APPENDIX E
BPL MODELING OUTPUT

E.1 INTRODUCTION

Extensive work was done at NTIA's Institute for Telecommunication Sciences (ITS) on a typical arrangement of medium voltage power lines. The modeled power lines consist of three horizontal parallel copper wires 8.5 meters (27.9 feet) above average ground. Each wire has a diameter of 0.01 meter and the wires are separated in the horizontal plane by 0.60 meter. The feed is at the center of one of the wires which runs along the x axis (y = 0). The equivalent of a coupler in series with the center segment of the wire is used with a voltage source of 1 volt. The other two wires run parallel to the x axis at y = 0.6 and y = 1.2 meters.

All three components of electric and magnetic fields E_x, E_y, E_z, H_x, H_y and H_z in dBμV/m were plotted in a plane 2 meters above the ground at frequencies 2, 5, 10, 20 and 40 MHz. Three different line lengths of 100m, 200m and 340m were used with four different impedance conditions for the source and loads. The near field data have been plotted for four different scales of x and y coordinates *i.e.*, 0 to 20 m (65.6 ft), 200 m (656 ft), 1,000 m (3,280 ft) and 1,800 m (59,040 ft). The far field radiation patterns were also plotted at several azimuth angles. The complete dataset of the radiation patterns and near-field plots are available at NTIA. A few representative radiation patterns and near field plots are given in this Appendix.

The trends observed from the near field plots of the three components of the electric fields are summarized in Tables E-1, E-2 and E-3 for E_z, E_x and E_y respectively.

E.2 TABLES AND NEC PLOTS

Table E-1 summarizes the characteristics of the vertical electric field E_z at various ranges of x and y and at z = 2m as deduced from the near field plots. Similarly Table E-2 and E-3 summarize the characteristics of the horizontal electric field parallel to the wire E_x and horizontal electric field perpendicular to the wire E_y respectively.

Figures E-1 thru E-12 show elevation power patterns for azimuth (Φ) = 0º and 90º for source impedance of 150 Ω, load impedance of 575 Ω and several combinations of line lengths 100m, 200m and 340 m and frequencies 2 MHz, 5 MHz, 10 MHz, 20 MHz and 40 MHz. Figures E-13 thru E-30 show near field plots for E_x, E_y and E_z for a line length of 200 m, source impedance of 150 Ω, load impedance of 575 Ω, frequencies 40 MHz, 10 MHz and 2 MHz, z = 2 m for two different scales of x and y, 0 to 20 m (65.6 ft) and 200 m (656 ft). Figures E-31 thru E-34 illustrate the effect a neutral wire has on the radiation pattern.

Table E-1: Summary of Electric Fields Seen by an Antenna Having Vertical Polarization

Source & Load	BPL Frequency	Length of Line	Peak Field	Number of Peaks[1]	Minimum Distance Between Peak Field and BPL Device
Impedance (Ω)	(MHz)	(m)	(dBµV/m)		(feet)
150 & 575	2	100	83-85	2	59-85
575 & 50	2	100	83-85	2	90
150 & 50	2	100	86	2	58-120
575 & 575	2	100	81	2	100
150 & 575	10	100	75-79	4	33
575 & 50	10	100	74-77	4	38
150 & 50	10	100	74-79	3	33
575 & 575	10	100	71-75	3	36
150 & 50	40	100	69-76	8	7
575 & 50	40	100	69-73	8	7
575 & 575	40	100	70-75	7	6
150 & 575	40	100	72-77	6	7
150 & 50	2	200	84-86	2	58-120
575 & 50	2	200	82-85	2	95
575 & 575	2	200	79-81	2	100
150 & 575	2	200	85	1	58-100
150 & 50	10	200	75-80	4	33
575 & 50	10	200	75-78	4	32
150 & 575	10	200	74-79	4	32
575 & 575	10	200	71-75	4	35
150 & 50	40	200	71-74	8	7
575 & 575	40	200	68-74	7	6
575 & 50	40	200	72-74	6	6
150 & 575	40	200	71-76	5	7
150 & 50	2	340	80-83	3	80
575 & 575	2	340	76-79	3	95
150 & 575	2	340	82	3	85
575 & 50	2	340	81	3	70
575 & 575	10	340	68-74	8	21
575 & 50	10	340	73-77	7	20
150 & 50	10	340	76-79	6	50
150 & 575	10	340	72-78	2	21
150 & 575	40	340	71-77	10	13
575 & 575	40	340	67-73	10	16
575 & 50	40	340	70-76	9	15
150 & 50	40	340	73	2	53

[1] All peak levels of vertically polarized electric field strength occurred near and under the power lines, and all local peaks had approximately the same level. The statistics are presented for one-half the overall length of the power line, which is center fed. Thus, the numbers of peaks for the entire power line are twice the values shown in the table.

Table E-2: Summary of Electric Fields Seen by an Antenna Having Horizontal-Parallel Polarization

Source & Load Impedance (Ω)	BPL Frequency (MHz)	Length of Line (m)	Field at Source[2] (dBμV/m)	Number of Secondary Peaks[3]
150 & 50	2	100	68	2
150 & 575	2	100	67	2
575 & 50	2	100	67	2
575 & 575	2	100	63	2
150 & 50	2	200	68	2
150 & 575	2	200	67	2
575 & 50	2	200	67	2
575 & 575	2	200	63	2
150 & 50	2	340	69	3
150 & 575	2	340	68	3
575 & 50	2	340	67	3
575 & 575	2	340	65	3
150 & 50	10	100	76	5
150 & 575	10	100	75	3
575 & 50	10	100	74	3
575 & 575	10	100	72	0
150 & 50	10	200	77	5
150 & 575	10	200	76	3
575 & 50	10	200	75	3
575 & 575	10	200	72	3
150 & 50	10	340	75	5
150 & 575	10	340	74	5
575 & 50	10	340	74	5
575 & 575	10	340	70	5
150 & 50	40	100	82	1
150 & 575	40	100	81	1
575 & 50	40	100	79	0
575 & 575	40	100	78	0
150 & 50	40	200	82	1
150 & 575	40	200	81	1
575 & 50	40	200	78	0
575 & 575	40	200	78	1
150 & 50	40	340	76	1
150 & 575	40	340	81	1
575 & 50	40	340	80	1
575 & 575	40	340	76	0

[2] Peak horizontal-parallel electric field strength always occurred near the BPL device.

[3] Secondary peaks levels were recorded if they were within 5 dB of the overall peak level near the BPL device. The statistics are presented for one-half the overall length of the power line, which is center fed. Thus, the numbers of peaks for the entire power line are twice the values shown in the table.

Table E-3: Summary of Electric Fields Seen by an Antenna Having Horizontal-Perpendicular Polarization

Source & Load Impedance (Ω)	BPL Frequency (MHz)	Length of Line (m)	Peak Field (dBµV/m)	Distance of Peak from the Line (ft)	Number of Peaks[4]	Minimum Distance From BPL Device (feet)
150 & 50	2	100	70	+/-10-20	1	60-100
150 & 575	2	100	64-69	+/-15-21	2	60-90
575 & 50	2	100	69	+/-10-20	1	65-100
575 & 575	2	100	58-65	+/-13-25	2	90
150 & 50	2	200	70	10-20	1	58-110
150 & 575	2	200	64-69	+/-15-25	2	90
575 & 50	2	200	69	+/-17	2	65-120
575 & 575	2	200	58-65	+/-15-25	2	95
150 & 50	2	340	60-67	0	4	50
150 & 575	2	340	61-66	+/-10-22	3	42-80
575 & 50	2	340	60-65	+/-10-22	2	90
575 & 575	2	340	57-63	+/-15-20	3	85
150 & 50	10	100	60-67	+/-10-25	2	32
150 & 575	10	100	63-67	+/-18	2	32
575 & 50	10	100	58-65	+/-12-23	2	32
575 & 575	10	100	57-63	+/-13-23	3	50
150 & 50	10	200	62-67	+/-10-25	3	32
150 & 575	10	200	61-67	+/-17-21	3	31
575 & 50	10	200	60-65	+/-10-25	3	17
575 & 575	10	200	57-63	+/-15-26	3	31
150 & 50	10	340	62-65	+/-10-25	12	50
150 & 575	10	340	60-65	16-21	2	21
575 & 50	10	340	60-63	+/-10-22	6	21
575 & 575	10	340	52-61	+/-12-23	7	22
150 & 50	40	100	71-73	+/-10-25	4	20
150 & 575	40	100	65-73	+/-15-38	4	32
575 & 50	40	100	69-71	+/-18-30	5	20
575 & 575	40	100	63-69	+/-15-35	6	19
150 & 50	40	200	68-73	+/-10-33	5	18
150 & 575	40	200	66-73	+/-10-30	5	33
575 & 50	40	200	62-72	+/-12-34	5	20
575 & 575	40	200	69	+/-18-30	5	19
150 & 50	40	340	64	+/-10-30	4	23
150 & 575	40	340	69-72	+/-18-23	6	10
575 & 50	40	340	64-70	+/-10-30	6	10
575 & 575	40	340	64-66	+/-17-23	5	10

[4] The statistics are presented for one-half the overall length of the power line, which is center fed. Thus, the numbers of peaks for the entire power line are twice the values shown in the table.

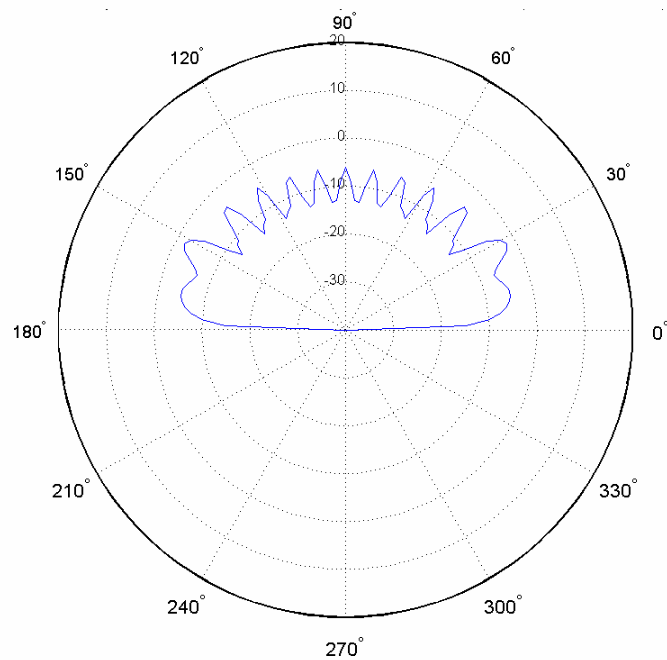

Figure E-1: Elevation pattern at azimuth (phi) = 0, line length = 340 m, frequency = 10 MHz, source impedance = 150 Ω, load impedance = 575 Ω [flc0.png]

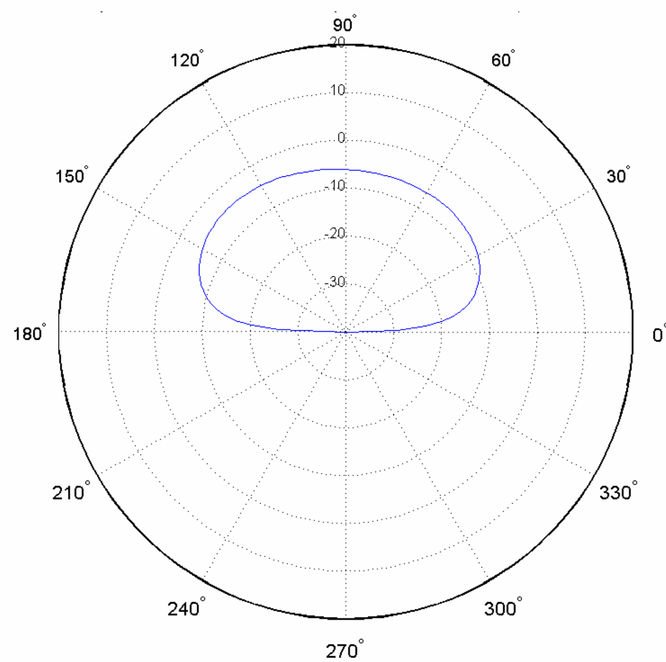

Figure E-2: Elevation pattern at azimuth (phi) = 90, line length = 340 m, frequency = 10 MHz, source impedance = 150 Ω, load impedance = 575 Ω [flc90.png]

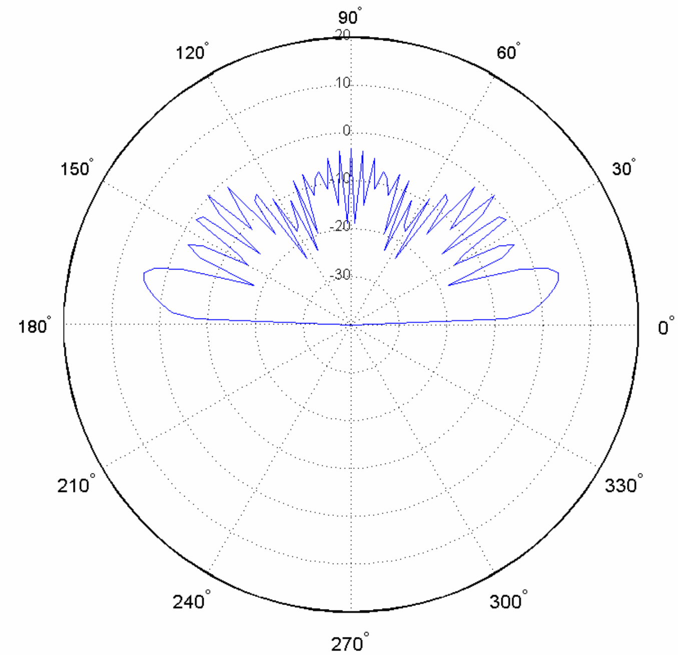

Figure E-3: Elevation pattern at azimuth (phi) = 0, line length = 200 m, frequency = 40 MHz, source impedance = 150 Ω, load impedance = 575 Ω [flf0.png]

