SECTION 2
PART 15 MEASUREMENT GUIDELINES

2.1 INTRODUCTION

In the Phase 1 Study, NTIA stated that adopting effective BPL measurement guidelines is critical to reducing the risk of harmful interference to federal radiocommunications.[6] The NTIA Phase 1 Study comments on the FCC's BPL NPRM, and subsequent correspondence with the Commission described NTIA's measurements and analyses of BPL emissions.[7] Emissions from Access BPL systems operating on overhead Medium Voltage (MV) power lines are atypical of most Part 15 devices in that the peak field strength often occurs at heights significantly greater than 1 meter and may occur at various distances along the power line.

NTIA's measurements and analyses showed that the strength of radiated emissions diminished more slowly with distance from the BPL source than would be expected of a typical point source radiator. Measurements of BPL field strength are typically performed in the near field where the relationship between the electric and magnetic fields is not easily quantified. In its earlier filings in the FCC's BPL proceeding, NTIA presented measurements and computer modeling of emissions from Access BPL sources and connected power lines in order to characterize the nature of these emissions. In the Phase 2 Study, NTIA further analyzes these characteristics of BPL emissions using the Commission's recently adopted measurement guidelines to demonstrate that these guidelines effectively balance measurement accuracy with a reasonably limited number of measurements.

2.2 POWER LINE MODELS USED IN THE ANALYSIS

NTIA used the NEC software program to create a number of power line models to gain a greater understanding of the effects various physical topologies might have on the electric fields radiated by BPL signals on power lines. Below 30 MHz, the magnetic field that would be measured by rotating a vertically positioned loop antenna 180 degrees about its vertical axis was determined by simulation over a range of heights and all along the length of the power line model. Where results below 30 MHz are shown in terms of electric field strength, the magnetic field strength was converted to vertical electric field strength using Equation 2-1, assuming a Cartesian coordinate system as shown in Figure 2-1 below:

$$E_z = \eta \cdot \sqrt{H_x^2 + H_y^2}\,, \qquad \text{(Equation 2-1)}$$

where η is the impedance of free space, nominally 377 ohms (Ω);

H_x is the x-component of the horizontal magnetic field, in A/m;

H_y is the y-component of the horizontal magnetic field, in A/m; and

E_z is the vertical electric field strength in V/m.

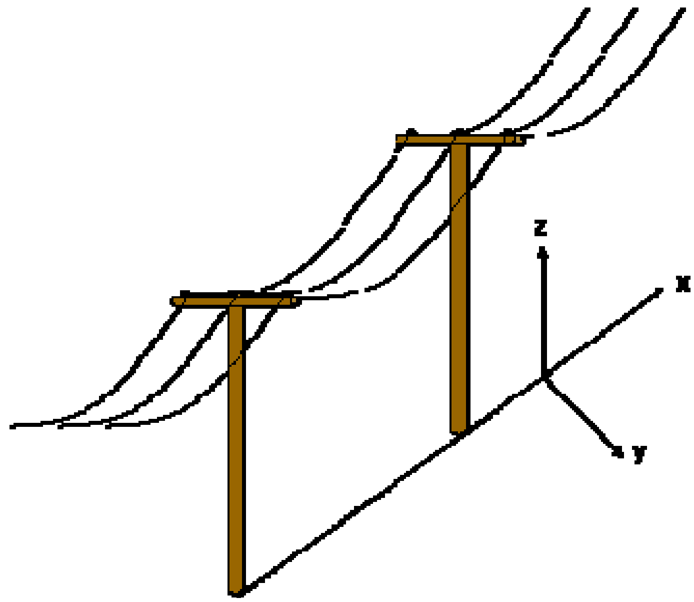


Figure 2-1: Power line and coordinate system

Above 30 MHz, the electric field strength in either the horizontal or vertical polarization was determined over a range of heights and at any position along the length of the NEC power line models.

NTIA evaluated a wide variety of power line topologies to calculate three-axis electric field values in a vertical grid located at a 10 meter horizontal distance from the power line (the measurement distance adopted in the BPL Report and Order), at heights ranging from 1 to 20 meters in one meter increments. These calculations were made horizontally along the length of the modeled power lines in one meter increments, and at frequencies ranging from 2 to 50 MHz in 2 MHz increments. Eighteen relatively simple power line topologies are listed in Table 2-1. Figure 2-2 depicts the orientation of power line conductors for each of these topologies.

Table 2-1: Power line topologies used to model antenna measurement height

Model Name	Number of Wires	Wire Configuration	Multi-grounded neutral with 3 transformers	Wire Spacing

Model Name	Number of Wires	Wire Configuration	Multi-grounded neutral with 3 transformers	Wire Spacing
tri26	2	triangular-horizontal	not included	0.6 meters
tri210	2	triangular-horizontal	not included	1.0 meters
tri36	3	triangular-horizontal	not included	0.6 meters
tri310	3	triangular-horizontal	not included	1.0 meters
tri26n	2	triangular-horizontal	included	0.6 meters
tri210n	2	triangular-horizontal	included	1.0 meters
tri36n	3	triangular-horizontal	included	0.6 meters
tri310n	3	triangular-horizontal	included	1.0 meters
ver1	1	vertical	not included	n/a
ver26	2	vertical	not included	0.6 meters
ver210	2	vertical	not included	1.0 meters
ver36	3	vertical	not included	0.6 meters
ver310	3	vertical	not included	1.0 meters
ver1n	1	vertical	included	n/a
ver26n	2	vertical	included	0.6 meters
ver210n	2	vertical	included	1.0 meters
ver36n	3	vertical	included	0.6 meters
ver310n	3	vertical	included	1.0 meters

The power line models listed in Table 2-1 were 340 meters in length, 12 meters above ground, and consisted of eight segments of catenary (hanging) wires (with catenary lengths of 43 meters each) as would be suspended between nine utility poles. The signal injection point for these models was on the segment next to the model's mid-point, on one of the outside wires. All wires were assumed to be copper, and all models with neutral wires included three simulated distribution transformers wired between one of the phases and neutral, with 7.7 Ω of real impedance.[8] On the models with a neutral wire, the neutral was connected to ground at each transformer point (in the center of the model and at each end).

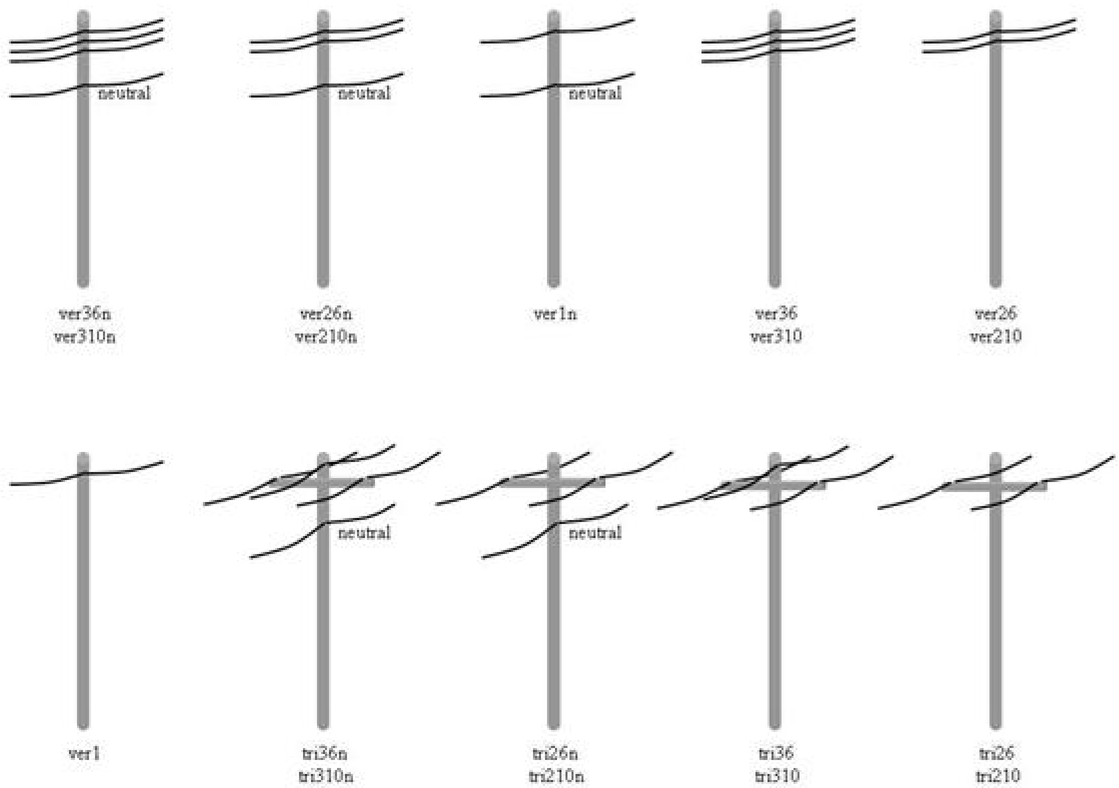


Figure 2-2: Power line topologies

Vertical-alignment models were designed such that all wires (including the neutral, if any) were arranged in a vertical line. Triangular-horizontal models with three wires were designed with the middle wire 0.25 meter higher than the outer two. The neutral wire (if one was included) was centered under the phase wires.

NTIA also constructed an elaborate NEC model based on the physical layout of an actual MV distribution branch in one of the BPL deployment areas where NTIA conducted field measurements. This model was designed using power line maps as well as actual observation (Figure 2-3). The model consisted of three-phase and multi-grounded neutral wiring. Included in the model are risers (connections of all three phases of overhead wiring to underground wiring having a characteristic impedance of 30 Ω), wire intersections, transformers and neutral grounds. Along most of the power line, the wiring topology is vertical, but at one pole (at a riser) it shifts to a horizontal-triangular configuration and then back to vertical. The model covered an area of some 240,000 square meters (600m × 400m), and was segmented and tested at 4.303 MHz, 8.192 MHz, 22.957 MHz and 28.298 MHz (frequencies which corresponded with measurement frequencies in the field).

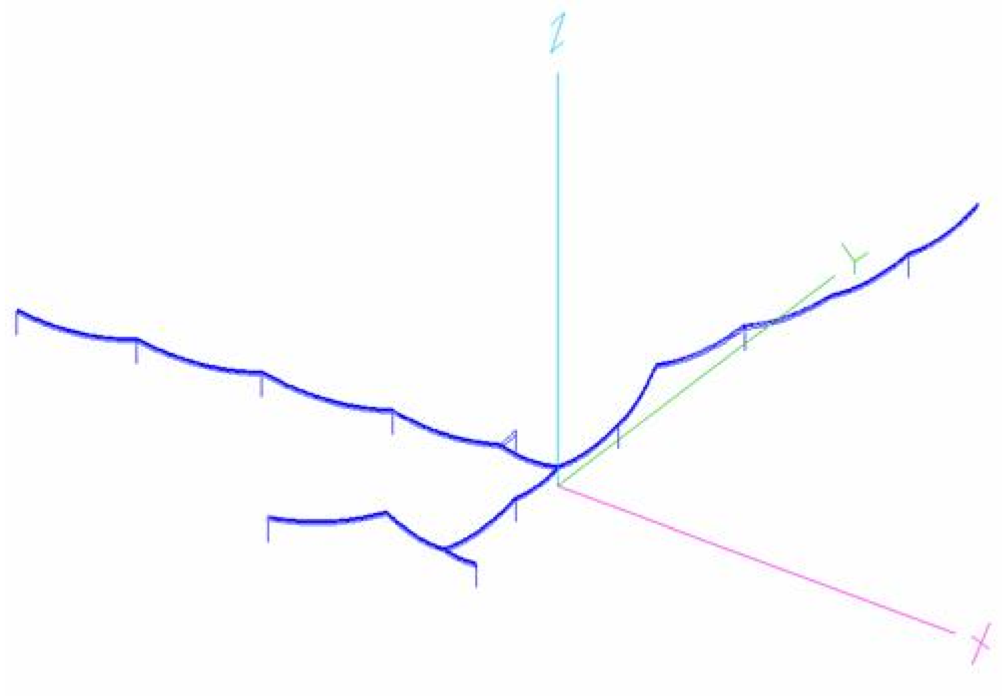


Figure 2-3: NEC model of actual power line carrying BPL signals

2.3 MEASUREMENT ANTENNA HEIGHT

NTIA analyzed the electric field strength calculated from a variety of power line models to determine the strength of radiated emissions as a function of height. In addition, NTIA analyzed the difference in peak field strength over the range of simulated heights, and the peak field strength at 1 meter off the ground (below 30 MHz) and at 1 to 4 meters off the ground (30 MHz and above). These results were used to assess the effectiveness of the measurement antenna heights specified in the measurement guidelines for estimating the field strength radiated from Access BPL systems. In lieu of measurements performed at various antenna heights, NTIA proposed the application of a height correction factor. The Commission's rules for Access BPL systems adopted a 5 dB height correction factor with a 1 meter measurement height, as an alternative to measuring field strength from 1 to 4 meters at or above 30 MHz.[9]

2.3.1 Height Corresponding To Peak Field Strength

Figures 2-4 through 2-7 show the heights where the peak electric field strength occurred over the frequency range of 2 to 50 MHz for two of the power line topologies described in Section 2.2. These results were obtained at a horizontal distance of 10 meters from the modeled power lines, and considered points all along the power line. The results for other power line configurations are provided in Appendix A.

