Directional Antennas
Instrumentation, Operation and Maintenance

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A directional antenna with driven elements is simply two or more nondirectional stations connected to form one unit. The typical nondirectional station consists of a base insulated tower, antenna ground system, antenna tuning unit in a weatherproof box or mounted in a small building and transmission line (Figure 1 and Figure 2).

As towers are combined to form the directional antenna, the ground systems are connected at locations where they would otherwise overlap (Figure 3). Installation of an expanded mesh ground screen at the base of the tower is generally advisable for towers having height in excess of 120 electrical degrees. However, ground screens require substantial attention for proper installation and are expensive.

The transmission lines from the towers terminate in the phasing equipment cabinet usually located near the transmitter. The phasor serves the purpose of providing the proper impedance match between the transmitter and antenna system and controls the magnitude and phase of the current to each tower.

Instrumentation

The following parameters of a directional antenna should be measured and monitored on a regular basis:

- Power into the directional antenna common point,
- the relative magnitude of the current at each tower, and
- the relative phase of the current of each tower compared with the reference tower.

Power can be measured by use of a rf ammeter, provided the resistance is known at the measurement point. An in-line impedance bridge is often utilized to measure common point impedance. Many modern transmitters incorporate a power meter, whose proper operation depends on having the proper impedance to terminate the output of the transmitter.

Antenna current can be sampled at the tower base with a toroidal transformer if the towers are less than approximately 120 electrical degrees in height. Sampling loops mounted on the towers, and located at the current maximum, can also be used for short towers and are required for taller towers. (Figure 4) The loop and the outer conductor of the transmission line should be electrically connected to the tower above the base insulator. Where the transmission line crosses the base of the tower, the transmission line itself may be wound into a coil forming an inductor, so as to minimize impact on the tower base impedance. If the expected base impedance is high, a capacitor can be employed to anti-resonate the inductor to further minimize base impedance effects. Use of a toroidal sampling system is preferable, as it is located out of the weather. The loops or toroids used for each of the towers should be identical so as to avoid inducing unknowns into the system.

The transmission lines to be employed in the sampling system should consist of foam filled dielectric and have solid outer conductors. The lines can be purchased from the manufacturer to have matched electrical characteristics; however, in more complicated antenna array, this may result in substantial surplus of line. Different length lines may be used; however, their electrical characteristics must be carefully measured.

Foam dielectric line is preferred as moisture is prevented from entering the line. In addition, the line is not easily crushed or kinked when bent. It is important to use the proper end connectors for the type cable employed and it is essential that the exposed connection at the loop be waterproof. Water and moisture in the connector can cause erroneous readings and may falsely indicate array instability.

Transmission lines from the tower bases to the transmitter should be buried to maintain temperature stability and for protection from damage or theft. Any surplus line used to maintain equal lengths should also be buried.

All sample lines terminate at the antenna monitor which is generally located near the phasing equipment, thereby permitting easy observation of parameters when antenna pattern changes are made. The current magnitude and phase angle is measured relative to the reference tower; therefore, in programming the monitor at the factory, the tower with the highest radiated field is generally selected as the reference tower.

Operation of the Antenna System

As with any electrical equipment which is to remain stable, cleanliness is the watchword.

At the base of the towers, vegetation must be controlled by regular cutting and removal. When putting in the ground system, the area near the base of the tower, perhaps 3 x 3 meters, can be covered with heavy black plastic, such as employed for agricultural purposes, to retard growth of vegetation. The ground wires can be placed over the plastic and then covered with gravel or sand (or left exposed if not subject to theft).

The components in the antenna tuning units should be cleaned and connections tightened annually. RF contactors (switches) should be monitored regularly to maintain good electrical connections and to replace "finger" stock when necessary.

Fences should be placed around the towers to prevent unauthorized access to the towers and to prevent excessive exposure of humans to RF radiation. The chart of Figure 5 lists distances employed in the U.S. so as not to exceed guidelines (Figure 5). These distances are very conservative when compared with actual measurements of power density.

Proof-of-Performance

How do we know that a directional antenna system is producing the desired pattern? The question is resolved by assuming that a single antenna (tower) radiates uniformly in all directions. From theory and confirmed by field strength measurements, the inverse distance field from the antenna can be determined. By comparing the measured field strength of the reference nondirectional tower in the system versus the directional field strength, a directional radiation pattern can be determined. The ratio of directional field strength to non-directional field strength is tabulated in Figure 6A.