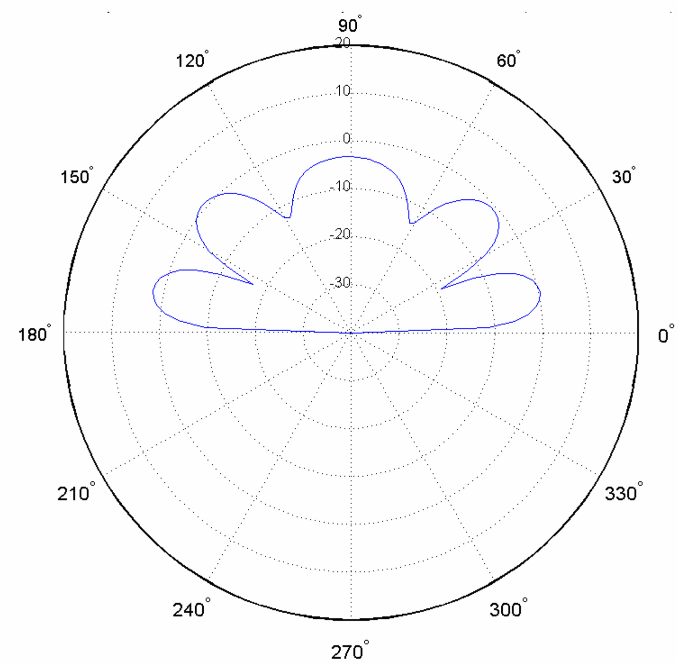

Figure E-4: Elevation pattern at azimuth (phi) =90, line length = 200 m, frequency = 40 MHz, source impedance = 150 Ω, load impedance = 575 Ω [flf90.png]

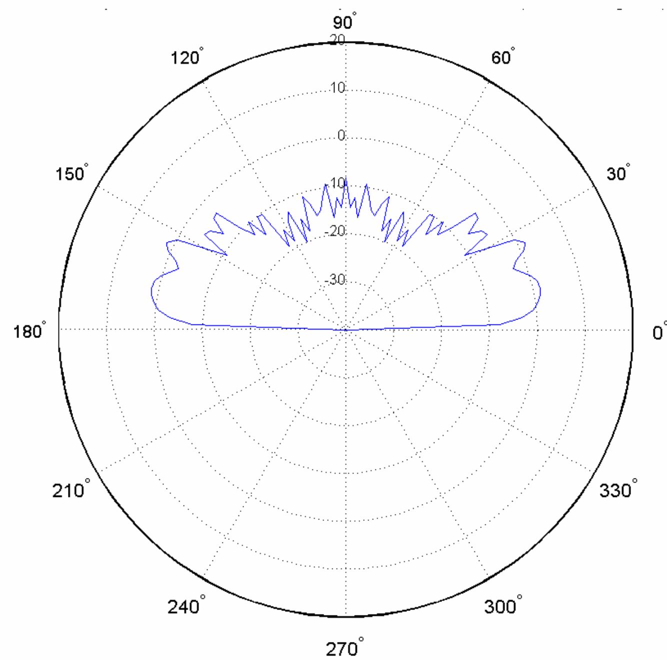

Figure E-5: Elevation pattern at azimuth (phi) = 0, line length = 200 m, frequency = 20 MHz, source impedance = 150 Ω, load impedance = 575 Ω [flg0.png]

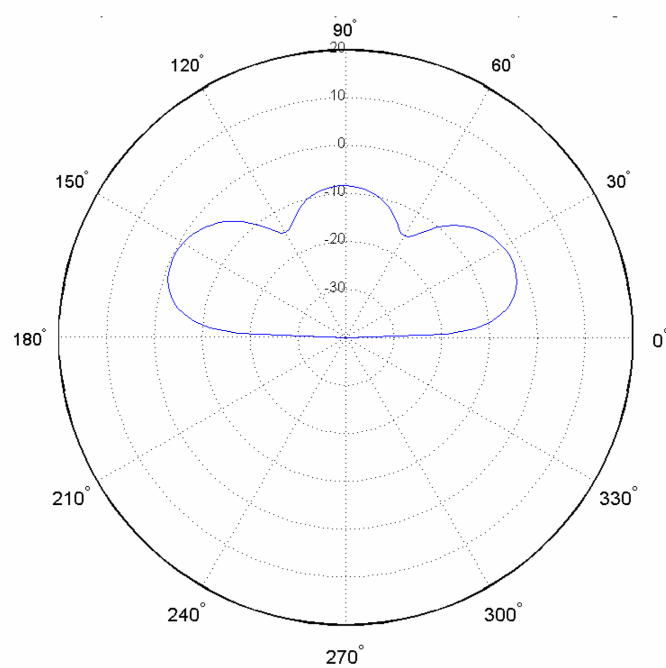

Figure E-6: Elevation pattern at azimuth (phi) = 90, line length = 200 m, frequency = 20 MHz, source impedance = 150 Ω, load impedance = 575 Ω [flg90.png]

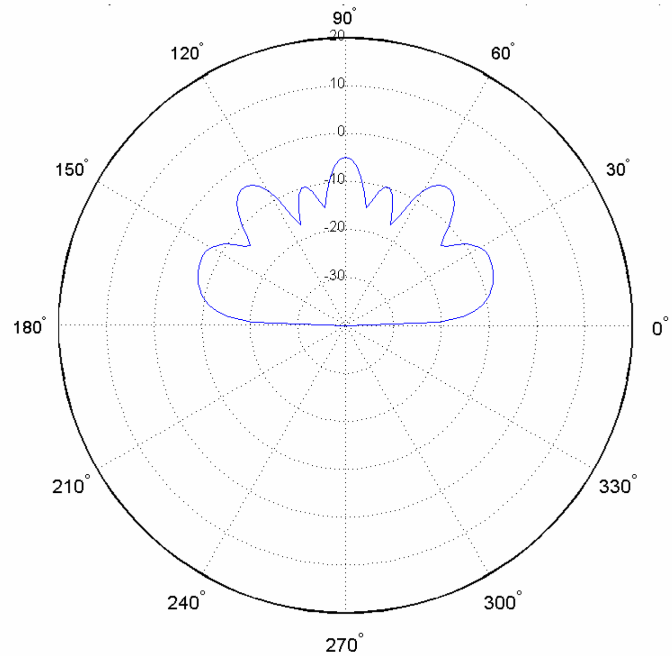

Figure E-7: Elevation pattern at azimuth (phi) = 0, line length = 200 m, frequency = 5 MHz, source impedance = 150 Ω, load impedance = 575 Ω [fli0.png]

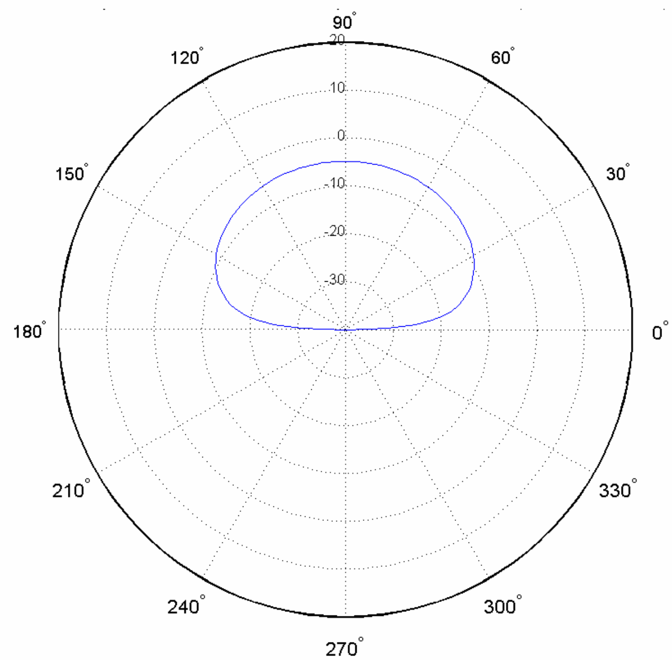

Figure E-8: Elevation pattern at azimuth (phi) =90, line length = 200 m, frequency = 5 MHz, source impedance = 150 Ω, load impedance = 575 Ω [fli90.png]

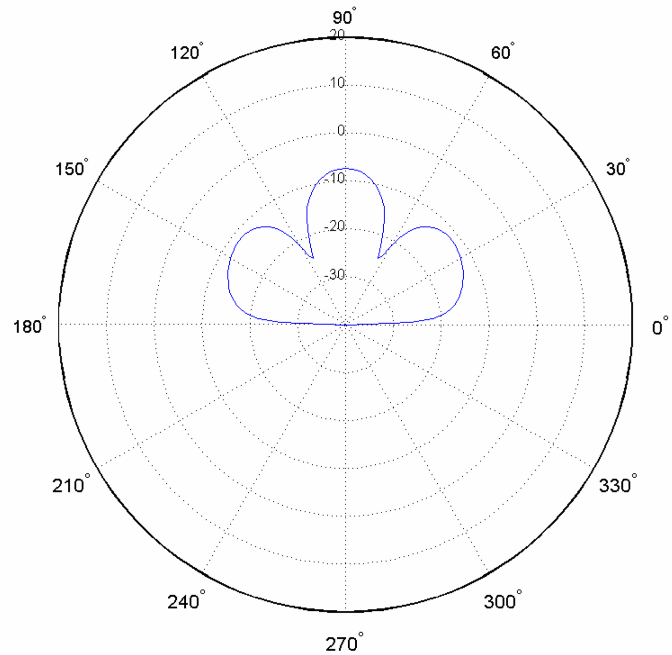

Figure E-9: Elevation pattern at azimuth (phi) = 0, line length = 200 m, frequency = 2 MHz, source impedance = 150 Ω, load impedance = 575 Ω [flj0.png]

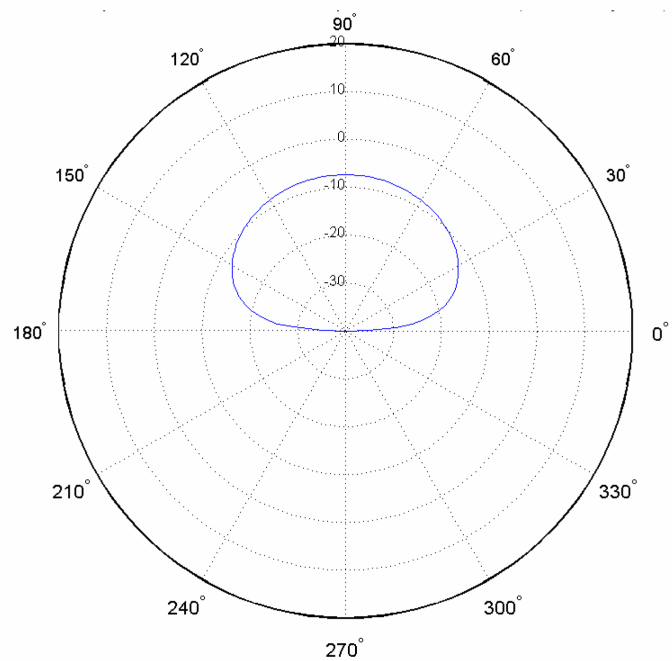

Figure E-10: Elevation pattern at azimuth (phi) = 90, line length = 200 m, frequency = 2 MHz, source impedance = 150 Ω, load impedance = 575 Ω [flj90.png]

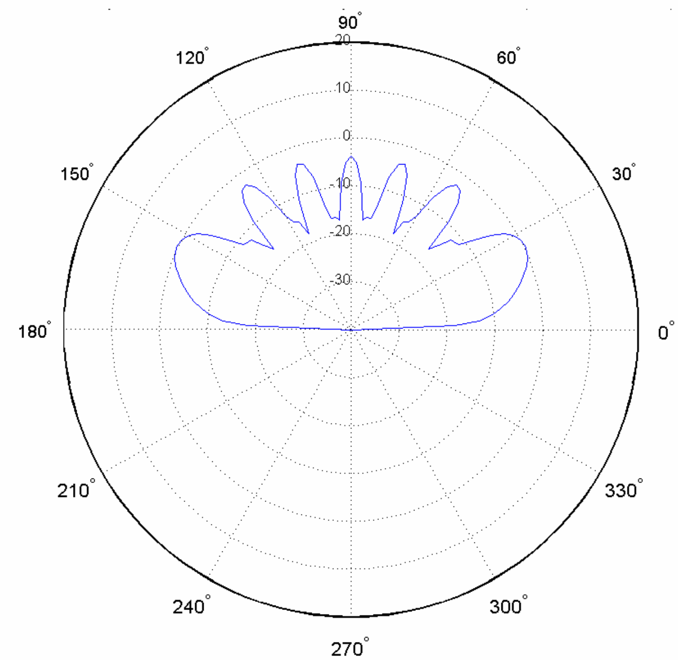

Figure E-11: Elevation pattern at azimuth (phi) = 0, line length = 100 m, frequency = 10 MHz, source impedance = 150 Ω, load impedance = 575 Ω [flm0.png]