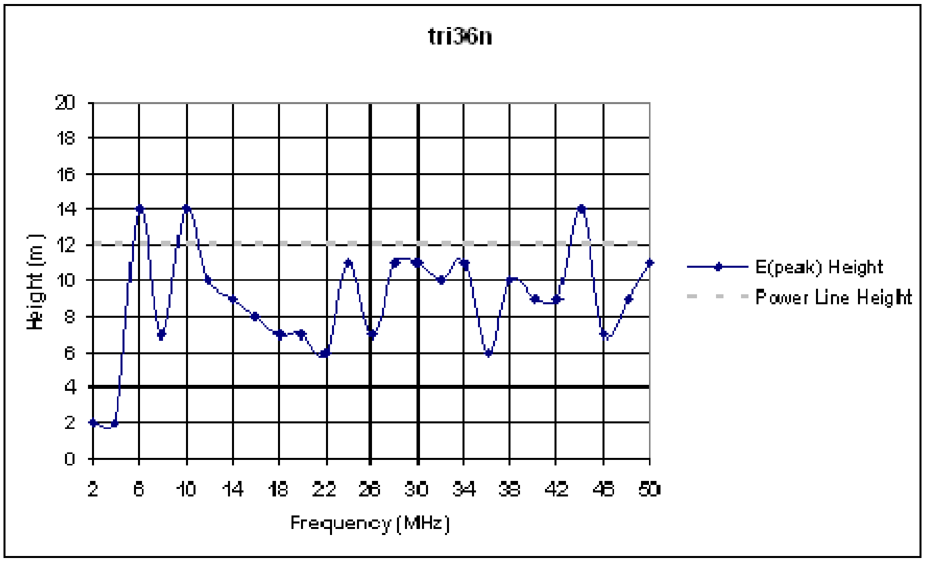


Figure 2-4: Height corresponding to peak electric field strength as a function of frequency

Figure 2-5: Height corresponding to peak electric field strength as a function of frequency

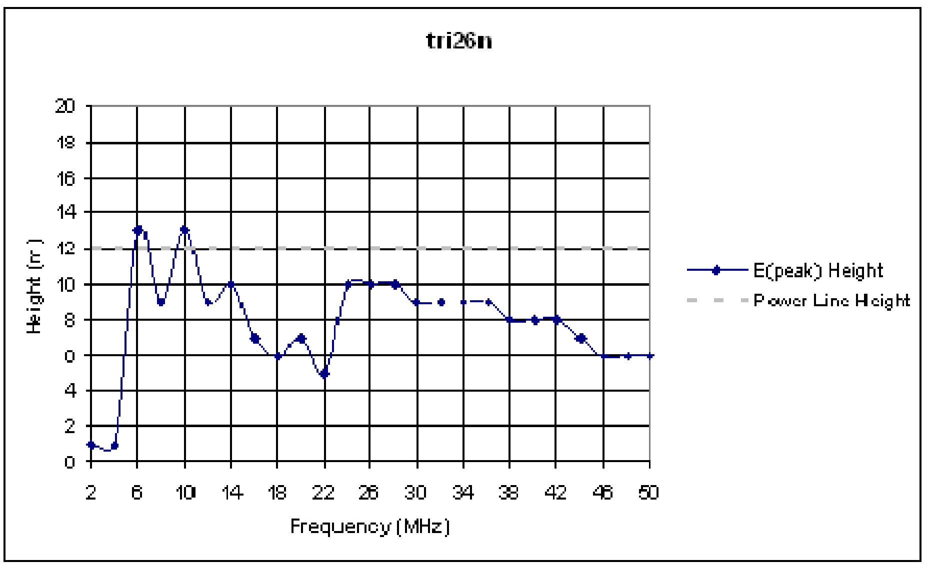
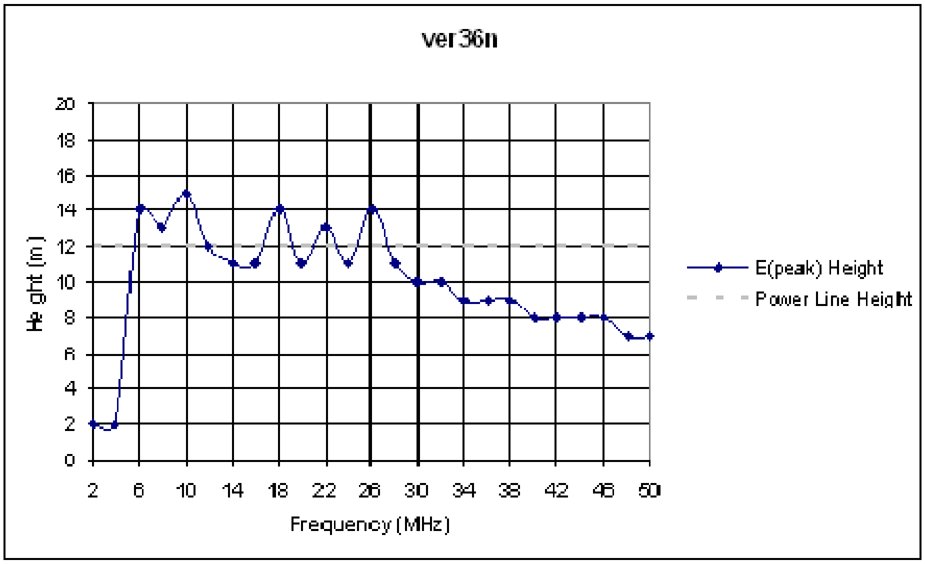


Figure 2-6: Height corresponding to peak electric field strength as a function of frequency



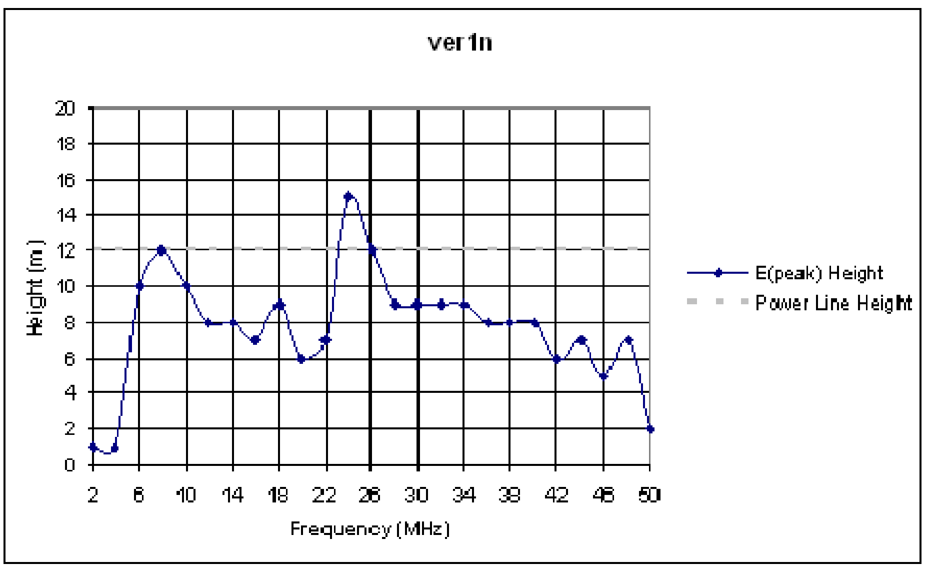


Figure 2-7: Height corresponding to peak electric field strength as a function of frequency

Figures 2-4 through 2-7 illustrate the variability of heights at which the peak electric field strength occurs. This variability can be seen over both frequency and power line topology. In those cases where the operating frequency is above 6 MHz, the peak field strength typically occurred at heights greater than 1 meter. Below 6 MHz, where the wavelengths are greater than four times the modeled power line height (12 meters), the increased in-phase coupling between the power line and ground will generally lead to the highest values of electric field at or near ground level.

2.3.2 Peak Electric Field Strength at the Compliance Measurement Heights

Although the peak field strength may occur at any height, the rules for Access BPL systems specify measurement heights of 1 meter below 30 MHz, and 1 to 4 meters at or above 30 MHz.[10] Figures 2-8 through 2-17 show the 80th percentile of peak electric field strength values along the power lines and over the range of simulated heights, relative to the peak field strength seen at the Part 15 compliance measurement height.[11] As previously stated in Section 2.2, the power line simulations computed electric field strength values at heights of 1 to 20 meters in one meter increments. The 80th percentile values eliminate the localized peaks that are unlikely to be encountered by a radio receiver randomly located in close proximity to an Access BPL power line.[12]

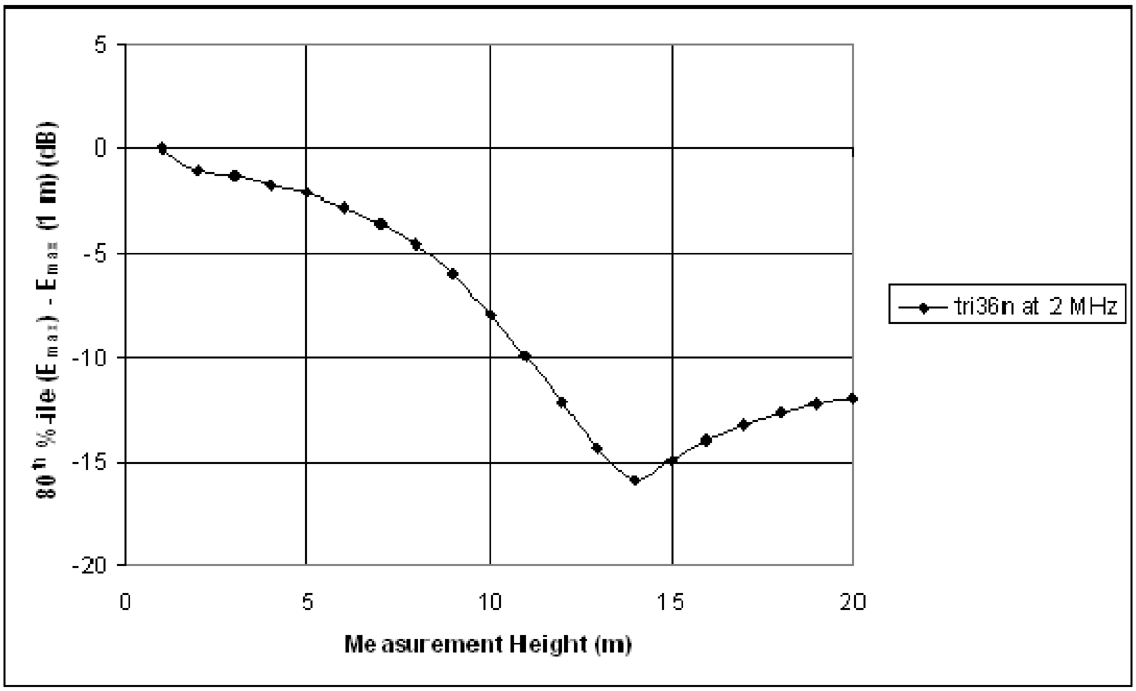


Figure 2-8: 80th percentile of peak electric field strength along the power line relative to the peak electric field strength at a 1 meter measurement height

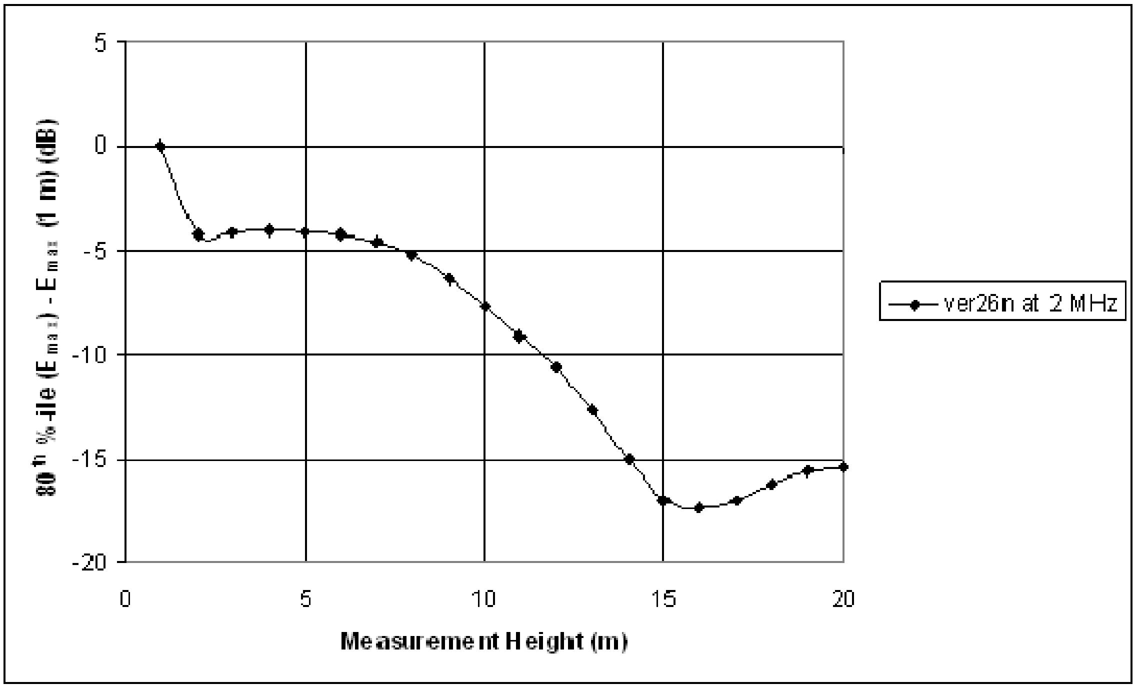


Figure 2-9: 80th percentile of peak electric field strength along the power line relative to the peak electric field strength at a 1 meter measurement height

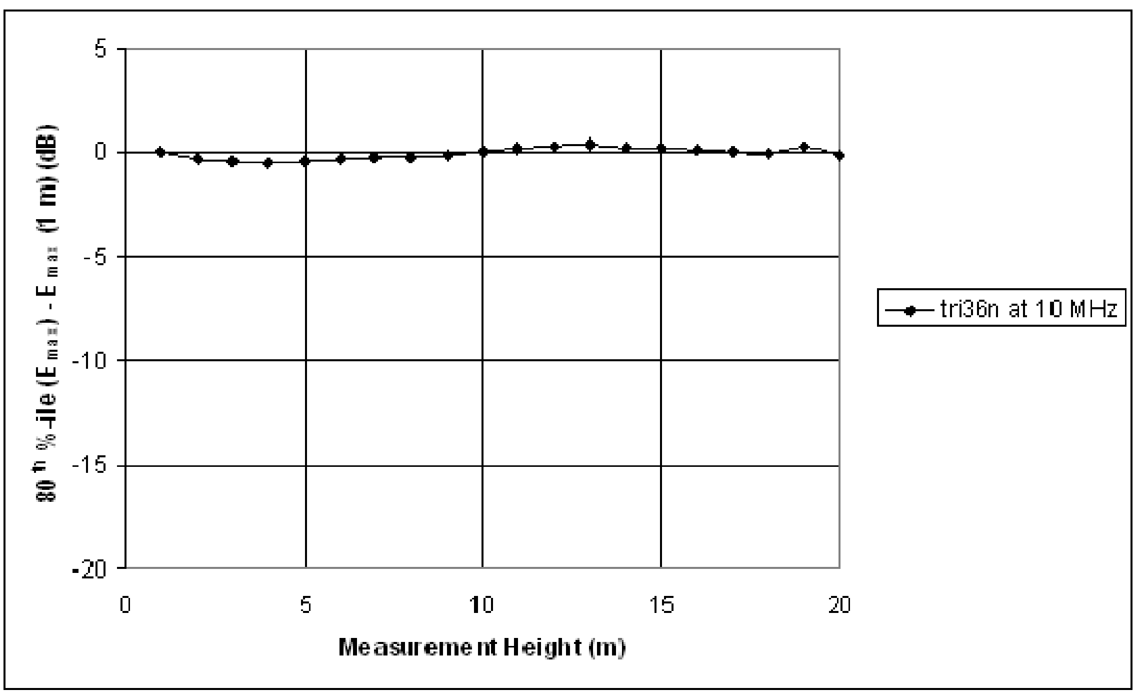


Figure 2-10: 80th percentile of peak electric field strength along the power line relative to the peak electric field strength at a 1 meter measurement height