With measured field strength information, the ground conductivity can also be determined. Figure 6B shows graphs of tabulated field strength from Figure 6A for directional and nondirectional operation, on a true bearing of 177 degrees.

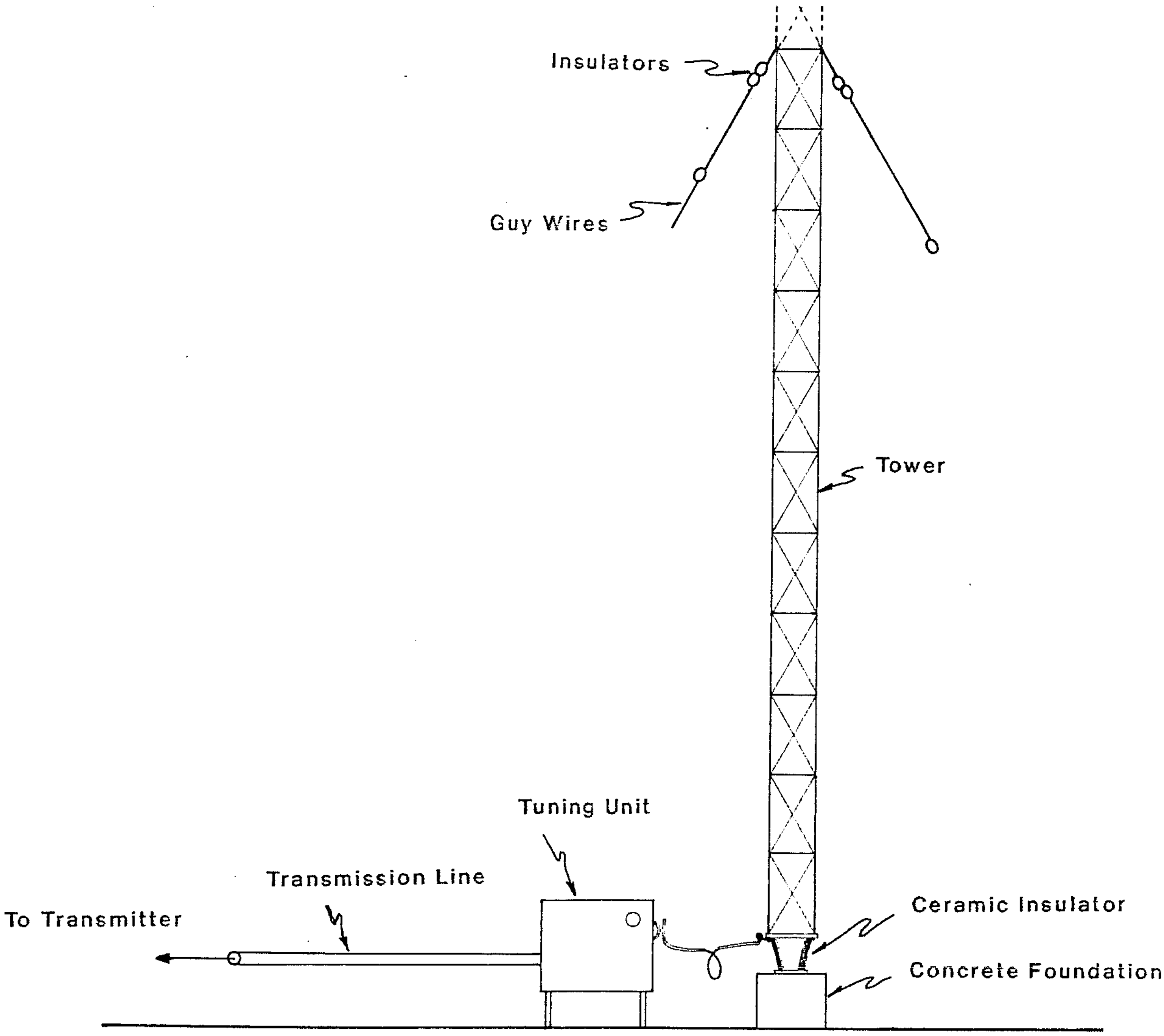
Generally, directional antennas are employed to provide protection to other co-channel or nearby adjacent channel stations; therefore, proof-of-performance measurements should be made in the null region (minima) of the pattern to demonstrate the proper operation of the antenna. If a directional antenna is installed simply to provide antenna gain, then only measurements in the major lobe (maxima) are of concern.

