OFFICE MEMORANDUM

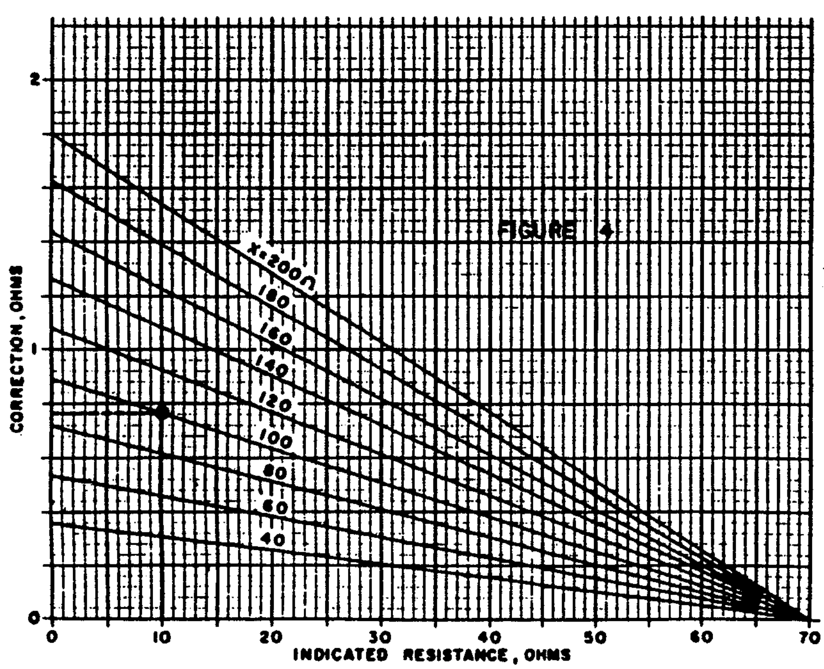
TO: All Engineers
FROM: Mike
SUBJECT: Data Electronics Correction in Formula
DATE: July 24, 1986

Several Delta Electronics instruction books for the Model OIB-3 impedance bridges contain an error in the formula for the resistance correction factor having large reactive component. The correct formula as per the graph (which has been verified with the manufacturer as correct*) is as follows:

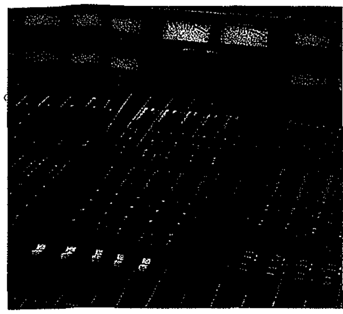
$$C_R = xf(.009-.00013R)$$

Examples: (1) 31 +j200 at 1 mHz
$C_R = 0.994$
(2) 0 -j100 at 1 mHz
$C_R = -0.900$
(3) 60 +j160 at 1 mHz
$C_R = 0.192$
(4) 40 -j40 at 1 mHz
$C_R = -0.152$

* Manufacturer confusion indicated the graph was in error. They later corrected themselves by indicating a correction to the formula; hence, the above.



CORRECTION FACTOR



Lower-cost directional antenna systems

By Grant W. Bingeman

Hot guy wires can make AM DAs more cost-effective.

There is a new technology available for AM directional antenna design that can dramatically reduce land and capital equipment costs. Instead of using two towers, for example, many applications could simply use one tower and a hot guy wire. Theoretically, for a new station, this technique would require roughly half the land and half the number of towers compared to conventional design. It might also be used when modification of an existing pattern was required. By tuning existing guy wire(s) or adding a simple slant wire, a station might be saved from having to relocate its antenna site, as is often required for such modifications.

This hot guy wire technology has been proven outside of the United States, but the FCC has yet to accept it. The commission requires certain traditional formulas to be used to calculate radiated fields. Although exceptions have been allowed in the past, additional measurements are usually required to prove that what the antenna designer has predicted is true if the standard formulas appear to be violated.

Studies indicate that better skywave radiation predictions could be obtained using such *moment-method* antenna design than with the existing FCC formulas. The moment-method is considered superior because it makes fewer assumptions and simplifications of the current distribution on the radiating elements in a directional array. This implies that less actual interference can be expected at night from directional antennas designed with the moment-method.

There is now some regulatory activity on this front. A Notice of Inquiry has been issued under MM Docket No. 93-177 under which the FCC may eventually accept moment-method antenna designs in place of the old sinusoidal current distribution designs. Meanwhile, consultant Clarence Beverage has studied hot guy wire antenna designs for implementation at WXCT, Hamden, CT. As a result, a Proposal for Rule Making recently has been filed specifying the technical characteristics of the active slant wire antenna.

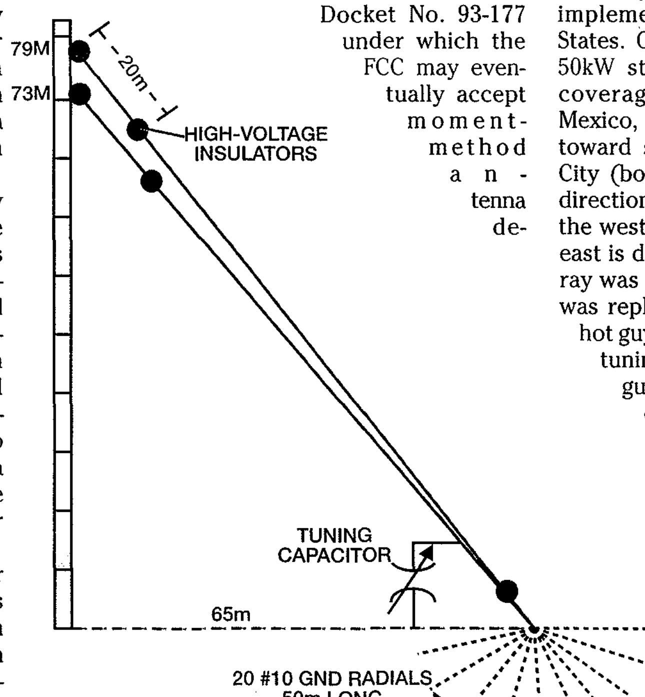


Figure 1. Section view of XEWB tower, showing top two northwest guy wires used as directional reflectors.

South of the border

This type of antenna has already been implemented outside of the United States. Consider the case of XEWB, a 50kW station that desires maximum coverage in and around Veracruz, Mexico, while reducing signal strength toward sister station XEW in Mexico City (both at 900kHz). To this end, a directional pattern with a minimum to the west and a maximum to the southeast is desired. The original 2-tower array was at the end of its useful life and was replaced by a single tower with a hot guy section. This was achieved by tuning a portion of the northwest guy wire as a reflector. A variable capacitor was used near the guy anchor to adjust the electrical length of the guy wire. (See Figure 1.)

XEWB is located northwest of Veracruz on sandy soil close to the ocean. Comparison of the (hot guy) directional to the non-directional measured field intensities shows a reduction in gain toward the west of 4dB to 5dB, depending on exact

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bearing, and a maximum increase of 3.5dB toward Boca del Rio, southeast of Veracruz. (See Figure 2.)

Thus, the creation of a 2-element directional array out of a single tower by exciting a guy wire as a parasitic element is a viable and economical means of doubling radiated power in a particular direction, and providing protection on one or two other bearings. Of course, if the guy wire was fully driven (via transmission line, power divider and phasing networks), so that independent current phase and ratio control were provided, additional pattern control would be available if needed.

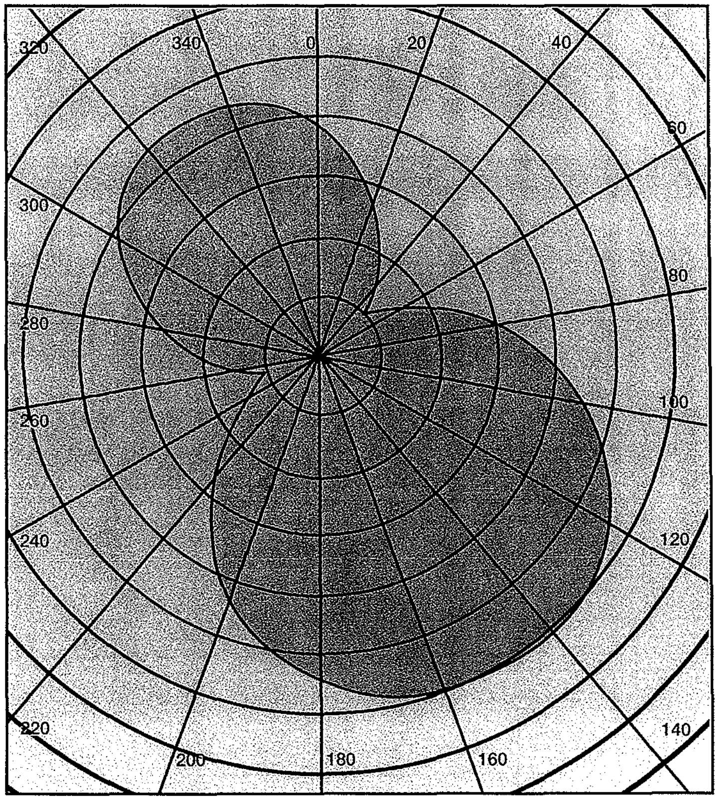


Figure 2. *Predicted pattern for XEWB after installation of hot guy wire system. Subsequent tuning adjustments reduced rear lobe.*

Installation

Some of the following details of the modification from a 2-tower to a 1-tower/hot guy configuration emphasize current and voltage concerns because of the high power of XEWB. These would be moot in the case of a significantly lower-power station (5kW or less).

Conversion of the quarter-wave tower to directional operation entailed adding jumpers across some of the existing guy insulators, replacing the remaining guy insulators with larger sizes having a higher voltage rating, laying 20 ground radials each 50 meters long around the guy anchor, adding a tuning capacitor between the nexus of these new radials and the bottom of the hot guy wire, and adjusting the tower impedance matcher for the reduced base resistance and increased base reactance.

The choice of what appears to be too small a number of ground radials bears some explanation. The minimum number of ground radials can be determined by knowing the RF current rating of the size of wire used for the radials. For example, if the wire can handle 1A without undue temperature rise, and you have 20 amperes at the bottom of the guy wire, then you know that you need at least 20 radials.

The second consideration is a compromise between efficiency and cost. An effective empirical approach to this question is to measure the self-base impedance of the active guy wire while radials are added to the circuit (the tower is detuned in the usual manner). When the self resistance no longer drops significantly with increasing radials, you have a good compromise. Keep in mind that the existing radials from the tower can assist. Thus a "standard" ground system of 120 long radials and another 120 short radials would clearly be overkill in this particular hot guy wire situation.

For 50kW XEWB, it was decided that the guy current was better shared between two guy-wires, so the top two northwest guy wires were excited simultaneously. They were simply jumpered together near the anchor and received the same insulator modifications. (See Figure 2.) It is important to note that the voltage gradient at the top of the hot guy wire can be quite high, and requires careful corona treatment. The insulator needs to be a high-voltage type with corona rings for all but the lowest power stations. Experiments at XEWB determined that a closely spaced string of large (8-inch long) egg insulators is adequate for no more than 10kW with modulation for the given tuning. Other patterns and guy wire configurations may limit this to 5kW.

Theoretical antenna analysis indicates that a *reflector* configuration is pref-

Continued on page 22

RE: Radio continued from page 20

erable to a *director* arrangement, based on current/voltage stresses and bandwidth. Nevertheless, if a director is required, it can easily be produced by adjusting the guy wire tuning reactance, or using a shorter portion of the guy as the active element.

Application notes

A weatherproof tuning box and a fence need to be erected around the hot guy wire anchor, because considerable voltage may be developed across the guy wire's bottom insulator. It is a good idea to provide an RF ammeter in series with the tuning reactance, and sampling for the antenna monitor.

In general, in order to avoid uncommonly high voltages and currents, and possible bandwidth problems, it is good practice to keep the guy wire base current below the level of the tower base current. At XEWB, guy wire current was about 80% of tower current. More gain can be obtained with higher currents, but the cost of increased insulation, bigger components or bandwidth treatments may not be justified for a few tenths of a dB higher gain.

Using a guy wire as a radiating element in a directional array will require fewer towers and thereby shrink an antenna site's requisite dimensions. The consequent reduction in capital outlay and debt service for land allows more room for profit at the radio station.

Acknowledgment: The author wishes to thank Sr. Miguel Barrientos of Sistema Radiopolis and Sr. Aguilar and his staff at XEWB. Thanks also to the Secretaria de Comunicaciones y Transportes (Mexico's FCC) for their cooperation and foresight.

Editor's note: For further technical information see "An Economical Directional Antenna for AM Stations," *41st Annual Broadcast Engineering Conference Proceedings* (NAB 1987). ■

FM Audio Processing continued from page 12

provided by the processor manufacturer. This allows engineering and programming staffs to adjust a processor located at the transmitter site while listening in a controlled environment at the studio (or elsewhere).

Implementation issues

Installation of FM audio processors varies, depending upon a number of factors. When the studio and transmitter are co-located, the processor is generally placed in a rack adjacent to the exciter/transmitter. The cable run containing the composite signal should be kept as short as practical between the processor and exciter input. Where long runs cannot be avoided, a composite signal distribution amplifier may be required, along with use of the exciter's balanced input or an external isolation transformer (to maintain signal levels and guard against the introduction of ground loops).

Some radio formats can tolerate a reduction in dynamic range more transparently than others.

When the transmitter site is at a remote location, a studio-transmitter-link (STL) must be employed, using either an RF path or leased telephone circuit(s). Either analog or digital transmission can be implemented, and signals may be delivered to the transmitter as discrete left audio, right audio and subcarriers, or as a composite signal ready for transmission.

With analog aural STLs, a *discrete* system will yield better signal-to-noise performance at greater distances than a composite approach because less bandwidth is required. This means that audio processing equipment must be located at the transmitter site, making the comprehensive (PC/modem) remote control available in the latest generation of audio processors all the more valuable. Subcarrier equipment, including RBDS, must also be located at the transmitter under this scenario. In addition, some peak protection or *preprocessing* must be placed in front of the STL transmitter to prevent overdeviation of the STL system. Similar concerns exist with equalized telco STL circuits.

A *composite analog* RF system allows all processing equipment to be kept at the studio, which can be advantageous, assuming that the STL signal-to-noise is still acceptable. *Composite digital* transmission is possible using T1 telco circuits or 23GHz RF links. The bandwidth limits of 950MHz aural STLs will not allow composite digital signals. In fact, they can only allow transmission of *discrete* digital signals with the use of bit-rate reduction via perceptual coding techniques.

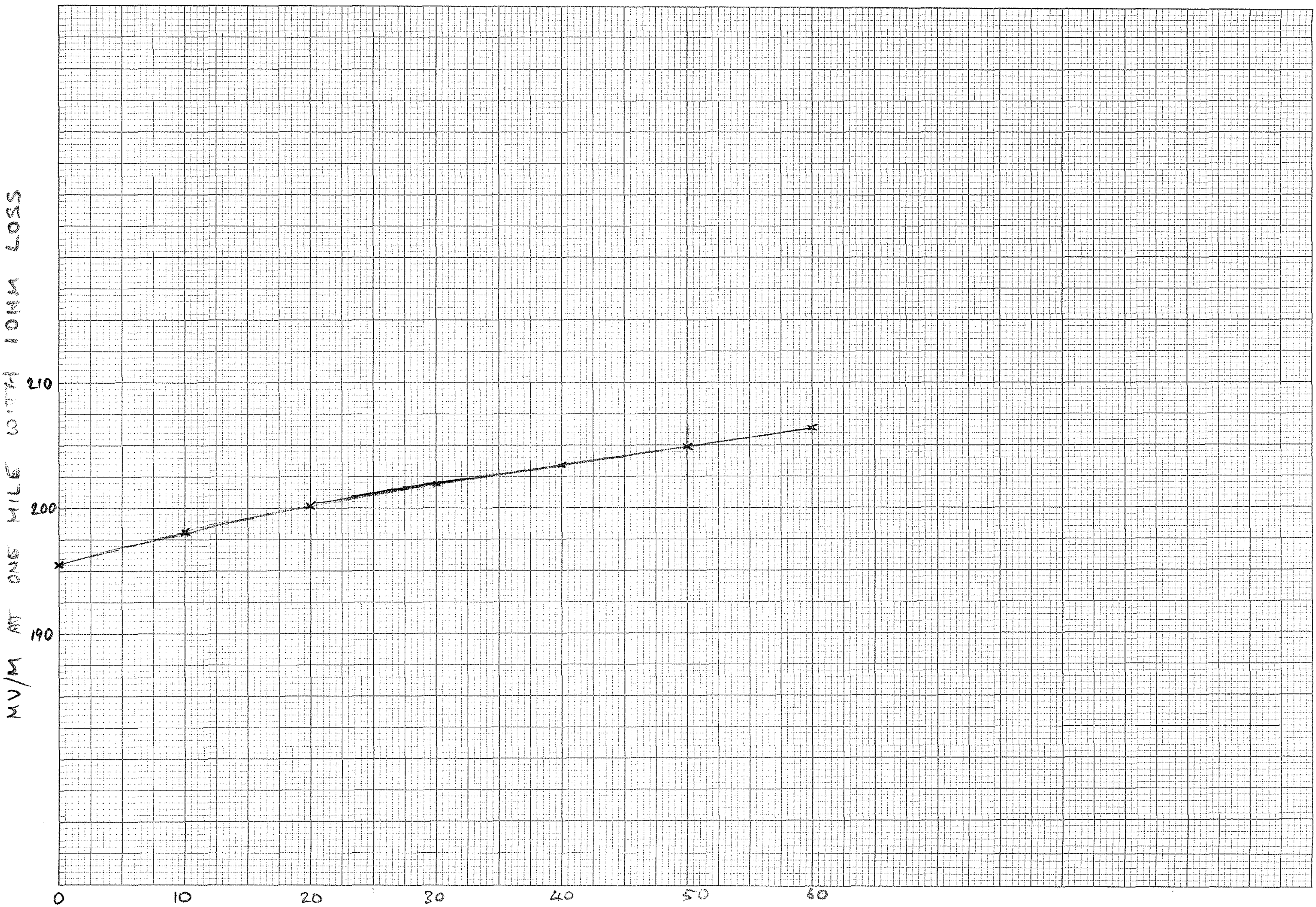
The processes of digital conversion, processing and rate reduction all generate *delay* in the audio path. Although this throughput delay is relatively low, some operators may find it annoying. Of course, it is only noticeable when the operator is announcing on-air because that is the only time when a real-time reference is available. To solve this problem, a matrix can be built that is fed by both the off-air signal and a console program output (the latter may include audio processing). The matrix is activated and steered by the console microphone logic output.

Continued on page 28

K+E 10 X 10 TO ½ INCH 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A.

