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TVA's 500-kV ELECTRIC AND MAGNETIC FIELDS:
MEASUREMENTS AND ANALYSES

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**TVA's 500-kV ELECTRIC AND MAGNETIC FIELDS:
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Prepared by:
Electrical Systems Group
Tennessee Valley Authority
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ABSTRACT

This report summarizes the results of the 500-kV electric and magnetic fields data project, performed by the Electrical Systems Group of the Tennessee Valley Authority (TVA). The objectives of the project were to measure, record, and analyze electric and magnetic fields in the vicinity of TVA's 500-kV transmission lines. Also the effects of transmission line fields on the growth and development of selected agricultural and forest plant species were to be investigated. This report contains only the categorization and the statistical analysis of the fields data:

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TABLE OF CONTENTS

Chapter		Page
1	INTRODUCTION	1
2	ANALYSIS OF ELECTRIC AND MAGNETIC FIELDS	5
	2.1 Electric Fields Analysis - Flat Terrain	5
	2.2 Electric Fields Analysis - Irregular Terrain	8
	2.3 Tree Shielding Analysis	17
	2.4 Magnetic Fields Analysis	17
3	FIELD MEASUREMENTS AND ERROR ANALYSIS	23
	3.1 TVA's 500-kV Grid	23
	3.2 Data Collection Sites	25
	3.3 Electric Fields Measurements	26
	3.3.1 Equipment	28
	3.3.2 Field Meter Calibration	29
	3.3.3 Sources of Error	29
	3.3.4 Height, Centerline, and Perpendicular Transverse Measurement Errors	30
	3.3.5 Electric Field Meter Errors	32
	3.3.6 Voltage and Current Recording Errors	32
	3.3.7 Meter Orientation and Position	32
	3.3.8 Error Analysis for Electric Field Measurements	32
	3.4 Magnetic Fields Measurement	34
	3.4.1 Error Analysis in Magnetic Fields Measurement	34
4	500-kV MEASURED ELECTRIC AND MAGNETIC FIELDS DATA	35
	4.1 Electric Fields Data - General Analysis	38
	4.2 Electric Fields Data - Detailed Analysis	47
	4.2.1 Electric Fields Data Analysis - Without Tree Shielding	47
	4.2.2 Electric Fields Data - Tree Shielding Effects	50
	4.2.3 Detailed Characterization of TVA's 500-kV Electric Fields	50
	4.3 Magnetic Fields Data	53
5	CONCLUDING REMARKS	54
	REFERENCES	55
A	Appendix A - Surface Charge Method	56
B	Appendix B - Typical TVA 500-kV Transmission Line	64
C	Appendix C - NBS Field Meters Test Report	69
D	Appendix D - Electric Fields Data Analysis - Without Tree Shielding	73

TABLE OF CONTENTS

(Continued)

Chapter		Page
E	Appendix E - Electric Fields Data Analysis - With Tree Shielding	85
F	Appendix F - Detailed Electric Fields Data Analysis Without Tree Shielding	97
G	Appendix G - Detailed Electric Fields Data Analysis With Tree Shielding	198

LIST OF FIGURES

Figure		Page
2.1	Computed Electric Fields Profile 9.15 m Phase Spacing, 12.2 m Phase Spacing	6,7
2.2	Computed Maximum Value of the Electric Field (EMAX) as a Function of Line Height	9
2.3	Comparison of Measured and Computed Electric Fields Profiles - with Those Computed Using the "Method of Images" - Flat Terrain	10
2.4	Comparison of Measured and Computed Electric Fields Profiles - with Those Computed Using the "Method of Images" - Irregular Terrain	12
2.5	Irregular Terrain	13
2.6	Comparison of Measured Electric Field Profile with Computed Profiles Using "Method of Images" and the Surface Charge Method	16
2.7	Comparison of Typical Measured Profiles with Computed Profiles Using the "Method of Images" with Tree Shielding	18
2.8(a)	Comparison of Measured and Computed Electric Profiles Using "Method of Images"	19
2.8(b)	Comparison of Measured and Computed Profiles Using Surface Charge Method	20
2.9	Computed Electric Field Profiles Using the Surface Charge Method	21
2.10	Comparison of Typical Measured Magnetic Field Profiles with Computed Profiles	22
3.1	TVA 500-kV Transmission System and Data Collection Sites	24
3.2(a)	Typical Plot of Raw Data Sheet	27
3.2(b)	Typical Plan View of a Site	28
4.1	Typical Box-and-Whisker Diagram	37
4.2	Scatter Diagram of Sample of the Electric Fields Data	40

LIST OF FIGURES

(Continued)

Figure		Page
4.3(a)	Box-and-Whisker Diagram of Electric Field Data at Road Crossing for 12.2 m Phase Spacing	43
4.3(b)	Box-and-Whisker Diagram of Electric Field Data at Road Crossing for 9.15 m Phase Spacing	44
4.4(a)	Box-and-Whisker Diagram of Electric Field Data Near Homes for 12.2 m Phase Spacing	45
4.4(h)	Box-and-Whisker Diagram of Electric Field Data Near Homes for 9.15 m Phase Spacing	46
4.5	Scatter Diagram of a Sample of the Magnetic Fields Data	52

LIST OF TABLES

Tables	Page
2.1 Electric Field Values Over a Terrain with 5° and 20° General Slope	15
3.1 Descriptive Statistics for Measures of Error	31
4.1 Statistical Summary of all the Electric Field Data (Without the Special Sites)	41
4.2 Statistical Summary of the Electric Field Data at Road Crossings	41
4.3 Statistical Summary of Electric Field Data Off the Right-of-Way	42
4.4 Fields Data Categories	48
4.5 Comparison of the Medians of EMAX with Computed Values for Flat Terrain Category (Ft @ 1)	51
4.6 Statistical Summary of all the Magnetic Field Data .	51

CHAPTER 1

INTRODUCTION

Increasing public awareness of the "electrical" and "biological" effects of electric and magnetic fields generated by ac overhead transmission lines has made it essential that the power industry be able to predict more accurately the electric and magnetic field values in the vicinity of extra-high-voltage (EHV) and ultra-high-voltage (UHV) transmission lines. The objective of this project, sponsored jointly by the U.S. Department of Energy (DOE) and the Tennessee Valley Authority (TVA), was to generate an EHV transmission line field data base that DOE and others could use to validate levels and characteristics of electric and magnetic fields under EHV transmission lines. The specific objectives were:

- o Measure, record, and analyze electric and magnetic field data in the vicinity of TVA's 500-kV transmission lines.
- o Develop models which account for various terrain and ground cover factors.
- o Assess the effects of electric and magnetic fields on the growth and development of selected agricultural and forest plants.

This report contains the results of the first two objectives. The assessment of EHV fields on agricultural and forest species, being more of an agronomical nature, will be dealt with in a separate report. The emphasis here will be on the measurement, categorization, and statistical analysis of the electric and magnetic fields near TVA's 500-kV transmission lines. The data base generated during the course of this project consists of about 2,700 profiles of measured electric and magnetic fields collected from different locations and transmission line configurations. The collection sites included road crossings, various crops fields, and wooded areas. The terrain ranged from flat terrain to steep mountain slopes.

Electric and magnetic fields generated by ac overhead transmission lines have been investigated extensively by the Electric Power Research Institute (EPRI) references [1], [2], the Institute of Electrical and Electronic Engineers (IEEE) reference [3], and many others references [4]-[10]. The EPRI report, reference [2] contains a detailed study dealing with measuring, calculating, and determining "electrical" effects on human beings. Previous measurements of electric and magnetic fields had been at specifically selected sites. In most cases, flat terrain with short vegetation was selected. The emphasis in this project was to collect field data correlated with ground cover heights, terrain descriptions and geometrical line parameters.

The influence of transmission line geometrical parameters, such as line height and phase spacing on the electric fields and transmission lines, are presented in reference [3]. In this report, the influence of ground cover height, terrain topography, and the shielding effects of trees and other objects on the electric field values under transmission lines is discussed. The measurement procedures are outlined and the error analysis gives an indication of the error bounds in the data. Generalized curves of statistical averages of the maximum values of the electric field values at 1 meter above the ground under TVA's 500-kV lines, for various line parameters, are presented. Similar curves for fields at the edge of right-of-way are also given. These curves give a line designer an indication of the range of field values under actual operating conditions. The possible use of the electric and magnetic field data collected during the course of this project in DOE's 60-Hz electric bioeffects research is outlined in reference [10].

The data were measured according to the IEEE Standard 644-1979 as outlined in reference [3]. Electric Field Measurement Company Model 110

field meter was used for measuring both the electric and magnetic fields. The initial categorization consisted of 18 categories reflecting all the possible permutations of terrain and ground cover factors. The 18 categories were:

1. Flat terrain - short vegetation
2. Flat terrain - medium vegetation
3. Flat terrain - tall vegetation
4. Flat terrain - rocky ground cover
5. Flat terrain - river or lake crossing
6. Flat terrain - road crossing
7. Flat terrain - irregular ground cover
8. Rolling terrain - short vegetation
9. Rolling terrain - medium vegetation
10. Rolling terrain - tall vegetation
11. Rolling terrain - rocky ground cover
12. Rolling terrain - irregular ground cover
13. Mountainous terrain - short vegetation
14. Mountainous terrain - medium vegetation
15. Mountainous terrain - tall vegetation
16. Mountainous terrain - irregular ground cover
17. Mountainous terrain - rocky ground cover
18. Off the right-of-way

A preliminary statistical analysis of the data showed that the original 18 categories could be reduced to the following 4 major categories:

- (i) Flat terrain, at a measurement height of 1 m above ground level.
- (ii) Flat terrain, at a measurement height of 1.5 m above ground level.
- (iii) Rolling terrain, at a measurement height of 1 m above ground level.
- (iv) Rolling terrain, at a measurement height of 1.5 m above ground level.

The statistical analysis also showed that the type (short, medium, irregular, etc.) and the height of the ground cover, as long as it did not affect the measurement height, had little influence on the electric field values. The presence of trees within or at the edge of right-of-way, however, distorts the shape of the electric field profile; therefore, the major categories were subdivided further into shielded (right-of-way bordered by trees) and unshielded subcategories.

The major sources of error were identified to be field meter reading and line height measurement. The error analysis showed that the overall error in the data was less than 10 percent which is acceptable for practical outdoor measuring conditions, reference [3].

The remainder of the report is organized as follows. Chapter 2 summarizes the methods of analyzing electric and magnetic fields. A surface charge method of computing electric fields over irregular terrains, which was developed in reference [9], is also outlined. A sensitivity analysis was developed to quantify how the measurement errors in the line geometrical parameters affect the quality of the electric and magnetic fields data. Chapter 3 gives a brief description of TVA's 500-kV grid. It also contains a summary of the electric and magnetic field measurement procedures. Sources of error and error bounds are also included. In Chapter 4 a statistical summary of the data is given. Chapter 5 contains the concluding remarks.

CHAPTER 2

ANALYSES OF ELECTRIC AND MAGNETIC FIELDS

This chapter summarizes the influence of geometrical line parameters and topographical factors on transmission line electric and magnetic fields. A method for computing transmission line electric fields over irregular terrain developed in this project is used to compute upper bounds on the electric field magnitudes due to topographical factors. Shielding effects due to trees in the vicinity of lines and at the edge of right-of-way are analyzed:

2.1 Electric Field Analysis - Flat Terrain

The electric field due to EHV overhead ac transmission lines are computed assuming the following:

- (i) There is no free charge.
- (ii) The permittivity constant ϵ is 8.85×10^{-12} F/M.
- (iii) Phase conductors form a set of parallel line charges over a flat, perfectly conducting earth.

The "method of images" described in detail in reference [2] for calculating electric fields in the vicinity of ac overhead transmission lines is used to predict electric fields levels for flat terrain cases. During the data collection task, nominal lateral electric field profiles were computed for the flat terrain for various line heights and phase spacing to give the field crews a way to check data that appeared questionable. If no simple explanation was found for questionable data, some points on the profile were remeasured. Figure 2.1 shows the electric field profiles for the flat terrain case computed using the "method of images" as a function of line height and phase spacings.

Figure 2.1(a). Computed electric fields profiles - 9.15 m phase spacing.

Figure 2.1(b). Computed electric fields profiles - 12.2 m phase spacing.

In order to estimate the errors that are introduced into the data due to incorrect measurement of line height, its influence on the electric field at 1 m above ground was determined. The relationship between minimum line height and the maximum field at the ground is developed in reference [2]. The empirical equation is:

$$E_1/E_2 = (H_1/H_2)^m \quad 2.1$$

where E_1 and E_2 are the maximum fields for lines of heights H_1 and H_2 , respectively; m is approximately -1.4 for a three-phase line with flat configuration.

Although the result using equation 2.1 gives an indication of the variation of the maximum electric field values under a transmission line, it is not accurate enough for measurement error analysis. Figure 2.2 shows a plot of the maximum value of the electric field (EMAX) at 1 m above ground, as a function of line height computed using the "method of images" for both 9.15 m and 12.2 m phase spacing. Figure 2.2 shows that at 1 m above ground, the maximum error in the measured electric field values due to $\pm 1/2$ m in line height measurement at a line height of 14 m and a phase spacing of 12.2 m is ± 0.3 kV/m.

Figure 2.3 shows a comparison of typical measured profiles for the flat terrain and the profile computed using the "method of images." The measured data agreed fairly well with the predicted values, provided the voltage measurements were reasonably accurate and there were no trees within or near the edge of the right-of-way at the data measurement site.

2.2 Electric Field Analysis - Irregular Terrain

Where the terrain is not flat, the "method of images" does not provide a good prediction of the electric field values under the transmission

Figure 2.2. Computed maximum value of the electric field (EMAX) as a function of line height.

Figure 2.3. Comparison of measured electric profiles with those computed using the "method of images" for flat terrain.

lines. Figure 2.4 shows a comparison of a typical measured profile in irregular terrain with the profile computed using the method of images. The following model was developed to account for the terrain topography.

The transmission lines and the terrain surface are assumed to be parallel and to extend to $\pm$ infinity in both directions, and the surface is assumed to be a perfect conductor (see Figure 2.5). The continuous charge distribution on the ground due to the overhead phase conductors is approximated by discrete line charges such that the electric field is normal to the surface at specified boundary locations, and the total charge is preserved. Application of these assumptions yields the following set of equations (for completeness reference [9] is included in Appendix A):

$$\sum_{n=1}^N \frac{(x_k - x_n) \cos\theta(x_k) + (y_k - y_n) \sin\theta(x_k)}{(x_k - x_n)^2 + (y_k - y_n)^2} \{\rho_{Ln}\} + \sum_{m=-M}^M \frac{(x_k - x_m) \cos\theta(x_k) + (y_k - y_m) \sin\theta(x_k)}{(x_k - x_m)^2 + (y_k - y_m)^2} \{\rho_{sm}\} = 0 \quad 2.2$$

$$\sum_{n=1}^N \{\rho_{Ln}\} + \sum_{m=-M}^M \{\rho_{sm}\} = 0 \quad 2.3$$

and

$$\{V_n\} = \frac{1}{2\pi\epsilon} \left(\{\rho_{Ln}\} \ln \frac{1}{R_n} + \sum_{\substack{\ell=1 \\ \ell \neq n}}^N \{\rho_{L\ell}\} \ln \frac{1}{D_{\ell n}} + \sum_{m=-M}^M \{\rho_{sm}\} \ln \frac{1}{D_{mn}} \right) \quad 2.4$$

Figure 2.4. Comparison of measured electric fields profiles using the "method of images" for irregular terrain.

Figure 2.5. Irregular terrain.

- (x_n, y_n) = conductor location
 (x_m, y_m) = discrete surface line charge location
 (x_k, y_k) = boundary condition location $\neq (x_m, y_m)$
 $\theta(x) = \tan^{-1} dy(x)/dx$ = terrain slope
 D_{ij} = distance between line charge i and j
 R_n = radius of conductor n
 $\{ \}$ = phasor notation

These equations are linear in $\{\rho_{sm}\}$ once the line charge locations and the boundary points are specified. The electric field equation is, then:

$$\begin{aligned}
 \{\vec{E}(x, y)\} = & \frac{1}{2\pi\epsilon} \left(\sum_{n=1}^N \frac{[(x-x_n)\hat{i} + (y-y_n)\hat{j}]}{[(x-x_n)^2 + (y-y_n)^2]} \{\rho_{Ln}\} \right. \\
 & \left. + \sum_{m=-M}^M \frac{[(x-x_m)\hat{i} + (y-y_m)\hat{j}]}{[(x-x_m)^2 + (y-y_m)^2]} \{\rho_{sm}\} \right) \quad 2.5
 \end{aligned}$$

Numerical experiments led to the choice of a linear placement of 100 line charges over a width of ± 50 meters to describe fields over a ± 30 -meter wide right-of-way.

The charge simulation method was used to calculate the electric fields induced by a 500-kV line over a terrain with a general slope of 15° and 20° . Table 2.1 shows the comparison of the maximum values of the electric fields for these terrains as a function of line height for both 9.15 m (30 feet) and 12.2 m (40 feet) phase spacing. Figure 2.6 shows a comparison of measured electric field data with field profiles computed using a newly developed model which uses the "method of images" and the surface charge method. As can be seen in the figure, the agreement is very good.

Table 2.1

COMPUTED ELECTRIC FIELD VALUES OVER A TERRAIN
WITH 5° AND 20° GENERAL SLOPE

Angle (Degrees)	Height (Meters)	EMAX (kV/m)		ERW (kV/m)	
		D = 12.2 m	D = 9.15 m	D = 12.2 m	D = 9.15 m
0° Flat Terrain	12	7.152	6.451	2.221	1.612
	14	5.651	5.023	2.252	1.604
	16	4.582	4.018	2.181	1.603
	18	3.775	3.252	2.095	1.501
	20	3.251	2.741	1.942	1.492
5° Flat Terrain	12	8.517	7.503	2.261	1.599
	14	6.584	5.755	2.343	1.689
	16	5.247	4.557	2.349	1.726
	18	4.292	3.696	2.297	1.720
	20	3.576	3.058	2.208	1.681
20° Rolling Terrain	12	13.855	10.920	1.582	1.127
	14	9.963	7.995	1.949	1.378
	16	7.562	6.123	2.221	1.575
	18	5.960	4.852	2.390	1.712
	20	4.830	3.945	2.462	1.788

D = Phase spacing

EMAX = Maximum electric field value

ERW = Electric field value at edge of right-of-way

Figure 2.6. Comparison of measured electric field profile with computed profiles using the "method of images" and the surface charge method [9].

2.3 Tree Shielding Analysis

Figure 2.7 shows a comparison of typical measured profiles for the flat terrain with profiles computed using the "method of images," for data measuring sites with trees within or near the edge of the right-of-way. In the cases shown there is partial agreement between the measured data and the computed values. Figure 2.8 shows comparisons of the measured profile with profiles computed using the newly developed model which uses the "method of images" and the surface charge method. Figure 2.9 shows electric fields profiles computed for a site with tree lines at 25 m and 28 m from the center phase. These profiles were generated using the newly developed model. Such curves can be used to estimate the tree shielding effects as a function of the distance from the center phase.

2.4 Magnetic Fields Analysis

Magnetic field computation is discussed in reference [2]. Magnetic fields are insensitive to terrain effects and only slightly sensitive to the earth resistivity. For calculations the terrain is assumed to be flat, and a permeability constant of μ equal to $4\pi \times 10^{-7}$ H/m is assumed for both air and ground. Unlike the electric field, the magnetic field near the earth's surface has a sizeable horizontal as well as a vertical component. The magnetic field near TVA's 500-kV grid was found to be relatively low (< 1 Gauss). A detailed analysis of the magnetic fields was not performed since the induced currents due to magnetic fields are much less than those due to electric fields [3]. Figure 2.10 shows a comparison of typical measured magnetic field profiles and profiles computed using the method outlined in [2].

Figure 2.7. Comparison of typical measured profiles with computed profiles using "method of images" with tree shielding.

Figure 2.8(a). Comparison of measured and computed electric field profile using the "method of images."

Figure 2.8(b). Comparison of measured and computed electric field profile using the surface charge method.

Figure 2.9(a). Ground contour and tree line location.

Figure 2.9(b). Computed electric field profiles using the surface charge method.

Figure 2.10. Comparison of typical measured magnetic field profiles with computed profiles.

CHAPTER 3

FIELDS MEASUREMENTS AND ERROR ANALYSES

This chapter contains a brief description of the TVA's 500-kV grid indicating the lines where data was collected. A general description of the data collection sites is also included. Methods of measuring electric and magnetic fields developed by IEEE [3] are also summarized. Major sources of error are analyzed, and error bounds in the data are established.

3.1 TVA's 500-kV Grid

The TVA service area consists of the State of Tennessee and portions of six adjacent states. Figure 3.1 shows the TVA's 500 kV and the lines along which the electric and magnetic field data were collected. The western part of the service area is relatively flat, while the central and eastern areas have rolling and mountainous terrains. The historic temperature averages are 30°F and 80°F in the winter and the summer, respectively, with the extremes ranging from -6°F to 103°F. The average precipitation across the Valley is about 52 inches per year. Data were collected during all seasons in 1979, 1980, and 1981.

TVA's 500-kV transmission system consists of the following lines:

- (i) Single circuit 500-kV line with vertical suspension insulator.
- (ii) Single circuit 500-kV line with constrained phase suspension insulator.
- (iii) Same as in (ii) with one 161-kV circuit underbuild.
- (iv) Same as in (ii) with two 161-kV circuit underbuild.

The vertical suspension insulator configurations have 12.2 m (40 feet) or phase spacing, and 61 m (200 feet) of right-of-way. The constrained phase suspension insulator configurations have 9.15 m (30 feet) phase spacing

Figure 3.1. TVA 500-kV transmission system and data collection sites.

and 53 m (175 feet) of right-of-way. Appendix B contains additional details of a typical TVA 500-kV transmission line.

3.2 Data Collection Sites

The data base that was generated during the course of this project consists of about 2,700 electric and magnetic profiles measured at various locations along the TVA's 500-kV grid. The locations include: road crossings; various crop patches; wooded areas; and flat, rolling, and mountainous terrains. The major factors considered were:

- (i) Flat terrain--a site with general slope of approximately less than 5° .
- (ii) Rolling terrain--a site with a general slope between 5° and 20° .
- (iii) Mountainous terrain--a site with a slope of over 20° .

The ground cover was classified according to height:

- (i) Short ground cover--vegetation of heights less than 15 cm.
- (ii) Medium ground cover--vegetation of heights between 15 cm and 60 cm.
- (iii) Tall ground cover--vegetation over 1.1 m.
- (iv) Irregular ground cover--combination of short, medium, and tall ground cover.

The selection of the sites was made so that the resulting data base would consist of profiles measured under various line configurations, and a variety of terrain with different ground cover heights. Lines with 161-kV underbuilds were not considered since the transmission line heights for the 500 kV with 161 kV underbuilds are higher than the 500-kV lines without underbuilds, and because the shielding effects of the underbuild reduce the electric field.

