



**ENGINEERING REPORT FOR
EXPERIMENTAL STATION WS2XTR
AND
REQUEST FOR APPLICATION OF
47 CFR 73.160(b)(2)
FOR THE KINSTAR AM TRANSMITTING
ANTENNA FOR GENERAL USE BY AM
RADIO STATIONS
IN THE UNITED STATES**

Prepared By:

Michael W. Jacobs
STAR-H CORPORATION
LANCASTER, PENNSYLVANIA

Thomas F. King
KINTRONIC LABORATORIES
BRISTOL, TENNESSEE

July 30, 2004

Executive Summary

This report describes the results of detailed technical analysis along with extensive field tests conducted on the KinStar low-profile AM transmitting antenna developed by STAR-H Corporation and Kintronic Laboratories, Incorporated, and recommends how this new antenna should be considered within the framework of the rules of the Federal Communications Commission (herein "FCC") when used by radio stations in the United States.

Experimental and theoretical analysis of the antenna's operation and the methods underlying the FCC's rules regarding licensing of AM transmitting antennas have been conducted to ensure that the antenna's performance is completely understood and able to be characterized by the existing body of regulation.

In particular, this report will show the following key conclusions:

- The efficiency of the KinStar antenna **meets the minimum field requirements** of 73.189(b)(2)(ii) for Class B, C, and D broadcast stations in the United States.
- The elevation pattern radiation characteristics of the KinStar antenna are represented with sufficient accuracy by the formula of 73.160(b)(2) as a single top-loaded monopole antenna to **permit licensing for full-time operation**.
- All other operating characteristics of the antenna are within accepted practice for existing AM antenna systems and that there exist no safety, technical, or regulatory reasons to prevent stations from using the KinStar antenna in both daytime and nighttime operation anywhere in the United States, subject to the normal engineering and licensing process.

The broadcasting community has expressed its opinion that the availability of an efficient low-profile transmitting antenna will significantly benefit the AM radio service in the United States by allowing them an economical solution to siting difficulties and height restrictions. Further, use of the KinStar can result in improved service to the public by permitting transmitting facilities to be located closer to their service communities without presenting the undesirable visual appearance of a marked, lighted radio tower. Figure 1 shows a comparison of the height of the KinStar antenna versus that of a quarterwave tower monopole at the same operating frequency of 1680 kHz as used in the test program described in this report.



Figure 1 – Composite photograph of quarterwave tower and KinStar antenna at the WS2XTR test site, showing height comparison. Both antennas operate at 1680 kHz.

Table of Contents

Executive Summary.....	2
Table of Contents.....	4
Table of Figures.....	5
1.0 The KinStar Antenna.....	8
1.1 Mechanical Design.....	10
1.2 Radiation Pattern Performance.....	12
2.0 Field Testing of Antenna - Experimental Station WS2XTR....	21
2.1 Introduction.....	21
2.2 Antenna Construction.....	22
2.3 Testing Configurations.....	23
2.4 Radial Proof Results.....	23
2.5 Current Distribution Measurements.....	24
3.0 Environmental Effects Modeling.....	31
3.1 Introduction.....	31
3.2 Effects of Wind and Ice.....	31
3.3 Ground Parameter and Frequency Effects.....	34
3.4 Effects of Uneven Ground Under Antenna.....	37
4.0 Elevation Radiation Pattern.....	40
5.0 RF Exposure Safety Analysis.....	46
Appendix 1.....	54
Appendix 2.....	58
EXHIBIT A.....	62
EXHIBIT B.....	63

Table of Figures

Figure 1 - Composite photograph of quarterwave tower and KinStar antenna at the WS2XTR test site, showing height comparison. . .	3
Figure 2 - KinStar Antenna final design configuration.....	9
Figure 3 - Original KinStar antenna design.....	9
Figure 4 - Azimuth pattern of original "A" design.....	13
Figure 5 - Elevation pattern of original "A" design.....	14
Figure 6 - Azimuth pattern of final "B" design.....	15
Figure 7 - Elevation pattern of final "B" design.....	16
Figure 8 - Azimuth pattern of original "A" design.....	17
Figure 9 - Elevation pattern of original "A" design.....	18
Figure 10 - Azimuth pattern of final "B" design.....	19
Figure 11 - Elevation pattern of final "B" design.....	20
Figure 12 - KinStar antenna at WS2XTR test site.....	21
Figure 13 - Currents on KinStar Antenna Case A.....	27
Figure 14 - Currents on KinStar Antenna Case B.....	27
Figure 15 - Currents on KinStar Antenna Case C.....	28
Figure 16 - KinStar azimuth pattern circularity.....	30
Figure 17 - Impedance sweep of 1680 kHz KinStar "A" version antenna from 1640 to 1720 kHz over average ground with ¼" radial ice.....	32
Figure 18 - Impedance sweep of 1680 kHz KinStar "A" version antenna from 1640 to 1720 kHz over average ground with 1/2" radial ice.....	32

Figure 19 - Normalized elevation field pattern for KinStar antenna with 1/4" radial ice coating over perfect ground.....	33
Figure 20 - KinStar antenna with 0, 2', and 5' deflection in one pair of top loading wires.	34
Figure 21 - Elevation pattern showing horizontally polarized radiation component of KinStar antenna.....	38
Figure 22- Elevation pattern showing horizontally polarized radiation component of quarterwave monopole tower antenna.....	39
Figure 23 - Example of disagreements between 73.160 formulas and NEC models of selected AM broadcasting antennas.....	43
Figure 24 - E-field magnitude directly under top loading wire for 1680 kHz at 1 kW input power at a height of 2 meters (Permissible level is 614 V/m).....	47
Figure 25 - E-field in area halfway between two top loading wires (45 degrees) for 1680 kHz at 1 kW input power at a height of 2 meters (Permissible level is 614 V/m).....	47
Figure 26 - Magnetic field directly under top loading wire for an input power of 1 kW at a height of 2 meters (Permissible level is 1.63 A/m).....	48
Figure 27 - Magnetic field in between wires for 1680 kHz at 1 kW at a height of 2 meters (Permissible level is 1.63 A/m).....	48
Figure 28 - E-field directly under top loading wire for 1680 kHz at 50 kW input power at a height of 2 meters (Permissible level is 614 V/m).....	49
Figure 29 - Magnetic field directly under top loading wire for 1680 kHz at an input power of 50 kW at a height of 2 meters (Permissible level is 1.63 A/m).....	49
Figure 30 - Electric field directly under top loading wire for 550 kHz at an input power of 1 kW at a height of 2 meters (Permissible level is 614 V/m).....	50
Figure 31 - Magnetic field directly under top loading wire for 550 kHz at an input power of 1 kW at a height of 2 meters (Permissible level is 1.63 A/m).....	50

Figure 32 - Electric field directly under top loading wire for 550 kHz at an input power of 50 kW at a height of 2 meters (Permissible level is 614 V/m)..... 51

Figure 33 - Magnetic field directly under top loading wire for 550 kHz at an input power of 50 kW at a height of 2 meters (Permissible level is 1.63 A/m, threshold not shown)..... 52

Figure 34 - Magnetic field directly under top loading wire for 550 kHz at an input power of 50 kW at a height of 2 meters (Permissible level is 1.63 A/m)..... 52

Figure 35 - E -Field plot for 90 degree tower at 1680 kHz at 1 kW along radial at height of 2 meters (Permissible level is 614 V/m). 53

Figure 36 - H -Field plot for 90 degree tower at 1680 kHz at 1 kW along radial at height of 2 meters (Permissible level is 1.63 A/m)..... 53

1.0 The KinStar Antenna

This new antenna design is intended for use by medium frequency AM broadcasting stations in areas where height restrictions or public concern limits the use of 90-degree monopole structures. It consists of a vertical wire cage monopole structure, approximately 0.05 to 0.08 wavelengths tall, with horizontal top loading wires extending radially outward from the top ends of each wire in the monopole cage, with the entire structure operating over a standard quarter-wavelength 120-radial wire ground screen. The top load wires extend a sufficient distance as to cause the desired linear current distribution on the vertical cage wires.

An impedance matching network consisting of either a single lumped-element antenna tuning unit, or a unique system using specific length phase-matched semi-rigid coaxial transmission lines matches the antenna impedance to $50 + j0$ Ohms for connection to the radio station transmitter. Figure 2 shows the general arrangement of the wires in the antenna in the final lumped-element "B" configuration that is intended to be the primary model offered to broadcasters and for which permission for use is requested. Figure 3 shows the original antenna design which uses transmission line matching and which was tested at WS2XTR as the "A" configuration, and which shows slightly higher efficiency and may be preferred for some applications.

Both models have nearly identical current distributions and radiation characteristics. Table 1 presents typical dimensions of this antenna at various frequencies in the AM band. A full technical explanation of the operation of the antenna was presented at the 2002 IEEE Broadcast Symposium in Washington, DC, and is included here in an appendix as Exhibit A. A summary of the operating characteristics is presented here with results of full-scale testing and additional effects modeling in the following sections of this report.

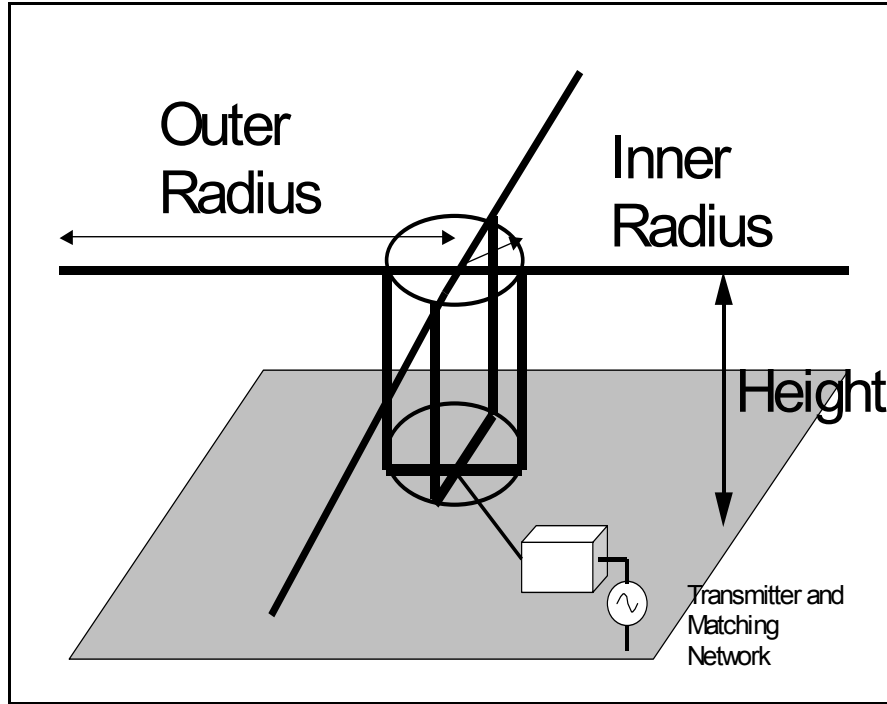


Figure 2 - KinStar Antenna final design configuration using lumped element matching and with top and bottom of vertical radiating wires connected together. Dimensions are shown in Table 1, below, for selected AM broadcast frequencies. All antenna wires are insulated from ground and supports. This design (less the connection at the top of the wires) was the KinStar “B” configuration in the WS2XTR test program

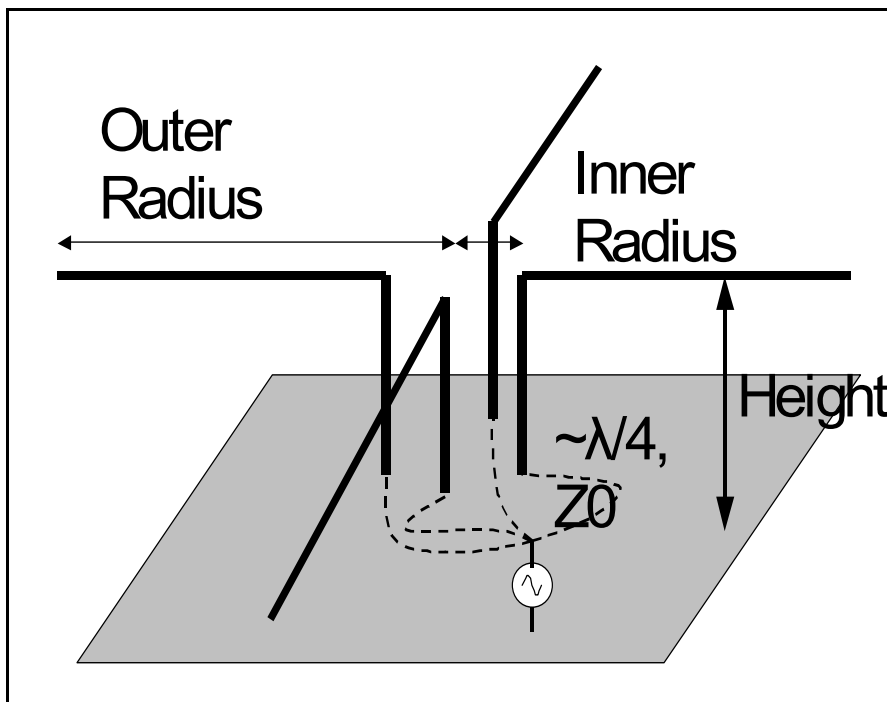


Figure 3 - Original KinStar antenna design using transmission line matching. Each wire is insulated in this configuration, which was tested at WS2XTR as configuration "A".

Table 1. Nominal KinStar Antenna Dimensions

Frequency	Height (ft)	Inner Radius (ft)	Outer Radius (ft)	1.5:1 Bandwidth (kHz)
550 kHz	136.3	16	306.6	16
1000 kHz	75	8.5	168.6	29
1680 kHz	44.9	5	100.1	49
General	Approx. 0.08λ	Approx. 0.008λ	Approx. 0.17λ	2.9%

Note: Dimensions are based on scaling from optimized 1700 kHz design using transmission line matching and 4 vertical wires. Broadbanding of the matching network or the antenna dimensions can improve the bandwidth performance at the lower frequencies to meet IBOC transmitter requirements.

1.1 Mechanical Design

The KinStar antenna's height varies with frequency from 44.1 feet at 1700 kilohertz to about 140 feet at 530 kilohertz. This compares with a height of 146 to 464 feet for a quarterwave tower at the same frequencies. The benefits of the reduced height are both practical and cosmetic. Even at 530 kilohertz, the KinStar antenna will not require marking and lighting at most locations away from registered airports. This results in a cost savings by not requiring a lighting system with its concomitant maintenance and operational costs, along with eliminating the requirement for periodic structure repainting. By reducing the antenna height, the potential hazard to air navigation is reduced, thus increasing safety for aircraft which may find themselves operating at lower altitudes than normal. Cosmetically, the appearance of the antenna will be identical to that of common overhead electrical utility lines, and with its reduced height, the area from which the antenna is visible is significantly reduced. These factors should make it easier for stations to obtain local approval for construction than if they were installing a tall tower with flashing obstruction lighting.

The precise antenna dimensions are determined using computer optimization techniques applied to the NEC-4.1 (Numerical Electromagnetics Code) Method of Moments antenna modeling program. Use of computer optimization allows the KinStar to be designed to meet strict height and bandwidth requirements even as the percentage bandwidth requirement increases with decreasing operating frequency. The dimensions of the antenna, therefore, are not simply scaled with frequency, but can be specifically tailored for each application to best

meet bandwidth requirements while minimizing antenna height. The bandwidth requirements for digital IBOC and DRM transmission have been considered and can be met by the optimized KinStar design for all allocated AM frequencies in the United States.

Common overhead utility line construction materials and techniques are used in the construction of the antenna. For stations operating above approximately 1200 kilohertz, the antenna wires can be supported from a choice of wooden, metal, or concrete utility poles, or from short sections of a small cross-section tower. Below 1200 kilohertz, the required antenna height exceeds 70 feet and wooden poles become less available and more expensive, so the use of tower sections as supports is anticipated. Guying to screw-type ground anchors is practical when using utility poles, and if set carefully with sufficiently compacted backfill, the support poles can be placed directly in augured holes in the ground, resulting in a very low-cost installation. Stations located in coastal hurricane areas, or in areas subject to heavy ice accumulation, or with significant Emergency Alert System responsibilities may wish to opt for more substantial support structures to improve the antenna survivability in extreme weather situations. The vertical support structures will be equipped with a lightning rod and downconductor to a lightning ground to prevent damage to the supports from a lightning strike.

For most omnidirectional applications, the KinStar antenna will consist of a cage of four vertical wires arranged symmetrically around the center of the antenna. Each vertical wire will be connected at the top to a horizontal top loading wire that will extend from the center of the antenna out to the specified length to achieve the required top loading. This length is always shorter than the radius of the ground screen, so it does not impact the land area required for the antenna. At the center, all four horizontal wires will be connected together to provide a shunt path for the reduction of any asymmetrical currents which may arise as a result of inexact placement of supports or uneven terrain effects. For antennas using the lumped element matching method, the bottom of each vertical wire will also be tied together to allow a single feedwire from the antenna tuning unit to be used, as is common practice.

1.2 Radiation Pattern Performance

NEC modeling shows that the KinStar antenna, in both the "A" and "B" variants exhibits a completely omnidirectional azimuth radiation pattern as though radiated from a single vertical conductor. The elevation radiation pattern resembles that from a short constant current element. Figures 4 through 11 show the azimuth and elevation radiation patterns over perfect ground for both antenna variants at 530 kHz and 1680 kHz.

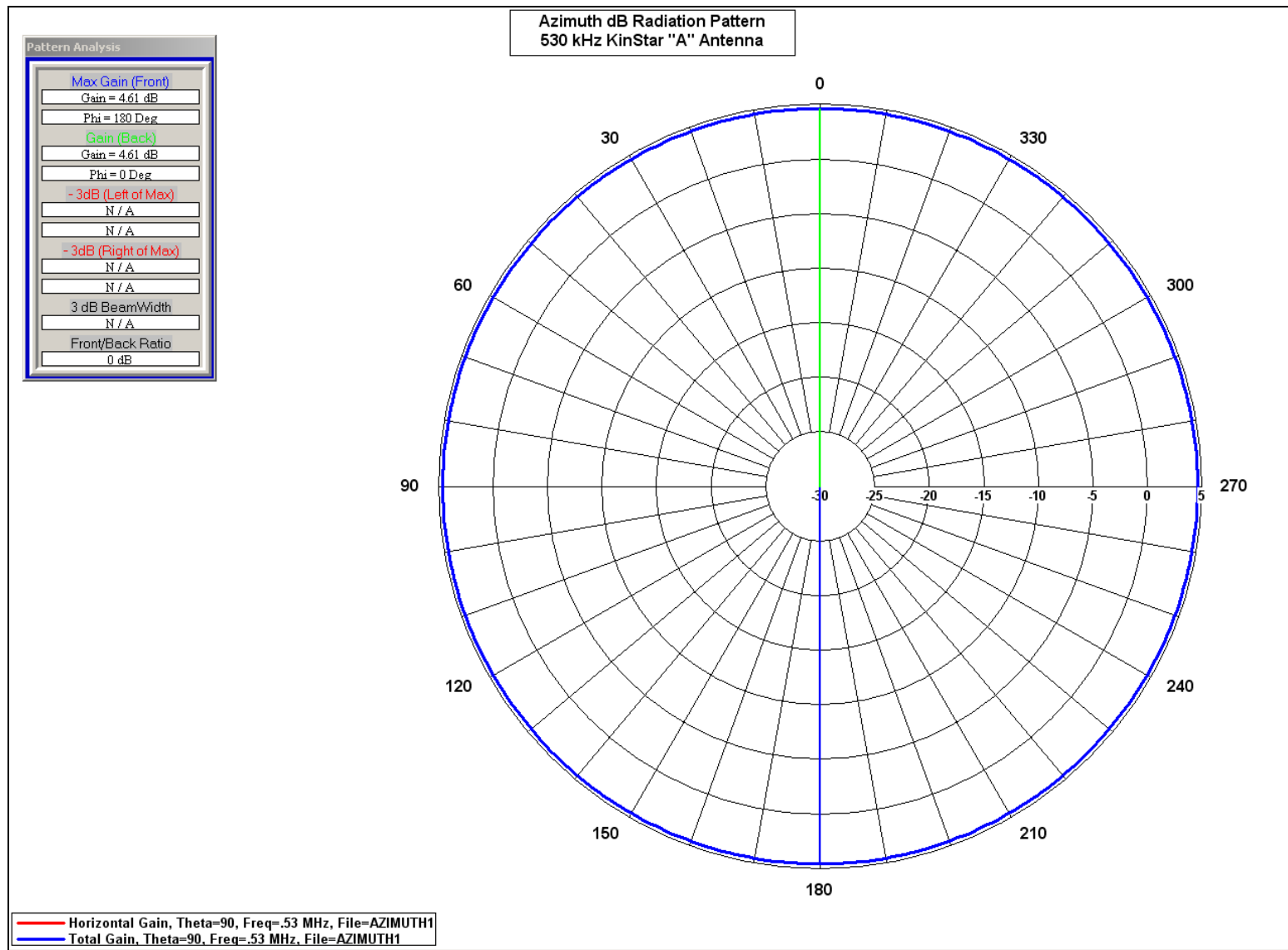


Figure 4 - Azimuth pattern of original "A" design using transmission line matching to isolated wire sections. Pattern is circular with gain of 4.61 dBi at 530 kHz over perfect ground. There is no radiated horizontally polarized component.