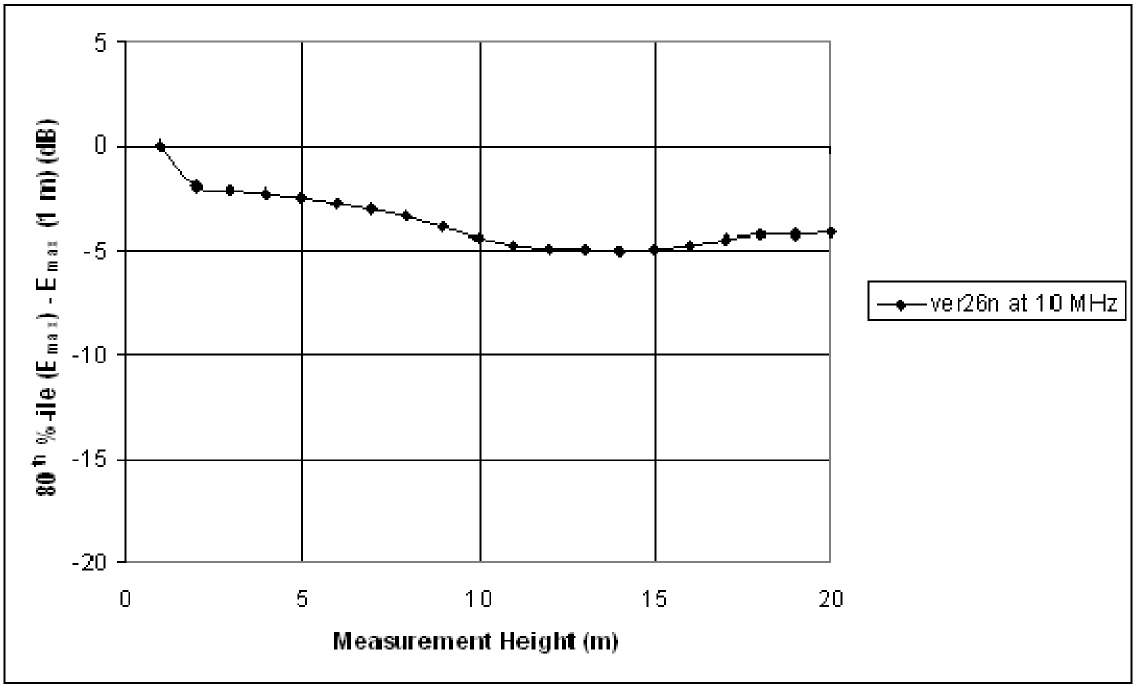


Figure 2-11: 80th percentile of peak electric field strength along the power line relative to the peak electric field strength at a 1 meter measurement height

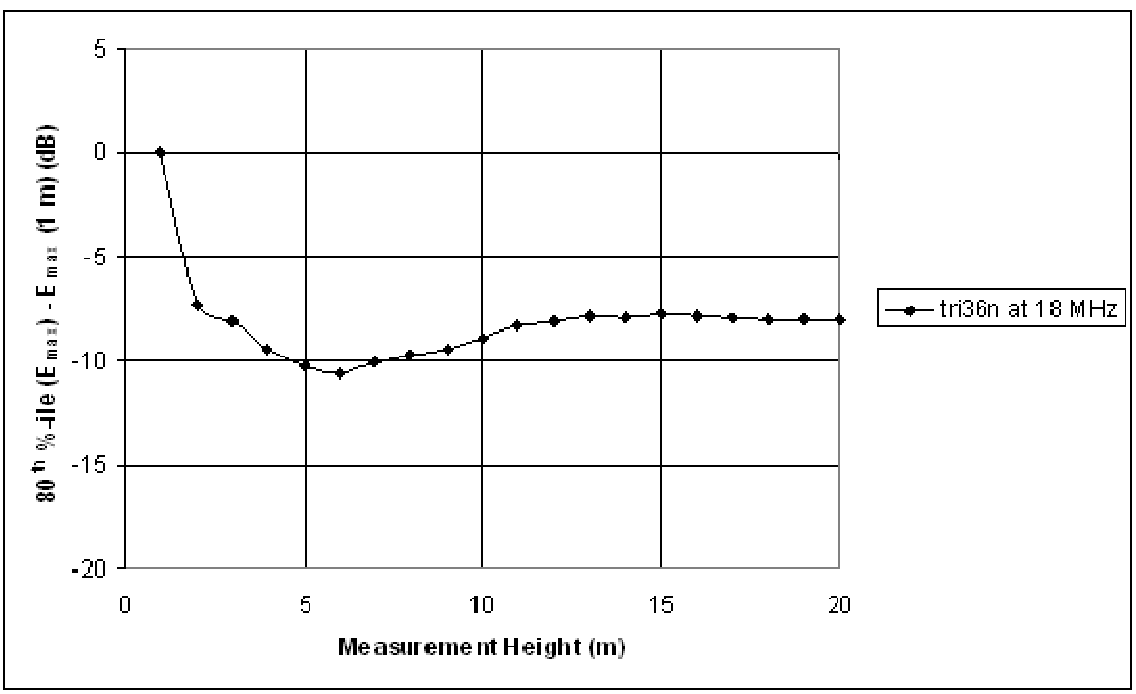


Figure 2-12: 80th percentile of peak electric field strength along the power line relative to the peak electric field strength at a 1 meter measurement height

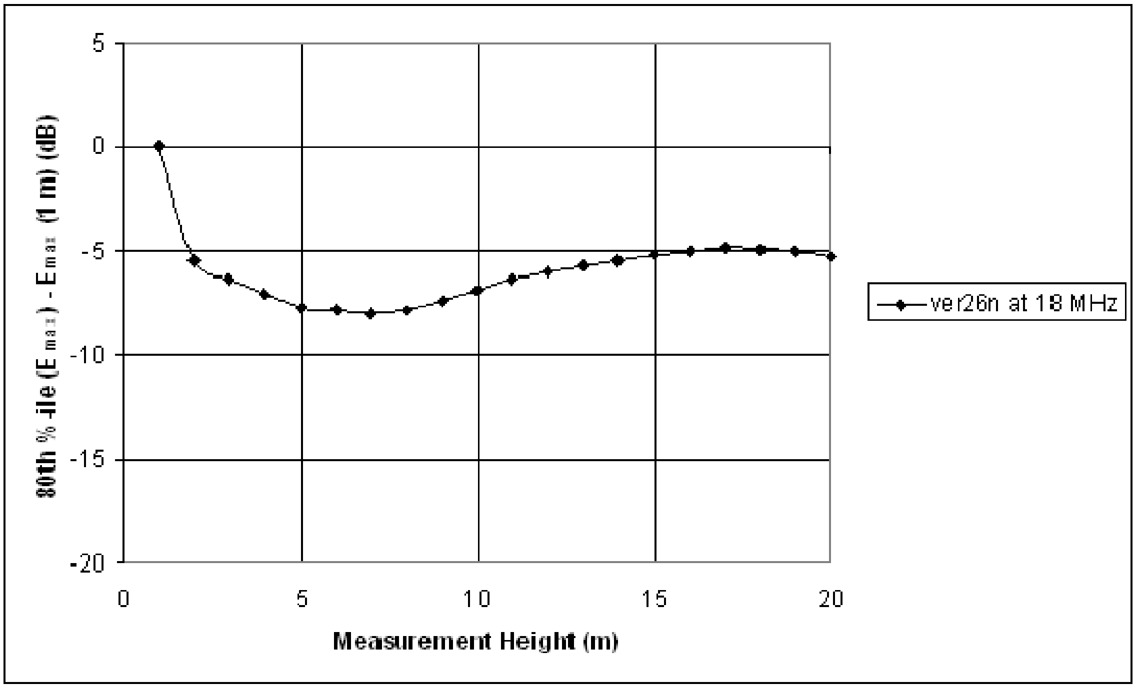


Figure 2-13: 80th percentile of peak electric field strength along the power line relative to the peak electric field strength at a 1 meter measurement height

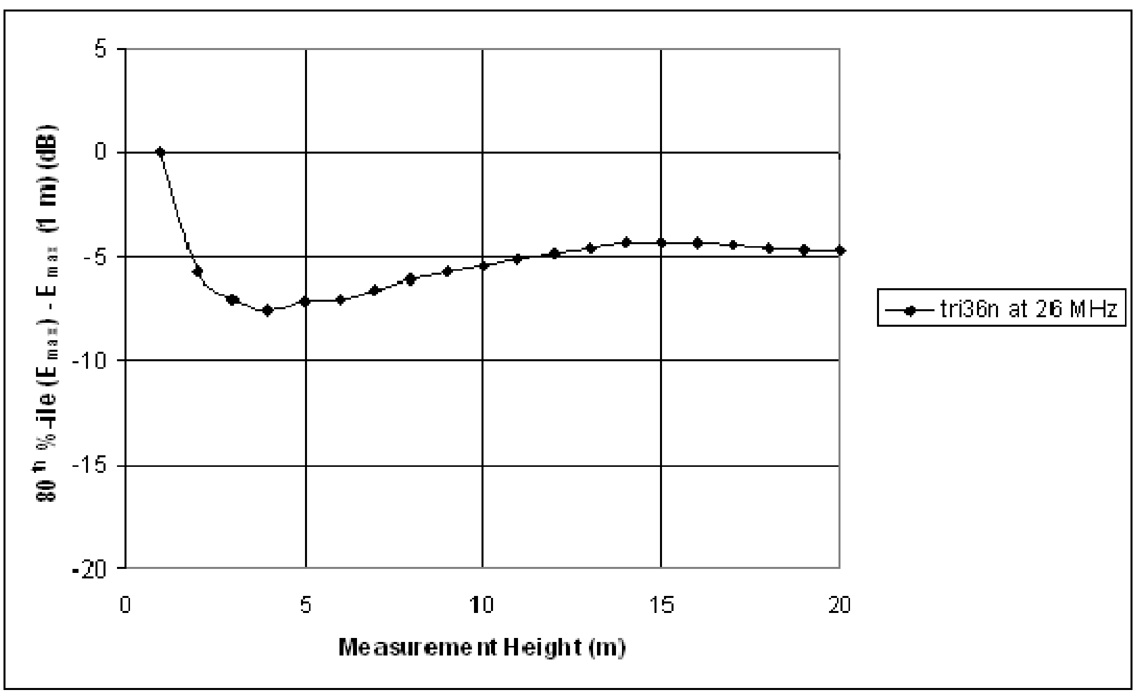


Figure 2-14: 80th percentile of peak electric field strength along the power line relative to the peak electric field strength at a 1 meter measurement height

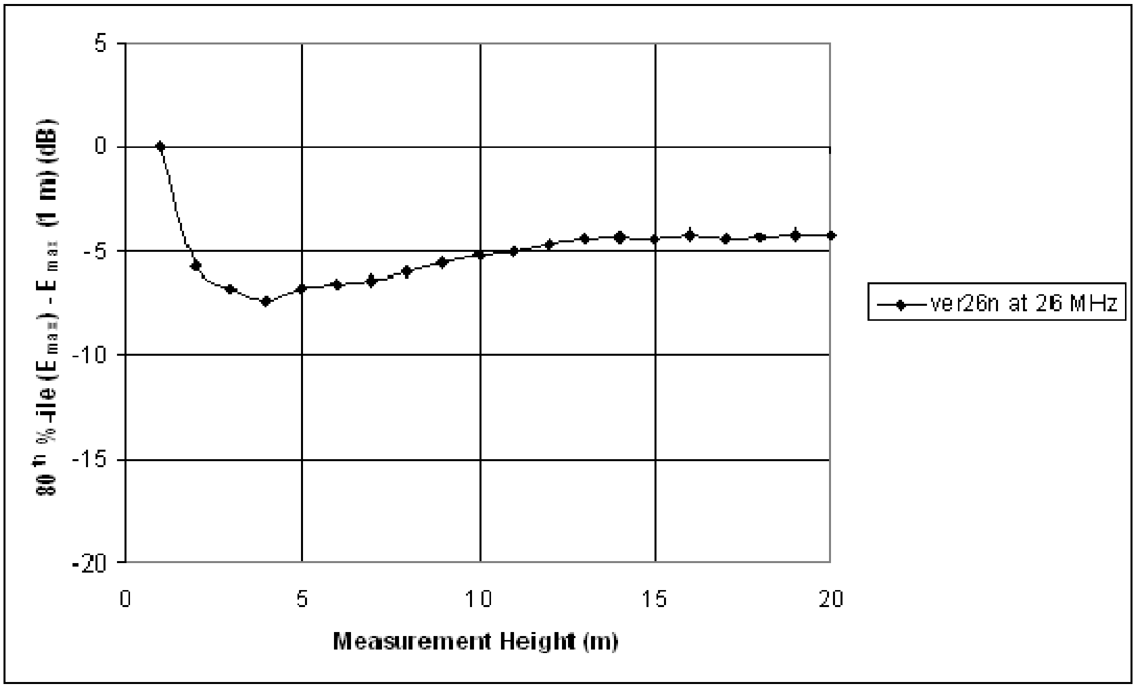


Figure 2-15: 80th percentile of peak electric field strength along the power line relative to the peak electric field strength at a 1 meter measurement height

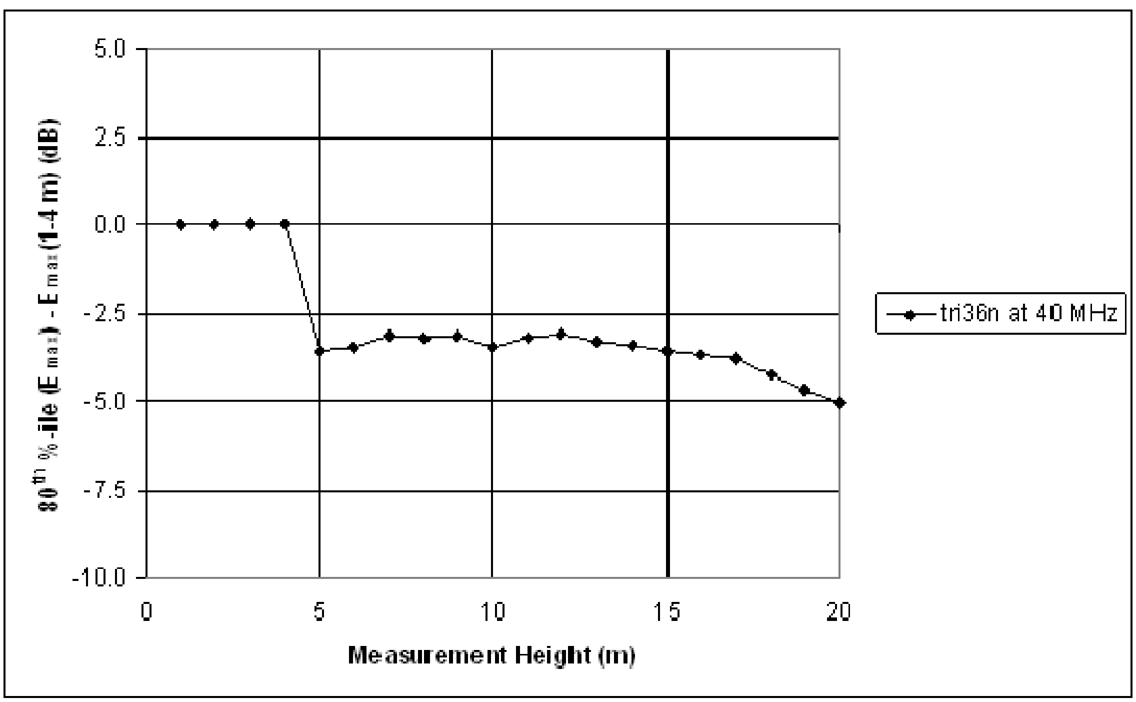


Figure 2-16: 80th percentile of peak electric field strength along the power line relative to the peak electric field strength at the 1 to 4 meter measurement height