46 1320

TOP LOADING OF 101° TOWER

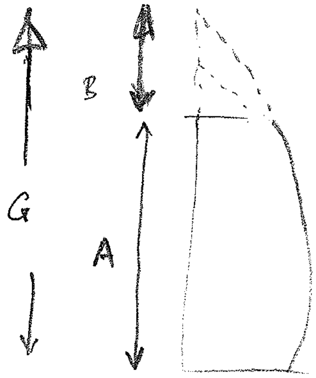


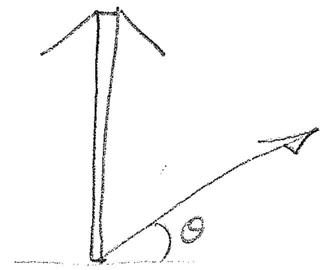
WMRF

WP. Book P. 26

Top Loaded Tower

$f(\Theta) =$





$$f(\Theta) = \frac{\cos B \cos(A \sin\Theta) - \cos G - \sin B . \sin\Theta \sin(A \sin\Theta)}{\cos\Theta (\cos B - \cos G)}$$

(See 73.160 of FCC Rules)

Need horizontal field efficiency for top loaded 101° antenna. $A = 101°$

→ B in 10° steps from 10° to 60°

$$P_r = \frac{1}{R_e} \int_0^{2\pi} \int_{-\Theta_2}^{+\pi/2} E^2 d^2 \cos d\Theta \, d\phi$$

H = 413' @ 670 kHz = 161°

FCCDA 11:04EST 01/10/86

WMRF
670. KHZ 1.00 KW

	VERT.HEIGHT*		TOP-LOADING		SPACING	
TWR	FEET	METERS	FEET	METERS	FEET	METERS
1	411.86	125.53	0.	0.	0.	0.

* ABOVE BASE INSULATOR

ELECTRICAL PARAMETERS,DEGREES:

TWR	HEIGHT	TOPL	FIELD	SPACING	L.O.T.	PHASING
1	101.00	0.	1.000	0.	0.	0.

LOOP
LOSS: VALUES IN MV/M

OHM= 0	RMS= 197.453	K= 197.453	RMS 1 KW= 197.453
OHM= 1	RMS= 195.526	K= 195.526	RMS 1 KW= 195.526
OHM= 2	RMS= 193.655	K= 193.655	RMS 1 KW= 193.655
OHM= 3	RMS= 191.836	K= 191.836	RMS 1 KW= 191.836

FOR A CURRENT LOOP RESISTANCE OF 1.0 OHMS

RSS= 195.526 RMS= 195.526 RSS/RMS=1.00
0.025*RSS= 4.89 6.215*SQR(1.00KW)= 6.21 QUAD FILL= 6.21

HORIZONTAL PLANE RADIATION PATTERN

AZIMUTH DEG. TRUE	THEORETICAL MV/M	STANDARD MV/M
	VERTICAL ANGLE= 0 DEGREES	
0	195.5	205.4
45	195.5	205.4
90	195.5	205.4
135	195.5	205.4
180	195.5	205.4
225	195.5	205.4
270	195.5	205.4
315	195.5	205.4

HORIZONTAL PLANE R.M.S. - STANDARD PATTERN= 205.4 MV/M

USED 17.57 UNITS

FCCDA 11:05EST 01/10/86

WMRF
670. KHZ 1.00 KW

TWR	VERT.HEIGHT* FEET	VERT.HEIGHT* METERS	TOP-LOADING FEET	TOP-LOADING METERS	SPACING FEET	SPACING METERS
1	411.86	125.53	40.78	12.43	0.	0.

* ABOVE BASE INSULATOR

ELECTRICAL PARAMETERS, DEGREES:

TWR	HEIGHT	TOPL	FIELD	SPACING	L.O.T.	PHASING
1	101.00	10.00	1.000	0.	0.	0.

LOOP
LOSS: VALUES IN MV/M

LOOP LOSS	RMS	K	RMS 1 KW
OHM= 0	RMS= 199.688	K= 199.688	RMS 1 KW= 199.688
OHM= 1	RMS= 198.117	K= 198.117	RMS 1 KW= 198.117
OHM= 2	RMS= 196.582	K= 196.582	RMS 1 KW= 196.582
OHM= 3	RMS= 195.083	K= 195.083	RMS 1 KW= 195.083

FOR A CURRENT LOOP RESISTANCE OF 1.0 OHMS

RSS= 198.117 RMS= 198.117 RSS/RMS=1.00
0.025*RSS= 4.95 6.215*SQR(1.00KW)= 6.21 QUAD FILL= 6.21

HORIZONTAL PLANE RADIATION PATTERN

VERTICAL ANGLE= 0 DEGREES

AZIMUTH DEG. TRUE	THEORETICAL MV/M	STANDARD MV/M
0	198.1	208.1
45	198.1	208.1
90	198.1	208.1
135	198.1	208.1
180	198.1	208.1
225	198.1	208.1
270	198.1	208.1
315	198.1	208.1

HORIZONTAL PLANE R.M.S. - STANDARD PATTERN= 208.1 MV/M

USED 17.61 UNITS

FCCDA 11:07EST 01/10/86

WMRF
670. KHZ 1.00 KW

TWR	VERT.HEIGHT* FEET	METERS	TOP-LOADING FEET	METERS	SPACING FEET	METERS
1	411.86	125.53	81.56	24.86	0.	0.

* ABOVE BASE INSULATOR

ELECTRICAL PARAMETERS,DEGREES:

TWR	HEIGHT	TOPL	FIELD	SPACING	L.O.T.	PHASING
1	101.00	20.00	1.000	0.	0.	0.

LOOP
LOSS: VALUES IN MV/M
OHM= 0 RMS= 201.528 K= 201.528 RMS 1 KW= 201.528
OHM= 1 RMS= 200.149 K= 200.149 RMS 1 KW= 200.149
OHM= 2 RMS= 198.798 K= 198.798 RMS 1 KW= 198.798
OHM= 3 RMS= 197.474 K= 197.474 RMS 1 KW= 197.474

FOR A CURRENT LOOP RESISTANCE OF 1.0 OHMS

RSS= 200.149 RMS= 200.149 RSS/RMS=1.00
0.025*RSS= 5.00 6.215*SQR(1.00KW)= 6.21 QUAD FILL= 6.21

HORIZONTAL PLANE RADIATION PATTERN

AZIMUTH DEG. TRUE	THEORETICAL MV/M	STANDARD MV/M
	VERTICAL ANGLE= 0 DEGREES	
0	200.1	210.3
45	200.1	210.3
90	200.1	210.3
135	200.1	210.3
180	200.1	210.3
225	200.1	210.3
270	200.1	210.3
315	200.1	210.3

HORIZONTAL PLANE R.M.S. - STANDARD PATTERN= 210.3 MV/M

USED 17.64 UNITS

FCCDA 11:08EST 01/10/86

WMRF
670. KHZ 1.00 KW

	VERT.HEIGHT*		TOP-LOADING		SPACING	
TWR	FEET	METERS	FEET	METERS	FEET	METERS
1	411.86	125.53	22.33	37.29	0.	0.

* ABOVE BASE INSULATOR

ELECTRICAL PARAMETERS,DEGREES:

TWR	HEIGHT	TOPL	FIELD	SPACING	L.O.T.	PHASING
1	101.00	30.00	1.000	0.	0.	0.

LOOP
LOSS: VALUES IN MV/M

OHM= 0	RMS= 203.160	K= 203.160	RMS 1 KW= 203.160
OHM= 1	RMS= 201.868	K= 201.868	RMS 1 KW= 201.868
OHM= 2	RMS= 200.601	K= 200.601	RMS 1 KW= 200.601
OHM= 3	RMS= 199.358	K= 199.358	RMS 1 KW= 199.358

FOR A CURRENT LOOP RESISTANCE OF 1.0 OHMS

RSS= 201.868 RMS= 201.868 RSS/RMS=1.00
0.025*RSS= 5.05 6.215*SQR(1.00KW)= 6.21 QUAD FILL= 6.21

HORIZONTAL PLANE RADIATION PATTERN

AZIMUTH DEG. TRUE	THEORETICAL MV/M	STANDARD MV/M
	VERTICAL ANGLE= 0	DEGREES
0	201.9	212.1
45	201.9	212.1
90	201.9	212.1
135	201.9	212.1
180	201.9	212.1
225	201.9	212.1
270	201.9	212.1
315	201.9	212.1

HORIZONTAL PLANE R.M.S. - STANDARD PATTERN= 212.1 MV/M

USED 17.66 UNITS

FCCDA 11:10EST 01/10/86

WMRF
670. KHZ 1.00 KW

	VERT.HEIGHT*		TOP-LOADING		SPACING	
TWR	FEET	METERS	FEET	METERS	FEET	METERS
1	411.86	125.53	63.11	49.72	0.	0.

* ABOVE BASE INSULATOR

ELECTRICAL PARAMETERS, DEGREES:

TWR	HEIGHT	TOPL	FIELD	SPACING	L.O.T.	PHASING
1	101.00	40.00	1.000	0.	0.	0.

LOOP
LOSS: VALUES IN MV/M

OHM= 0	RMS= 204.703	K= 204.703	RMS 1 KW= 204.703
OHM= 1	RMS= 203.418	K= 203.418	RMS 1 KW= 203.418
OHM= 2	RMS= 202.156	K= 202.156	RMS 1 KW= 202.156
OHM= 3	RMS= 200.918	K= 200.918	RMS 1 KW= 200.918

FOR A CURRENT LOOP RESISTANCE OF 1.0 OHMS

RSS= 203.418 RMS= 203.418 RSS/RMS=1.00
0.025*RSS= 5.09 6.215*SQR(1.00KW)= 6.21 QUAD FILL= 6.21

HORIZONTAL PLANE RADIATION PATTERN

AZIMUTH DEG. TRUE	THEORETICAL MV/M	STANDARD MV/M
	VERTICAL ANGLE= 0 DEGREES	
0	203.4	213.7
45	203.4	213.7
90	203.4	213.7
135	203.4	213.7
180	203.4	213.7
225	203.4	213.7
270	203.4	213.7
315	203.4	213.7

HORIZONTAL PLANE R.M.S. - STANDARD PATTERN= 213.7 MV/M

USED 17.62 UNITS

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FCCDA       11:11EST    01/10/86


 WMRF
  670. KHZ            1.00 KW


         VERT.HEIGHT*       TOP-LOADING       SPACING
 TWR       FEET  METERS     FEET  METERS      FEET  METERS
   1   411.86  125.53    03.89   62.15      0.        0.
 * ABOVE BASE INSULATOR


    ELECTRICAL PARAMETERS,DEGREES:


TWR   HEIGHT  TOPL     FIELD   SPACING     L.O.T.   PHASING
  1   101.00  50.00    1.000      0.         0.        0.
  LOOP
  LOSS:              VALUES IN MV/M
  OHM= 0    RMS= 206.256  K= 206.256   RMS 1 KW= 206.256
  OHM= 1    RMS= 204.897  K= 204.897   RMS 1 KW= 204.897
  OHM= 2    RMS= 203.564  K= 203.564   RMS 1 KW= 203.564
  OHM= 3    RMS= 202.257  K= 202.257   RMS 1 KW= 202.257


  FOR A CURRENT LOOP RESISTANCE OF  1.0 OHMS

  RSS=  204.897   RMS=  204.897   RSS/RMS=1.00
  0.025*RSS=  5.12   6.215*SQR(   1.00KW)=  6.21   QUAD FILL=  6.21




              HORIZONTAL PLANE RADIATION PATTERN
  AZIMUTH      THEORETICAL      STANDARD
  DEG. TRUE        MV/M            MV/M
                   VERTICAL ANGLE=  0  DEGREES
   0               204.9               215.2
  45               204.9               215.2
  90               204.9               215.2
 135               204.9               215.2
 180               204.9               215.2
 225               204.9               215.2
 270               204.9               215.2
 315               204.9               215.2
   HORIZONTAL PLANE R.M.S. - STANDARD PATTERN=  215.2  MV/M



                   VERTICAL ANGLE=  5  DEGREES
   0               203.3               213.5
  45               203.3               213.5
  90               203.3               213.5
 135               203.3               213.5
 180               203.3               213.5
 225               203.3               213.5
 270               203.3               213.5
 315               203.3               213.5
   VERTICAL R.M.S. AT  5 DEGREES =  213.5
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FCCDA 11:13EST 01/10/86

WMRF
670. KHZ 1.00 KW

TWR	VERT.HEIGHT* FEET	METERS	TOP-LOADING FEET	METERS	SPACING FEET	METERS
1	411.86	125.53	44.67	74.58	0.	0.

* ABOVE BASE INSULATOR

ELECTRICAL PARAMETERS,DEGREES:

TWR	HEIGHT	TOPL	FIELD	SPACING	L.O.T.	PHASING
1	101.00	60.00	1.000	0.	0.	0.

LOOP
LOSS: VALUES IN MV/M

LOOP LOSS	RMS	K	RMS 1 KW
OHM= 0	RMS= 207.918	K= 207.918	RMS 1 KW= 207.918
OHM= 1	RMS= 206.386	K= 206.386	RMS 1 KW= 206.386
OHM= 2	RMS= 204.887	K= 204.887	RMS 1 KW= 204.887
OHM= 3	RMS= 203.420	K= 203.420	RMS 1 KW= 203.420

FOR A CURRENT LOOP RESISTANCE OF 1.0 OHMS

RSS= 206.386 RMS= 206.386 RSS/RMS=1.00
0.025*RSS= 5.16 6.215*SQR(1.00KW)= 6.21 QUAD FILL= 6.21

HORIZONTAL PLANE RADIATION PATTERN

AZIMUTH DEG. TRUE	THEORETICAL MV/M	STANDARD MV/M
	VERTICAL ANGLE= 0 DEGREES	
0	206.4	216.8
45	206.4	216.8
90	206.4	216.8
135	206.4	216.8
180	206.4	216.8
225	206.4	216.8
270	206.4	216.8
315	206.4	216.8

HORIZONTAL PLANE R.M.S. - STANDARD PATTERN= 216.8 MV/M

USED 17.62 UNITS

Simple, Effective, Elevated Ground-Plane Antennas

Here's an easier and better way to use your grounded tower as a vertical antenna on 160 or 80 meters.

By Thomas Russell, N4KG
29836 Country Lane
Harvest, AL 35749

This article describes a simple and effective means of using a grounded tower, with or without top-mounted antennas, as an elevated ground-plane antenna for 80 and 160 meters.

Grounded towers have been used as shunt-fed verticals on the low-frequency amateur bands for many years. Generally, they required a gamma- or omega-type matching network and an extensive radial system for efficient operation. Recent computer studies reveal that simple elevated radial systems consisting of only four wires can produce results equivalent to 120 buried radials. Typically, these antennas are modeled as isolated monopoles. Presumably, grounded towers could be used with an appropriate shunt-fed matching network.

I've found an even easier method!

From Sloper to Vertical

Recall the quarter-wavelength sloper, also known as the half-sloper. It consists of an isolated quarter wavelength of wire, sloping from an elevated feedpoint on a grounded tower. Best results were usually obtained when the feedpoint was somewhere below a top-mounted Yagi antenna. You feed a sloper by attaching the center conductor of a coaxial cable to the wire and the braid of the cable to the tower leg. Now, imagine four (or more) slopers, but instead of feeding each individually, connect them together to the center conductor of a single feed line. *Voilà*! Instant elevated ground plane.

Now, all you need to do is determine how to tune the antenna to resonance. With no antennas on the top of the tower, the tower can be thought of as a fat conductor and should be approximately 4% shorter than a quarter wavelength in free space. Calculate this length and attach four insulated quarter-wavelength radials at this distance from the top of the tower. For 80 meters, a feedpoint 65 feet below the top of an unloaded tower is called for. The tower guys must be broken up with insulators for all such installations. For 160 meters, 130 feet of tower above the feedpoint is needed.

That's a lot of tower to dedicate to a single-band antenna, especially for someone with limited real estate. What can be done with a typical grounded-tower-and-Yagi installation?

A top-mounted Yagi acts as a large capacitance hat, top loading the tower. Fortunately, top loading is the most efficient means of loading a vertical antenna. The amount of loading can be approximated by using an empirical formula developed by John Devoldere, ON4UN.[1]

Devoldere found that the electrical height of a top-loaded tower can be approximated by:

$$L=0.38F\left(H+\sqrt{2S-H/500}\right) \qquad \text{(Eq 1)}$$

where

L is the approximate electrical length in degrees
F is the frequency in MHz
H is the height of the tower under the Yagi in feet
S is the area of the Yagi in square feet

To check Eq 1, consider the case of no antenna on top, where S = 0. Then $L = 0.38 \times 3.6 \times 65 = 88.9°$, which is very close to the desired 90° quarter wavelength.

The effective loading of a Yagi is the portion of the equation under the radical. The examples in Table 1 should give us an idea of how much top loading might be expected from typical amateur antennas. The term H/500 is ignored as insignificant compared with 2S.

The values listed in the Equivalent Loading column of Table 1 tell us the approximate vertical height replaced by the antennas listed in a top-loaded vertical antenna. To arrive at the remaining amount of tower needed for resonance, subtract these numbers from the nonloaded tower height needed for resonance. Note that for all but the 10-meter antennas, the equivalent loading equals or exceeds a quarter wavelength on 40 meters. For typical HF Yagis, this method is best used only on 80 and 160 meters.

[1]J. Devoldere, *Antennas and Techniques for Low Band DXing* (Newington: ARRL, 1994).

Table 1
Effective Loading of Common Yagi Antennas

Antenna	*Boom Length (feet)*	*S (area, ft²)*	*Equivalent Loading (feet)*
3L 20	24	768	39
5L 15	26	624	35
4L 15	20	480	31
3L 15	16	384	28
5L 10	24	384	28
4L 10	18	288	24
3L 10	12	192	20
TH7	24	—	40 (estimated)
TH3	14	—	27 (estimated)

Construction Examples

Consider this example: A TH7 Yagi mounted on a 40-foot tower. The TH7 has approximately the same overall dimensions as a full-sized 3-element 20-meter beam, but has more interlaced elements. I estimate its equivalent loading to be 40 feet. At 3.6 MHz, 65 feet of tower is needed without loading. Subtracting 40 feet of equivalent loading, the feedpoint should be 25 feet below the TH7 antenna.

I ran 10 quarter-wavelength (65-foot) radials from a nylon rope tied between tower legs at the 15-foot level, to various supports 10 feet high. I tied nylon cord to the insulated, stranded, 18-gauge wire, without using insulators. The radials are all connected together and to the center of an exact half wavelength (at 3.6 MHz) of RG-213 coax, which will repeat the antenna feed impedance at the other end. Figure 1 is a drawing of the installation. I used a Hewlett-Packard low-frequency impedance analyzer to measure the input impedance across the 80-meter band.

An exact resonance (zero reactance) was seen at 3.6 MHz, just as predicted. The radiation resistance was found to be 17 Ω. The next question is, how to feed and match the antenna.

