Testing Results of the Low-Profile Kinstar AM Broadcast Antenna

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Introduction

The Kinstar antenna [1] (patent pending) is a new reduced height antenna designed for AM broadcasting applications based on a design by Dr. James K. Breakall of the Pennsylvania State University. A single omnidirectional Kinstar antenna (shown in Figure 1) consists of a number of vertical and horizontal radiating wires operating over a standard radial wire ground plane. The lengths and arrangements of the wires are designed by computer optimization methods to provide the best compromise between reduced antenna height, antenna gain at the horizon, and frequency bandwidth. A typical Kinstar omnidirectional antenna is approximately 0.05 wavelengths high, 0.4 wavelengths in diameter, and is constructed of 4 insulated sections of 3/8" diameter stranded aluminum conductor. A standard 0.25 or 0.4 wavelength ground screen is currently used to ensure efficient groundwave coupling. The details of the number of conductors, exact height and diameter are determined for each application by computer optimization techniques using the NEC Method of Moments antenna analysis code [2]. Multiple Kinstar antennas can be arrayed for directional applications.

A full-sized omnidirectional single-element Kinstar antenna was constructed and tested by a joint development effort between Star-H Corporation and Kintronic Laboratories, Inc. near Evergreen Hills, Virginia in late 2002 under FCC experimental license WS2XTR on a frequency of 1680 kHz. The test compared signal strengths over the same radial ground plane at the same location between the Kinstar antenna and a quarterwave vertical tower monopole antenna. A standard program of field strength measurements was conducted by Donald Crane, an independent consulting engineer and the data analyzed by Ronald Rackley of duTreil, Lundin, and Rackley [3]. The results showed that the Kinstar antenna, despite being approximately 1/5th the height of the monopole, achieved a field strength of at least 98% of the monopole, sufficient to meet FCC efficiency requirements for Class B, C, and D AM broadcast stations in the United States.

Reference Monopole Antenna

All antenna testing was conducted in an open alfalfa field in a rural area of low rolling hills. The first test series consisted of the construction of a quarterwave guyed tower monopole with the top section cut off so that its height was precisely 146 feet above ground level. A 120-radial copper wire ground screen was laid out on top of the ground with a radius also of 146 feet. A Nautel Ampfet 500-Watt broadcast transmitter was operated at an output power of 250 Watts through a Kintronic Laboratories T-matching network and fed to the base of the tower. Antenna input current was measured at the matching network shown in Figure 2, and the transmitter was adjusted to 250 Watts of input power. Field measurements were then taken at locations on 6 radials in accordance with FCC Section 73.186 and the locations marked for repeatability using GPS instrumentation. These measurements were made by Mr. Crane using a Potomac Instruments type FIM-41 Field Strength Meter. Raw measurement data are on file at Star-H and Kintronic Laboratories and is available for independent analysis.

Analysis of the measurements was in accordance with the "best fit" method of FCC 73.186 and using Graph 20 of 73.184 to determine the conductivity of the ground. 73.110 shows an effective field of 306 mV/m at 1 kilometer for 1 kilowatt of input power for the quarterwave monopole. This corresponds to an effective field of 153 mV/m for 0.25 kW of input power as was used in these tests. Figure 3 shows the data points for the measurements on the 30-degree radial of the field from the monopole antenna with 250 Watts of input power. Average calculated ground conductivity is shown for three regions of 6, 4, and 2 mS/m extending to approximately 8, 15, and 20 km, respectively. The average measured unattenuated field at 1 km over all 6 radials was 153 V/m for the monopole, which agrees with the FCC Figure 8 of 73.110 of 306 mV/m for 1kW input.

Kinstar Antenna Configuration "A"

The original Kinstar antenna design is based on an independent feed for each isolated vertical wire radiator in the antenna, using a transmission line matching section on each wire to bring its input impedance to close to 200 + j0 so that when the four transmission lines are connected together a net input impedance of 50 + j0 is realized. The length of the matching sections is determined along with the antenna wire lengths by computer optimization for the specified center frequency, bandwidth, and line impedance. By choosing the type of coaxial transmission line, the loss in the matching sections can be managed to a very low level. For this test, 46 feet of 7/8" Cablewave Systems LCF78-50J cable, with an electrical length of 0.089λ was used. At a VSWR of 1.0, this cable has an attenuation of 0.049 dB/100ft. In this application, the VSWR is no longer 1.0, and the loss in the line can be calculated to be approximately 0.011 dB.