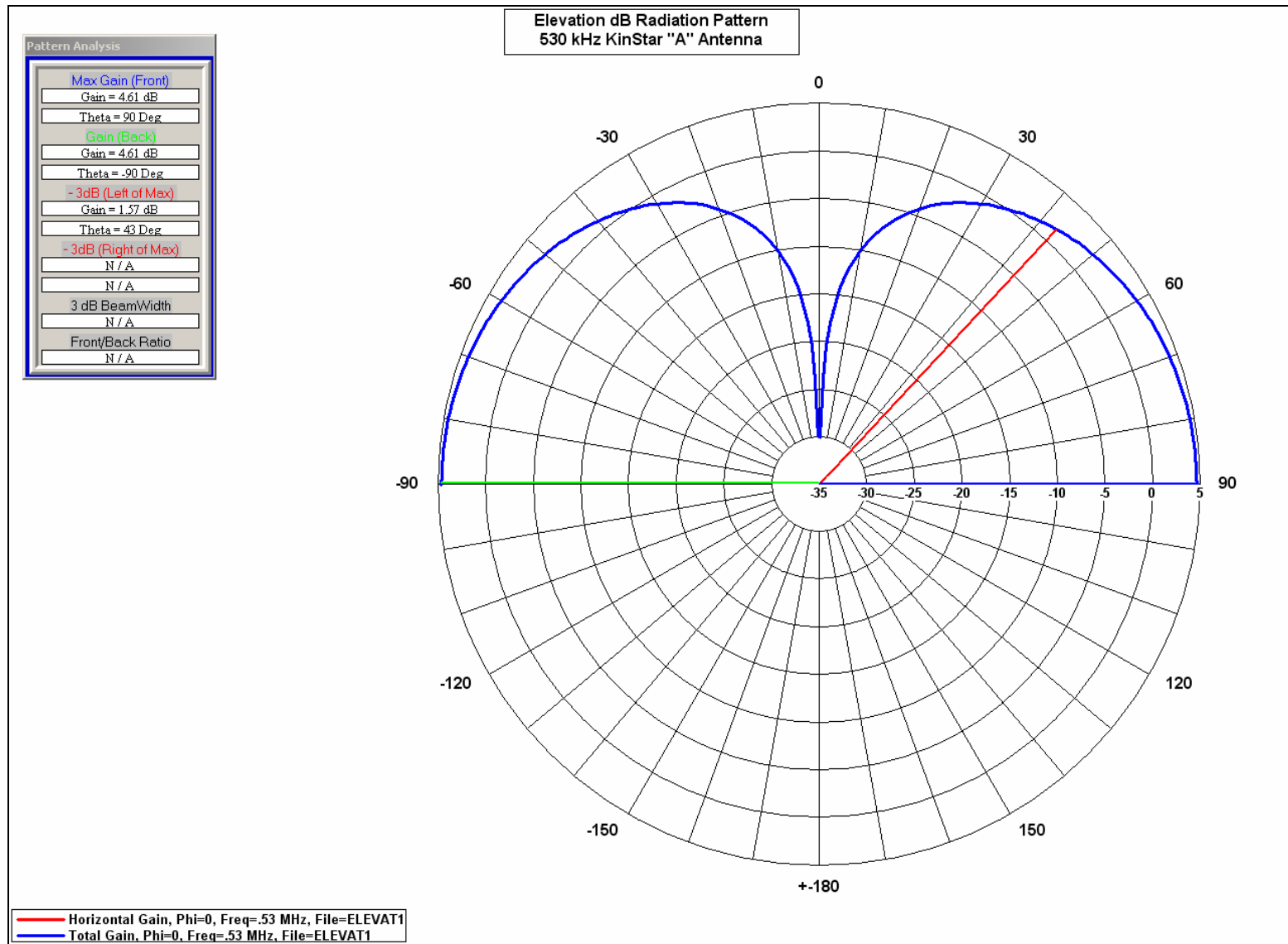


Figure 5 - Elevation pattern of original "A" design using transmission line matching to isolated wire sections. Pattern is sinusoidal with a half-power beamwidth of 43 degrees at 530 kHz over perfect ground. There is no radiated horizontally polarized component.

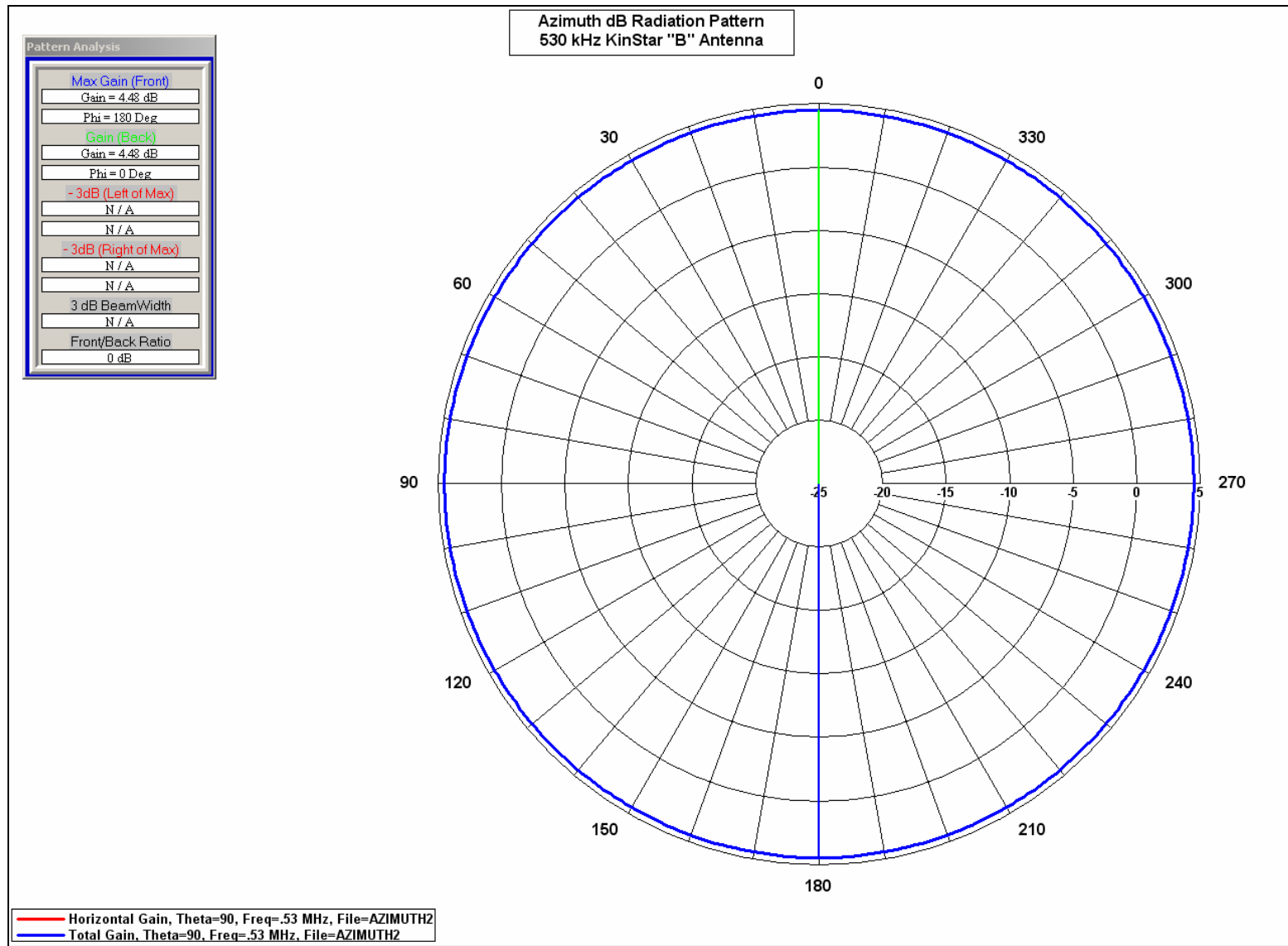


Figure 6 - Azimuth pattern of final "B" design using lumped element matching to top and bottom commoned wire sections. Pattern is circular with gain of 4.48 dBi at 530 kHz over perfect ground. There is no radiated horizontally polarized component.

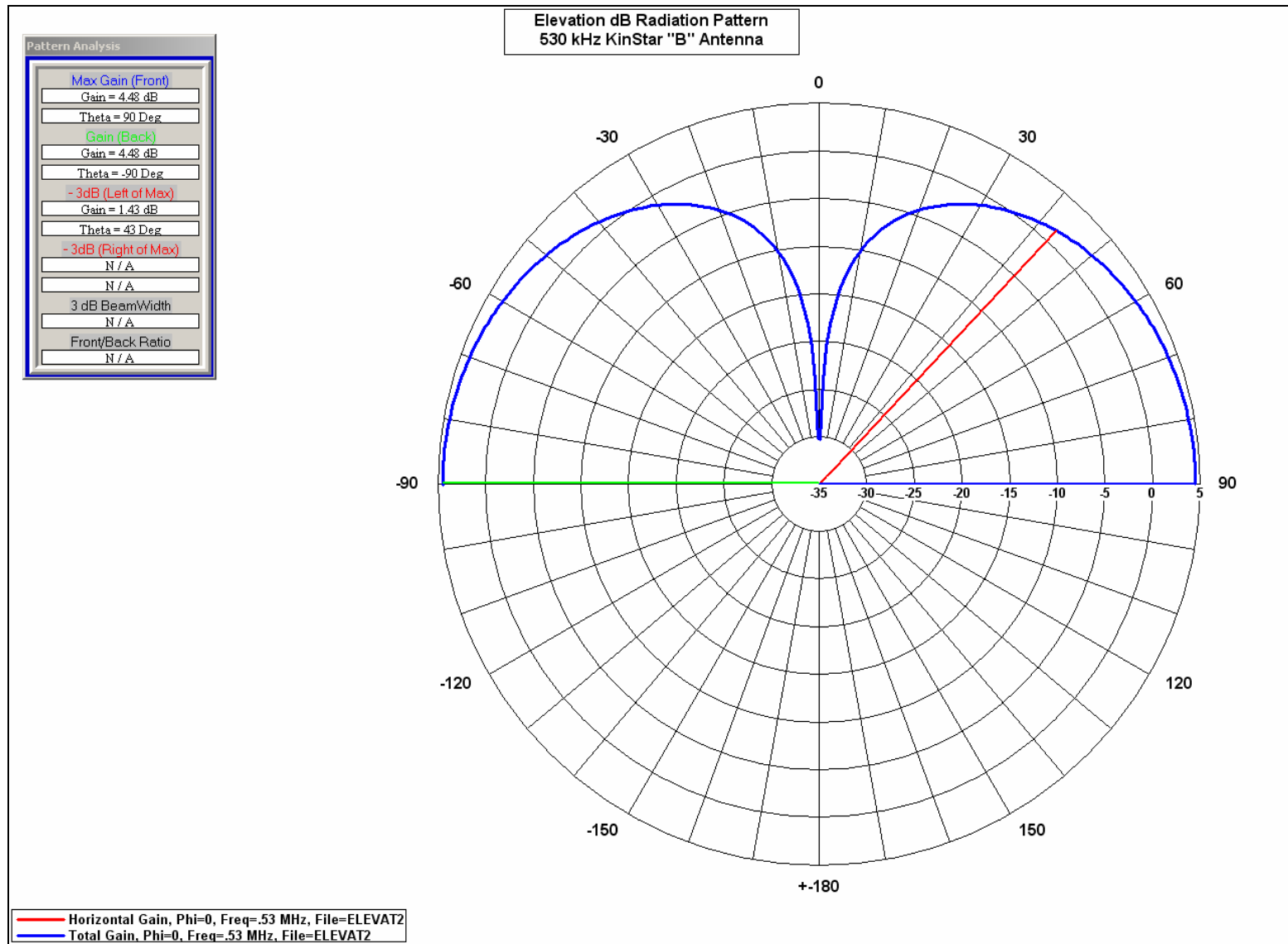


Figure 7 – Elevation pattern of final "B" design using lumped element matching to commoned wire sections. Pattern is sinusoidal with a half-power beamwidth of 43 degrees at 530 kHz over perfect ground. There is no radiated horizontally polarized component.

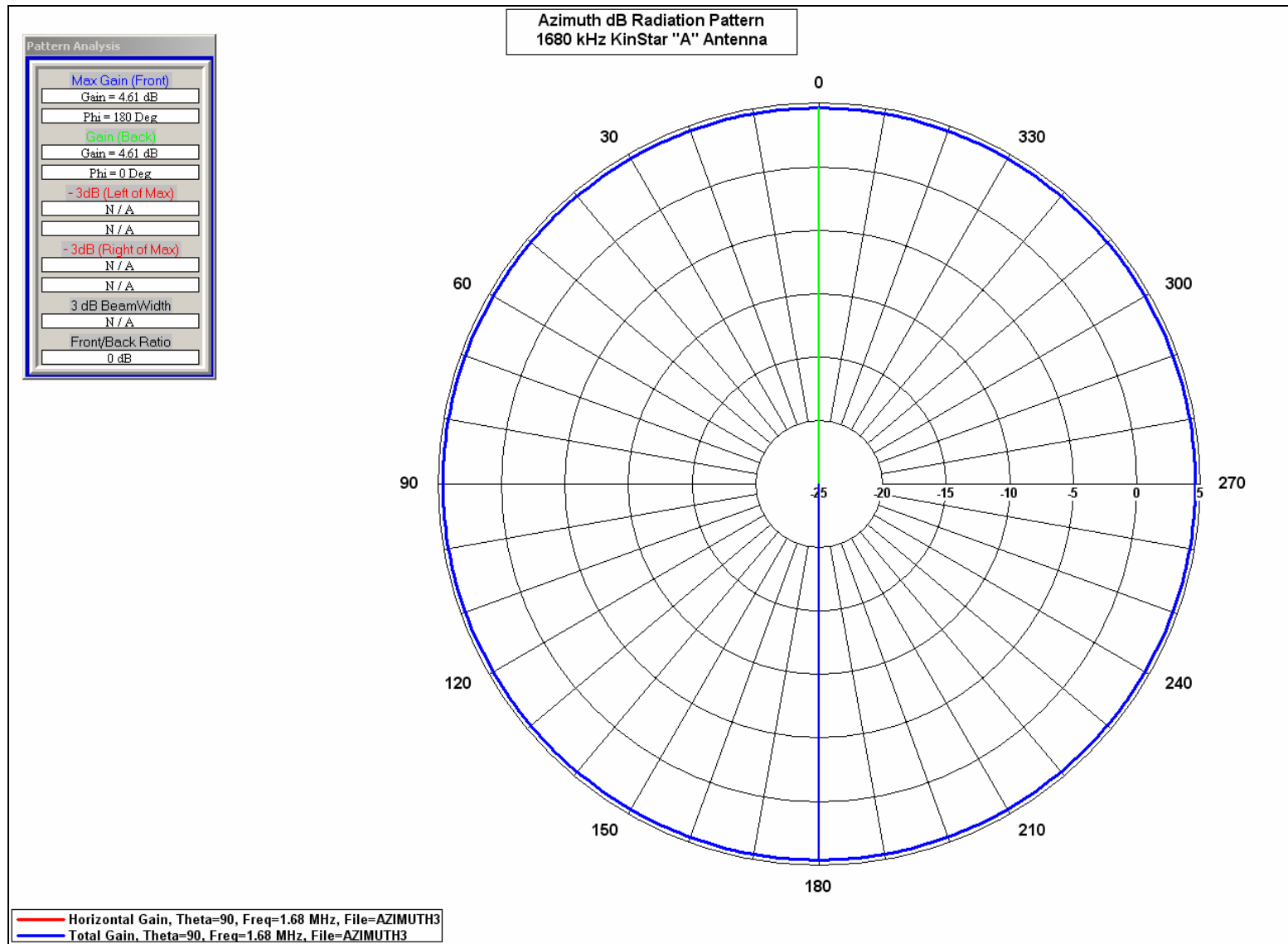


Figure 8 - Azimuth pattern of original "A" design using transmission line matching to isolated wire sections. Pattern is circular with gain of 4.61 dBi at 1680 kHz over perfect ground. There is no radiated horizontally polarized component.

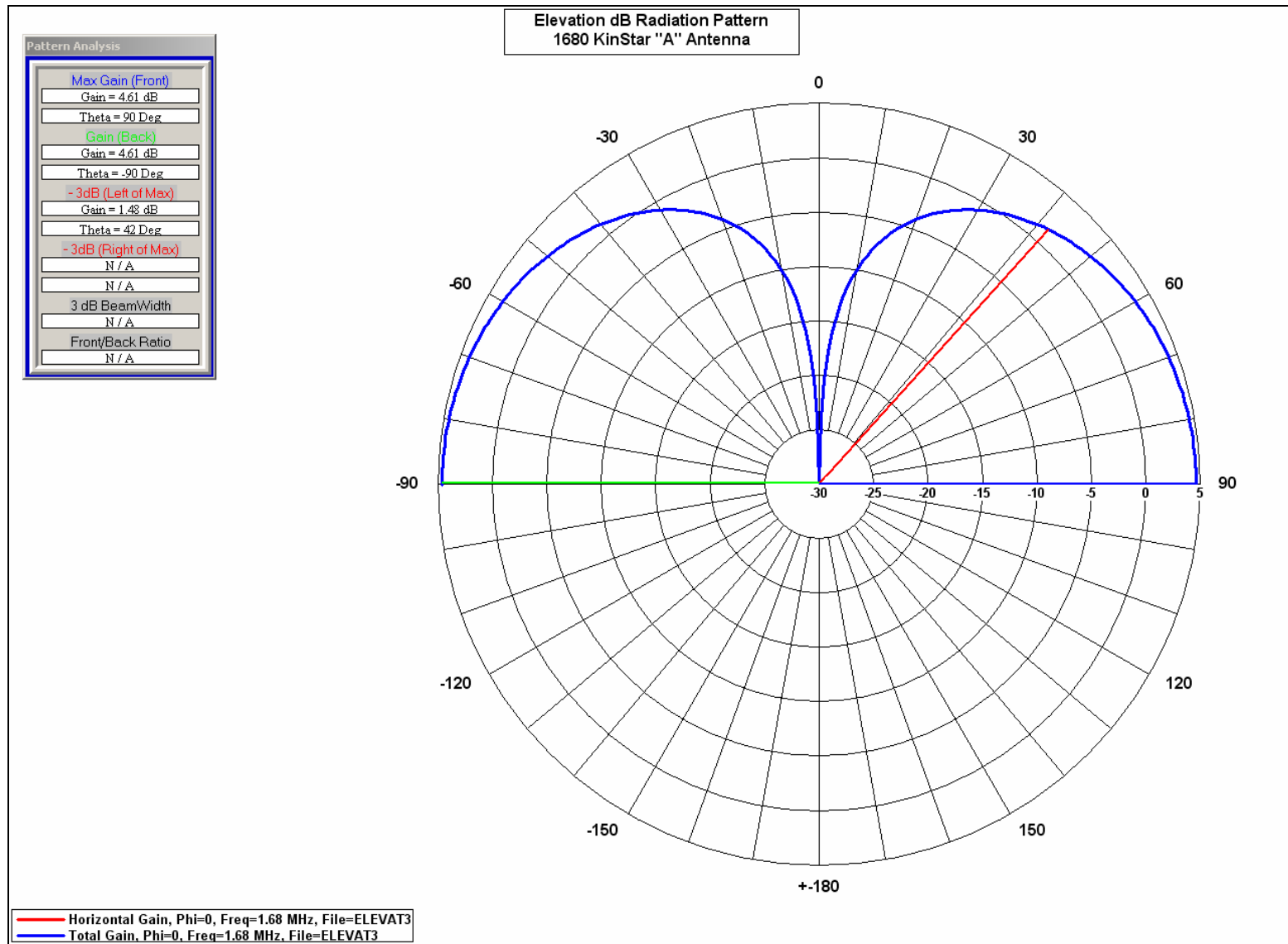


Figure 9 - Elevation pattern of original "A" design using transmission line matching to isolated wire sections. Pattern is sinusoidal with a half-power beamwidth of 42 degrees at 1680 kHz over perfect ground. There is no radiated horizontally polarized component.