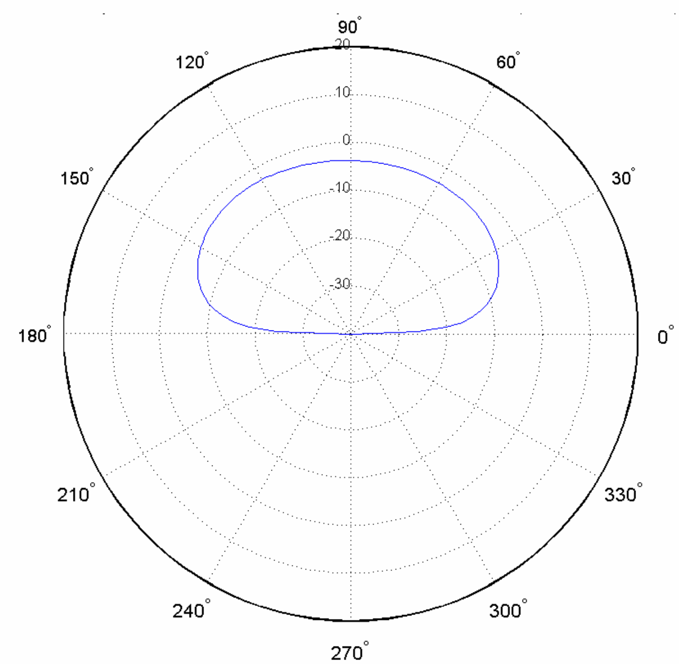

Figure E-12: Elevation pattern at azimuth (phi) =90, line length = 100 m, frequency = 10 MHz, source impedance = 150 Ω, load impedance = 575 Ω [flm90.png]

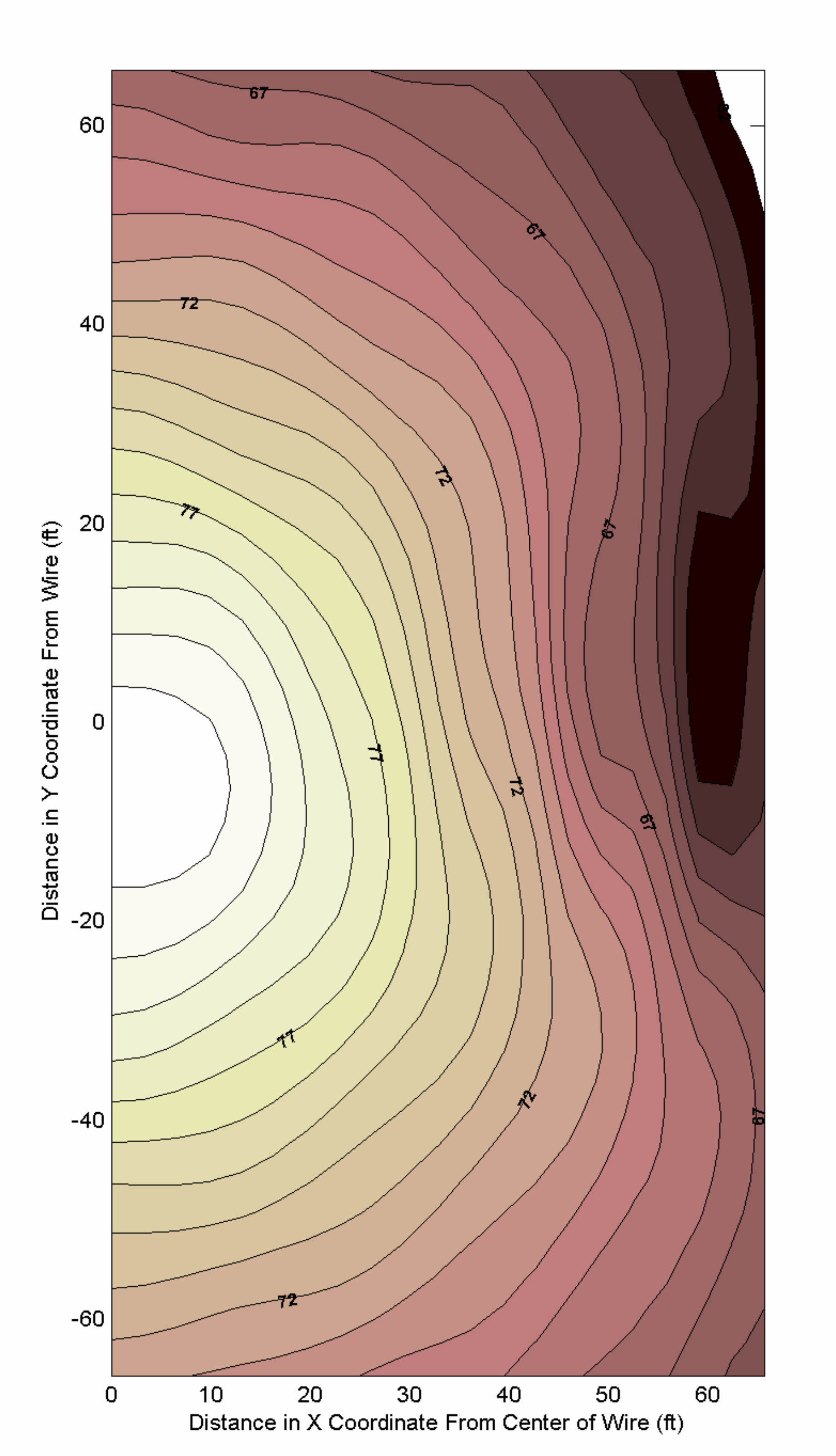

Figure E-13: Electric field strength (E_x) in dBµV/m from 0 to 65.6 feet, line length = 200 m, frequency = 40 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nlfex1.png]

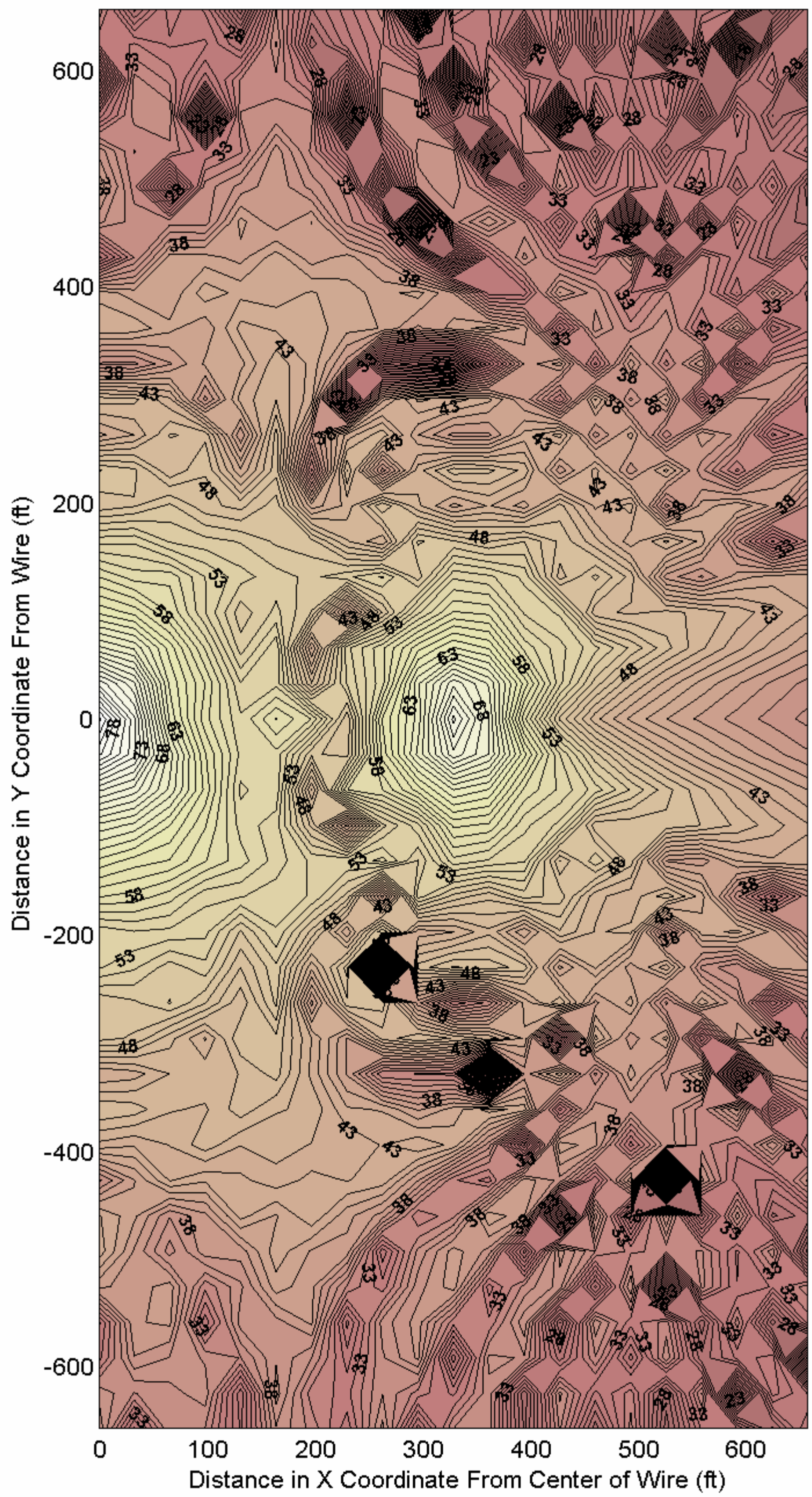

Figure E-14: Electric field strength (E_x) in dBμV/m from 65.6 to 656 feet, line length = 200 m, frequency = 40 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nlfex2.png]

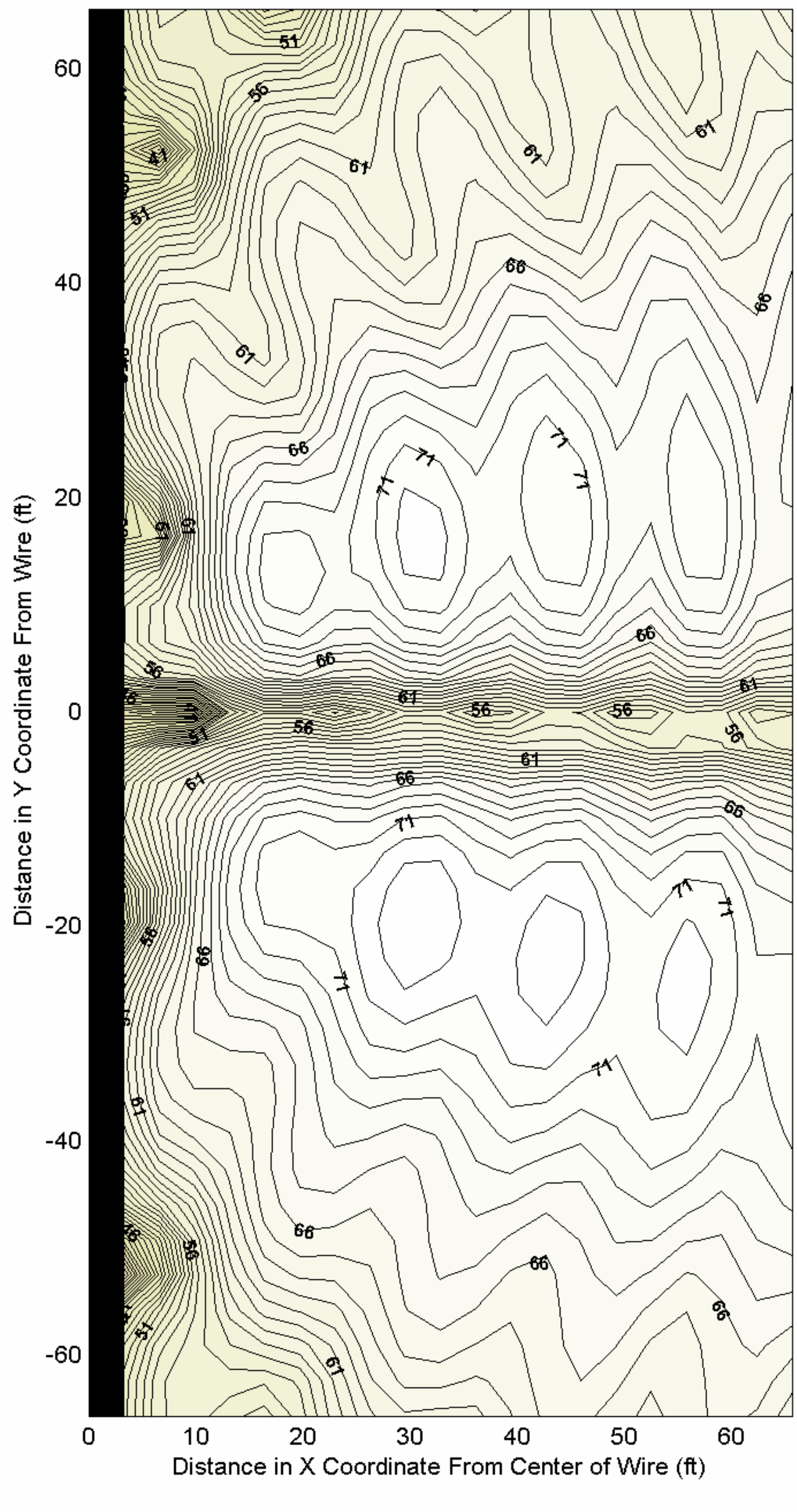

Figure E-15: Electric field strength (E_y) in dBµV/m from 0 to 65.6 feet, line length = 200 m, frequency = 40 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nlfey1.png]