My approach to 80-meter antennas is to tune them to the low end of the band, use a low-loss transmission line, and switch an antenna tuner in line for operation in the higher portions of the band. With a 50-Ω line, the 17-Ω radiation resistance represents a 3:1 SWR, meaning that an antenna tuner should be in-line for all frequencies. For short runs, it would be permissible to

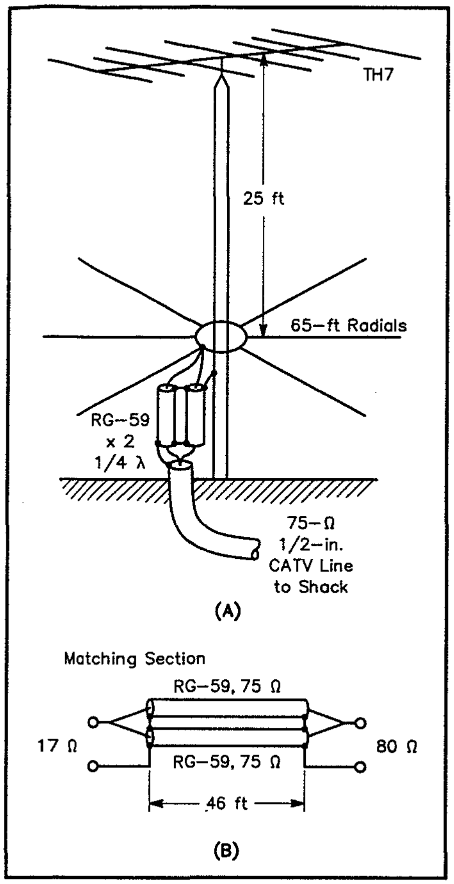


Figure 1—At A, an 80-meter top-loaded, reverse-fed elevated ground plane, using a 40-foot tower carrying a TH7 triband Yagi antenna. At B, dimensions of the 3.6 MHz matching network, made from RG-59.

use RG-8 or RG-213 directly to the tuner. Since I have a plentiful supply of low-loss 75-Ω CATV rigid coax, I took another approach.

I made a quarter-wave (70 feet×0.66 velocity factor = 46 foot) 37-Ω matching line by paralleling two pieces of RG-59 and connecting them between the feedpoint and a run of the rigid coax to the transmitter. The magic of quarter-wave matching transformers is that the input impedance (R_i) and output impedance (R_o) are related by:

$$Z_o^2 = R_i \times R_o \quad \text{(Eq 2)}$$

For $R_i = 17\ \Omega$ and $Z_o = 37\ \Omega$, $R_o = 80\ \Omega$, an almost perfect match for the 75-Ω CATV coax. The resulting 1.6:1 SWR at the transmitter is good enough for CW operation without a tuner.

The Proof is in the Log

How effective is this antenna? Well, I used to install a 60-foot aluminum tower and 100 radials, 100 feet long in a clear one-acre field every winter, and remove it every spring for mowing. The top-loaded reverse-fed elevated ground-plane antenna has replaced that antenna with no regrets. My only other 80-meter antenna is a dipole at 110 feet, broadside to Europe and the South Pacific.

I use the elevated ground plane for South Africa, South America, the Caribbean, parts of the Pacific and Asia, both long and short path. With it I have worked everything I can hear, with 1200 W output, including HL (rare in Alabama); HS; UA9; UAØ; UI; UJ; UL; most of the VK9s; XV; ZS1; ZS8MI; ZS9; 3Y5X; 8Q; 9M2; and 9V1. While running 5 W output, I have even worked two JAs with this antenna, which may say more for its effectiveness than anything else.

Will it Work on 160 Meters?

You bet it will, but it takes another tower. For the 160-meter band, a resonant quarter-wavelength requires 130 feet of tower above the radials. That's a pretty tall order. Subtracting 40 feet of top loading for a 3-element 20-meter or TH7 antenna brings us to a more reasonable 90 feet above the radials. Additional top loading in the form of more antennas will reduce that even more.

Recently, a friend moved to the country, and he needed a 160-meter antenna in a hurry for an upcoming contest. He had stacked TH6s on a 75-foot tower. I suggested he try four elevated radials at 10 feet above ground, with a tuner if necessary. He connected four radials about 120 feet long and a piece of RG-58. The SWR measured under 2:1 and he worked everything he heard in the contest. Figure 2 is a drawing of this installation.

Another friend had a 120-foot tower

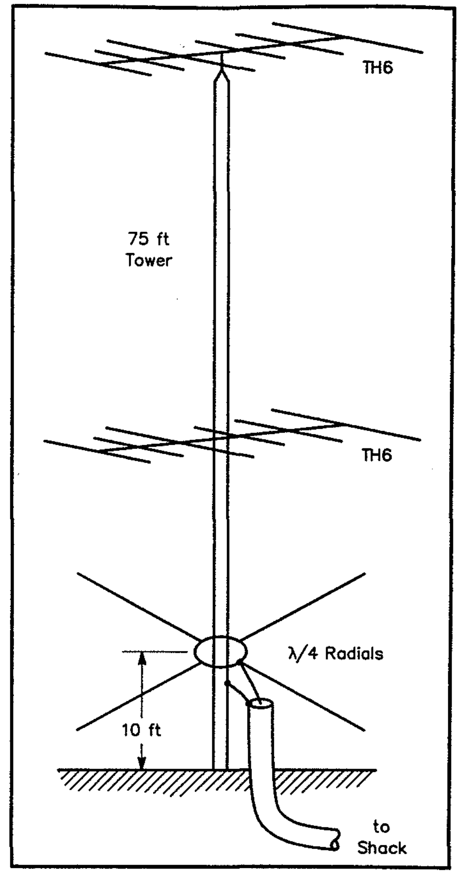


Figure 2—A 160-meter antenna using a 75-foot tower carrying stacked triband Yagis.

with no antennas on it. He ran four elevated radials at 10 feet and obtained an SWR below 1.5:1 with a 50-Ω feed line. During the contest, he even beat out some big guns.

Elevated ground-plane antennas work! This simple, reverse-feed system makes it possible to feed grounded towers easily and efficiently.

References

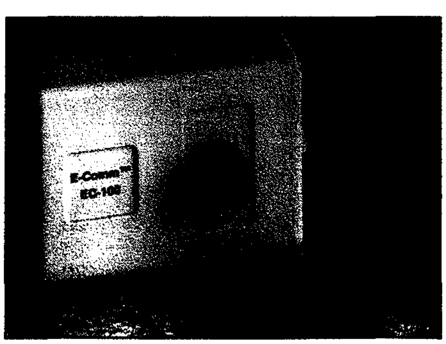
A. Christman, "Elevated Vertical Antenna Systems," *QST*, Aug 1988, pp 35-42 (Feedback, *QST*, Oct 88, p 44).

A. Christman, "More on Elevated Radials," *QST*, Mar 1993, p 72 (Technical Correspondence).

New Products

"SECRET" EARPHONE-MIKE

◊ In certain situations, operating a radio may disturb others or you may prefer not to draw attention to your communications. At a hamfest or other event, you don't want to strain to hear and shout to be heard. Here's a solution for hams who want to operate in "stealth" mode: The Ear-Mike is a combination of a tiny microphone and speaker developed for security applications that demand discreet communications. It permits convenient and unobtrusive two-way



voice communications. A comfortable in-ear foam earbud allows only the wearer to hear received audio. Voice is transmitted through the same transducer, and is activated by pressing a push-to-talk switch on the interface module. The manufacturer states that even whispers can be transmitted. The miniature interface module is normally clipped to the belt, and features all-metal construction, a gain control and is powered by an internal AA-size battery. It's compatible with most commercial amateur transceivers. Retail price is about $135. Telex Communications Inc, 9600 Aldrich Ave S, Minneapolis, MN 55420; tel 612-884-4051, fax 612-884-0043.

OFFICE MEMORANDUM

MEMO
TO: ALL ENGINEERS
FROM: WALTER L. DAVIS
Date: September 13, 1974

Re: AM Radiator Efficiency

Harold Russell at the Commission indicates that when 120 ground radials are used and are shorter than 1/4 wave, the Commission engineers are using as a guide the following table for reduction in radiation with reduction in length of radials:

Radial Length / Wave Length	Reduction
.2401-.25	No Reduction
.2301-.24	- 2 mv
.2201-.23	- 4
.2101-.22	- 6
.2001-.2	- 8
.1901-.20	-10
.1801-.19	-12
.1701-.18	-14
.1601-.17	-16
.1501-.16	-18

W

DIRECT SYNTHESIS OF ANTENNA ARRAY PARAMETERS ACCORDING TO SPECIFIED RADIATION PATTERNS

Jindřich BRADÁČ, *TESLA national enterprise, Prague-Hloubětín*

The paper describes one of the optimizing methods, called the steepest descent technique, as a possible way for direct antenna array parameter design complying with specified radiation patterns. The description has been supplemented with computation results, obtained in designing medium wave antenna arrays. The described method may find use even when other types of antenna arrays have to be designed.

Signal coverage studies of the respective zones are being performed before taking steps to design a transmitting antenna system, destined for certain types of transmissions such as broadcasting or television. Certain criteria must be taken into consideration in the course of these studies, for example, the geography of the respective territory, the audience expected to listen to the planned transmissions and others.

The desired shape of the transmitting array radiation patterns is one of the results of the performed studies. The expected shape of radiation patterns, generally specified as horizontal or vertical radiation patterns, may take various forms, since it is desired to radiate more energy in some directions than in others and in some directions the radiation has to be suppressed. Considering e.g. television vertical transmitting antenna array patterns, null filling in a prescribed way and often tilting the main radiation beam lobe, are desired.

The radiation patterns of the desired form may be obtained or approximated by sophisticated directional antenna array design. The final radiation pattern shape of the directional antenna system is given by the radiators arrangement, their mutual spacing and also by feeding current magnitudes and feeding current phases.

The first step in designing a transmitting antenna array is a tentative proposal of the antenna parameters based on experience. Then the radiation pattern of this antenna proposal is computed. The computed radiation pattern is compared with the desired one. If an optimum approximation of the computed pattern to the specified one is not obtained the antenna parameters are changed and the computation is repeated. This procedure is lengthy and it may happen that the optimum solution will not be found.

Direct antenna system parameter synthesis methods, giving results in accordance with the specified radiation patterns, especially when digital computers are used, can make the antenna array design easier and more precise.

Several general optimizing methods are described in [1], [2], [3]. The steepest descent method is one of the optimizing methods suitable for transmitting antenna array synthesis [4].

STEEPEST DESCENT METHOD

Let function $F = f(x_1, x_2, x_3, \ldots, x_n)$ express in a certain way a deviation of computed radiation pattern *1* (dashed lines in *Fig. 1*), from the specified pattern *2*.

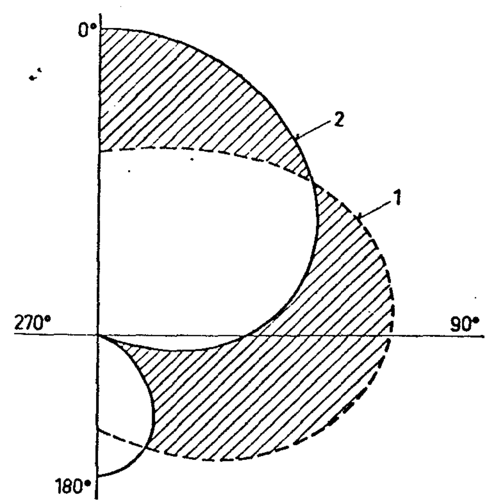


Fig. 1. *The difference between the computed and the specified pattern, expressed as an error function, obtained during the antenna system synthesis using the steepest descent technique: 1 — computed radiation pattern, 2 — specified radiation pattern*

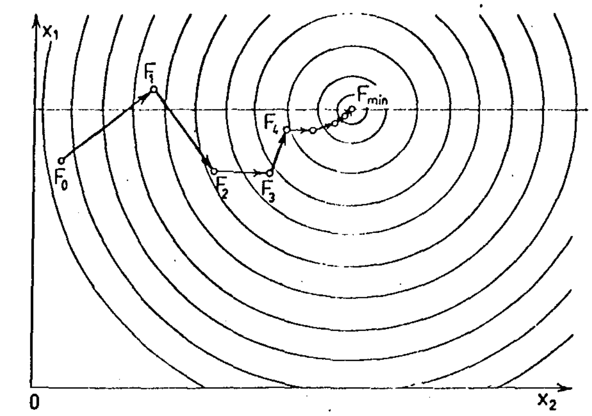


Fig. 2. *Process showing the search for minimum F value:*

$F_0 = f(x_{10}, x_{20})$
$F_1 = f(x_{11}, x_{21})$
$F_2 = f(x_{12}, x_{22})$
$F_3 = f(x_{13}, x_{23})$
.
.
.
$F_n = f(x_{1n}, x_{2n})$

Fig. 3. *An example of a horizontal radiation pattern which can be obtained by a two element antenna system given in Fig. 4*

Only one half of the patterns is shown in the drawing because the pattern in this case is symmetrical about the lengthwise radiators axis. Values $x_1, x_2, x_3, \ldots, x_n$ represent the parameters of the given antenna array, for example, the radiators position angles, their mutual spacing, the amplitude and phase values of the feeding currents. Function F for certain parameters $x_1, x_2, \ldots, x_n$ will have a minimum value and the antenna array with these parameters will produce the radiation pattern that will either comply with the desired specified pattern or will be optimally near it.

Let us demonstrate this technique giving an example of the function $F = f(x_1, x_2)$ with two variables. We shall search for values of x_1 and x_2 that will minimize function value F. The choice of x_1 and x_2 starting values is arbitrary. We denote them x_{10} and x_{20} and proceed to compute $F_0 = f(x_{10}, x_{20})$. New values of F will be looked for in the following step. The new F will be described as F_1 and should express a smaller computed pattern error from the specified pattern than F_0. Using the steepest descent technique we shall proceed from F_0 to F_1. The direction of the steepest descent is expressed by gradient $f(x_1, x_2)$. The gradient will be designated as *grad F* from now on. The computation of new values x_1, x_2, to be named x_{11}, x_{21} will be performed as follows:

$$x_{11} = x_{10} - k\, grad_{x_1} F_0 \qquad (1)$$

$$x_{21} = x_{20} - k\, grad_{x_2} F_0 \qquad (2)$$

where $grad_{x_1} F_0$ is the x_1 component of *grad F*, computed at x_{10}, x_{20}
$grad_{x_2} F_0$ is the x_2 component of *grad F*, computed at x_{10}, x_{20}.

The computed values x_{11}, x_{21} will be used for finding function values $F_1 = f(x_{11}, x_{21})$.

Then F_1 will be compared with F_0 to see if a minimum is being approached. Value F_1 must be lower than F_0. If this is not the case, the iteration cycle "k" has to be corrected and the computation will be repeated with a new value of "k". If F_1 is smaller than F_0, we compute $F_2 = f(x_{21}, x_{22})$

where
$$x_{21} = x_{11} - k\, grad_{x_1} F_1 \qquad (3)$$

$$x_{22} = x_{21} - k\, grad_{x_2} F_1. \qquad (4)$$

Then we compare F_2 with F_1 and proceed in this way until the minimum is reached. The steps are shown in *Fig. 2.*

THE STEEPEST DESCENT TECHNIQUE APPLICATION TO AN ANTENNA ARRAY DESIGN

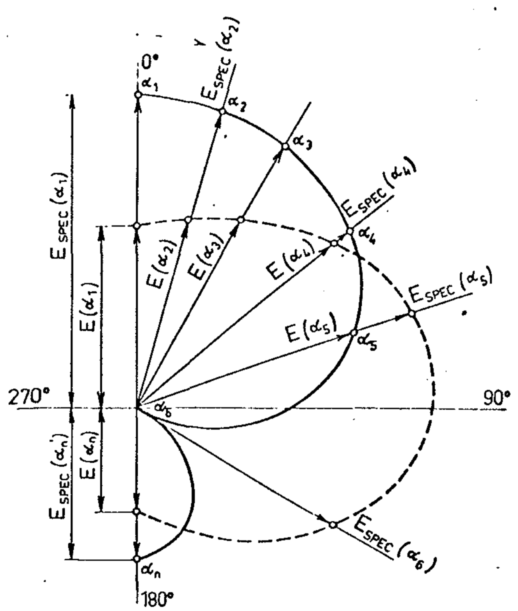
Let us demonstrate the method on synthesis examples of certain types of antenna arrays satisfying the specified horizontal radiation patterns. Let us set out from the patterns shown in *Fig. 3.* These patterns may be obtained using the two element antenna array, shown in *Fig. 4.* (The examples have been chosen to describe the technique by means of simple cases, which normally would not be treated by the above mentioned method. Simpler ways exist that facilitate two element antenna array design, satisfying the desired radiation pattern. The two element antenna array has been chosen since it enables a comprehensive demonstration on the use of the described method to be shown).

Error function F may be expressed as follows:

$$F = \sum_{i=1}^{n} W(\alpha_i) D^2(\alpha_i) = \sum_{i=1}^{n} W(\alpha_i) [|E(\alpha_i)| - |E_{spec}(\alpha_i)|]^2, \qquad (5)$$

where $W(\alpha_i)$ is a weighting function that permits more accurate approximation to the desired pattern form in some specified directions during the synthesis computation process (for instance, $W(\alpha_6)$ in *Fig. 3* may equal 3, etc.).

$E(\alpha_i)$ in *Fig. 3* represents the computed magnitude of field strength in α_i, $E_{spec}(\alpha_i)$ is the specified (desired) field strength in α_i.



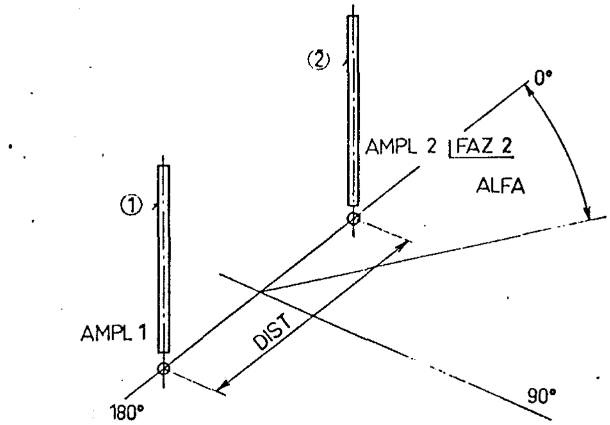


Fig. 4. *A simple two element antenna system: ALFA — azimuth; FAZ2 — relative phase (antenna 2 feeding current phase compared with the current phase of antenna 2); AMPL1, AMPL2 — current amplitudes in antenna 1 and 2; DIST — spacing between antennas*

Function F is the sum from $i = 1$ up to $i = n$ error squares, multiplied by corresponding weighting functions $W(\alpha_i)$; $E(\alpha_i)$ and thus also F is a function of the treated antenna array parameters and azimuths or elevation angles. Thus for a two-element antenna array to be dealt with we get according to *Fig. 4*,

$$F = f(\text{ALFA}, \text{AMPL1}, \text{AMPL2}, \text{DIST}, \text{FAZ2}) \quad (6)$$

where ALFA = azimuth,
AMPL1 — antenna *1* feeding current amplitude,
AMPL2 — antenna *2* feeding current amplitude,
DIST — antenna spacing, and
FAZ2 — antenna *2* feeding current relative phase as compared with antenna *1* feeding current phase.