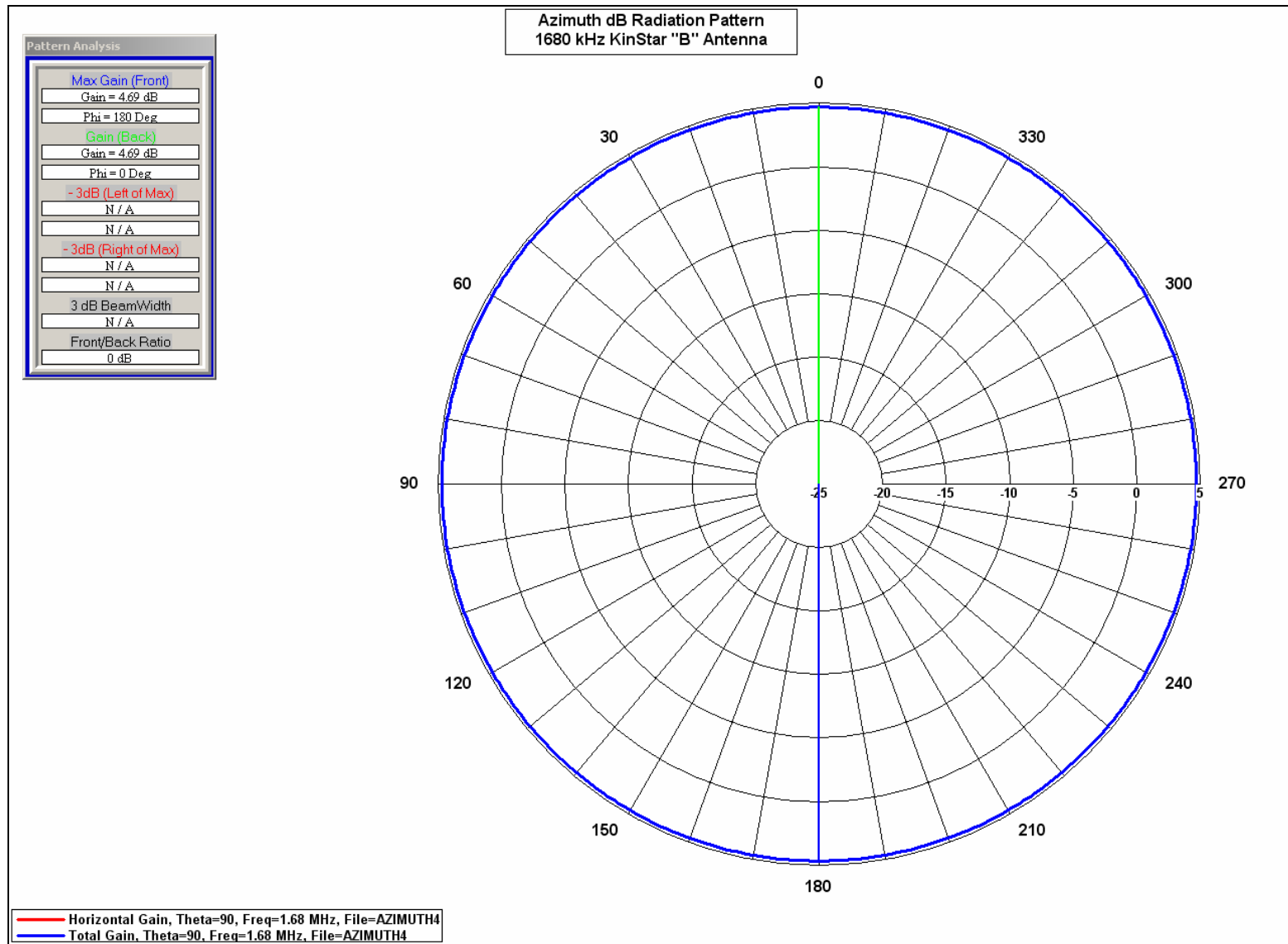


Figure 10 - Azimuth pattern of final "B" design using lumped element matching to commoned wire sections. Pattern is circular with gain of 4.69 dBi at 1680 kHz over perfect ground. There is no radiated horizontally polarized component.

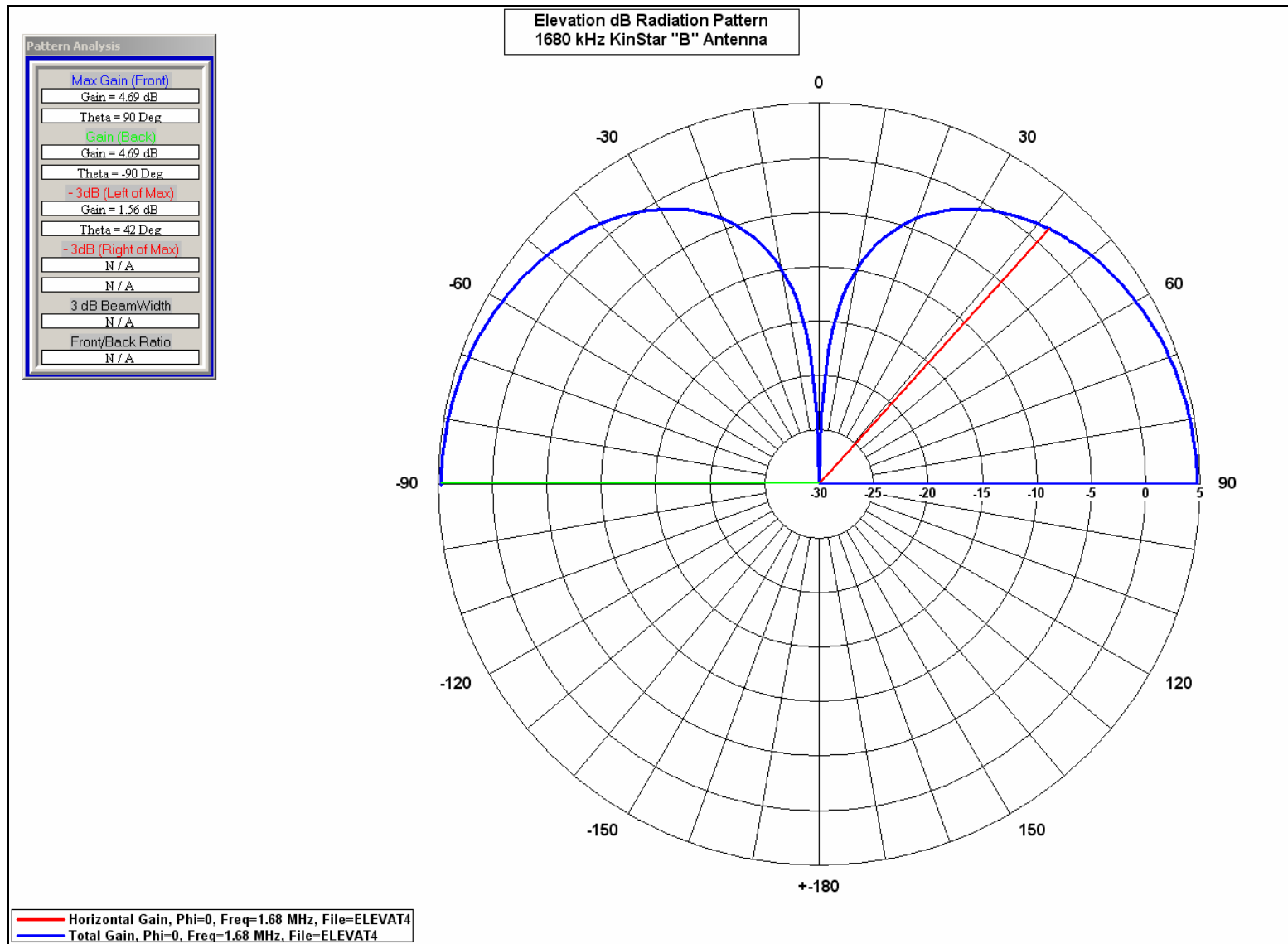


Figure 11 - Elevation pattern of final "B" design using lumped element matching to commoned wire sections. Pattern is sinusoidal with a half-power beamwidth of 42 degrees at 1680 kHz over perfect ground. There is no radiated horizontally polarized component.

2.0 Field Testing of Antenna - Experimental Station WS2XTR

2.1 Introduction

The KinStar antenna has been predicted by NEC-4.1 modeling to exceed the minimum efficiency requirements for class B, C, and D stations given in Section 73.189(b)(2)(i) of the FCC Regulations. The antenna does not meet the minimum height requirements of 73.190 Figure 7, so in accordance with 73.189(b)(5) a request was made for an experimental license to perform a complete field strength survey on an actual full-scale antenna. This request was granted and experimental license WS2XTR was issued for daytime-only testing at a frequency of 1680 kHz from a site in Evergreen, VA. The site was in an area of low rolling hills in an active alfalfa field. The test location was surrounded by farmland for several miles in all directions, and no large metal structures, towers, or high voltage utility lines were located nearby.



Figure 12 - KinStar antenna at WS2XTR test site. Vertical radiating and top loading wires have been enhanced for visibility. The pole structure is about 50 feet tall, and 105 feet in radius for operation at 1680 kHz to support the radiating antenna with a height of 45 feet and 100 foot radius. Each pole is approximately 55 feet long, with approximately 7 feet of that in the ground.

2.2 Antenna Construction

The antenna was constructed using wooden utility poles placed in augur-drilled holes directly in the ground of a rural alfalfa field, which was rented for the purpose of conducting this test. Installation of the antenna, once the ground system was completed, took a relatively short time, and could easily be completed in one day if a utility line construction bucket truck was used instead of having personnel climb the wooden poles. Uninsulated 3/8-inch diameter All-Aluminum Conductor (AAC) stranded cable was used for the vertical radiating and horizontal loading wires. Fiberglass rod insulators were used to insulate the antenna wires from the support poles and anchors. Each support pole was guyed in two directions to oppose the pull of the tension on the horizontal top loading wires. The wires were tensioned so that no sag was visible in the horizontals. The nominal design dimensions of the antenna for 1680 kHz were 44.97 feet high, with each vertical wire located 5 feet from the center and with the horizontal wires extending out 95.1 feet to an outer radius of 100.1 feet from the center. Construction of the antenna conformed to the 2002 National Electrical Safety Code.

The construction crew, either by error or by encountering rock below the surface, was unable to accurately place the four screw anchors for the vertical wires, with a typical error of approximately +1 foot in the inner radial distance (6 feet instead of 5). Table 2 compares the as-built dimensions of the antenna with those specified in the design. A photograph of the antenna, with the wires enhanced, is shown in Figure 12.

Table 2. Deviation of radial spacing of vertical radiating wire anchors, from design specification

Wire	Deviation from design spacing (Feet), approximate
1	1.1
2	0.8
3	0.3
4	1.1

2.3 Testing Configurations

Tests were conducted using two antenna feed configurations. These two configurations are shown in Figures 1 and 2. The Trial A configuration combined the use of four phase-matched and length-optimized sections of 50-Ohm 7/8" foam dielectric coaxial cables, one end of each of which was connected to the bottom end of each of the vertical antenna elements. The other ends of the cables were connected in parallel at the output of a simple lumped element "T" matching network. The Trial B configuration consisted of the use of a commoning ring at the top and bottom of the four vertical antenna elements with a single conductor connecting the bottom commoning element to the "T" matching network. This configuration results in the antenna wires behaving as a single fat top-loaded monopole antenna.

There was no significant difference in the radiation characteristics and electrical performance between the two methods, with the transmission line matching showing slightly higher efficiency than the top-loaded "fat" monopole approach. With broad-banding techniques, the top-loaded monopole configuration may offer wider bandwidth and higher power handling capabilities, while the transmission line matching system offers lower cost of implementation for low-power stations. Even with the transmission line matching, a simple T or L network of lumped elements was used to allow for easier tuning adjustment of the antenna impedance to match the feedline than having to adjust the lengths of the antenna wires or transmission lines.

A 400-Watt Nautel Ampfet transmitter was adjusted to apply 250 Watts of input power to the antenna and tuning system for testing. The transmitter and ATU were installed in two metal enclosures near the base of the antenna. The entire area was fenced off with wooden stockade fencing to prevent public contact with the wires or exposure to RF fields. Suitable warning signage was placed at the site to advise personnel of potential RF hazard areas.

2.4 Radial Proof Results

A complete six-radial proof of performance was conducted by Mr. Don Crane for each of the two antenna configurations and a reference quarterwave tower monopole at the same location using the same ground system. The

measured field strength data was then analyzed and reported by Mr. Ronald D. Rackley, P.E., of duTreil, Lundin, and Rackley, Inc., and is provided as Exhibit B in this document. Table 3 summarizes the results of the data analysis from Exhibit B, which shows that the measurements confirm fully the NEC-4.1 antenna efficiency predictions.

Table 3. Measured antenna efficiency and field values.

Antenna	Measured Field @ 1km	Equivalent Field with 1kW @ 1km	Average Radial Efficiency
Monopole Reference	153 mV/m	306 mV/m	1.00
Kinstar Config. A	152 mV/m	304 mV/m	0.995
Kinstar Config. B	150 mV/m	300 mV/m	0.980

(all values by duTreil, Lundin, and Rackley)

The predicted unattenuated field value for a 27.65 degree antenna, with 76.0 degrees of top loading to place the 90 degree point from the effective end at the center of its physical height and provide essentially uniform current along its vertical length, is 286.7 mV/M at one kilometer for one kilowatt input power and one ohm loss. This is within 0.5 and 0.4 dB of the measured field values of Configuration A and Configuration B, respectively.

2.5 Current Distribution Measurements

After completion of the field strength proof testing, it was decided to measure the current distribution on the vertical wires in order to be able to calculate the vertical radiation characteristics of the antenna. Kintronic Laboratories personnel constructed and calibrated a measurement and logging device, under the direction of Mr. Rackley, which consisted of a toroidal current transformer mounted on a Teflon tube with a battery-powered data logger. Individual vertical element current distribution measurements were conducted by routing the wire through the Teflon tube and raising the unit to the top of the element. The unit was then lowered in 2.5 foot increments with the transmitter on and the data logger operating continuously. Approximately 100 measurements were made on each vertical wire, resulting in a resolution of approximately 0.4 feet per measurement. The lowest 5

feet of the vertical wires consisted of the insulating rod and turnbuckle assembly, and thus carried no current and are not included in the measurement. Some opposing current is present in the ground straps from the coaxial cable endpoints at the base of the vertical wires, this can be assumed to be of equal magnitude and opposite phase to the first 5 feet of measured currents on the vertical wires. These ground straps were not present when testing with the lumped element matching network, however. NEC-4.1 modeling which placed the antenna feedpoint at the 5-foot above ground point did not show any difference in the vertical radiation pattern with that having the feedpoint 6 inches from the ground, so that the effect of the currents in the ground straps can be effectively ignored in calculating the vertical radiation pattern.

Initial evaluation of the current measurement results, shown in Figures 13 and 14 showed an unexpected asymmetry in the current magnitudes on the four vertical wires. Inspection of the site, and experience with other AM antenna systems suggested that the metal transmitter and ATU enclosures might have influenced the current distribution by being closer to two of the wires. These boxes were thus moved 16 feet outside the fenced area, thus reducing any coupling effects from the antenna wires. The current measurements were repeated for both antenna-matching configurations, and with the addition of having the horizontal wires shunted together at the tops of the vertical wires (a feature not included in the original antenna design). Table 4 summarizes each case for which current measurements were made.

Table 4. Antenna Test Configurations

Case	Matching Method	Wires Shunted	Comments
A	Transmission Line	No	Boxes inside fence
B	Lumped Element	Bottom Only	Boxes inside fence
C	Lumped Element	Bottom and Top	Boxes inside fence
D	Lumped Element	Bottom and Top	Boxes 16ft. Outside
E	Transmission Line	No	Boxes 16ft. Outside

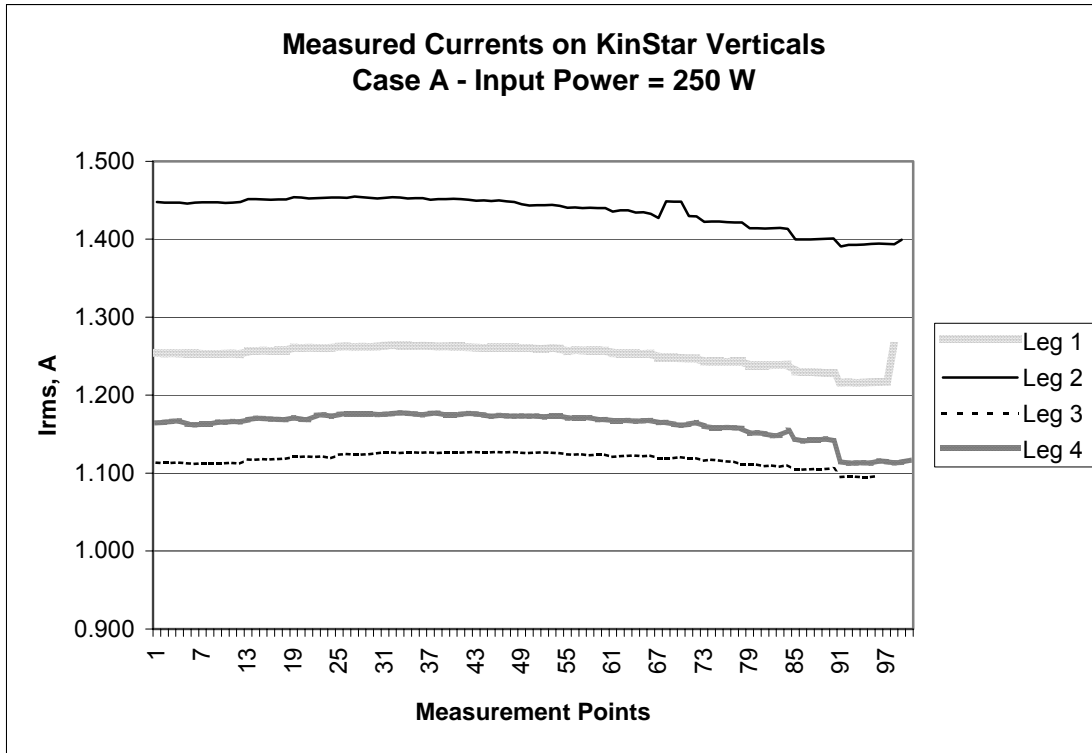


Figure 13 - Currents on KinStar Antenna Case A, with independent feeds to each leg of the antenna through transmission line matching sections and with all legs insulated.