The nominal size of the Kinstar Antenna is 45 feet high by 105 feet in radius, with four L-shaped radiating wires arranged symmetrically around the center. The vertical wires are arranged symmetrically on a circle with a radius of 5 feet. From above the antenna has the appearance of an X. A schematic representation of the Kinstar antenna is shown in Figure 1. The same ground system was used for the Kinstar as the monopole.

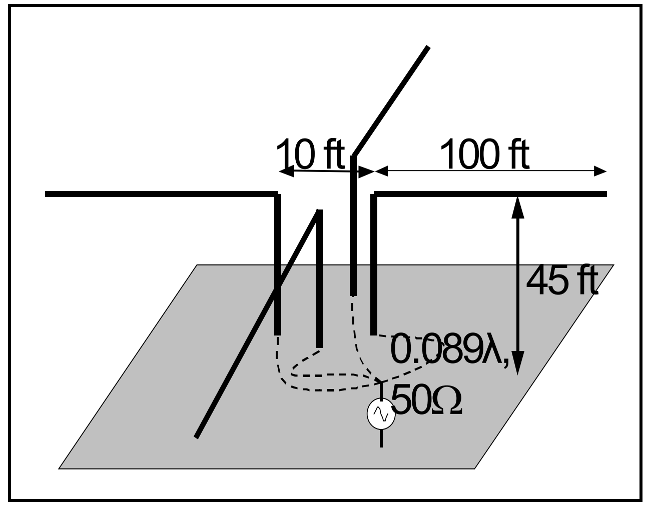

Figure 1 - Kinstar antenna design showing vertical and horizontal radiating wires, along with quarterwave transmission line matching sections.