Function F could be expressed otherwise as well, e.g., by the maximum deviation.

Let us first choose in our example antenna system parameters and then compute the horizontal radiation pattern. The pattern computed in this way will be used for field strength specification in specified azimuths. Now suppose that one or more parameters are not known and try to find back their original values using the described techniques for computation. The problem is a simple one for the present since the desired pattern can be realized so that it enables us to verify the usefulness of the described method on this example.

First we shall perform the computation for one unknown parameter and then for two parameters. The field strength indications are for the present specified in the non-normalized form.

The following example was chosen: Two vertical radiators are spaced by 120° (the spacing between the radiators is 1/3 of the wavelength), the current amplitude in radiator *2* is $I_2 = 0.9\ I_1$, current I_2 lags by 120° against current I_1.

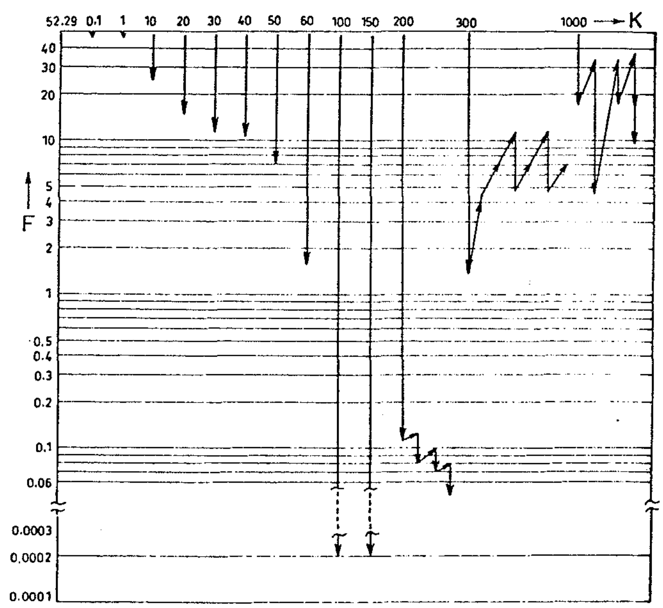


Fig. 5. *An example of function F magnitude after 10 iterations, when the value of iteration cycle was k = 0.1 up to k = 1000:*

k = 0.1	*1*	*10*	*20*	*30*	*40*	*50*	*60*
F = 52.24	*49.0*	*25.9*	*15.25*	*11.99*	*10.75*	*7.04*	*1.63*

k = 100	*150*	*200*	*300*	*1000*
F = 0.0002	*0.0002*	*0.05*	*7.32*	*9.8*

For k = 100 a value of F = 0.0002 was reached in eight iteration steps, for k = 150 a value of F = 0.0002 was reached in six iteration steps; k = 200, 300, 1000 — function F oscillates

We assume now that we do not know, for example, current I_2 phase. To initiate the computation we choose the phase arbitrarily, for example, such a value that current I_2 will advance by 50° against current I_1. By

Results of synthesis of the two-element antenna system shown in Fig. 4: x_1 - desired phase, x_2 - desired spacing between antennas, F - deviation of the computed pattern from the specified one; k_1, k_2 - values of the iteration cycles

TABLE I

$k_1 = 100$		$k_2 = 50$	
F		x_1	x_2
37.30	37.33	40.43	50.28
35.25	35.27	37.74	44.81
34.66	34.69	38.43	40.28
34.21	34.24	42.58	35.39
33.37	33.41	51.42	28.89
31.23	31.29	66.65	19.29
26.03	26.13	87.67	5.28
17.22	17.31	105.16	—11.56
9.91	9.91	108.14	—25.42
6.71	6.68	107.37	—34.26
5.41	5.39	106.58	—39.92
4.87	4.85	105.75	—43.65
4.64	4.62	105.12	—46.20
4.52	4.51	104.63	—47.97
4.46	4.45	104.26	—49.23
.	.	.	.
.	.	.	.
4.4043	4.4029	103.34	—52.09
4.4035	4.4025	103.29	—52.24

iteration techniques we find the new phase value

$$x_{11} = x_{10} - k\, grad_{x_1} F_0, \tag{7}$$

where x_{11} is the new value of current I_2 phase,
x_{10} — chosen starting value of current I_2 phase, and
k — arbitrary iteration cycle.

The deviation magnitude, expressed by error function F must be smaller for each new value x_{1i}, with i increasing from 1 up to n, if the technique works correctly. The number of cycles needed for reaching the minimum error value has been influenced by the chosen magnitude of the iteration cycle. Let us demonstrate it on an example. Ten iterations were to be used in the computation, the magnitude of the iteration cycles being chosen as follows:

$k = 0.1, 1, 10, 20, 30, 40, 50, 60, 100, 150, 200, 300$ and 1000.

The computation results are given in *Fig. 5* where the value of F is the deviation value according to expression (5) and k is the chosen iteration cycle.

Fig. 6 shows for $k = 20$ how the computed pattern approximates the specified one, traced by a full line. The approximation is being shown for several phase values, obtained by the described method.

It is obvious from *Fig. 6*, that using this method we approach the solution, although still slowly with $k = 20$; with 10 iterations chosen for the computation, we do not yet reach the accord of the computed and specified pattern.

When choosing higher values of k the situation will improve. The computation results for higher values of k are given in *Fig. 5* as well. The optimum values are $k = 100$ and $k = 150$. Using them we approach relatively quickly an I_2 current phase magnitude of —120° and thus the accord of the computed and specified pattern will be established.

Using the values of $k = 300$ and $k = 1000$ oscillation around the optimum state takes place and the specified pattern will not be reached. (The searched parameter magnitudes given in this and the following examples are presented with two decimal places, due to the printed computer outputs. In parameter synthesis for engineering practice it will be sufficient to work with less accurate indications, e.g., phase data of $\pm 2°$ should be acceptable).

Let us come now to the case when in the given example we do not know two antenna system parameters, e.g. the radiators spacing and current I_2 phase. Let us assume for example the initial phase value 50° and the radiators spacing 60 electrical degrees (1/6 wavelength). One wavelength distance represents a phase difference of 360 degrees between current I_2 and current I_1, if the direction along the radiators axis is considered (ALFA = = 0 in *Fig. 4*). Let us choose 25 iterations. Now we shall try to find the magnitude of the two variables x_1 (phase) and x_2 (spacing),

$$x_{11} = x_{10} - k_1\, grad_{x_1} F_0,$$
$$x_{21} = x_{20} - k_1\, grad_{x_2} F_0,$$

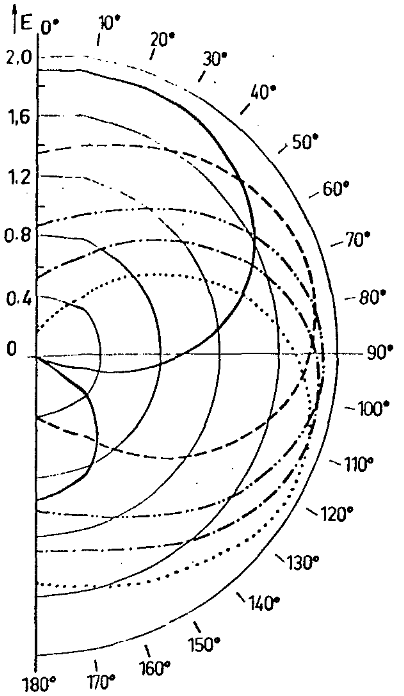
where x_{11} is the new current I_2 phase value in the first iteration step,
x_{21} — the new radiators spacing value in the first iteration step.

The computation results for values $k_1 = 100$ and $k_2 = 50$ are given in *Table I*. The results show that a satisfactory approximation was not obtained. The specified values were $x_1 = —120°$ (computed value 103.29°) and $x_2 = 120°$ (computed value —52.24°). Changing the magnitude of iteration cycles k_1 and k_2 and leaving values of x_1 and x_2 unchanged, we do not succeed in finding system parameters that would comply with the desired pattern. The computed results obtained by using several chosen values of iteration cycles k_1 and k_2 are presented in *Table II*.

The computed results are given in *Fig. 7*. The difficulties were caused by the desired pattern form which was not sufficiently smooth and showed a pronounced minimum. The minimum error value was actually found but since no weighting functions were introduced, the desired approximation of the computed and the specified pattern was not reached.

Let us introduce weighting functions $W(\alpha_i)$ with e.g. the following values:

α_i^0	below 95	95 to 105	105 to 135	135 to 165	above 165
W	1	2	5	3	1



◀ Fig. 6. *Computed horizontal radiation patterns shown in Fig. 4: k = 20,*
value x_1*: . . . . 50°;*
—.—.— 37°;
—..—..— minus 4.8°,
— — — — minus 35°

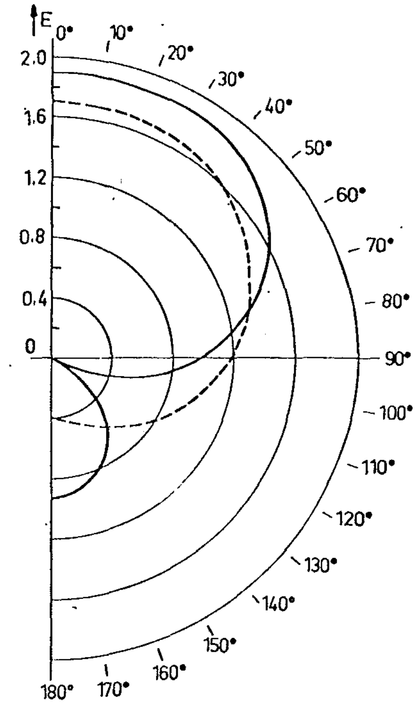
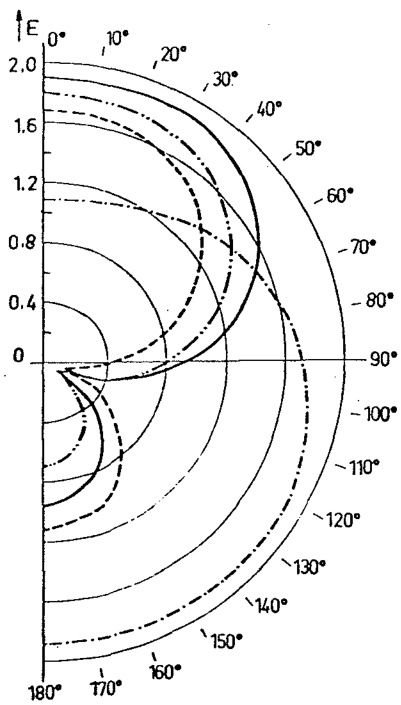


Fig. 7. *Synthesis results of two-element antenna system shown in Fig. 4* ▶



◀ Fig. 8. *Synthesis results of two-element antenna system shown in Fig. 4 using weighting functions:*
————— specified pattern,
—.—.— initial search $x_{10} = 50°$, $x_{20} = 60°$;
— — — — $x_1 = 153°$, $x_2 = -99°$;
—..—..— $x_1 = 129°$, $x_2 = -93°$

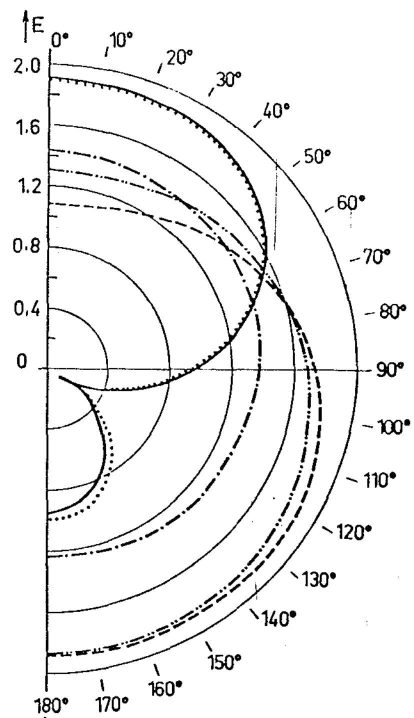


Fig. 9. *Synthesis of two-element antenna system shown in Fig. 4 by which an accord between the computed and the specified patterns was reached:* ▶
————— specified pattern;
— — — — — initial search;
—..—..— and —.—.— progressive approximation to the specified pattern;
. . . . final pattern:

azimuth °	*0*	*10*	*20*	*30*	*40*	*50*	*60*	*70*	*80*	*90*
E specified	*1.90*	*1.90*	*1.89*	*1.88*	*1.84*	*1.76*	*1.64*	*1.46*	*1.23*	*0.95*
E computed	*1.90*	*1.89*	*1.89*	*1.88*	*1.84*	*1.76*	*1.63*	*1.44*	*1.20*	*0.90*
azimuth °	*100*	*110*	*120*	*130*	*140*	*150*	*160*	*170*	*180*	
E specified	*0.64*	*0.32*	*0.10*	*0.30*	*0.53*	*0.71*	*0.84*	*0.92*	*0.95*	
E computed	*0.58*	*0.26*	*0.12*	*0.38*	*0.62*	*0.80*	*0.94*	*1.01*	*1.04*	

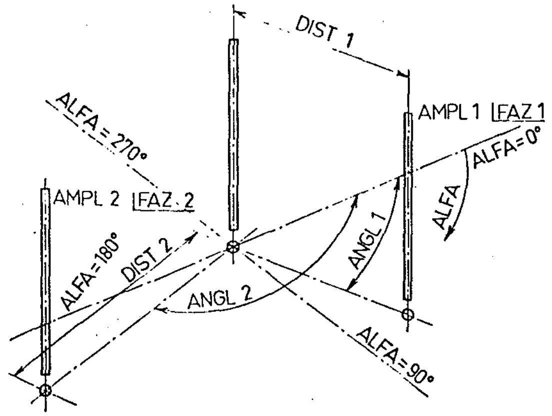


Fig. 10. Three-element antenna system

Synthesis of two-element antenna system shown in Fig. 4 for different values of iteration cycles k_1 and k_2 TABLE II

$k_1 = 100$		$k_2 = 100$		$k_1 = 150$		$k_2 = 150$		$k_1 = 100$		$k_2 = 200$	
F		x_1	x_2	F		x_1	x_2	F		x_1	x_2
37.30	37.33	40.43	40.56	37.30	37.33	35.65	30.84	37.30	37.33	40.43	21.12
34.15	34.19	45.00	29.36	33.52	33.55	49.68	17.57	31.80	31.84	57.51	— 4.65
32.24	32.29	58.57	14.41	29.40	29.47	82.39	— 9.92	22.67	22.75	89.65	—47.58
26.64	26.73	83.02	— 8.63	13.82	13.92	120.24	—48.65	5.67	5.73	105.56	—62.28
14.00	14.10	107.61	—35.08	6.18	6.06	88.85	—47.23	4.79	4.78	100.01	—50.07
.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.
4.40	4.40	103.25	—52.43	4.50	4.48	99.87	—51.29	4.41	4.41	102.72	—52.72

Let us choose — as in the previous example — an initial phase value $x_{10} = 50°$ and spacing $x_{20} = 60°$. Now the iteration cycles can be chosen $k_1 = 100$, $k_2 = 100$. The computation results are given in *Table III*, from which it is clear that the accord was reached as far as the pronounced minimum of the pattern is concerned. The optimum solution however, using the chosen values of k_1 and k_2 and parameters values $x_{10} = 50°$ and $x_{20} = 60°$, was not reached. The solution oscillates around the optimum as can be seen in *Fig. 8* from the behaviour of the smaller pattern lobe.

Let us perform the computation once more this time changing the value of initial parameters, say $x_{10} = -10°$ and antenna spacing $x_{20} = 60°$, iteration cycle $k_1 = 50$, $k_2 = 80$ and let the weighting functions be the same as in the previous case. The computation results are shown in *Table IV* together with results of other computed examples for the following values:
$x_{10} = -20°$, $x_{20} = 100°$, $k_1 = 50$, $k_2 = 80$ and $x_{10} = 50°$, $x_{20} = 60°$, $k_1 = 50$, $k_2 = 80$.

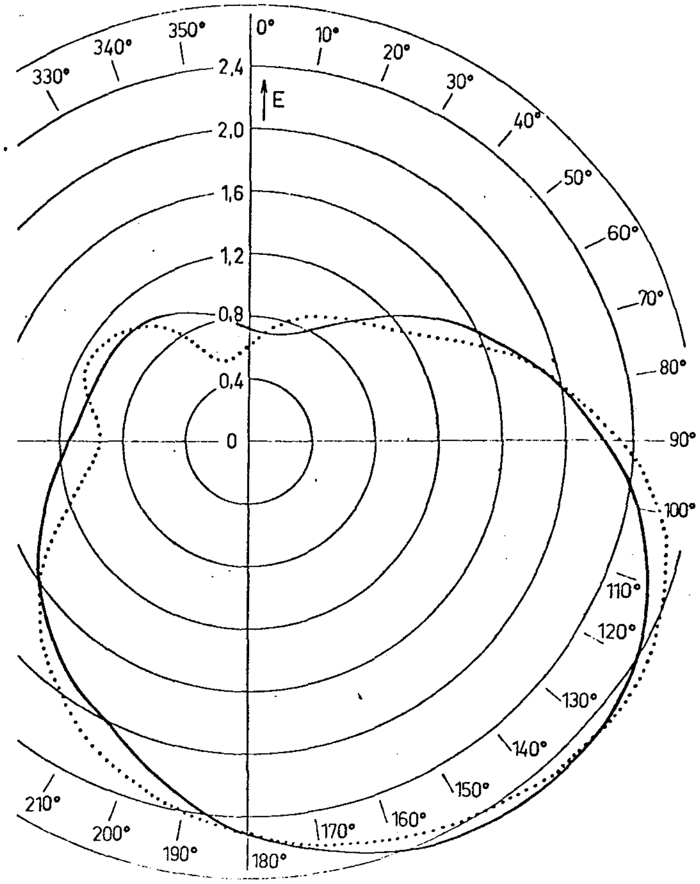
Graphical representation of the specified pattern and the approximating patterns are in *Fig. 9*. It is evident, that a good accord has been reached.