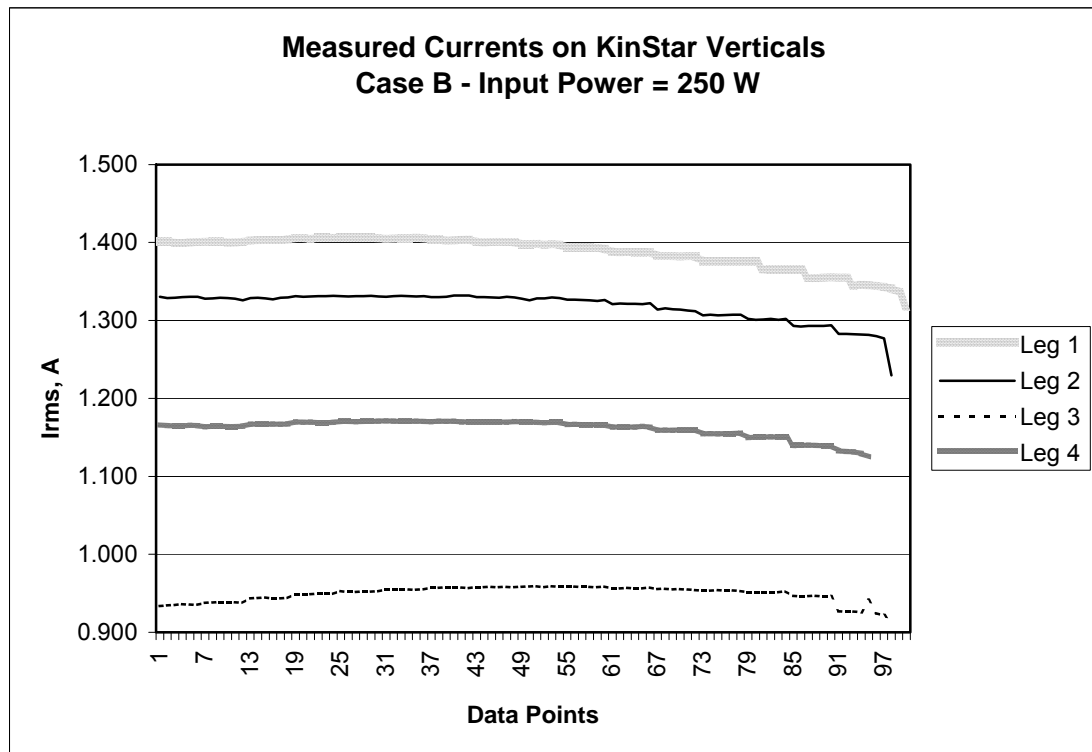


Figure 14 - Currents on KinStar Antenna Case B, with a common feed from lumped element matching network.

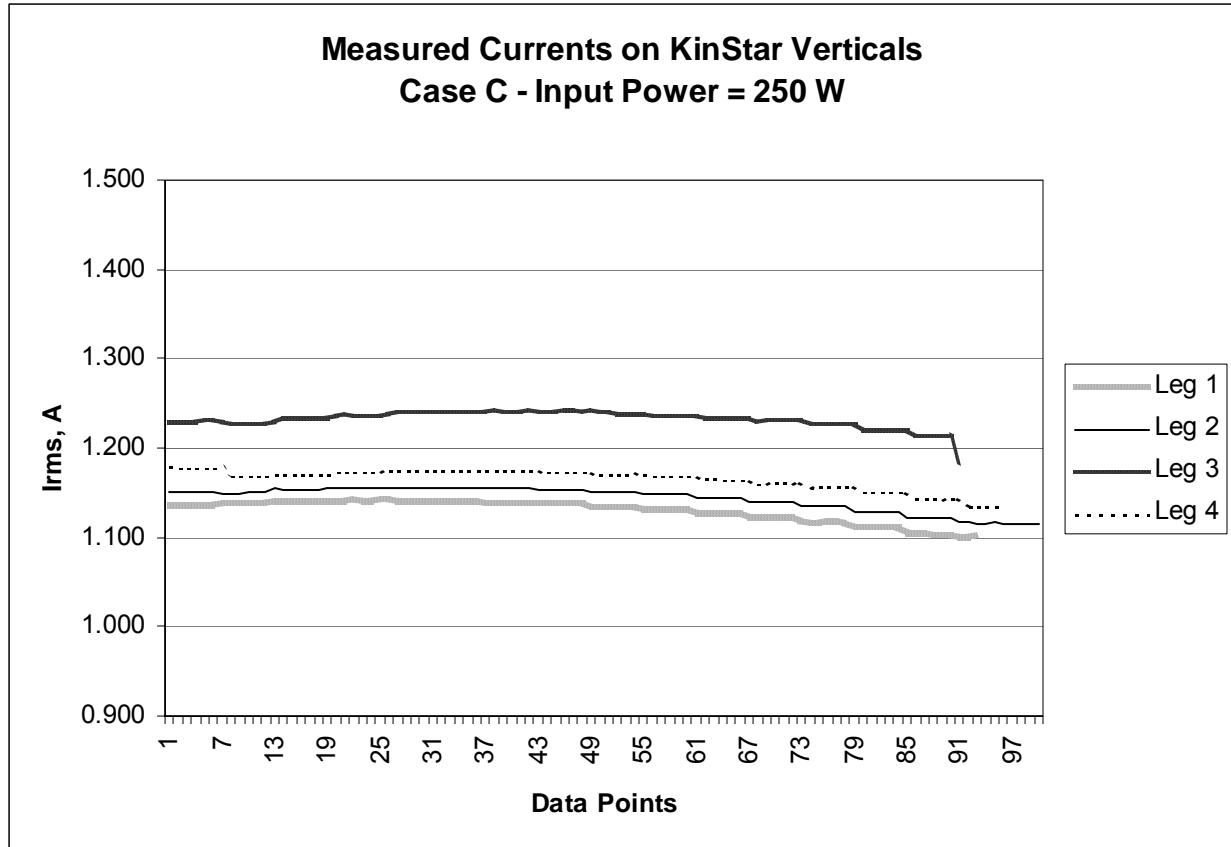


Figure 15 - Currents on KinStar Antenna Case C, with common feed from lumped element matching network and wires connected together at top and bottom of vertical radiating conductors. This shows significant equalization of currents compared with Case B above. This arrangement with the vertical wires connected at the top will be used in all KinStar installations as a precautionary measure to ensure that current symmetry is maintained as close as possible under all conditions.

These tests showed that proximity of the metal equipment cabinets did not cause the observed current asymmetry. Significant improvement in the current symmetry was seen for the test cases with the wires shunted at the top of the antenna, as shown in Figure 15. Later comparison with NEC-4.1 modeling data shows that the current asymmetry was most likely caused by a combination of the misplacement of the vertical wire anchors and the uneven terrain of the alfalfa field resulting in differing effectiveness of each top loading wire. While a surveyor was called in to stake the locations of the five support poles at approximately equal elevations, his survey of the site showed that several feet of variation were seen over the entire area covered by the ground system. Table 5

shows the average elevation variation along a line under each of the four top loading wires.

Table 5. Average ground elevations under horizontal wires.

Location	Average Elevation (Feet)	Difference from Center (Feet)
Center	100	-
Wire 1	99.33	-0.67
Wire 2	101.43	1.43
Wire 3	99.31	-0.69
Wire 4	98.79	-1.21

The concern for the uneven currents is not that it affects the azimuthal radiation pattern, indeed both the field measurement data and subsequent NEC-4.1 modeling showed that the vertical wires are so close together that they radiate effectively as a single vertical current element, as shown in Figure 16. Rather, in accordance with Kirchoff's current law, the currents on the horizontal loading elements are determined by the current magnitude at the top end of the vertical wires. When the horizontal wires are insulated from each other the current distribution on them is essentially sinusoidal, going from a maximum at the connection to the vertical down to zero at the outer end. The current maximum at the inner end of the horizontal is equal to that at the top end of the connected vertical wire, so efforts have to be made to ensure that the current distribution is evenly balanced throughout the structure.

Modeling shows that addition of the commoning ring at the top of the vertical wires has an equalizing effect on the horizontal element currents by redistributing any unequal currents which may tend to flow on the antenna. This feature will be incorporated in all KinStar antenna installations as a standard feature.

NEC modeling was used to study the unexpected unequal currents and to understand the causes. First, models were

made to recreate the observed current distribution for the insulated wire version (Case A). This model was then adapted to include the as-built dimensions including the actual vertical wire anchor positions. The modeling suggested that the offset of the wire base positions did not alone account for the observed current asymmetry. The modeling did verify, however, that connecting the four wires together at the top of the vertical radiating elements significantly improved the current differences and reduced any resulting horizontally polarized radiation by up to 6 dB compared with identical models without the top wires connected.

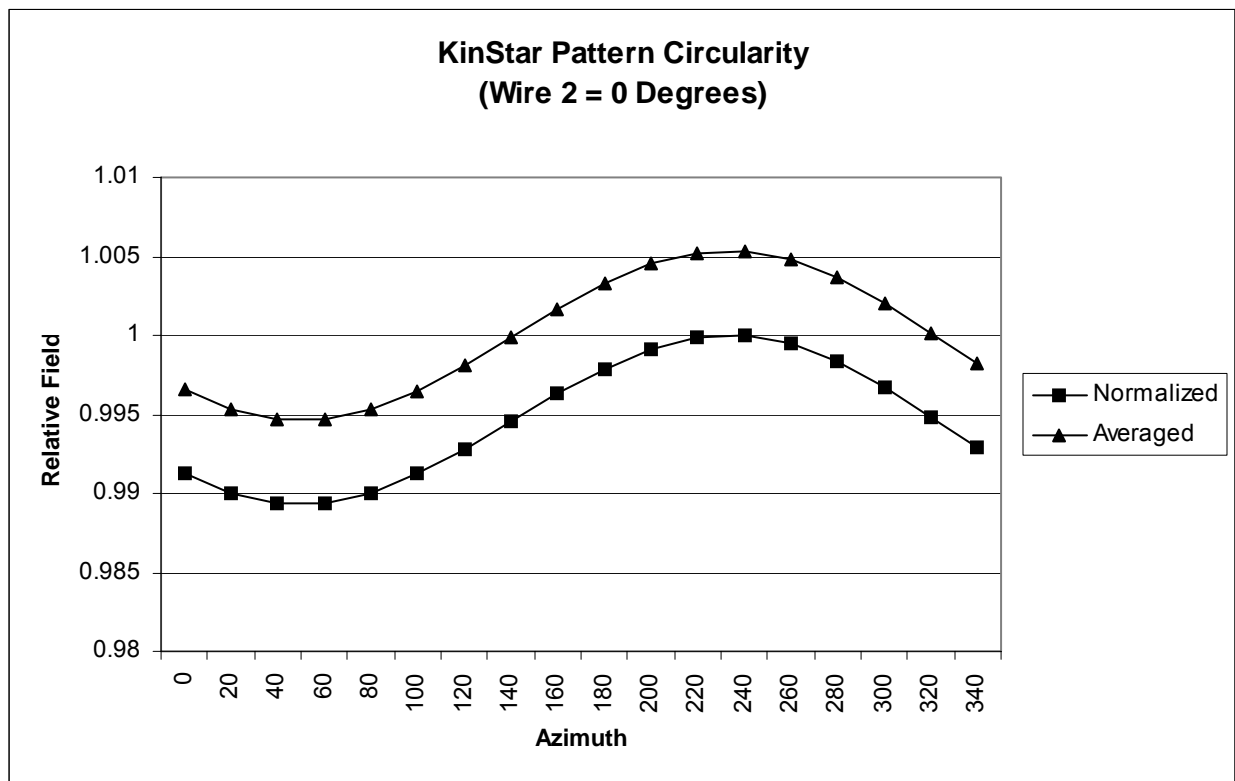


Figure 16 - KinStar azimuth pattern circularity at 0 degrees elevation calculated from the measured currents for Case A. Even with the significant asymmetry in the vertical wire currents, in the far-field (calculations were made for 1km distance) the field remains circular to within 0.6% for the worst observed case. This shows that the cage wire construction of the KinStar radiates essentially as a single vertical current element even in the uninsulated independent feedpoint version. For the proposed commercial version of the antenna, with the top of the vertical wires commoned together, the circularity error will be much reduced from this.

3.0 Environmental Effects Modeling

3.1 Introduction

NEC-4.1 modeling was also used to evaluate the effects of other expected environmental effects on the performance of the antenna. The KinStar is shown to respond to weather and environmental effects in a predictable manner that is consistent with the performance of other types of antennas. The antenna can operate normally in all anticipated survivable wind conditions and with up to $\frac{1}{2}$ " of radial ice (on $\frac{3}{8}$ " diameter radiating wires) before causing the transmitter protection circuitry to act due to the lowering of the antenna's resonant frequency. The efficiency of the KinStar is unaffected by local ground conditions or by operating frequency and is thus usable in all locations in the United States and on all allocated AM band frequencies.

3.2 Effects of Wind and Ice

Modeling shows that the impedance performance of the KinStar remains acceptable for all transmitter types with up to $\frac{1}{4}$ " of radial ice accumulation on the antenna wires. As the ice radius increases to beyond $\frac{1}{2}$ ", the impedance begins to deviate significantly as the antenna's resonant frequency drops, resulting in activation of transmitter protection circuitry. This situation is not different from the effects seen with significant ice accumulations on tower radiators and other antennas exposed to winter conditions. Because of the lighter weight construction techniques of the KinStar, it is expected to survive higher ice accumulations than many tower structures. Utility lines constructed of like materials typically do not fail due to ice unless a tree or other structure falls onto them.

Figures 17 and 18 show the impact on the matched input impedance of the antenna with $\frac{1}{4}$ and $\frac{1}{2}$ inch of radial ice. With $\frac{1}{4}$ inch of ice, the transmitter should be able to continue operation into the antenna. Figure 19 shows the elevation radiation pattern due to the effect of ice only. This shows no significant change in the radiation pattern.

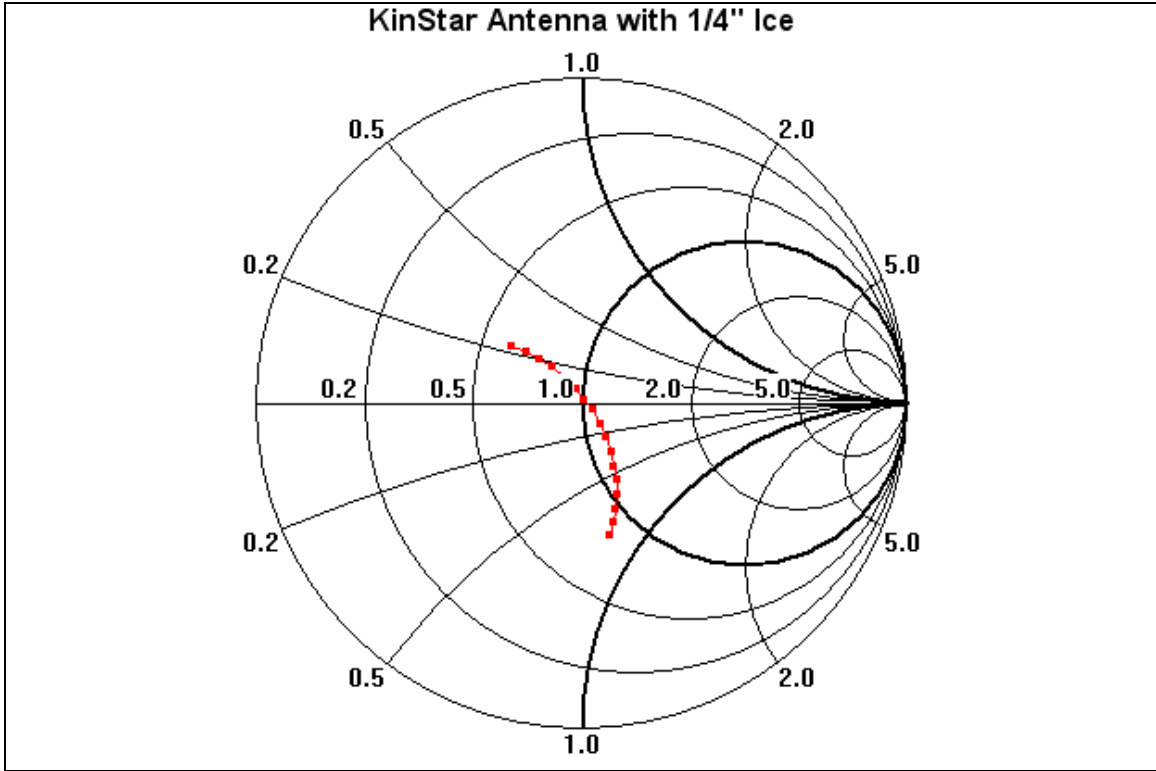


Figure 17 - Impedance sweep of 1680 kHz KinStar "A" version antenna from 1640 to 1720 kHz over average ground with 1/4" radial ice.

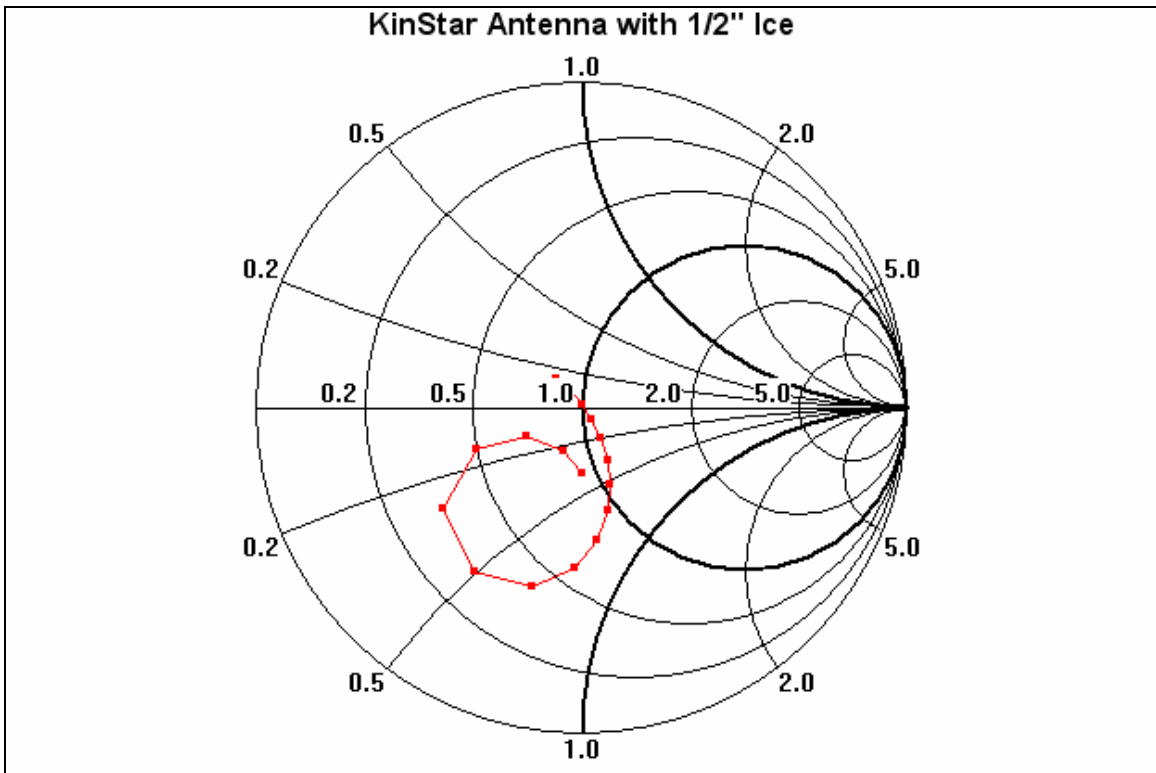


Figure 18 - Impedance sweep of 1680 kHz KinStar "A" version antenna from 1640 to 1720 kHz over average ground with 1/2" radial ice.