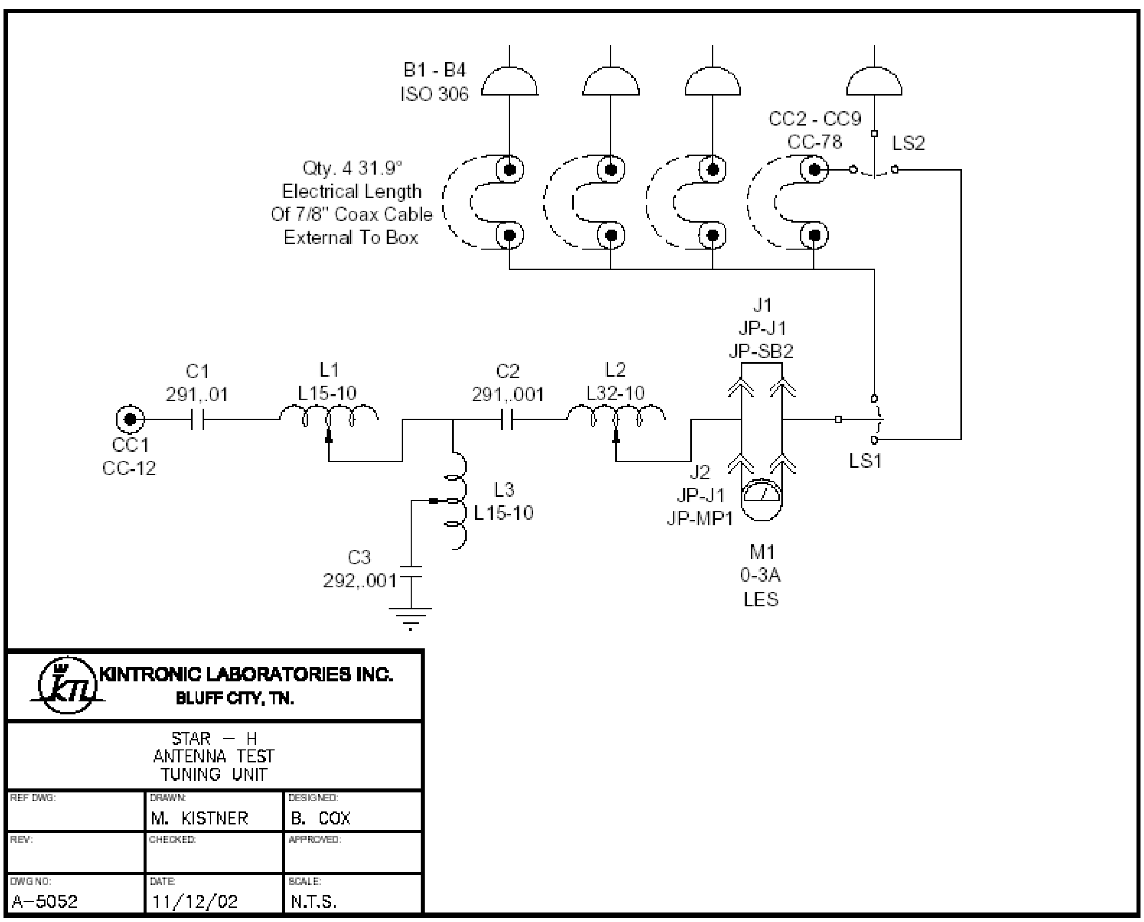

Figure 2 - Antenna matching unit used for all tests. For monopole tests, the jumpers LS1 and LS2 were set to provide a single direct output connection not passing through any of the transmission line matching sections. For configuration "A", the jumpers were reversed and each of the four Kinstar antenna vertical wire radiators were connected separately through each of the four transmission line matching sections shown. For configuration "B" tests, the coaxial line sections were bypassed and the vertical wires connected directly in parallel at LS1.