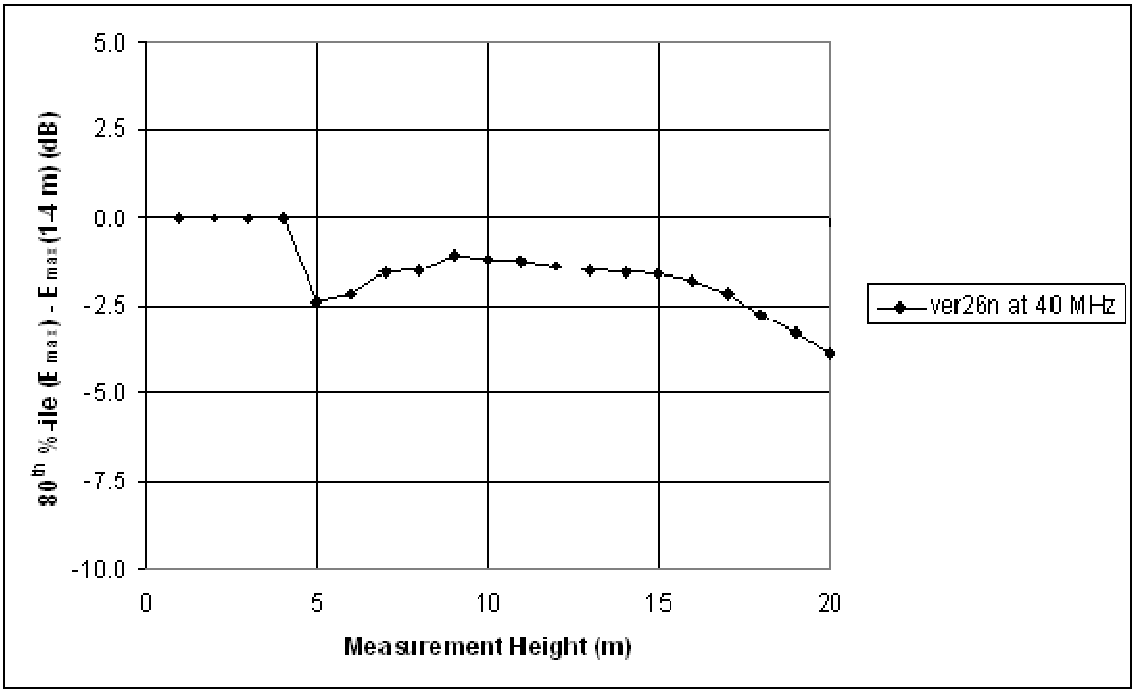


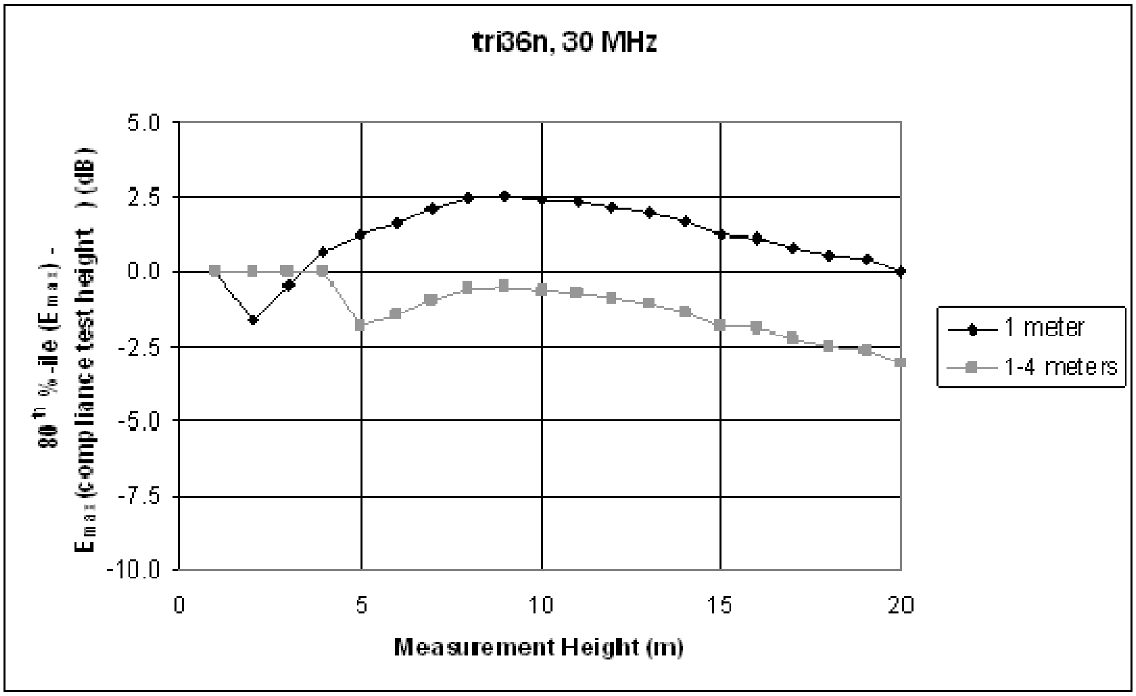
Figure 2-17: 80th percentile of peak electric field strength along the power line relative to the peak electric field strength at the 1 to 4 meter measurement height

As can be seen in Figures 2-8 through 2-17, and in Appendix A, the Part 15 measurement heights underestimated the 80th percentile of peak electric field strength for the various power line models by no more than 1 dB. The use of these measurement heights is expected to result in reasonable estimates of peak field strength at the most locations surrounding overhead Access BPL power lines.

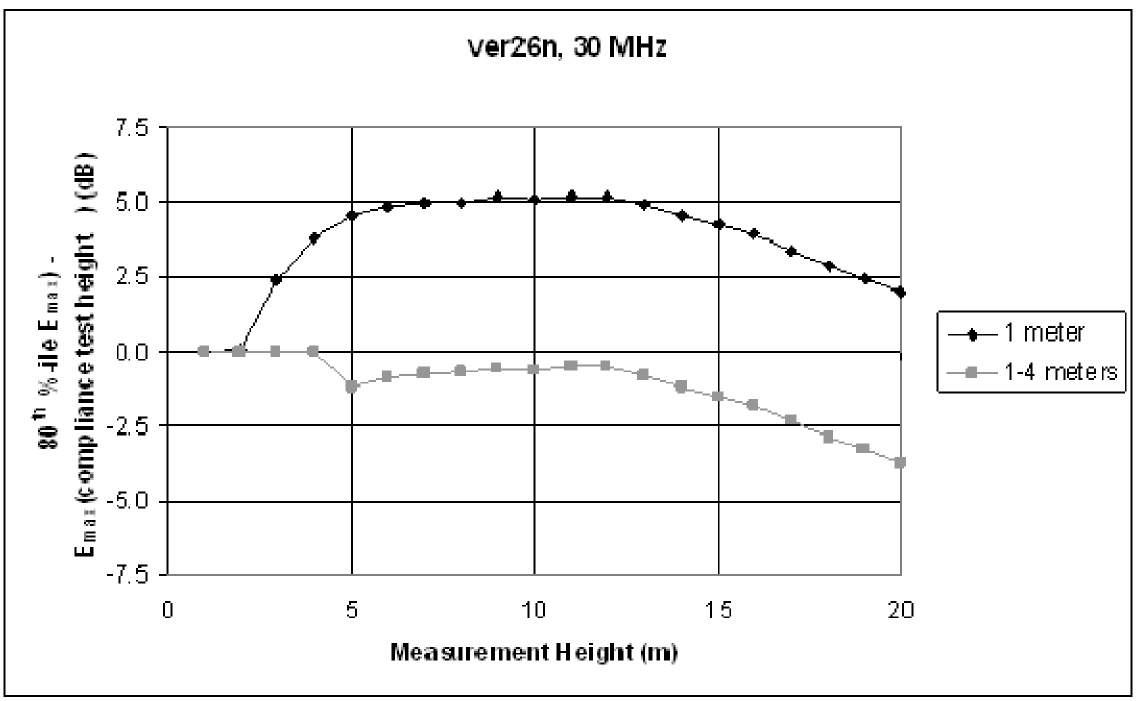
2.3.3 Antenna Measurement Height Correction Factor above 30 MHz

Above 30 MHz, the option to perform compliance measurements at a 1 meter measurement height coupled with a 5 dB height correction factor provides a much simpler measurement approach than to perform measurements over the specified 1 to 4 meter range of measurement heights. Figures 2-18 through 2-23 illustrate the difference between the overall peak field strength (80th percentile values), which could occur at any height, relative to the peak field strength at the specified measurement height(s) for two of the simulated power line configurations. These figures show two cases: use of the specified 1 to 4 meter measurement height, and use of the optional 1 meter measurement height. The NEC simulation data were scaled to the peak levels seen in either the horizontal or vertical polarizations at the FCC-specified compliance measurement locations for the 1 meter and 1 to 4 meter height cases.[13]

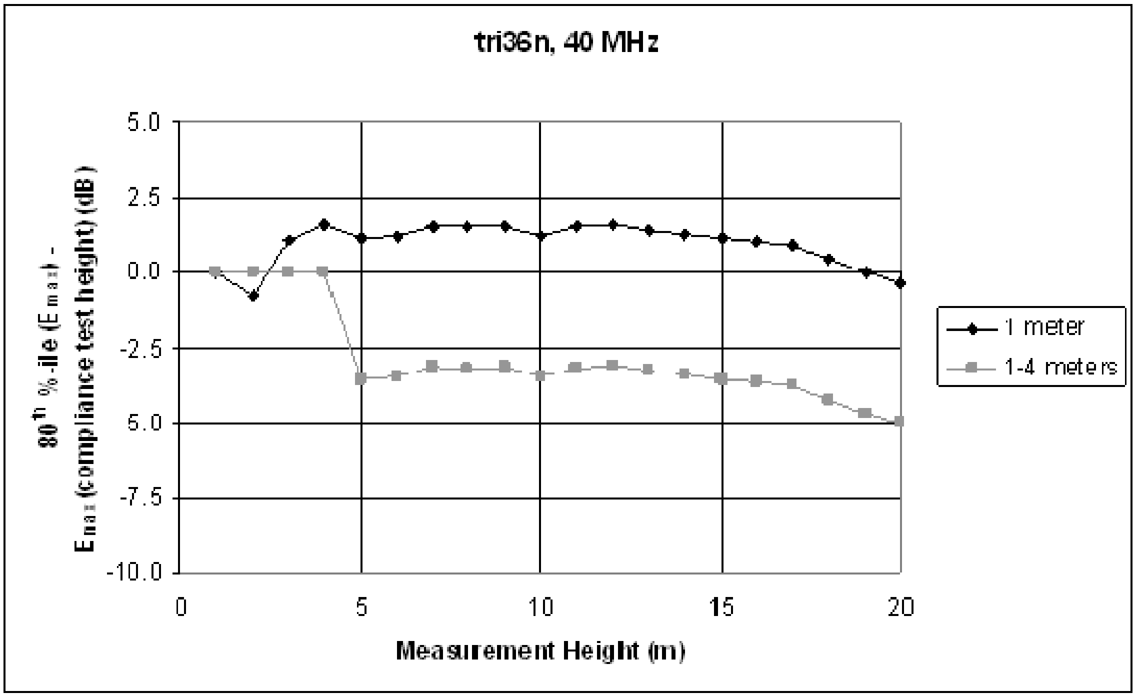
The results for other power line configurations modeled by NTIA are provided in Appendix A.



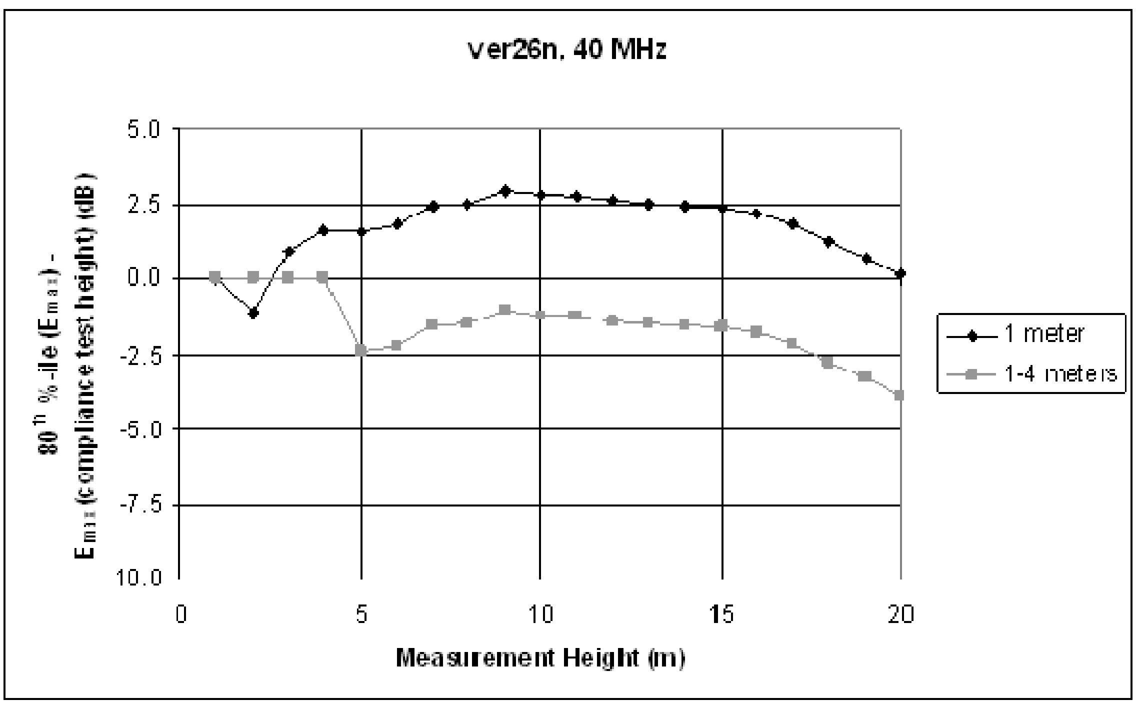
2-18: Comparison of electric field strength as a function of measurement height, if compliance measurements were performed at heights of 1 meter, or at 1 to 4 meters



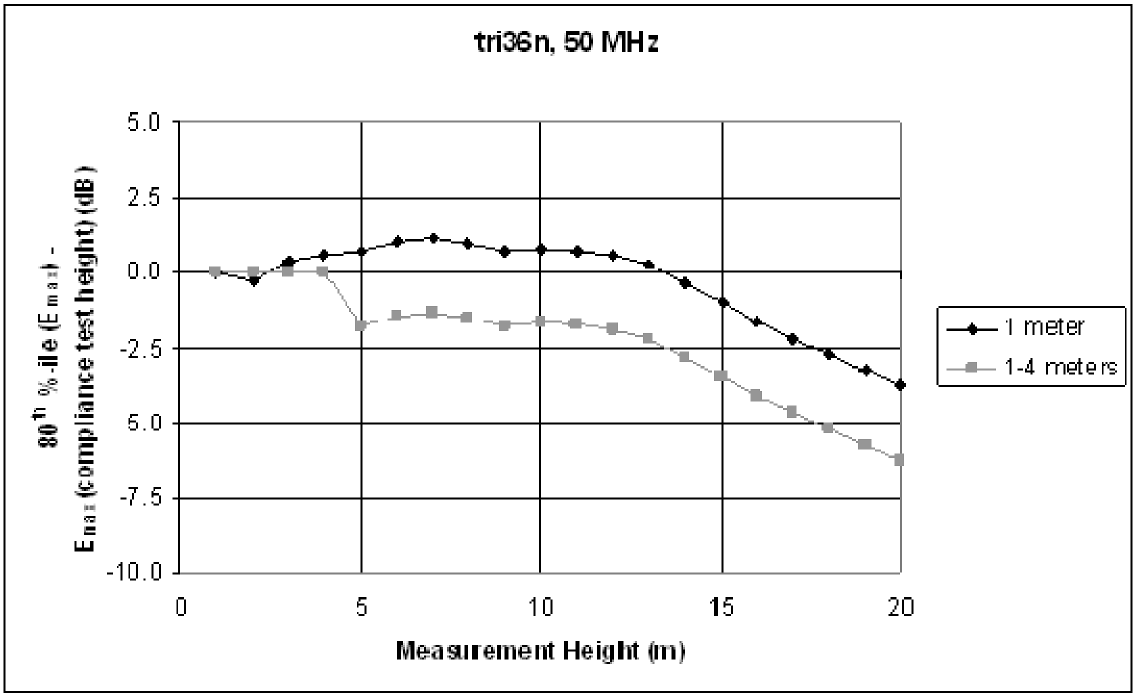
2-19: Comparison of electric field strength as a function of measurement height, if compliance measurements were performed at heights of 1 meter, or at 1 to 4 meters