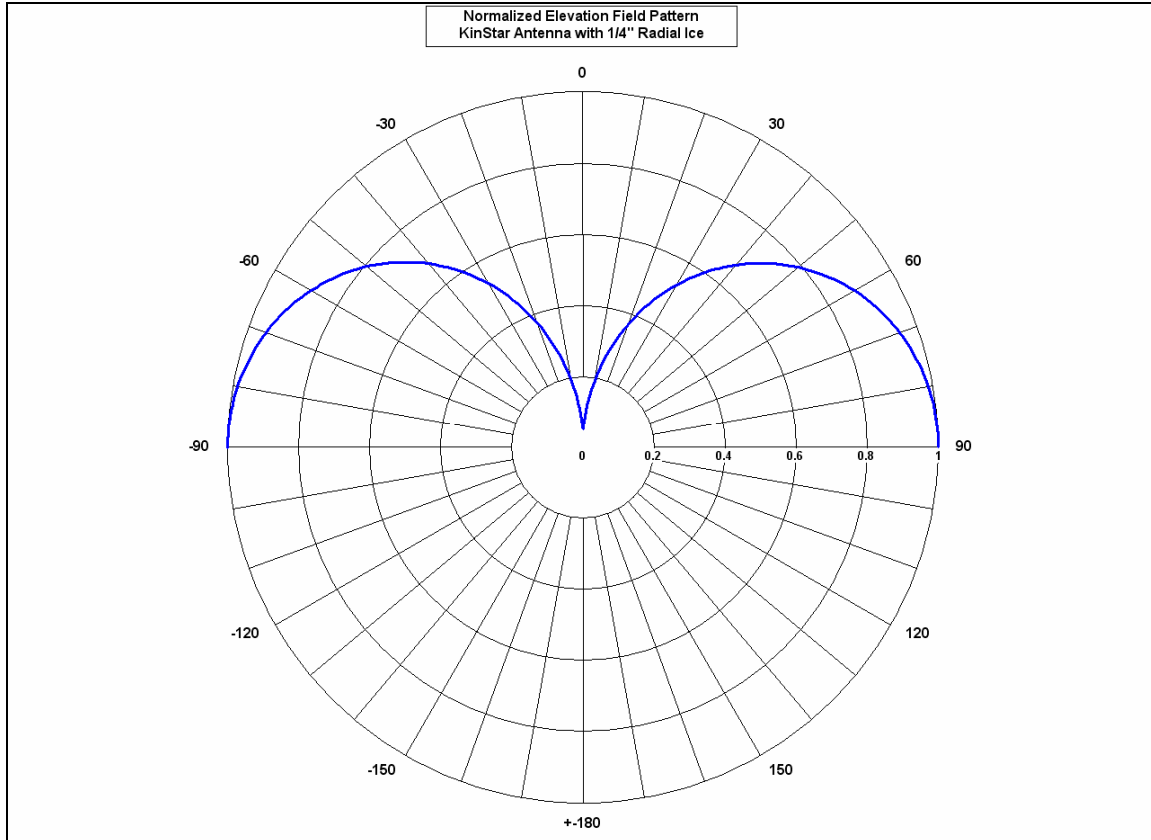


Figure 19 – Normalized elevation field pattern for KinStar antenna with 1/4" radial ice coating over perfect ground.

In high wind situations, the KinStar antenna wires will not significantly deform due to their installation with a high stringing tension, required to minimize sag in the horizontal wires, and their small surface area. During the course of the testing period in Virginia, no significant motion or displacement of the wires due to wind was observed. Should galloping or other undesired motion occur, dampening devices are commercially available for installation on the wires to reduce or eliminate this effect. Construction using high tensile strength aluminum (AAC) or aluminum coated steel reinforced wire (ACSR), depending on the span lengths, will allow the wires to be strung with sufficiently high tension during construction to minimize any significant wind deformation.

NEC modeling of the elevation radiation patterns shows that even with unexpectedly large wire deflections, the degradation to the radiation pattern is minimal. Figure 20 shows a comparison of the calculated elevation pattern with no wind, 2 feet of deflection, and 5 feet of deflection of

one pair of opposing top loading wires over perfect ground at 1680 kHz. The only effect is a very slight increase in the horizontally polarized radiation component, which even with 5 feet of deflection remains less than -32 dBi, over 36 dB below the peak lobe of the antenna pattern.

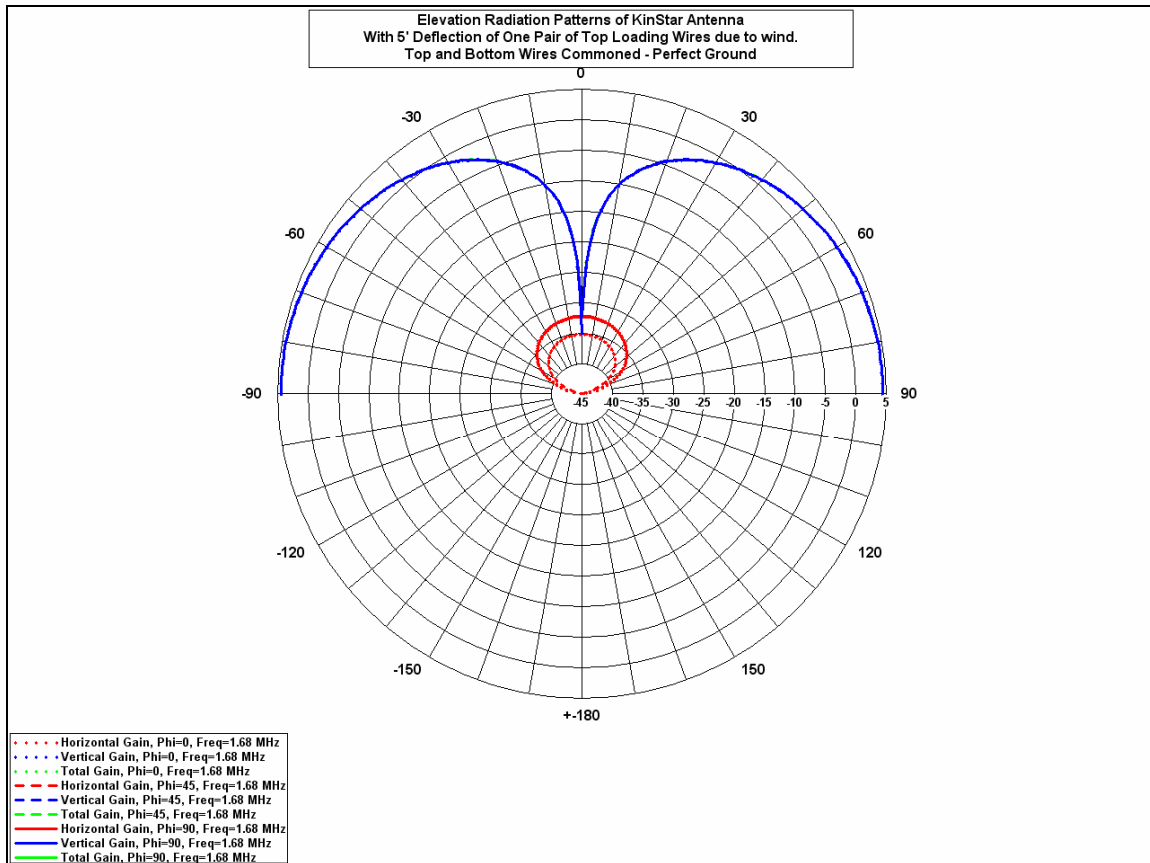


Figure 20 - KinStar antenna with 0, 2', and 5' deflection in one pair of top loading wires. This asymmetry results in some horizontally radiated component falling at most 35 dB below the main lobe of the antenna with 5' deflection, 40 dB below the main lobe with 2' deflection. No significant distortion to the main elevation pattern is seen with any deflection.

3.3 Ground Parameter and Frequency Effects

The field efficiency of the KinStar antenna is shown by NEC-4.1 modeling to not vary significantly with changes in ground constant values. NEC-4.1 uses the Sommerfeld-Norton method to model ground loss effects due to returning currents traveling through the ground. A parameter variation study was conducted to model the efficiency of the KinStar antenna over the AM frequency band with varying ground conditions. Models were tested at 530, 1000, and

1680 kHz over Perfect, Good, Average, Poor and Very Poor ground conditions at each frequency using the ground constants shown in Table 6. The models each included quarterwave copper #10 wire 120-radial ground screens located just above the surface of the ground, and included wire conductivity effects on the copper ground system and the aluminum antenna wires. A model of a one-quarter wavelength tall monopole triangular lattice tower, and a thin wire monopole were also analyzed for comparison. The RMS attenuated field for 1kW of input power for each model was calculated by NEC for the KinStar, and then compared with expected values from NEC calculations of thin quarterwave monopoles to find the resulting unattenuated field. The use of the model with the Perfect ground parameters allowed us to calculate correction factors to find the expected unattenuated field at the 1km point for each model.

In determining the field values at 530 kHz, modeling showed that the NEC calculated field at one kilometer from the antenna did not exhibit the expected roll-off with decreasing ground conductivity, so calculations for all antennas at this frequency were repeated at 10 kilometers to ensure that there was no residual nearfield effect. Results at 10km continued to show a slight increase in expected field strength for good ground conditions. This effect is small but consistent and represents either an artifact in the Sommerfeld-Norton formulas in the NEC program, or a possible real physical effect resulting from increasing penetration depth at lower frequencies. In any case, it is sufficiently small as to not significantly affect the key conclusion that the KinStar antenna retains its efficiency across the entire AM broadcast band.

The resulting calculated unattenuated 1km fields fell sufficiently close to the expected values that it is reasonable to conclude that there is no significant decrease in antenna or ground system efficiency with changes in frequency or ground characteristics. At all frequencies and ground conditions, the minimum efficiency requirements are met.

Table 7 summarizes the results of the NEC field modeling with varying ground conditions and frequencies. The complete data for all frequencies and ground constant values is given in Appendix 1. The results in Appendix 1 show that for the average ground case, the NEC predicted

fields for both the KinStar and the quarterwave monopole fall reasonably close to the expected values consistently across all frequencies. There are some minor differences at various ground and frequency combinations due to accumulated computational error or modeling variations, but a comparison of the modeling results and measured field data from the WS2XTR testing suggest that the NEC results tend to be conservative, lending confidence to the conclusion that antenna efficiency will meet or exceed predictions.

Table 6. Ground constant values used in modeling.

	Relative Permittivity	Conductivity (mS/m)
Perfect	-	∞
Good	15	30
Average	15	5
Poor	15	1
Very Poor	15	0.1

Table 7. Summary of calculated unattenuated fields with frequency over average ground conditions using NEC Sommerfeld-Norton calculations. All values in mVrms/m at 1km with 1kW input power to antenna.

	Calculated Unattenuated Field (average ground)			Perfect Ground with Ground Screen		
Frequency	KinStar A	KinStar B	QW Tower	KinStar A	KinStar B	QW Tower
1680	294.39	290.47	318.29	293.54	293.36	318.75
1000	291.33	286.25	315.80	290.43	290.30	317.70
530	285.41	277.96	306.37	283.88	286.65	314.00

In the case of the field test at WS2XTR, the overall measured unattenuated field was found to be 304 and 300 mV/m for the two test configurations, which agree within a few percent with the NEC predicted results shown here and suggest that the antenna efficiency as calculated by NEC is a conservative value. Since the NEC models consistently show the KinStar meeting the minimum field requirements of

73.189(b)(2)(ii), it is concluded that the KinStar antenna meets these requirements for all locations in the United States and that the efficiency of the KinStar antenna is independent of ground conditions and operating frequency when used with a suitable quarterwave or greater 120 radial ground system.

3.4 Effects of Uneven Ground Under Antenna

Efforts to model the effects of uneven terrain under the antenna yielded interesting results. These models relied on sloping half of the 120-wire radial ground screen above the plane of the model ground since NEC's only ground models are planar. The models suggest that some sloping ground conditions may result in asymmetric currents in both the antenna and ground system, resulting in a horizontal component to the radiation. As a check, the same sloping ground wire system was modeled with a quarterwave tower, showing the same result.

The monopole model also showed asymmetries in the ground wire currents (as expected). This resulted in a horizontal component to the radiated field as in the case of the KinStar model. This indicates that any antenna whose ground system is not perfectly planar can have some horizontally polarized radiation. It is always desirable to have the most level grade over the area of the ground screen for any AM broadcast antenna system, and this recommendation will be passed to stations interested in installing KinStar antennas, but it should not be considered an absolute requirement.

Figures 21 and 22 show the NEC results for the effect of a simulated sloping ground on the KinStar and a quarterwave tower monopole, respectively. The performance of the KinStar is no worse than that of the monopole, suggesting that the KinStar will respond to placement on uneven ground in a similar manner as more traditional antennas.

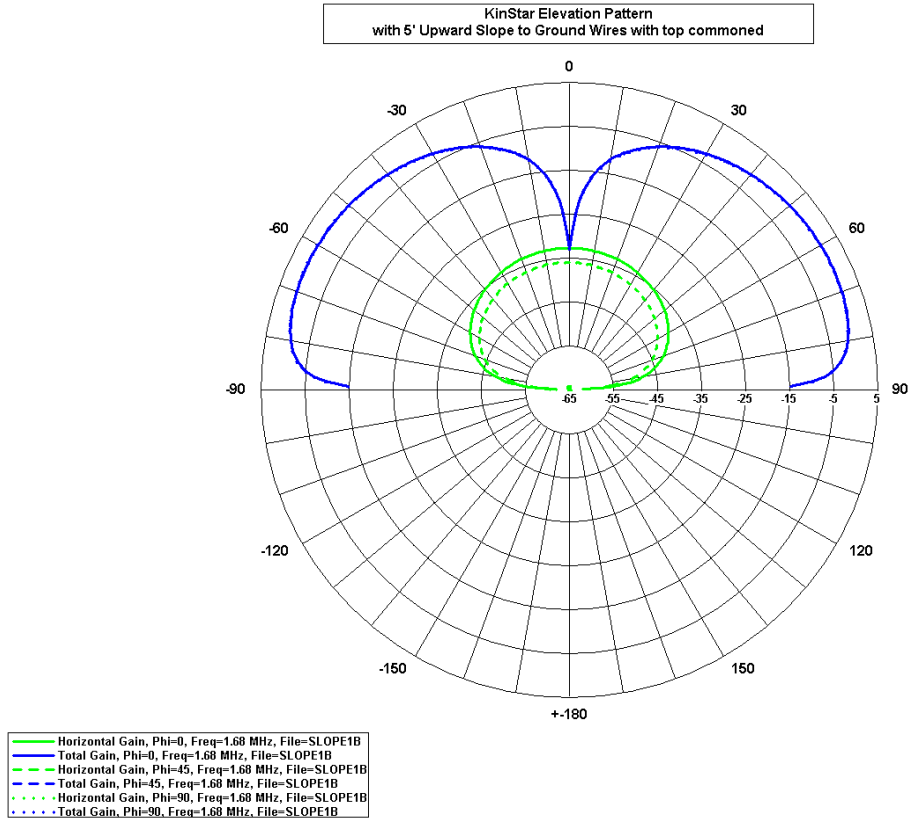


Figure 21 – Elevation pattern showing horizontally polarized radiation component of KinStar antenna (green trace) at least 35 dB below the pattern maximum due to effect of simulated sloping ground.

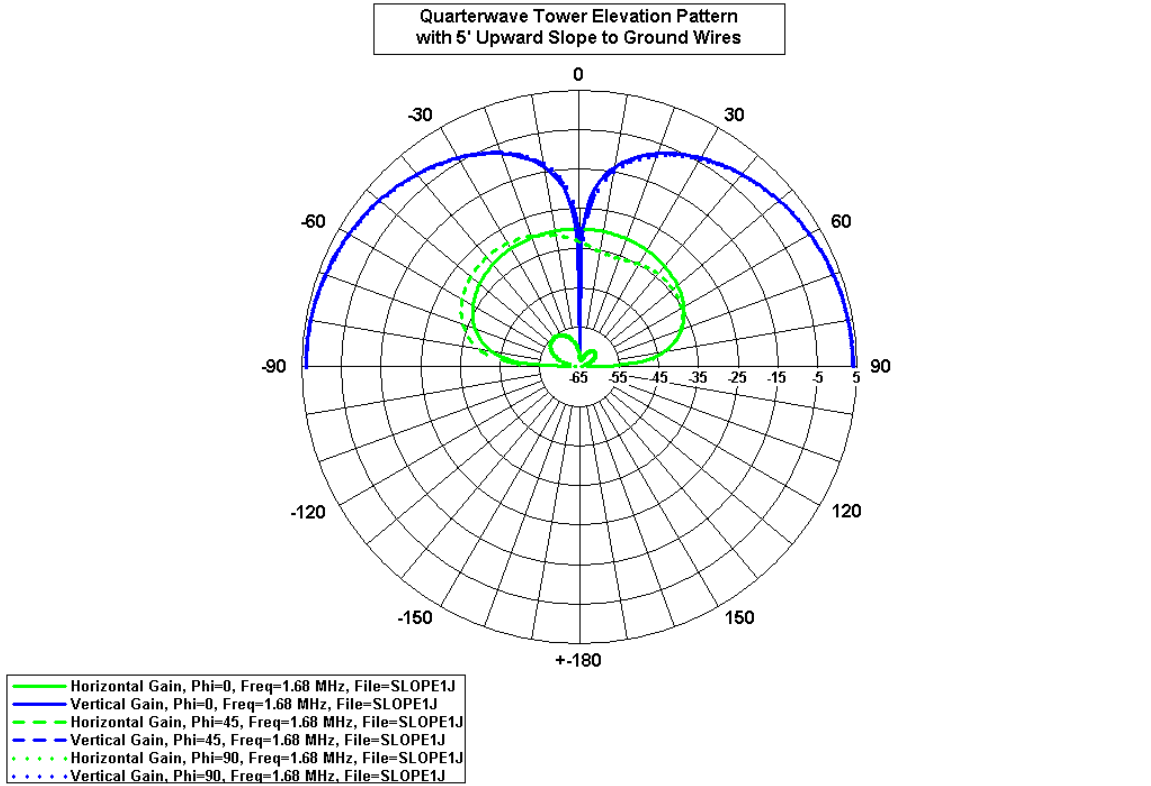


Figure 22- Elevation pattern showing horizontally polarized radiation component of quarterwave monopole tower antenna (green trace) at least 30 dB below the pattern maximum due to effect of simulated sloping ground. Result is similar to that seen with the KinStar.

4.0 Elevation Radiation Pattern

The KinStar antenna's elevation plane radiation pattern behaves almost exactly as predicted by the classical model of a short vertical constant current element having a cosine(theta) distribution, where theta is the elevation angle above the horizontal. The antenna produces a single radiation lobe aimed at the horizon with a deep null aimed directly overhead. The elevation pattern of a single KinStar antenna can be described by considering it as a single short monopole with a high degree of top loading, consistent with section 73.160(2) of the commission's rules.

$$f(\theta) = \frac{\cos B \cos(A \sin \theta) - \sin \theta \sin B \sin(A \sin \theta) - \cos(A + B)}{\cos \theta (\cos B - \cos(A + B))}$$

For the 1680 kHz KinStar antenna tested at WS2XTR, the physical height of the antenna, A, is 27.65 degrees, and inspection of the current distribution shows an effective electrical top loading of approximately 76 degrees. This results in a calculated relative field distribution as shown in Table 8. Agreement of results between the NEC calculated current distribution and the measurements from the WS2XTR test antenna is nearly perfect, showing the accuracy of the NEC modeling. It is thus possible to accurately confirm the effective electrical top loading value from any KinStar design using the NEC calculations for that antenna.

