of Rx Antenna Height at Site 2a: Max-Hold Spectra for V Polarization



Effect of Rx Antenna Height at Site 2a: Max-Hold Spectra for H Polarization

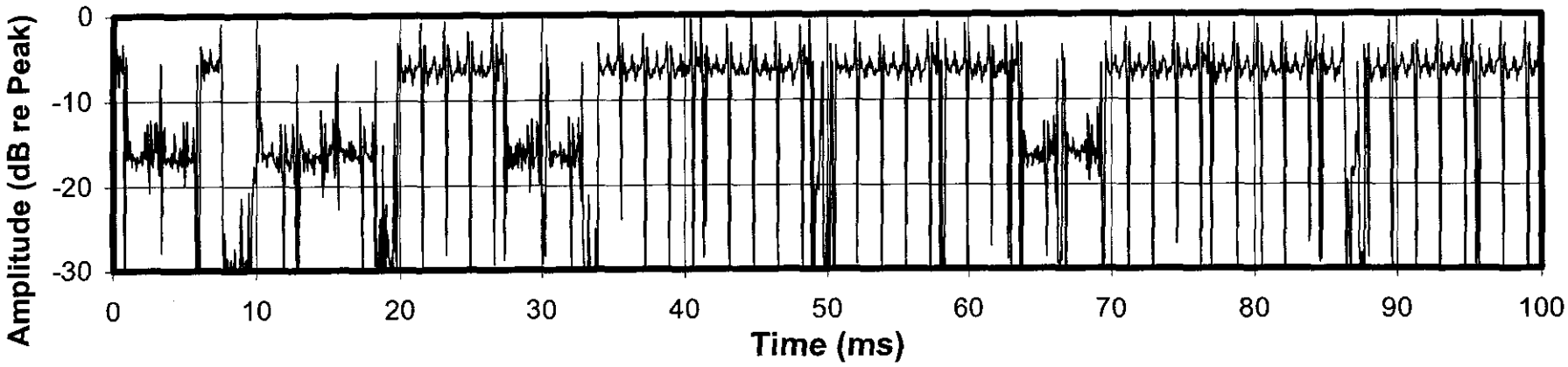


Effect of Rx Antenna Height at Site 2a: Peak Spectrum Level



Temporal Measurements

Temporal Measurements: DUT 1, Site 1



- **Desired measurement conditions achieved**
  - Requirement for >20 Hz rep-rate achieved
  - Percentage of 61-μs temporal bins containing BPL signals = 69% (avg of three, 0.5-second intervals, with signal presence defined by threshold 10 dB below peak)
- **Measurement Setup**
  - Test Config. 2
  - Analyzer settings
    - RBW=3 MHz, VBW=3 MHz
    - Center frequency 36.3 MHz (set to encompass broadband spectral peak)
    - 8192-point sweep with duration 0.5 seconds (61 μsec bin width)