3.3 Electric Field Measurements

The procedures for measuring electric fields near EHV transmission lines, IEEE Standard 644-1979 outlined in reference [3], were used. Electric Fields Measuring Company's Model 110 field meters were used for both electric and magnetic field measurements. A 40-cm clearance between the field meter and the nearest object is recommended by the field meter manufacturer, therefore, for ground cover above 60 cm but less than 110 cm, the measurements were taken at 1.5 m above ground level. The electric field was measured at 1 m above ground level whenever the ground cover height was below 60 cm. If the height of the ground cover exceeded 110 cm, an area of about a square meter was cleared and the measurements were taken at 1 m above ground level. The field meter was oriented to read the vertical component of the electric field. The distance between the field meter and the observer was maintained at 2 m by using the "long pole" method.

The electric field was measured mainly for transmission line heights of 14 m, 16 m, 18 m, and 20 m, respectively. The target line height was found by walking under the center conductor until an appropriate line height was found. The data on the electric field lateral profiles was measured in a direction perpendicular to the transmission line, at 2 m intervals for distances between 0 and 12 m and continued at 3-m intervals to the edge of the right-of-way (30 m).

Data were immediately plotted on the field data (Figure 3.2 is a typical field plot of raw data). A general description of the terrain, location of trees and other structures, was recorded on the field data sheet. Local time was also recorded so that voltage and current measurements, recorded on strip charts at the substations, could be correlated

ELECTRIC AND MAGNETIC FIELD DATA SHEET

LOCATION ROANE - WATTS BAR #50A CATEGORY 1 0
 DATE 4/6/81 TIME 9:55 ^{APR 6 1981} _{2 3.5} LINE SPACING 9.15 (CM)
107m TOWER 137 DISTANCE 77 ~~4~~ ~~77~~ DIRECTION NE 14.4
 HEIGHT 18 (CM) HUMIDITY 47 (X) TEMP. 58°F (30)
 POWER (MW) VOLTAGE 520.4 (KV) CURRENT 340. (AMPS)

4 taken
 at 3.9 m
 1 ft from
 wooden ampoule
 1 piece 2H

X METERS	0	2	* 4	6	8	10	12	15
E KV/M	1.55	1.65	1.8	2.2	2.55	2.8	3.0	2.8
B GAUSS	.0295	.03	.029	.0285	.028	.027	.0265	.0235
Z METERS	17.0m	55.5'	56.5'	58'	61'	64.5'	67.5'	74'
#		16.9	17.2	17.7	18.6	19.7	20.6	22.6

X METERS	18	21	24	27	30			
E KV/M	2.25	1.35	.7	.38	.35			
B GAUSS	.0198	.017	.0145	.012	.0105			
Z METERS	81'	88'	95'	104'	112'			

27m

3.00
 2.6m
 1.4m
 35.5m
 Reading on tape
 Overlaid &
 10m along tape
 from 30 to 20m

SKETCHES AND COMMENTS ON REVERSE

METER NO. 13

Figure 3.2(a). Typical raw data sheet.

Figure 3.2(b). Typical plan view of a site.

with the time the field measurements were taken. Other pertinent data as suggested in reference [3] were also recorded.

3.3.1 Equipment

Fields Meters--The field meter used was Electric Fields Measurement Company Model 110.

Height Meter--The line heights were measured using a Leitz model 8026, optical rangefinder.

Voltage and Current Recorder--A Leeds and Northrup model 250 strip chart record was used to record voltage and current.

3.3.2 Field Meter Calibration

Three of the field meters were checked by the National Bureau of Standards (NBS). Appendix C contains the NBS test report. The three meters checked were fairly accurate and no recalibration was recommended by NBS; but the meter reading deviations from known NBS laboratory fields were used to adjust the raw data for meter bias. The calibrations of all the meters were checked every week using the current injection method and a 1-m^2 coil, as recommended in the IEEE Standard 644-1979!

3.3.3 Sources of Error

Major sources of error were:

- (i) Measurement of line height, location of the center line, and aligning the profile so that it was perpendicular to the transmission line.
- (ii) Reading the electric field meter and observer shading.
- (iii) Measuring and recording voltages and currents.
- (iv) Temperature and mechanical imbalance.

3.3.4 Height, Centerline, and Perpendicular Transverse Measurement Errors

Initially, there was a great deal of concern about these types of errors and how they affected the data. A short experiment was designed to determine if during the field measurements systematic measurement errors occurred. The experiment was set up as follows.

1. Height Error

Transmission line height was determined by one member of the crew using an optical rangefinder to measure the lowest of the three conductors of the center bundle above ground. This measurement was confirmed by a second member of the crew. In practice, the determination-confirmation procedure was iterated until the two observers agreed.

The field crew made optical height measurements along the line and marked locations under the center bundle, corresponding to target heights of 14 m, 16 m, 18 m, and 20 m, respectively. Surveyors were then used to check the transmission line height at each previously marked location. The difference between the height measured by the surveyors and target height was defined as the height error.

2. Centerline Error

After finding a location for a particular target height, the crew members determined the transmission line centerline. After the field crews had determined the centerline, the surveyors determined the centerline using their instruments. The difference between the field crews' and surveyors' determination was defined as the centerline error.

3. Angular Error

The field crew made electric and magnetic field readings normal to the transmission line. After the field crew recorded their readings, the traverse used was marked by the crew. The surveyors then determined the angle between the marked traverse and the powerline. The difference of this angle from 90° was defined as the "angular error."

Table 3.1 summarizes the results of the experiment.

Table 3.1
DESCRIPTIVE STATISTICS FOR MEASURES OF ERROR

	<u>Mean</u>	<u>Standard Deviation</u>	<u>Minimum</u>	<u>Maximum</u>
Height error (m)	.0004	.14	-.35	.55
Centerline error (m)	.002	.12	-.28	.23
Angular error (deg)	.84	3.0	-6.58	7.13

No trends or systematic errors were found in the determining the centerline or traverse angle. Some trends were observed in the height determinations. These attained statistical significance, meaning that the differences seen, though small, are probably not due only to random variations that occur in any experiment or measurement process. A preliminary sensitivity analysis of the electric field with respect to the various measured parameters indicated that centerline and perpendicular transverse measurement errors could be neglected. Since there were no systematic errors in line height measurements, it is concluded that the field crews, their instruments, and their procedures were providing data of acceptable accuracy.

3.3.5 Electric Field Meter Errors

The electric field meter errors identified were:

- (i) Meter bias and the residual error after adjusting the raw data for the bias.
- (ii) Meter scale reading error.
- (iii) Observer proximity effects.
- (iv) Meter orientation and position.

3.3.6 Voltage and Current Recording Errors

The voltage and the current variations on the TVA's 500-kV grid change relatively slow over the hour, so the match of the field data with the voltage and current data was fairly accurate. The major errors were in determining the voltage and the current values from the recorder strip charts.

3.3.7 Meter Orientation and Position

The meter positioning errors for the electric field measurements were minimized by using a stake of appropriate height attached at the end of the pole for positioning the meter.

3.3.8 Error Analysis for Electric Field Measurements

There were three major types of errors:

- (i) Electric field meter errors.
- (ii) Transmission line parameter measurement errors.
- (iii) Voltage measurement errors.

The field meter and the line parameter errors affect the field data directly, while the voltage measurement errors affect the data whenever it is normalized with respect to the voltage.

The electric field measurement error is defined as the rms value of the random errors. Analysis of the test data by NBS showed an overall

bias of 2-1/2 percent above the known field. After adjusting the raw data for this bias, the computed residual error, ϵ_c , on the 10-kV scale was ± 0.05 kV/m. A meter resolution error, ϵ_r , of $\pm 1/2$ a scale division or ± 0.25 kV/m was assumed. Temperature and mechanical imbalance error, ϵ_T , was estimated to be ± 1 percent of full scale or ± 0.1 kV/m on the 10-kV/m scale. The "worst case" electric field meter rms error on the 10-kV/m scale, ϵ_m , then, is given by

$$\epsilon_m = \pm (\epsilon_c^2 + \epsilon_r^2 + \epsilon_T^2)^{1/2} \text{ kV/m} = \pm 0.27 \text{ kV/m} \quad 3.1$$

The transmission line heights were measured using an optical range finder. The maximum height reading error was estimated to be $\pm 1/2$ m. A line height measurement error of $\pm 1/2$ m using the sensitivity analysis developed in the previous section, results in a change of ± 0.3 kV/m in the predicted maximum field at a 14 m line height. It also results in an error in the data since the profile will be associated with the wrong line height. So ϵ_h , the height error, for a 12.2 m (40 feet) phase spacing at a line height of 14 m is given by ± 0.3 kV/m.

A phase voltage measurement error of 3 percent was assumed. This results in a 3-percent error in the data when normalized with respect to the voltage. The maximum voltage-measurement error, ϵ_v , is ± 0.26 kV/m.

The maximum total rms error, ϵ_E , in the data for the electric field measurements is given by

$$\epsilon_E = \pm (\epsilon_m^2 + \epsilon_h^2 + \epsilon_v^2)^{1/2} \text{ kV/m} \quad 3.2$$

$$\epsilon_E = \pm 0.48 \text{ kV/m}$$

and is assumed to be the maximum possible measurement error in the electric field measurements. This is within the 10-percent range which is acceptable for practical outdoor measuring conditions as suggested in reference [3].

3.4 Magnetic Field Measurement

The magnetic field data was measured at a height of 1 m above ground level whenever the ground cover height was less than 60 cm. For consistency with the method used in the electric fields measurements, if the ground cover height was above 60 cm, the fields were measured at 1.5 m. For ground cover over 110 cm, the fields were measured in the area that was cleared for measuring the electric field.

Lateral profiles of the magnetic field were measured as in the electric field up to a distance of 30 m from the center bundle. Strip charts were used to record the phase currents and voltages at the respective substations. The current harmonic content effects were neglected.

3.4.1 Error Analysis in Magnetic Field Measurement

The major sources of error were the magnetic probe orientation error, meter reading error, and current measurement error. A meter reading error of $\pm 1/2$ of a scale division was assumed. Since measuring the magnetic field requires orienting the probe to find the maximum value of the field, a probe orientation error of about one scale division was assumed. The meter measurement error, ϵ_m , is given by

$$\epsilon_m = \pm (\epsilon_r^2 + \epsilon_o^2)^{1/2} \text{ Gauss} \quad 3.3$$

where ϵ_r is the meter reading error and ϵ_o is the probe orientation error. Since the magnetic fields were relatively low, the 0.3 Gauss scale was used so $\epsilon_r = \pm 0.0015$ Gauss and $\epsilon_o = \pm 0.003$ Gauss. A current measurement error of 5 percent was assumed, so ϵ_c the current measurement error, is

± 0.0015 Gauss. The maximum error ϵ_M in the magnetic field data is approximately

$$\begin{aligned}\epsilon_M &= \pm (c_m^2 + \epsilon_c^2)^{\frac{1}{2}} \text{ Gauss} & 3.4 \\ &= \pm 0.0034 \text{ Gauss}\end{aligned}$$

CHAPTER 4

500-kV MEASURED ELECTRIC MAGNETIC FIELD DATA

This chapter contains the statistical summary of the data. The data base consists of about 2,700 profiles of measured electric and magnetic field data collected from different terrain categories, ground cover heights, line heights, and tower configurations. The form for presenting the data in this report was selected so it can be easily used by transmission line designers and electric fields bioeffects research [10]. In the line design, the maximum values of both electric and magnetic field at 1 m above ground and the field values at the edge of the right-of-way at 1 m above ground are of major importance. The influence of the line geometry on electric and magnetic fields near the ground can be easily quantified using widely accepted methods assuming the terrain is flat with short ground cover and no shielding. The spread of the data in this report is an indication of the maximum values of both the electric and magnetic fields at 1 m above ground for various line configurations. The data gives the real-world exposure levels in the vicinity of energized 500-kV transmission lines in DOE's 60-Hz electric fields bioeffects research program. For this research work, the maximum value of the electric fields 1 m above ground level and the electric field levels at the edge of right-of-way again are considered important factors. The values at these locations give upper bounds on exposure levels under the transmission lines and at the edge of right-of-way.

In the statistical summary of the data, the "box-and-whisker" method is used [11]. Figure 4.1 shows a typical box-and-whisker diagram. The box-and-whisker diagram summarizes a set of data by the median (shown as the center line), the 25th and 75th percentiles (the lower and upper edges

Figure 4.1: Typical box-and-whisker diagram.

of the box), and the maximum and minimum values. It also shows the extreme points that lie sufficiently far beyond the 25th and 75th percentiles. The box-and-whisker presentation is used because the data has unknown statistical distributions. Since such data can best be interpreted from cumulative probability distributions, probability distributions for some key categories are also given.

4.1 Electric Field Data - General Analysis

The data base generated by the project consists of about 2,700 profiles measured at various locations along TVA's 500-kV grid. The data is organized as follows. Each measured electric and magnetic profile is identified by the transmission line name and a data collection site number. Geometrical data includes tower numbers for both towers adjacent to the site, the phase spacing, and the line height. Electrical data consists of line voltage, line current, and power. Weather data includes temperature and humidity. A general description of the terrain is included in terms of the elevations of each of the points on the profile referenced to the elevation at the center bundle.

The electric and magnetic field data is normalized on a 500-kV and 1-kA base, respectively. The electric field data is adjusted for the measuring instrument bias. The bias factors were obtained by applying a least squares fit to the data given in Appendix C for each meter scale. Variables EMAX and ERW have been added to each observation for the electric field data. EMAX corresponds to the maximum measured electric field value on the profile and ERW is the measured electric field value at 30 m for the 12.2-m phase spacing (200 feet right-of-way). For the 9.15-m phase spacing (175 feet right-of-way), ERW is the measured electric field value at 27 m.

A scatter diagram of a random sample of the data is shown in Figure 4.2. The scatter is due to the different line geometry such as line heights and phase spacing. The extreme values are due to topography factors like rolling terrain, ground cover height, and shielding effects. Table 4.1 is a statistical summary of the data. The maximum value is from a profile measured over a rolling terrain.

The low values near the center phase are due to the presence of a fence, while the low values at the edge of right-of-way are mainly due to the presence of trees.

Special Sites

Because of the likelihood of the presence of people, an attempt was made to collect as much data as possible at transmission line road crossing and at sites where there were houses near the edge of the right-of-way. Electric and magnetic field profiles were measured along the road from the center phase regardless of whether the road was perpendicular to the transmission line. For the data near homes, off the right-of-way, profiles were measured up to about 60 m from the center phase whenever permission could be obtained.

The data from these sites is limited so a detailed analysis is not warranted. Figure 4.3 shows box-and-whisker diagrams of the road crossing data. Out of the 86 profiles, 20 profiles were measured near lines with 9.15 m phase spacing, 60 profiles were measured near lines with 12.2 m phase spacing, and the rest near lines with odd phase spacings. Table 4.2 is the statistical summary. Figure 4.4 gives box-and-whisker diagrams of electric field data measured near homes. The number of observations were about evenly divided between the 9.15 m and 12.2 m phase spacings. The statistical summary of the data is shown in Table 4.3.

Figure 4.2. Scatter diagram of sample of the electric fields data.

Table 4.1

STATISTICAL SUMMARY OF ALL THE ELECTRIC
FIELDS DATA (WITHOUT THE SPECIAL SITES)

Distance from Center Phase (m)	N	Mean kV/m	Standard Deviation kV/m	Minimum Value kV/m	Maximum Value kV/m
0	2678	2.426	1.130	0.098	6.928
2	2678	2.485	1.062	0.705	6.446
4	2678	2.608	0.922	0.569	5.870
6	2678	2.854	0.865	0.190	5.850
8	2678	3.232	0.953	0.000	6.824
10	2678	3.641	1.118	0.569	7.583
12	2678	3.939	1.253	0.009	8.540
15	2676	3.994	1.338	0.473	8.689
18	2671	3.581	1.297	0.141	8.023
21	2659	2.854	1.253	0.000	6.606
24	2569	2.129	1.231	0.000	5.344
27	2350	1.669	1.056	0.000	4.052
30	2244	1.314	0.874	0.000	3.724

Table 4.2

STATISTICAL SUMMARY OF ELECTRIC FIELDS
DATA AT ROAD CROSSINGS

Distance from Center Phase*	N	Mean kV/m	Standard Deviation kV/m	Minimum Value kV/m	Maximum Value kV/m
0	86	2.191	0.971	0.182	5.121
2	86	2.245	0.931	0.203	5.034
4	86	2.338	0.866	0.442	4.833
6	86	2.477	0.842	0.611	4.870
8	86	2.745	0.960	0.734	5.548
10	86	3.089	1.123	0.825	6.531
12	86	3.333	1.266	0.896	7.427
15	86	3.463	1.299	0.952	7.539
18	86	3.255	1.222	0.913	6.826
21	85	2.827	1.201	0.589	5.564
24	83	2.343	1.263	0.000	5.712
27	82	1.913	1.281	0.000	5.906
30	80	1.543	1.232	0.000	6.017

*Measurements were made along the road instead of perpendicular to the line.

Table 4.3

STATISTICAL SUMMARY OF ELECTRIC FIELDS
DATA OFF THE RIGHT-OF-WAY

<u>Distance from Center Phase (m)</u>	<u>N</u>	<u>Mean kV/m</u>	<u>Standard Deviation kV/m</u>	<u>Minimum Value kV/m</u>	<u>Maximum Value kV/m</u>
0	20	2.225	0.8422	0.900	3.900
2	20	2.355	0.7644	1.000	3.750
4	20	2.690	0.6269	1.450	3.700
6	20	3.097	0.6122	2.000	4.200
8	20	3.617	0.6487	2.400	4.800
10	20	4.105	0.7161	2.800	5.400
12	20	4.342	0.7284	3.000	5.650
16	20	4.242	0.6424	3.000	5.250
18	20	3.812	0.5510	2.700	4.500
21	20	3.197	0.4560	2.300	4.000
24	20	2.627	0.3511	1.900	3.300
27	20	2.075	0.3559	1.300	2.700
30	23	1.565	0.3124	0.700	2.200
33	5	1.196	0.4409	0.720	1.800
35	15	1.130	0.1161	1.000	1.350
36	5	0.922	0.3566	0.580	1.400
39	5	0.664	0.3579	0.240	1.150
40	15	0.793	0.1025	0.700	1.000
42	4	0.545	0.2530	0.300	0.900
45	18	0.552	0.1297	0.250	0.740
48	3	0.373	0.1193	0.290	0.510
50	15	0.403	0.1409	0.055	0.570
51	3	0.310	0.0692	0.230	0.350
54	3	0.268	0.0529	0.220	0.325
55	14	0.317	0.1088	0.000	0.450
57	3	0.261	0.0201	0.250	0.286
60	16	0.267	0.0415	0.230	0.350

Figure 4.3(a). Box-and-Whisker diagram of electric field data at road crossing for 12.2 m phase spacing.

Figure 4.3(b). Box-and-Whisker diagram of electric field data at road crossing for 9.15 m phase spacing.

Figure 4.4(a). Box-and-Whisker diagram of electric field data near homes for 12.2 m phase spacing.

Figure 4.4(b). Box-and-Whisker diagram of electric field data near homes for 9.15 m phase spacing.

4.2 Electric Fields Data - Detailed Analysis

TVA's 500-kV grid consists of two standard line configurations, one with 9.5 m (30 feet) phase spacing and one with 12.2 m (40 feet) phase spacing. Turning towers, however, have phase spacings ranging from 12 m to 14 m. Data were collected mainly for line heights of 14, 16, 18, and 20 m, respectively. In order to maintain a 40-cm clearance between the field meter and the nearest object as required by the manufacturer, measurement heights of 1 m and 1.5 m were used; therefore, the four main terrain categories are as follows:

- (i) Flat terrain, at a measurement height of 1 m above ground level.
- (ii) Flat terrain, at a measurement height of 1.5 m above ground level.
- (iii) Rolling terrain, at a measurement height of 1 m above ground level.
- (iv) Rolling terrain, at a measurement height of 1.5 m above ground level.

This grouping reflects the topography and the ground cover height factors. These categories were further subdivided for electric fields into shielded and unshielded subcategories depending on the presence of trees near the data collection sites. The final data categorization is given in Table 4.4.

4.2.1 Electric Field Data Analysis - Without Tree Shielding

A preliminary statistical data analysis using the t-test when applied to data measured at 1 m above ground showed the influence of the ground cover height to be minimal. The topography data was used to subdivide the data into subcategories depending on the presence of trees within or near the edge of the right-of-way. Appendix D consists of the box-and-whisker diagrams for the maximum values of the measured electric field (EMAX) for the two phase spacings at line heights of 14, 16, 18, and 20 m for the four major categories:

Table 4.4

FIELDS DATA CATEGORIES

ROW - Right-of-way.

1. Flat terrain, at a measurement height of 1 m above ground level - (FT @ 1).
2. Flat terrain, at a measurement height of 1.5 m above ground level - (FT @ 1.5).
3. Rolling terrain, at a measurement height of 1 m above ground level - (RT @ 1).
4. Rolling terrain, at a measurement height of 1.5 m above ground level - (RT @ 1.5).

Box-and-whisker diagrams for measured electric field values at the edge of right-of-way (ERW) are also given. Cumulative distributions for EMAX and ERW were also developed for the various line heights and phase spacings.

The analysis of the electric field over terrain with a 5° general slope showed a possible deviation of ± 0.7 kV/m for the maximum vertical electric field (see Table 2.1) from a perfectly flat terrain. The statistical summary and the box-and-whisker diagram show an interquartile distance of 0.5 kV/m which is within the predicted ranges since the flat terrain category included sites with general slopes of up to 5°. The data for the medium and irregular ground cover, as would be expected, have a slightly higher mean due to the slight rising of the effective ground level due to the vegetation, and to the measurement height of 1.5 m being nearer to the overhead phase conductors. The charge simulation method, reference [9], for rolling terrain with a general slope between 5° and 20° showed a variation of ± 2 kV/m for the maximum electric field value from the values predicted assuming flat terrain. Therefore, a larger standard deviation is expected in the data for measurement heights of 1 m and 1.5 m in rolling terrain.

Table 4.5 shows the comparison of the values computed using "method of images" and the medians of the maximum values of the measured electric

field (EMAX) for the flat terrain category with no trees at the edge of right-of-way. Note that the computed values are consistently higher by about 0.5 kV/m than the medians of the measured data.

4.2.2 Electric Field Data - Tree Shielding Effects

The most common naturally occurring electric field shielding is trees at the edge of the right-of-way. Appendix E contains the box-and-whisker diagrams for EMAX and ERW for the sites where there were trees in the vicinity of the transmission line or at the edge of right-of-way, for the various line heights, phase spacing, and terrain. Cumulative distributions and a statistical summary are also included. Note the effects of tree shielding on the median of the measured electric fields at the edge of the right-of-way. The medians of ERW are less than 1 kV/m for all categories. Since the tree locations are random, no general trend in the electric field values with respect to height is expected at the edge of the right-of-way.