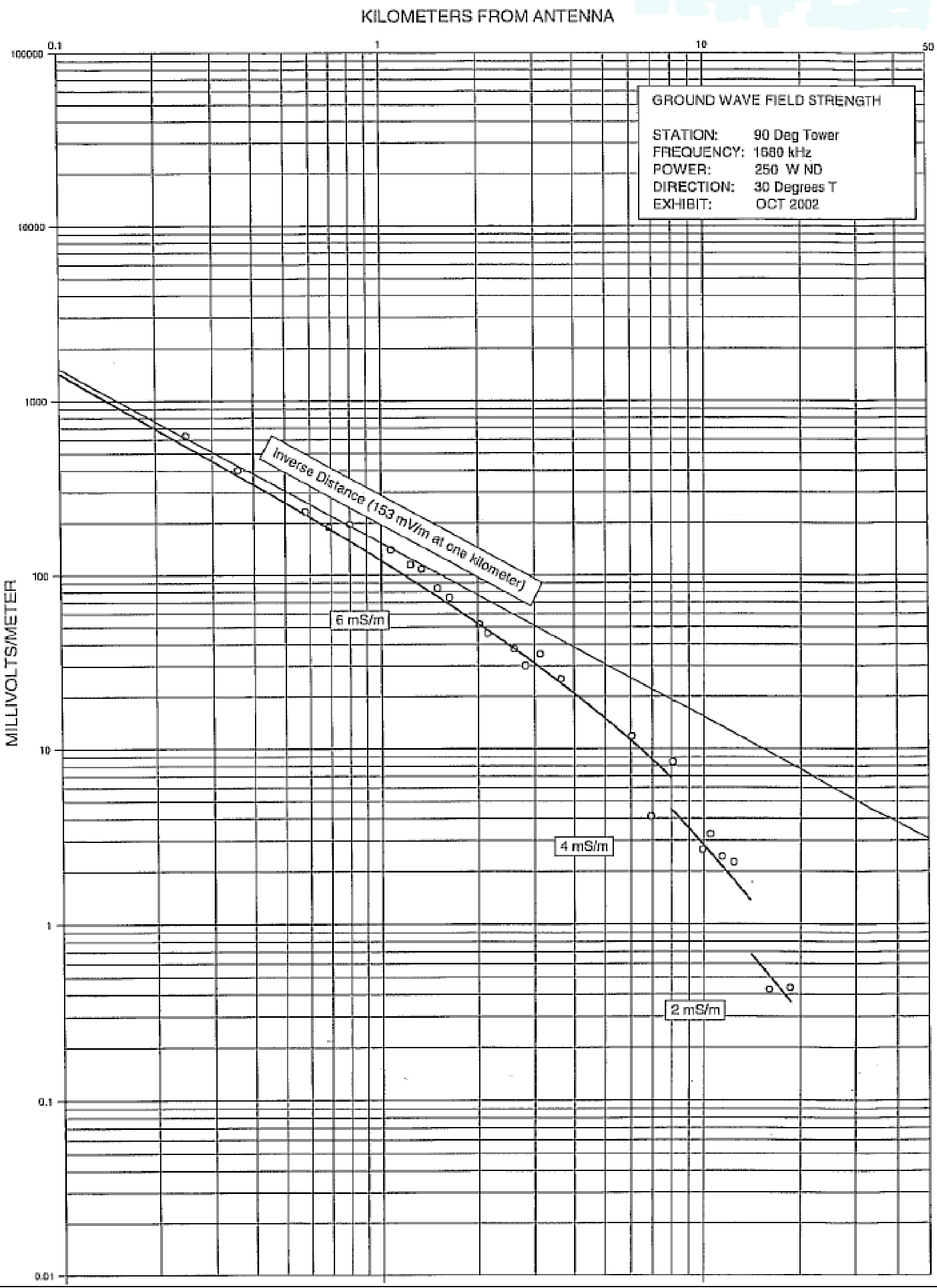

Figure 3 - Field measurement points along 30 degree radial for monopole antenna with 250 Watts input power to antenna. Ground conductivity calculations shown for each identifiable region of discrete ground conductivity. (Figure by duTreil, Lundin, and Rackley)

As built, the Kinstar antenna was supported at its center and at the ends of each horizontal wire by a wooden utility pole approximately 55 or 60 feet in length. The bottom 7 feet of each pole was set in the ground resulting in a net pole height of 48 or 52 feet above the ground. The four outer poles were guyed to standard utility screw-in type anchors at two places, each 45 degrees from the radius line. Some variation was observed in the locations of the poles due to the natural tendency of the earth augur to wander during the digging of the hole and the ability to position the equipment. There was thus an error of a few feet in the as-built location of the poles, and a resulting slight variation in the symmetry of the horizontal sections of the antenna. Likewise, the vertical wires were anchored into screw anchors located approximately 5 feet from the center of the antenna. Variation of approximately 6 inches was seen in some of these anchor locations as well, resulting in slight misalignment of the as-built antenna compared with the antenna design. In terms of wavelengths, these variations are minimal and will have no consequence as to the radiation pattern or efficiency, although the antenna input impedance may vary slightly from the predicted. The effects of wire deadends and fiberglass insulating rods are also not included in the NEC-based design and add some uncertainty to the final antenna performance. The height and length of the wires were easily controlled by adjustment of the wire tensions during construction. The vertical wires extend to a height of approximately 44’ 6” above the ground (an error of about 6 inches too short), while the horizontal wires are estimated to be within a few inches of the design length of 100 feet.

These unforeseeable effects can be tuned out by the time consuming practice of adjusting the wire or transmission line lengths, but in practice it was determined to be easier and more in line with current industry practice to use a variable impedance matching network to make the final adjustments. Thus, the same matching network used with the monopole is used with the Kinstar antenna configured with the transmission lines. By using the transmission lines, the inherent input impedance of the antenna can be brought very close to 50 + j0 over the design bandwidth, requiring minimal additional contribution by the lumped element network to make any final adjustments necessary. The ability to make future adjustments as the ground system ages and other effects on the antenna occur makes the use of the adjustable matching network a valuable addition to the antenna.

Figures 4 and 5 show details and a general view of the center area of the antenna and the antenna feedpoint connections with the coaxial matching sections. The other ends of the coax lines terminate inside the Kintronic antenna matching unit.