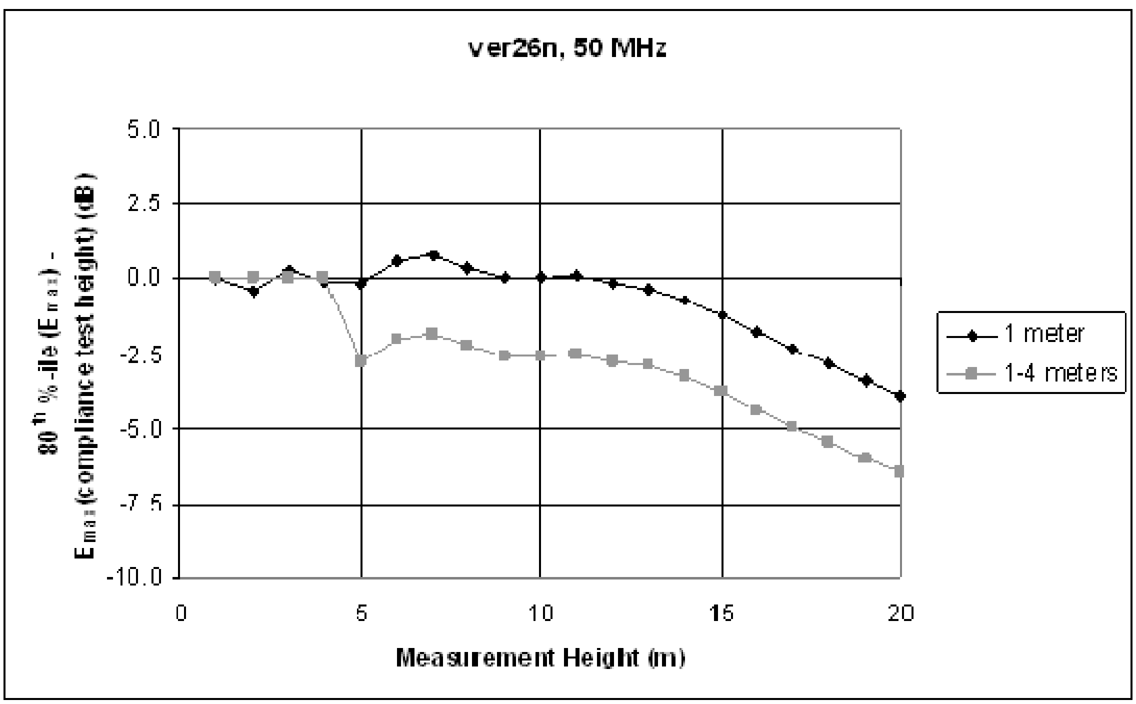
2-20: Comparison of electric field strength as a function of measurement height, if compliance measurements were performed at heights of 1 meter, or at 1 to 4 meters



2-21: Comparison of electric field strength as a function of measurement height, if compliance measurements were performed at heights of 1 meter, or at 1 to 4 meters



2-22: Comparison of electric field strength as a function of measurement height, if compliance measurements were performed at heights of 1 meter, or at 1 to 4 meters



2-23: Comparison of electric field strength as a function of measurement height, if compliance measurements were performed at heights of 1 meter, or at 1 to 4 meters

NTIA's simulation results shown here and in Appendix A indicate that scaling the field strength data to meet the Part 15 limits using a 1 meter antenna height tends to underestimate the peak field strength at any height by anywhere from 2.5 to 7.5 dB. The optional use of a 1 meter measurement height, with the corresponding 5 dB height correction factor, would result in limiting peak field strength to levels that would likely be seen if the measurements were performed at the specified 1 to 4 meter height above 30 MHz.

2.4 MEASUREMENT DISTANCE ALONG THE POWER LINE

As noted in NTIA's Phase 1 Study, compliance measurement testing commissioned by BPL equipment vendors and service providers has generally focused on radiated emissions measured on radials from the BPL device under test. However, FCC rules state that Part 15 devices and all attached wiring should be considered when measuring radiated emissions.[14] In the Commission's BPL Report and Order, the measurement guidelines specify the measurement locations along the power line away from a BPL device.[15] In this section, NTIA provides its simulation results from evaluating the field strength along the length of the power line and comparing this to the field strength levels at the prescribed measurement locations.

NTIA evaluated the field strength along the length of the power line in 1 meter increments for six simulated power line configurations described in Section 2.2. These calculations were performed over the frequency range of 2 to 28 MHz. Figures 2-24 through 2-31 show the electric field strength levels along the power line for a subset of the cases considered. Each figure includes an electric field strength level that corresponds to the Part 15 radiated emissions limit, when extrapolated from a horizontal distance of 30 meters to the horizontal measurement distance of 10 meters, and assuming a power line height of 12 meters.[16] In addition, these figures show the Part 15 compliance measurement points specified in the measurement guidelines for overhead Access BPL systems. The peak value of electric field strength at these measurement points was used to scale the simulated signal source level so that the power line model satisfies the Part 15 limit based on the compliance measurement procedure. The emissions limit is extrapolated to the 10 meter measurement distance using the slant range distance between the simulated power line and the simulated measurement antenna at a height of 1 meter. Electric field strength values were determined from NEC magnetic field strength simulations of the power line models using the methodology described in Section 2.2. Results for other power line configurations are provided in Appendix B.

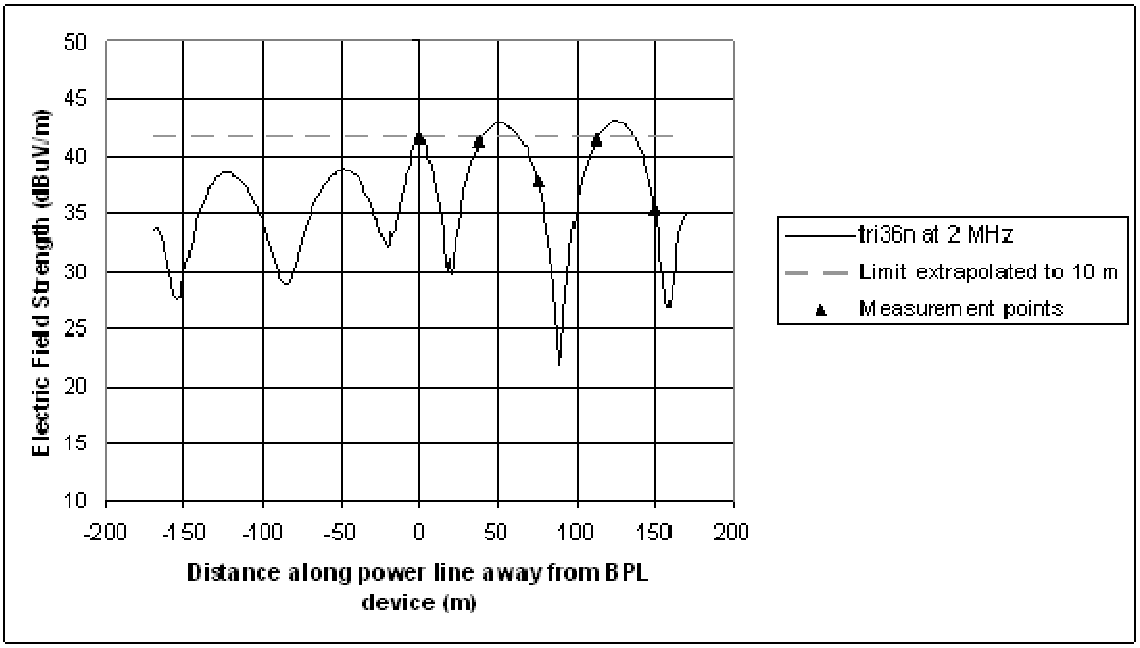


Figure 2-24: Vertical electric field strength along tri36n power line model at 2 MHz

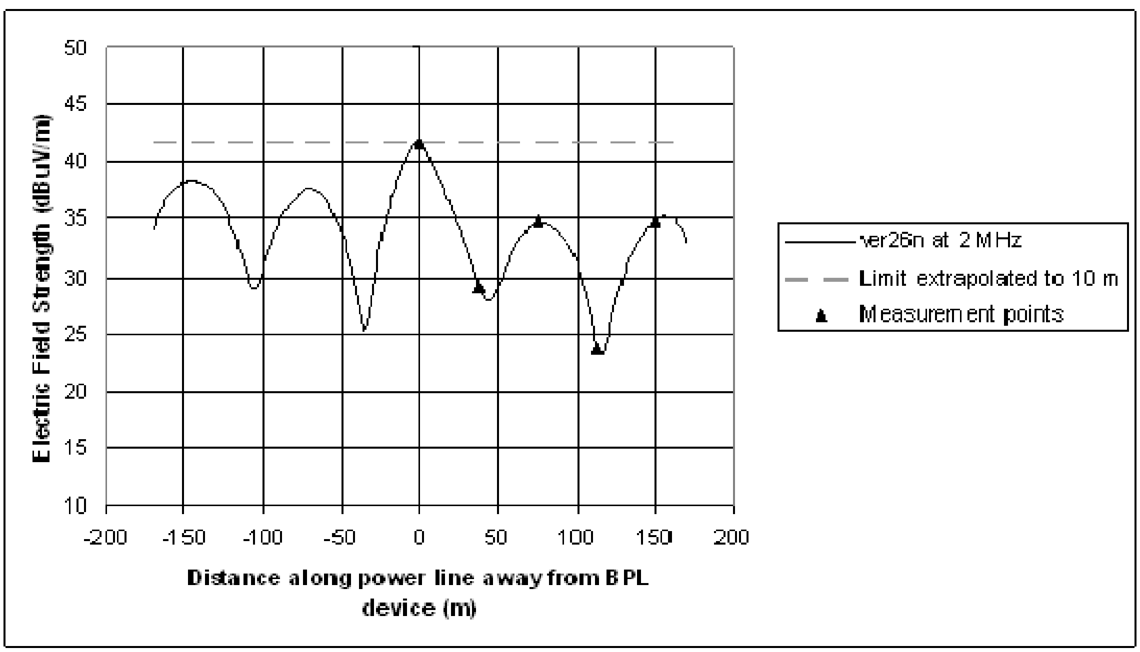


Figure 2-25: Vertical electric field strength along ver26n power line model at 2 MHz

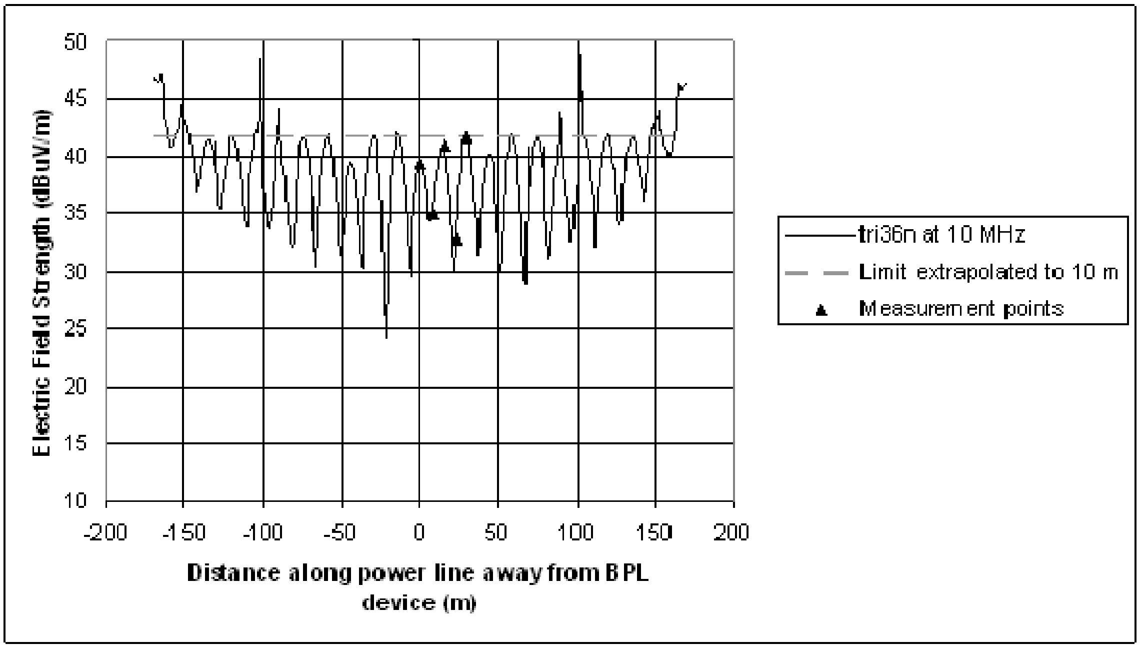


Figure 2-26: Vertical electric field strength along tri36n power line model at 10 MHz

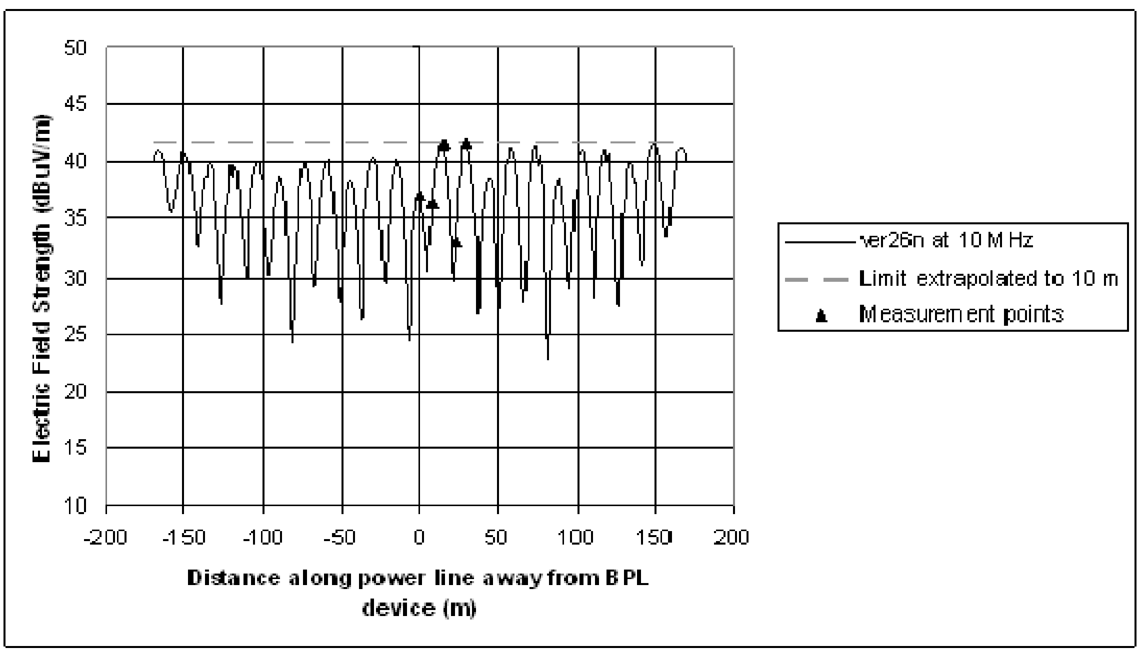


Figure 2-27: Vertical electric field strength along ver26n power line model at 10 MHz