As another example of the steepest descent technique application we will introduce a pattern which, we assume, can be realized using a three-element antenna array, shown in *Fig. 10*. In this case we choose the initial

Synthesis of the two-element antenna system shown in Fig. 4 for $k_1 = 100$, $k_2 = 100$ after weighting functions introduction
TABLE III

$k_1 = 100$		$k_2 = 100$	
F		x_1	x_2
120.08	120.20	62.53	31.24
100.54	100.84	139.06	— 31.67
18.15	17.75	82.77	— 33.73
33.92	34.22	179.95	— 89.60
26.89	26.04	74.98	— 65.79
26.48	26.77	153.12	— 99.07
7.23	6.89	100.35	— 84.00
14.18	14.29	129.67	— 93.10
1.73	1.72	140.4	—111.48
3.42	3.25	102.59	— 94.8
10.68	10.79	151.83	—125.74
14.18	13.88	78.72	— 85.36
20.36	20.51	122.79	— 92.09
3.27	3.22	150.42	—118.78
10.58	10.29	85.65	— 85.37
17.81	17.95	116.62	— 83.01
8.59	8.68	154.49	—115.19
12.15	11.80	84.55	— 81.65
18.16	18.30	121.5	— 84.20
6.04	6.11	155.28	—116.80
13.29	12.93	82.48	— 81.16
18.99	19.14	124.58	— 87.15
4.16	4.20	152.55	—116.71
11.31	10.99	85.30	— 83.37
17.88	18.03	118.36	— 83.00

Fig. 11. *Three element antenna system synthesis results:* ——— *specified pattern;* .... *final computed pattern*



parameters DIST1, DIST2, FAZ1, FAZ2, ANGL1, ANGL2. To make the problem simpler we consider the current values $I_1 = I_2 = I_3$ and we will look for final parameters with which the antenna system would approximate the specified pattern. Thus we look for six system parameters. Using the same technique as in the previous case with a two-element system we succeed in approaching the desired pattern — the picture on the cover of this journal and *Fig. 11* can be taken as an example.

Both examples shown here were computed using no weighting functions, therefore the accord of the computed and specified pattern is not perfect yet. Nevertheless it is clear from both cited examples, that the technique is suitable for practical applications and also for the synthesis of larger numbers of unknown parameters of antenna systems that would satisfy the requirements of specified radiation pattern.

Synthesis of the two-element antenna system shown in Fig. 4 by which the accord between the computed and the specified pattern was reached

TABLE IV

$k_1 = 50$, $x_{10} = -10°$		$k_2 = 80$, $x_{20} = 60°$		$k_1 = 50$, $x_{10} = -20°$		$k_2 = 80$, $x_{20} = 100°$		$k_1 = 50$, $x_{10} = 50°$		$k_2 = 80$, $x_{20} = 60°$	
F		x_1	x_2	F		x_1	x_2	F		x_1	x_2
96.28	96.16	— 54.33	104.38	63.33	63.19	— 71.80	124.75	120.08	120.20	56.26	36.99
31.23	31.30	— 86.26	119.28	19.10	19.13	—104.97	141.08	108.26	108.53	86.73	— 4.11
.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.
0.65	0.63	—112.57	120.90	0.67	0.72	—107.92	139.97	0.58	0.61	126.63	—119.99
0.50	0.53	—120.71	128.26	0.55	0.58	—108.09	137.38	0.66	0.61	118.01	—112.34
0.55	0.54	—113.62	119.87	0.44	0.48	—109.89	136.09	0.51	0.53	125.51	—121.27
0.43	0.46	—121.23	126.97	0.37	0.40	—110.42	134.23	0.59	0.55	117.38	—113.68
0.49	0.47	—114.40	119.12	0.29	0.32	—111.64	133.00	0.46	0.48	124.73	—122.10
0.38	0.41	—121.60	126.01	0.24	0.27	—112.25	131.58	0.54	0.50	117.00	—114.63
0.45	0.43	—114.98	118.58	0.19	0.22	—113.14	130.50	0.42	0.45	124.17	—122.65
0.34	0.37	—121.86	125.30	0.16	0.18	—113.72	129.38	0.50	0.47	116.73	—115.31
0.42	0.39	—115.42	118.20	0.13	0.15	—114.39	128.46	0.39	0.42	123.75	—123.00
0.32	0.34	—122.03	124.77	0.11	0.12	—114.90	127.56	0.47	0.44	116.58	—115.81
0.39	0.37	—115.74	117.94	0.08	0.10	—115.42	126.80	0.36	0.39	123.44	—123.21
0.30	0.32	—122.13	124.37	0.07	0.08	—115.85	126.08	0.45	0.41	116.50	—116.18
0.37	0.35	—115.99	117.77	0.05	0.07	—116.27	125.46	0.34	0.37	123.30	—123.30
0.28	0.30	—122.19	124.07	0.04	0.05	—116.62	124.88	0.42	0.39	116.46	—116.00

Let us now present a flow chart of the main steps of the considered method:

(1) We choose arbitrarily the initial values of the required antenna system parameters.

(2) We specify the desired radiation pattern.

(3) For chosen antenna system parameters we compute the pattern and find the deviation from the specified pattern.

(4) We compute the gradients and the new antenna system parameters.

(5) Using thus computed antenna system parameters we compute the pattern again and once more we find the deviation from the specified pattern. If the error is large, we return to point (4) and repeat the computation. If the error is within the specified limits, we compute the pattern and print the computation results as well as the found antenna system parameters.

CONCLUSION

The steepest descent method — illustrated on examples — is useful for the synthesis of antenna systems complying with specified radiation patterns. The main steps of the antenna system parameter synthesis in accordance with a specified pattern were described. It was shown that during the synthesis it is very important to choose correctly the iteration cycles in order to reach fast convergence.

The choice of iteration cycles may be made directly during computer work, estimating the computed results. In doing so we observe how the magnitude of the error, as expressed by function F, changes. The error is increasing or decreasing and according to this we correct the magnitude of the iteration cycle. The iteration cycle can also be fixed automatically by the computer itself — see for example [5]. The collaboration in this field with specialists of the Electromagnetic Field Department of the Czech Technical University in Prague was succesfully developed and positive results have already been reported.

In this article examples were given of antenna system parameters synthesis specified in non-normalized form and actually realizable by a given antenna system. The same results will be reached in those cases when the pattern is specified in the normalized form (maximum value of field strength in certain direction equalling unity) and when we look for parameters of an antenna system, that cannot conform to the desired pattern. In this case we at least come as near as possible to the realizable minimum.

The possibility of prescribing minimum and maximum limits of the wanted parameters, facilitating the physical realization of a given antenna system is the great advantage of this method; thus it may be used, for example, in fixing the maximum and minimum values of spacing among radiators, the values of feeding currents and reasonable phases of these currents.

REFERENCES

[1] Eveleigh, V.: Adaptive Control and Optimization Techniques. New York, McGraw-Hill, 1967

[2] Leon, A.: A Comparison among Eight Known Optimizing Procedures. Recent Advances in Optimization Techniques. Edition A. Lavi and T. P. Vogl, New York, Willey, 1966, pp. 23—44

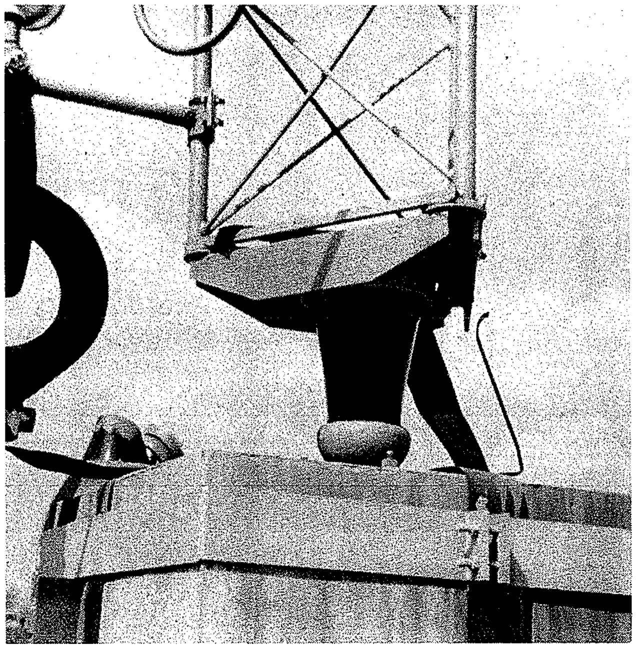
[3] Powell, J. J. D.: An Efficient Method for Finding the Minimum of a Function of Several Variables without Calculating Derivatives. Comput. Journ., vol. 7, 1964, pp. 155

[4] Perini, J. — Idselis, M. H.: Radiation Pattern Synthesis for Broadcast Antennas. IEEE Trans. on Broadcasting, vol. BC-18. No. 3, Sept. 1972

[5] Lasdon, L. S. — Waren, A. D.: Mathematical Programming for Optimal Design. Electro-Technology, Nov. 1967, pp. 55—70

Reducing AM tower static

By Robert A. Jones*



In all cases, the attempt should be to install a low resistance path to ground. Of course, gaps and arrestors should be maintained. An intense lightning strike may still jump the gap. But static build-up arcing can be greatly reduced.

Static on AM towers has been a problem for all stations from the day the first one went up. However, there are ways to reduce, if not eliminate this problem. Possibly you think you already know all about this kind of difficulty, but I have found it helpful from time to time, to review those subjects we think we know all about.

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Let's start by defining static. Static electricity on AM towers is that effect caused by the gradual build up of negatively charged particles on metal wires and towers. These little particles can be caused in one of three common ways. First, and most common is that caused by lightning. Second is by rain or snow, and third, is that type caused by charged particles carried on the wind, in front of storms.

The Greeks were the first to discover that static could be caused by rubbing amber. They attracted bits of cloth and caused their hair to stand on end! You may now know that the Greek word for amber was "Elektron". This name has stuck with us today and is the word we use to represent a negative charge of electricity.

Old Ben Franklin was the first one to prove the connection between static electricity and lightning. This was proved by his famous Kite and wet string experiment. (The Zap . . . ouch test.)

The map of the United States included here shows a number of thunderstorm days to be expected in each part of the country. The isobars represent these numbers. As the reader will note, the greatest number of thunderstorms occur in Florida. In fact, almost every fourth day, on the average, you can expect a storm in Florida.

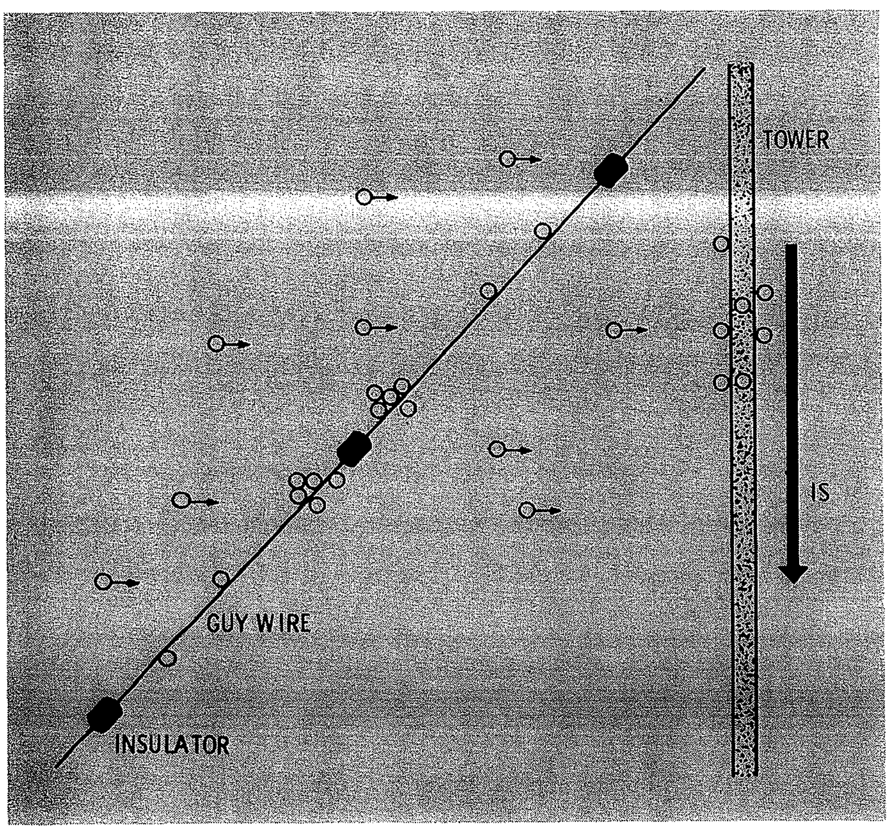


Fig. 1 Negative particles build up on the guys and tower. Since arcing across the insulators can occur, it is standard practice to securely ground the anchor points.

Now let's consider what happens when these negative particles accumulate on the tower and guys. As you can see in Figure 1 those particles which hit the guys will build up, since they are prevented from leaking off by the guy wire insulators. Those that strike the tower will bleed off to ground (normally) through RF chokes or tower lightning neutral wires. In addition to RF chokes an lightning chokes, most stations will install "Ball Gaps" at the tower pier. These are usually of the ball type, or can be of the flat stock type. In addition, many stations have found it helpful to add lightning rods atop their towers. This is particularly recommended in areas of high storm density.

Crackle . . . Bang

The negative particles that gather on the guy wires can not bleed off to ground. As you may know, they continue to build up until . . . Bang! . . . there is an arc across the guy wire insulators.

Usually all insulators appear to arc, or flash, at the same time. Actually this is not what happens. Somewhere one insulator will arc first. The radiation from this one, traveling with the speed of light, trips all the other charged sections of guy wire. This is why they all appear to jump at the same time. (I should point out that it is standard practice to securely ground the guy anchor points, since this lowers the danger of fracturing an insulator.) This arcing of the guy wires will cause a sudden burst of static into the tower. And this is what causes the biggest headache to broadcasters.

This static induced into the tower flows toward ground at an extremely high rate of speed. In most antennas it finds too much inductance in the RF choke. The result is that this sudden surge of current jumps the ball gap at the tower base. If the power of the transmitter is 5 kW or higher, the arc may be sustained. Once the air across the lightning gap has ionized, its resistance falls to a mere fraction. Because the resistance is then low, the power of the transmitter can maintain it. Most higher power stations have found it convenient to install some protective device that effectively breaks this arc, by momentarily shutting off the transmitter. Lower power stations usually find their transmitters will recycle by themselves, since their power is too low to maintain the arc.

Figure 3 shows how this can occur. For this example I have assumed a typical low impedance tower with a base value of 50 ohms plus j 75 ohms. Also, let's assume a typical "Tee network" and a one-quarter wave length transmission line. With the values shown, the transmitter will look into a matched load. When the ball gap arcs, it in effect, can be considered a short across the tower base. Calculating this through the network and transmission line, we find the transmitter seeing a load of 410-j 670 ohms. This instantaneous change in load causes the plate current to shift, which in turn causes the plate overload to trip. With normal transmit-

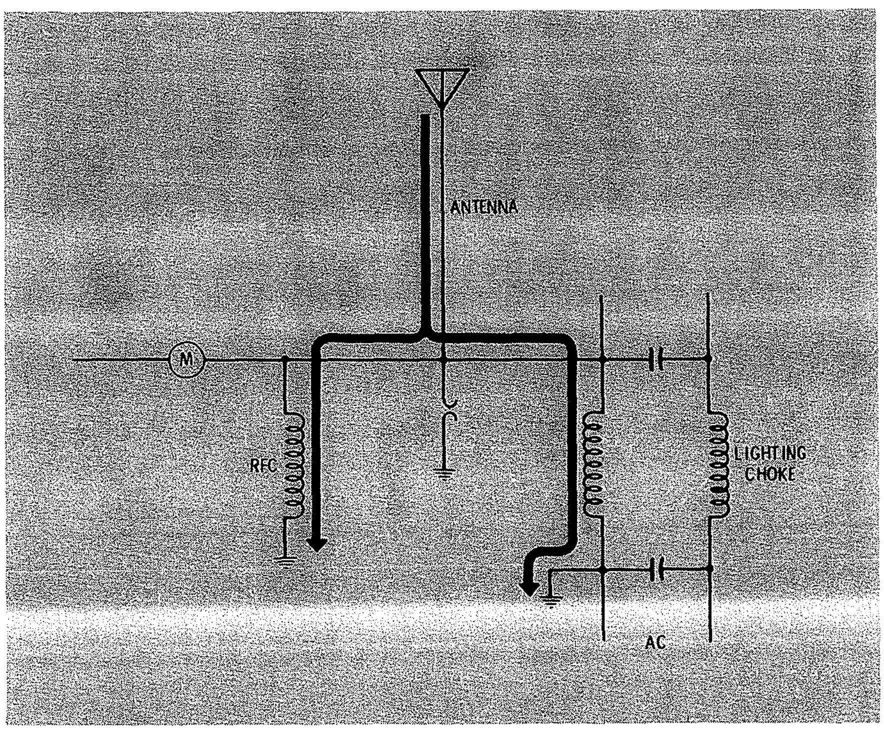


Fig. 2 Buildup on the tower can be bled off through a choke arrangement.

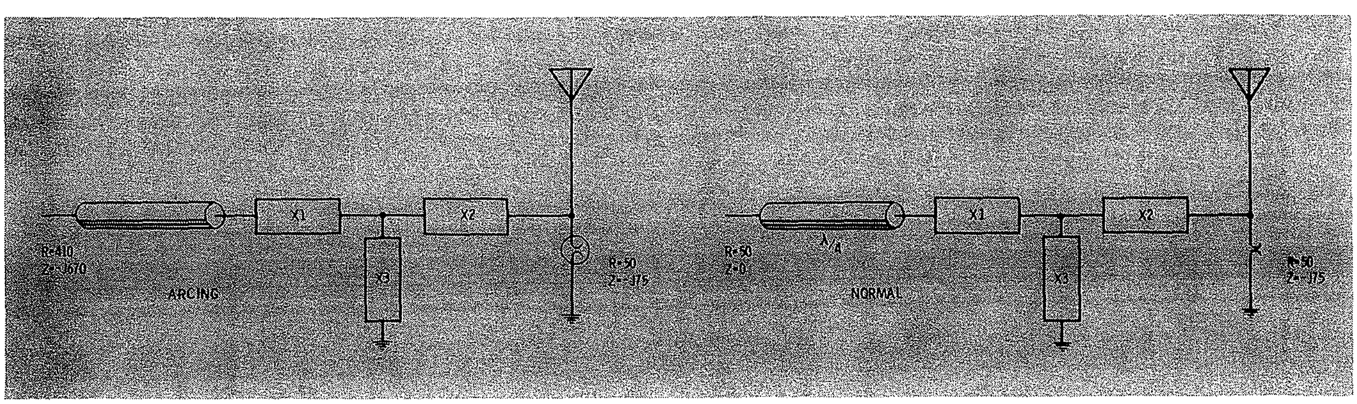


Fig. 3 With the arc at the ball gap, the air is ionized, lowering the resistance to a mere fraction. And this momentary low resistance will cause RF arcing.

ters, the recycling circuit turns the transmitter back on in a second or so.

Some people claim that shunt feed towers are immune from static. While it is true that there is no base insulator, the high static charges can be induced in the slant wire and cause trouble. I would agree that there may be less trouble, but it is not eliminated.

The big nusiance to flash-overs is not the danger of damage to equipment but one of interruption to station programming. These pops and arcs, on the air can be fatiguing to the listener. It is not unusual to sustain as many as five to ten arcs a minute under high static conditions. If your competitor's station is not popping off the air you may lose listeners.