4.2.3 Detailed Characterization of TVA's 500-kV Electric Fields

Box-and-whisker diagrams are used to develop a detailed characterization of electric field data measured near TVA's 500-kV transmission lines for each of the subcategories outlined in Table 4.4. The diagrams are included in Appendices F and G. Generalized electric field profiles are constructed from the box-and-whisker diagrams of the data with the same horizontal distance from the center phase for the respective topographical category, line height, and phase spacing. For example, all the data measured at 3 m from center phase for sites identified as flat terrain with measurement height of 1 m, 9.15-m phase spacing, and line height 14 m,

Table 4.5

COMPARISON OF THE MEDIANS OF EMAX WITH COMPUTED
VALUES FOR THE FLAT TERRAIN CATEGORY (FT @ 1)

<u>Height</u>	<u>Median of EMAX (kV/m)</u>		<u>Computed EMAX (kV/m)</u>	
	<u>D = 12.2 m</u>	<u>D = 9.5 m</u>	<u>D = 12.2 m</u>	<u>D = 9.5 m</u>
14	5.30	4.75	5.85	5.19
16	4.06	3.57	4.71	4.13
18	3.09	2.77	3.86	3.36
20	2.71	2.15	3.25	2.79

Table 4.6

STATISTICAL SUMMARY OF ALL THE MAGNETIC
FIELDS DATA

<u>Distance from Center Phase (Meters)</u>	<u>N</u>	<u>Mean (Gauss/kA)</u>	<u>Standard Deviation (Gauss/kA)</u>	<u>Minimum Value (Gauss/kA)</u>	<u>Maximum Value (Gauss/kA)</u>
0	2031	0.098	0.039	0.011	0.917
2	2032	0.098	0.042	0.009	1.200
4	2032	0.099	0.035	0.009	0.459
6	2032	0.099	0.040	0.007	0.882
8	2032	0.098	0.037	0.003	0.473
10	2032	0.095	0.037	0.012	0.481
12	2032	0.091	0.037	0.012	0.450
15	2031	0.083	0.034	0.009	0.397
18	2027	0.073	0.030	0.009	0.390
21	2022	0.062	0.026	0.005	0.497
24	1994	0.052	0.020	0.002	0.247
27	1903	0.043	0.017	0.000	0.210
30	1848	0.037	0.016	0.000	0.365

Figure 4.5. Scatter diagram of a sample of the magnetic fields data.

and no trees at the edge of right-of-way, is summarized using the box-and-whisker diagram. Therefore, it is possible to estimate the mean and any required percentage confidence interval of the electric fields for the various topography categories, line height, and phase openings.

4.3 Magnetic Fields Data

A detailed data analysis was not performed, since the magnetic field values are relatively low due to low phase currents (600 A to 1200 A) on TVA's 500-kV transmission lines and since magnetic fields are not sensitive to measurement site topography. Figure 4.5 shows the scatter diagram of all the data, and Table 4.6 gives a statistical summary. After normalizing with respect to the current the maximum measured magnetic field values at 1 m above ground level were less than 1.5 Gauss/kA.

CHAPTER 5

CONCLUDING REMARKS

The results of an extensive project to measure and analyze electric and magnetic fields in the vicinity of TVA's EHV transmission lines have been summarized. From the statistical summaries it is possible to approximate the range of electric fields under TVA's 500-kV transmission lines for a variety of terrain and ground cover. Means and ranges for various confidence levels can be estimated from the cumulative probability distributions. A statistical summary of the tree shielding effects indicates the general shielding efficiency of trees.

Specifically, the data shows the characteristics of the electric and magnetic fields under TVA's 500-kV transmission grid. Although the data spread reflects measurement errors, transmission line geometry and topography, the medians of the measured electric field data are lower than predicted when using standard methods for all line heights and phase spacings. A new model has been developed for calculating electric and magnetic fields accurately in various types of topography and ground cover. The model has been tested on data obtained from actual field conditions and the results indicate good agreement.

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APPENDIX A
SURFACE CHARGE METHOD

For completeness a paper describing the surface charge method of computing transmission line electric fields over irregular terrain is given below.

ELECTRIC FIELDS INDUCED BY EHV TRANSMISSION OVER IRREGULAR TERRAIN

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Abstract - A method for calculating electric fields induced by transmission lines over irregular terrain using a simulated surface charge distribution is outlined. The method approximates the two-dimensional physical charge distribution induced by the lines with a set of discrete line charges. Solution to the quasi-static electric field profiles is sought by constraining the discrete charge distribution such that the field is perpendicular to the surface at a finite set of points. The accuracy of the method depends on the number of charges used and the location of the charges. The analytical flat earth solution is used to establish accuracy as a function of charge configuration. Finally, the method is used to predict fields for irregular terrain. The predicted fields show good agreement with measured data in several examples where there was significant departure from the field predicted by a flat earth solution.

I. INTRODUCTION

Recently, the electric and magnetic fields induced by EHV transmission lines have been a subject of great interest [1]-[3]. The Tennessee Valley Authority, sponsored by the Division of Electric Energy Systems of the U.S. Department of Energy, is conducting a project to measure, document, and analyze electric and magnetic field profiles under 500-kV transmission lines.

The data collected indicates that electric fields are sensitive to the terrain and to the proximity of ground objects. Magnetic fields, though insensitive to local topology, are sensitive to the soil conductivity. Various papers ([4], [5]) have addressed magnetic field calculations over lossy ground, but terrain effects on the electric field have not been considered in equivalent detail. The objective of this paper is to present a method for calculating electric fields from transmission lines over irregular terrain.

Several approaches to solving this problem exist. Extension of the classical method of images by the addition of more images to account for surface irregularities is appealing, but no direct approach to synthesis of appropriate images has been found. Alternative approaches involve numerical solutions using the digital computer. Direct solution of the

partial differential equations governing the field is a possibility. This is a boundary value problem which must be solved iteratively and is both time consuming and expensive. Accordingly, a substitute for the direct solution was developed which retains some of the advantages of the analytical solution and avoids iteration.

In the present paper, a charge simulation method related to that in [6] is used. Charge simulation involves representation of the distribution of physical charges by a set of discrete charges selected to satisfy boundary conditions at a discrete set of points. In [6], point charges are placed outside the space in which the field is to be computed. Here, discrete line charges are placed on the terrain surface to simulate the physical charge location. The magnitude of the charge at each discrete location is governed by the requirement that their total contribution to the electric field at selected boundary points satisfies the condition that the field be normal to the conducting surface. As long as the number of surface charge locations is one more than the number of points where the boundary conditions are to be satisfied, the problem has a unique algebraic solution. The accuracy of the overall field simulation will improve as the number of discrete charges increases and is also a function of charge location. To determine the number and location of charges required to provide acceptable solution accuracy, the flat terrain case was used to develop error measures between the analytical solution and the discrete charge simulation solution. Finally, the discrete charge simulation method was used to predict fields over irregular terrain for cases measured in the field survey. Comparison of the predicted and measured fields shows good agreement.

The organization of the balance of the paper is as follows. Section II describes the discrete charge simulation method. Appropriate charge distributions and quantities are numerically established in Section III. Section IV contains comparisons between the measured and predicted data for irregular terrain, and concluding remarks appear in Section V.

II. DISCRETE CHARGE SIMULATION

It will be assumed that there are no free space charges, and that the earth is a perfect conductor with an irregular surface. Classical electric field solutions use the field equations derived from Coulomb's law for line charges. The boundary condition induced by the assumption that the earth is a perfect conductor is that

$$\vec{n} \times \vec{E} = \vec{0} \quad (1)$$

where $\vec{n}$ is a local normal to the surface, which is easily satisfied in the flat terrain case by constructing image conductors below the surface.

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An approach to this problem which retains the simple structure of the line charge-based model while allowing the satisfaction of the boundary condition for irregular terrain is based on distributing discrete line charges along the contour of the surface. This requires the assumption of parallel line charges of infinite length to avoid complicating the field expression, but this model is reasonable for most transmission line geometries and was adequate to describe the field measurements for irregular terrain. This method is physically appealing, since it simulates the actual continuous charge distribution which must appear on and close to the surface of the earth. Thus, the situation to be approximated is a continuous line charge distribution $\rho_s(x)$ induced by line charges ρ_{Ln} in overhead conductors. Consider a line configuration typical of 500 kV transmission systems.

Figure 1 Transmission Line Over Irregular Terrain

The electric field at point $(x, y(x))$ is;

$$\vec{E}(x, y(x)) = \sum_{n=1}^N \frac{[(x - x_n)\hat{i} + (y(x) - y_n)\hat{j}]}{[(x - x_n)^2 + (y(x) - y_n)^2]^{3/2}} \frac{\rho_{Ln}}{2\pi\epsilon_0} + \frac{1}{2\pi\epsilon_0} \int_{-\infty}^{\infty} \frac{\rho_s(u) [(x-u)\hat{i} + (y(x)-y(u))\hat{j}]}{(y-u)^2 + (y(x) - y(u))^2} \frac{du}{\cos\theta(u)} \quad (2)$$

where

$\hat{i}, \hat{j}$ = unit vectors in the x, y direction
 ϵ_0 = permittivity of air
 $\theta(u) = \tan^{-1} [dy(u)/du]$
 N = total number of conductors.

The surface charge distribution, $\rho_s(x)$, is such that (1) is satisfied, i.e., the tangential component of the electric field at the surface is zero,

$$E_t(x, y(x)) = E_x(x, y(x)) \cos\theta(x) + E_y(x, y(x)) \sin\theta(x) \quad (3)$$

where $\vec{E}(x, y) = E_x(x, y)\hat{i} + E_y(x, y)\hat{j}$,

and that the total surface charge is equal in magnitude to the line charge;

$$\int_{-\infty}^{\infty} \rho_s(u) du = -\sum_{n=1}^N \rho_{Ln} \quad (4)$$

For the flat terrain case, it is possible to satisfy these equations analytically. The solution is derived in the Appendix and leads to the result;

$$\rho_s(x) = \frac{1}{\pi} \sum_{n=1}^N \frac{\rho_{Ln} y_n}{y_n^2 + (x - x_n)^2} \quad (5)$$

where it is assumed that the earth plane is at $y = 0$. This charge distribution yields exactly the same field solution as that given by the method of images.

Finally, the charge simulation method consists of approximating the continuous distribution $\rho_s(x)$ by a set of discrete line charges on the surface of the irregular terrain. The strength of the line charges will be specified to satisfy the conditions that the field be normal to the surface at a number of discrete points which will be one less than the number of surface line charges and that the sum of the charges be zero. The resulting discretized equations are;

$$\left[\sum_{n=1}^N \frac{(x_k - x_n) \rho_{Ln}}{[(x_k - x_n)^2 + (y_k - y_n)^2]} + \sum_{m=-M}^M \frac{\rho_{sm} (x_k - x_m)}{[(x_k - x_m)^2 + (y_k - y_m)^2]} \right] \cos\theta(x_k) + \left[\sum_{n=1}^N \frac{(y_k - y_n) \rho_{Ln}}{[(x_k - x_n)^2 + (y_k - y_n)^2]} + \sum_{m=-M}^M \frac{\rho_{sm} (y_k - y_m)}{[(x_k - x_m)^2 + (y_k - y_m)^2]} \right] \sin\theta(x_k) = 0 \quad (6)$$

and

$$\sum_{n=1}^N \rho_{Ln} + \sum_{m=-M}^M \rho_{sm} = 0 \quad (7)$$

Condition (6) is written for each boundary point (x_k, y_k) which must be distinct from the surface charge locations (x_n, y_n) . Assuming $2M+1$ surface charges, $2M$ boundary points plus condition (7) provide a set of simultaneous equations linear in charge. Since conductor voltages are normally prescribed, one additional set of relations is required to specify the charges to satisfy voltage constraints.

$$\{V_n\} = \frac{1}{2\pi\epsilon} \left[\{\rho_{Ln}\} \ln(1/R_n) + \sum_{\substack{l=1 \\ l \neq n}}^N \{\rho_{Ln}\} \ln(1/D_{ln}) + \sum_{m=-M}^M \{\rho_{sm}\} \ln(1/D_{mn}) \right] \quad (8)$$

where R_n = radius of conductor n .
 D_{ln}^n = distance between n th and l th conductor.
 D_{mn}^n = distance between the m th surface charge and n th conductor.

The step remaining is to represent the quasi-static electric field for the ac transmission line by letting $\{x_n\}$, $\{\rho_{Ln}\}$ and $\{\rho_{sm}\}$ be phasor quantities [1]. Taken together, (6), (7), and (8) describe $2M+1+n$ equations which may be solved for the surface charges, which may

then be used to solve for the electric field at arbitrary points in space.

III. NUMERICAL DEVELOPMENT OF DISCRETE CHARGE DISTRIBUTION

In order to relate the accuracy of the simulated charge solution to the number and location of the discrete line charges, it was necessary to work against a precise solution of the field equations. The flat terrain case provided a vehicle for this development. The economics of numerical calculations make it desirable to minimize the number of charges used while holding accuracy at an acceptable level. After an acceptable distribution was found for the flat terrain case, the stability of the solution for a typical irregular terrain case was confirmed by examining changes due to increasing the number of line charges.

In Figure 2, the average absolute error across the right of way (± 30 meters from the center phase) is plotted for uniform distribution of the discrete charges between ± 40 meters and ± 100 meters.

Figure 2 Error as a Function of Number of Charges

This evaluation was made for a typical arrangement (see Figure 1), with a phase height of 15 m, phase spacing of 12.2 m and neutral lines 9.9 m above the phases with a spread of 20.3 m. The bundles of three conductors for each phase were represented individually, making a total of 11 conductors. For all these distributions, the boundary value conditions were applied midway between each pair of line charges. This arrangement evidently provided the best numerical conditioning for the matrix inversion required.

Examination of the error behavior makes it clear that the density of the line charges under the conductors is the most critical parameter. However, as the total number of charges grows, inversion of the large matrix develops increasing numerical errors which puts a lower bound on the accuracy available (the simultaneous equation solution used double precision arithmetic with the IMSL subroutine LEQPIF). From Figure 2, it was concluded that a charge density of one line charge per meter offered the minimum absolute error. A second series of trials was made to determine the best width at the fixed charge density. The result appears in Figure 3.

Figure 3 Variation of Mean Absolute Error and Maximum Error with Width for Fixed Charge Density, (1 Charge/Meter)

From analytical considerations, the maximum and mean error should decrease uniformly with increasing width. Figure 3 shows decreasing errors initially, but then an increase in error with increasing width. The increase is again attributed to numerical errors that grow with the dimension of the system, although these errors appear to be approaching a limit rather than growing uniformly. From this error behavior, the best choice for width appears to be ± 50 meters. It should be observed that the mean absolute and maximum errors for this case are less than .04 and .10 kV/m respectively, which is within the expected precision of measurement. Additional investigations of nonuniform distributions did not result in any significant improvement in error control.

To establish the stability of the one charge/meter distribution for irregular terrain, one of the irregular terrain cases was solved for that distribution and then for spacings of 1.33 line charges/meter and 2 line charges/meter. The average and maximum differences between the resulting solutions, again calculated over a ± 30 -meter span, are tabulated below.

	Difference, kV/m	
	Average	Maximum
(1 c./m) - (1.33 c./m)	0.00437	0.0152
(1 c./m) - (2 c./m)	0.00467	0.0146

Since these errors are less than the solution accuracy determined above, it was concluded that the irregular terrain solution is consistent with respect to the charge distribution.

IV. RESULTS FOR IRREGULAR TERRAIN AND COMPARISON WITH FIELD TESTS

Three field measurement results involving irregular terrain and significant departures from flat terrain predictions were studied using the discrete charge simulation technique. The field measurements provided values for the electric field at a height of 1 meter from the surface over a width of ± 30 meters from the center phase. The measurements were taken at intervals of 2 meters across the width. Additional

data taken were the height of the center phase using an optical range finder and the phase voltage magnitude from records at the nearest substation. For the general field tests, the terrain was specified qualitatively, with a description of the general contour of vegetation, and of any obstacles in the right of way. The three sites chosen for study were also level surveyed to provide a careful description of the terrain contour.

The first case was taken from the Sequoyah-Watts Bar No. 2 500-kV line in rolling terrain with short vegetation. The terrain contour showed a general slope across the right of way which was nearly linear. The surface was regular, with no major discontinuities. The ground contour is illustrated in Figure 4.

Figure 4 Ground Profile for First Irregular Terrain Case

A comparison of the measured electric field and the field predicted by the flat terrain solution appears in Figure 5. The flat terrain solution is based on a flat surface horizontal under the line phases at the elevation of the ground contour at the center phase.

Figure 5 Comparison of Measured Data and Flat Terrain Electric Field Prediction for First Case

Finally, the electric field generated by the discrete line charge simulation is plotted together with the measured field in Figure 6. The distribution derived in the prior section was used for all the cases studied, i.e., 100 charges spaced across ± 50 meters.

Figure 6 Comparison of Measured Data and Electric Field Predicted by Discrete Charge Simulation for First Case

The discrete charge simulation provides a significant improvement over the flat terrain solution, and matches the left-hand profile very well. The right-hand peak is about 10 percent low, but the general shape of the field profile is captured and the prediction close to the edges of the right of way is very good. The 10-percent error is attributed to contour measurement difficulties. For this particular case, the transit was moved, probably introducing a systematic bias in the measurements.

The second case, also on the Sequoyah-Watts Bar No. 2 500-kV line, involved a cupped terrain with the minimum located off the centerline. The terrain profile for this case appears in Figure 7.

Figure 7 Ground Profile for Second Irregular Terrain Case

Again, the ground was locally regular. The flat terrain prediction is compared to the measurements in Figure 8.

Figure 8 Comparison of Measured Data and Flat Terrain Electric Field Prediction for Second Case

Again, the flat terrain prediction is relatively inaccurate. The electric field generated by the discrete charge simulation method is compared with the measured data in Figure 9.

Figure 9 Comparison of Measured Data and Electric Field Predicted by Discrete Charge Simulation for Second Case

The agreement in this case is uniformly excellent.

The third case, measured on the Sequoyah-Bowen 500-kV line, involved a terrain condition frequently encountered on the power system. One side of the right of way was closely bordered by dense pine trees. A profile for this case is in Figure 10. Only one side is shown, since the other side was virtually flat.

Figure 10 Ground Profile for Third Irregular Terrain Case

The ground was locally regular as before. A comparison of the flat terrain electric field prediction and the measured data appears in Figure 11.

Figure 11 Comparison of Measured Data and Flat Terrain Electric Field Prediction for Third Case

Field prediction including tree contours posed some difficulties for the problem implementation used, since it labeled line charges by their x location, and could not handle multiple charges at the same place. Rather than changing to surface distance, the tree line was approximated by a steep slope (8°) at the start of the tree line. The measured tree line edge was at 24.5 m, but best results were obtained at 25.25 m, pushing back the effective tree contour. The field was relatively insensitive to edge locations in the range ± 5 m, and to small slope changes (2° - 8°), however, larger edge changes degraded the prediction greatly. The best match is illustrated in Figure 12.

Figure 12 Comparison of Measured Data and Electric Field Predicted by Discrete Charge Simulation for the Third Case

Again, after the terrain contour adjustment to replace the trees by equivalent conducting surfaces, the agreement between the measured and predicted fields is excellent.

Summarizing the results of the three comparisons with measured electric field data, the discrete charge simulation method is shown to be a distinct improvement over the flat terrain approach. In the first two cases, absolutely no manipulation of the terrain contour was required to produce very good agreement with the measured data. In the case of trees bordering the right of way, it was necessary to construct an equivalent contour to account for the conduction properties of the trees.

V. CONCLUDING REMARKS

A method for calculating the electric field over irregular terrain has been outlined. The primary limitation of the method is that it requires a line and terrain geometry that is two-dimensional, i.e., the lines and terrain surface are assumed to extend to $\pm\infty$ parallel to their positions in the plane of analysis. Relationships between the accuracy of the method and the number of discrete line charges in the surface and their locations were developed, and it was established that good accuracy can be obtained with a reasonable number of surface charges (100 in the case of the line geometry studied). Moreover, the solution was consistent for varying numbers of charges in the irregular terrain case. Finally, the discrete line charge simulation produced field values that agreed very well with measured field data for three example cases with irregular terrain.

An immediate application for this technique would be the development of normalized curves of either direct field values or of corrections to the flat terrain field prediction for a number of standardized terrain profiles. This would provide designers with a tool for selecting line heights to ensure acceptable field strengths when irregular terrain is encountered.

Further developments of this technique are envisioned to account for irregularities in three dimensions. This will allow solutions for line sag,

discrete objects in the right of way (such as line towers), and prediction of fields in switchyards and similar complex environments.

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APPENDIX

A line charge ρ_L over a flat conducting surface at $y = 0$ induces a continuous surface charge distribution $\rho_s(x)$. The induced charge is such that at any point on the surface (a perfect conductor), the electric field direction is normal to the surface. Hence

$$\vec{E}(x, 0) = E_y \hat{j}, \text{ and} \quad A-1$$

$$E_x \hat{i} = 0 \quad A-2$$

This implies that

$$\frac{x}{2\pi\epsilon} \frac{\rho_L}{x_s^2 + y_L^2} + \frac{1}{2\pi\epsilon} \int_{-\infty}^{\infty} \frac{\rho_s(u)}{x-u} du = 0 \quad A-3$$

where the conductor is located at $(0, y_L)$. Converting the integral above into a complex integral yields

$$\int_{-\infty}^{\infty} \frac{\rho_s(u) du}{x-u} = \oint_C \frac{\rho_s(z) dz}{x-z} \quad A-4$$

where C encloses the top half of the complex plane and includes the pole at $z = x$. Apply the residue theorem to this integral,

$$\oint_C \frac{\rho_s(z) dz}{x-z} = 2\pi j \sum \text{res} \left[\frac{\rho_s(z)}{x-z} \right] + \phi(z), \quad A-5$$

where $\phi(z)$ is the principal value of $\rho_s(z)/(x-z)$ evaluated at z . Assuming $\rho_s(z)$ is analytic in the neighborhood of $x = z$, the principle value is;

$$\int_{-\pi}^0 \frac{\rho_s(x)[-jre^{j\theta}]}{re^{j\theta}} d\theta = -j\pi \rho_s(x). \quad A-6$$

Assume that there is only one pole of $\rho_s(z)$ inside C , since there is only one source due to ρ_L , located at z_1 . Let $\psi(z_1)$ be the residue of $\rho_s(z)$ at the pole z_1 . Substituting this, (A-5) and (A-6) into (A-3) gives

$$\frac{x\rho_L}{x_s^2 + y_s^2} - j\pi \rho_s(x) + 2\pi j \frac{\psi(z_1)}{x-z_1} = 0, \quad A-7$$

Conservation of charge yields

$$\int_{-\infty}^{\infty} \rho_s(x) dx = -\rho_L \quad A-8$$

It follows from (A-7) and (A-8) that

$$\int_{-\infty}^{\infty} \frac{x\rho_L}{j\pi(x^2 + y_L^2)} + 2 \frac{\psi(z_1)}{x-z_1} dx = -\rho_L. \quad A-9$$

Let $\psi(z_1) = \psi_R(z_1) + j\psi_I(z_1)$ and let $z_1 = \alpha + j\beta$. Then the imaginary part of (A-9) becomes:

$$\int_{-\infty}^{\infty} \frac{-x\rho_L}{\pi(x^2 + y_L^2)} + 2 \frac{[\psi_I(z_1)(x-\alpha) + \psi_R(z_1)\beta]}{(x-\alpha)^2 + \beta^2} dx = 0 \quad A-10$$

and the real part becomes

$$2 \int_{-\infty}^{\infty} \frac{\psi_R(z_1)(x-\alpha) - \beta\psi_I(z_1)}{(x-\alpha)^2 + \beta^2} dx = -\rho_L. \quad A-11$$

Since $\frac{x}{x^2 + \beta^2}$ is an odd function of x , the integrals involving that quantity will be zero. Hence

$$\psi_R(z_1) = 0 \text{ and } \psi_I(z_1) = \frac{\rho_L}{2\pi} \quad A-12$$

so

$$\psi(z_1) = \frac{j\rho_L}{2\pi} \quad A-13$$

Substituting (A-13) into (A-7) yields that

$$\rho_s(x) = \frac{1}{j\pi} \left[\frac{x\rho_L}{x^2 + y_L^2} - \frac{\rho_L}{x-\alpha-j\beta} \right] \quad A-14$$

Since $\rho_s(x)$ is a real function of x , equation of the imaginary parts of (A-14) gives

$$-\frac{x\rho_L}{(x^2 + y_L^2)} + \frac{\rho_L(x-\alpha)}{(x-\alpha)^2 + \beta^2} = 0. \quad A-15$$

From (A-15) and the symmetry of $\rho_s(x)$, it follows that $\alpha = 0$ and $\beta = y_L$. Hence, from the real part of (A-14)

$$\rho_s(x) = -\frac{\rho_L y_L}{\pi(x^2 + y_L^2)}. \quad A-16$$

By superposition, the charge distribution induced by one conductor can be extended to the N conductor case where the conductors are located at (x_n, y_n) .

$$\rho_s(x) = -\frac{1}{\pi} \sum_{n=1}^N \frac{\rho_{Ln} y_n}{(x-x_n)^2 + y_n^2} \quad A-17$$

DISCLAIMER

This paper was prepared by Musoke Sendaula of the University of Tennessee at Chattanooga (UTC), Richard R. Johnson of the North Carolina State University (NCSU), and D. Wayne Hilson and Randall Meyer of Tennessee Valley Authority (TVA). Neither, UTC, NCSU, TVA, nor any person acting on their behalf (a) made any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this paper, or that the use of any of the information, method, or process disclosed in this paper may not infringe privately owned rights or (b) assumes any liabilities with respect to the use of or for damages resulting from the use of, any information, method, or process disclosed in this paper.