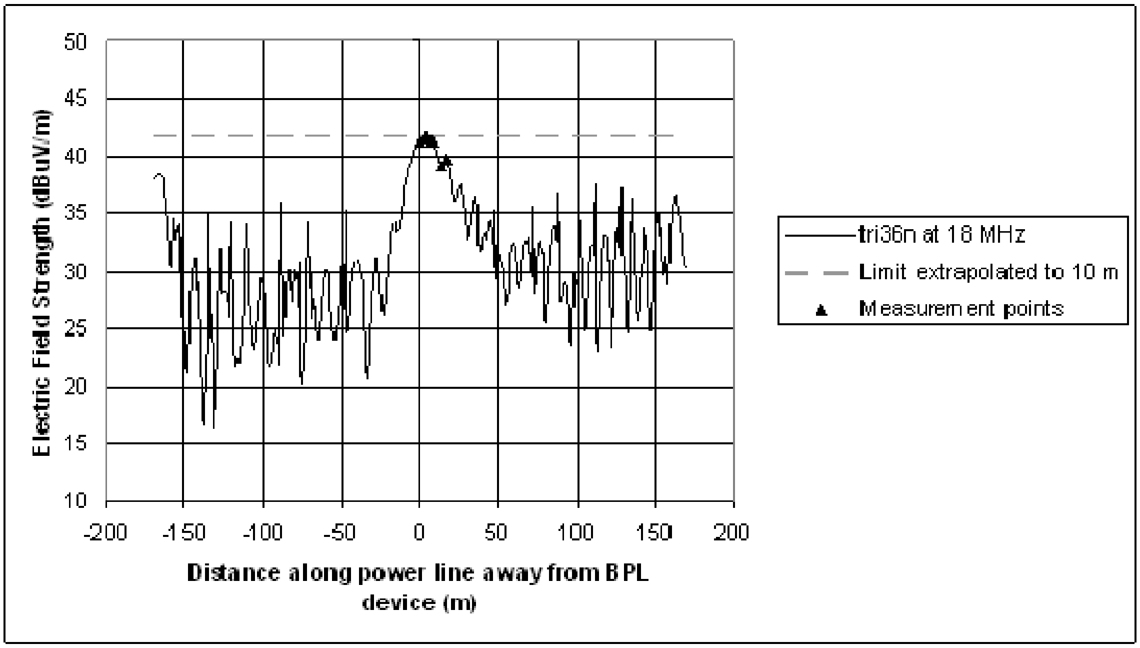


Figure 2-28: Vertical electric field strength along tri36n power line model at 18 MHz

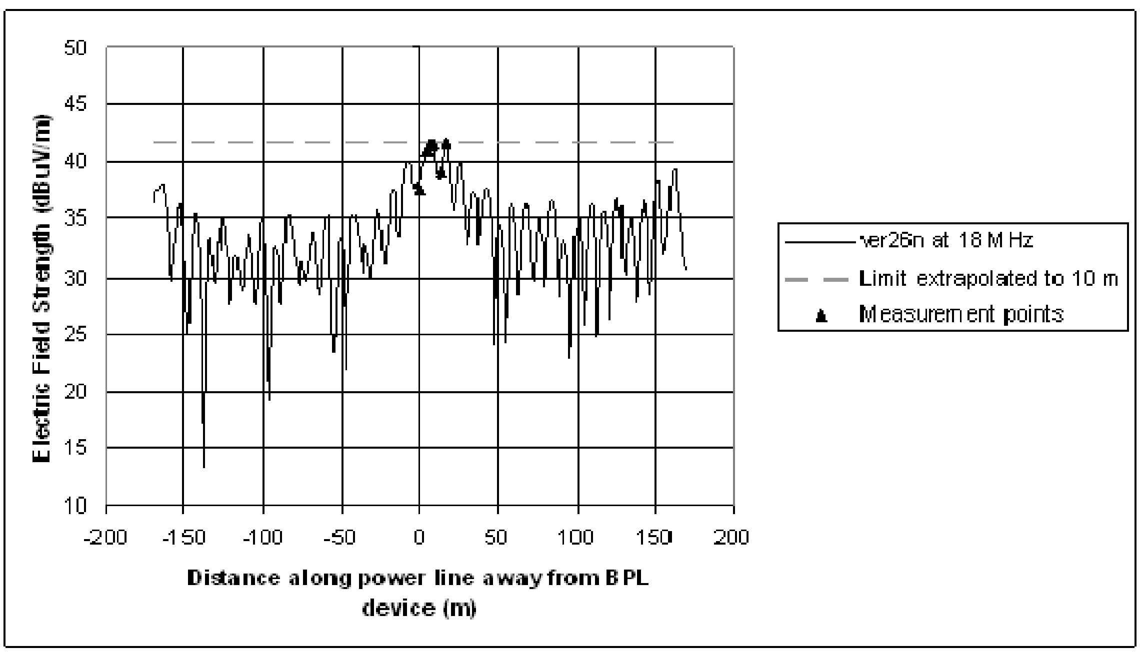


Figure 2-29: Vertical electric field strength along ver26n power line model at 18 MHz

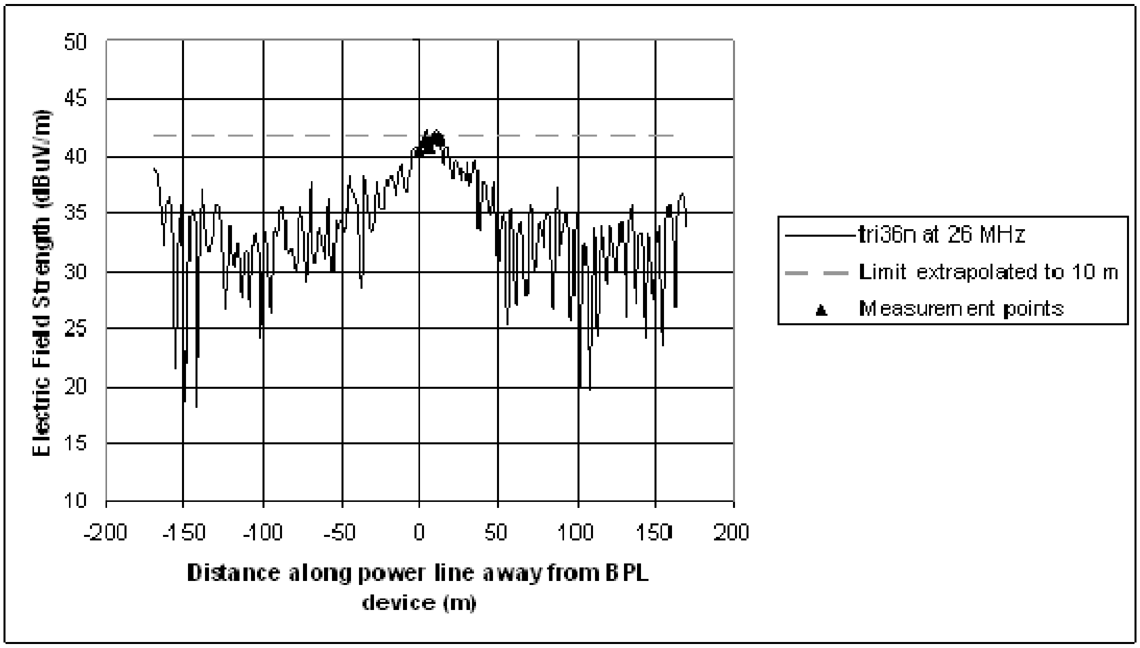


Figure 2-30: Vertical electric field strength along tri36n power line model at 26 MHz

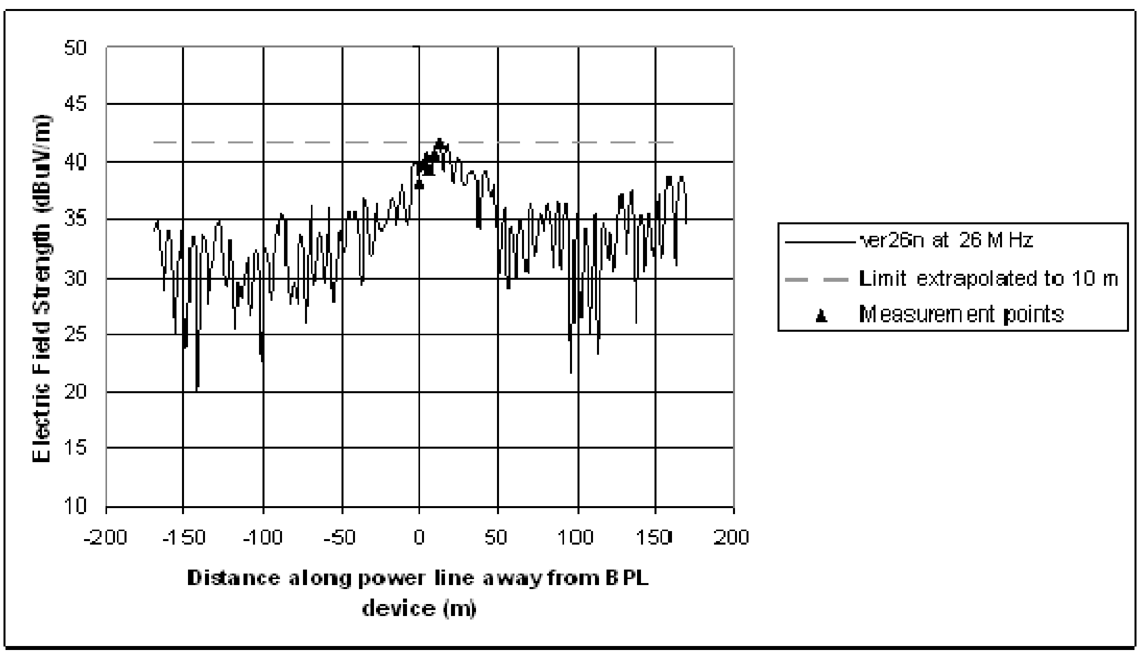


Figure 2-31: Vertical electric field strength along ver26n power line model at 26 MHz

The figures presented here, and those presented in Appendix B, reveal that there are some cases where the peak field strength may be underestimated by up to 5 dB. These cases generally occur at frequencies at or below 10 MHz. Where the results show occurrences of stronger field strength levels than the peak field strength levels seen at the Part 15 measurement locations specified for Access BPL systems, these occurrences are spatially limited along the length of the power line. Based on the power line simulations considered in this analysis, the emissions from Access BPL devices can be characterized for demonstrating compliance with the Part 15 limits using a limited number of measurement points, as specified in the Commission's measurement guidelines.

2.5 MEASUREMENT DISTANCE EXTRAPOLATION

The distance extrapolation rules for Part 15 devices define a 40 dB per decade of distance roll-off factor from the equipment under test (EUT) for frequencies below 30 MHz, and a 20 dB per decade distance extrapolation factor above 30 MHz.[17] Distance from the EUT is described as the horizontal distance projected on the ground. NTIA's measurements of Access BPL systems, documented in its Phase 1 Study, shows that the roll-off of radiated emissions with increasing distance from the overhead MV power lines occurs at a slower rate than the distance extrapolation factors specified above.[18]

In the BPL Report and Order, the Commission modified the measurement guidelines as they apply to distance extrapolation for Access BPL systems on overhead MV power lines by replacing the horizontal distance between the Access BPL power lines and the measurement antenna with the slant range distance between them.[19] Prior to adoption of the measurement guidelines, NTIA analyzed the use of slant range distance to compare the Part 15 limits, extrapolated to other measurement distances, with the expected field strength decay of a variety of modeled power line structures. NTIA found that this modification to the rules for distance extrapolation resulted in good agreement between the extrapolated field strength limit and the rate in which field strength decays from the overhead MV power line.[20]

2.5.1 New Approach for Distance Extrapolation

When it is necessary to make field strength measurements for overhead Access BPL systems at distances other than the specified Part 15 measurement distance, the field strength measurements are extrapolated to the Part 15 measurement distance as described in Equations 2-2 and 2-3 below. Figure 2-32 illustrates the concept of distance extrapolation using the slant path distance between the antenna and the BPL power line.

$$d_{slant} = \sqrt{(h_{pwr\_line} - h_{ant})^2 + (d_h)^2} \quad \text{(Equation 2-2)}$$

where:

d_{slant} is the slant path distance, in meters;

d_h is the horizontal distance, in meters;

h_{pwr_line} is the height of the power line wiring carrying BPL signals, in meters; and

h_{ant} is the measurement antenna height, in meters.

$$E_{extrap} = E_{meas} - N \cdot Log_{10}\left(\frac{d_{limit}}{d_{slant}}\right)$$ (Equation 2-3)

where:

N is distance extrapolation factor: 40 for frequencies < 30 MHz, or 20 for frequencies ≥ 30 MHz;

d_{limit} is the horizontal measurement distance corresponding to the Part 15 emissions limits: 30 meters, for frequencies < 30 MHz, or 10 meters, for frequencies ≥ 30 MHz;

d_{slant} is the slant path distance, in meters;

E_{meas} is the measured electric field strength at a horizontal distance, d_h, in dBV/m; and

E_{extrap} is the electric field strength value after applying the distance extrapolation factor, in dBV/m.