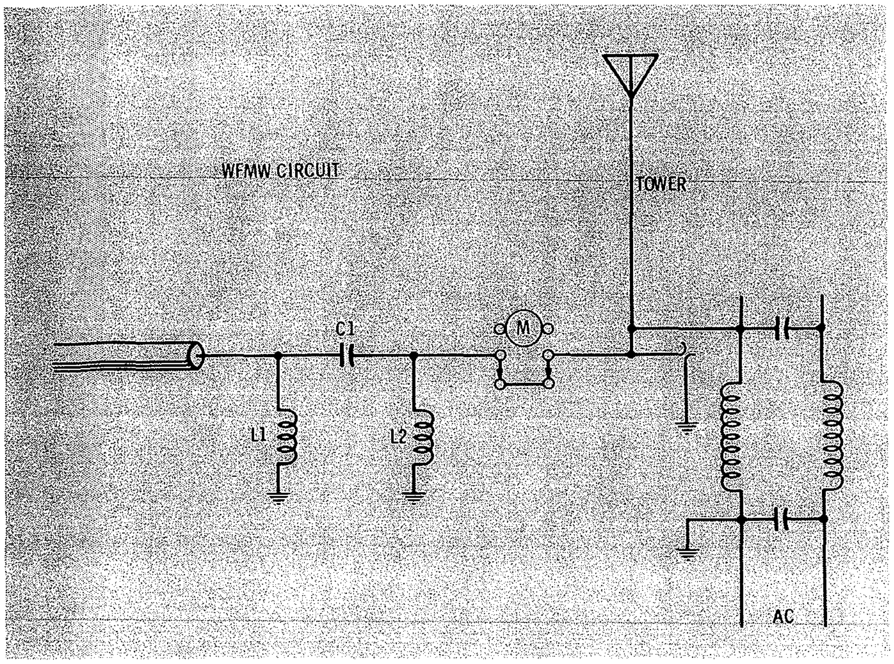


Fig. 4 The WFWM setup, using a low resistance low inductance across the tower base to eliminate arcing across the ball gap. Eliminating the arc eliminates transmitter load shifts and shutdown or recycling.

Standard Solutions

There are two standard solutions to reducing arcs to a minimum. These are not new ideas I've concocted . . . but are common knowledge to most consultants. Let's refer to the first type of solution as that of a "Low Impedance" tower. For this I would refer the reader to the case of WFMW. The natural resistance of their tower is 62 + j2 ohms. The network designed to match this tower is shown in Figure 4. This is a not so typical "pi" network. As you will see it has two coils with one capacitor, whereas the normal "pi" has one with two capacitors. The idea is to use a coil with low inductance across the tower base. By using a low resistance low inductance in place of a normal high inductance RF choke, we can pass these sudden static strikes to ground without arcing the ball gaps. With this type of circuit the lightning gap seldom ever sparks. Hence, there is no more shift in load by the transmitter and few carrier interruptions.

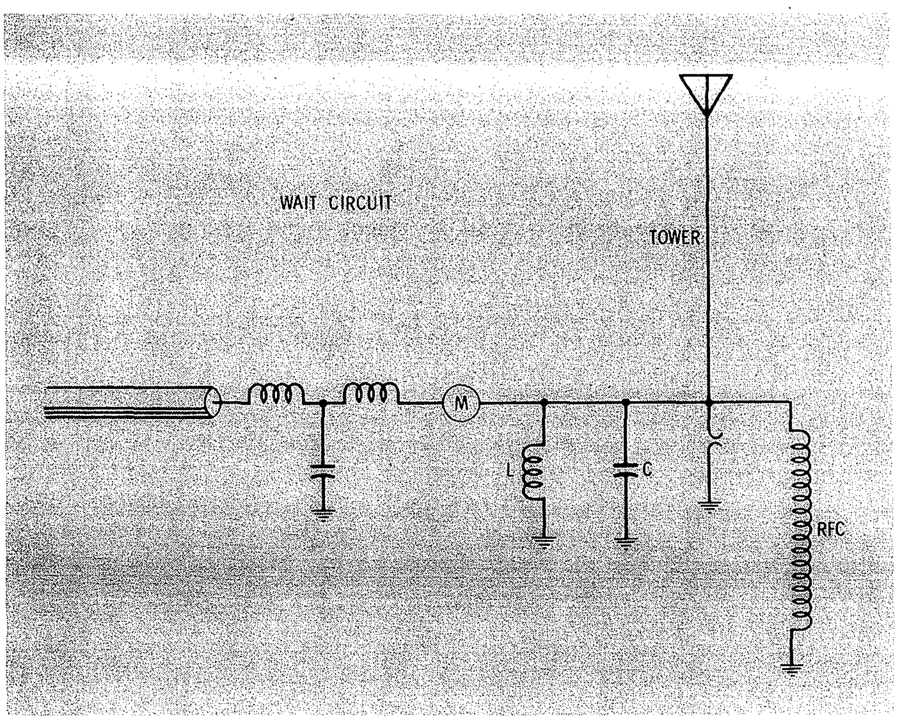


Fig. 5 The WAIT circuit. This arrangement offers a fast path to ground.

The second case involves what I would call a "Hi Impedance" tower. For this example I refer to WAIT. Their tower has a self resistance of 440 + j560 ohms. The solution employed at WFMW would not work in this case because we would have had to use a coil with two or three times the inductance. Instead of a 'pi'" network we chose to install a special static circuit across the tower base. The reason we couldn't use a "pi" type approved is that the coils at this frequency with this high impedance would have contained too much inductance. For WAIT we decided to use a 10 μh coil. On 820 KHz this would give a reactance of 51.5

ohms. WAIT operates with 5 kW. This produces a base voltage of approximately 1600 volts which yields a branch current of 32.0 amps.

Now any station operator knows you just don't go hang a 10 μh coil across a 440 + j560 tower. If you did, the self resistance would be all wrong. This is solved by placing a capacitor in parallel with the 10 μh coil. Some would call this a tank circuit, but it really isn't. What it is, is a circuit used to eliminate or cancel, the effect of the coil, at 820 KHz, but not the advantage of a fast static path to ground. In our example, we found a 0.004 μfd capacitor was a good choice. We selected vacuum capacitors, because of the high branch current. Keep in mind that the current through the capacitor will be about the same as that through the coil. Figure 5 shows WAIT's circuit.

Installation

It is recommended that you use a Radio Frequency Bridge to correctly install this static circuit. The first step is to measure the self resistance of the tower. Then add the coil and capacitor to the circuit. This will probably cause the resistance to change slightly from the natural or self resistance of the tower. If so, adjust the coil slightly, until the resistance returns to the original value. At this point we have the static circuit properly tuned so that it does not upset the licensed operation of the station.

One area for the reader to keep in mind is the need for good, heavy guard straps between the static circuits and the ground system. For example, a single number 10 wire will not do. At WAIT we used a four-inch copper strap from the tower to the static circuit, and another four-inch strap from the circuit to the ground system at the base of the tower. We installed their circuit in a weatherproof box directly on the tower pier. By so installing the circuit we kept all leads to a very minimum. You must keep in mind that the object here is to construct the lowest possible resistance path to ground.

It might be of interest to call the readers attention to the fact that the earth's atmosphere resembles a large spherical condenser with the ionosphere and earth serving as the upper and lower plates. The atmosphere then serves as a leaky dielectric. The production of static is due directly or indirectly to atmospheric motions. Ben Franklin dealt chiefly with very intense and sporadic electrical effects accompanying storms. These cummulated in his invention of the lightning rod. The sharp point on the lightning rod has the effect of increasing the field strength in its vicinity and thus accelerates the motion of the ions in the air. Under normal conditions this sharp point produces an attractive field for the positive ions.

In summary, there is a need to solve your static problems. They can be solved, giving you an advantage over your competitor. ▲

EXAMINATION OF
NON-DIRECTIONAL IMPEDANCE DATA
VERSUS ELECTRICAL HEIGHT
FROM INFORMATION FILED AT THE FCC
JULY 1987

Purpose:

Study whether or not a correlation from existing measurement impedance data can establish a relationship between physical height and electrical height for a vertical, base insulated, radiator. Compare these results with the procedure developed in Document 7-E of the First Session Conference "RARC to Establish a Plan for the Broadcasting Service in the Band 1605-1705 kHz in Region 2" as supplemented by Document J1WP10-3-8/1-30 Document: CAN2, April 30, 1987.

Method:

Acquire, study and analyze impedance measurement data for various height towers. Supplement the study with selected measured RMS values (non-directional and directional) and compare from proof-of-performance reports to that predicted by current Region 2 methods. Restrict the measured RMS portion of the study (non-directional and directional) proof information to recent information having a frequency between 1500 and 1600 kHz and omit from consideration those proof-of-performances which are taken in unusually rugged terrain or in areas having multiple arrays.

Discussion:

The computation of an accurate base impedance value for an insulated vertical antenna is difficult, as many factors can affect its value. For example, the actual base impedance is dependent upon many physical factors such as tower width, type of structure (guyed or self supported), length of feed line, the relationship of the feed point and antenna base to the ground system, etc. Other factors can be present such as isolation circuits for AC, sample line, other communications antenna (FM and TV, etc). Depending upon the method of detuning isolation circuit(s), each may contribute to the actual base impedance of the tower.

Table I provides impedance measurement data in electrical height order. This information is found in the FCC records and represents data catalogued by the Audio Services Division (AM Branch) of the FCC over a period of ten years. An effort was made to obtain only series-fed base-insulated data and to exclude any impedance data for less conventional configurations, such as top-loaded or grounded base facilities. Documented is the call letter, the measured impedance, the frequency, and the free-space electrical antenna height. Table II provides the same information in frequency order. Accompanying the data are plots of resistance (Figure 1) and reactance (Figure 2) in ohms along the ordinate and free-space electrical height in degrees along the abscissa. In addition, the resistance and reactance information from Document 7-E referred to above has been plotted. Also shown on Figure 1 and Figure 2 is the calculated resistance/reactance derived for Zo equals 600 (thin wire) from the equation shown on Page 2-1-15 of the fourth edition (1949) of "National Association of Broadcasters Engineering Handbook".

The tables contain over 260 sets of impedance data with over 190 sets shown from 51.6 through 110 electrical degrees. Beyond 110 electrical degrees, there are 66 sets of impedance data. Examination of the FCC resistance values reveals the data behavior to be generally uniform from 51.6 through 110 electrical degrees. Beyond 110 electrical degrees, the data are divergent and are less uniform and as shown do not exhibit a predictable behavior particularly when compared to that data provided by Document 7-E. This significant data departure represents one-third of the data in this segment.

The procedure outlined in the supplementary information from Document 7E has been examined and a computer program was developed to simulate that approach to analyze the data contained in Table I. The data in Table I was evaluated with this program. Table III provides the computer program and Table IV provides the computer results in a format similar to supplemental information from Document 7E. Table V provides the "best-fit" evaluation method. Fourteen sets of data have been excluded due to the uncertainties of interpretation of Formula 2.1 in the supplementary information to Document 7E. Figure 3 is a plot of that information.

In addition, historic data is attached shown in Figures 4 and 5. While these plots may not represent typical values currently observed, they demonstrate the differences occurring with the impedance (magnitude and shape) as a function of the type of tower and its height.

Examination of FCC files was made of recent proof-of-performances conducted on stations above a frequency of 1500 kHz. Table VI provides that information by frequency including call letter and state. Also provided are the listed electrical heights based on free-space for both the non-directional and directional antennas, the RMS in mV/m for 1 kW at one kilometer both for the non-directional and directional modes as obtained from Figure 1 of Annex 2/p13 of the "Final Acts of the Regional Administrative MF Broadcasting Conference (Region 2) Rio de Janeiro 1981" and the measured value obtained from the proof-of performance. Also provided is the non-directional impedance for that operation. Where possible, the type of tower structure whether self supporting or guyed is shown for the non-directional tower. Proof-of-performances taken in unusually rugged terrain or in areas having multiple directional arrays were not considered.

A comparison of the non-directional and directional measured RMS values reveals good correlation to the predicted values in accordance with Region 2 standards. However, no apparent corresponding increase in radiation efficiency is observed which might be expected if the effective antenna height is sufficiently greater than the free-space value.

Conclusion:

To date, no correlation using the FCC data has been found which would permit a more accurate assessment of a tower's electrical height than that currently used under Region 2 methods.

TABLE I
MEASURED NON-DIRECTIONAL
RESISTANCE AND REACTANCE DATA
FILED AT THE FCC
IN ORDER OF ELECTRICAL HEIGHT
JULY 1987

Call	Measured Impedance ohms	Frequency kHz	Free-Space Electrical Height degrees
KBCC	11.2-j53	1410	51.6
WVNH	12-j115.6	1110	52.82
WEKU	12.3-j114	930	54.5
WHJB	21.5-j164.5	620	56.7
WQBS	16.7-j128.6	630	57.62
KWBZ	15.11-j90	1150	58.9
WQKI	14.6+j128.2	710	59
WMJJ	16.5-j119	680	60
KLFB	11.5-j87	1420	62.4
WXCE	15.7-j63.5	1260	63.1
WARO	18.5-j125.9	540	63.5
KAYR	21-j44	1060	64
WHP	28.9+j20.7	580	65
KTHO	20-j69.3	590	65
WAUC	20.75-j65	1310	65
WICC	10-j28.8	600	65.9
WDNC	12.2-j58	620	67
KAPZ	27-j72.5	710	67
WINI	20.4-j23.9	1420	67
WAYS	27.8-j22.6	610	68.2
WGTO	29.5-j48.1	540	69
KBOX	26.1-j22.2	1480	69.3
WUIV	16.7-j71.6	1500	69.4
WABT	19.3-j28.2	1360	69.8
WADS	25-j65	690	70
WRNR	23.1-j43.2	740	70

Call	Measured Impedance ohms	Frequency kHz	Free-Space Electrical Height degrees
WKRC	23.8-j42.9	550	70.5
WCQL	21.8-j34.6	1370	70.7
KLEH	25-j12	1290	70.8
WFSO	24.9-j49.1	570	73
WYMC	27.5-j1.5	1430	73
WVOY	27.3+j7.8	1270	73.4
KPAR	34.5-j23.9	1420	75.3
WOBL	37.0+j16	1320	76
WMEL	29+j3.26	920	76.1
WSKE	26.5+j0.8	1050	76.8
WYFE	26+j17.4	1150	76.8
KGOE	29-j8.7	850	77.8
KGOE	26.8-j9	850	77.8
KVNU	32-j13	610	78.1
KOJM	34.0-j33	610	78.1
KHAD	34+j2	1190	78.4
KRZJ	54+j37.8	1190	78.4
KALV	31.8-j6.96	1430	78.5
WRNG	30.5+j1	680	79.4
WKED	36+j70	1130	80
KCJJ	37.5+j40.4	1560	80
WOKY	31.5+j35.9	920	80.8
KQLA	32.3+j27.01	1480	81
WKVE	30.5+j1	800	82
WEAK	33.8+j18	900	82.3
WHLO	33.5+j23	640	82.4
KIXZ	34+j53.9	940	82.5
WINU	38+j47	1510	83
WAVL	39.5+j36	910	83.27
WHP	34.3+j43	580	84.9
KRRP	38.8+j32.6	950	85
WMCL	34+j67.9	1060	85

Call	Measured Impedance ohms	Frequency kHz	Free-Space Electrical Height degrees
WQRO	43+j49.7	1080	86.9
KNCO	66+j95.2	1250	86.9
WPRO	43.5+j56.3	630	87.5
WRBN	40+j77.5	1600	87.7
KTWO	38.5+j46	560	88
WLUZ	45.25+j75.2	1600	88
KITI	55+j69.58	1420	88.4
WRGI	51.5+j96	1510	88.4
WQBX	49.5+j74.2	710	88.5
WJJQ	64+j55	810	88.9
WKBN	44.5+j92.1	570	89
KKBJ	52.2+j77.2	1360	89.1
KKLS	48.5-j113	920	89.2
KAKA	46.81+j69.2	1110	89.3
WZAM	48+j54.1	1110	89.3
WTHI	55+j93	1480	89.4
WMUF	59+j94	1000	89.6
WTNX	49+j79.2	1290	89.6
WKDC	36.5+j44.4	1530	89.6
WLPQ	39+j43	1600	89.6
WPIP	49.7+j86	980	89.7
WTIM	92-j220	1410	89.7
WUNN	50+j84	1110	89.8
KBTN	57.9+j94	1420	89.8
WEWO	46.3+j76.8	1460	89.8
KFND	41+j92.3	1170	89.9
KNMX	46.5+j71.8	540	90
WDLV	44+j64.9	550	90
WTCM	49+j70	580	90
KQRX	44+j56.9	720	90
KCRL	49.1+j60	780	90
WPTB	42+j87.9	850	90

Call	Measured Impedance ohms	Frequency kHz	Free-Space Electrical Height degrees
WLAS	47.0+j92	910	90
WPLA	50+j64	910	90
KSDN	38+j118.3	930	90
WCAP	47+j88	980	90
WRNJ	47+j57	1000	90
KOTD	47+j67	1000	90
WPMH	62+j118.8	1010	90
KTWO	48+j72	1030	90
WOSO	48+j107	1030	90
WVCG	55.5+j67	1080	90
KFAX	46+j52	1100	90
KTEK	50+j70	1110	90
WKEG	52+j75	1110	90
WKWM	49.1+j72	1140	90
KCCT	55+j94.88	1150	90
WBRW	48.5+j104.3	1170	90
WJMQ	49+j88	1170	90
KGYN	46.4+j64.5	1210	90
WNRK	55+j87	1260	90
KBDF	62.5+j105	1280	90
WOPP	46+j76	1290	90
WCHK	47+j75.2	1290	90
WXRL	56+j96	1300	90
WEGA	59+j88.9	1350	90
WKYO	52+j106	1360	90
WLLN	44+j50.4	1370	90
KLBA	52+j72.9	1370	90
WGFT	55+j98	1500	90
WAAY	60.5+j113.5	1550	90
WMAD	58+j107.2	1550	90
WSHY	55.2+j85.3	1560	90
KAJN	56.8+j82	1560	90

Call	Measured Impedance ohms	Frequency kHz	Free-Space Electrical Height degrees
WOBL	123+j130.6	1570	90
KDJS	55+j107	1590	90
KATZ	51+j76.2	1600	90
WHOY	66+j66	1210	90.3
KMTX	48+j71	950	90.4
KCSJ	50+j110	590	90.5
KRWL	52+j87	1300	90.5
WHOY	61+j69	1210	90.8
WEEO	56.5+j76	1130	91
KQTI	57.5+j80	1130	91
KWBY	58.3+j83.2	1130	91
KQTI	58+j75	1130	91
KAYO	64.2+j109.3	1190	91.5
WJBT	62+j117.7	1590	91.7
WJBY	51+j90.1	930	91.9
KXEW	63.5+j114.4	1600	91.9
KUKA	68+j116	1250	92
KSXX	48.5+j78.8	630	92.27
KAKC	45+j94.9	970	92.3
KSUZ	54+j68	1150	92.5
WKKX	50.5+j147.1	1310	92.5
WMRL	60+j96.8	1270	93
KRAD	94+j111	1590	93
WHPY	68+j121	1590	93.1
WIBR	61+j99	1300	93.2
WKRP	59.5+j90	1500	93.3
KMAS	66.1+j105.04	1280	93.77
KYKR	57.9+j84	1510	93.9
WAEB	37.5+j71	790	94
WTJS	64+j61.9	1390	94.6
WARE	44+j28	1250	94.7
WPGC	73+j134	1580	95.5