APPENDIX B

TYPICAL TVA 500-kV TRANSMISSION LINE

Figures B.1 and B.2 show the typical tower configurations on the 500-kV grid and Table B-1 contains the detailed characteristics of TVA's 500-kV grid [2].

Figure B.1. TVA 500-kV tangent tower constraint phase configuration.

Figure B.2. TVA 500-kV tangent tower vertical insulator configuration.

Table B-1

TYPICAL LINE CHARACTERISTICS ON
THE TVA'S 500-kV GRID [2]

1. Line name or no.	Watts Bar-Roane
2. Voltage (nominal) kV, ac or dc	500; ac
3. Year of construction	1977-1978
4. Length, miles, total miles	39.5; 207
5. Altitude range, ft.	900-1200
6. Design load district	Special

STRUCTURES

7. Material	S
8. Type	5L7
9. Average no./mile	5.3
10. Average wt/structure/lbs	18,800
11. Designed for _____ ckts; _____ config.	1:H

CONDUCTORS

12. Type	ACSR
13. Dia., in., stranding	1.165; 45/7
14. Weights, lbs/ft	1.075
15. No./phase; spacing, in.	3; 18
16. Average span length, ft	997
17. Final sag, ft; @ °F	31.8 @ 120°F
18. Tension, 10 ³ lb; @ °F	4.28 @ 120°F
19. % of ultimate	16
20. Designed for _____ amps/phase	3000

MINIMUM CLEARANCES

21. Phase to tower, ft	10.5
22. Phase to ground, ft	30 @ 120°F
23. Phase to phase, ft	30

SUSPENSION STRINGS

24. Configuration	V
25. Insulator size, in., strength, 10 ³ lb	5 3/4 x 10; 25
26. No. strings/phase	2
27. No. units/string	24

STRAIN STRINGS

28. Insulator size, in.; strength, 10 ³ lb	5 3/4 x 10; 25
29. No. strings/phase	3
30. No. units/string	26

Table B-1

(Continued)

LIGHTNING PROTECTION

31. No. shield wires; material	2; Alumoweld
32. Diameter, in., stranding	0.343; 7 No. 9
33. Sag, ft @ °F	21.7 @ 60°F
34. Tension, 10 ³ lb; @ °F	1.2 @ 60°F
35. % of ultimate	10
36. Separation at tower, ft	
37. Shield angle, deg. @ tower; @ midspan	12°; 6°
38. Grounding method	GR; G
39. Tower footing resistance, ohms	15-75
40. Isokeraunic level	60
41. Lightning faults/100 mile/year	0.82; C

CONDUCTOR MOTION SUPPRESSION

42. Damper, type	None
43. Damper, No./cond./span	-
44. Damper, location, ft	-
45. Spacers, type	None
46. Spacers, spacing, ft	-
47. Spacer-damper, type	Alcoa Spring
48. Spacer-damper, spacing, ft	250 max.

APPENDIX C

NBS FIELD METERS TEST REPORT

The test data on the three field meters checked by the National Bureau of Standards given below was analyzed and the measured data was adjusted to remove the bias.

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
WASHINGTON, D.C. 20234

REPORT OF CALIBRATION

60 Hz Electric Field Meters

Electric Field Measurements Company Model 110
Serial Numbers 1-12, 1-13, 1-14

Submitted by

Tennessee Valley Authority
Chattanooga, Tennessee 37401

Measurements of a nearly uniform 60-Hz electric field were made in January 1980 with the above electric field strength meters at a room temperature of about 25 °C and relative humidity of about 26%. The results are given in the following table.

Serial Number 1-12

<u>Applied Electric Field</u> (rms kV/m)	<u>Field Meter</u> <u>Reading (kV/m)</u>	<u>Field Meter</u> <u>Scale (kV/m)</u>
9.73	9.95	10.0
7.60	7.80	
6.30	6.49	
5.06	5.20	
3.80	3.87	
3.12	3.20	
2.54	2.63	3.0
1.90	1.97	
1.27	1.30	
0.971	1.000	1.0
0.926	0.950	
0.635	0.652	
0.444	0.458	
0.317	0.325	
0.254	0.260	0.3
0.190	0.195	
0.127	0.130	
0.0888	0.090	

722/G-43875

Tennessee Valley Authority
60 Hz Electric Field Meters

Page 2

Serial Number 1-13

Applied Electric Field (rms kV/m)	Field Meter Reading (kV/m)	Field Meter Scale (kV/m)
9.73	10.00	10.0
7.60	7.80	
6.30	6.50	
5.06	5.20	
3.80	3.90	
3.12	3.20	
2.54	2.62	3.0
1.90	1.95	
1.27	1.30	
0.978	1.000	1.0
0.926	0.950	
0.635	0.650	
0.444	0.457	
0.317	0.325	
0.254	0.260	0.3
0.190	0.195	
0.127	0.130	
0.0888	0.091	

Serial Number 1-14

9.73	9.95	10.0
7.60	7.80	
6.30	6.48	
5.06	5.20	
3.80	3.85	
3.12	3.20	
2.54	2.62	3.0
1.90	1.96	
1.27	1.30	
0.978	1.000	1.0
0.926	0.950	
0.635	0.650	
0.444	0.452	
0.317	0.322	

722/G-43875

Tennessee Valley Authority
60 Hz Electric Field Meters

Page 3

Serial Number 1-14

<u>Applied Electric Field</u> <u>(rms kV/m)</u>	<u>Field Meter</u> <u>Reading (kV/m)</u>	<u>Field Meter</u> <u>Scale (kV/m)</u>
0.254	0.259	0.3
0.190	0.195	
0.127	0.130	
0.0888	0.091	

The vertical axis of the field meter was aligned with the field direction and the analog display was read from a distance of about 2 m using a cathetometer. The applied electric field is estimated to be within ± 1 percent of the indicated value and the field meter reading is estimated to be accurate to within ± 1.5 percent of full scale. After each set of measurements was completed, the battery reading exceeded 8.5.

For the Director
National Engineering Laboratory

Robert E. Hebner, Group Leader
Applied Electrical Measurements
Electrosystems Division

Test No: 722/G-43875
Order No: 80PL7-169054
Date: February 4, 1980

APPENDIX D

ELECTRIC FIELDS DATA ANALYSIS - WITHOUT TREE SHIELDING

The presence of trees within or at the edge of the right-of-way distorts the shape of the measured electric field profile. The data analyzed in this appendix was taken from sites with minimal tree shielding.

Figure D-1 shows the box-and-whisker diagram for the maximum value of the measured vertical electric field (EMAX) for 9.2 m (30 feet) and 12.2 m (40 feet) phase spacing as a function of line height for various topographical factors. Figure D-2 shows the measured vertical electric field for 9.2 m and 12.2 m phase spacing at the edge of right-of-way (ERW) as a function of line height for various terrain factors. The cumulative distribution functions for EMAX and ERW are shown in Figures D-3 and D-4, respectively. Table D-1 shows the statistical summary of the data of the four major categories for the various line heights.

12.2

Figure D-1(a). Box-and-whisker diagram - EMAX for 12.2 m phase spacing (without tree shielding).

Figure D-1(b). Box-and-whisker diagram - EMAX for 9.15 m phase spacing (without tree shielding).

D=12.2

Figure D-2(a). Box-and-whisker diagram - ERW for 12.2 m phase spacing (without tree shielding).

Figure D-2(b). Box-and-whisker diagram - EMAX for 9.15 m phase spacing (without tree shielding).

Figure D-3(a). Cumulative distribution function for the maximum measured values of the electric field (EMAX) for 12.2 m phase spacing (without tree shielding).

Figure D-3(b). Cumulative distribution function for the maximum measured values of the electric field (EMAX) for 12.2 m phase spacing (without tree shielding).

Figure D-4(a). Cumulative distribution for the measured values of the electric field at the edge of the right-of-way (ERW) for 9.15 m phase spacing (without tree shielding).

Figure D-4(b). Cumulative distribution for the measured values of the electric field at the edge of the right-of-way (ERW) for 12.2 m phase spacing (without tree shielding).

Table D-1

STATISTICAL SUMMARY OF MEASURED ELECTRIC FIELD VALUES FOR THE
FOUR MAJOR CATEGORIES (WITHOUT TREE SHIELDING)

S T A T I S T I C A L A N A L Y S I S S Y S T E M					
D=9.15 H=14 CAT=FT21 8:28 WE					
VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
EMAX	20	4.940	0.455	4.210	5.987
ERW	20	1.832	0.162	1.530	2.211
----- D=9.15 H=14 CAT=FT21.5 -----					
EMAX	13	5.295	0.327	4.410	5.695
ERW	13	1.833	0.173	1.384	2.063
----- D=9.15 H=14 CAT=RT21 -----					
EMAX	15	4.792	0.633	3.959	5.345
ERW	15	1.687	0.222	1.018	1.978
----- D=9.15 H=14 CAT=RT21.5 -----					
EMAX	2	4.973	1.063	4.219	5.729
ERW	2	1.627	0.087	1.567	1.691
----- D=9.15 H=16 CAT=FT21 -----					
EMAX	21	3.931	0.262	3.465	4.576
ERW	21	1.820	0.123	1.599	2.039
----- D=9.15 H=16 CAT=FT21.5 -----					
EMAX	20	4.083	0.282	3.519	4.495
ERW	20	1.762	0.170	1.232	1.969
----- D=9.15 H=16 CAT=RT21 -----					
EMAX	23	3.951	0.471	3.153	4.797
ERW	23	1.755	0.255	1.020	2.131
----- D=9.15 H=16 CAT=RT21.5 -----					
EMAX	9	4.040	0.495	3.331	4.994
ERW	9	1.747	0.262	1.477	2.267
----- D=9.15 H=18 CAT=FT21 -----					
EMAX	18	3.157	0.349	2.625	4.010
ERW	18	1.685	0.171	1.382	2.160
----- D=9.15 H=18 CAT=FT21.5 -----					
EMAX	13	3.373	0.202	3.042	3.746
ERW	13	1.592	0.152	1.462	2.027
----- D=9.15 H=18 CAT=RT21 -----					
EMAX	22	3.082	0.332	2.475	3.819
ERW	22	1.517	0.204	1.054	1.925

Table D-1
(Continued)

STATISTICAL ANALYSIS SYSTEM					
D=12.2 N=16 CAT=RT01					
VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
E1AX	45	4.854	0.713	3.760	6.342
ERW	45	2.029	0.239	1.224	2.545
----- D=12.2 N=16 CAT=RT01.5 -----					
E1AX	19	4.680	0.791	3.161	6.520
ERW	19	1.807	0.474	0.945	2.482
----- D=12.2 N=18 CAT=FT01 -----					
E1AX	63	3.905	0.333	2.975	5.004
ERW	63	1.951	0.201	1.140	2.299
----- D=12.2 N=18 CAT=FT01.5 -----					
E1AX	20	4.121	0.291	3.759	4.654
ERW	19	1.925	0.114	1.820	2.197
----- D=12.2 N=13 CAT=RT01 -----					
E1AX	47	4.049	0.534	3.191	5.285
ERW	47	1.899	0.407	0.282	2.549
----- D=12.2 N=18 CAT=RT01.5 -----					
E1AX	14	4.220	0.471	3.392	4.947
ERW	14	2.021	0.232	1.621	2.397
----- D=12.2 N=20 CAT=FT01 -----					
E1AX	53	3.225	0.299	2.475	4.414
ERW	53	1.365	0.177	1.238	2.299
----- D=12.2 N=20 CAT=FT01.5 -----					
E1AX	11	3.160	0.211	2.789	3.425
ERW	11	1.675	0.263	1.095	1.965
----- D=12.2 N=20 CAT=RT01 -----					
E1AX	32	3.317	0.443	2.373	4.337
ERW	32	1.725	0.449	0.615	2.451
----- D=12.2 N=20 CAT=RT01.5 -----					
E1AX	14	3.470	0.435	2.881	4.222
ERW	14	1.943	0.252	1.625	2.419

Table D-1
(Continued)

STATISTICAL ANALYSIS SYSTEM						8:29 WEDN
D=9.15 H=18 CAT=RT91.5						
VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	
EMAX	10	3.033	0.405	2.492	3.745	
ERW	10	1.444	0.312	0.669	1.750	
----- D=9.15 H=20 CAT=FT91.5 -----						
EMAX	14	2.352	0.291	2.143	3.224	
ERW	14	1.533	0.209	1.027	1.865	
----- D=9.15 H=20 CAT=FT91.5 -----						
EMAX	7	2.752	0.187	2.487	2.997	
ERW	7	1.575	0.107	1.428	1.685	
----- D=9.15 H=20 CAT=RT91.5 -----						
EMAX	13	2.513	0.313	1.929	3.064	
ERW	13	1.542	0.304	1.194	2.200	
----- D=9.15 H=20 CAT=RT91.5 -----						
EMAX	7	2.773	0.461	2.123	3.307	
ERW	7	1.717	0.243	1.384	2.045	
----- D=12.2 H=14 CAT=FT91.5 -----						
EMAX	75	5.844	0.431	4.959	7.207	
ERW	75	2.055	0.313	0.572	2.453	
----- D=12.2 H=14 CAT=FT91.5 -----						
EMAX	23	5.103	0.519	4.997	7.682	
ERW	27	2.083	0.241	1.358	2.375	
----- D=12.2 H=14 CAT=RT91.5 -----						
EMAX	35	5.903	0.734	4.455	7.443	
ERW	35	2.043	0.345	0.479	2.435	
----- D=12.2 H=14 CAT=RT91.5 -----						
EMAX	17	5.192	0.513	5.235	7.091	
ERW	17	2.074	0.375	1.013	2.754	
----- D=12.2 H=15 CAT=FT91.5 -----						
EMAX	73	4.704	0.341	4.046	5.754	
ERW	77	2.031	0.253	0.819	2.885	
----- D=12.2 H=16 CAT=FT91.5 -----						
EMAX	24	5.003	0.323	4.255	5.489	
ERW	24	2.067	0.259	1.125	2.372	

APPENDIX E

ELECTRIC FIELDS DATA ANALYSIS - WITH TREE SHIELDING

Figure E-1 summarizes the data for EMAX where there are trees near the fields' measuring sites for various terrain categories for 9.2 m and 12.2 m phase spacings, respectively. Figure E-2 shows the summary for ERW for the various line heights and phase spacings. Figures E-4 and E-5 show the associated cumulative distribution functions. Table E-1 contains the statistical summary of both EMAX and ERW with trees at the edge of the right-of-way.

Figure E-1(a). Box-and-Whisker diagram - EMAX for 12.2 m phase spacing (with tree shielding).

9.15

Figure E-1(b). Box-and-Whisker diagram - EMAX for 9.15 m phase spacing (with tree shielding).

Figure E-2(a). Box-and-whisker diagram - ERW for 12.2 m phase spacing (with tree shielding).

Figure E-2(b). Box-and-whisker diagram - ERW for 9.15 m phase spacing (with tree shielding).

Figure E-3(a). Cumulative distribution functions of the maximum values of the measured electric field for 9.15 m phase spacing (with tree shielding).

Figure E-3(b). Cumulative distribution functions for the maximum values of the electric field (EMAX) for 12.2 m phase spacing (with tree shielding).

Figure E-4(a). Cumulative distribution functions of the measured electric field values at the edge of right-of-way (ERW) for 12.2 m phase spacing (with tree shielding).

Figure E-4(b). Cumulative distribution functions of the measured electric field values at the edge of right-of-way (ERW) for 9.15 m phase spacing (with tree shielding).

Table E-1

STATISTICAL SUMMARY OF MEASURED ELECTRIC FIELD VALUES FOR THE
FOUR MAJOR CATEGORIES (WITH TREE SHIELDING)

STATISTICAL ANALYSIS SYSTEM					
D=9.15 H=14 CAT=FT01					
VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
EMAX	20	4.752	0.375	4.154	5.347
ERW	16	0.697	0.723	0.000	2.066
----- D=9.15 H=14 CAT=FT01.5 -----					
EMAX	14	4.854	0.775	2.903	5.895
ERW	10	0.730	0.733	0.000	1.642
----- D=9.15 H=14 CAT=RT01 -----					
EMAX	5	4.965	0.887	4.142	6.215
ERW	5	0.557	0.405	0.094	0.958
----- D=9.15 H=14 CAT=RT01.5 -----					
EMAX	14	5.215	0.701	3.953	6.274
ERW	12	0.603	0.564	0.000	1.683
----- D=9.15 H=15 CAT=FT01 -----					
EMAX	43	3.565	0.379	2.655	4.379
ERW	32	0.425	0.551	0.000	1.745
----- D=9.15 H=16 CAT=FT01.5 -----					
EMAX	19	3.712	0.430	3.190	4.481
ERW	12	0.405	0.415	0.000	1.124
----- D=9.15 H=16 CAT=RT01 -----					
EMAX	23	3.601	0.562	2.749	4.994
ERW	21	0.555	0.549	0.000	1.442
----- D=9.15 H=16 CAT=RT01.5 -----					
EMAX	30	3.719	0.676	2.402	5.678
ERW	26	0.254	0.411	0.000	1.661
----- D=9.15 H=18 CAT=FT01 -----					
EMAX	30	2.765	0.425	2.015	3.809
ERW	27	0.324	0.529	0.000	1.616
----- D=9.15 H=18 CAT=FT01.5 -----					
EMAX	10	2.779	0.337	2.211	3.237
ERW	3	0.640	0.539	0.000	1.551
----- D=9.15 H=13 CAT=RT01 -----					
EMAX	19	2.793	0.515	1.852	3.522
ERW	15	0.337	0.589	0.000	1.931

Table E-1
(Continued)

STATISTICAL ANALYSIS SYSTEM					
D=9.15 H=18 CAT=RT31.5					
VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
EMAX	27	3.073	0.657	2.123	4.897
ERW	23	0.365	0.507	0.000	1.760
----- D=9.15 H=20 CAT=FT31					
EMAX	22	2.147	0.323	1.537	2.748
ERW	21	0.324	0.504	0.000	1.505
----- D=9.15 H=20 CAT=FT21.5					
EMAX	13	2.195	0.293	1.612	2.626
ERW	10	0.382	0.515	0.000	1.369
----- D=9.15 H=20 CAT=RT31					
EMAX	13	2.180	0.425	1.557	2.809
ERW	11	0.342	0.545	0.000	1.853
----- D=9.15 H=20 CAT=RT21.5					
EMAX	13	2.529	0.513	1.747	3.955
ERW	10	0.693	0.564	0.000	1.853
----- D=12.2 H=14 CAT=FT31					
EMAX	32	5.299	0.607	4.140	6.535
ERW	13	0.599	0.593	0.000	1.676
----- D=12.2 H=14 CAT=FT31.5					
EMAX	41	5.074	0.559	3.992	6.749
ERW	26	0.234	0.445	0.000	1.511
----- D=12.2 H=14 CAT=RT31					
EMAX	23	5.215	0.779	3.819	6.805
ERW	9	0.775	0.925	0.000	2.089
----- D=12.2 H=14 CAT=RT21.5					
EMAX	27	5.579	0.875	3.719	6.915
ERW	13	0.465	0.645	0.000	2.075
----- D=12.2 H=16 CAT=FT31					
EMAX	31	4.053	0.485	2.975	4.929
ERW	12	0.406	0.464	0.000	1.425
----- D=12.2 H=16 CAT=FT21.5					
EMAX	41	4.163	0.512	3.397	6.232
ERW	24	0.157	0.387	0.000	1.584

Table E-1
(Continued)

STATISTICAL ANALYSIS SYSTEM					
D=12.2 M=16 CAT=RT01					
VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
EMAX	29	3.995	0.715	2.965	5.751
ERW	13	0.953	0.901	0.000	2.215
----- D=12.2 M=16 CAT=RT01.5 -----					
EMAX	38	4.365	0.770	2.959	5.742
ERW	21	0.463	0.695	0.000	2.142
----- D=12.2 M=18 CAT=FT01 -----					
EMAX	29	3.089	0.497	2.056	3.895
ERW	12	0.792	0.773	0.000	1.921
----- D=12.2 M=18 CAT=FT01.5 -----					
EMAX	29	3.434	0.463	2.860	4.793
ERW	15	0.344	0.529	0.000	1.521
----- D=12.2 M=18 CAT=RT01 -----					
EMAX	25	3.587	0.801	2.169	5.539
ERW	14	0.723	0.802	0.000	2.357
----- D=12.2 M=18 CAT=RT01.5 -----					
EMAX	30	3.523	0.683	2.173	5.340
ERW	15	0.223	0.329	0.000	0.936
----- D=12.2 M=20 CAT=FT01 -----					
EMAX	11	2.712	0.404	2.241	3.325
ERW	7	0.595	0.723	0.000	1.682
----- D=12.2 M=20 CAT=FT01.5 -----					
EMAX	31	2.539	0.342	2.026	3.257
ERW	13	0.095	0.217	0.000	0.838
----- D=12.2 M=20 CAT=RT01 -----					
EMAX	15	2.923	0.503	1.451	4.468
ERW	11	0.980	0.635	0.096	2.100
----- D=12.2 M=20 CAT=RT01.5 -----					
EMAX	30	2.807	0.614	1.759	4.410
ERW	13	0.130	0.227	0.000	0.806

APPENDIX F

DETAILED ELECTRIC FIELDS DATA ANALYSIS WITHOUT TREE SHIELDING

Table F-1 to Table F-4 show the frequency distribution of the sample populations in the various categories for different line heights for 9.15 m and 12.2 m phase spacings. Figure F-1 to Figure F-32 show the "box-and-whisker" diagrams for each of the subcategories. Table F-5 contains the associated statistical summary.