In order to monitor the radiated pattern, it may be prudent to establish monitor points -- physical locations where the directional and non-directional field strength is known. This monitoring point can be used as a tool to evaluate proper operation of the array. For example, if the antenna monitor exhibits a large change in phase or current ratio, but there is no change in the monitoring point field strength, the operation of the sampling system becomes suspect. As a monitoring point is affected by its environment, its location should be clear of reradiating objects.

A directional antenna pattern can be distorted due to reradiating objects such as other towers, power lines, water tanks, etc. If sufficient reradiation occurs, it may be impossible to prove a directional antenna radiation pattern. However, there are techniques for detuning structures as shown in Figure 7.

With a degree of care and maintenance, a directional antenna can perform satisfactorily for long periods of time.

Figure 1



BASE INSULATED TOWER, TUNING UNIT

AND TRANSMISSION LINE

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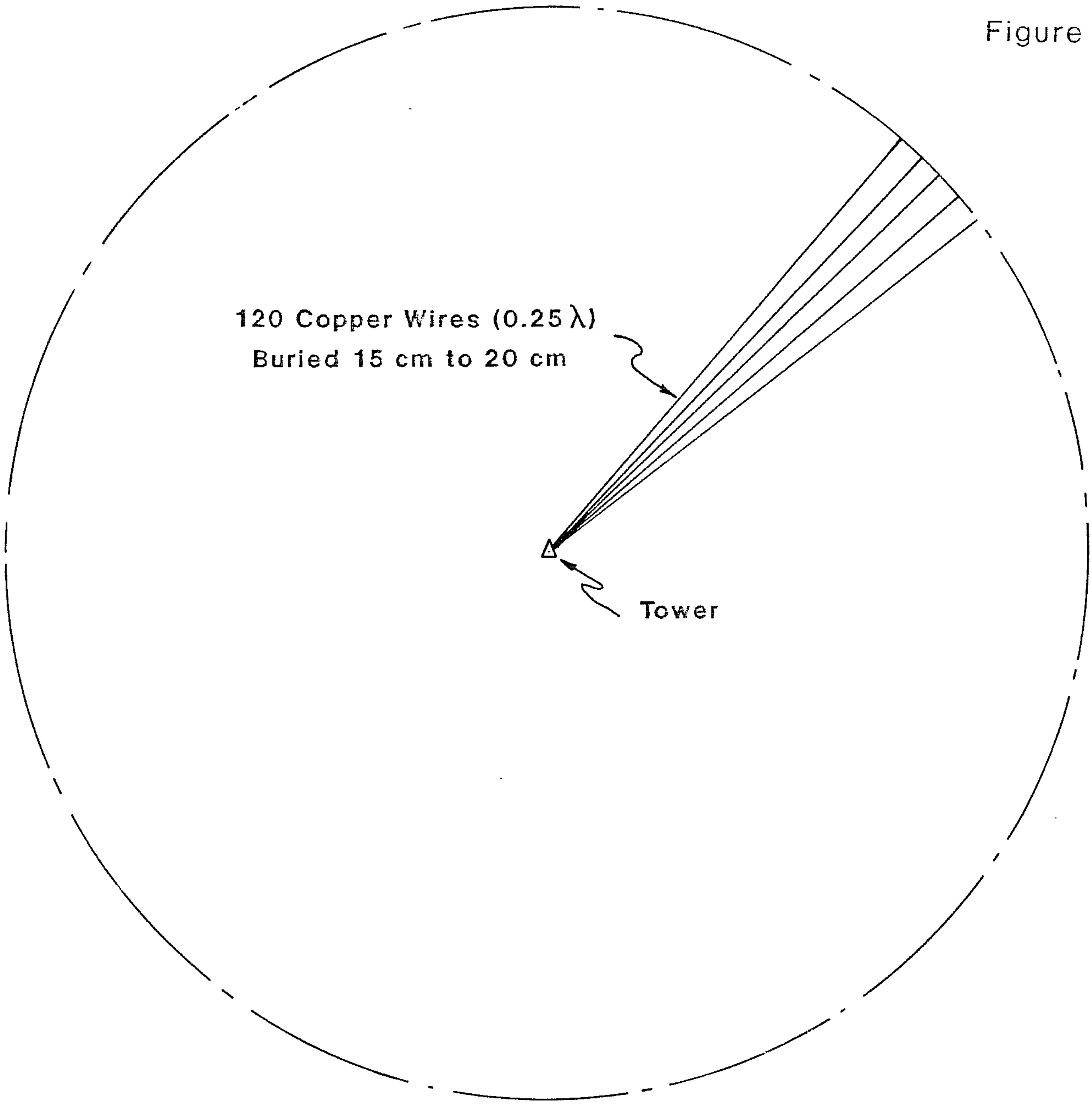
Figure 2