Call	Measured Impedance ohms	Frequency kHz	Free-Space Electrical Height degrees
KBOZ	71+j117	1090	95.7
KEEL	70+j104	710	96
KRVN	51+j119	880	96.6
WAGY	69+j115	1320	96.6
KERR	90+j171	1070	97.8
KULF	71+j158	790	98.2
KANI	111+j86	1000	98.7
WNIS	98+j144.5	1350	99
WKCK	76.4+j153.55	1470	99.49
KKIK	45.3+j117	1010	99.8
WBDY	89+j128.6	1190	100
KOZY	84.5+j144	1320	100
WCOA	83+j182	1370	100
KMJJ	88.5+j138.9	1140	100.1
WTMP	54+j113	1150	100.17
KSOP	103+j167	1370	100.3
WIND	140+j180	560	100.8
WDJZ	57.5+j64.3	1530	100.8
WDAT	106.5+j163	1380	100.9
KITN	81.5+j125	920	100.95
WPHM	95+j185	1380	101
WNRE	88.5+j176	1540	101
WBEV	88.5+j190.9	1430	102
WINZ	154+j217	940	103
KUCH	127+j219.9	1410	103
WMIX	110+j159	940	103.2
KFIA	98+j203	710	103.9
WTAR	100+j212	790	104
KBUF	65.5+j164	1050	104.4
WQDI	133+j236	1430	104.6
WROW	64+j159.3	590	105
WHYT	115+j184.6	1110	105.6

Call	Measured Impedance ohms	Frequency kHz	Free-Space Electrical Height degrees
WHYT	150+j207	1110	105.6
WACO	82+j175	1460	106.9
KVLH	212.9+j270	1470	107
KNDE	582+j410	1470	108
WISM	79+j204	1480	108
WPOE	95+j193	1520	109
WYIS	70+j137	690	109.8
KYST	178+j257	920	110
WLNA	200+j224.4	1420	110
KVAN	215.1+j253.8	1480	110
KWUN	50+j130	1480	110
WIXY	200+j237.5	1600	110
KDKO	193+j205	1510	110.5
WEEP	126+j264	1080	111
KKOY	234+j277	1190	113.2
KBRF	169+j280	1250	114
KGST	117.33+j232.25	1600	114.2
WPNS	339+j187	1080	114.5
WRDD	164+j297	1440	115
WWCA	227+j288	1270	116
WPMP	215+j341	1580	116
KYOS	242+j412	1480	119.3
KGNR	320+j289	1320	120
WTVR	187+j298	1380	121.2
WNLC	140+j298	1510	121.53
WASA	128+j268	1330	121.7
WKIN	194+j343	1320	125
WJCW	155+j302	910	130
WHIO	340-j55	1290	130
KSUM	530+j292	1370	130.3
KIRO	473+j324	710	134
WAKY	113.65+j311.45	790	136.8

Call	Measured Impedance ohms	Frequency kHz	Free-Space Electrical Height degrees
KFRN	178+j90.5	1280	137.7
WCTW	560+j292	1550	138
WKRS	134.8+j22	1220	142
KCPX	80.5-j150	1320	142
VLC	225-j350	1170	145.5
WCMG	245+j924	1050	146
KEYS	248.7+j418	1440	146
WMPS	230-j475	680	149
WEUP	50+j121.9	1600	149
WAMR	130-j265.9	1320	150
WSOL	842-j86.3	1370	150
WLAP	710-j238	630	152
WGHB	54.5+j409.6	1250	152.8
WEEZ	28+j155	1590	153
WEEZ	800+j315	1590	153
KLO	507.2-j457.98	1430	157
KWK	267-j390	1380	161
WIZO	548-j210	1380	164
WTGR	56-j297	1520	166.8
WOKB	212-j405	1600	166.8
WICH	133-j286	1310	168
WEOO	36.5-j21	940	169
KTNQ	85-j202	1020	180
KJNP	596-j270	1170	180
KOMA	158-j222	1520	181
WHET	121-j541	1330	185
WTTL	24-j214	1310	186
WVAM	92-j249	1430	188
WCPC	122-j306	940	189
WPLM	36-j142	1390	190
KHUG	82-j218	1300	190.3
WTJZ	85-j189.2	1270	192.9

Call	Measured Impedance ohms	Frequency kHz	Free-Space Electrical Height degrees
WCKY	52-j113	1530	198.7
KWK	66-j196	1380	200
WFIA	66-j249	970	201.3
KMTI	142-j268	1590	202.5
WAIK	116-j865	1590	203.7
KDTH	100-j222	1370	210
WCRJ	56-j156	1530	210
WPOM	51.5-j166.8	1600	212
WKVL	32.2-j136.4	1550	219.5
KAAM	31.5-j118	1310	225
WDOT	39.5+j106.6	1390	225
KOLM	36-j82	1520	225
KLLO	47.5-j228	1410	226
WCIN	28.5-j53.0	1480	227.2

TABLE II
MEASURED NON-DIRECTIONAL
RESISTANCE AND REACTANCE DATA
FILED AT THE FCC
IN ORDER OF FREQUENCY
JULY 1987

Call	Measured Impedance ohms	Frequency kHz	Free-Space Electrical Height degrees
WARO	18.5-j125.9	540	63.5
WGTO	29.5-j48.1	540	69
KNMX	46.5+j71.8	540	90
WKRC	23.8-j42.9	550	70.5
WDLV	44+j64.9	550	90
KTWO	38.5+j46	560	88
WIND	140+j180	560	100.8
WFSO	24.9-j49.1	570	73
WKBN	44.5+j92.1	570	89
WHP	28.9+j20.7	580	65
WHP	34.3+j43	580	84.9
WTCM	49+j70	580	90
KTHO	20-j69.3	590	65
KCSJ	50+j110	590	90.5
WROW	64+j159.3	590	105
WICC	10-j28.8	600	65.9
WAYS	27.8-j22.6	610	68.2
KVNU	32-j13	610	78.1
KOJM	34.0-j33	610	78.1
WHJB	21.5-j164.5	620	56.7
WDNC	12.2-j58	620	67
WQBS	16.7-j128.6	630	57.62
WPRO	43.5+j56.3	630	87.5
KSXX	48.5+j78.8	630	92.27
WLAP	710-j238	630	152
WHLO	33.5+j23	640	82.4

Call	Measured Impedance ohms	Frequency kHz	Free-Space Electrical Height degrees
WMJJ	16.5-j119	680	60
WRNG	30.5+j1	680	79.4
WMPS	230-j475	680	149
WADS	25-j65	690	70
WYIS	70+j137	690	109.8
WQKI	14.6+j128.2	710	59
KAPZ	27-j72.5	710	67
WQBX	49.5+j74.2	710	88.5
KEEL	70+j104	710	96
KFIA	98+j203	710	103.9
KIRO	473+j324	710	134
KQRX	44+j56.9	720	90
WRNR	23.1-j43.2	740	70
KCRL	49.1+j60	780	90
WAEB	37.5+j71	790	94
KULF	71+j158	790	98.2
WTAR	100+j212	790	104
WAKY	113.65+j311.45	790	136.8
WKVE	30.5+j1	800	82
WJJQ	64+j55	810	88.9
KGOE	29-j8.7	850	77.8
KGOE	26.8-j9	850	77.8
WPTB	42+j87.9	850	90
KRVN	51+j119	880	96.6
WEAK	33.8+j18	900	82.3
WAVL	39.5+j36	910	83.27
WLAS	47.0+j92	910	90
WPLA	50+j64	910	90
WJCW	155+j302	910	130
WMEL	29+j3.26	920	76.1
WOKY	31.5+j35.9	920	80.8
KKLS	48.5-j113	920	89.2

Call	Measured Impedance ohms	Frequency kHz	Free-Space Electrical Height degrees
KITN	81.5+j125	920	100.95
KYST	178+j257	920	110
WEKU	12.3-j114	930	54.5
KSDN	38+j118.3	930	90
WJBY	51+j90.1	930	91.9
KIXZ	34+j53.9	940	82.5
WINZ	154+j217	940	103
WMIX	110+j159	940	103.2
WEOO	36.5-j21	940	169
WCPC	122-j306	940	189
KRRP	38.8+j32.6	950	85
KMTX	48+j71	950	90.4
KAKC	45+j94.9	970	92.3
WFIA	66-j249	970	201.3
WPIP	49.7+j86	980	89.7
WCAP	47+j88	980	90
WMUF	59+j94	1000	89.6
WRNJ	47+j57	1000	90
KOTD	47+j67	1000	90
KANI	111+j86	1000	98.7
WPMH	62+j118.8	1010	90
KKIK	45.3+j117	1010	99.8
KTNQ	85-j202	1020	180
KTWO	48+j72	1030	90
WOSO	48+j107	1030	90
WSKE	26.5+j0.8	1050	76.8
KBUF	65.5+j164	1050	104.4
WCMG	245+j924	1050	146
KAYR	21-j44	1060	64
WMCL	34+j67.9	1060	85
KERR	90+j171	1070	97.8
WQRO	43+j49.7	1080	86.9

Call	Measured Impedance ohms	Frequency kHz	Free-Space Electrical Height degrees
WVCG	55.5+j67	1080	90
WEEP	126+j264	1080	111
WPNS	339+j187	1080	114.5
KBOZ	71+j117	1090	95.7
KFAX	46+j52	1100	90
WVNH	12-j115.6	1110	52.82
KAKA	46.81+j69.2	1110	89.3
WZAM	48+j54.1	1110	89.3
WUNN	50+j84	1110	89.8
KTEK	50+j70	1110	90
WKEG	52+j75	1110	90
WHYT	115+j184.6	1110	105.6
WHYT	150+j207	1110	105.6
WKED	36+j70	1130	80
WEEO	56.5+j76	1130	91
KQTI	57.5+j80	1130	91
KWBY	58.3+j83.2	1130	91
KQTI	58+j75	1130	91
WKWM	49.1+j72	1140	90
KMJJ	88.5+j138.9	1140	100.1
KWBZ	15.11-j90	1150	58.9
WYFE	26+j17.4	1150	76.8
KCCT	55+j94.88	1150	90
KSUZ	54+j68	1150	92.5
WTMP	54+j113	1150	100.17
KFND	41+j92.3	1170	89.9
WBRW	48.5+j104.3	1170	90
WJMQ	49+j88	1170	90
VLC	225-j350	1170	145.5
KJNP	596-j270	1170	180
KHAD	34+j2	1190	78.4
KRZJ	54+j37.8	1190	78.4

Call	Measured Impedance ohms	Frequency kHz	Free-Space Electrical Height degrees
KAYO	64.2+j109.3	1190	91.5
WBDY	89+j128.6	1190	100
KKOY	234+j277	1190	113.2
KGYN	46.4+j64.5	1210	90
WHOY	66+j66	1210	90.3
WHOY	61+j69	1210	90.8
WKRS	134.8+j22	1220	142
KNCO	66+j95.2	1250	86.9
KUKA	68+j116	1250	92
WARE	44+j28	1250	94.7
KBRF	169+j280	1250	114
WGHB	54.5+j409.6	1250	152.8
WXCE	15.7-j63.5	1260	63.1
WNRK	55+j87	1260	90
WVOY	27.3+j7.8	1270	73.4
WMRL	60+j96.8	1270	93
WWCA	227+j288	1270	116
WTJZ	85-j189.2	1270	192.9
KBDF	62.5+j105	1280	90
KMAS	66.1+j105.04	1280	93.77
KFRN	178+j90.5	1280	137.7
KLEH	25-j12	1290	70.8
WTNX	49+j79.2	1290	89.6
WOPP	46+j76	1290	90
WCHK	47+j75.2	1290	90
WHIO	340-j55	1290	130
WXRL	56+j96	1300	90
KRWL	52+j87	1300	90.5
WIBR	61+j99	1300	93.2
KHUG	82-j218	1300	190.3
WAUC	20.75-j65	1310	65
WKKX	50.5+j147.1	1310	92.5

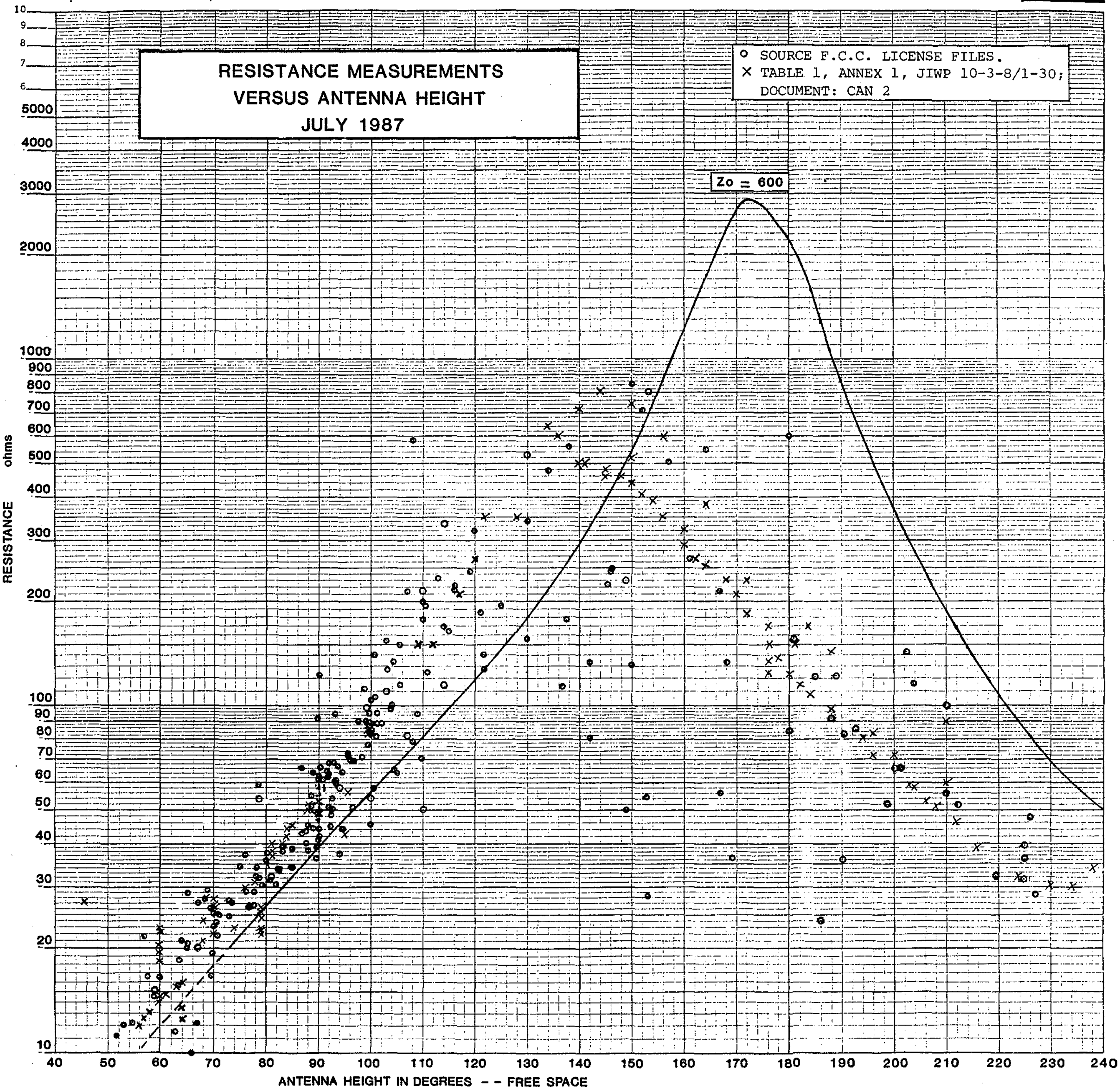
Call	Measured Impedance ohms	Frequency kHz	Free-Space Electrical Height degrees
WICH	133-j286	1310	168
WTTL	24-j214	1310	186
KAAM	31.5-j118	1310	225
WOBL	37.0+j16	1320	76
WAGY	69+j115	1320	96.6
KOZY	84.5+j144	1320	100
KGNR	320+j289	1320	120
WKIN	194+j343	1320	125
KCPX	80.5-j150	1320	142
WAMR	130-j265.9	1320	150
WASA	128+j268	1330	121.7
WHET	121-j541	1330	185
WEGA	59+j88.9	1350	90
WNIS	98+j144.5	1350	99
WABT	19.3-j28.2	1360	69.8
KKBJ	52.2+j77.2	1360	89.1
WKYO	52+j106	1360	90
WCQL	21.8-j34.6	1370	70.7
WLLN	44+j50.4	1370	90
KLBA	52+j72.9	1370	90
WCOA	83+j182	1370	100
KSOP	103+j167	1370	100.3
KSUM	530+j292	1370	130.3
WSOL	842-j86.3	1370	150
KDTH	100-j222	1370	210
WDAT	106.5+j163	1380	100.9
WPHM	95+j185	1380	101
WTVR	187+j298	1380	121.2
KWK	267-j390	1380	161
WIZO	548-j210	1380	164
KWK	66-j196	1380	200
WTJS	64+j61.9	1390	94.6

Call	Measured Impedance ohms	Frequency kHz	Free-Space Electrical Height degrees
WPLM	36-j142	1390	190
WDOT	39.5+j106.6	1390	225
KBCC	11.2-j53	1410	51.6
WTIM	92-j220	1410	89.7
KUCH	127+j219.9	1410	103
KLLO	47.5-j228	1410	226
KLFB	11.5-j87	1420	62.4
WINI	20.4-j23.9	1420	67
KPAR	34.5-j23.9	1420	75.3
KITI	55+j69.58	1420	88.4
KBTN	57.9+j94	1420	89.8
WLNA	200+j224.4	1420	110
WYMC	27.5-j1.5	1430	73
KALV	31.8-j6.96	1430	78.5
WBEV	88.5+j190.9	1430	102
WQDI	133+j236	1430	104.6
KLO	507.2-j457.98	1430	157
WVAM	92-j249	1430	188
WRDD	164+j297	1440	115
KEYS	248.7+j418	1440	146
WEWO	46.3+j76.8	1460	89.8
WACO	82+j175	1460	106.9
WKCK	76.4+j153.55	1470	99.49
KVLH	212.9+j270	1470	107
KNDE	582+j410	1470	108
KBOX	26.1-j22.2	1480	69.3
KQLA	32.3+j27.01	1480	81
WTHI	55+j93	1480	89.4
WISM	79+j204	1480	108
KVAN	215.1+j253.8	1480	110
KWUN	50+j130	1480	110
KYOS	242+j412	1480	119.3