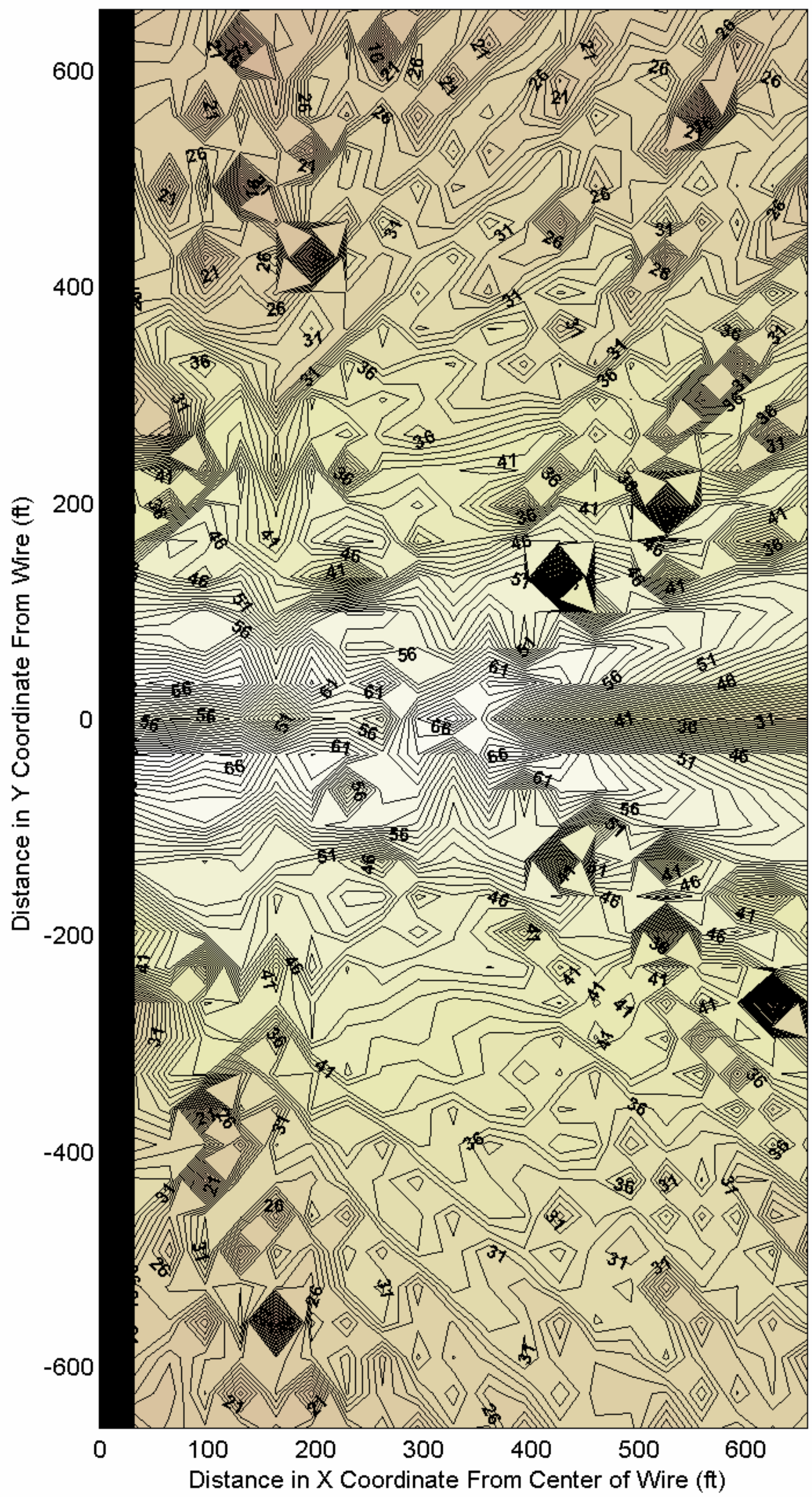

Figure E-16: Electric field strength (E_y) in dBμV/m from 65.6 to 656 feet, line length = 200 m, frequency = 40 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nlfey2.png]

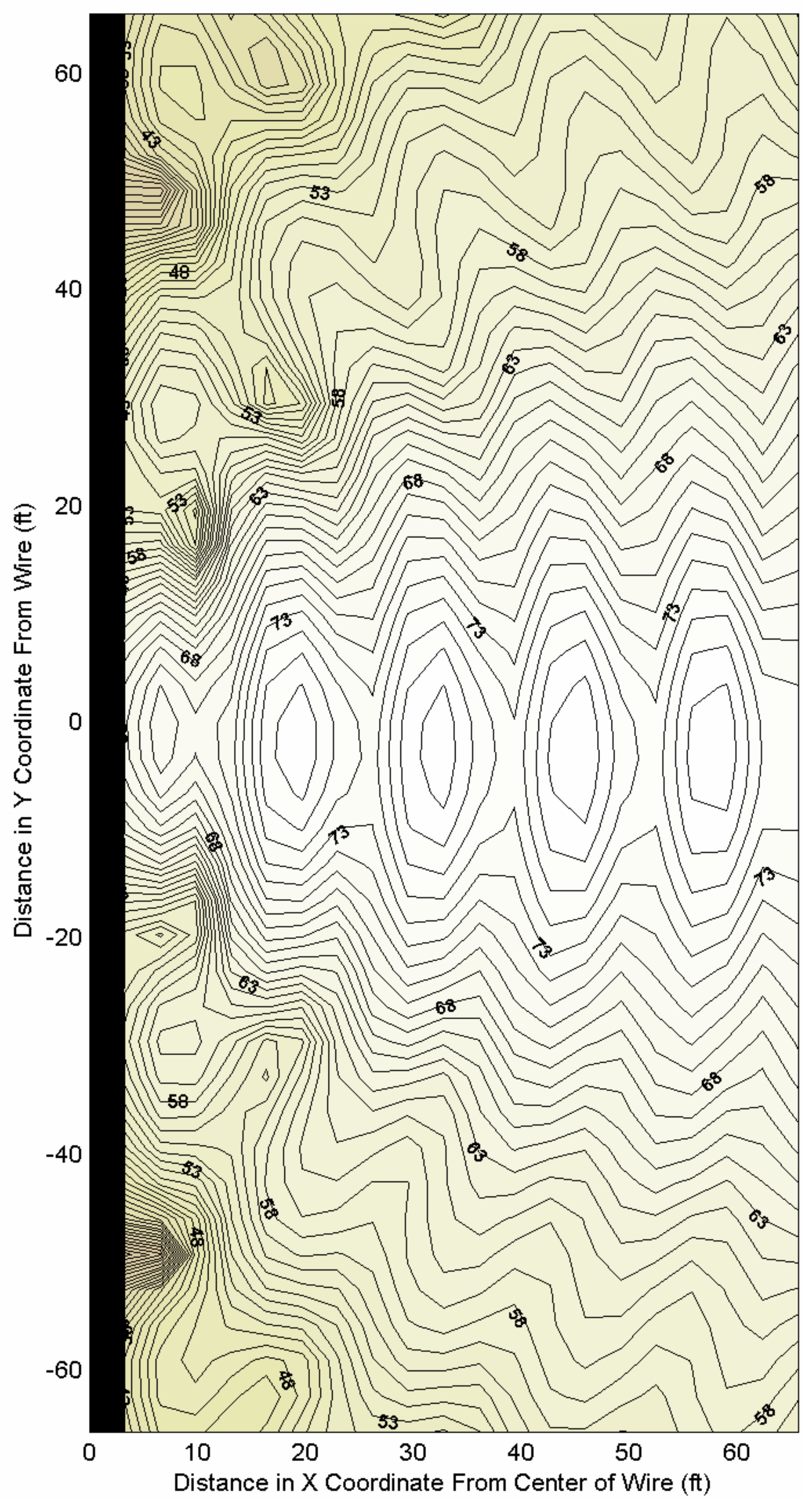

Figure E-17: Electric field strength (E_z) in dBμV/m from 0 to 65.6 feet, line length = 200 m, frequency = 40 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nlfez1.png]

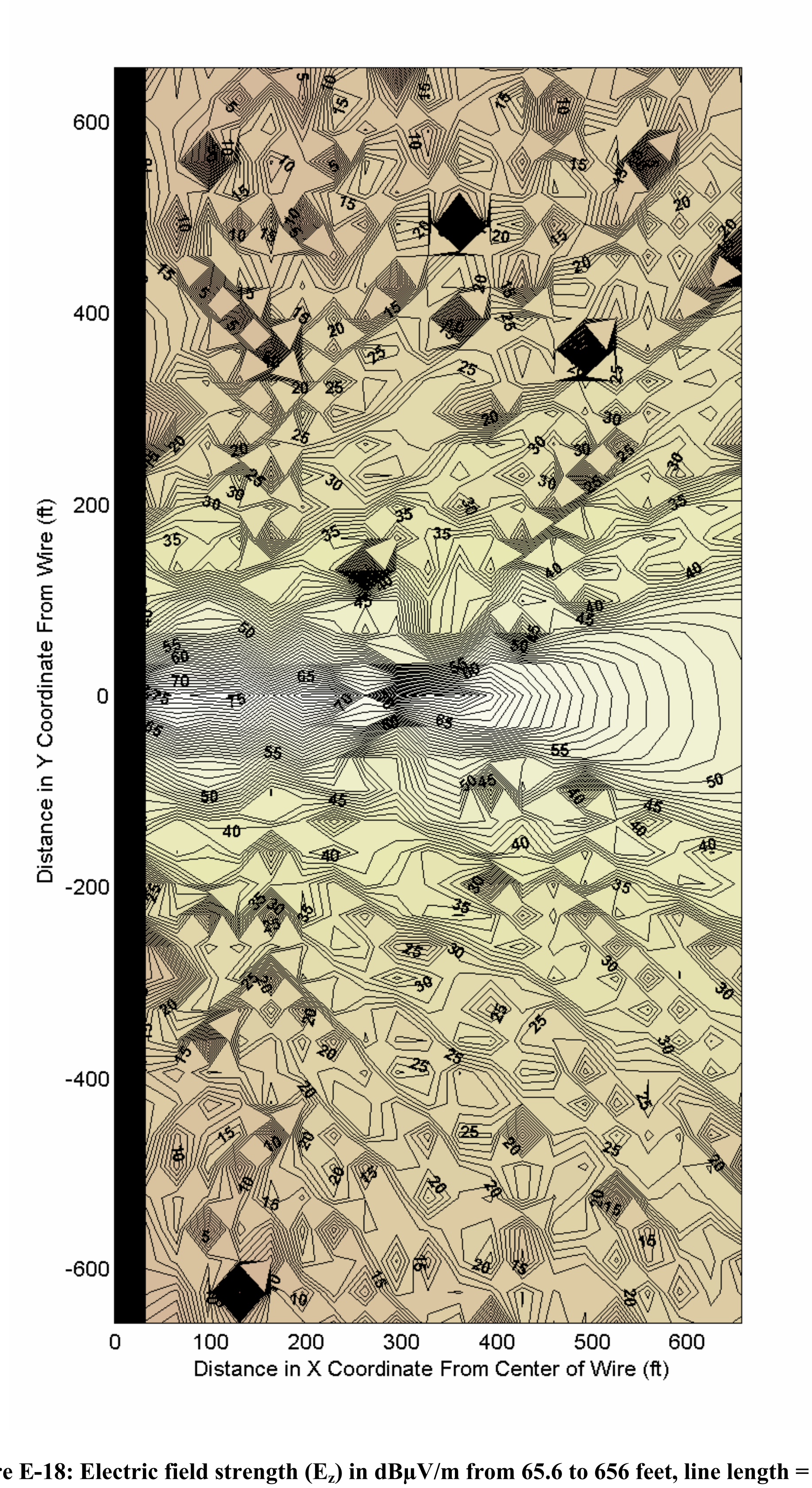

Figure E-18: Electric field strength (E_z) in dBµV/m from 65.6 to 656 feet, line length = 200 m, frequency = 40 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nlfez2.png]