The current distribution measurement data, NEC-4.1 calculations, and radiation pattern and field proof data support the consideration of the antenna as a single radiating vertical current element. Inspection of the antenna dimensions and the current distribution readily yields A and B values suitable for application to equation 73.160(2). The construction of the KinStar "B" version is clearly seen as a top-loaded monopole structure, exactly as intended to be described in 73.160(2). Since the radiation performance of both the KinStar "A" version and KinStar "B" version are identical, both versions can be justifiably described in terms of A and B values for purposes of licensing.

Table 8 shows the elevation field ratio values as calculated by NEC-4.1 for the KinStar antenna over perfect ground, the application of 73.160(2), and from a derived

field calculation from the measured currents on the vertical wires of the WS2XTR antenna. The NEC-4.1 values show a higher relative field (broader elevation pattern) at higher angles than either the 73.160(2) formula or the derived field calculation. The NEC-4.1 calculation accounts for more terms, including effects of the relatively wide wire spacing in the antenna on the phase velocity, and thus produces a more accurate result than either of the other methods, which are based on mathematical approximations. The disagreement between the NEC-4.1 and the 73.160(2) results is under approximately 8% at the critical skywave interference angles below 60 degrees, and well under 5% below 40 degrees.

Table 8 - Comparison of Elevation Field Ratios

Angle	NEC-4.1 Prediction	73.160(2) Calculation	Calculation from Measured Currents	Percent Error between 73.160(2) and NEC-4.1
0	1	1	1	-
10	0.9871	0.9836	0.9848	0.350
20	0.9481	0.9353	0.9397	1.35
30	0.8827	0.8575	0.8660	2.86
40	0.7905	0.7535	0.7660	4.67
50	0.6720	0.6279	0.6428	6.56
60	0.5291	0.4852	0.5000	8.29
70	0.3655	0.3301	0.3420	9.67
80	0.1867	0.1670	0.1736	10.6

The NEC-4.1 calculated values have been verified with two independent alternative Method of Moments formulations, the MININEC Broadcast Professional program and the WIPL program. All agree on the calculated values shown here to better than 1 percent. The field ratios shown calculated from measured currents do not include phase data along the vertical extent of the wires. This calculation was based on the superposition of fields from the measured current elements and the as-built antenna geometry using a derivation of the following standard formula for the elevation pattern of a short constant current element:

$$E_{\theta} \approx j\eta \frac{\beta I_0 l e^{-j\beta R}}{4\pi R} \sin \theta [2 \cos(\beta h \cos \theta)]$$

The values calculated by the formula match those for the cosine distribution and are dominated by the $\sin(\theta)$ component. θ in this formula is measured according to the spherical coordinate system as being the angle from the zenith, not the horizon.

This difference between NEC-4.1 and the 73.160 formulas is observed not only with the KinStar, but also is consistent with observed differences for a number of other licensed antenna systems currently in common operation in the United States. Modeling data shows that these antennas tend to have large cross-section geometries (H/a ratio) relative to height, resulting in a modified phase velocity along the vertical axis of the structure compared with the usual thin wire approximation. This causes the phase distribution over the length of the antenna to increase over that for the thin wire case and changes slightly the elevation pattern of the antenna. Antenna models which show this effect include the KinStar, a wide-base tapered self-supporting tower, and the Blaw-Knox style of double pyramidal towers. All of these antennas show a deviation between the 73.160 calculated elevation pattern and the NEC calculated pattern similar to that seen with the KinStar, with some showing errors larger than seen with the KinStar. Studies showing the effect of H/a ratio on the elevation radiation pattern have been made by G.H. Brown, and more recently by V. Trainotti, and historical experience at WLW and other stations verifies this effect.

In actual practice, over locally varying ground conditions, the elevation pattern of any medium frequency antenna will differ somewhat from its predicted performance no matter what the approximation or modeling technique. Considering these factors, it is felt that the application of 73.160(b) will provide sufficient accuracy for calculation of nighttime skywave interference to permit 24-hour operation of the KinStar. Indeed, NEC-4.1 modeling demonstrates that the 73.160 formulas are applicable for the KinStar antenna with no greater degree of vertical radiation pattern uncertainty than is the case for other tower antennas that are routinely authorized and are in common use today. Examples of other antennas where the NEC calculated elevation pattern differs from the 73.160 calculated elevation pattern are shown in Figure 23.

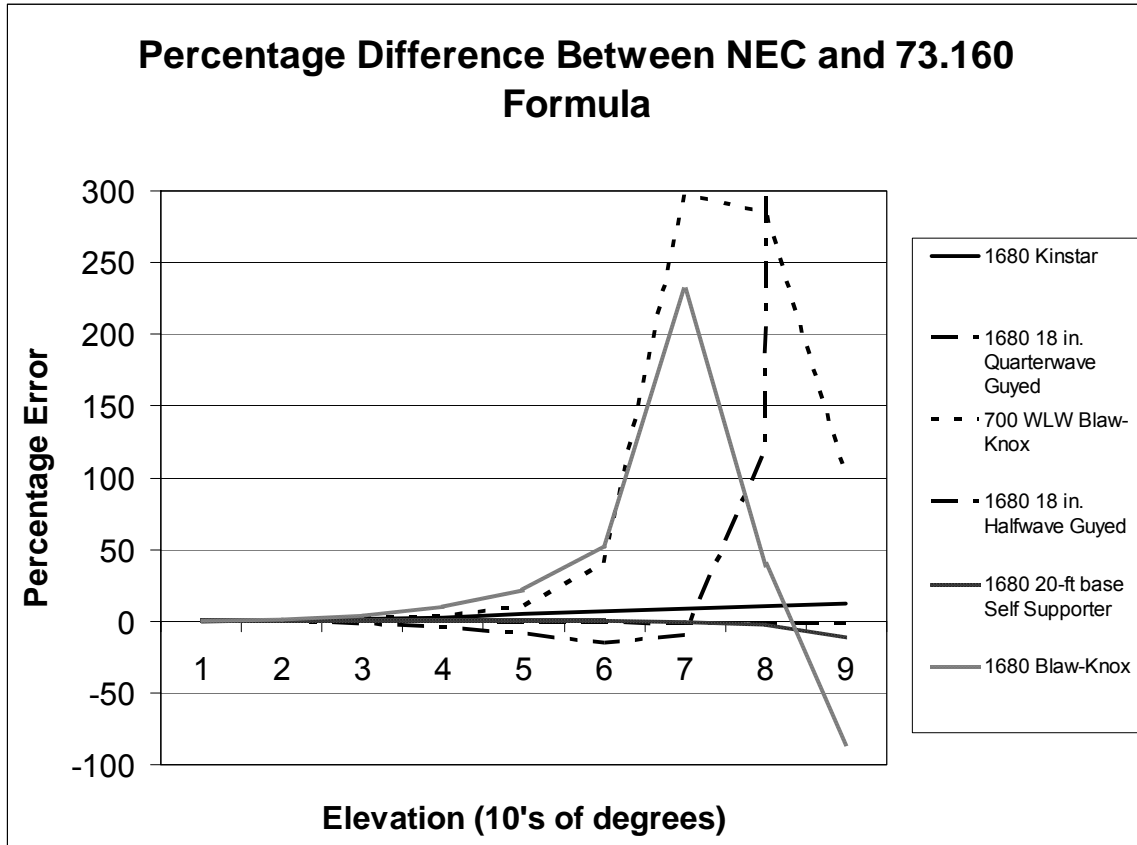


Figure 23 - Example of disagreements between 73.160 formulas and NEC models of selected AM broadcasting antennas. The KinStar error is small compared with large cross-section radiators such as wide-base self supporting towers and Blaw-Knox type antennas. See Appendix 2 for complete tables of elevation field patterns.

Tables of NEC-4.1 calculated field ratios, at 5 degree increments over both perfect and average ($\epsilon R=15$, $\sigma=5mS$) ground follow for both the KinStar A and B versions at 530 and 1680 kHz. Patterns for both versions of the antenna agree to within better than one percent.

**Table 9 - KinStar "A" Version Field Ratios
Calculated Using NEC-4.1 For Perfect and Average
Ground Conditions**

Angle	1680 kHz		550 kHz	
	Perfect	Average	Perfect	Average
0	1	1.26E-07	1	1.94E-07
5	0.996764	0.570873	0.996838	0.700932
10	0.987058	0.810635	0.987114	0.898286
15	0.970809	0.926173	0.970986	0.973737
20	0.947982	0.981114	0.948217	1
25	0.918507	1	0.918808	0.998959
30	0.882347	0.994041	0.882758	0.979267
35	0.839431	0.968944	0.839987	0.945079
40	0.789867	0.928142	0.790442	0.898639
45	0.733689	0.873857	0.734343	0.841373
50	0.671111	0.807655	0.671824	0.774332
55	0.602453	0.730849	0.603186	0.698415
60	0.528107	0.64465	0.528832	0.614502
65	0.448604	0.55022	0.449292	0.523503
70	0.364622	0.448831	0.365215	0.426418
75	0.276882	0.341726	0.277358	0.32433
80	0.18624	0.230273	0.186576	0.2184
85	0.093621	0.115876	0.093794	0.109862
90	1.9E-09	1.54E-08	4.23E-10	1.68E-07

**Table 10 - KinStar "B" Version Field Ratios
Calculated Using NEC-4.1 For Perfect and Average
Ground Conditions**

Angle	1680 kHz		550 kHz	
	Perfect	Average	Perfect	Average
0	1	1.26E-07	1	1.94E-07
5	0.996759	0.570967	0.996768	0.701047
10	0.987021	0.810758	0.987059	0.898398
15	0.970747	0.092625	0.97083	0.973807
20	0.947878	0.981175	0.948021	1
25	0.918354	1	0.918568	0.998863
30	0.882128	0.993917	0.882418	0.979084
35	0.83918	0.968751	0.839549	0.944799
40	0.789547	0.927893	0.789993	0.898275
45	0.73334	0.873542	0.733849	0.840944
50	0.670755	0.807303	0.671313	0.773866
55	0.602096	0.73049	0.602681	0.697946
60	0.527775	0.644311	0.528363	0.614062
65	0.448326	0.549948	0.448889	0.523133
70	0.364396	0.448625	0.364904	0.42615
75	0.276734	0.341618	0.277162	0.324187
80	0.186185	0.230279	0.186511	0.218403
85	0.093365	0.116011	0.093875	0.110024
90	0.000211	0.000315	3.19E-05	4.22E-05

5.0 RF Exposure Safety Analysis

The analysis is based on models of the KinStar antenna at 1 kW and 50 kW of power at 550 and 1680 kHz using the NEC-4.1 code and Sommerfeld-Norton ground approximation for average earth. The permissible exposure levels from 47 CFR § 1.1310 are 614 V/m for E-field and 1.63 A/m for H-field for both occupational and general public exposure. Since the physical size of the antenna is large, we need to evaluate both the electric and magnetic fields in the near field of the antenna, specifically in the areas in and around the vertical wires and under the horizontal loading wires where people might walk.

The electric and magnetic field exposures for the 1 kW KinStar antenna exceed allowable levels for both the general public and occupational exposure only in the immediate vicinity of the vertical wires. This area will require fencing to prevent contact and possible RF burns, as well as to protect the feedpoints from damage. An enclosed area containing the vertical wires would suffice.

At 50 kW, the E-field does not exceed permissible levels anywhere away from the vertical wires, but the H-field significantly exceeds the limit out to a radius of 12 meters at 1680 kHz and to 10 meters at 550 kHz, measured from the geometric center of the antenna. Personnel should not be within this radius while the antenna is transmitting. This area will require fencing and marking in accordance with the Commission's regulations. Personnel should also not contact the vertical wires while transmitting to avoid RF contact burns.

Standard fencing and marking procedures will be satisfactory for the KinStar antenna, although the areas requiring restricted access may be larger than for conventional towers. The areas to which access should be restricted may be based on either modeling data or post-construction field measurements.

Figures 24 through 33 show the NEC calculated fields for the 1 and 50 kW KinStar antennas at 1680 and 550 kHz. E and H-Field plots for a quarterwave monopole at 1kW follow the KinStar plots in Figures 34 and 35 for comparison. Note that the scales on the plots vary. These modeling results agree with the Mininec results shown in OET Bulletin 65 (revised).

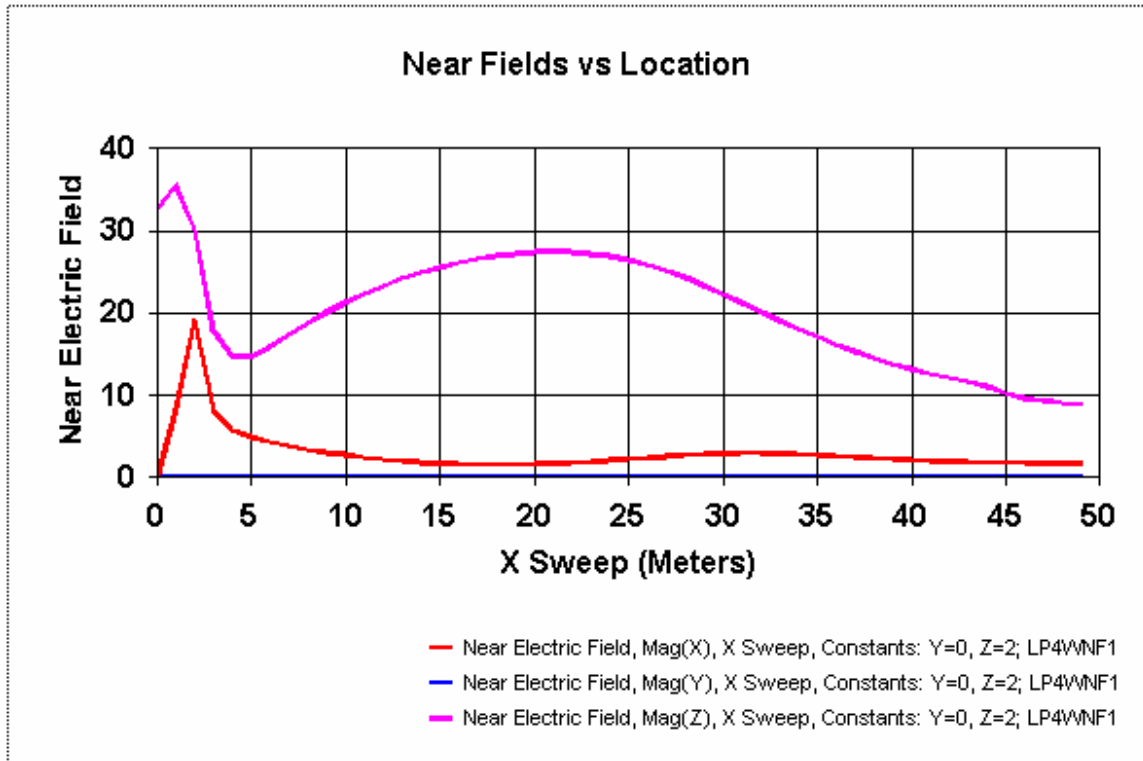


Figure 24 - E-field magnitude directly under top loading wire for 1680 kHz at 1 kW input power at a height of 2 meters (Permissible level is 614 V/m).

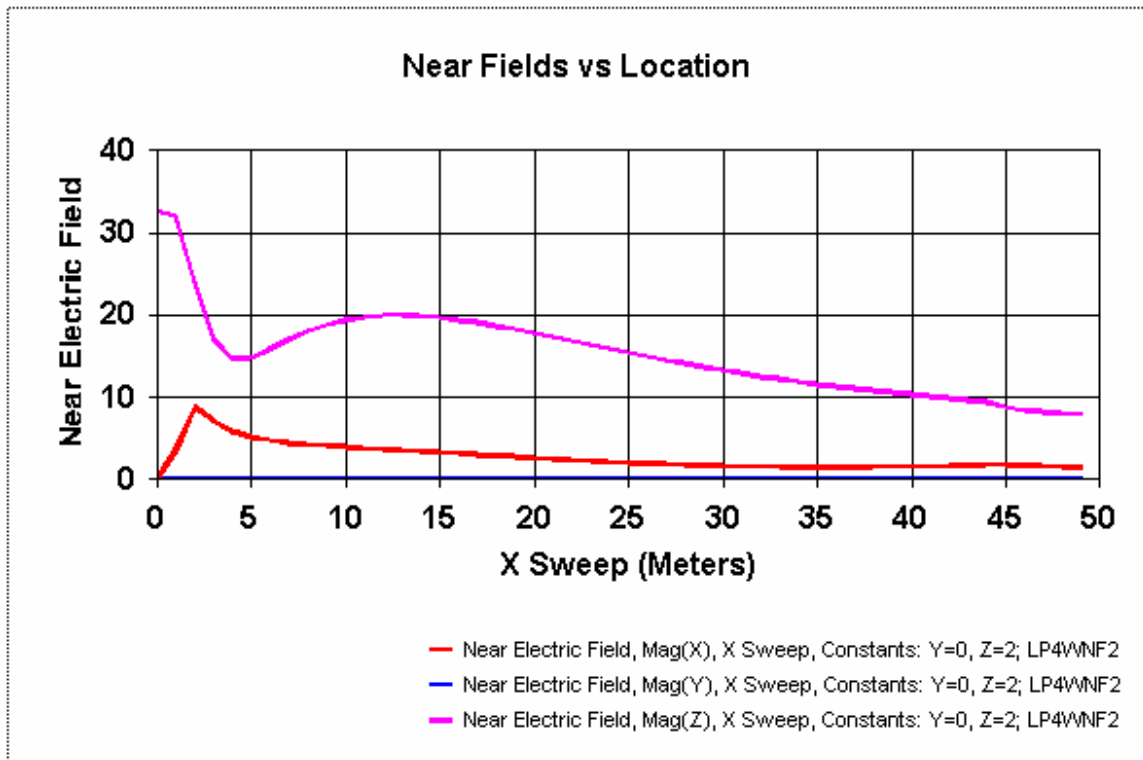


Figure 25 - E-field in area halfway between two top loading wires (45 degrees) for 1680 kHz at 1 kW input power at a height of 2 meters (Permissible level is 614 V/m).

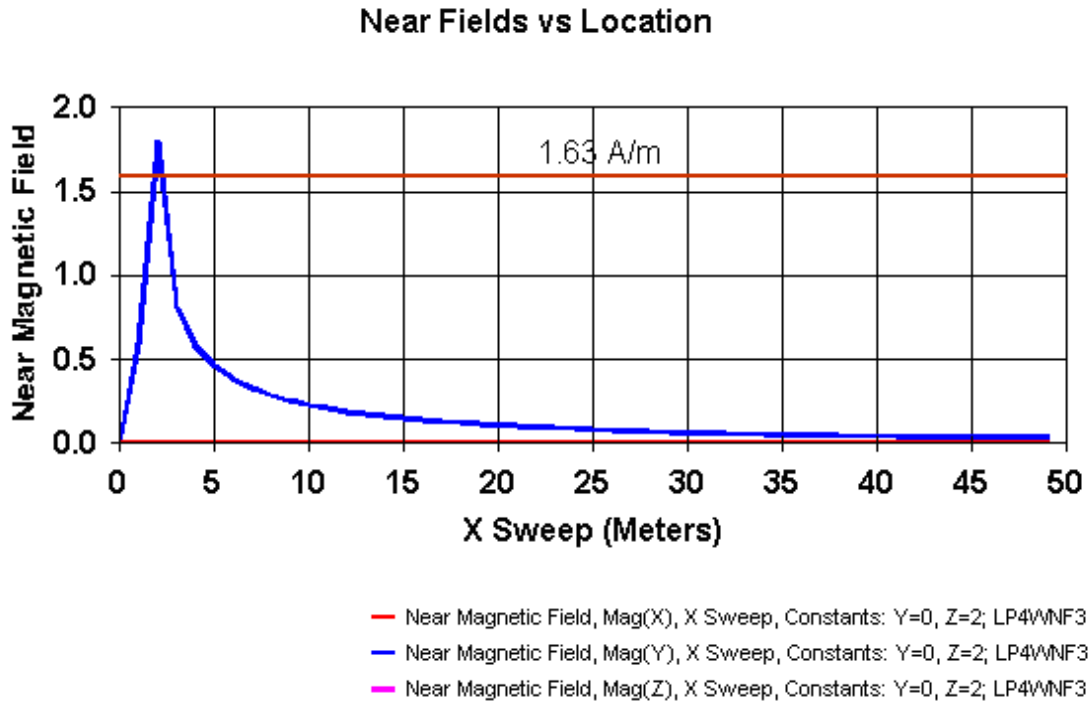


Figure 26 - Magnetic field directly under top loading wire for an input power of 1 kW at a height of 2 meters (Permissible level is 1.63 A/m).