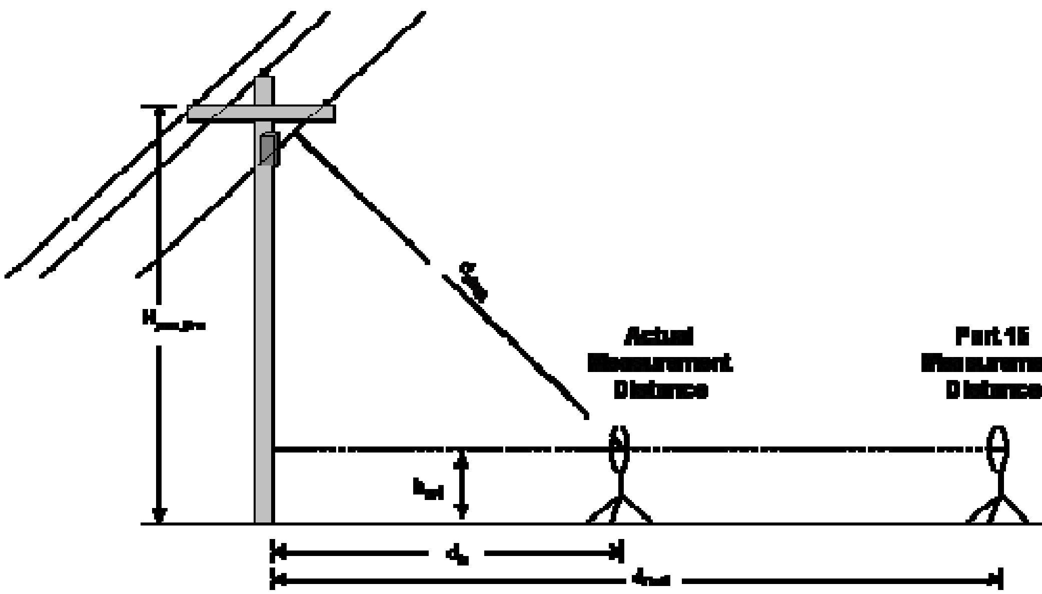


Figure 2-32: Slant path distance used for distance extrapolation of measurement limits

Table 2-2 shows the emissions levels at a measurement distance of 10 meters that satisfy the Part 15 limits for the distance extrapolation methodology based on horizontal distance and the slant-range methodology adopted in the BPL Report and Order. Figures 2-33 and 2-34 illustrate the electric field strength levels relative to the measurement distance for both distance extrapolation techniques.[21]

Table 2-2: An example of Access BPL emissions levels that meet Part 15 limits when extrapolated to a 10 meter measurement distance using horizontal and slant range extrapolation

Measurement Location

Assumed power line height	12 meters	
Measurement height	1 meters	
Measurement distance	10 meters	
Part 15 Limit & Distance Extrapolation		
< 30 MHz limit	29.5 dBµV/m	30 meters
≥ 30 MHz limit (Class A)	39.1 dBµV/m	10 meters
Extrapolation < 30 MHz	40 dB/decade of distance	
Extrapolation ≥ 30 MHz (Class A)	20 dB/decade of distance	
Extrapolated levels @ 10 m under 47 C.F.R. § 15.31(f)(1)-(2)		
< 30 MHz limit	48.58 dBµV/m	
≥ 30 MHz limit (Class A)	39.10 dBµV/m	
Extrapolated levels @ 10 m using slant-range distance specified for BPL devices		
< 30 MHz limit	41.70 dBµV/m	
≥ 30 MHz limit (Class A)	35.66 dBµV/m	

Figure 2-33: Extrapolated field strength levels meeting Part 15 emissions limits based on horizontal distance to a device under test, in accordance with 47 C.F.R. § 15.31(f)(1)-(2)

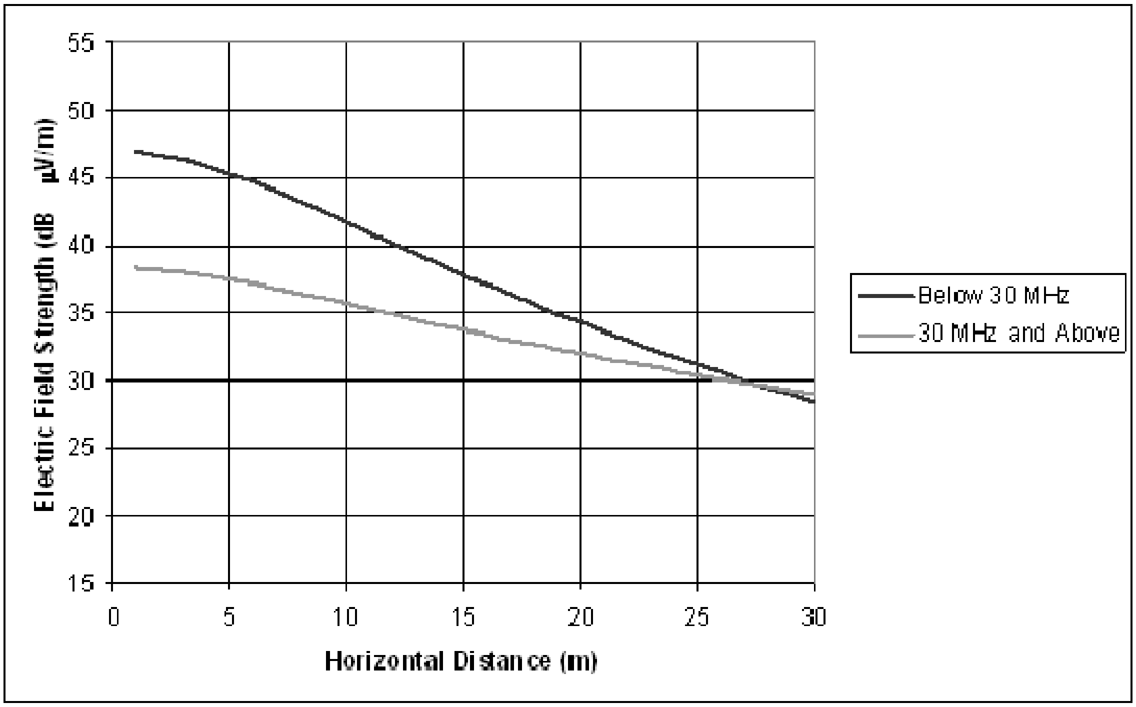


Figure 2-34: Extrapolated field strength levels meeting Part 15 emissions limits based on slant-range distance to the BPL power line

2.5.2 Calculated Electric Field Strength Decay for Distance Extrapolation

NTIA evaluated the field strength decay relative to the distance characteristics of the various power line models to evaluate the Commission's slant-range distance extrapolation methodology. The signal source for each power line model was scaled such that the radiated field strength met the Part 15 emission limits extrapolated to the 10 meter measurement distance for the specified measurement points along the length of the power line. Figures 2-35 through 2-39 show the electric field strength of the modeled power lines and the extrapolated field strength levels meeting the Part 15 emissions limit for distances out to 30 meters from the power line for a subset of frequencies modeled below 30 MHz. Additional results are provided in Appendix C.

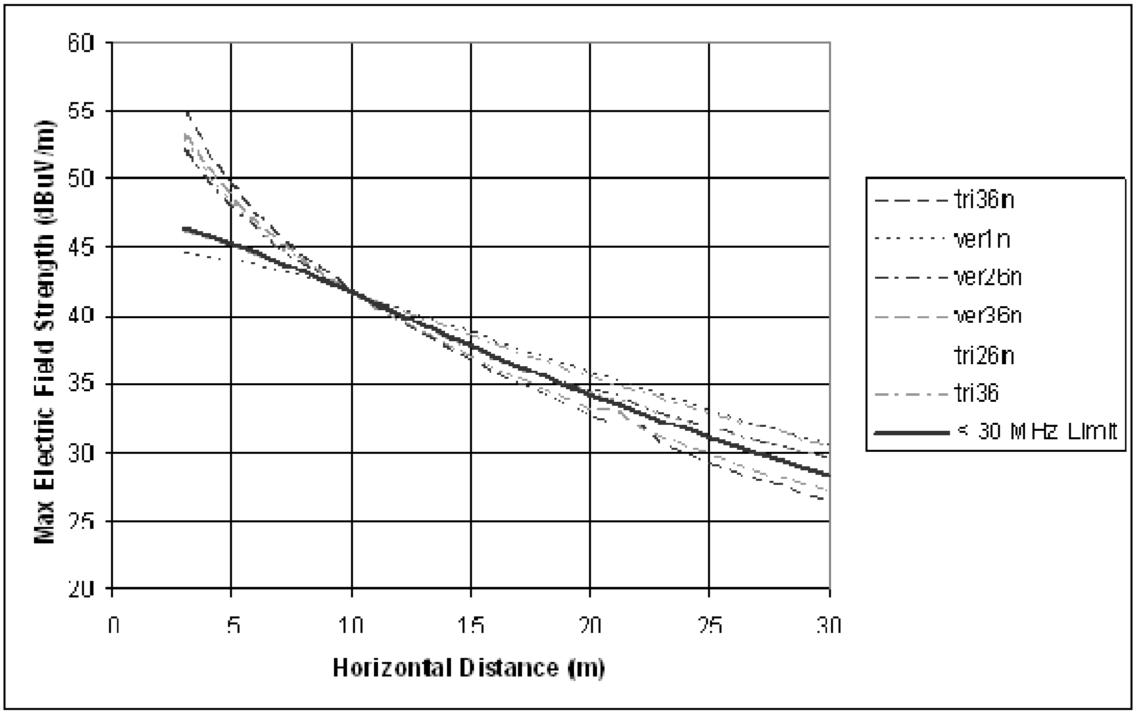


Figure 2-35: Electric field strength compared to emissions limit based on slant-range extrapolation for various power line models – 2 MHz

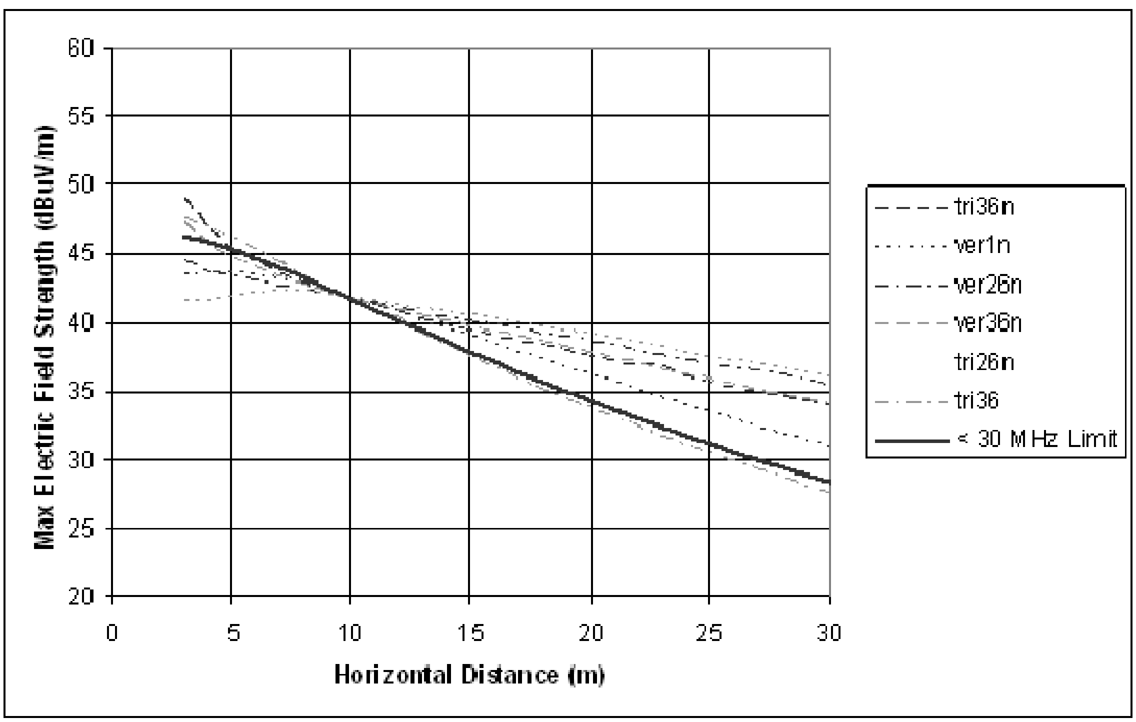


Figure 2-36: Electric field strength compared to emissions limit based on slant-range extrapolation for various power line models – 8 MHz

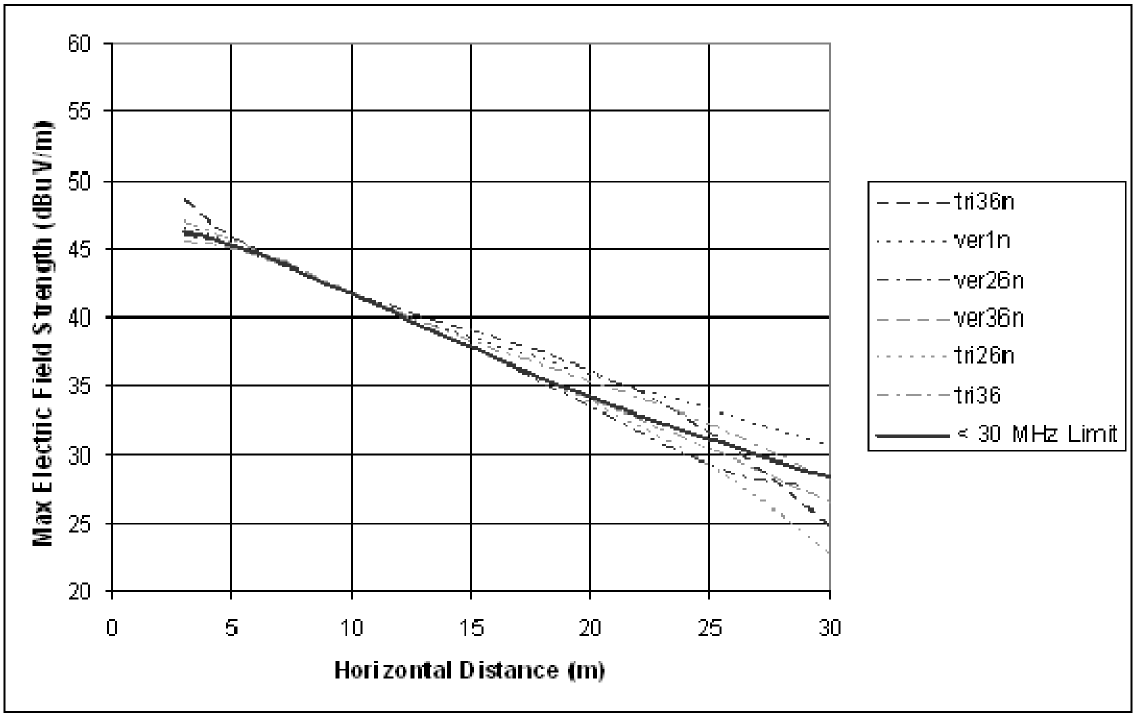


Figure 2-37: Electric field strength compared to emissions limit based on slant-range extrapolation for various power line models – 14 MHz

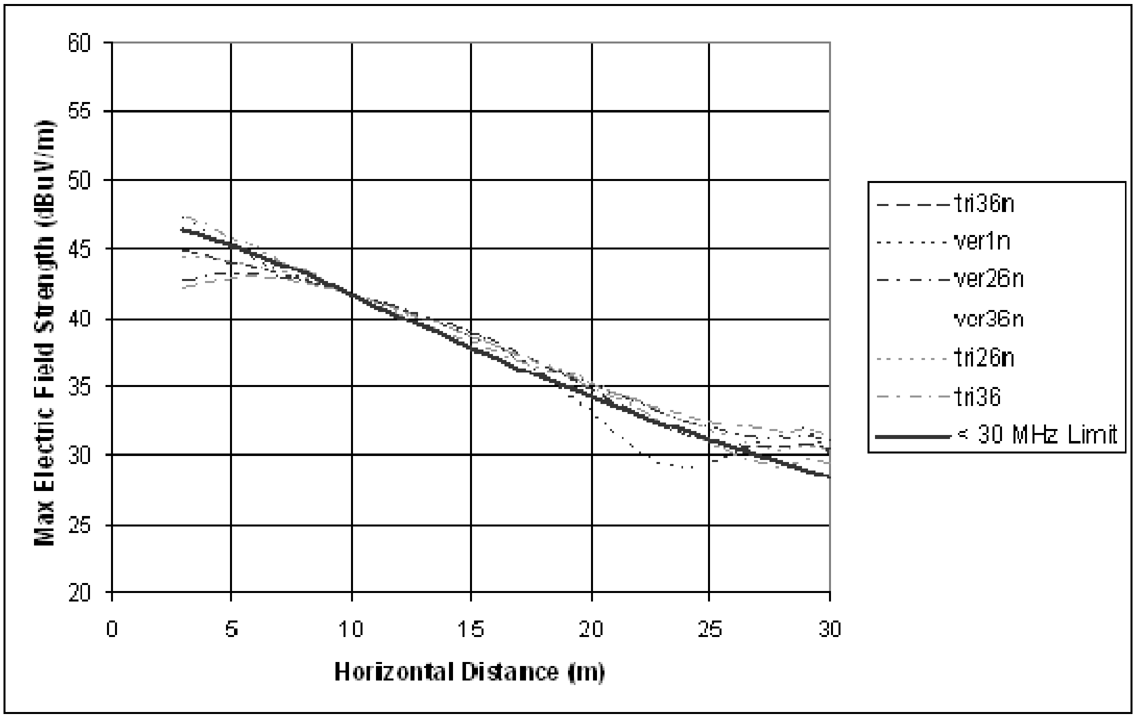


Figure 2-38: Electric field strength compared to emissions limit based on slant-range extrapolation for various power line models – 20 MHz