ANTENNA GROUND SYSTEM

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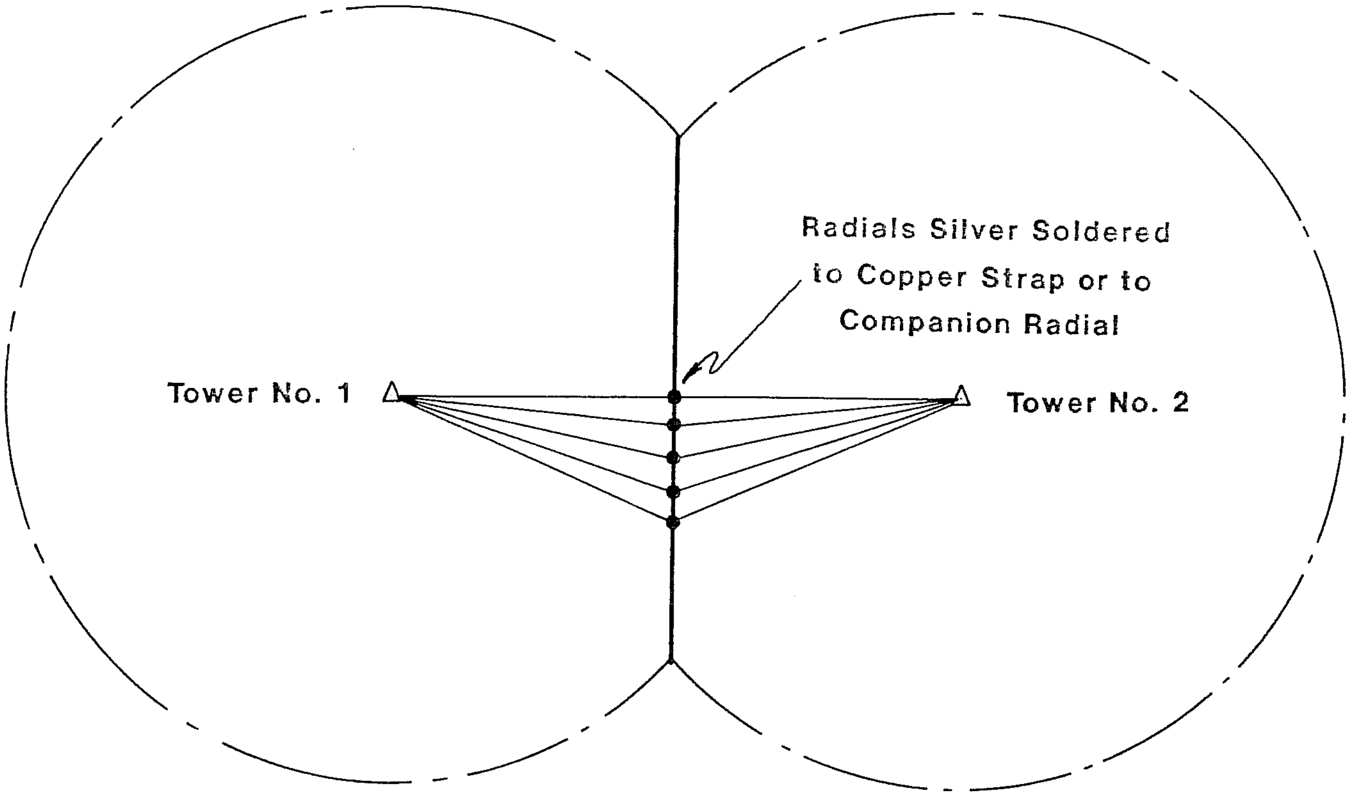
Figure 3