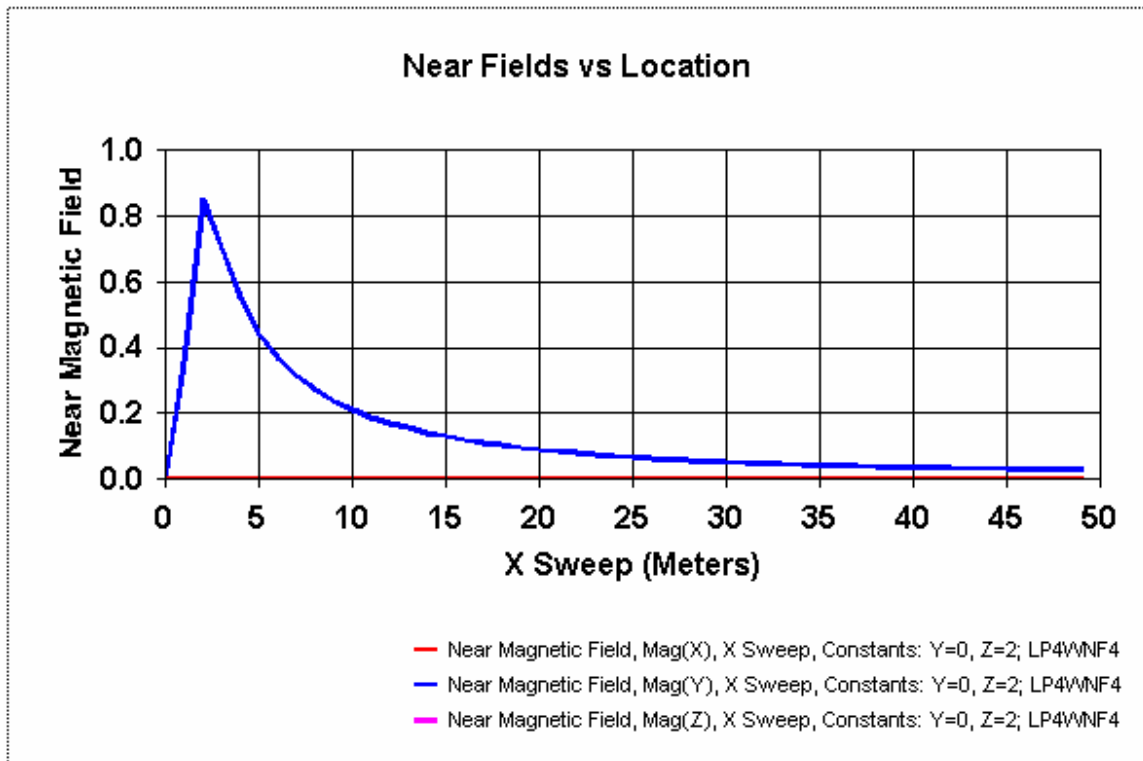


Figure 27 - Magnetic field in between wires for 1680 kHz at 1 kW at a height of 2 meters (Permissible level is 1.63 A/m).

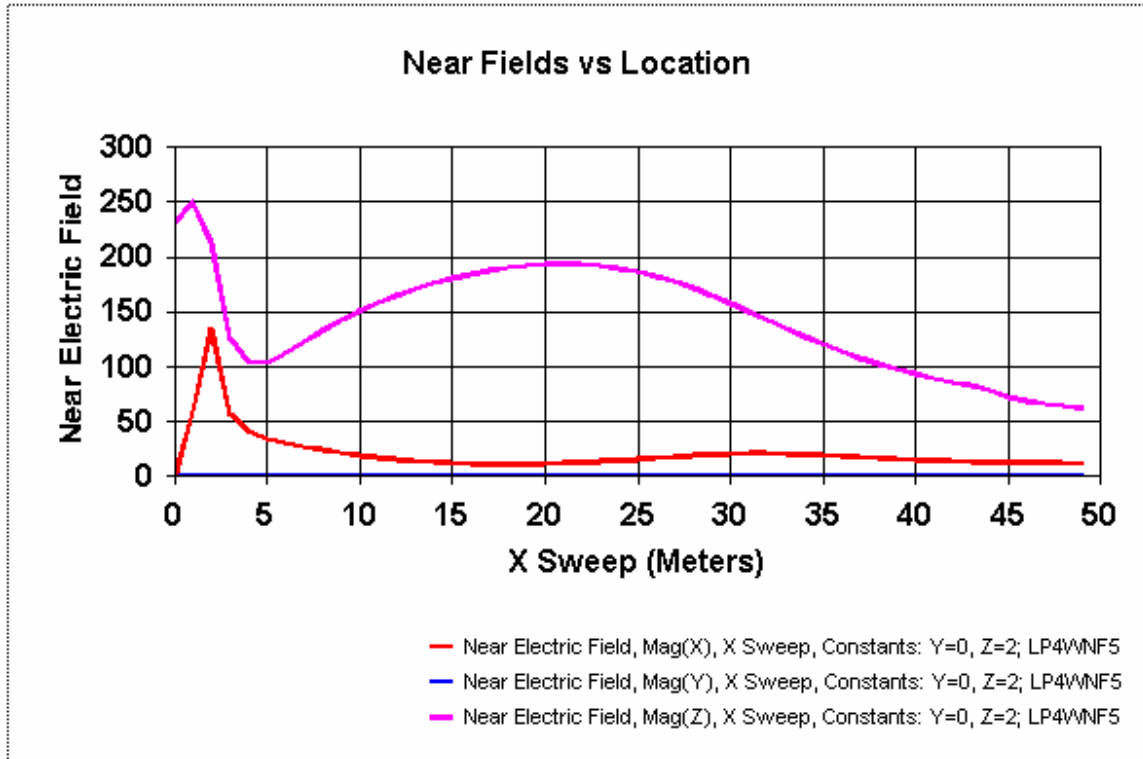


Figure 28 - E-field directly under top loading wire for 1680 kHz at 50 kW input power at a height of 2 meters (Permissible level is 614 V/m).

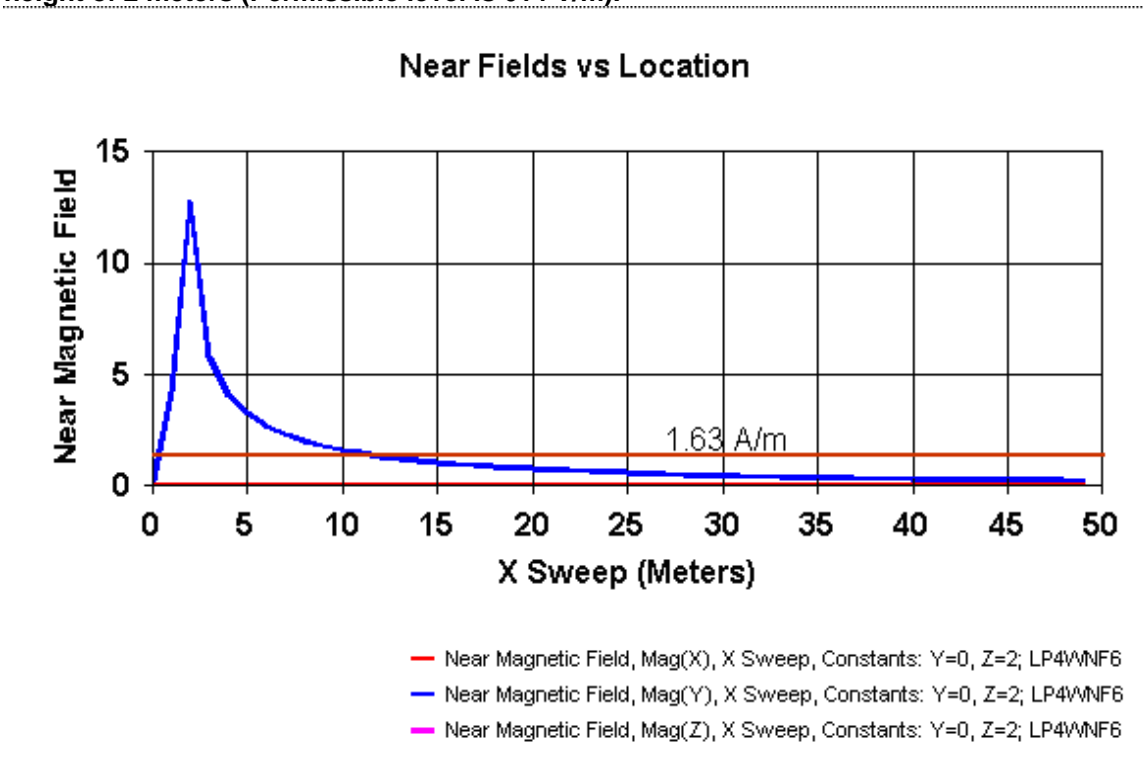


Figure 29 - Magnetic field directly under top loading wire for 1680 kHz at an input power of 50 kW at a height of 2 meters (Permissible level is 1.63 A/m).

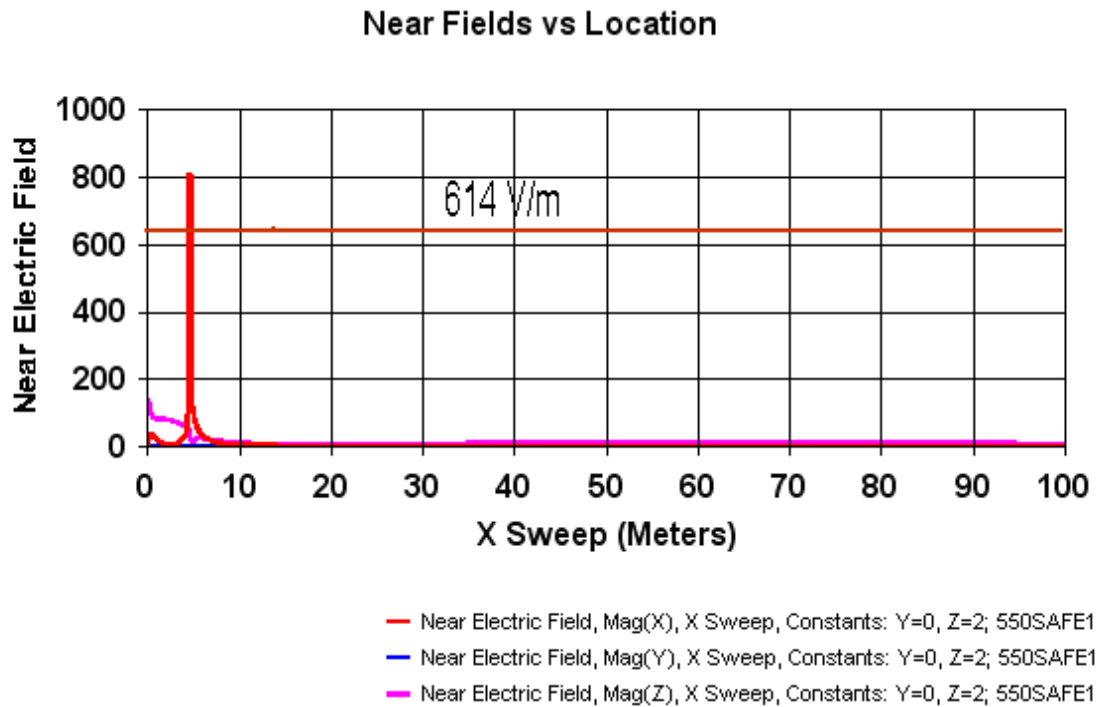


Figure 30 - Electric field directly under top loading wire for 550 kHz at an input power of 1 kW at a height of 2 meters (Permissible level is 614 V/m).

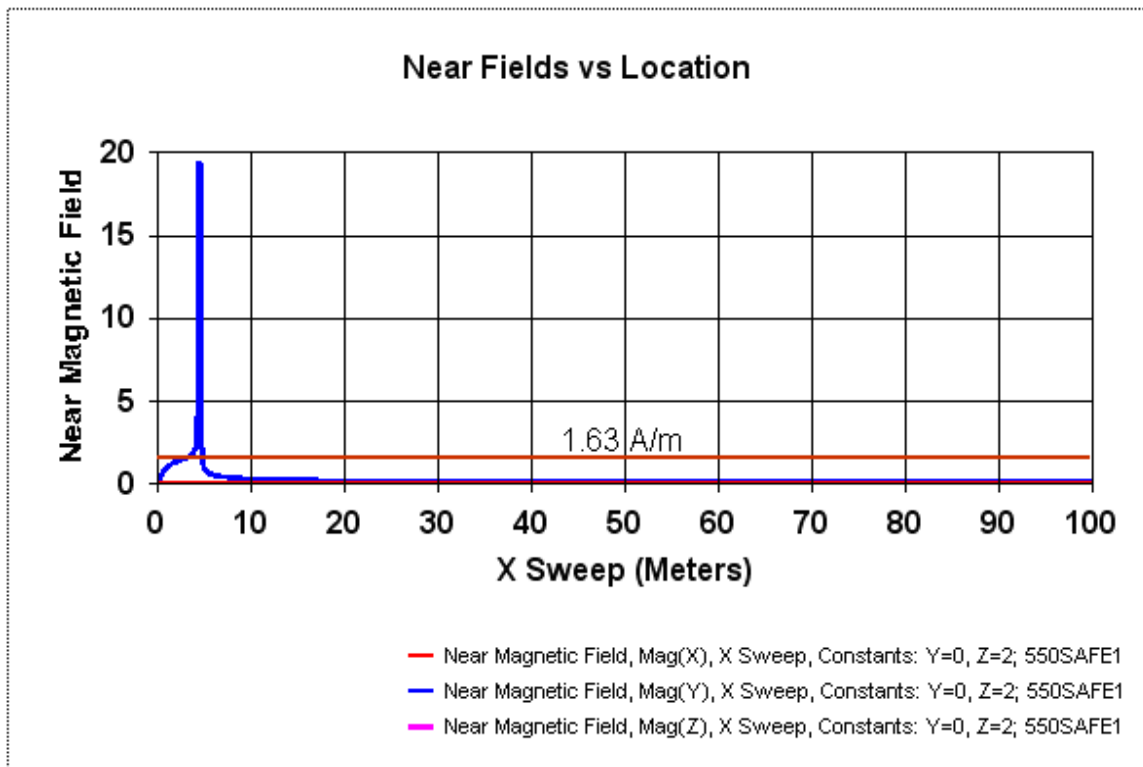


Figure 31 - Magnetic field directly under top loading wire for 550 kHz at an input power of 1 kW at a height of 2 meters (Permissible level is 1.63 A/m).

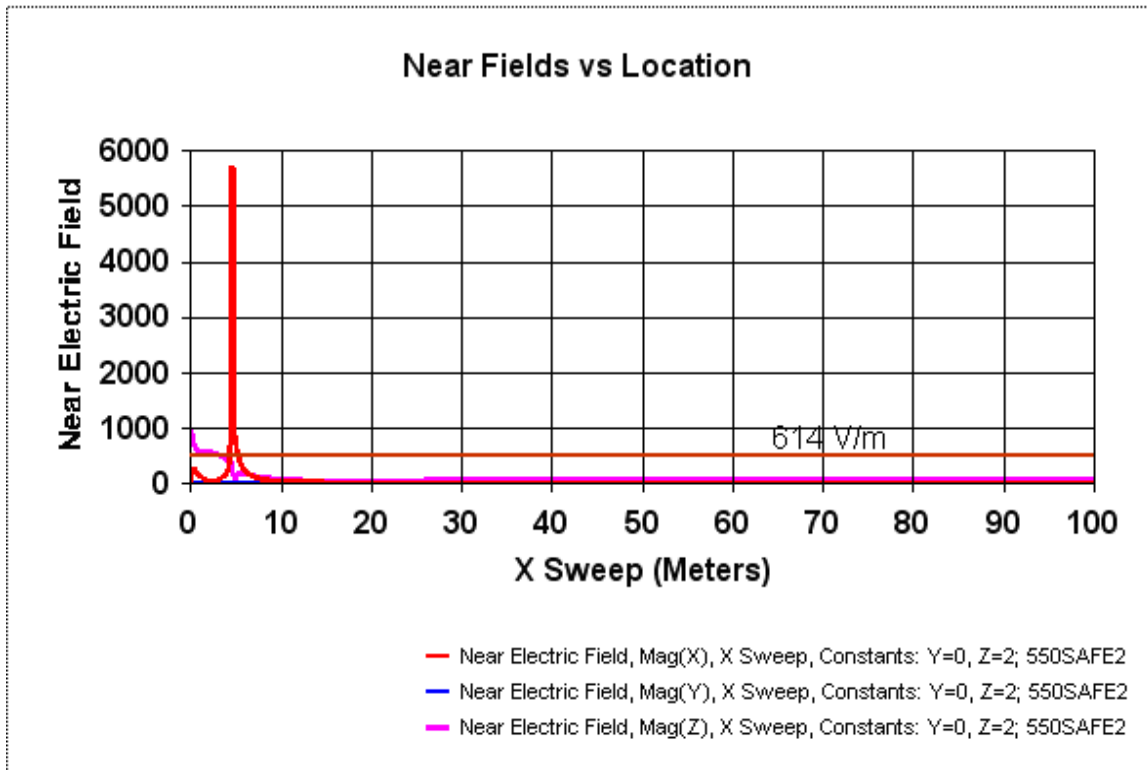


Figure 32 - Electric field directly under top loading wire for 550 kHz at an input power of 50 kW at a height of 2 meters (Permissible level is 614 V/m).

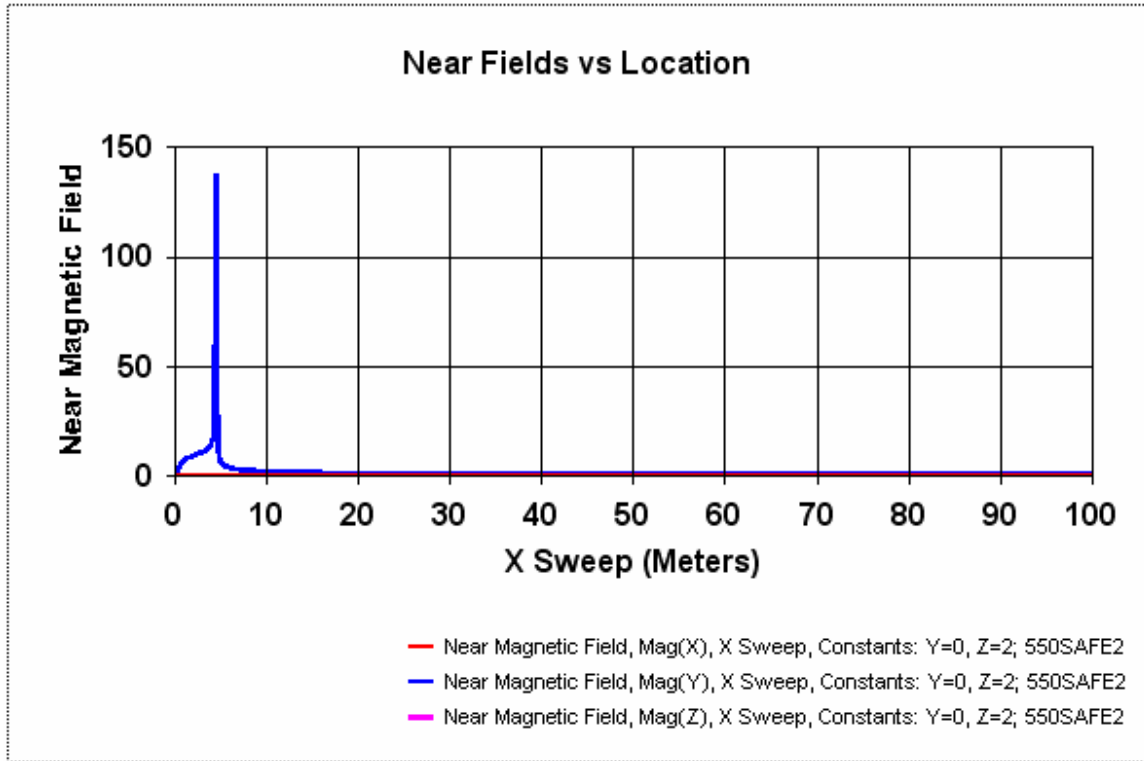


Figure 33 - Magnetic field directly under top loading wire for 550 kHz at an input power of 50 kW at a height of 2 meters (Permissible level is 1.63 A/m, threshold not shown).