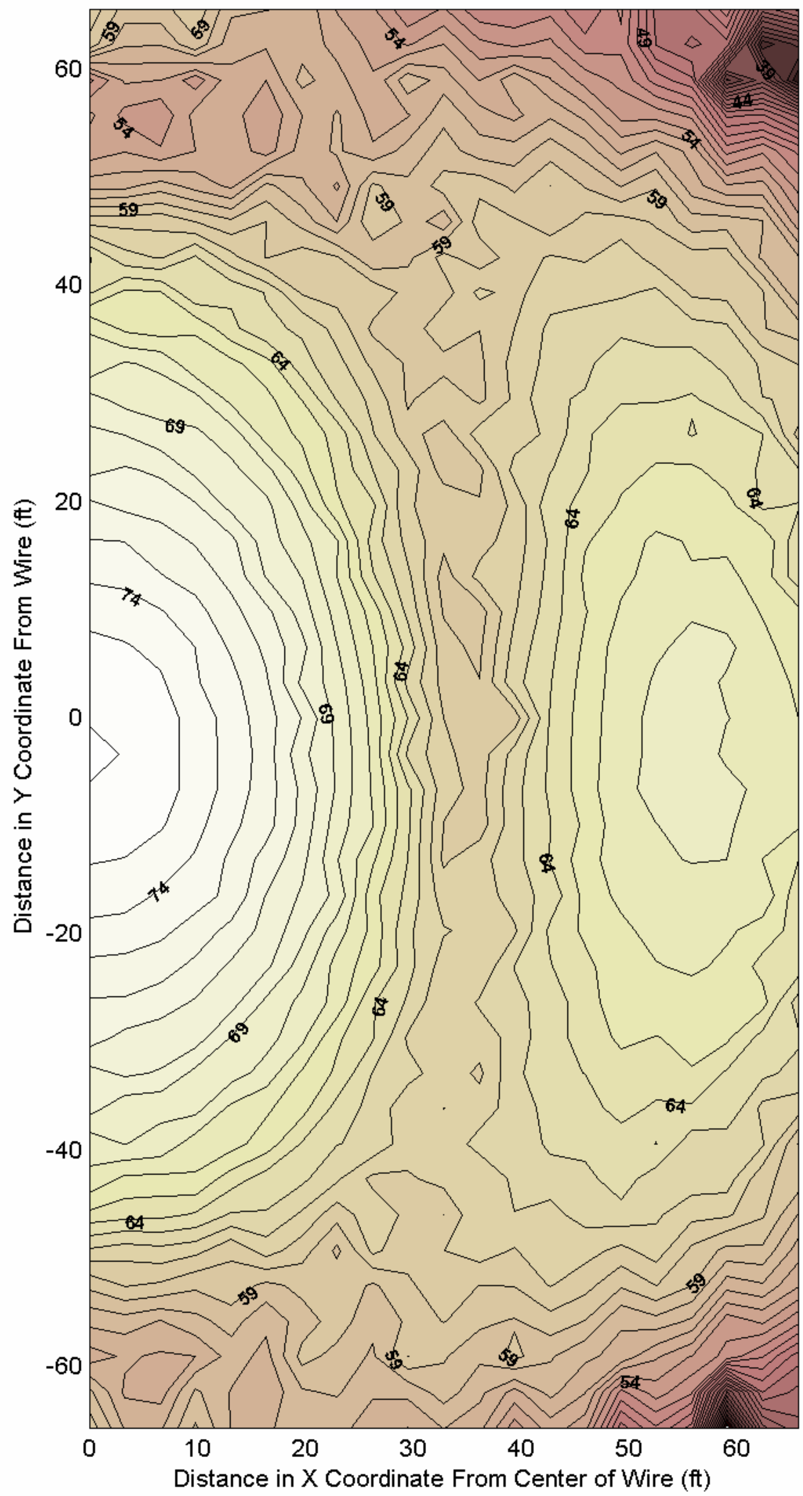

Figure E-19: Electric field strength (E_x) in dBµV/m from 0 to 65.6 feet, line length = 200 m, frequency = 10 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nlhex1.png]

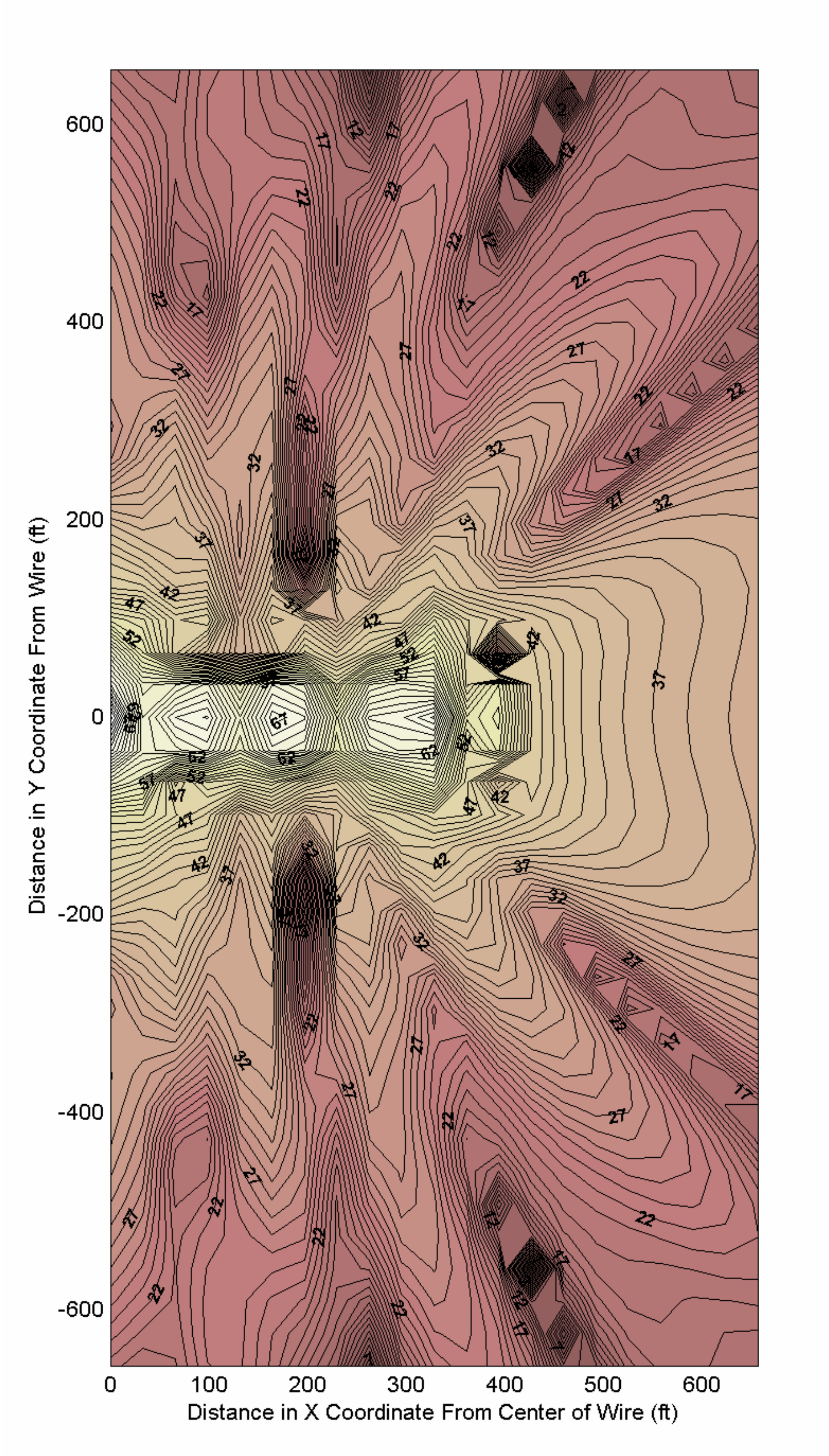

Figure E-20: Electric field strength (E_x) in dBμV/m from 65.6 to 656 feet, line length = 200 m, frequency = 10 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nlhex2.png]

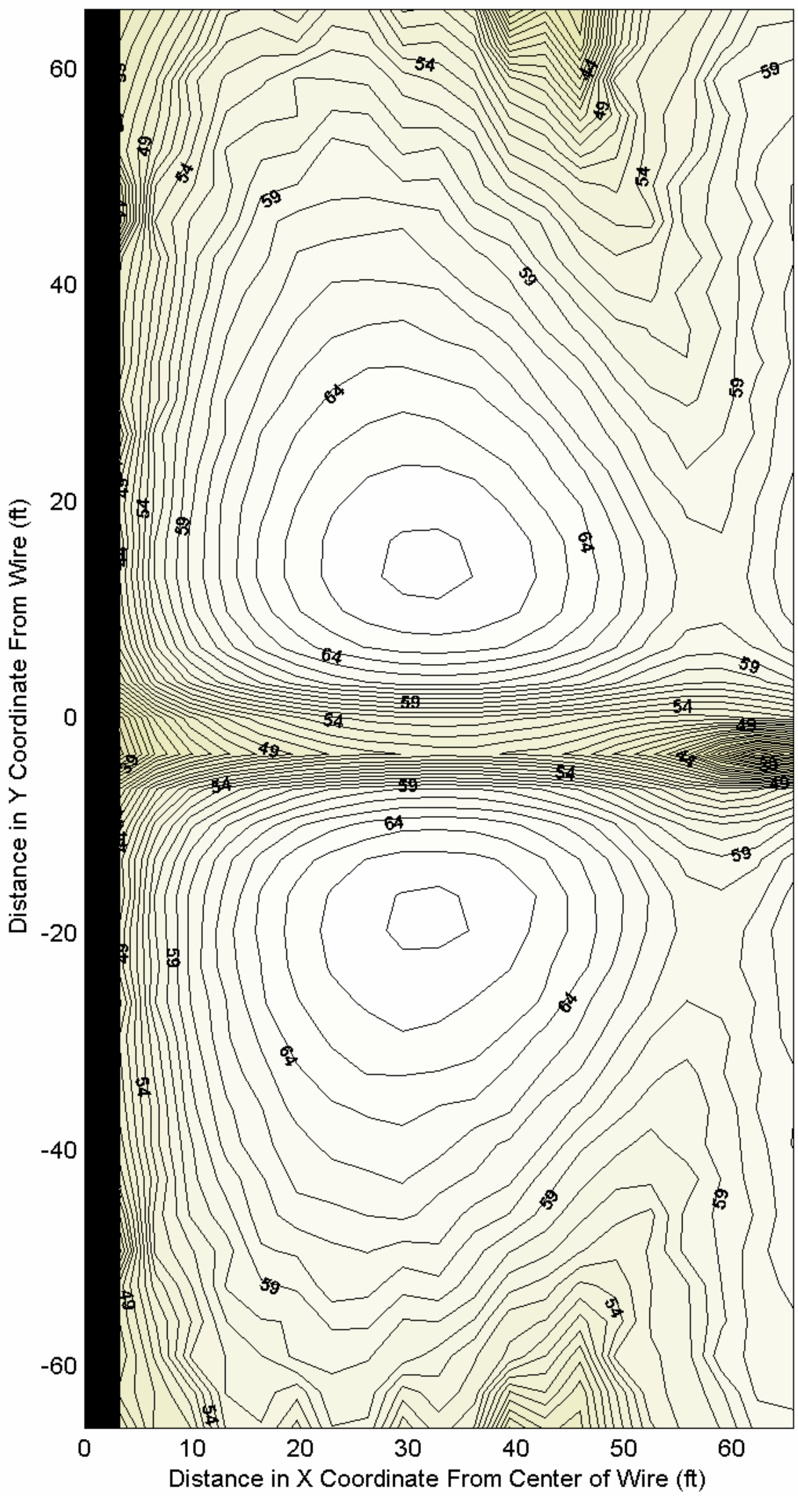

Figure E-21: Electric field strength (E_y) in dBμV/m from 0 to 65.6 feet, line length = 200 m, frequency = 10 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nlhey1.png]

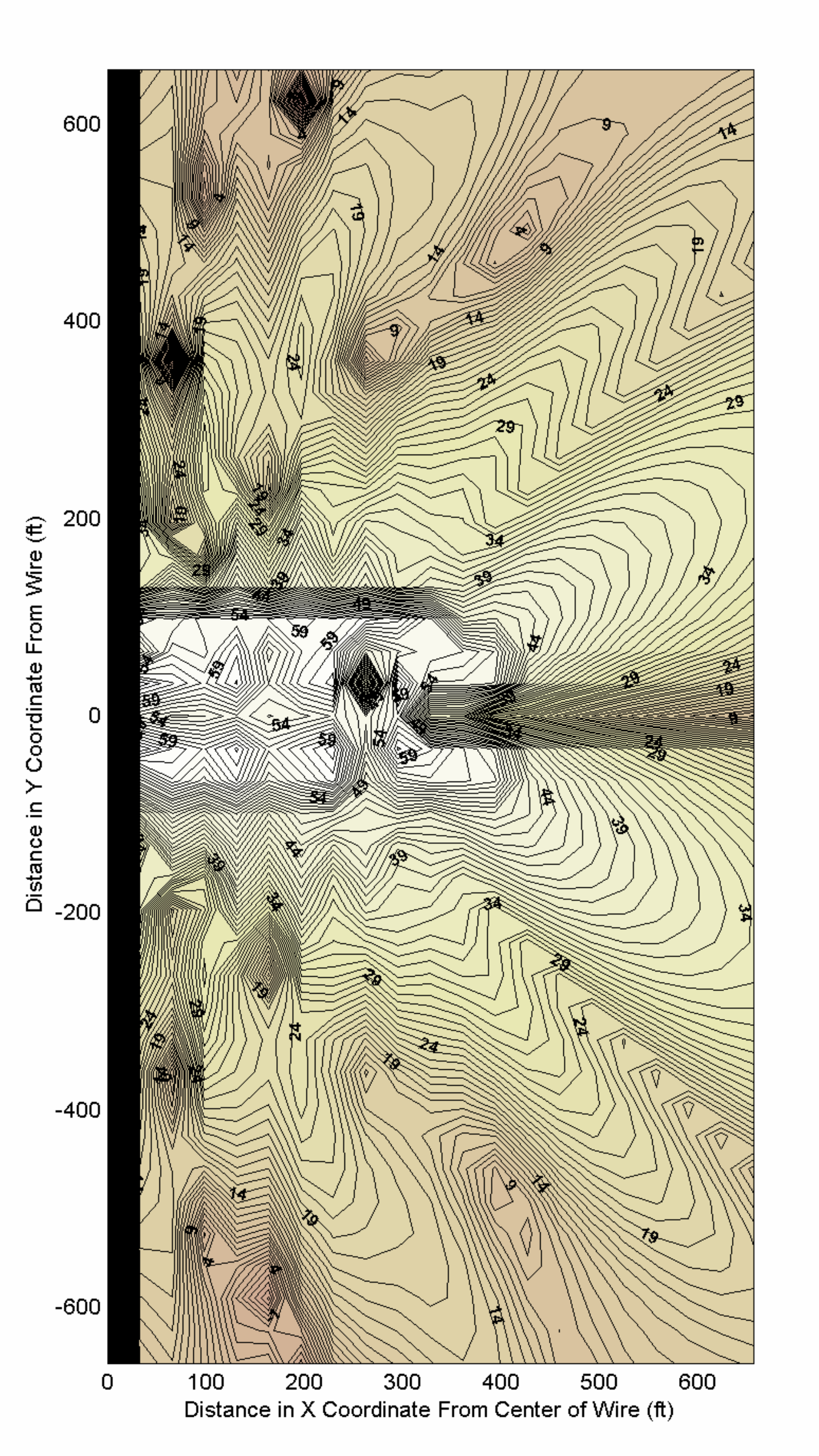

Figure E-22: Electric field strength (E_y) in dBμV/m from 65.6 to 656 feet, line length = 200 m, frequency = 10 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nlhey2.png]