Figure 4 - Kinstar antenna configuration "A" feedpoint showing connection from coaxial matching section to insulated vertical radiator and ground strap from coax outer conductor to ground system. Turnbuckle for tensioning wires and fiberglass insulator are also visible.

Figure 5 - Kinstar antenna center section and support pole.

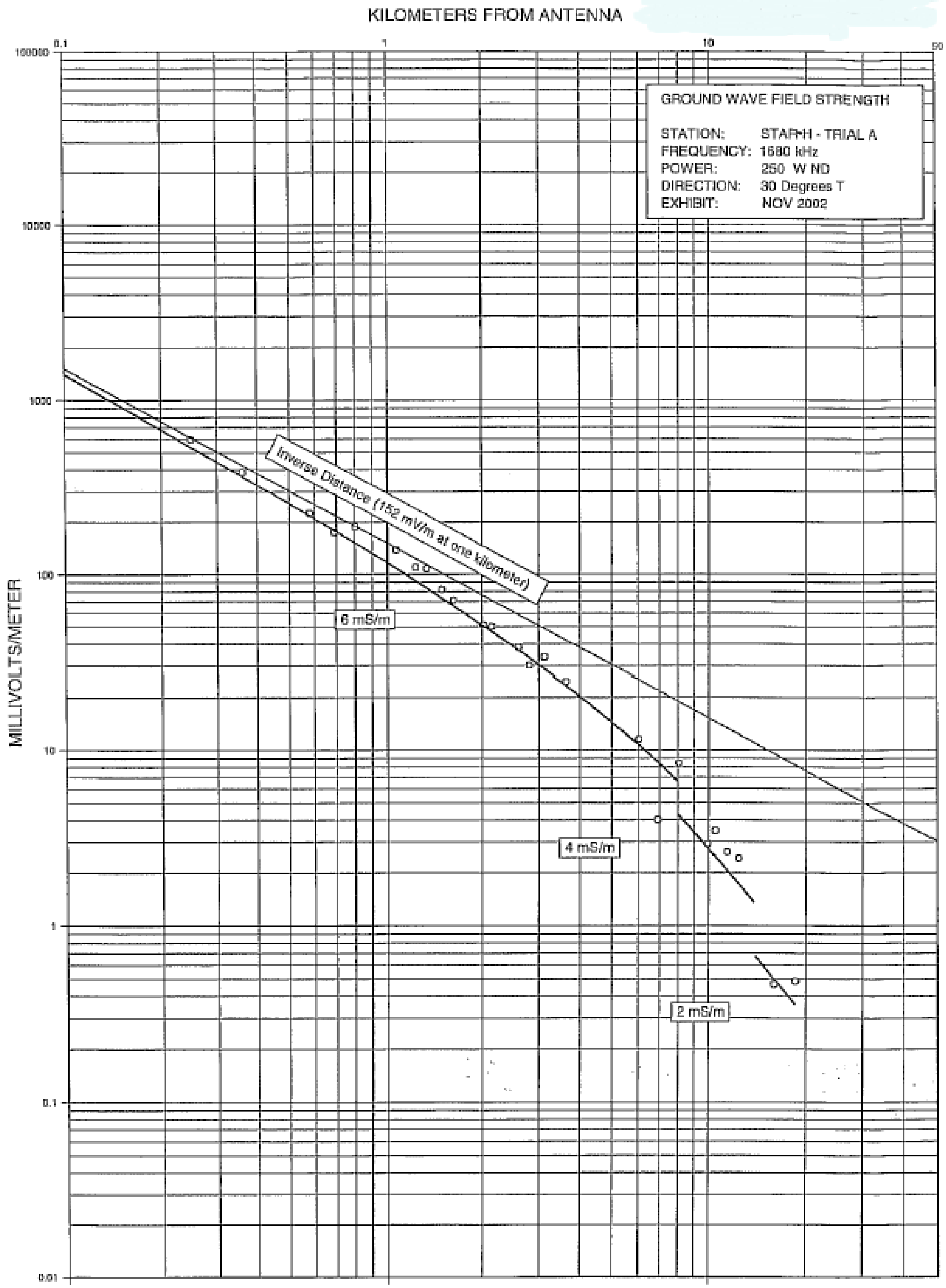

Figure 6 - Field measurement points along 30 degree radial for configuration "A" with 250 Watts input power to antenna. Ground conductivity calculations shown for each identifiable region of discrete ground conductivity. (Figure by duTreil, Lundin, and Rackley)