A TWO TOWER DIRECTIONAL ANTENNA
GROUND SYSTEM

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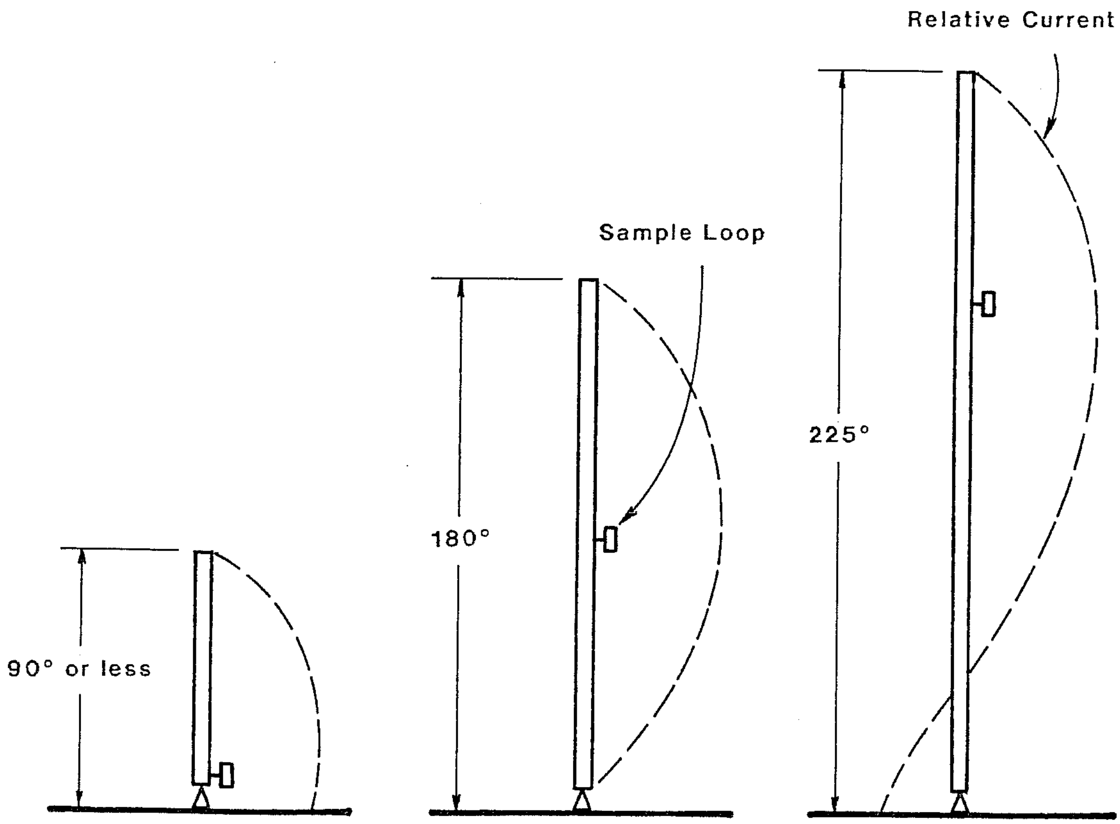
Figure 4



CURRENT DISTRIBUTION IN TOWERS AND LOOP PLACEMENT

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Figure 5

TABLE 1

DISTANCES (IN METERS) AT WHICH FIELDS FROM AM STATIONS ARE PREDICTED TO FALL BELOW VARIOUS ELECTRIC FIELD STRENGTHS
(*See notes below)

Electric Field Strength (V/m)	Magnetic Field Strength (A/m)	Transmitter Power (kW)								
		50.00	25.00	10.00	5.00	2.50	1.00	0.50	0.25	0.10
25	0.06	109	83	60	47	37	27	22	18	13
50	0.13	65	51	37	29	23	18	14	11	8
75	0.19	49	38	28	23	18	13	11	8	6
100	0.25	40	31	23	19	15	11	9	7	5
150	0.38	30	24	18	15	11	8	6	5	4
200	0.50	25	20	15	12	9	7	5	4	3
300	0.75	20	16	11	9	7	5	4	3	<2
400	1.00	16	13	9	7	6	4	3	<2	<2
500	1.25	14	11	8	6	5	3	3	<2	<2
632 (ANSI)	1.58 (ANSI)	12	9	7	5	4	3	<2	<2	<2
750	1.88	11	8	6	5	4	3	<2	<2	<2
1000	2.50	9	7	5	4	3	<2	<2	<2	<2

*Notes: (1) This table can be used for any AM frequency or electrical height.

(2) The entries in this table apply to both electric field strength and the corresponding magnetic field strength (assuming impedance of free-space equals 400 ohms). See text for further discussion.