Table F-6 shows the sample populations for the various categories for measuring sites adjacent to turning towers with nonstandard phase spacing. Figure F-33 to Figure F-48 shows the "box-and-whisker" diagram for each of the subcategories, and Table F-7 shows the associated statistical summary.

Table F-1

FREQUENCY DISTRIBUTION FOR (FT@1) BY PHASE SPACING AND LINE HEIGHT
(WITHOUT TREE SHIELDING).

TABLE OF D BY H CONTROLLING FOR CAT=FT@1					
D H					
FREQUENCY PERCENT COL PCT	14	16	18	20	TOTAL
9.15	250	273	234	192	949
	5.75	6.33	5.17	4.32	20.57
	27.40	29.77	24.56	19.18	
	20.33	21.21	22.22	19.44	
12.2	933	1014	819	754	3520
	21.34	22.41	19.10	16.37	79.22
	27.54	28.36	22.71	21.39	
	79.17	78.79	77.76	90.56	
TOTAL	1248	1237	1053	936	4474
	27.59	28.45	23.28	20.59	100.00

Table F-2

FREQUENCY DISTRIBUTION FOR (FT@1.5) BY PHASE SPACING AND LINE HEIGHT
(WITHOUT TREE SHIELDING)

TABLE OF J BY H CONTROLLING FOR CAT=FT@1.5						
J	H					
FREQUENCY PERCENT ROW PCT	COL PCT	14	16	18	20	TOTAL
1.15		234 12.77	250 14.18	159 9.22	71 4.96	754 41.13
		31.93 39.13	34.43 45.45	22.41 39.39	12.97 38.39	
12.2		354 19.36	312 17.02	250 14.18	143 7.30	1079 58.27
		33.73 50.37	28.92 54.55	24.10 50.61	13.25 51.11	
TOTAL		598 32.52	572 31.21	429 23.60	254 12.77	1853 100.20

Table F-3

FREQUENCY DISTRIBUTION FOR (RT@1) BY PHASE SPACING AND LINE HEIGHT
(WITHOUT TREE SHIELDING)

TABLE OF J BY H CONTROLLING FOR CAT=RT@1					
J	H				
FREQUENCY PERCENT ROW PCT					
COL PCT	14	16	18	20	TOTAL
9.15	208	354	296	234	1092
	6.96	11.43	9.02	7.38	54.43
	19.05	33.33	26.19	21.43	
	30.77	38.36	31.38	26.00	
12.2	458	535	511	416	2030
	14.75	18.44	19.26	13.11	65.57
	22.50	26.13	29.38	20.00	
	69.23	51.54	58.12	54.00	
TOTAL	676	949	897	650	3172
	21.31	29.92	23.28	20.49	100.00

Table F-4

FREQUENCY DISTRIBUTION FOR (RT@1.5) BY PHASE SPACING AND LINE HEIGHT
(WITHOUT TREE SHIELDING)

TABLE OF J BY H CONTROLLING FOR CAT=RT@1.5					
J	H				
FREQUENCY PERCENT ROW PCT	14	16	18	20	TOTAL
9.15	26 2.20 7.41 10.53	104 8.79 29.63 29.53	130 10.99 37.04 41.57	31 7.57 25.33 33.33	351 29.57
12.2	221 18.58 26.55 89.47	247 20.32 29.59 70.37	132 15.38 21.98 58.33	192 15.33 21.98 36.57	632 70.33
TOTAL	247 20.32	351 29.57	312 26.37	273 23.38	1133 100.00

Figure F-1: "Box-and-Whisker" for RT@1.5, D=12.2 m, and H=18 m.

Figure F-2: "Box-and-Whisker" for RT@1.5, D=12.2 m, and H=16 m.

Figure F-3: "Box-and-Whisker" for RT@1.5, D=12.2 m, and H=14 m.

Figure F-4: "Box-and-Whisker" for RT@1.5, D=9.15 m, and H=20 m.

Figure F-5: "Box-and-Whisker" for RT@1.5, D=9.15 m, and H=18 m.

Figure F-6: "Box-and-Whisker" for RT@1.5, D=9.15 m, and H=16 m.

Figure F-7: "Box-and-Whisker" for RT@1.5, D=9.15 m, and H=14 m.

Figure F-8: "Box-and-Whisker" for RT@1, D=12.2 m, and H=20 m.

Figure F-9: "Box-and-Whisker" for RT@1, D=12.2 m, and H=13 m.

Figure F-10: "Box-and-Whisker" for RT@1, D=12.2 m, and H=16 m.

Figure F-11: "Box-and-Whisker" for RT@1, D=12.2 m, and H=14 m.

Figure F-12: "Box-and-Whisker" for RT@1, D=9.15 m, and H=20 m.

Figure F-13: "Box-and-Whisker" for RT@1, D=9.15 m, and H=18 m.

Figure F-14: "Box-and-Whisker" for RT@1, D=9.15 m, and H=16 m.

Figure F-15: "Box-and-Whisker" for RT@1, D=9.15 m, and H=14 m.

Figure F-16: "Box-and-Whisker" for FT@1.5, D=12.2 m, and H=20 m.

Figure F-17: "Box-and-Whisker" for FT@1.5, D=12.2 m, and H=18 m.

Figure F-18: "Box-and-Whisker" for FT@1.5, D=12.2 m, and H=16 m.

Figure F-19: "Box-and-Whisker" for FT@1.5, D=12.2 m, and H=14 m.

Figure F-20: "Box-and-Whisker" for FT@1.5, D=9.15 m, and H=20 m.

Figure F-21: "Box-and-Whisker" for FT@1.5, D=9.15 m, and H=18 m.

Figure F-22: "Box-and-Whisker" for FT@1.5, D=9.15 m, and H=16 m.

Figure F-23: "Box-and-Whisker" for FT@1.5, D=9.15 m, and H=14 m.

Figure F-24: "Box-and-Whisker" for FT@1, D=12.2 m, and H=20 m.

Figure F-25: "Box-and-Whisker" for FT@1, D=12.2 m, and H=13 m.

Figure F-26: "Box-and-Whisker" for FT@1, D=12.2 m, and H=16 m.

Figure F-27: "Box-and-Whisker" for FT@1, D=12.2 m, and H=14 m.

Figure F-28: "Box-and-Whisker" for FT@1, D=9.15 m, and H=20 m.

Figure F-29: "Box-and-Whisker" for FT@1, D=9.15 m, and H=18 m.

Figure F-30: "Box-and-Whisker" for FT@1, D=9.15 m, and H=16 m.

Figure F-31: "Box-and-Whisker" for FT@1, D=9.15 m, and H=14 m.

Figure F-32: "Box-and-Whisker" for RT@1, D=12.2 m, and H=20 m.

Table F-5

DETAILED STATISTICAL SUMMARY OF MEASURED ELECTRIC
FIELDS DATA AS A FUNCTION OF LINE HEIGHT
(WITHOUT TREE SHIELDING)

D=12.2 H=14 CAT=RT01					
VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
EMAX	36	5.908	0.734	4.456	7.448
ERW	36	2.043	0.345	0.473	2.435
E1	36	3.822	0.306	3.053	4.331
E2	36	3.828	0.230	3.395	4.331
E3	36	3.748	0.257	3.301	4.235
E4	36	3.946	0.291	3.359	4.716
E5	36	4.417	0.403	3.635	5.234
E6	36	5.079	0.504	4.177	6.052
E7	36	5.532	0.657	4.005	5.766
E8	36	5.863	0.758	4.456	7.448
E9	36	5.312	0.747	3.678	5.392
E10	36	4.358	0.505	3.112	5.294
E11	36	3.453	0.450	2.227	4.174
E12	36	2.676	0.424	1.316	3.339
E13	36	2.063	0.345	0.479	2.435
D=12.2 H=14 CAT=RT01.5					
EMAX	17	5.192	0.513	3.256	7.091
ERW	17	2.074	0.373	1.013	2.754
E1	17	4.096	0.250	3.739	4.765
E2	17	4.076	0.260	3.741	4.860
E3	17	3.958	0.232	3.643	4.479
E4	17	4.020	0.204	3.574	4.299
E5	17	4.523	0.351	4.004	5.217
E6	17	5.231	0.422	4.753	5.931
E7	17	5.815	0.433	5.256	6.541
E8	17	6.135	0.557	5.256	7.091
E9	17	5.623	0.633	4.530	6.700
E10	17	4.744	0.630	3.643	5.676
E11	17	3.683	0.460	2.752	4.458
E12	17	2.750	0.392	1.657	3.295
E13	17	2.074	0.373	1.013	2.754
D=12.2 H=16 CAT=FT01					
EMAX	78	4.704	0.341	3.045	5.754
ERW	77	2.031	0.253	0.819	2.886
E1	78	2.657	0.308	0.750	3.112
E2	78	2.715	0.234	1.777	3.176
E3	78	2.849	0.208	2.232	3.235
E4	78	3.118	0.226	2.613	3.624
E5	78	3.550	0.213	3.013	4.042
E6	78	4.049	0.248	3.374	4.638
E7	78	4.447	0.291	3.775	5.177
E8	78	4.654	0.344	3.942	5.411
E9	78	4.422	0.407	3.325	5.754
E10	77	3.873	0.327	3.110	4.699
E11	77	3.232	0.321	2.016	3.867
E12	77	2.555	0.253	1.896	3.094
E13	77	2.031	0.253	0.819	2.836

Table F-5
(Continued)

J=12.2 H=15 CAT=RT01.5					
VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
EMAK	24	3.095	1.328	4.255	5.489
ERW	24	2.067	1.259	1.126	2.372
E1	24	3.096	1.176	2.615	3.292
E2	24	3.024	0.209	2.632	3.323
E3	24	3.077	1.193	2.671	3.370
E4	24	3.338	1.219	2.951	3.817
E5	24	3.814	0.279	3.310	4.655
E6	24	4.325	1.259	3.638	4.841
E7	24	4.747	1.313	3.954	5.205
E8	24	4.970	1.351	4.255	5.439
E9	24	4.645	1.357	3.817	5.205
E10	24	3.936	1.349	3.054	4.666
E11	24	3.290	1.328	2.253	3.809
E12	24	2.620	1.277	1.576	2.873
E13	24	2.057	1.259	1.125	2.372
J=12.2 H=15 CAT=RT01					
EMAK	45	4.854	1.718	3.750	5.342
ERW	45	2.029	1.239	1.224	2.545
E1	45	2.757	1.240	2.173	3.350
E2	45	2.775	1.201	2.234	3.350
E3	45	2.893	1.214	2.558	3.445
E4	45	3.142	1.261	2.553	3.828
E5	45	3.539	1.298	2.821	4.402
E6	45	4.050	1.414	3.038	4.977
E7	45	4.562	1.576	3.417	5.756
E8	45	4.893	1.741	3.417	5.342
E9	45	4.572	1.741	3.257	5.201
E10	45	3.942	1.552	3.073	5.004
E11	45	3.219	1.422	2.334	4.056
E12	45	2.532	1.314	1.870	3.292
E13	45	2.029	1.239	1.224	2.545
J=12.2 H=15 CAT=RT01.5					
EMAK	19	4.620	1.791	3.151	5.520
ERW	19	1.809	0.474	1.945	2.432
E1	19	2.903	1.316	2.531	4.027
E2	19	2.909	1.252	2.459	3.643
E3	19	2.792	1.250	2.551	3.452
E4	19	3.171	1.275	2.743	3.835
E5	19	3.579	1.414	2.832	4.890
E6	19	3.998	1.625	2.950	5.040
E7	19	4.335	1.724	3.058	5.232
E8	19	4.646	1.801	3.151	5.520
E9	19	4.357	1.757	3.058	5.862
E10	19	3.726	1.778	2.459	5.359
E11	19	3.023	1.627	2.113	3.979
E12	19	2.335	1.501	1.356	3.142
E13	19	1.809	1.474	1.945	2.432

Table F-5
(Continued)

D=12.2 H=13 CAT=RT01.5					
VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
EMAX	14	4.220	1.471	3.332	4.949
ERW	14	2.021	0.232	1.621	2.397
E1	14	2.091	0.121	1.870	2.374
E2	14	2.089	0.139	1.870	2.374
E3	14	2.232	0.216	2.017	2.849
E4	14	2.507	0.179	2.239	2.814
E5	14	2.878	0.201	2.553	3.282
E6	14	3.335	0.144	3.071	3.572
E7	14	3.840	0.411	3.275	4.924
E8	14	4.157	0.394	3.272	4.751
E9	14	4.052	0.511	3.179	4.949
E10	14	3.623	0.510	2.850	4.455
E11	14	3.054	0.375	2.333	3.620
E12	14	2.591	0.400	1.977	3.379
E13	14	2.021	0.232	1.621	2.397
D=12.2 H=20 CAT=FT01					
EMAX	58	3.225	0.298	2.475	4.414
ERW	58	1.656	0.179	1.258	2.298
E1	58	1.396	0.167	0.958	1.781
E2	58	1.483	0.161	1.124	1.792
E3	58	1.675	0.137	1.435	1.908
E4	58	1.955	0.144	1.647	2.272
E5	58	2.302	0.141	2.070	2.603
E6	58	2.604	0.161	2.251	2.993
E7	58	2.910	0.217	2.475	3.334
E8	58	3.143	0.241	2.475	3.674
E9	58	3.172	0.298	2.475	4.414
E10	58	2.911	0.279	2.330	3.052
E11	58	2.552	0.236	2.070	3.475
E12	58	2.202	0.189	1.619	2.943
E13	58	1.856	0.179	1.238	2.298
D=12.2 H=20 CAT=FT01.5					
EMAX	11	3.150	0.211	2.739	3.425
ERW	11	1.676	0.233	1.075	1.965
E1	11	1.458	0.082	1.232	1.557
E2	11	1.603	0.084	1.474	1.739
E3	11	1.747	0.035	1.555	1.852
E4	11	2.081	0.125	1.955	2.331
E5	11	2.377	0.132	2.176	2.558
E6	11	2.636	0.145	2.472	2.949
E7	11	2.954	0.103	2.742	3.330
E8	11	3.135	0.204	2.759	3.425
E9	11	3.055	0.252	2.633	3.425
E10	11	2.750	0.303	2.139	3.234
E11	11	2.432	0.235	2.141	2.807
E12	11	2.040	0.268	1.459	2.378
E13	11	1.676	0.263	1.095	1.965

Table F-5
(Continued)

D=12.2 H=20 CAT=RT01

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
EMAX	32	3.317	0.448	2.373	4.337
ERW	32	1.726	0.449	0.615	2.451
E1	32	1.475	0.134	1.074	2.113
E2	32	1.545	0.157	1.074	1.921
E3	32	1.713	0.117	1.521	1.921
E4	32	1.977	0.156	1.637	2.509
E5	32	2.226	0.175	2.032	2.750
E6	32	2.696	0.268	2.217	3.374
E7	32	2.994	0.333	2.373	3.653
E8	32	3.223	0.443	2.137	4.145
E9	32	3.213	0.535	2.140	4.337
E10	32	2.954	0.593	1.843	3.856
E11	32	2.533	0.578	0.957	3.458
E12	32	2.136	0.501	1.070	3.094
E13	32	1.726	0.449	0.615	2.451

D=12.2 H=20 CAT=RT01.5

EMAX	14	3.470	0.435	2.831	4.222
ERW	14	1.948	0.252	1.625	2.419
E1	14	1.518	0.038	1.347	1.646
E2	14	1.582	0.076	1.442	1.675
E3	14	1.696	0.097	1.453	1.850
E4	14	1.950	0.124	1.646	2.142
E5	14	2.323	0.158	2.133	2.769
E6	14	2.672	0.236	2.378	3.190
E7	14	3.043	0.309	2.551	3.628
E8	14	3.356	0.391	2.743	3.941
E9	14	3.356	0.521	2.531	4.222
E10	14	3.077	0.494	2.434	4.000
E11	14	2.686	0.453	2.175	3.689
E12	14	2.356	0.373	1.979	3.216
E13	14	1.948	0.252	1.625	2.419

Table F-5
(Continued)

D=9.15 H=14 CAT=FT01					
VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
EMAX	20	4.940	0.455	4.210	5.987
ERW	20	1.832	0.152	1.530	2.211
E1	20	2.457	0.071	2.293	2.577
E2	20	2.653	0.155	2.441	3.251
E3	20	3.099	0.141	2.751	3.283
E4	20	3.757	0.143	3.442	3.936
E5	20	4.351	0.251	3.739	4.877
E6	20	4.796	0.395	4.210	5.627
E7	20	4.928	0.452	4.210	5.987
E8	20	4.570	0.433	3.929	5.333
E9	20	3.794	0.358	3.041	4.400
E10	20	3.019	0.298	2.301	3.466
E11	20	2.279	0.196	2.025	2.809
E12	20	1.832	0.152	1.530	2.211
E13	20	1.416	0.156	0.956	1.704
D=9.15 H=14 CAT=FT01.5					
EMAX	19	5.293	0.327	4.410	5.695
ERW	18	1.833	0.179	1.334	2.063
E1	18	2.723	0.199	2.446	3.142
E2	18	2.914	0.212	2.534	3.332
E3	18	3.274	0.151	2.909	3.522
E4	18	3.990	0.275	3.234	4.576
E5	18	4.676	0.271	4.129	5.148
E6	18	5.143	0.330	4.410	5.577
E7	18	5.234	0.327	4.410	5.695
E8	18	4.818	0.346	3.938	5.411
E9	18	4.055	0.275	3.370	4.457
E10	18	3.194	0.223	2.759	3.518
E11	18	2.391	0.195	2.030	2.626
E12	10	1.833	0.179	1.334	2.063
E13	18	1.400	0.145	1.015	1.592
D=9.15 H=14 CAT=RT01					
EMAX	15	4.792	0.633	3.939	5.945
ERW	15	1.699	0.222	1.018	1.978
E1	15	2.453	0.127	2.251	2.785
E2	15	2.004	0.150	1.333	2.956
E3	15	2.092	0.197	1.739	3.453
E4	15	3.717	0.235	3.256	4.315
E5	15	4.257	0.488	3.146	5.190
E6	15	4.651	0.572	3.913	5.662
E7	15	4.755	0.565	3.939	5.945
E8	15	4.252	0.559	3.540	5.275
E9	15	3.630	0.536	3.028	4.783
E10	15	2.836	0.351	2.313	3.644
E11	15	2.143	0.275	1.430	2.639
E12	15	1.699	0.222	1.018	1.978
E13	15	1.328	0.241	0.602	1.671

Table F-5
(Continued)

D=9.15 H=14 CAT=RTD1.5					
VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
EMAX	2	4.973	1.068	4.218	5.729
ERW	2	1.629	0.037	1.537	1.691
E1	2	2.630	0.133	2.536	2.724
E2	2	2.746	0.102	2.674	2.818
E3	2	3.590	0.046	3.458	3.533
E4	2	3.929	0.520	3.552	4.297
E5	2	4.656	1.234	3.934	5.729
E6	2	4.878	0.933	4.218	5.538
E7	2	4.830	0.866	4.218	5.442
E8	2	4.171	0.824	3.679	4.774
E9	2	3.594	0.531	3.073	3.915
E10	2	2.654	0.232	2.470	2.818
E11	2	2.117	0.051	2.075	2.150
E12	2	1.629	0.037	1.537	1.691
E13	2	1.163	0.051	1.127	1.199
D=9.15 H=15 CAT=FTD1					
EMAX	21	3.931	0.262	3.455	4.575
ERW	21	1.820	0.129	1.579	2.039
E1	21	1.624	0.095	1.412	1.878
E2	21	1.841	0.117	1.651	1.995
E3	21	2.290	0.150	2.059	2.634
E4	21	2.853	0.170	2.615	3.209
E5	21	3.333	0.131	3.170	3.010
E6	21	3.731	0.193	3.278	4.051
E7	21	3.911	0.255	3.455	4.575
E8	21	3.767	0.296	3.273	4.239
E9	21	3.314	0.235	2.822	3.915
E10	21	2.749	0.253	2.334	3.265
E11	21	2.220	0.178	2.018	2.615
E12	21	1.820	0.128	1.579	2.039
E13	21	1.436	0.118	1.174	1.622
D=9.15 H=15 CAT=FTD1.5					
EMAX	20	4.033	0.232	3.518	4.495
ERW	20	1.752	0.170	1.232	1.959
E1	20	1.734	0.106	1.559	1.923
E2	20	1.940	0.147	1.651	2.257
E3	20	2.351	0.174	2.034	2.656
E4	20	2.897	0.231	2.478	3.266
E5	20	3.454	0.250	2.836	4.034
E6	20	3.857	0.215	3.347	4.130
E7	20	4.078	0.254	3.513	4.495
E8	20	3.850	0.231	3.432	4.322
E9	20	3.331	0.221	3.051	3.990
E10	20	2.748	0.158	2.414	3.090
E11	20	2.257	0.171	1.777	2.534
E12	20	1.752	0.170	1.232	1.959
E13	19	1.321	0.207	0.949	1.566

Table F-5
(Continued)

D=9.15 H=15 CAT=RT01					
VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
EMAX	28	3.951	0.471	3.159	4.737
ERW	28	1.756	0.256	1.020	2.131
E1	28	1.682	0.139	1.472	2.254
E2	28	1.861	0.158	1.554	2.442
E3	28	2.319	0.176	2.059	2.724
E4	28	2.832	0.190	2.449	3.246
E5	28	3.406	0.229	2.825	3.819
E6	28	3.776	0.396	3.159	4.679
E7	28	3.954	0.477	3.111	4.797
E8	28	3.802	0.525	2.732	4.774
E9	28	3.374	0.507	2.313	4.297
E10	28	2.772	0.424	1.855	3.486
E11	28	2.285	0.325	1.371	2.657
E12	28	1.756	0.256	1.020	2.131
E13	28	1.395	0.256	0.650	1.668
D=9.15 H=15 CAT=RT01.5					
EMAX	8	4.040	0.495	3.331	4.994
ERW	8	1.747	0.262	1.477	2.257
E1	8	1.711	0.121	1.559	1.830
E2	8	1.954	0.151	1.754	2.152
E3	8	2.318	0.174	2.079	2.656
E4	8	2.923	0.277	2.528	3.352
E5	8	3.476	0.366	3.073	4.177
E6	8	3.784	0.234	3.234	4.034
E7	8	3.956	0.504	3.331	4.802
E8	8	3.811	0.581	3.190	4.994
E9	8	3.337	0.625	2.759	4.610
E10	8	2.723	0.416	2.215	3.458
E11	8	2.105	0.227	1.830	2.400
E12	8	1.747	0.262	1.477	2.257
E13	8	1.294	0.194	0.930	1.559
D=9.15 H=13 CAT=FT01					
EMAX	18	3.159	0.369	2.625	4.010
ERW	18	1.635	0.191	1.332	2.150
E1	18	1.135	0.161	1.017	1.599
E2	18	1.354	0.165	1.157	1.693
E3	18	1.731	0.145	1.432	2.086
E4	18	2.148	0.147	1.945	2.338
E5	18	2.551	0.139	2.351	2.818
E6	18	2.847	0.205	2.634	3.318
E7	18	3.103	0.220	2.625	3.732
E8	18	3.065	0.335	2.522	4.010
E9	18	2.747	0.330	2.255	3.819
E10	18	2.421	0.305	2.050	3.246
E11	18	2.021	0.210	1.714	2.536
E12	18	1.635	0.191	1.332	2.150
E13	18	1.367	0.152	1.115	1.725