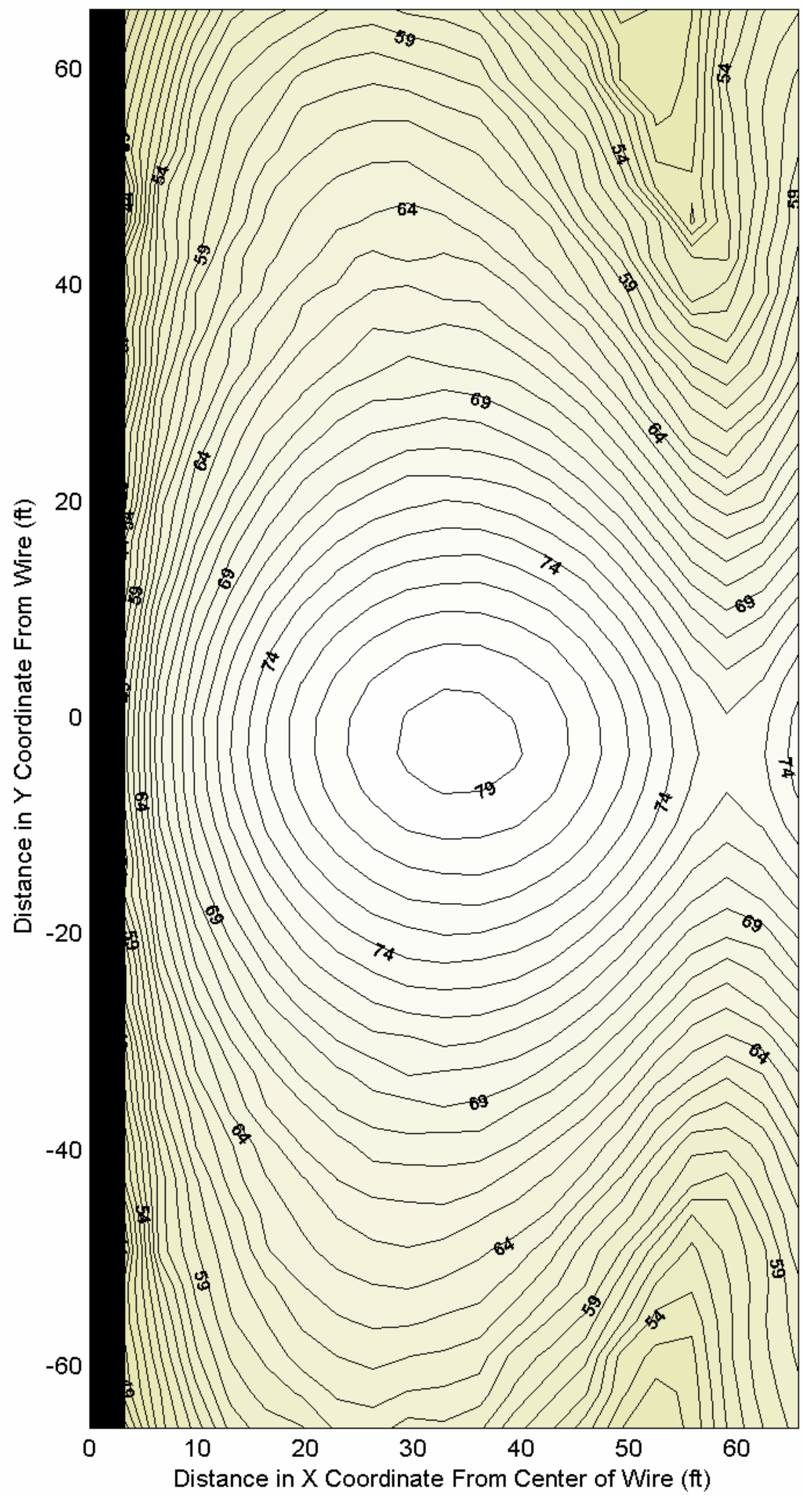

Figure E-23: Electric field strength (E_z) in dBµV/m from 0 to 65.6 feet, line length = 200 m, frequency = 10 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nlhez1.png]

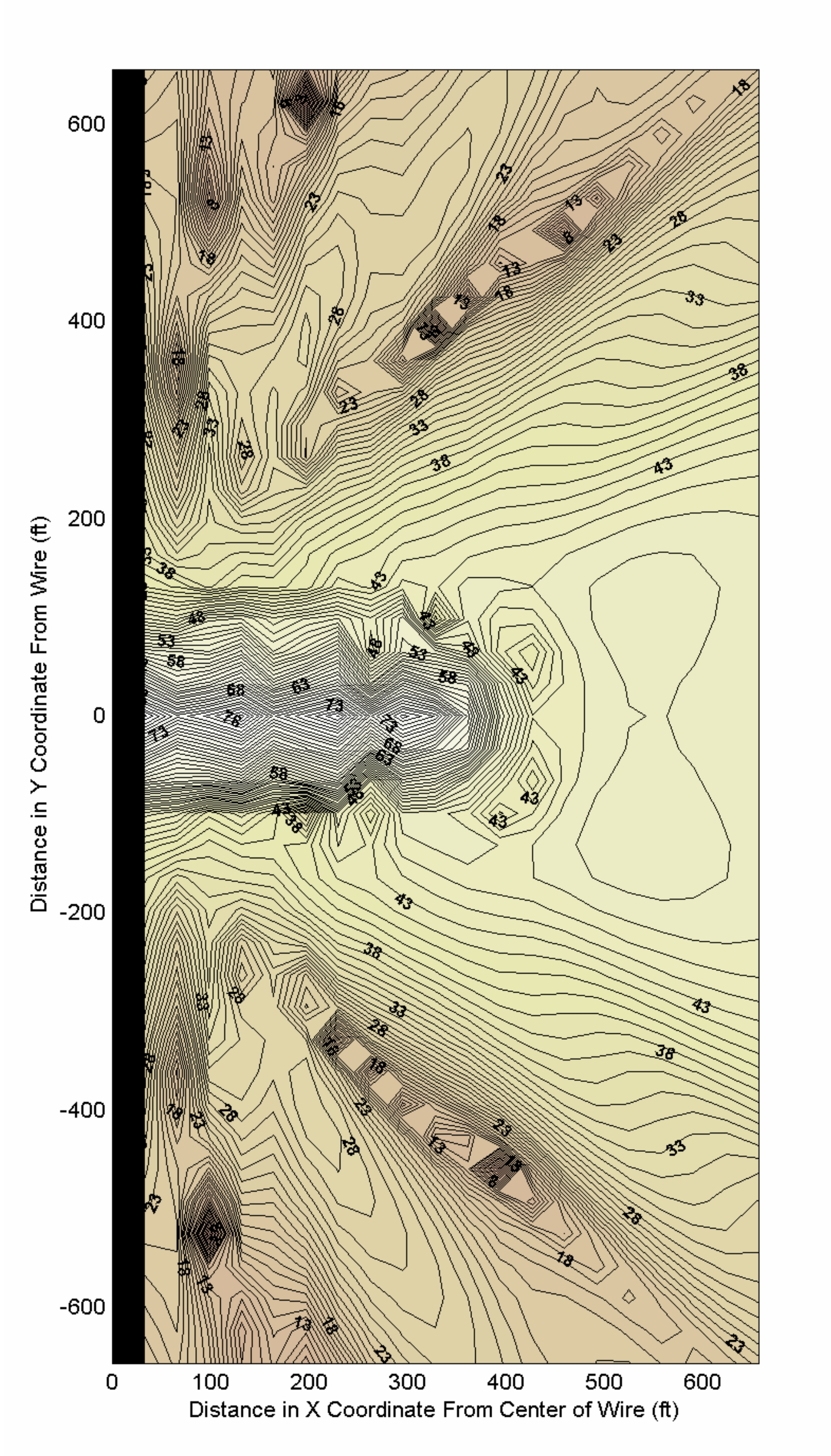

Figure E-24: Electric field strength (E_z) in dBµV/m from 65.6 to 656 feet, line length = 200 m, frequency = 10 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nlhez2.png]

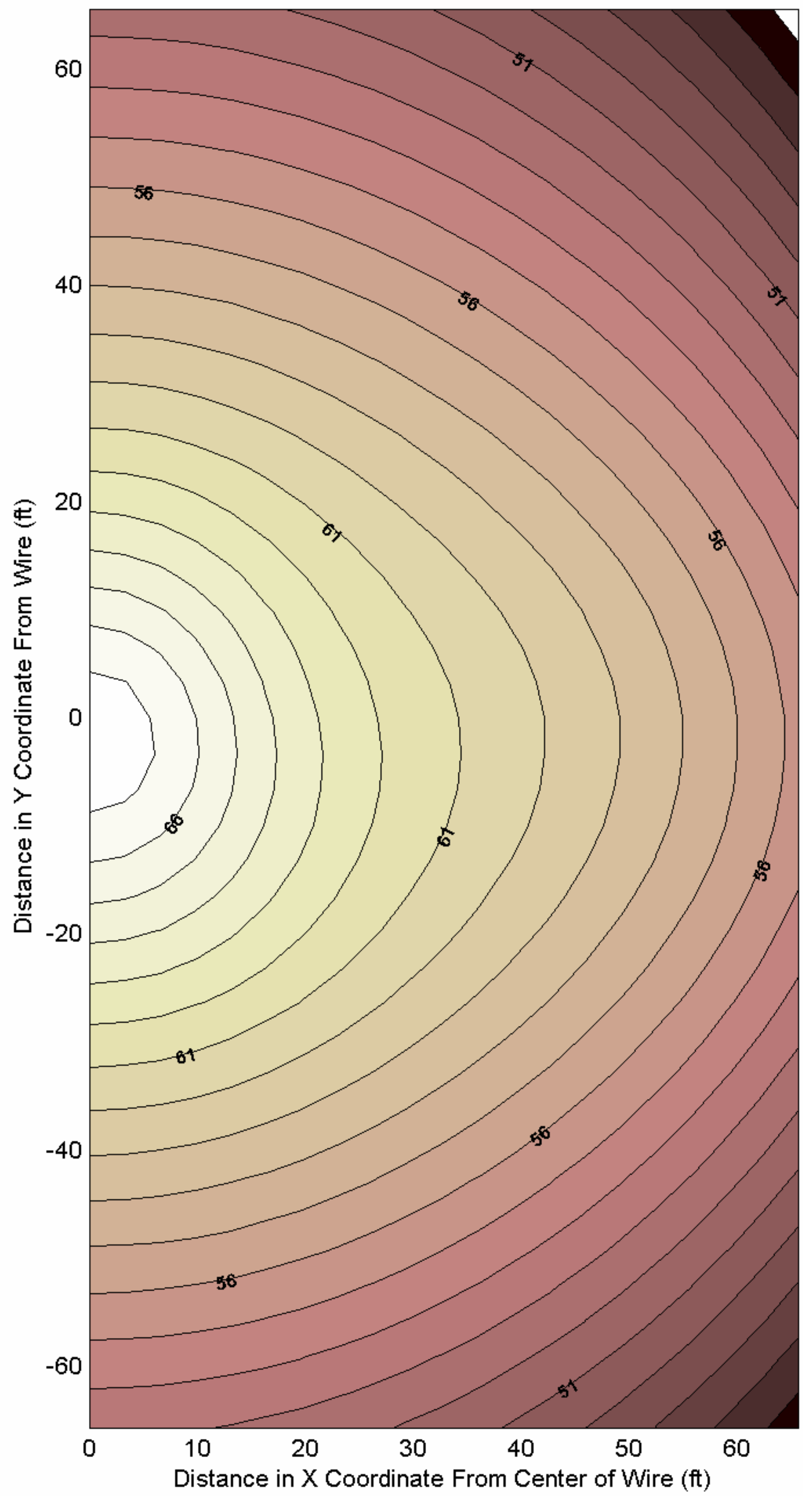

Figure E-25: Electric field strength (E_x) in dBµV/m from 0 to 65.6 feet, line length = 200 m, frequency = 2 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nljex1.png]