Figure 6A

Comparison of Non-Directional and Directional Field Strength

177° True Radial

Distance (km)	Non-DA 500 watts Field Strength (mV/m)	Directional 500 watts Field Strength (mV/m)	Ratio (DA/ND)
0.6	330.	---	---
0.8	270.	---	---
1.0	208.	---	---
1.2	160.	---	---
1.4	148.	---	---
1.6	126.	---	---
1.8	112.	---	---
2.0	95.0	---	---
2.2	91.0	---	---
2.4	66.0	---	---
2.6	83.0	---	---
2.8	69.0	---	---
3.0	67.0	8.00	0.12
4.0	46.0	7.70	0.17
5.0	37.0	4.60	0.12
6.0	31.0	3.60	0.12
7.0	28.5	2.10	0.07
8.0	28.0	2.90	0.10
9.0	21.0	1.85	0.09
10.0	16.0	1.80	0.11
11.0	16.8	1.60	0.10
12.2	15.5	1.41	0.09
13.0	12.0	1.50	0.13
14.0	9.40	.600	0.06
15.0	7.20	.760	0.11
18.0	8.60	.890	0.10
21.1	4.70	.760	0.16
24.1	5.90	1.15	0.19
27.2	4.10	.920	0.22
29.2	2.45	.340	0.14