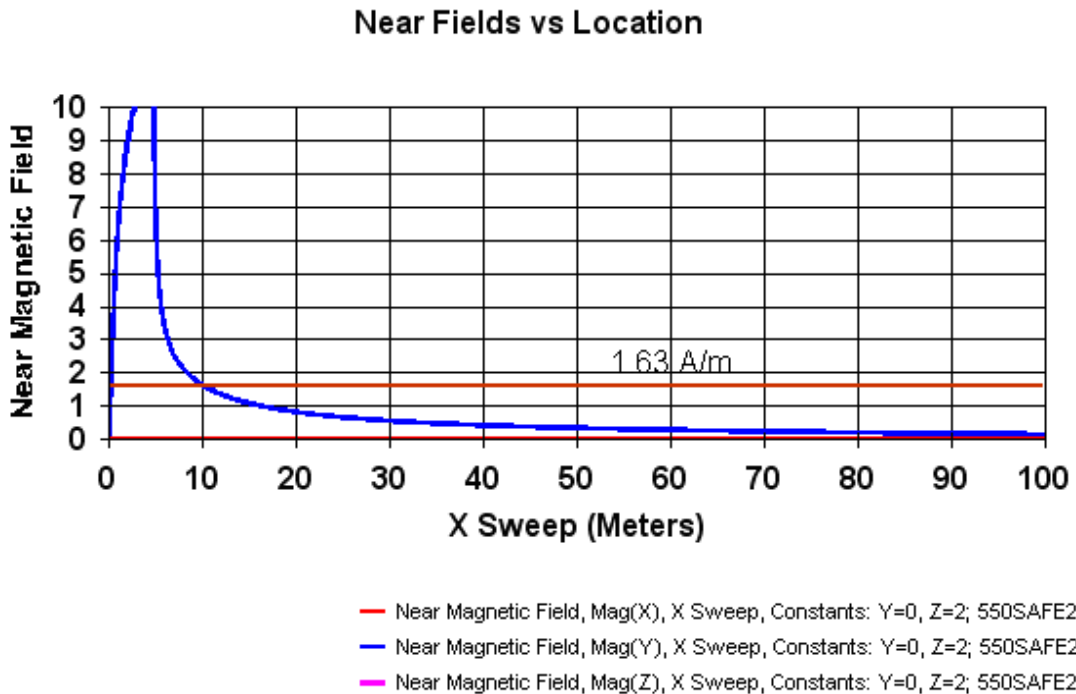


Figure 34 - Magnetic field directly under top loading wire for 550 kHz at an input power of 50 kW at a height of 2 meters (Permissible level is 1.63 A/m).

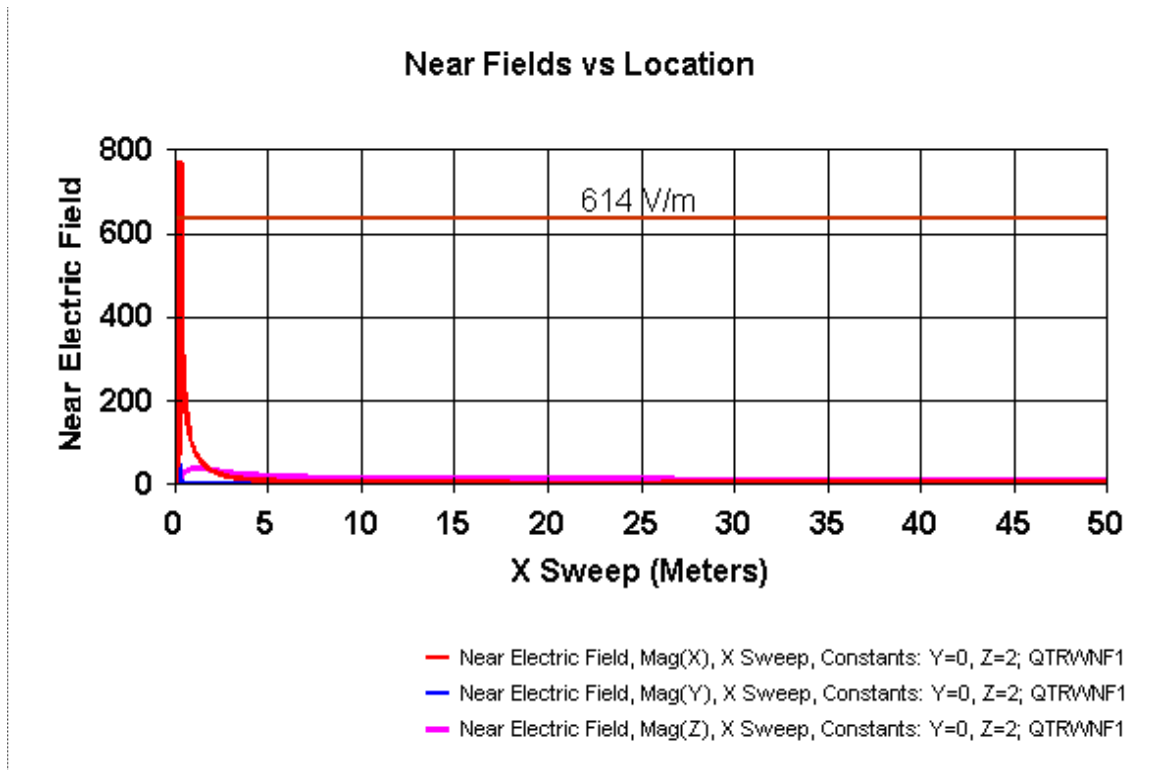


Figure 35 - E-Field plot for 90 degree tower at 1680 kHz at 1 kW along radial at height of 2 meters (Permissible level is 614 V/m).

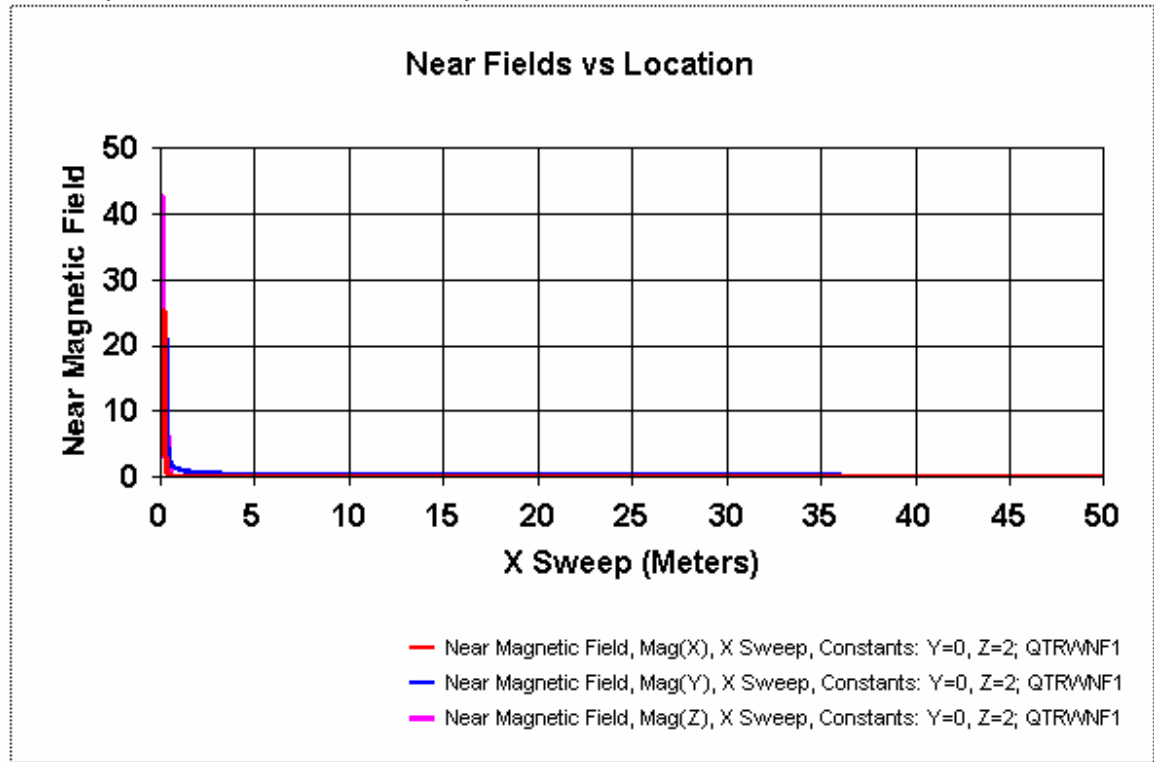


Figure 36 - H-Field plot for 90 degree tower at 1680 kHz at 1 kW along radial at height of 2 meters (Permissible level is 1.63 A/m).

Appendix 1

Ground Parameter and Frequency Variation Study
For KinStar Antenna and Quarterwave Tower

Modeling Results Data

1680 kHz – KinStar A - Transmission Line Match

Conditions	Relative Permittivity	Conductivity (S/m)	NEC Calculated RMS Field at 1km for 1kW input power (mV/m)	Correction Factor from Thin Monopole NEC Model	Calculated Unattenuated RMS Field at 1km for 1kW input power (mV/m)
Perfect with Ground Screen			293.54	-	293.54
Good	15	0.03	273.43	1.069	292.29
Average	15	0.005	215.67	1.365	294.39
Poor	15	0.001	116.56	2.477	288.72
Very Poor	15	0.0001	93.95	3.040	285.61

1680 kHz – KinStar B - Common Top/Bottom Lumped Element Match

Conditions	Relative Permittivity	Conductivity (S/m)	NEC Calculated RMS Field at 1km for 1kW input power (mV/m)	Correction Factor from Thin Monopole NEC Model	Calculated Unattenuated RMS Field at 1km for 1kW input power (mV/m)
Perfect with Ground Screen			293.36	-	293.36
Good	15	0.03	270.6	1.069	289.27
Average	15	0.005	212.8	1.365	290.47
Poor	15	0.001	116.3	2.477	288.08
Very Poor	15	0.0001	94.0	3.040	285.76

1680 kHz - Quarterwave 18” Tower – 146.37 Feet Tall

Conditions	Relative Permittivity	Conductivity (S/m)	NEC Calculated RMS Field at 1km for 1kW input power (mV/m)	Correction Factor from Thin Monopole NEC Model	Calculated Unattenuated RMS Field at 1km for 1kW input power (mV/m)
Perfect with Ground Screen			318.75	-	318.75
Good	15	0.03	297.53	1.069	318.06
Average	15	0.005	233.18	1.365	318.29
Poor	15	0.001	128.67	2.477	318.71
Very Poor	15	0.0001	104.83	3.040	318.68

Correction factor calculation – from thin monopole model

	Attenuated 1 km Field	Unattenuated Field	Calculated Correction Factor
Good	293.59	313.88	1.069
Average	229.91	313.88	1.365
Poor	126.73	313.88	2.477
Very Poor	103.25	313.88	3.040

1000 kHz – KinStar A - Transmission Line Match

Conditions	Relative Permittivity	Conductivity (S/m)	NEC Calculated RMS Field at 1km for 1kW input power (mV/m)	Correction Factor from Thin Monopole NEC Model	Calculated Unattenuated RMS Field at 1km for 1kW input power (mV/m)
Perfect with ground screen			290.43	-	290.43
Good	15	0.03	283.88	1.014	287.85
Average	15	0.005	255.78	1.139	291.33
Poor	15	0.001	172.36	1.695	292.15
Very Poor	15	0.0001	126.12	2.277	287.18

1000 kHz – KinStar B - Common Top/Bottom Lumped Element Feed

Conditions	Relative Permittivity	Conductivity (S/m)	NEC Calculated RMS Field at 1km for 1kW input power (mV/m)	Correction Factor from Thin Monopole NEC Model	Calculated Unattenuated RMS Field at 1km for 1kW input power (mV/m)
Perfect with Ground Screen			290.30	-	290.30
Good	15	0.03	279.51	1.014	283.42
Average	15	0.005	251.32	1.139	286.25
Poor	15	0.001	171.04	1.695	289.91
Very Poor	15	0.0001	125.36	2.277	285.44

1000 kHz - Quarterwave 18” Tower – 245.9 Feet Tall

Conditions	Relative Permittivity	Conductivity (S/m)	NEC Calculated RMS Field at 1km for 1kW input power (mV/m)	Correction Factor from Thin Monopole NEC Model	Calculated Unattenuated RMS Field at 1km for 1kW input power (mV/m)
Perfect with Ground Screen			317.68		317.68
Good	15	0.03	307.27	1.014	311.57
Average	15	0.005	277.26	1.139	315.80
Poor	15	0.001	189.93	1.695	321.93
Very Poor	15	0.0001	140.35	2.277	319.58

Correction factor calculation – from thin monopole model

	Attenuated 1 km Field	Unattenuated Field	Calculated Correction Factor
Good	307.47	311.92	1.014
Average	273.85	311.92	1.139
Poor	184.06	311.92	1.695
Very Poor	136.96	311.92	2.277

530 kHz – KinStar A - Transmission Line Match

Conditions	Relative Permittivity	Conductivity (S/m)	NEC Calculated RMS Field at 10 km for 1kW input power (mV/m)	Correction Factor from Thin Monopole NEC Model	Calculated Unattenuated RMS Field at 1km for 1kW input power (mV/m)
Perfect with ground screen			28.388	-	283.88
Good	15	0.03	28.007	1.0814	302.87
Average	15	0.005	23.33	1.2234	285.41
Poor	15	0.001	10.826	2.7849	301.49
Very Poor	15	0.0001	4.2671	6.7906	289.76

530 kHz – KinStar B - Common Top/Bottom Lumped Element Feed

Conditions	Relative Permittivity	Conductivity (S/m)	NEC Calculated RMS Field at 10 km for 1kW input power (mV/m)	Correction Factor from Thin Monopole NEC Model	Calculated Unattenuated RMS Field at 1km for 1kW input power (mV/m)
Perfect with Ground Screen			28.665		286.65
Good	15	0.03	28.226	1.0814	305.24
Average	15	0.005	22.662	1.2234	277.24
Poor	15	0.001	10.653	2.7849	296.67
Very Poor	15	0.0001	4.1932	6.7906	284.74

530 kHz - Quarterwave 18” Tower – 464 Feet Tall

Conditions	Relative Permittivity	Conductivity (S/m)	NEC Calculated RMS Field at 10 km for 1kW input power (mV/m)	Correction Factor from Thin Monopole NEC Model	Calculated Unattenuated RMS Field at 1km for 1kW input power (mV/m)
Perfect with Ground Screen			31.401		314.01
Good	15	0.03	30.23	1.0814	326.91
Average	15	0.005	25.043	1.2234	306.37
Poor	15	0.001	11.775	2.7849	327.92
Very Poor	15	0.0001	4.698	6.7906	319.02

Correction factor calculation – from thin monopole model

	Attenuated 10 km Field	Unattenuated Field	Calculated Correction Factor
Good	28.837	31.185	1.0814
Average	25.491	31.185	1.2234
Poor	11.198	31.185	2.7849
Very Poor	4.5924	31.185	6.7906

Appendix 2

Elevation Pattern Ratio Comparison Between NEC-4.1 And
73.160 Calculation Formula For Selected Licensed AM
Broadcasting Antennas

**Comparison of Elevation Field Ratios
1680 kHz 18" Face Guyed Tower Monopole**

Angle	NEC-4.1 Prediction	73.160 Calculation	Percent NEC Error between 73.160 and NEC-4.1
0	1	1	0
10	0.97725	0.977886	-0.06497621
20	0.912001	0.914259	-0.24699648
30	0.812156	0.816497	-0.53155512
40	0.688781	0.694639	-0.84337481
50	0.551768	0.558941	-1.28325901
60	0.410828	0.417794	-1.66718741
70	0.27107	0.27656	-1.98483826
80	0.134391	0.137414	-2.19952011

**Comparison of Elevation Field Ratios
700 kHz WLW Blaw-Knox Tower**

Angle	NEC-4.1 Prediction	73.160 Calculation	Percent NEC Error between 73.160 and NEC-4.1
0	1	1	0
10	0.936057	0.933598	0.263305243
20	0.766383	0.75709	1.227487314
30	0.545881	0.526416	3.697673407
40	0.336205	0.303337	10.83540992
50	0.183008	0.131218	39.46931114
60	0.103505	0.026061	297.1629107
70	0.070655	0.018339	285.266962
80	0.039787	0.019898	99.95096892

**Comparison of Elevation Field Ratios
1680 kHz Halfwave Guyed Tower Monopole**

Angle	NEC-4.1 Prediction	73.160 Calculation	Percent NEC Error between 73.160 and NEC-4.1
0	1	1	0
10	0.936152	0.940704	-0.48385188
20	0.766105	0.781863	-2.01537124
30	0.543208	0.570865	-4.84468971
40	0.327374	0.361148	-9.35183726
50	0.162953	0.191854	-15.0641815
60	0.071734	0.079347	-9.59439182
70	0.044627	0.020366	119.1225034
80	0.027587	0.000251	10884.29397

**Comparison of Elevation Field Ratios
1680 kHz 20-Ft Base Halfwave Self Supporting Tower**

Angle	NEC-4.1 Prediction	73.160 Calculation	Percent NEC Error between 73.160 and NEC-4.1
0	1	1	0
10	0.9416	0.941733	-0.01409596
20	0.784996	0.78546	-0.05911828
30	0.576513	0.57735	-0.14507243
40	0.368538	0.369635	-0.29671267
50	0.199657	0.200816	-0.57720268
60	0.08625	0.087276	-1.17592284
70	0.025409	0.02616	-2.86826635
80	0.002887	0.003279	-11.9653009

**Comparison of Elevation Field Ratios
1680 kHz Blaw-Knox Halfave Tower**

Angle	NEC-4.1 Prediction	73.160 Calculation	Percent NEC Error between 73.160 and NEC-4.1
0	1	1	0
10	0.9416	0.941733	-0.01409596
20	0.784996	0.78546	-0.05911828
30	0.576513	0.57735	-0.14507243
40	0.368538	0.369635	-0.29671267
50	0.199657	0.200816	-0.57720268
60	0.08625	0.087276	-1.17592284
70	0.025409	0.02616	-2.86826635
80	0.002887	0.003279	-11.9653009

EXHIBIT A

A Novel Short AM Monopole Antenna with
Low-Loss Matching System

Technical Proceedings of the
IEEE Broadcast Symposium, October 2002

SEE PDF FILE ATTACHMENT

KINSTAR_IEEE_ARTICLE.PDF

EXHIBIT B

Summary of Consulting Engineer's Report on Field Proof Testing
and Measured Antenna Efficiency

SEE PDF FILE ATTACHMENT:

KINSTAR_CONSULTING_ENGINEERS_REPORT.PDF