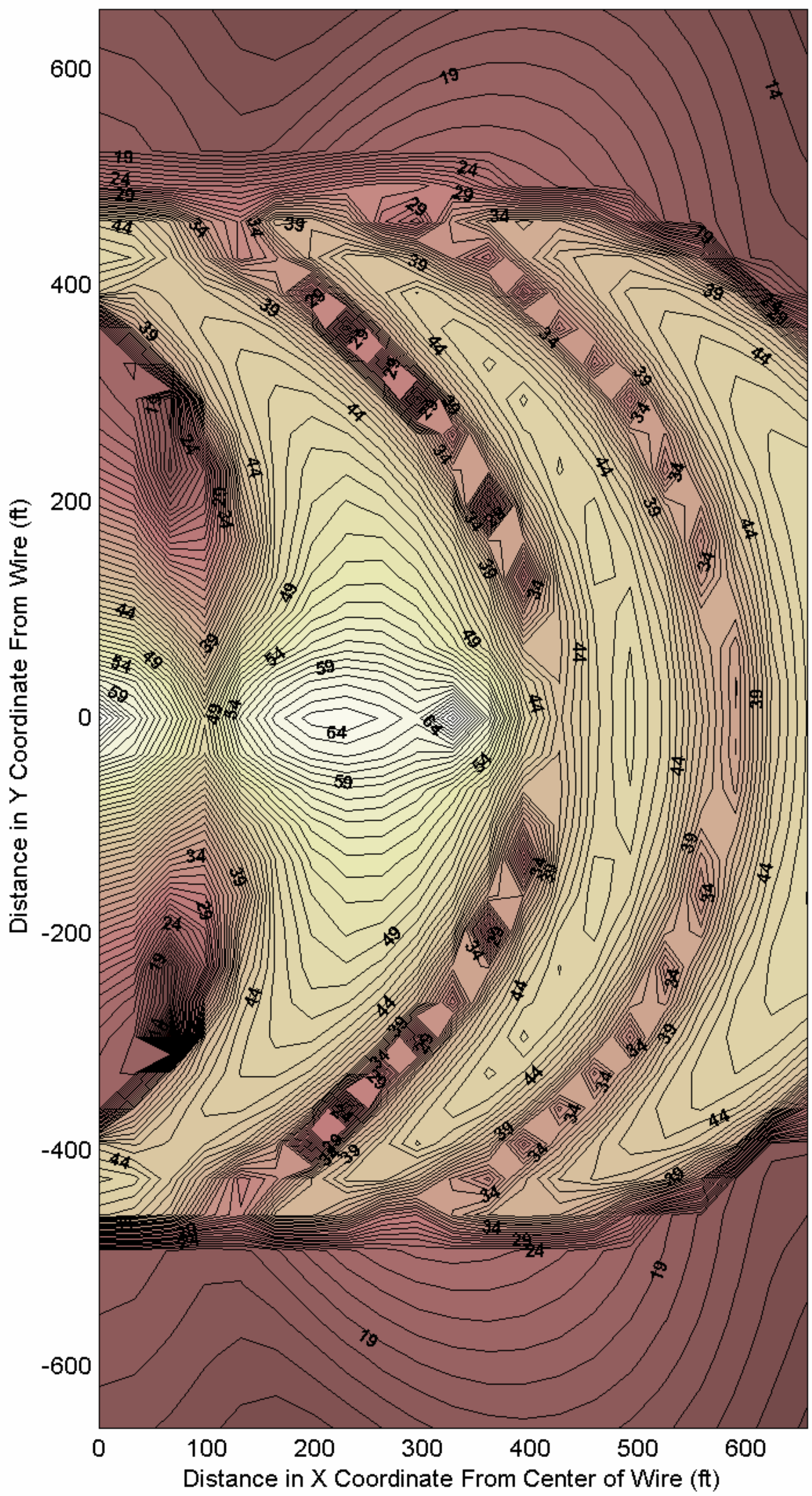

Figure E-26: Electric field strength (E_x) in dBμV/m from 65.6 to 656 feet, line length = 200 m, frequency = 2 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nljex2.png]

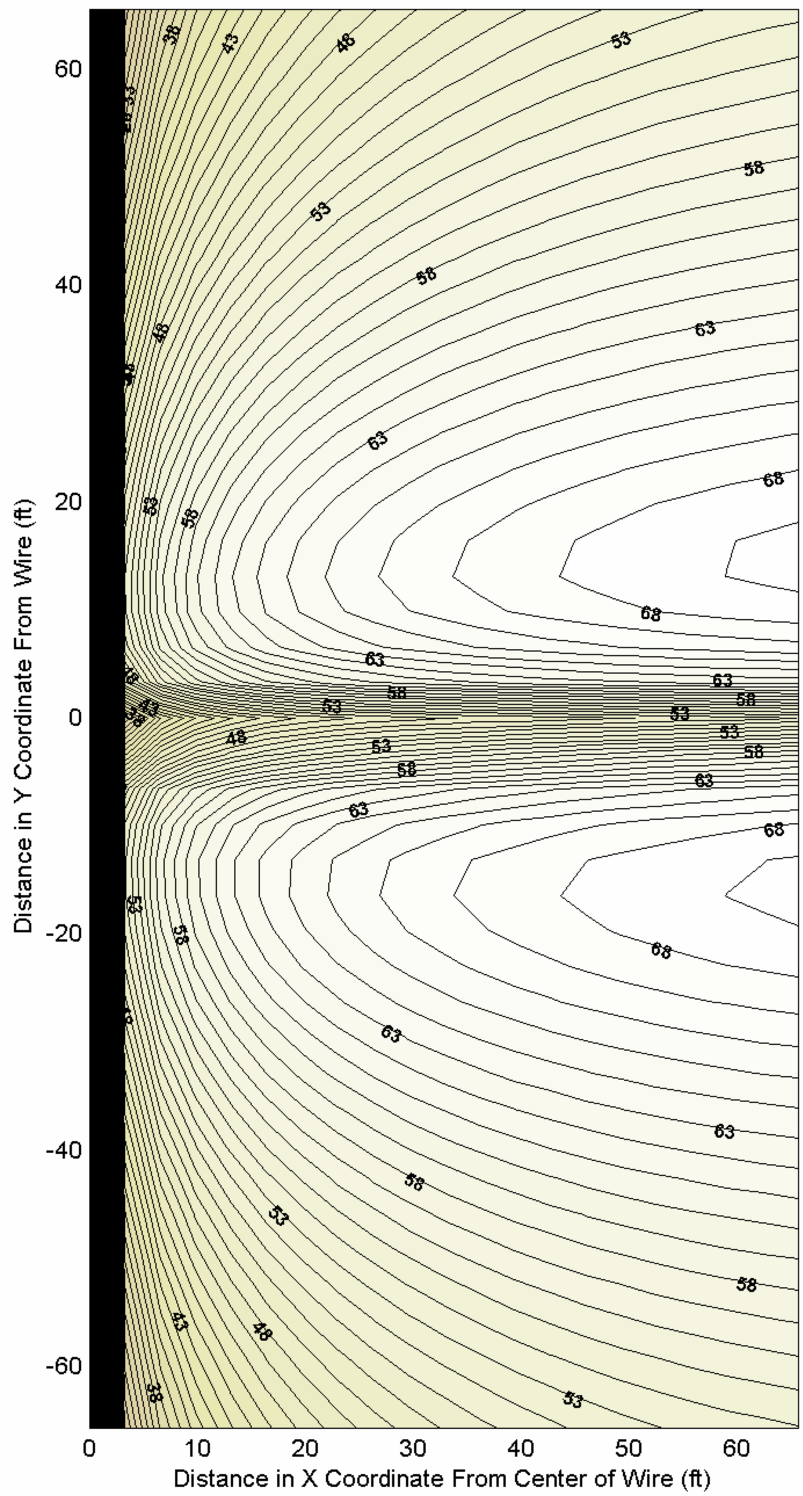

Figure E-27: Electric field strength (E_y) in dBμV/m from 0 to 65.6 feet, line length = 200 m, frequency = 2 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nljey1.png]

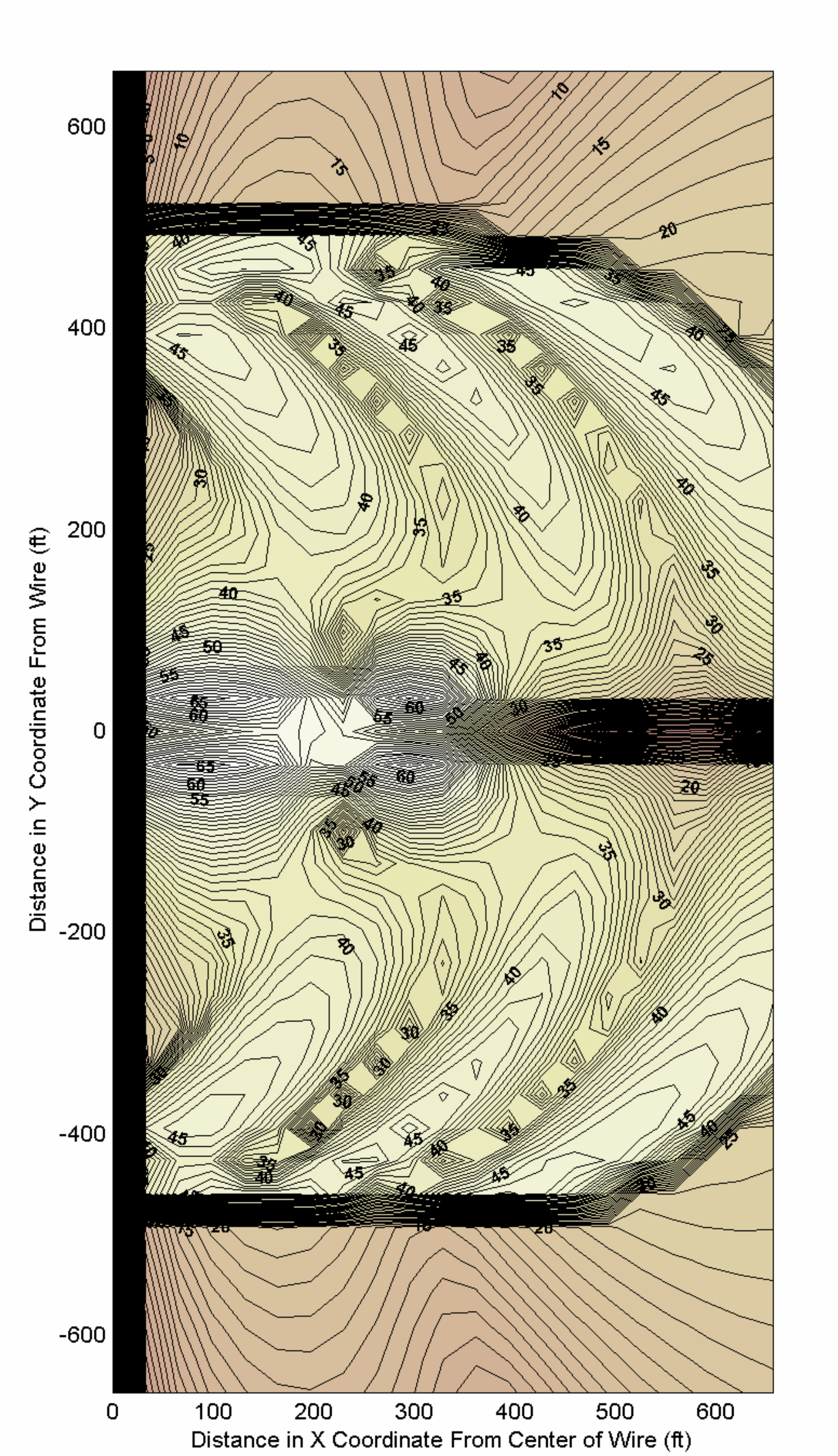

Figure E-28: Electric field strength (E_y) in dBµV/m from 65.6 to 656 feet, line length = 200 m, frequency = 2 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nljey2.png]