Table F-5
(Continued)

D=9.15 H=13 CAT=FTD1.5					
VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
EMAX	13	3.373	0.232	3.042	3.746
ERW	13	1.638	0.157	1.452	2.027
E1	13	1.197	0.112	1.015	1.403
E2	13	1.367	0.153	1.061	1.594
E3	13	1.731	0.131	1.477	2.060
E4	13	2.272	0.193	1.932	2.618
E5	13	2.750	0.199	2.396	3.046
E6	13	3.111	0.217	2.759	3.427
E7	13	3.357	0.130	3.042	3.605
E8	13	3.235	0.221	2.967	3.746
E9	13	3.013	0.252	2.712	3.455
E10	13	2.587	0.177	2.400	2.997
E11	13	2.133	0.148	1.939	2.437
E12	13	1.698	0.152	1.452	2.027
E13	13	1.336	0.139	1.125	1.556
D=9.15 H=13 CAT=RTD1					
EMAX	22	3.032	0.332	2.475	3.819
ERW	22	1.519	0.204	1.054	1.925
E1	22	1.134	0.290	0.756	2.348
E2	22	1.394	0.213	1.036	1.785
E3	22	1.735	0.159	1.517	2.056
E4	22	2.209	0.157	1.834	2.446
E5	22	2.573	0.217	2.251	3.060
E6	22	2.867	0.259	2.429	3.442
E7	22	3.033	0.290	2.475	3.629
E8	22	2.954	0.352	2.333	3.819
E9	22	2.616	0.347	2.052	3.437
E10	22	2.229	0.298	1.696	2.818
E11	22	1.865	0.243	1.375	2.348
E12	22	1.519	0.204	1.054	1.925
E13	22	1.252	0.172	0.772	1.691
D=9.15 H=13 CAT=RTD1.5					
EMAX	10	3.035	0.426	2.412	3.746
ERW	10	1.444	0.313	0.659	1.750
E1	10	1.139	0.120	1.015	1.329
E2	10	1.420	0.196	1.177	1.735
E3	10	1.813	0.190	1.555	2.124
E4	10	2.230	0.208	1.934	2.653
E5	10	2.632	0.211	2.317	2.947
E6	10	2.830	0.326	2.400	3.327
E7	10	2.997	0.353	2.472	3.517
E8	10	2.851	0.377	2.351	3.746
E9	10	2.545	0.348	2.059	3.371
E10	10	2.197	0.352	1.599	2.997
E11	10	1.771	0.290	1.129	2.211
E12	10	1.444	0.313	0.659	1.750
E13	10	1.153	0.317	0.332	1.403

Table F-5
(Continued)

D=9.15 H=20 CAT=FT01					
VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
EMAX	14	2.552	0.291	2.148	3.224
ERW	14	1.530	0.239	1.027	1.855
E1	14	0.752	0.098	0.559	0.854
E2	14	0.924	0.101	0.753	1.051
E3	14	1.332	0.125	1.055	1.477
E4	14	1.672	0.159	1.337	1.934
E5	14	2.023	0.134	1.537	2.303
E6	14	2.300	0.212	1.774	2.612
E7	14	2.452	0.237	1.774	3.035
E8	14	2.539	0.298	2.148	3.224
E9	14	2.374	0.337	1.951	3.129
E10	14	2.128	0.235	1.537	2.612
E11	14	1.834	0.206	1.411	2.239
E12	14	1.530	0.209	1.027	1.855
E13	14	1.255	0.244	0.559	1.586
D=9.15 H=20 CAT=FT01.5					
EMAX	7	2.752	0.187	2.437	2.937
ERW	7	1.575	0.107	1.428	1.696
E1	7	0.858	0.150	0.571	1.006
E2	7	1.049	0.131	0.857	1.191
E3	7	1.428	0.117	1.244	1.555
E4	7	1.857	0.155	1.636	2.150
E5	7	2.222	0.130	1.930	2.333
E6	7	2.527	0.195	2.211	2.805
E7	7	2.659	0.198	2.349	2.947
E8	7	2.726	0.201	2.437	2.977
E9	7	2.527	0.176	2.379	2.805
E10	7	2.243	0.220	1.957	2.525
E11	7	1.892	0.135	1.673	2.119
E12	7	1.575	0.107	1.428	1.696
E13	7	1.343	0.058	1.137	1.405
D=9.15 H=20 CAT=RT01					
EMAX	18	2.518	0.318	1.929	3.054
ERW	18	1.542	0.304	1.174	2.200
E1	18	0.809	0.053	0.737	1.117
E2	18	1.074	0.155	0.748	1.397
E3	18	1.351	0.147	1.058	1.523
E4	18	1.715	0.105	1.472	1.838
E5	18	2.056	0.206	1.771	2.643
E6	18	2.252	0.251	1.857	2.740
E7	18	2.394	0.296	1.929	2.977
E8	18	2.418	0.352	1.857	3.054
E9	18	2.348	0.432	1.745	2.959
E10	18	2.097	0.408	1.552	2.732
E11	18	1.823	0.348	1.373	2.449
E12	18	1.542	0.374	1.174	2.200
E13	18	1.237	0.258	0.942	1.833

Table F-5
(Continued)

J=9.15 H=20 CAT=RT01.5					
JAR TABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
EMAX	7	2.770	0.451	2.123	3.307
ERW	7	1.717	0.243	1.334	2.045
E1	7	0.777	0.099	0.611	0.945
E2	7	0.915	0.129	0.751	1.115
E3	7	1.261	0.123	1.108	1.497
E4	7	1.697	0.156	1.477	1.952
E5	7	2.130	0.272	1.642	2.417
E6	7	2.384	0.352	1.825	2.739
E7	7	2.556	0.352	2.017	2.929
E8	7	2.750	0.494	2.050	3.307
E9	7	2.650	0.477	1.914	3.213
E10	7	2.398	0.400	1.825	2.739
E11	7	2.034	0.349	1.551	2.417
E12	7	1.717	0.243	1.334	2.045
E13	7	1.446	0.199	1.108	1.673
J=12.2 H=14 CAT=FT31					
EMAX	76	5.844	0.431	4.959	7.209
ERW	76	2.055	0.313	0.572	2.458
E1	76	3.839	0.251	3.074	4.423
E2	76	3.853	0.253	3.074	4.710
E3	76	3.771	0.291	2.653	4.614
E4	76	3.951	0.231	3.074	4.897
E5	76	4.465	0.315	3.517	5.479
E6	76	5.126	0.341	4.254	5.960
E7	76	5.614	0.407	4.755	7.011
E8	76	5.826	0.440	4.870	7.209
E9	76	5.309	0.435	4.138	5.728
E10	76	4.444	0.414	3.145	5.575
E11	76	3.483	0.363	1.875	4.325
E12	76	2.658	0.341	1.031	3.258
E13	76	2.055	0.313	0.572	2.458
J=12.2 H=14 CAT=FT01.5					
EMAX	28	6.123	0.519	4.977	7.622
ERW	27	2.088	0.241	1.358	2.375
E1	28	4.153	0.258	3.677	4.681
E2	28	4.051	0.279	3.300	4.473
E3	28	3.954	0.250	3.314	4.376
E4	29	4.129	0.231	3.533	4.490
E5	29	4.647	0.241	3.950	5.063
E6	28	5.295	0.347	4.511	5.930
E7	28	5.535	0.423	4.714	5.645
E8	28	5.057	0.430	4.977	7.293
E9	27	5.552	0.563	4.621	7.632
E10	27	4.570	0.328	3.874	5.250
E11	27	3.533	0.329	2.717	4.296
E12	27	2.707	0.250	2.033	3.076
E13	27	2.088	0.241	1.358	2.375

Table F-5
(Continued)

J=12.2 N=13 CAT=FF21					
VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
EMAX	53	2.925	0.338	2.975	5.004
ERW	53	1.951	0.201	1.140	2.299
E1	53	1.971	0.159	1.417	2.306
E2	53	2.030	0.128	1.559	2.353
E3	53	2.208	0.132	1.870	2.456
E4	53	2.495	0.151	2.171	2.931
E5	53	2.853	0.220	2.350	3.364
E6	53	3.274	0.253	2.569	3.849
E7	53	3.613	0.236	2.737	4.248
E8	53	3.886	0.327	2.975	5.004
E9	53	3.754	0.312	2.832	4.655
E10	53	3.384	0.261	2.770	3.957
E11	53	2.914	0.255	2.375	3.724
E12	53	2.354	0.190	1.615	2.632
E13	53	1.951	0.201	1.140	2.299
J=12.2 N=19 CAT=FF21.5					
EMAX	20	4.121	0.291	3.759	4.654
ERW	19	1.956	0.114	1.820	2.197
E1	20	2.032	0.123	1.843	2.290
E2	20	2.156	0.135	1.935	2.382
E3	20	2.294	0.129	2.012	2.473
E4	20	2.564	0.151	2.175	2.748
E5	20	2.928	0.250	2.177	3.212
E6	20	3.377	0.293	2.555	3.808
E7	20	3.816	0.301	3.347	4.470
E8	20	4.074	0.237	3.725	4.654
E9	20	3.830	0.283	3.347	4.297
E10	20	3.449	0.244	3.022	3.966
E11	20	2.958	0.259	2.555	3.470
E12	19	2.453	0.221	2.179	3.151
E13	19	1.986	0.114	1.820	2.197
J=12.2 N=13 CAT=RF21					
EMAX	47	4.069	0.534	3.121	5.295
ERW	47	1.879	0.409	0.232	2.549
E1	47	1.925	0.223	1.258	2.254
E2	47	1.936	0.226	1.358	2.552
E3	47	2.135	0.209	1.610	2.552
E4	47	2.336	0.135	1.923	2.836
E5	47	2.858	0.272	2.313	3.641
E6	47	3.301	0.302	2.653	3.940
E7	47	3.723	0.425	2.834	5.242
E8	47	3.999	0.523	3.191	5.285
E9	47	3.903	0.572	2.993	5.235
E10	47	3.506	0.474	2.519	4.517
E11	47	2.974	0.454	2.134	3.777
E12	47	2.399	0.373	1.412	3.053
E13	47	1.879	0.409	0.232	2.549

Table F-6

FREQUENCY DISTRIBUTION FOR ELECTRIC FIELDS DATA ADJACENT TO TURNING TOWERS
(WITHOUT TREE SHIELDING)

TABLE OF CAT BY H					
CAT H					
FREQUENCY PERCENT NO. PCT CO. PCT	114	116	118	120	TOTAL
FTB1	611 12.57 25.42 53.41	539 13.95 29.12 45.69	533 10.79 22.53 41.00	533 10.79 22.53 53.75	2156 47.37
FTB1.5	78 1.58 16.22 6.32	195 3.75 40.54 12.93	117 2.37 24.32 9.20	91 1.84 18.72 9.21	471 9.74
FTB1	338 6.34 22.22 29.55	455 9.21 29.91 50.17	517 10.26 33.33 39.30	321 4.47 14.53 22.37	1521 30.79
FTB1.5	117 2.37 20.45 10.23	159 3.42 29.55 11.21	143 2.89 25.00 11.20	143 2.89 25.00 14.47	572 11.58
TOTAL	1144 23.15	1508 30.53	1300 26.32	939 20.35	4990 100.00

Figure F-33. "Box-and-Whisker" diagram for FT@1, H=14 m, turning tower.

Figure F-34. "Box-and-Whisker" diagram for FT@1, H=16 m, turning tower.

Figure F-35. "Box-and-Whisker" diagram for FT@1, H=18 m, turning tower.

Figure F-36. "Box-and-Whisker" diagram for FT@1, H=20 m, turning tower.

Figure F-37. "Box-and-Whisker" diagram for FT@1.5, H=14 m, turning tower.

Figure F-38. "Box-and-Whisker" diagram for FT@1.5, H=16 m, turning tower.

Figure F-39. "Box-and-Whisker" diagram for FT@1.5, H=18 m, turning tower.

Figure F-40. "Box-and-Whisker" diagram for FT@1.5, H=20 m, turning tower.

Figure F-41. "Box-and-Whisker" diagram for RT@1, H=14 m, turning tower.

Figure F-42. "Box-and-Whisker" diagram for RT@1, H=16 m, turning tower.

Figure F-43. "Box-and-Whisker" diagram for RT@1, H=18 m, turning tower.

Figure F-44. "Box-and-Whisker" diagram for RT@1, H=20 m, turning tower.

Figure F-45. "Box-and-Whisker" diagram for RT@1.5, H=14 m, turning tower.

Figure F-46. "Box-and-Whisker" diagram for RT@1.5, H=16 m, turning tower.

Figure F-47. "Box-and-Whisker" diagram for RT@1.5, H=18 m, turning tower.

Figure F-48. "Box-and-Whisker" diagram for RT@1.5, H=20 m, turning tower.

Table F-7

DETAILED STATISTICAL SUMMARY OF MEASURED ELECTRIC
FIELDS DATA ADJACENT TO TURNING TOWERS
(WITHOUT TREE SHIELDING)

t=14 CAT=ETM					
VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
E1	47	4.053	0.606	2.231	4.892
E2	47	3.941	0.602	2.449	4.950
E3	47	3.775	0.525	1.970	4.541
E4	47	3.976	0.393	2.748	4.349
E5	47	4.252	0.361	3.237	4.898
E6	47	4.372	0.448	3.914	5.750
E7	47	5.418	0.508	4.303	5.421
E8	47	5.714	0.556	4.415	5.956
E9	47	5.375	0.736	3.926	5.860
E10	47	4.606	0.725	2.939	5.097
E11	47	3.650	0.624	2.315	5.002
E12	47	2.854	0.521	1.710	3.923
E13	47	2.174	0.427	0.675	3.131
t=14 CAT=FT01.5					
E1	6	3.755	0.544	2.834	4.319
E2	6	3.646	0.360	3.139	4.146
E3	6	3.738	0.352	3.332	4.179
E4	6	4.042	0.362	3.634	4.656
E5	6	4.663	0.312	4.303	5.086
E6	6	5.279	0.452	4.735	5.935
E7	6	5.827	0.351	5.530	5.407
E8	6	6.025	0.447	5.532	5.719
E9	6	5.277	0.703	4.517	5.345
E10	6	4.393	0.626	3.650	5.374
E11	6	3.445	0.503	2.740	4.199
E12	6	2.642	0.325	2.173	3.236
E13	6	2.011	0.228	1.701	2.295
t=14 CAT=RT01					
E1	26	3.997	0.644	2.532	4.850
E2	26	3.972	0.532	2.536	4.514
E3	26	3.850	0.409	2.748	4.552
E4	26	3.926	0.277	3.236	4.331
E5	26	4.253	0.393	3.439	5.179
E6	26	4.935	0.621	3.735	5.426
E7	26	5.501	0.604	4.235	5.521
E8	26	5.823	0.735	4.355	7.479
E9	26	5.432	0.975	3.242	7.197
E10	26	4.627	0.816	2.720	5.100
E11	26	3.632	0.731	1.939	5.154
E12	26	2.839	0.557	1.876	5.913
E13	26	2.177	0.392	1.501	2.817

Table F-7
(Continued)

I=14 CAT=RT01.5					
VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
E1	9	3.748	0.720	2.834	4.894
E2	9	3.755	0.544	3.233	4.612
E3	9	3.745	0.454	3.233	4.701
E4	9	4.019	0.245	3.775	4.536
E5	9	4.556	0.427	4.047	5.282
E6	9	5.196	0.696	4.612	6.521
E7	9	5.605	0.801	4.719	7.088
E8	9	5.716	0.892	4.530	5.710
E9	9	5.095	1.019	3.535	5.581
E10	9	4.139	1.074	2.925	5.641
E11	9	3.231	0.874	2.135	4.701
E12	9	2.420	0.755	1.310	3.667
E13	9	1.791	0.679	0.755	3.012
I=15 CAT=FT01					
E1	53	2.872	0.636	1.490	3.834
E2	53	2.871	0.593	1.471	3.650
E3	53	2.926	0.469	1.553	3.650
E4	53	3.111	0.377	1.635	3.842
E5	53	3.403	0.357	2.023	4.226
E6	53	3.806	0.418	2.433	4.798
E7	53	4.197	0.471	2.838	5.273
E8	53	4.527	0.548	3.272	5.667
E9	53	4.358	0.657	2.972	5.820
E10	53	3.833	0.649	2.543	5.238
E11	53	3.259	0.629	2.157	4.656
E12	53	2.633	0.557	1.522	3.733
E13	53	2.190	0.506	1.032	3.724
I=15 CAT=FT01.5					
E1	15	2.379	0.313	1.790	3.026
E2	15	2.468	0.306	1.831	3.062
E3	15	2.685	0.311	2.157	3.556
E4	15	3.101	0.233	2.449	3.457
E5	15	3.515	0.217	2.959	3.903
E6	15	4.001	0.316	3.034	4.461
E7	15	4.310	0.335	3.352	4.739
E8	15	4.352	0.302	3.639	4.939
E9	15	3.951	0.342	3.054	4.642
E10	15	3.404	0.331	2.638	3.951
E11	15	2.743	0.324	2.251	3.556
E12	15	2.152	0.250	1.740	2.720
E13	15	1.741	0.219	1.334	2.235

Table F-7
(Continued)

4=2) CAT=FTD1					
VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
E1	41	1.562	0.320	0.750	2.079
E2	41	1.622	0.247	1.024	2.079
E3	41	1.770	0.195	1.377	2.173
E4	41	1.936	0.154	1.602	2.315
E5	41	2.273	0.176	1.835	2.672
E6	41	2.555	0.210	2.132	3.047
E7	41	2.848	0.231	2.359	3.458
E8	41	3.105	0.336	2.450	3.650
E9	41	3.145	0.377	2.157	3.842
E10	41	2.915	0.407	1.978	3.842
E11	41	2.582	0.395	1.759	3.554
E12	40	2.224	0.372	1.517	3.073
E13	40	1.875	0.352	1.172	2.551
4=2) CAT=FTD1.5					
E1	7	1.553	0.327	1.175	1.979
E2	7	1.583	0.258	1.233	1.887
E3	7	1.695	0.213	1.472	2.025
E4	7	1.940	0.224	1.656	2.301
E5	7	2.204	0.229	1.759	2.465
E6	7	2.441	0.236	1.851	2.671
E7	7	2.646	0.404	1.851	3.043
E8	7	2.851	0.420	1.970	3.324
E9	7	2.827	0.415	1.944	3.278
E10	7	2.661	0.334	1.944	2.997
E11	7	2.317	0.298	1.759	2.634
E12	7	1.973	0.352	1.250	2.314
E13	7	1.592	0.305	0.941	1.851
4=2) CAT=RTD1					
E1	17	1.552	0.405	0.952	2.156
E2	17	1.647	0.444	0.952	2.256
E3	17	1.811	0.369	1.172	2.438
E4	17	2.058	0.279	1.547	2.514
E5	17	2.431	0.314	1.959	2.947
E6	17	2.796	0.411	2.103	3.589
E7	17	3.109	0.549	2.246	4.365
E8	17	3.546	0.741	2.231	5.141
E9	17	3.528	0.753	1.971	5.044
E10	17	3.330	0.774	1.741	4.734
E11	17	3.029	0.749	1.457	4.171
E12	17	2.525	0.590	1.172	3.717
E13	17	2.062	0.591	1.003	2.719

Table F-7
(Continued)

4=13 CAT=FY01.5					
VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
E1	9	1.793	0.253	1.539	2.233
E2	9	1.870	0.256	1.601	2.326
E3	9	2.050	0.175	1.957	2.352
E4	9	2.333	0.086	2.137	2.429
E5	9	2.711	0.134	2.512	2.899
E6	9	3.056	0.193	2.605	3.273
E7	9	3.392	0.170	3.027	3.591
E8	9	3.594	0.172	3.253	3.852
E9	9	3.436	0.339	2.731	3.973
E10	9	3.144	0.370	2.538	3.794
E11	9	2.692	0.526	2.201	3.734
E12	9	2.150	0.438	1.651	3.027
E13	9	1.752	0.357	1.233	2.332
4=13 CAT=RT01					
E1	39	2.053	0.459	1.130	3.099
E2	39	2.129	0.435	1.272	3.241
E3	39	2.313	0.414	1.601	3.856
E4	39	2.512	0.254	2.017	3.073
E5	39	2.867	0.230	2.341	3.459
E6	39	3.256	0.401	2.338	4.034
E7	39	3.639	0.475	2.532	4.706
E8	39	3.621	0.708	2.331	5.282
E9	39	3.758	0.840	1.939	5.432
E10	39	3.371	0.832	1.722	4.898
E11	38	2.915	0.735	1.594	4.520
E12	38	2.452	0.719	1.125	3.892
E13	39	1.938	0.524	0.772	3.029
4=13 CAT=RT01.5					
E1	11	1.910	0.331	1.415	2.407
E2	11	2.025	0.315	1.509	2.497
E3	11	2.199	0.229	1.837	2.542
E4	11	2.402	0.143	2.255	2.730
E5	11	2.820	0.251	2.439	3.350
E6	11	3.251	0.271	2.732	3.628
E7	11	3.613	0.355	3.131	4.402
E8	11	3.327	0.542	3.337	5.234
E9	11	3.922	0.706	3.035	5.551
E10	11	3.619	0.738	2.430	5.360
E11	11	3.013	0.636	1.942	4.534
E12	11	2.470	0.522	1.634	3.541
E13	11	2.020	0.460	1.295	2.957

Table F-7
(Continued)

I=1.5 CAT=RTS1					
VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
E1	35	2.859	0.502	1.770	3.716
E2	35	2.929	0.453	1.978	3.716
E3	35	2.964	0.352	2.241	3.621
E4	35	3.143	0.255	2.574	3.630
E5	35	3.552	0.344	2.779	4.510
E6	35	3.952	0.450	3.113	4.836
E7	35	4.362	0.578	3.275	5.571
E8	35	4.632	0.755	3.332	5.387
E9	35	4.527	0.907	3.046	5.371
E10	35	4.083	0.872	2.573	5.540
E11	35	3.457	0.757	2.117	4.825
E12	35	2.723	0.521	1.379	3.822
E13	35	2.171	0.436	0.955	3.220
I=1.5 CAT=RTS1.5					
E1	13	2.457	0.571	1.724	3.198
E2	13	2.570	0.540	1.814	3.568
E3	13	2.758	0.380	2.036	3.311
E4	13	3.077	0.308	2.338	3.558
E5	13	3.735	0.609	2.859	3.274
E6	13	4.117	0.391	3.412	4.610
E7	13	4.609	0.332	3.955	5.090
E8	13	4.920	0.727	3.914	5.641
E9	13	4.702	0.853	3.448	5.047
E10	13	4.048	0.891	2.750	5.268
E11	13	3.296	0.742	2.200	4.497
E12	13	2.542	0.520	1.614	3.550
E13	13	1.958	0.404	1.375	2.590
I=1.3 CAT=FTS1					
E1	41	2.036	0.475	1.027	2.812
E2	41	2.185	0.430	1.033	2.954
E3	41	2.277	0.302	1.447	2.824
E4	41	2.474	0.212	1.818	3.049
E5	41	2.781	0.228	2.359	3.375
E6	41	3.155	0.239	2.517	3.814
E7	41	3.413	0.290	2.853	4.002
E8	41	3.621	0.453	2.801	5.121
E9	41	3.556	0.473	2.521	4.444
E10	41	3.257	0.470	2.241	4.193
E11	41	2.836	0.459	1.770	3.715
E12	41	2.370	0.417	1.319	3.030
E13	41	1.927	0.344	1.035	2.451

(Continued)

4=2.0 CAT=RI21.5

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
E1	11	1.658	0.338	1.226	2.518
E2	11	1.654	0.347	1.252	2.425
E3	11	1.850	0.313	1.374	2.518
E4	11	2.058	0.248	1.776	2.518
E5	11	2.394	0.211	2.017	2.705
E6	11	2.657	0.233	2.212	3.151
E7	11	2.943	0.237	2.557	3.353
E8	11	3.134	0.354	2.659	3.757
E9	11	3.111	0.405	2.557	3.851
E10	11	2.972	0.406	2.374	3.757
E11	11	2.501	0.528	1.434	3.296
E12	11	2.142	0.421	1.149	2.697
E13	11	1.776	0.475	0.437	2.139

APPENDIX G

DETAILED ELECTRIC FIELDS DATA ANALYSIS WITH TREE SHIELDING

Table G-1 to Table G-4 show the frequency distribution of the sample populations in the various categories for different line heights for 9.15 m and 12.2 m phase spacings. Figure G-1 to Figure G-32 show the "box-and-whisker" diagrams for each of the subcategories. Table G-5 contains the associated statistical summary.