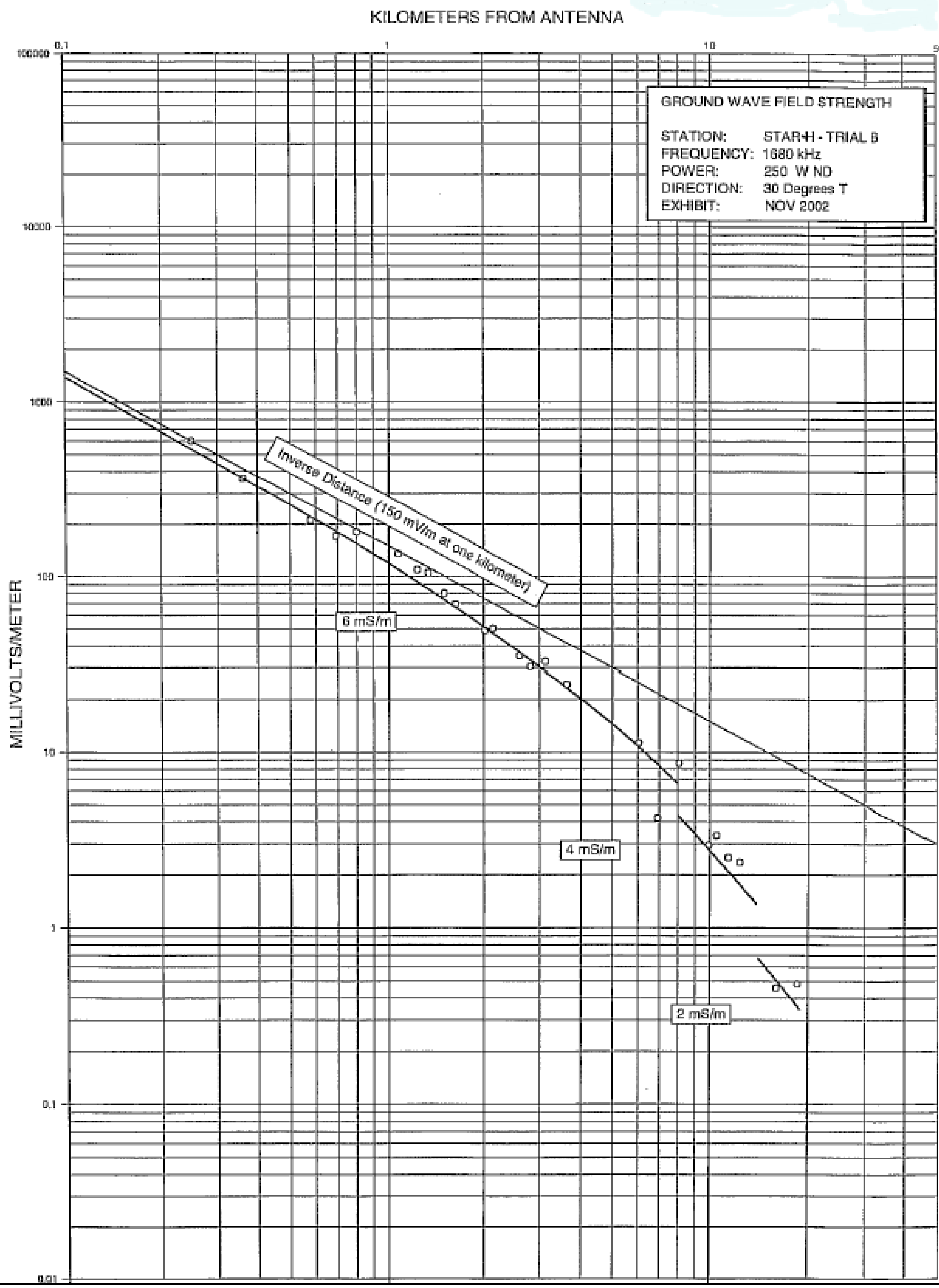

Figure 7 - Field measurement points along 30 degree radial for configuration “B” with 250 Watts input power to antenna. Ground conductivity calculations shown for each identifiable region of discrete ground conductivity. (Figure by duTreil, Lundin, and Rackley)