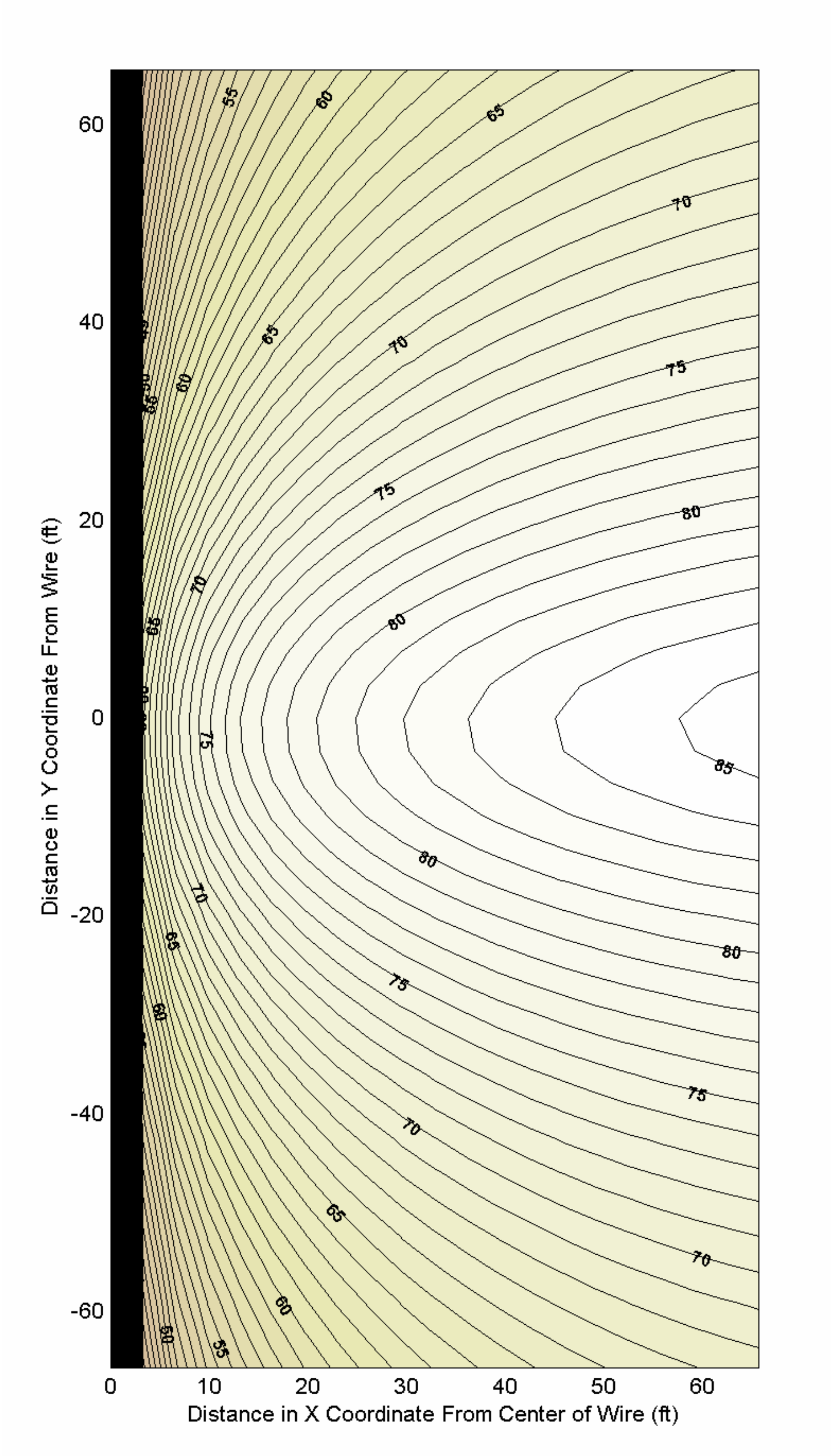

Figure E-29: Electric field strength (E_z) in dBμV/m from 0 to 65.6 feet, line length = 200 m, frequency = 2 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nljez1.png]

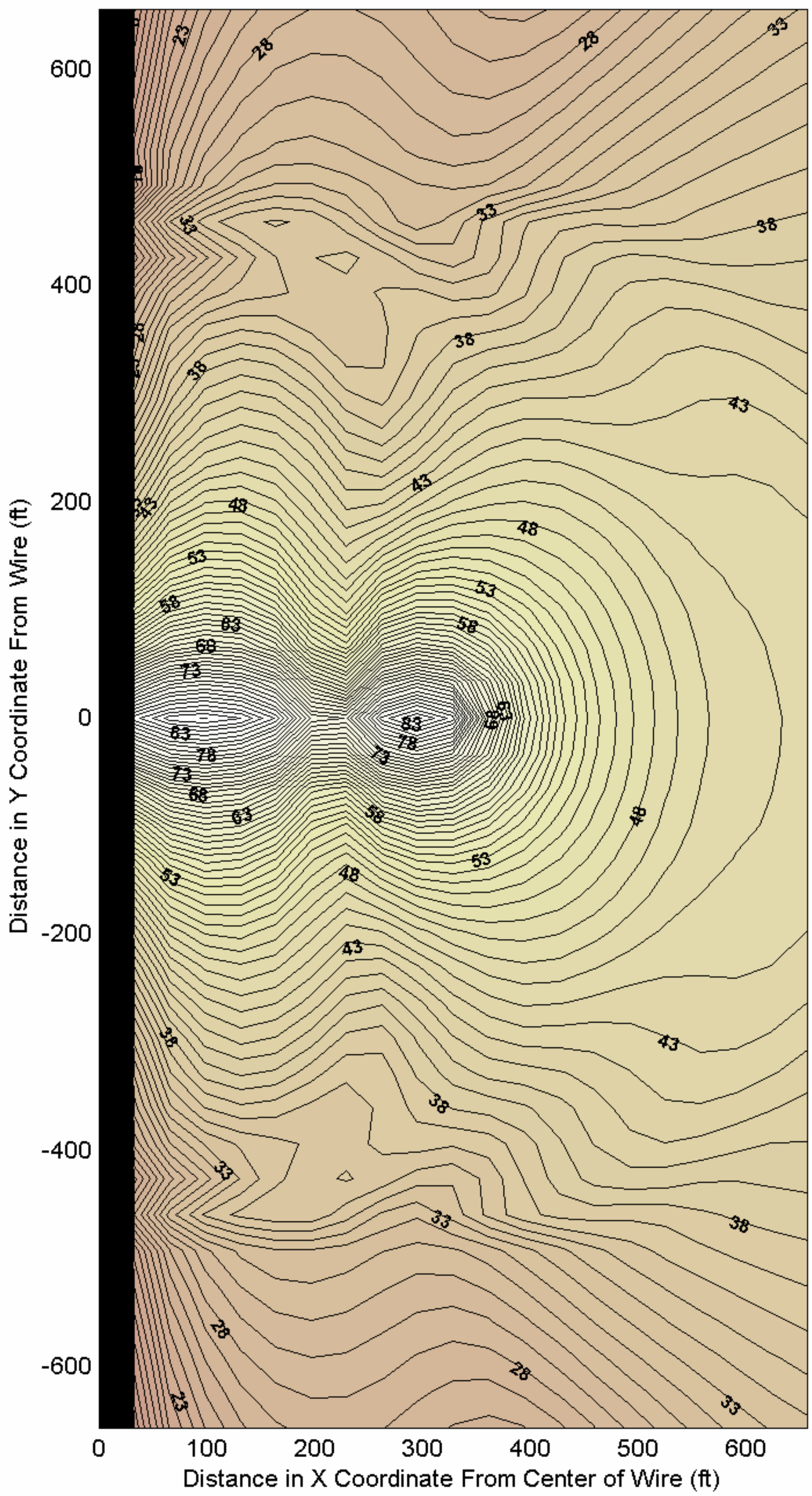

Figure E-30: Electric field strength (E_z) in dBμV/m from 65.6 to 656 feet, line length = 200 m, frequency = 2 MHz, source impedance = 150 Ω, load impedance = 575 Ω [nljez2.png]

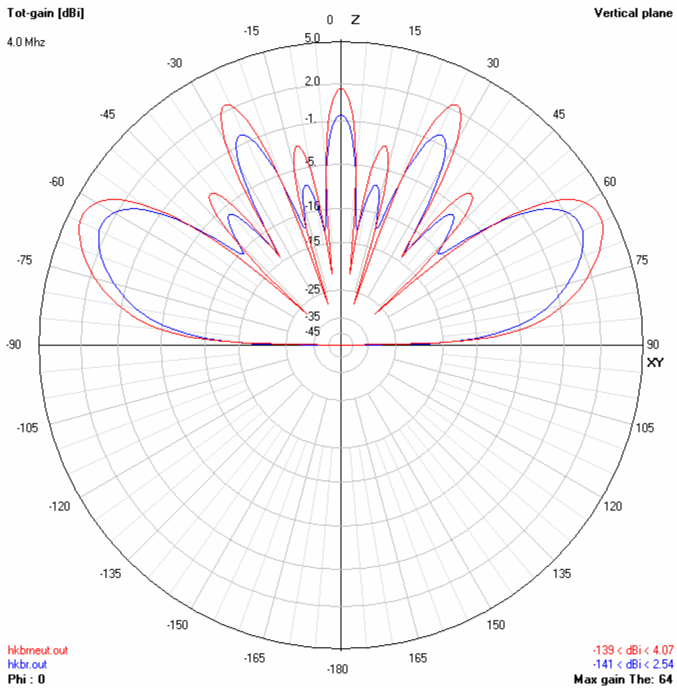

Figure E-31: Comparison of NEC model with and without a parasitic multi-grounded neutral. Red curve is with neutral, blue curve is without a neutral (4 MHz).

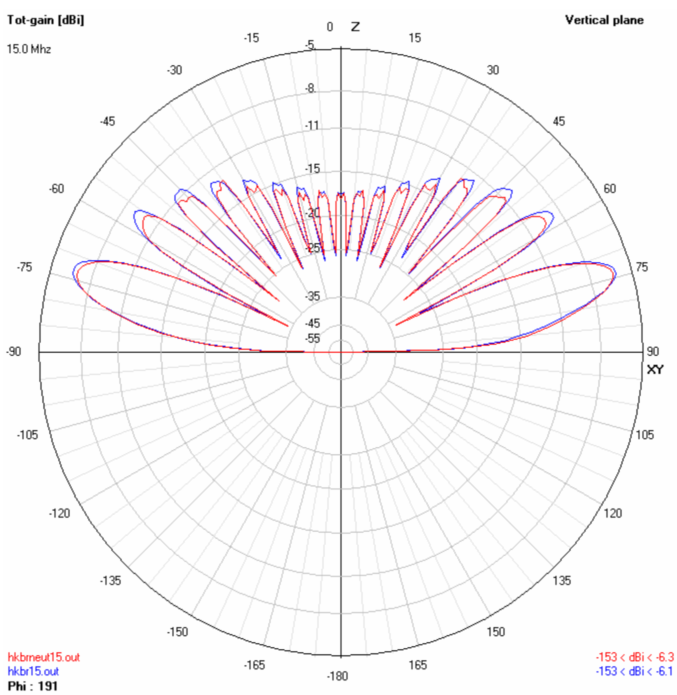

Figure E-32: Comparison of NEC model with and without a parasitic multi-grounded neutral. Red curve is with neutral, blue curve is without a neutral (15 MHz).

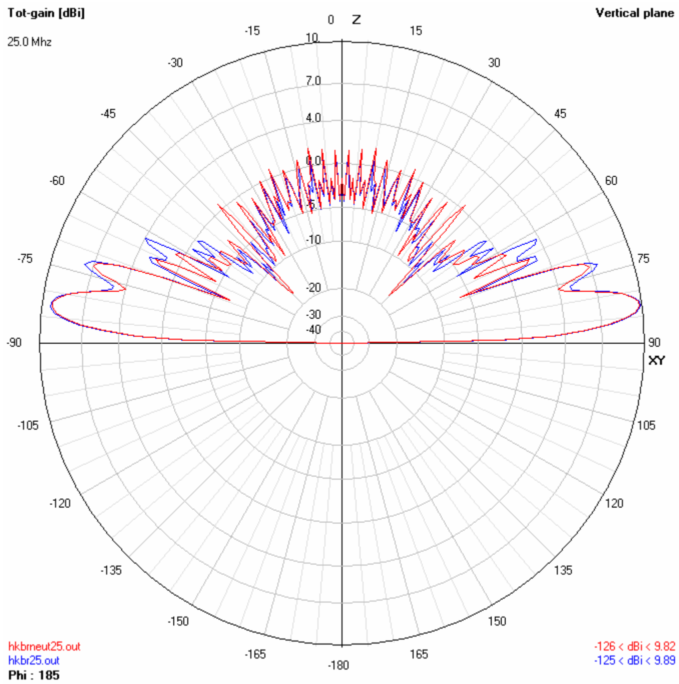

Figure E-33: Comparison of NEC model with and without a parasitic multi-grounded neutral. Red curve is with neutral, blue curve is without a neutral (25 MHz).

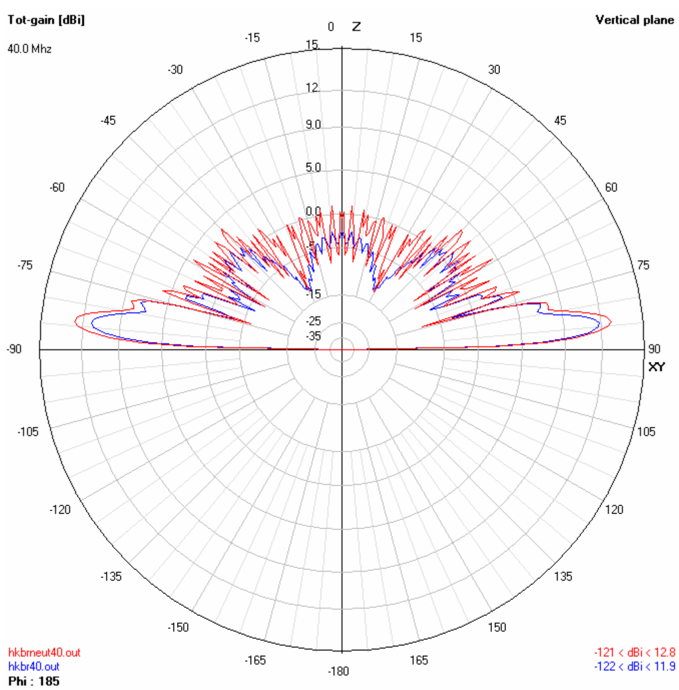

Figure E-34: Comparison of NEC model with and without a parasitic multi-grounded neutral. Red curve is with neutral, blue curve is without a neutral (40 MHz).