Table G-6 shows the sample populations for the data taken near turning towers. Figures G-33 to G-48 show the "box-and-whisker" diagrams for each of the subcategories, and Table G-7 shows the statistical summary for the data in these subcategories.

Table G-1

FREQUENCY DISTRIBUTION FOR (FT@1) BY PHASE SPACING AND LINE HEIGHT
(WITH TREE SHIELDING)

TABLE OF D BY H CONTROLLING FOR CAT=FT@1					
D	H				
FREQUENCY PERCENT RD 1 PCT					
COL PCT	14	16	18	20	TOTAL
7.15	250 9.22	559 17.32	370 13.32	235 10.14	1475 53.10
	17.39	37.39	26.09	19.13	
	38.45	58.11	51.72	55.57	
12.2	415 14.75	423 14.29	354 12.90	143 5.07	1336 47.10
	31.57	30.39	27.45	10.78	
	51.54	41.39	48.28	33.33	
TOTAL	675 23.35	962 34.10	754 25.73	429 15.21	2821 100.10

Table G-2

FREQUENCY DISTRIBUTION FOR (FT@1.5) BY PHASE SPACING AND LINE HEIGHT
(WITH TREE SHIELDING)

TABLE OF J BY H CONTROLLING FOR CAT=FT@1.5					
FREQUENCY! PERCENT! 30 J PCT!					
CO. PCT	14	16	18	20	TOTAL
7.15	132	247	130	159	726
	7.11	9.54	5.78	6.50	29.43
	25.30	33.93	17.36	23.21	
	25.45	31.67	26.32	29.55	
12.2	533	533	354	423	1833
	20.31	20.31	14.21	15.74	71.57
	29.38	29.38	19.36	21.79	
	74.55	58.33	73.68	70.45	
TOTAL	715	730	434	572	2551
	27.92	30.46	19.29	22.34	100.00

Table G-3

FREQUENCY DISTRIBUTION FOR (RT@1) BY PHASE SPACING AND LINE HEIGHT
(WITH TREE SHIELDING)

TABLE OF D BY H
CONTROLLING FOR CAT=RT@1

D H

FREQUENCY
PERCENT
RD 4 PCT

COL PCT	14	16	18	20	TOTAL
7.15	55 3.27 8.47 17.36	299 15.03 32.78 44.23	234 11.76 30.51 40.91	159 8.30 22.03 44.33	737 38.56
12.2	232 15.13 24.47 32.14	377 18.75 30.35 35.77	338 15.79 27.56 59.39	209 10.46 17.32 55.17	1222 51.44
TOTAL	334 19.30	676 33.99	572 28.76	377 18.95	1939 100.00

Table G-4

FREQUENCY DISTRIBUTION FOR (RT@1.5) BY PHASE SPACING AND LINE HEIGHT
(WITH TREE SHIELDING)

TABLE OF J BY H CONTROLLING FOR CAT=RT@1.5					
J H					
FREQUENCY PERCENT ROW PCT					
COL PCT	14	15	18	20	TOTAL
7.15	132 6.70	390 14.35	351 12.92	159 5.22	1072 40.19
	16.57	35.71	32.14	15.48	
	34.15	44.12	47.37	30.23	
12.2	351 12.92	494 13.13	390 14.35	390 14.35	1625 59.31
	21.50	30.40	24.00	24.00	
	55.35	55.38	52.33	59.77	
TOTAL	533 19.52	834 32.54	741 27.27	559 20.57	2717 100.00

Figure G-1. "Box-and-Whisker" diagram for FT@1, phase spacing = 9.15 m line height = 14 m.

Figure G-2. "Box-and-Whisker" diagram for FT@1, phase spacing = 9.15 m line height = 16 m.

Figure G-3. "Box-and-Whisker" diagram for FT@1, phase spacing = 9.15 m line height = 18 m.

Figure G-4. "Box-and-Whisker" diagram for FT@1, phase spacing = 9.15 m line height = 20 m.

Figure G-5. "Box-and-Whisker" diagram for FT@1, phase spacing = 12.2 m line height = 14 m.

Figure G-6. "Box-and-Whisker" diagram for FT@1, phase spacing = 12.2 m line height = 16 m.

Figure G-7. "Box-and-Whisker" diagram for FT@1, phase spacing = 12.2 m line height = 18 m.

Figure G-8. "Box-and-Whisker" diagram for FT@1, phase spacing = 12.2 m line height = 20 m.

Figure G-9. "Box-and-Whisker" diagram for FT@1.5, phase spacing = 9.15 m line height = 14 m.

Figure G-10. 'Box-and-Whisker' diagram for FT@1.5, phase spacing = 9.15 m line height = 16 m.

Figure G-11. "Box-and-Whisker" diagram for FT@1.5, phase spacing = 9.15 m line height = 18 m.

Figure G-12. "Box-and-Whisker" diagram for FT@1.5, phase spacing = 9.15 m line height = 20 m.

Figure G-13. "Box-and-Whisker" diagram for FT@1.5, phase spacing = 12.2 m line height = 14 m.

Figure G-14. "Box-and-Whisker" diagram for FT@1.5, phase spacing = 12.2 m line height = 16 m.

Figure G-15. "Box-and-Whisker" diagram for FT@1.5, phase spacing = 12.2 m line height = 18 m.

Figure G-16. "Box-and-Whisker" diagram for FT@1.5, phase spacing = 12.2 m line height = 20 m.

Figure G-17. "Box-and-Whisker" diagram for RT@1.5, phase spacing = 9.15 m line height = 14 m.

Figure G-18 "Box-and-Whisker" diagram for RT@1, phase spacing = 9.15 m line height = 16 m.

Figure G-19. "Box-and-Whisker" diagram for RT@1, phase spacing = 9.15 m line height = 18 m.

Figure G-20. "Box-and-Whisker" diagram for RT@1, phase spacing = 9.15 m line height = 20 m.

Figure G-21. "Box-and-Whisker" diagram for RT@1, phase spacing = 12.2 m line height = 14 m.

Figure G-22. "Box-and-Whisker" diagram for RT@1, phase spacing = 12.2 m line height = 16 m.

Figure G-23. "Box-and-Whisker" diagram for RT@1, phase spacing = 12.2 m line height = 18 m.

Figure G-24. "Box-and-Whisker" diagram for RT@1, phase spacing = 12.2 m line height = 20 m.

Figure G-25. "Box-and-Whisker" diagram for RT@1.5, phase spacing = 9.15 m line height = 14 m.

Figure G-26. "Box-and-Whisker" diagram for RT@1.5, phase spacing = 9.15 m line height = 16 m.

Figure G-27. "Box-and-Whisker" diagram for RT@1.5', phase spacing = 9.15 m line height = 18 m.

Figure G-28. "Box-and-Whisker" diagram for RT@1.5, phase spacing = 9.15 m line height = 20 m.

Figure G-29. "Box-and-whisker" diagram for RT@1.5, phase spacing = 12.2 m line height = 14 m.

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Figure G-31. "Box-and-Whisker" diagram for RT@1.5, phase spacing = 12.2 m line height = 18 m.

Figure G-32. "Bcx-and-Whisker" diagram for RT@1.5, phase spacing = 12.2 m line height = 20 m.

Table G-5

DETAILED STATISTICAL SUMMARY OF ELECTRIC FIELDS DATA
(WITH TREE SHIELDING)

D=9.15 H=14 CAT=FL31					
VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
E1	20	2.376	0.553	1.036	2.653
E2	20	2.615	0.230	1.631	3.024
E3	20	3.153	0.151	2.977	3.496
E4	20	3.639	0.246	3.256	4.252
E5	20	4.237	0.194	3.815	4.569
E6	20	4.707	0.371	4.154	5.347
E7	20	4.700	0.407	3.921	5.347
E8	20	4.232	0.499	3.237	5.012
E9	20	3.332	0.555	2.276	4.297
E10	20	2.190	0.723	1.518	3.495
E11	19	1.117	0.813	0.047	2.419
E12	16	0.697	0.720	0.030	2.055
E13	16	0.335	0.458	0.030	1.409
D=9.15 H=14 CAT=FL01.5					
E1	14	2.603	0.259	2.211	3.142
E2	14	2.755	0.222	2.437	3.237
E3	14	3.132	0.239	2.579	3.605
E4	14	3.635	0.456	2.614	4.474
E5	14	4.325	0.593	2.933	5.522
E6	14	4.712	0.697	2.933	5.617
E7	14	4.773	0.837	2.733	5.835
E8	14	4.210	0.923	1.842	5.481
E9	14	3.212	0.870	1.230	4.536
E10	13	2.197	0.754	1.632	3.303
E11	11	1.384	0.746	0.401	2.377
E12	10	0.730	0.733	0.030	1.642
E13	9	0.425	0.504	0.030	1.140
D=9.15 H=14 CAT=RL01					
E1	5	2.422	0.053	2.351	2.496
E2	5	2.629	0.093	2.530	2.732
E3	5	3.198	0.297	2.959	3.639
E4	5	3.739	0.357	3.357	4.393
E5	5	4.372	0.509	3.954	4.972
E6	5	4.792	0.930	4.113	5.215
E7	5	4.850	0.709	4.142	5.737
E8	5	4.373	0.775	3.644	5.554
E9	5	3.496	0.715	2.778	4.303
E10	5	2.396	0.510	1.945	3.064
E11	5	1.390	0.370	1.111	1.834
E12	5	0.537	0.406	0.034	0.958
E13	5	0.116	0.170	0.030	0.332

Table G-5
(Continued)

D=9.15 H=14 CAT=FI01.5					
VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
E1	14	2.615	0.346	1.951	3.222
E2	14	2.804	0.234	2.334	3.422
E3	14	3.244	0.393	2.423	3.899
E4	14	3.773	0.372	3.032	4.278
E5	14	4.430	0.500	3.417	5.133
E6	14	5.041	0.634	3.721	5.894
E7	14	5.135	0.804	3.349	5.274
E8	14	4.538	0.939	2.552	5.989
E9	14	3.621	0.935	1.555	4.753
E10	14	2.324	0.935	0.502	3.422
E11	13	1.274	0.910	0.073	2.525
E12	12	0.608	0.764	0.070	1.633
E13	11	0.179	0.316	0.070	1.029
D=9.15 H=15 CAT=FI01					
E1	43	1.535	0.154	1.401	2.395
E2	43	1.333	0.144	1.530	2.442
E3	43	2.217	0.139	1.921	2.540
E4	43	2.715	0.174	2.351	3.208
E5	43	3.193	0.254	2.656	3.608
E6	43	3.473	0.357	2.698	4.379
E7	43	3.470	0.375	2.513	4.201
E8	43	3.170	0.510	2.015	4.014
E9	43	2.456	0.653	0.803	3.546
E10	43	1.616	0.748	0.002	2.874
E11	42	0.790	0.738	0.000	2.296
E12	38	0.426	0.551	0.000	1.745
E13	37	0.219	0.424	0.000	1.377
D=9.15 H=15 CAT=FI01.5					
E1	19	1.720	0.157	1.559	2.063
E2	19	1.995	0.123	1.651	2.435
E3	19	2.413	0.225	2.123	2.956
E4	19	2.910	0.255	2.534	3.237
E5	19	3.371	0.521	2.909	4.004
E6	19	3.625	0.435	3.032	4.336
E7	19	3.663	0.455	2.892	4.401
E8	19	3.354	0.384	2.753	4.094
E9	19	2.536	0.505	1.676	3.255
E10	19	1.542	0.657	0.625	2.622
E11	15	0.793	0.631	0.000	1.845
E12	12	0.426	0.413	0.000	1.124
E13	9	0.227	0.234	0.000	0.655

Table G-5
(Continued)

D=9.15 H=15 CAT=RF01					
VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
E1	23	1.633	0.233	0.759	1.855
E2	23	1.892	0.150	1.438	2.069
E3	23	2.193	0.154	1.919	2.540
E4	23	2.625	0.216	2.234	3.347
E5	23	3.034	0.348	2.534	4.016
E6	23	3.478	0.555	2.749	4.877
E7	23	3.441	0.732	1.459	4.994
E8	23	3.219	0.839	2.015	4.592
E9	23	2.558	0.813	1.252	3.874
E10	23	1.653	0.895	0.135	3.155
E11	22	0.954	0.776	0.000	2.307
E12	21	0.555	0.542	0.000	1.442
E13	21	0.314	0.457	0.000	1.477
D=9.15 H=15 CAT=RF01.5					
E1	30	1.752	0.213	1.471	2.254
E2	30	1.911	0.150	1.615	2.241
E3	30	2.236	0.177	1.938	2.801
E4	30	2.751	0.240	2.253	3.407
E5	30	3.324	0.421	2.412	4.198
E6	30	3.581	0.558	2.355	4.603
E7	30	3.636	0.799	2.310	5.678
E8	30	3.290	0.734	2.079	5.016
E9	30	2.503	0.654	1.200	3.753
E10	29	1.624	0.746	0.042	3.731
E11	28	0.753	0.627	0.000	2.400
E12	25	0.254	0.411	0.000	1.651
E13	25	0.091	0.255	0.000	1.334
D=9.15 H=13 CAT=FF01					
E1	30	1.154	0.078	1.027	1.405
E2	30	1.338	0.150	1.113	1.779
E3	30	1.649	0.140	1.375	1.957
E4	30	2.070	0.227	1.650	2.716
E5	30	2.450	0.232	1.957	3.055
E6	30	2.618	0.319	2.013	3.342
E7	30	2.723	0.412	1.924	3.808
E8	30	2.481	0.507	1.559	3.158
E9	30	1.955	0.625	1.017	2.876
E10	30	1.231	0.704	0.000	2.341
E11	30	0.536	0.645	0.000	1.859
E12	27	0.324	0.529	0.000	1.615
E13	25	0.177	0.431	0.000	1.339

Table G-5
(Continued)

D=9.15 H=13 CAT=RT@1.5					
VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
E1	10	1.146	0.09	1.015	1.235
E2	10	1.308	0.10	1.154	1.520
E3	10	1.695	0.12	1.477	1.838
E4	10	2.108	0.15	1.932	2.441
E5	10	2.449	0.12	2.211	2.753
E6	10	2.652	0.27	2.211	3.030
E7	10	2.750	0.33	2.119	3.134
E8	10	2.653	0.32	1.953	3.237
E9	10	2.145	0.43	1.177	2.715
E10	10	1.455	0.75	0.038	2.243
E11	9	0.932	0.73	0.037	1.825
E12	8	0.640	0.51	0.030	1.531
E13	8	0.391	0.50	0.030	1.377
D=9.15 H=13 CAT=RT@1					
E1	12	1.174	0.08	1.019	1.297
E2	18	1.297	0.13	1.130	1.554
E3	18	1.593	0.12	1.397	1.754
E4	18	2.027	0.15	1.759	2.449
E5	18	2.351	0.22	1.852	2.639
E6	18	2.658	0.39	1.835	3.332
E7	13	2.725	0.54	1.637	3.522
E8	13	2.546	0.67	1.250	3.526
E9	19	2.077	0.71	1.019	3.365
E10	18	1.350	0.81	0.037	2.992
E11	17	0.755	0.77	0.032	2.391
E12	16	0.357	0.53	0.030	1.931
E13	16	0.173	0.42	0.030	1.554
D=9.15 H=13 CAT=RT@1.5					
E1	27	1.252	0.21	1.015	1.853
E2	27	1.374	0.24	1.133	1.978
E3	27	1.701	0.23	1.352	2.316
E4	27	2.112	0.24	1.678	2.638
E5	27	2.506	0.32	1.938	3.313
E6	27	2.830	0.42	2.077	3.851
E7	27	2.977	0.53	2.123	4.237
E8	27	2.635	0.74	1.346	4.877
E9	27	2.326	0.79	1.138	4.520
E10	27	1.524	0.81	0.425	3.831
E11	26	0.794	0.74	0.030	2.779
E12	23	0.355	0.50	0.030	1.750
E13	22	0.142	0.25	0.030	1.138

Table G-5
(Continued)

J=9.15 H=20 CAT=FT01					
VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
E1	22	0.779	0.104	0.573	1.000
E2	22	0.945	0.102	0.749	1.117
E3	22	1.247	0.132	1.039	1.611
E4	22	1.556	0.155	1.232	1.802
E5	22	1.670	0.250	1.374	2.369
E6	22	2.070	0.232	1.511	2.606
E7	22	2.118	0.329	1.444	2.614
E8	22	2.017	0.439	1.071	2.749
E9	22	1.639	0.525	0.530	2.464
E10	22	1.135	0.625	0.095	2.274
E11	22	0.636	0.603	0.030	1.800
E12	21	0.324	0.504	0.030	1.525
E13	20	0.132	0.362	0.030	1.035
J=9.15 H=20 CAT=FT01.5					
E1	13	0.846	0.079	0.702	0.953
E2	13	1.025	0.117	0.846	1.313
E3	13	1.325	0.113	1.110	1.520
E4	13	1.670	0.131	1.474	1.929
E5	13	1.953	0.190	1.612	2.251
E6	13	2.129	0.281	1.612	2.526
E7	13	2.151	0.333	1.420	2.626
E8	12	2.018	0.404	1.117	2.532
E9	12	1.630	0.570	0.453	2.190
E10	11	1.146	0.657	0.252	1.916
E11	11	0.636	0.643	0.030	1.642
E12	10	0.322	0.516	0.030	1.359
E13	7	0.350	0.403	0.030	1.034
J=9.15 H=20 CAT=RT01					
E1	13	0.794	0.113	0.573	0.951
E2	13	0.998	0.153	0.705	1.309
E3	13	1.190	0.207	1.012	1.633
E4	13	1.547	0.240	1.239	2.151
E5	13	1.662	0.250	1.557	2.431
E6	13	2.037	0.357	1.455	2.805
E7	13	2.097	0.505	0.833	2.610
E8	13	1.857	0.652	0.754	2.809
E9	13	1.551	0.655	0.436	2.341
E10	13	1.127	0.746	0.030	2.435
E11	12	0.700	0.649	0.030	1.992
E12	11	0.342	0.545	0.030	1.853
E13	11	0.161	0.501	0.030	1.633

Table G-5
(Continued)

J=9.15 H=20 CAT=RT91.5					
VAR TABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
E1	13	0.926	0.137	0.702	1.317
E2	13	1.049	0.220	0.777	1.411
E3	13	1.333	0.275	1.011	1.975
E4	13	1.576	0.254	1.237	2.316
E5	13	1.952	0.224	1.471	2.257
E6	13	2.249	0.271	1.747	2.634
E7	13	2.334	0.335	1.747	2.954
E8	13	2.299	0.457	1.471	2.296
E9	13	2.038	0.734	0.748	3.955
E10	13	1.505	0.909	0.140	3.573
E11	13	0.929	0.777	0.000	2.686
E12	10	0.599	0.554	0.000	1.853
E13	10	0.256	0.393	0.000	1.100
J=12.2 H=14 CAT=FT91					
E1	32	3.954	0.256	3.270	4.324
E2	32	3.065	0.251	3.384	4.545
E3	32	3.730	0.253	3.219	4.402
E4	32	3.841	0.431	2.049	4.608
E5	32	4.195	0.517	1.853	5.158
E6	32	4.813	0.454	3.737	5.742
E7	32	5.211	0.544	4.140	5.245
E8	32	5.144	0.715	3.630	5.535
E9	31	4.355	0.750	2.555	5.756
E10	31	2.966	0.956	0.934	4.565
E11	29	1.577	1.191	0.000	3.552
E12	20	1.025	0.851	0.000	2.329
E13	18	0.598	0.393	0.000	1.675
J=12.2 H=14 CAT=FT91.5					
E1	41	4.037	0.257	3.206	4.743
E2	41	4.015	0.274	3.017	4.592
E3	41	3.817	0.276	2.670	4.258
E4	41	3.858	0.237	2.732	4.531
E5	41	4.215	0.299	3.300	4.773
E6	41	4.695	0.373	3.374	5.405
E7	41	4.951	0.479	3.932	5.050
E8	41	4.870	0.722	3.250	5.749
E9	41	3.832	0.848	2.215	5.050
E10	41	2.329	0.899	0.650	4.215
E11	37	1.052	0.829	0.000	2.932
E12	26	0.537	0.717	0.000	2.229
E13	26	0.234	0.445	0.000	1.511

Table G-5
(Continued)

J=12.2 H=14 CAT=RT31					
VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
E1	23	3.733	0.770	0.859	4.356
E2	23	3.769	0.444	2.534	4.647
E3	23	3.726	0.255	3.126	4.134
E4	23	3.824	0.245	3.315	4.235
E5	23	4.231	0.434	3.410	5.243
E6	23	4.728	0.531	3.919	5.847
E7	23	5.103	0.676	3.919	5.452
E8	23	4.942	0.977	3.432	5.805
E9	23	4.020	1.028	2.440	5.156
E10	23	2.475	1.013	0.934	4.651
E11	19	1.137	1.100	0.030	3.721
E12	13	0.636	1.192	0.030	3.070
E13	9	0.775	0.925	0.030	2.099
J=12.2 H=14 CAT=RT31.5					
E1	27	4.047	0.317	3.251	4.524
E2	27	4.072	0.337	3.357	4.698
E3	27	3.959	0.379	3.245	4.755
E4	27	3.939	0.345	3.254	4.544
E5	27	4.339	0.525	3.336	5.320
E6	27	4.955	0.593	3.533	5.127
E7	27	5.358	0.840	3.347	5.691
E8	27	5.136	1.057	3.440	5.915
E9	27	4.254	1.031	1.630	5.040
E10	27	2.739	1.193	0.477	4.602
E11	24	1.345	1.110	0.035	3.452
E12	14	0.534	0.810	0.030	2.735
E13	13	0.485	0.646	0.030	2.075
J=12.2 H=15 CAT=FT31					
E1	31	2.758	0.199	2.353	3.451
E2	31	2.737	0.204	2.333	3.451
E3	31	2.020	0.187	2.379	3.259
E4	31	2.933	0.253	2.239	3.313
E5	31	3.335	0.233	2.333	3.770
E6	31	3.658	0.378	2.519	4.446
E7	31	3.991	0.447	2.975	4.929
E8	31	3.952	0.550	2.578	4.927
E9	31	3.325	0.747	1.735	4.833
E10	31	2.139	0.842	0.532	3.953
E11	29	0.977	0.848	0.030	2.811
E12	16	0.711	0.633	0.030	1.933
E13	12	0.406	0.454	0.030	1.426