Average Ratio 0.12

Directional Field Strength = 205 mV/m x 0.12 = 24 mV/m

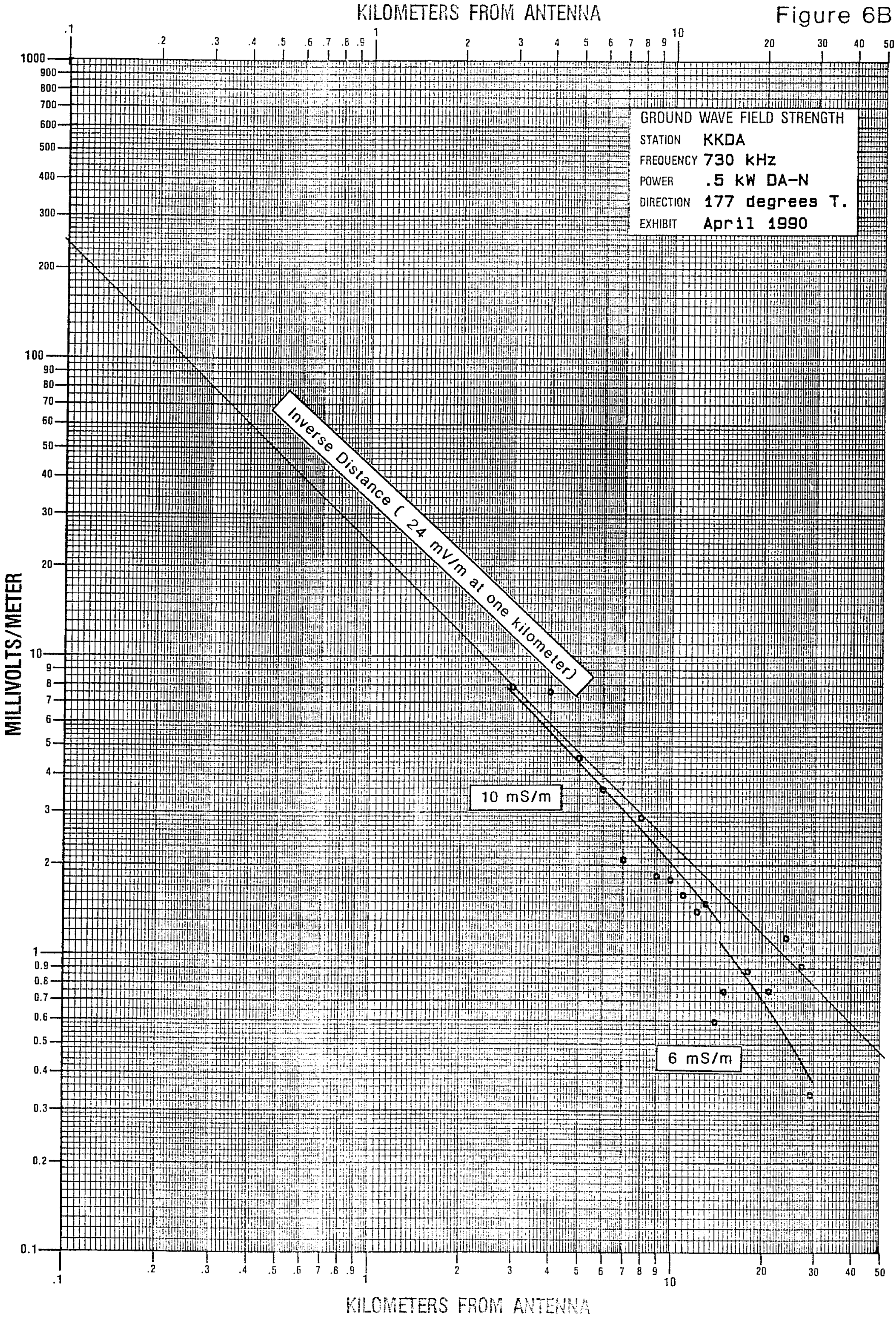
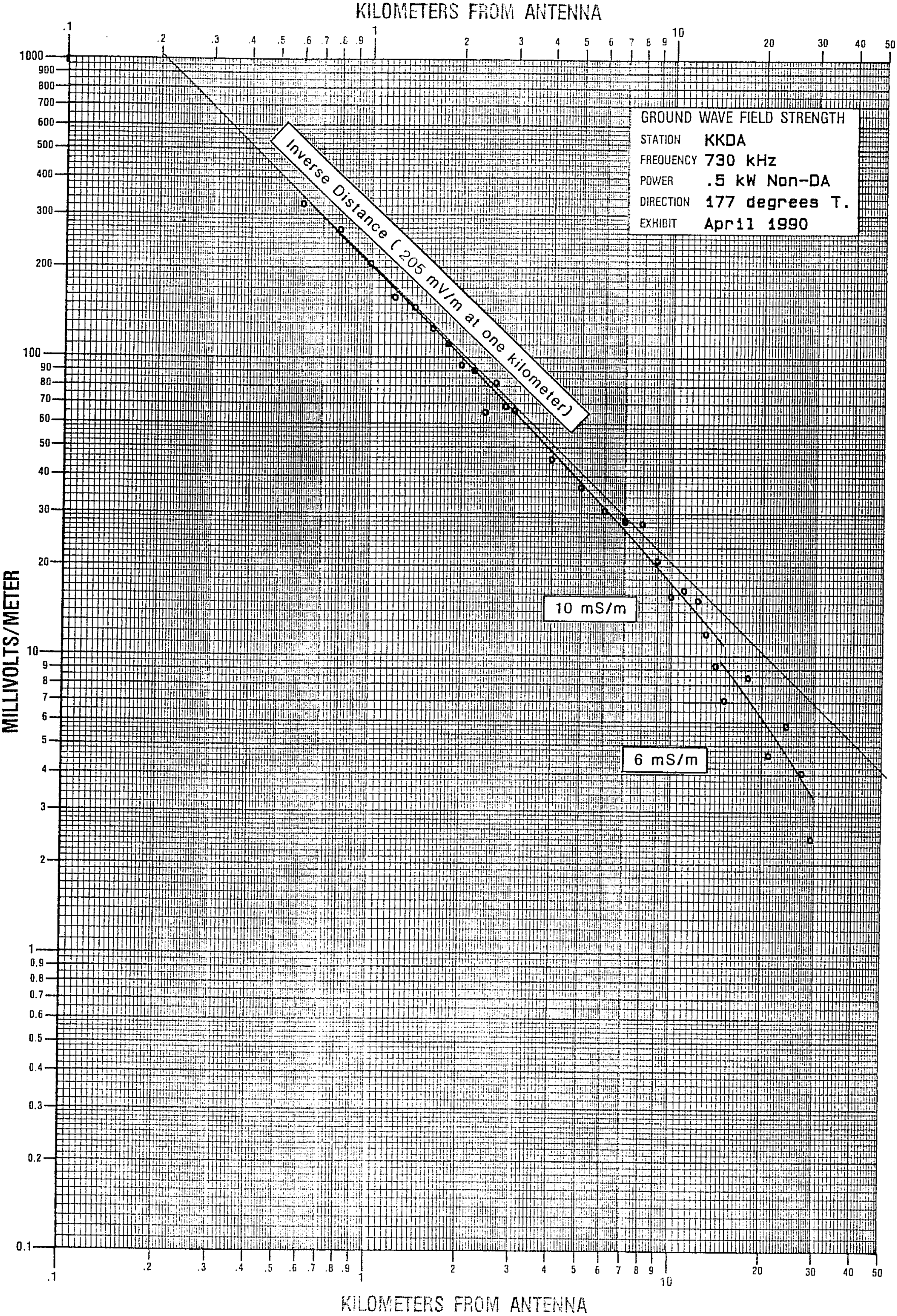