Kinstar Antenna Configuration "B"

The Kinstar configuration "B" omits the transmission line matching and simply connects each of the vertical wires to a common point at the output of the matching network using low-inductance wire or tubing such as is commonly used for connecting a typical monopole antenna to its antenna matching unit. The same T network is used as was used with both the monopole and "A" configuration, but the variable inductor values are adjusted to bring the antenna to the correct match. In this case, the T network is directly matching the common point impedance of the antenna without the aid of the transmission line matching, resulting in an expected increase in matching network losses and subsequent reduction in efficiency.

All other antenna components and ground system are identical with those of the configuration "A" antenna.

Results

Testing of the monopole antenna was done in early October 2002 during relatively mild and dry weather. Because of the time required to disassemble the monopole and erect the poles for the Kinstar antenna, and an unanticipated bout of very rainy weather, testing of the Kinstar antenna configurations was delayed until late November 2002. This resulted in some changes in ground conductivity between the test series, which is observable in the raw data. To minimize the effect of this on the analysis, Mr. Rackley used the ratios of the field measurements within a 3-kilometer radius of the test site to make the efficiency comparisons. Over these data points, the ground conductivities maintained a good agreement between each of the Kinstar antenna configurations and that of the reference monopole.

Figures 6 and 7 show the corresponding 30-degree radial field measurements for the Kinstar configuration "A" and "B" antennas, respectively. The unattenuated field at 1 kilometer for the Kinstar configuration "A" antenna is calculated to be 152 mV/m for the 0.25 kW input power. The unattenuated field at 1 kilometer for the Kinstar configuration "B" antenna is calculated to be 150 mV/m for the 0.25 kW input power. These compare with the value of 153 mV/m found for the quarterwave monopole antenna tested earlier. A summary of the final 1 kW@1km field calculations and efficiencies are shown in Table 1. Table 2 shows the aggregate average efficiency values for each radial, along with the calculated overall efficiency for each antenna configuration.

Table 1 – Antenna efficiency and field calculations.

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 by duTreil, Lundin, and Rackley)

Table 2 – Antenna average radial efficiencies (monopole = 1.000)

Radial (degrees)	Configuration A	Configuration B
30	0.981	0.954
90	1.080	0.981
150	0.998	1.027
210	0.990	0.960
270	0.994	0.976
330	0.986	0.980
Overall Average	0.995	0.980

(all values by by duTreil, Lundin, and Rackley)

Conclusion

The Kinstar antenna, in two matching system configurations, was tested against a monopole reference antenna with identical ground systems and power inputs. In each configuration, the Kinstar antenna efficiency exceeded that required by the FCC for class B, C, and D operations in the United States, and demonstrates sufficient efficiency to be readily used as an alternative to much taller monopole antennas throughout the world. Independent consulting engineers conducted measurement and analysis of the antenna's performance. Interested parties may review the engineers' reports, raw data, and inspect the antenna by arrangement with Kintronic Laboratories, Inc.

The Kinstar antenna is expected to be available from Kintronic Laboratories, Inc, in the near future, pending regulatory approval. Operation in directional arrays is pending additional development work by Star-H Corporation and Kintronic Laboratories.

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[1] Breakall, J. K., et al, "A Novel Short AM Monopole Antenna with Low-Loss Matching System", *52nd Annual IEEE Broadcast Technology Symposium*, Washington, DC, October, 20002.

[2] J. K. Breakall, G. J. Burke, and E. K. Miller, "The Numerical Electromagnetics Code (NEC)," EMC Symposium and Exhibition, Zurich, Switzerland, 1985.