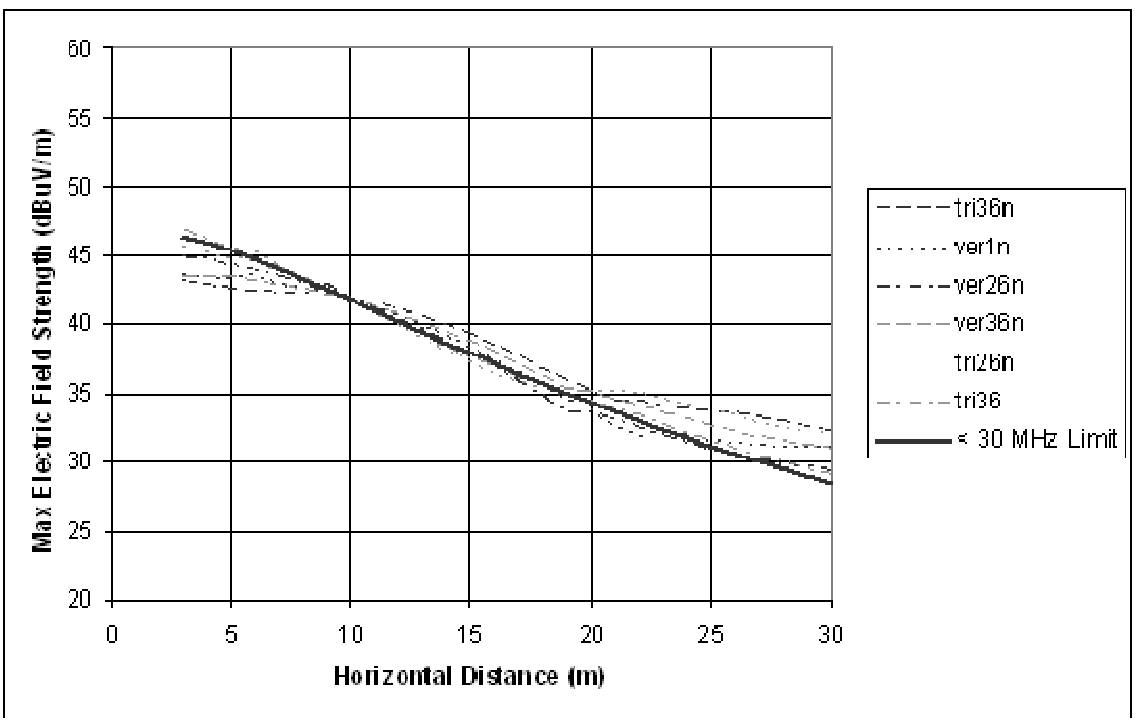


Figure 2-39: Electric field strength compared to emissions limit based on slant-range extrapolation for various power line models – 26 MHz

The simulation results in the 4 to 8 MHz frequency range showed that some of the power line models exhibited slower rates of field strength decay with distance than would be expected by the distance extrapolation rate in the Part 15 rules for Access BPL systems. This difference in the roll-off of field strength is as much as 6 dB less than the distance extrapolation rate.

At or above 10 MHz, the simulation results show good agreement between the rate that field strength decays and the distance extrapolation rate in the Part 15 rules, when slant path distance to the Access BPL device and power lines is used. The effect of the combination of direct and ground reflected rays at the simulated distances becomes more pronounced at frequencies above 14 MHz.

2.6 USE OF LOOP ANTENNA BELOW 30 MHz

Below 30 MHz, electric field strength is determined by measurement of the peak magnetic field in the horizontal plane using a loop antenna situated 1 meter above the ground. These measurements, conducted at a measurement distance of 10 meters from the power line, fall well within the near field region for many overhead MV power lines. To assess the validity of making measurements using the loop antenna below 30 MHz, NTIA evaluated the ratio of the peak vertical electric field to the peak magnitude of the horizontal magnetic field given by Equation 2-4 below:

$$\eta = \frac{E_z}{\sqrt{H_x^2 + H_y^2}} \qquad \text{(Equation 2-4)}$$

where η is the wave impedance, in Ω;

E_z is the vertically polarized electric field strength in μV/m; and

H_x, H_y are the x- and y-components of the horizontally polarized magnetic field strength in μA/m.

The value of η is nominally 377 Ω in the far field. The magnetic and electric field strength data were calculated at a distance of 10 meters from the various NEC power line models at a height of 1 meter. The peak vertical electric field was calculated for the entire length of the modeled power lines, in one-meter steps. The magnitude of the horizontal magnetic field was calculated as shown in the denominator of Equation 2-4 and its peak value along the length of the power line was determined. The ratio of these two values (η) was then computed. Figure 2-40 illustrates the values of η determined for a variety of NEC power line models for the frequency range of 2 to 28 MHz. The calculated values of η tend to vary from approximately 200 to 400 Ω.

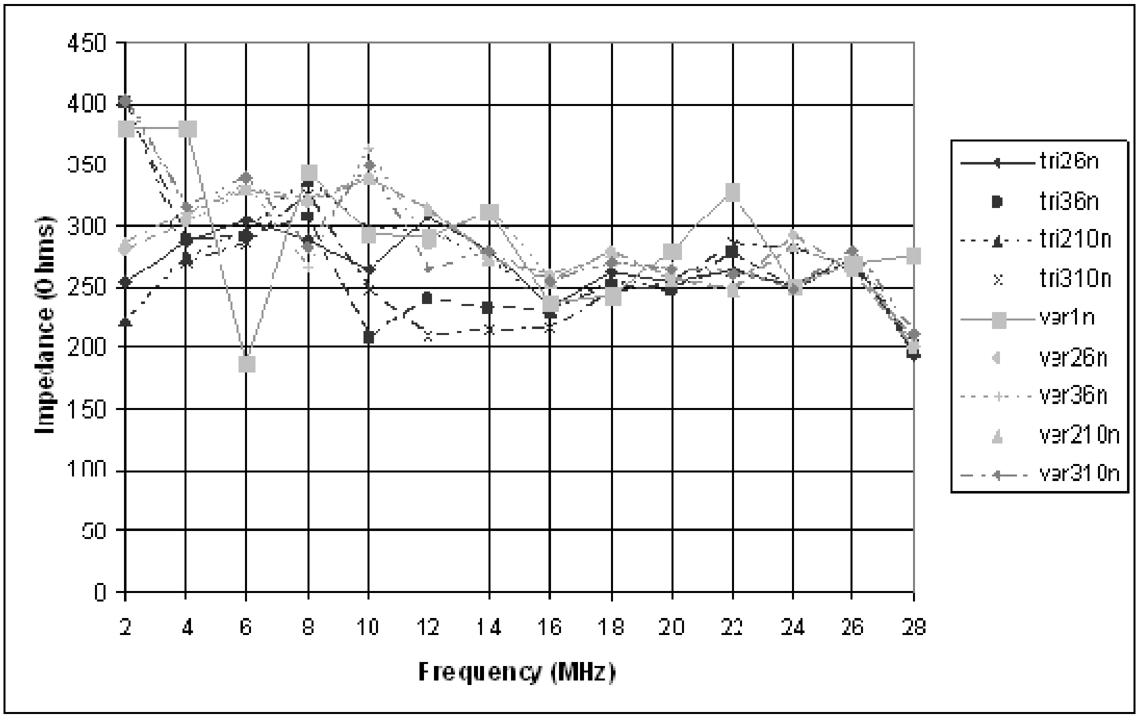


Figure 2-40: Ratio of peak electric to peak magnetic field strength at 10 meters from the power line

2.7 MEASUREMENT ANTENNA POLARIZATION

The Commission's measurement guidelines for Access BPL systems specify measurement with a loop antenna below 30 MHz, with the plane of the loop antenna oriented vertically at a height of 1 meter. The loop antenna is to be rotated 180° about its vertical axis to identify the maximum field strength. For frequencies above 30 MHz, the Commission specified measurements in both the vertical and horizontal polarizations using an electric field sensing antenna. The measurements at or above 30 MHz are made at antenna heights of 1 to 4 meters.

A vertically oriented loop antenna measures the horizontal magnetic field. This corresponds to the vertical component of the electric field. By rotating the antenna about its vertical axis, the peak horizontal magnetic field, and thus the peak vertical electric field, can be measured. This is ideally the case in the far field region where the electric and magnetic fields are orthogonal and their values differ by the wave impedance, 377 Ω (a reasonable assumption in the near field), as shown in Section 2.6.

Although the measurement guidelines specify that field strength measurements should address the horizontal magnetic field (vertical electric field) below 30 MHz, NTIA calculated both the horizontal and vertical polarizations of field strength from a number of NEC power line models. The calculations were performed from 2 to 30 MHz, in 2 MHz increments. The resulting field strength values were used to identify which electric field polarization corresponds to the overall peak at the 10 meter measurement distance for each power line model. The vertical electric field polarization was consistently the strongest for the frequencies simulated below 30 MHz.

2.8 GUIDELINES FOR CHOOSING REPRESENTATIVE SYSTEMS

The Commission's measurement guidelines specify *in-situ* testing of three representative overhead, and three underground, BPL installations that include all Access BPL electronic devices such as couplers, injectors, extractors, repeaters, boosters and concentrators.[22] NTIA has shown in its field tests and NEC modeling of BPL power lines that, in addition to the BPL devices themselves, certain typical features of a MV power line give rise to the strongest levels of radiated emissions. These features include distribution transformers, risers connecting overhead and underground distribution circuits, distribution line endpoints and sharp direction changes.[23]

Other features to consider when picking representative sites for *in-situ* testing include power lines with asymmetrical features, stacked 3-phase conductors, transitions between three phases and one or two phases, and, where appropriate for the BPL equipment involved, multiple co-located BPL devices. Figures 2-41 through 2-45 provide examples of these characteristics.

Figure 2-41: Offset 3-phase power line conductors

Figure 2-42: Offset 2-phase power line conductors

Figure 2-43: Stacked 3-phase power line conductors

Figure 2-44: Transition from 3-phase to 2-phase conductors

Figure 2-45: Multiple BPL devices located on the same utility pole

2.9 SUMMARY

The FCC's BPL Report and Order specified the rules and measurement guidelines for Access BPL systems. These rules and measurement guidelines were applied in the analyses described in this section.

The results from NEC simulations of a number of power line structures indicate that the peak field strength seen in close proximity to a BPL energized overhead power line will occur at various heights, and often near the height of the power line. NTIA further analyzed the peak field strength at the specified measurement heights and found that use of the Commission's measurement guidelines effectively estimated the 80th percentile values of peak field strength at any height. As noted earlier, the 80th percentile values eliminate the localized peaks that are unlikely to be encountered by a radio receiver randomly located in close proximity to an Access BPL power line.

The Commission's measurement guidelines allow field strength measurements on overhead Access BPL power lines operating in the Very High Frequency (VHF) band to optionally be performed at a 1 meter height combined with application of a 5 dB height correction factor. This simplification of the measurement procedure substantially reduces the number of measurements to be performed. Results from NTIA's NEC simulations show that measurements at a 1 meter height tend to underestimate by anywhere from 2.5 to 7.5 dB the peak field strength that would be seen using a measurement height in the 1 to 4 meter range. The use of a 5 dB height correction factor improves the field strength estimate at the 1 meter measurement height to a reasonable level while greatly reducing the number of measurements taken.

The BPL Report and Order specifies measurement at a limited number of locations along the power line. When the electric field strength was scaled to be within the Part 15 limits using the Access BPL measurement guidelines, NTIA's NEC simulation results indicated that the percent of measurement points where the field strength exceeded the Part 15 limits was small.

NTIA evaluated the Commission's modification of the distance extrapolation rules, which replaced the use of the horizontal distance between the BPL device and the measurement antenna with the slant range distance between them. NTIA's NEC simulations in the 4 to 8 MHz frequency range exhibited somewhat slower rates of field strength decay with distance than would be expected by the distance extrapolation rate in the Part 15 rules for Access BPL systems. This difference was up to 6 dB less than the distance extrapolation rate. At or above 10 MHz, the simulation results show good agreement between the rate that field strength decays and the Part 15 distance extrapolation rate using the slant range distance to the Access BPL device and power lines. As noted earlier, the effect of the combination of ground and reflected rays at the simulated distances becomes more pronounced at frequencies above 14 MHz.

The use of slant range distance with the extrapolation rates (40 dB per decade of slant range distance below 30 MHz, and 20 dB per decade of slant range distance at or above 30 MHz) defined in the rules most accurately estimates electric field strength when extrapolation is performed in close proximity to the BPL device and associated power lines. At great distances, the accuracy of this approach diminishes. At larger distances between the BPL device and measurement antenna, the slant range distance and the horizontal distance are approximately the same, and the extrapolation rate effectively becomes the same as if the horizontal distance was used. The Commission's rules state that measurements shall not be performed at distances greater than the specified measurement distance, or less, unless it is impractical to do so.[24]

Below 30 MHz, the electric field strength is determined by measuring the peak magnetic field strength in the horizontal plane using a loop antenna situated 1 meter above the ground, and applying a magnetic to electric field conversion factor of 377 Ω. These measurements, conducted at a distance of 10 meters from the BPL device and associated power lines, fall well within the near field region for many overhead MV power lines. NTIA evaluated the relationship between the magnetic and electric fields at 10 meters using a number of NEC power line models and determined that use of the loop antenna with this conversion factor provides a reasonable approximation at this distance. NTIA simulations investigating the field strength of both the vertical and horizontal polarizations showed that below 30 MHz, the vertical electric field (horizontal magnetic field) corresponds to the peak field strength when measured at 10 meters from the power line. This is consistent with the polarization specified by the Commission's measurement guidelines for Access BPL systems.

In Section 2.8, NTIA provided recommendations for choosing representative overhead MV Access BPL locations for *in-situ* testing. NTIA field tests and NEC modeling of BPL power lines identified that, in addition to the BPL devices themselves, many features of MV power lines give rise to the strongest levels of radiated emissions. NTIA suggests that a variety of these features should exist in power lines chosen as representative sites for compliance measurement testing.