KILOMETERS FROM ANTENNA
MILLIVOLTS/METER
GROUND WAVE FIELD STRENGTH
STATION KKDA
FREQUENCY 730 kHz
POWER .5 kW DA-N
DIRECTION 177 degrees T.
EXHIBIT April 1990
Inverse Distance (24 mV/m at one kilometer)
10 mS/m
6 mS/m
KILOMETERS FROM ANTENNA

Figure 6B

A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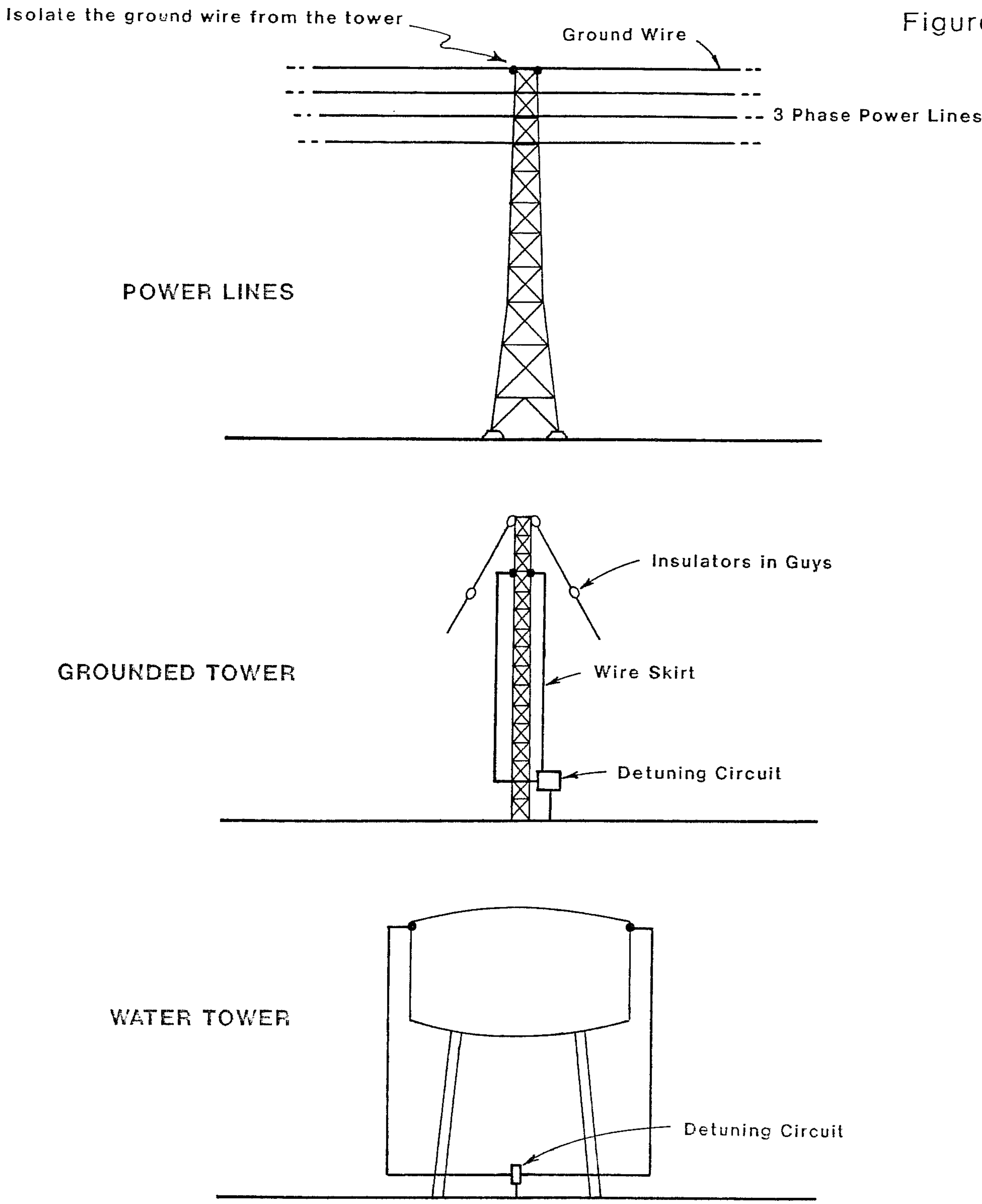
MILLIVOLTS/METER
KILOMETERS FROM ANTENNA

A



DETUNING TECHNIQUES

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