Table G-5
(Continued)

J=12.2 H=15 CAT=RTD1.5					
VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
E1	41	2.835	0.210	2.478	3.449
E2	41	2.924	0.132	2.579	3.258
E3	41	2.956	0.210	2.591	3.545
E4	41	3.132	0.192	2.739	3.639
E5	41	3.431	0.222	2.925	3.892
E6	41	3.822	0.232	3.279	4.410
E7	41	4.044	0.401	3.340	5.273
E8	41	3.973	0.634	2.611	5.232
E9	41	3.253	0.632	2.171	5.115
E10	40	1.954	0.733	0.757	4.262
E11	37	0.858	0.994	0.010	3.356
E12	39	0.330	0.615	0.010	2.469
E13	24	0.157	0.337	0.010	1.534
J=12.2 H=15 CAT=RTD1					
E1	29	2.652	0.511	0.474	3.272
E2	29	2.630	0.410	1.630	3.340
E3	29	2.789	0.334	2.136	3.338
E4	29	2.922	0.311	2.271	3.451
E5	29	3.323	0.432	2.473	4.601
E6	29	3.655	0.539	2.734	5.129
E7	29	3.870	0.674	2.854	5.751
E8	29	3.720	0.848	2.475	5.751
E9	29	3.143	1.047	1.714	5.560
E10	29	2.296	1.133	0.434	4.637
E11	22	1.542	1.139	0.010	3.738
E12	19	1.035	1.053	0.010	2.057
E13	13	0.953	0.301	0.010	2.216
J=12.2 H=16 CAT=RTD1.5					
E1	38	2.931	0.243	2.353	3.551
E2	38	2.973	0.302	2.259	3.746
E3	38	2.955	0.267	2.391	3.554
E4	38	3.130	0.271	2.635	3.769
E5	39	3.417	0.301	2.755	4.027
E6	38	3.875	0.573	2.357	4.949
E7	38	4.193	0.758	2.815	5.641
E8	38	4.105	0.952	2.315	5.740
E9	38	3.449	1.075	1.030	5.273
E10	38	2.335	1.164	0.010	4.751
E11	34	1.350	1.142	0.010	3.748
E12	24	0.878	0.700	0.010	1.655
E13	21	0.438	0.575	0.010	2.142

Table G-5
(Continued)

D=12.2 H=13 CAT=FTD1					
VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
E1	28	1.852	0.400	0.819	2.351
E2	28	1.926	0.355	1.105	2.549
E3	28	2.056	0.358	0.975	2.549
E4	28	2.206	0.355	0.975	2.670
E5	28	2.521	0.339	1.537	3.004
E6	28	2.750	0.481	1.345	3.408
E7	28	2.954	0.538	1.345	3.739
E8	28	2.975	0.503	1.632	3.895
E9	28	2.500	0.740	1.171	3.603
E10	28	1.798	0.944	0.324	3.320
E11	22	1.212	1.002	0.000	2.881
E12	16	0.850	0.833	0.000	2.305
E13	12	0.792	0.773	0.000	1.921
D=12.2 H=18 CAT=FTD1.5					
E1	28	2.048	0.163	1.659	2.352
E2	28	2.113	0.174	1.659	2.473
E3	28	2.210	0.170	1.777	2.546
E4	28	2.413	0.163	2.171	2.735
E5	28	2.757	0.226	2.378	3.259
E6	28	3.032	0.335	2.514	3.737
E7	28	3.344	0.387	2.777	4.314
E8	28	3.322	0.526	2.442	4.745
E9	28	2.849	0.715	1.777	4.793
E10	28	1.936	0.799	0.813	3.865
E11	28	0.957	0.948	0.000	3.403
E12	20	0.504	0.737	0.000	2.216
E13	15	0.344	0.528	0.000	1.521
D=12.2 H=18 CAT=RTD1					
E1	26	2.034	0.233	1.303	2.442
E2	26	2.033	0.247	1.316	2.602
E3	26	2.136	0.257	1.532	2.839
E4	26	2.429	0.357	1.675	3.312
E5	26	2.752	0.391	2.047	3.724
E6	26	3.113	0.503	2.153	4.489
E7	26	3.413	0.748	1.873	5.156
E8	26	3.433	0.927	1.532	5.538
E9	26	3.152	1.032	1.245	5.347
E10	26	2.310	1.175	0.173	4.488
E11	23	1.594	1.102	0.000	3.547
E12	20	0.950	0.936	0.000	2.972
E13	14	0.728	0.802	0.000	2.357

Table G-5
(Continued)

D=12.2 N=13 CAT=RTD1.5					
VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
E1	30	2.089	0.140	1.857	2.341
E2	30	2.123	0.233	1.193	2.483
E3	30	2.227	0.182	1.934	2.672
E4	30	2.401	0.210	1.931	2.834
E5	30	2.633	0.251	2.170	2.822
E6	30	3.039	0.413	2.126	3.746
E7	30	3.311	0.533	2.034	4.274
E8	30	3.332	0.735	1.849	5.059
E9	30	3.856	0.904	1.274	5.340
E10	30	1.851	0.829	0.575	4.403
E11	27	0.959	0.843	0.010	3.135
E12	16	0.435	0.493	0.010	1.555
E13	15	0.223	0.329	0.010	1.935
D=12.2 N=20 CAT=FTD1					
E1	11	1.390	0.211	0.855	1.530
E2	11	1.439	0.219	0.950	1.719
E3	11	1.639	0.217	1.121	1.909
E4	11	1.921	0.196	1.632	2.027
E5	11	2.136	0.122	1.932	2.377
E6	11	2.373	0.216	2.013	2.552
E7	11	2.617	0.366	2.034	3.230
E8	11	2.635	0.435	2.037	3.325
E9	11	2.308	0.617	1.574	3.236
E10	11	1.826	0.872	0.074	3.040
E11	10	1.359	0.856	0.170	2.616
E12	8	0.973	0.834	0.010	2.243
E13	7	0.696	0.728	0.010	1.532
D=12.2 N=20 CAT=FTD1.5					
E1	31	1.493	0.200	1.174	1.823
E2	31	1.565	0.192	1.156	1.874
E3	31	1.697	0.190	1.239	2.004
E4	31	1.910	0.171	1.573	2.195
E5	31	2.139	0.133	1.739	2.640
E6	31	2.368	0.239	1.942	3.057
E7	31	2.493	0.313	1.729	3.257
E8	31	2.326	0.417	1.640	3.243
E9	31	1.873	0.460	1.013	2.591
E10	31	1.140	0.564	0.019	2.220
E11	27	0.483	0.474	0.010	1.655
E12	19	0.171	0.277	0.010	1.931
E13	18	0.036	0.219	0.010	1.839

Table G-5
(Continued)

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
E1	16	1.515	0.190	0.272	1.658
E2	16	1.559	0.253	0.854	1.870
E3	16	1.629	0.291	1.025	2.338
E4	16	1.546	0.381	1.325	2.947
E5	16	2.126	0.521	1.151	3.612
E6	16	2.475	0.620	1.326	4.038
E7	16	2.672	0.735	1.355	4.373
E8	16	2.777	0.859	1.056	4.458
E9	16	2.635	0.957	0.571	5.993
E10	16	2.135	0.944	0.295	5.652
E11	16	1.557	0.790	0.020	5.257
E12	13	1.055	0.754	0.357	2.422
E13	11	0.930	0.635	0.096	2.100

J=12.2	H=20	CAT=RF01.5			
E1	30	1.541	0.123	1.277	1.744
E2	30	1.604	0.143	1.277	1.939
E3	30	1.797	0.130	1.535	2.035
E4	30	1.878	0.158	1.535	2.188
E5	30	2.130	0.225	1.574	2.532
E6	30	2.365	0.254	1.759	2.892
E7	30	2.593	0.428	1.656	3.419
E8	30	2.657	0.572	1.157	4.129
E9	30	2.425	0.805	0.716	4.410
E10	30	1.732	0.904	0.151	4.128
E11	29	0.947	1.074	0.030	3.135
E12	21	0.410	1.554	0.030	1.825
E13	18	0.150	0.227	0.030	0.805

Table G-6

FREQUENCY DISTRIBUTION FOR ELECTRIC FIELDS DATA ADJACENT TO TURNING TOWERS
(WITH TREE SHIELDING)

TABLE OF CAT BY H					
CAT	H				
FREQUENCY PERCENT NO. & PCT GR. PCT	114	115	118	120	TOTAL
T01	159 5.33 29.12 27.55	208 5.93 23.53 22.85	273 9.09 30.39 33.33	234 7.79 26.47 35.29	834 29.44
T01.5	143 4.76 26.33 23.40	208 6.72 39.02 22.35	31 3.23 17.37 11.11	71 3.23 17.37 13.73	533 17.75
T01	143 4.75 16.72 23.40	225 9.52 33.35 31.43	228 6.93 24.52 25.40	223 6.93 24.52 31.37	845 28.14
T01.5	156 5.19 21.75 25.53	208 6.93 23.07 22.35	247 9.23 33.33 30.16	130 4.53 17.54 17.51	741 24.58
TOTAL	611 20.35	910 30.30	819 27.37	653 22.08	3033 100.00

Figure G-33. "Box-and-Whisker" for FT@1, line height 14 m, irregular phase spacing.

Figure G-34. "Box-and-Whisker" for FT@1, line height 16 m, irregular phase spacing.

Figure G-35. "Box-and-Whisker" for FT@1, line height 18 m, irregular phase spacing.

Figure G-36. "Box-and-Whisker" for FT@1, line height 20 m, irregular phase spacing.

Figure G-37. "Box-and-Whisker" for FT@1.5, line height 14 m, irregular phase spacing.

Figure G-38. "Box-and-Whisker" for FT@1.5, line height 16 m, irregular phase spacing.

Figure G-39. "Box-and-Whisker" for FT@1.5, line height 18 m, irregular phase spacing.

Figure G-40. "Box-and-Whisker" for FT@1.5, line height 20 m, irregular phase spacing.

Figure G-41. "Box-and-Whisker" for RT@1, line height 14 m, irregular phase spacing.

Figure G-42. "Box-and-Whisker" for RT@1, line height 16 m, irregular phase spacing.

Figure G-43. "Box-and-Whisker" for RT@1, line height 18 m, irregular phase spacing.

Figure G-44. "Box-and-Whisker" for RT@1, line height 20 m, irregular phase spacing.

Figure G-45. "Box-and-Whisker" for RT@1.5, line height 14 m, irregular phase spacing.

Figure G-46. "Box-and-Whisker" for RT@1.5, line height 16 m, irregular phase spacing.

Figure G-47. "Box-and-Whisker" for RT@1.5, line height 18 m, irregular phase spacing.

Figure G-48. "Box-and-Whisker" for RT@1.5, line height 20 m, irregular phase spacing.

Table G-7

DETAILED STATISTICAL SUMMARY OF MEASURED ELECTRIC
FIELDS DATA ADJACENT TO TURNING TOWERS
(WITH TREE SHIELDING)

I=14 CAT=FT21					
VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
E1	47	4.052	0.606	2.251	4.892
E2	47	3.941	0.592	2.449	4.850
E3	47	3.776	0.525	1.990	4.541
E4	47	3.275	0.323	2.748	4.348
E5	47	4.252	0.351	3.257	4.895
E6	47	4.872	0.448	3.914	5.750
E7	47	5.419	0.503	4.308	5.421
E8	47	5.714	0.658	4.405	5.956
E9	47	5.375	0.736	3.925	5.850
E10	47	4.696	0.725	2.959	5.037
E11	47	3.650	0.624	2.355	5.002
E12	47	2.854	0.521	1.770	3.923
E13	47	2.174	0.427	1.576	3.131
I=14 CAT=FT21.5					
E1	6	3.755	0.544	2.834	4.318
E2	6	3.646	0.360	3.159	4.146
E3	6	3.738	0.352	3.352	4.199
E4	6	4.042	0.352	3.634	4.656
E5	6	4.663	0.312	4.333	5.025
E6	5	5.299	0.452	4.735	5.955
E7	6	5.237	0.351	5.550	5.407
E8	6	5.025	0.447	5.532	5.719
E9	6	5.277	0.703	4.517	5.345
E10	6	4.393	0.626	3.650	5.374
E11	5	3.446	0.503	2.740	4.199
E12	6	2.642	0.395	2.173	3.266
E13	5	2.011	0.228	1.731	2.295
I=14 CAT=RT21					
E1	26	3.997	0.644	2.532	4.850
E2	26	3.972	0.532	2.558	4.524
E3	26	3.858	0.409	2.748	4.552
E4	25	3.906	0.279	3.206	4.331
E5	26	4.253	0.393	3.439	5.179
E6	26	4.955	0.621	3.735	5.426
E7	26	5.501	0.604	4.236	5.521
E8	25	5.823	0.735	4.355	7.479
E9	26	5.482	0.975	3.242	7.197
E10	26	4.627	0.816	2.790	5.108
E11	26	3.632	0.731	1.959	5.154
E12	25	2.839	0.557	1.875	3.913
E13	25	2.137	0.392	1.511	2.917

Table G-7
(Continued)

I=1.5 CAT=RT01					
VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
E1	35	2.859	0.503	1.710	3.715
E2	35	2.929	0.453	1.979	3.715
E3	35	2.954	0.352	2.241	3.621
E4	35	3.143	0.255	2.574	3.650
E5	35	3.552	0.344	2.777	4.510
E6	35	3.952	0.450	3.102	4.836
E7	35	4.262	0.578	3.296	5.571
E8	35	4.682	0.755	3.332	5.597
E9	35	4.597	0.937	3.045	5.371
E10	35	4.033	0.872	2.573	5.540
E11	35	3.457	0.767	2.107	4.826
E12	35	2.723	0.621	1.379	3.922
E13	35	2.171	0.456	0.955	3.220
I=1.5 CAT=RT01.5					
E1	13	2.457	0.571	1.724	3.138
E2	13	2.570	0.540	1.814	3.558
E3	13	2.732	0.390	2.035	3.311
E4	13	3.037	0.328	2.338	3.559
E5	13	3.735	0.609	2.859	5.274
E6	13	4.117	0.331	3.412	4.610
E7	13	4.609	0.332	3.935	5.090
E8	13	4.990	0.727	3.914	5.541
E9	13	4.792	0.853	3.449	5.047
E10	13	4.048	0.891	2.750	5.253
E11	13	3.296	0.742	2.290	4.497
E12	13	2.542	0.520	1.624	3.562
E13	13	1.952	0.404	1.375	2.590
I=1.3 CAT=FT01					
E1	41	2.036	0.475	1.027	2.812
E2	41	2.155	0.450	1.033	2.954
E3	41	2.277	0.302	1.447	2.824
E4	41	2.474	0.212	1.878	3.047
E5	41	2.791	0.228	2.359	3.375
E6	41	3.155	0.239	2.577	3.814
E7	41	3.413	0.270	2.853	4.072
E8	41	3.621	0.459	2.301	5.121
E9	41	3.556	0.479	2.521	4.444
E10	41	3.257	0.470	2.241	4.193
E11	41	2.856	0.459	1.770	3.715
E12	41	2.370	0.417	1.319	3.030
E13	41	1.927	0.344	1.036	2.451

Table G-7
(Continued)

I=14 CAT=RT01.5

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
E1	9	3.768	0.720	2.854	4.694
E2	9	3.755	0.544	3.223	4.512
E3	9	3.745	0.454	3.223	4.701
E4	9	4.019	0.245	3.775	4.536
E5	9	4.556	0.427	4.047	5.282
E6	9	5.196	0.535	4.612	5.521
E7	9	5.605	0.801	4.719	7.088
E8	9	5.715	0.822	4.530	5.710
E9	9	5.035	1.019	3.535	5.521
E10	9	4.139	1.074	2.925	5.641
E11	9	3.231	0.374	2.135	4.701
E12	9	2.420	0.755	1.330	3.557
E13	9	1.791	0.679	0.755	3.012

I=15 CAT=FT01

E1	53	2.872	0.636	1.470	3.834
E2	53	2.871	0.593	1.471	3.650
E3	53	2.926	0.469	1.533	3.650
E4	53	3.111	0.377	1.655	3.842
E5	53	3.403	0.357	2.023	4.225
E6	53	3.826	0.419	2.433	4.798
E7	53	4.197	0.471	2.873	5.273
E8	53	4.527	0.542	3.272	5.667
E9	53	4.358	0.657	2.932	5.820
E10	53	3.833	0.549	2.543	5.238
E11	53	3.259	0.629	2.137	4.656
E12	53	2.638	0.557	1.522	3.723
E13	53	2.100	0.506	1.052	3.724

I=15 CAT=FT01.5

E1	15	2.379	0.313	1.730	3.026
E2	15	2.448	0.306	1.831	3.062
E3	15	2.685	0.311	2.137	3.556
E4	15	3.121	0.233	2.449	3.457
E5	15	3.515	0.217	2.939	3.903
E6	15	4.001	0.316	3.034	4.451
E7	15	4.310	0.335	3.332	4.739
E8	15	4.362	0.302	3.639	4.937
E9	15	3.951	0.342	3.034	4.642
E10	15	3.404	0.331	2.638	3.951
E11	15	2.743	0.324	2.231	3.556
E12	15	2.152	0.250	1.748	2.720
E13	15	1.741	0.218	1.334	2.235

Table G-7
(Continued)

I=13 CAT=RTG1.5					
VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
E1	9	1.793	0.253	1.559	2.233
E2	9	1.870	0.236	1.631	2.326
E3	9	2.050	0.175	1.877	2.332
E4	9	2.333	0.075	2.157	2.429
E5	9	2.711	0.134	2.512	2.899
E6	9	3.056	0.193	2.615	3.273
E7	9	3.332	0.170	3.027	3.591
E8	9	3.574	0.172	3.253	3.652
E9	9	3.435	0.339	2.751	3.973
E10	9	3.144	0.390	2.532	3.794
E11	9	2.692	0.526	2.231	3.794
E12	9	2.150	0.435	1.651	3.027
E13	9	1.752	0.357	1.238	2.332
I=13 CAT=RTG1					
E1	39	2.063	0.455	1.150	3.095
E2	39	2.129	0.435	1.272	3.241
E3	39	2.313	0.414	1.631	3.855
E4	39	2.512	0.234	2.017	3.073
E5	39	2.847	0.250	2.341	3.453
E6	39	3.255	0.431	2.338	4.034
E7	39	3.609	0.435	2.532	4.705
E8	39	3.821	0.738	2.371	5.232
E9	39	3.758	0.840	1.959	5.432
E10	39	3.371	0.362	1.732	4.898
E11	38	2.915	0.785	1.574	4.530
E12	38	2.432	0.712	1.125	3.932
E13	38	1.938	0.524	0.772	3.029
I=13 CAT=RTG1.5					
E1	11	1.910	0.331	1.415	2.427
E2	11	2.025	0.315	1.537	2.477
E3	11	2.199	0.229	1.837	2.542
E4	11	2.432	0.143	2.255	2.730
E5	11	2.820	0.251	2.459	3.350
E6	11	3.251	0.291	2.752	3.829
E7	11	3.618	0.355	3.131	4.402
E8	11	3.927	0.562	3.357	5.254
E9	11	3.922	0.736	3.055	5.551
E10	11	3.619	0.738	2.450	5.350
E11	11	3.013	0.526	1.942	4.594
E12	11	2.470	0.522	1.554	3.541
E13	11	2.020	0.450	1.275	2.957

Table G-7
(Continued)

4=2) CAT=FT01					
VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
E1	41	1.542	0.320	0.750	2.079
E2	41	1.622	0.247	1.034	2.079
E3	41	1.770	0.195	1.397	2.173
E4	41	1.986	0.134	1.622	2.315
E5	41	2.273	0.175	1.835	2.672
E6	41	2.555	0.210	2.132	3.047
E7	41	2.848	0.291	2.359	3.458
E8	41	3.133	0.335	2.450	3.650
E9	41	3.145	0.397	2.157	3.842
E10	41	2.915	0.407	1.978	3.842
E11	41	2.532	0.396	1.759	3.554
E12	40	2.224	0.372	1.517	3.073
E13	40	1.875	0.352	1.172	2.551
4=2) CAT=FT01.5					
E1	7	1.553	0.327	1.176	1.979
E2	7	1.533	0.258	1.238	1.897
E3	7	1.695	0.218	1.472	2.025
E4	7	1.940	0.224	1.656	2.301
E5	7	2.204	0.229	1.759	2.435
E6	7	2.441	0.296	1.851	2.671
E7	7	2.645	0.404	1.831	3.043
E8	7	2.851	0.420	1.920	3.324
E9	7	2.827	0.415	1.944	3.278
E10	7	2.641	0.334	1.914	2.997
E11	7	2.317	0.293	1.759	2.634
E12	7	1.973	0.352	1.250	2.314
E13	7	1.598	0.305	0.941	1.851
4=2) CAT=RT01					
E1	17	1.552	0.406	0.952	2.156
E2	17	1.647	0.444	0.952	2.256
E3	17	1.611	0.359	1.172	2.438
E4	17	2.058	0.299	1.547	2.514
E5	17	2.401	0.314	1.857	2.947
E6	17	2.796	0.411	2.132	3.539
E7	17	3.109	0.549	2.245	4.365
E8	17	3.546	0.741	2.271	5.141
E9	17	3.528	0.763	1.971	5.044
E10	17	3.300	0.774	1.741	4.734
E11	17	3.029	0.749	1.457	4.171
E12	17	2.525	0.630	1.122	3.717
E13	17	2.042	0.501	1.019	2.719

(Continued)

t=2.1 CAI=RTAIL.5

JAR TABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
E1	11	1.658	0.338	1.226	2.518
E2	11	1.654	0.347	1.232	2.425
E3	11	1.850	0.313	1.374	2.518
E4	11	2.058	0.248	1.725	2.518
E5	11	2.394	0.211	2.017	2.705
E6	11	2.657	0.233	2.272	3.161
E7	11	2.943	0.237	2.557	3.358
E8	11	3.184	0.354	2.659	3.767
E9	11	3.111	0.405	2.557	3.861
E10	11	2.972	0.406	2.334	3.767
E11	11	2.501	0.500	1.434	3.236
E12	11	2.162	0.621	1.129	2.687
E13	11	1.776	0.475	0.437	2.138

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