Call	Measured Impedance ohms	Frequency kHz	Free-Space Electrical Height degrees
WCIN	28.5-j53.0	1480	227.2
WUIV	16.7-j71.6	1500	69.4
WGFT	55+j98	1500	90
WKRP	59.5+j90	1500	93.3
WINU	38+j47	1510	83
WRGI	51.5+j96	1510	88.4
KYKR	57.9+j84	1510	93.9
KDKO	193+j205	1510	110.5
WNLC	140+j298	1510	121.53
WPOE	95+j193	1520	109
WTGR	56-j297	1520	166.8
KOMA	158-j222	1520	181
KOLM	36-j82	1520	225
WKDC	36.5+j44.4	1530	89.6
WDJZ	57.5+j64.3	1530	100.8
WCKY	52-j113	1530	198.7
WCRJ	56-j156	1530	210
WNRE	88.5+j176	1540	101
WAAY	60.5+j113.5	1550	90
WMAD	58+j107.2	1550	90
WCTW	560+j292	1550	138
WKVL	32.2-j136.4	1550	219.5
KCJJ	37.5+j40.4	1560	80
WSHY	55.2+j85.3	1560	90
KAJN	56.8+j82	1560	90
WOBL	123+j130.6	1570	90
WPGC	73+j134	1580	95.5
WPMP	215+j341	1580	116
KDJS	55+j107	1590	90
WJBT	62+j117.7	1590	91.7
KRAD	94+j111	1590	93
WHPY	68+j121	1590	93.1

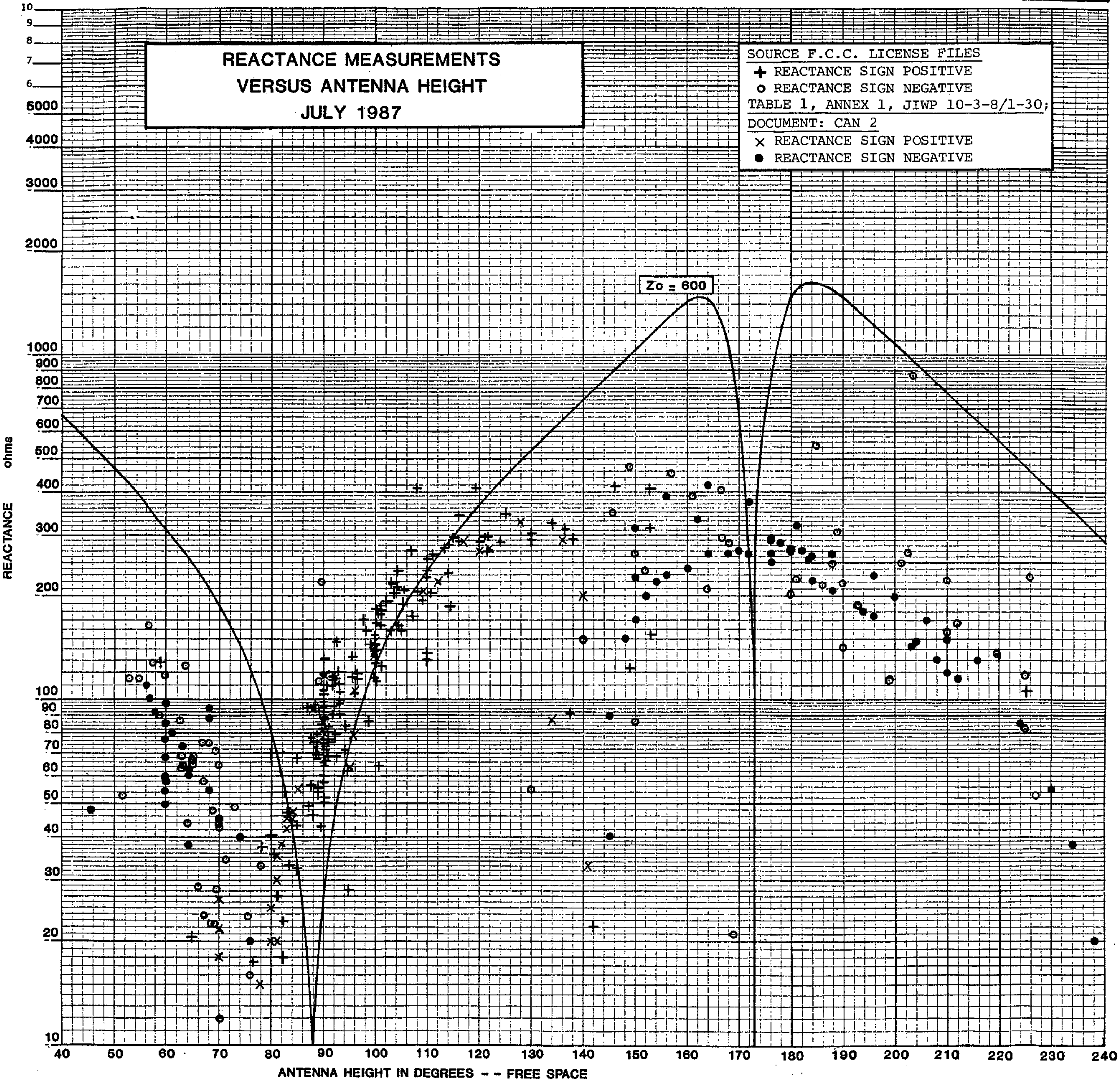
Call	Measured Impedance ohms	Frequency kHz	Free-Space Electrical Height degrees
WEEZ	28+j155	1590	153
WEEZ	800+j315	1590	153
KMTI	142-j268	1590	202.5
WAIK	116-j865	1590	203.7
WRBN	40+j77.5	1600	87.7
WLUZ	45.25+j75.2	1600	88
WLPQ	39+j43	1600	89.6
KATZ	51+j76.2	1600	90
KXEW	63.5+j114.4	1600	91.9
WIXY	200+j237.5	1600	110
KGST	117.33+j232.25	1600	114.2
WEUP	50+j121.9	1600	149
WOKB	212-j405	1600	166.8
WPOM	51.5-j166.8	1600	212

FIGURE 1



RESISTANCE MEASUREMENTS
VERSUS ANTENNA HEIGHT
JULY 1987
O SOURCE F.C.C. LICENSE FILES.
X TABLE 1, ANNEX 1, JIWP 10-3-8/1-30;
DOCUMENT: CAN 2
Zo = 600
RESISTANCE ohms
10
9
8
7
6
5000
4000
3000
2000
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240
ANTENNA HEIGHT IN DEGREES - - FREE SPACE

FIGURE 2



REACTANCE MEASUREMENTS
VERSUS ANTENNA HEIGHT
JULY 1987
SOURCE F.C.C. LICENSE FILES
+ REACTANCE SIGN POSITIVE
o REACTANCE SIGN NEGATIVE
TABLE 1, ANNEX 1, JIWP 10-3-8/1-30;
DOCUMENT: CAN 2
× REACTANCE SIGN POSITIVE
● REACTANCE SIGN NEGATIVE
Zo = 600
REACTANCE ohms
10
9
8
7
6
5000
4000
3000
2000
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240
ANTENNA HEIGHT IN DEGREES - - FREE SPACE

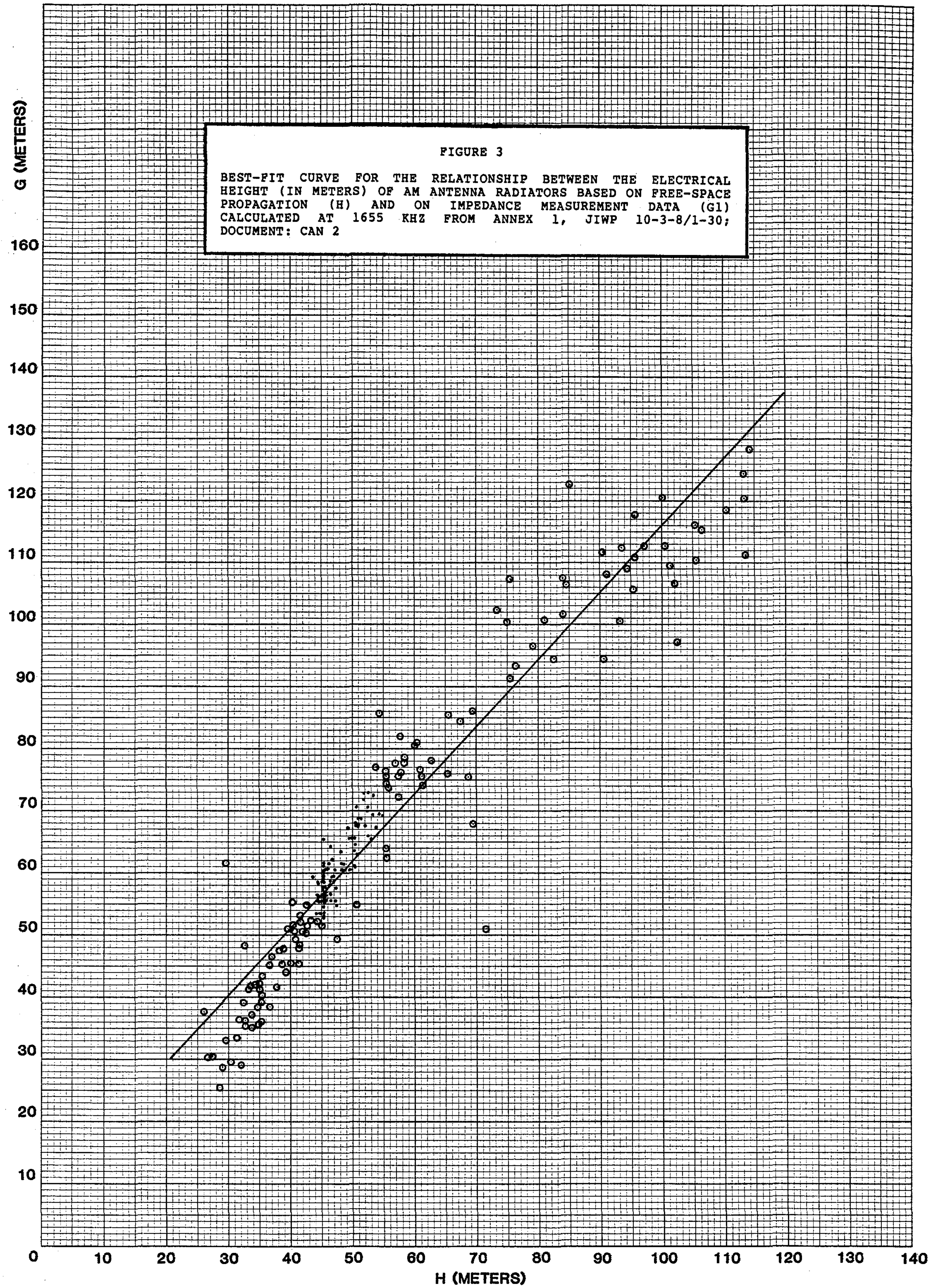
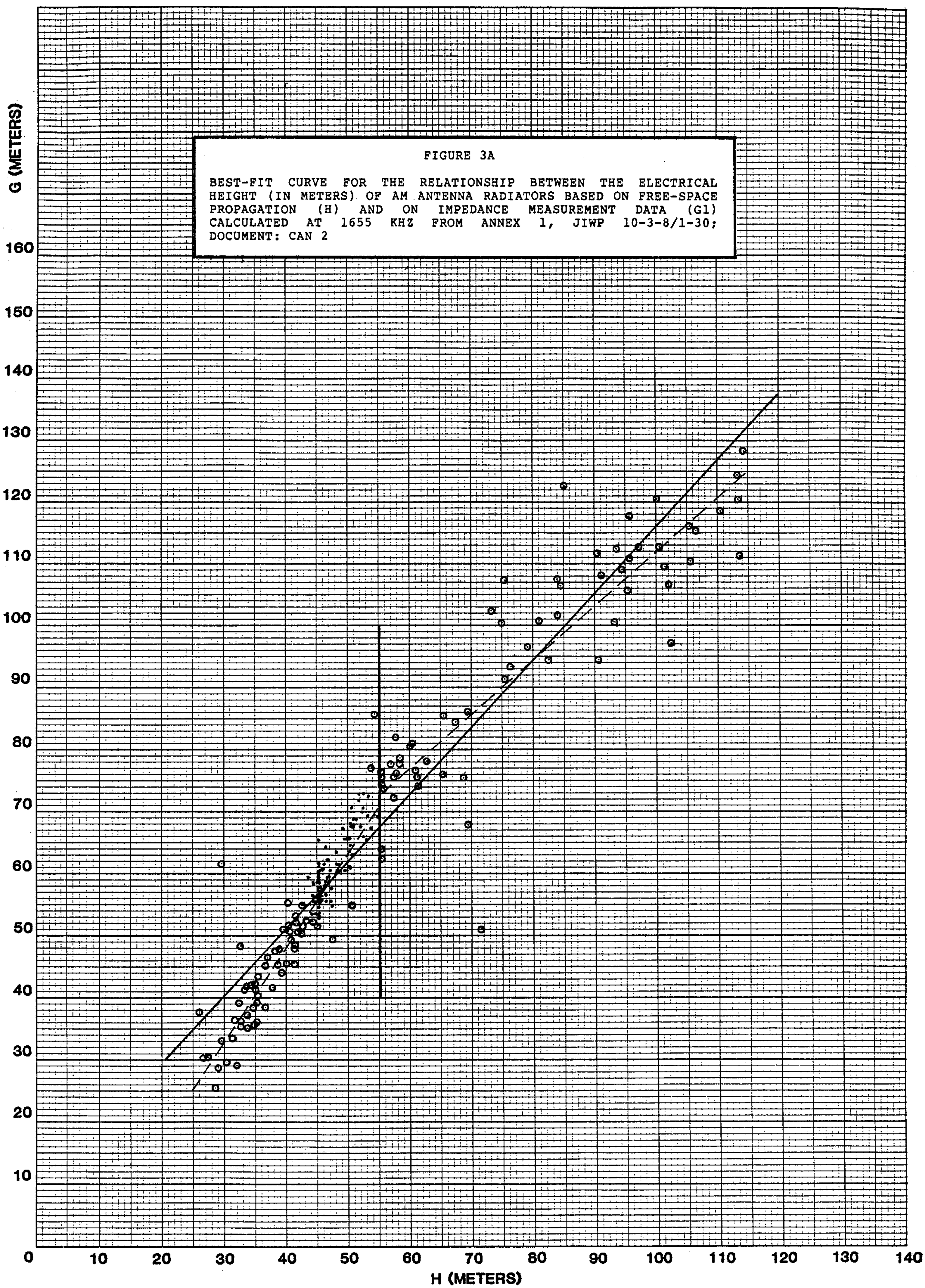
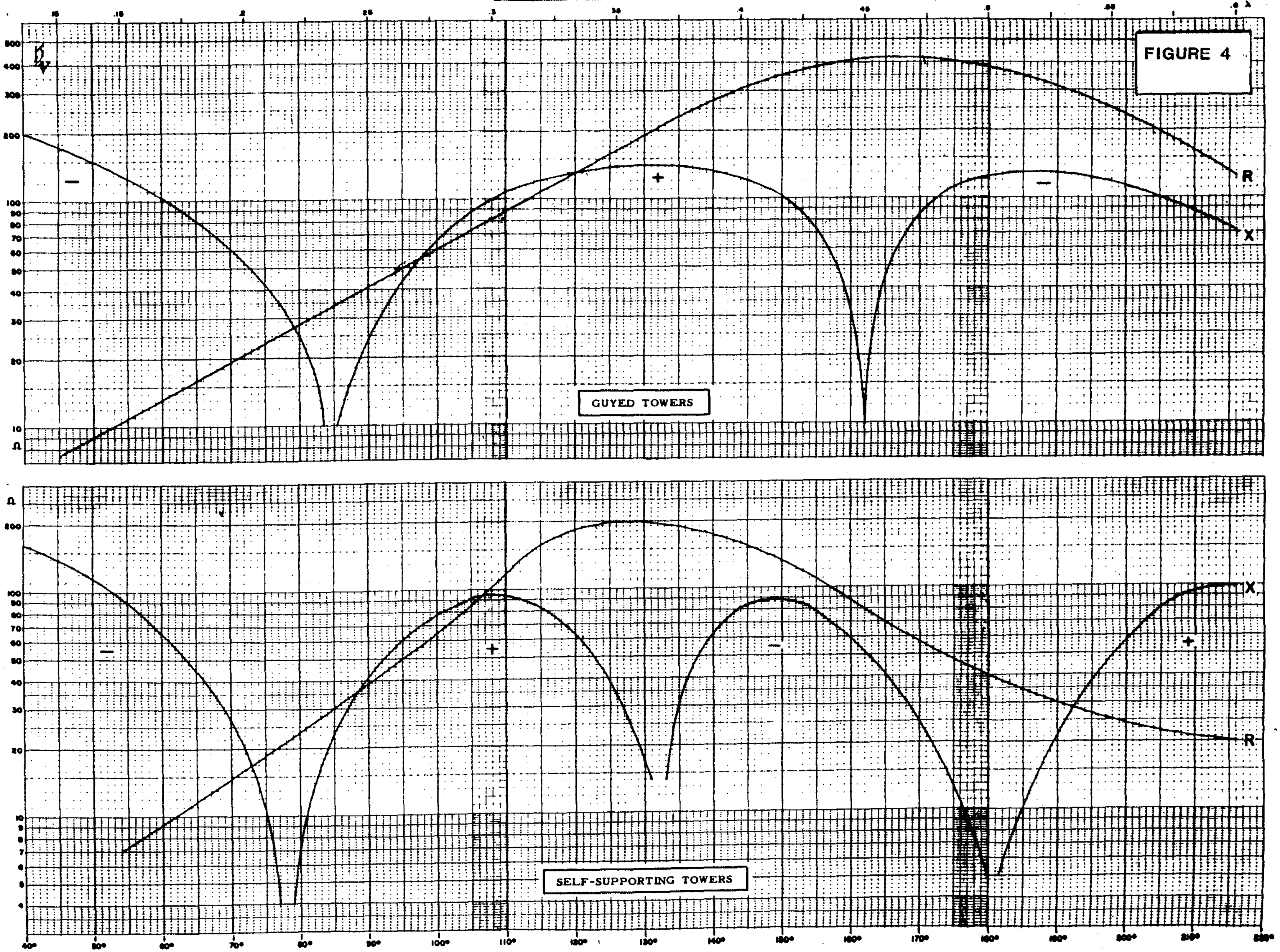


FIGURE 3

BEST-FIT CURVE FOR THE RELATIONSHIP BETWEEN THE ELECTRICAL HEIGHT (IN METERS) OF AM ANTENNA RADIATORS BASED ON FREE-SPACE PROPAGATION (H) AND ON IMPEDANCE MEASUREMENT DATA (G1) CALCULATED AT 1655 KHZ FROM ANNEX 1, JIWP 10-3-8/1-30; DOCUMENT: CAN 2


G (METERS)
FIGURE 3A
BEST-FIT CURVE FOR THE RELATIONSHIP BETWEEN THE ELECTRICAL HEIGHT (IN METERS) OF AM ANTENNA RADIATORS BASED ON FREE-SPACE PROPAGATION (H) AND ON IMPEDANCE MEASUREMENT DATA (G1) CALCULATED AT 1655 KHZ FROM ANNEX 1, JIWP 10-3-8/1-30; DOCUMENT: CAN 2
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
H (METERS)

HISTORICAL INFORMATION



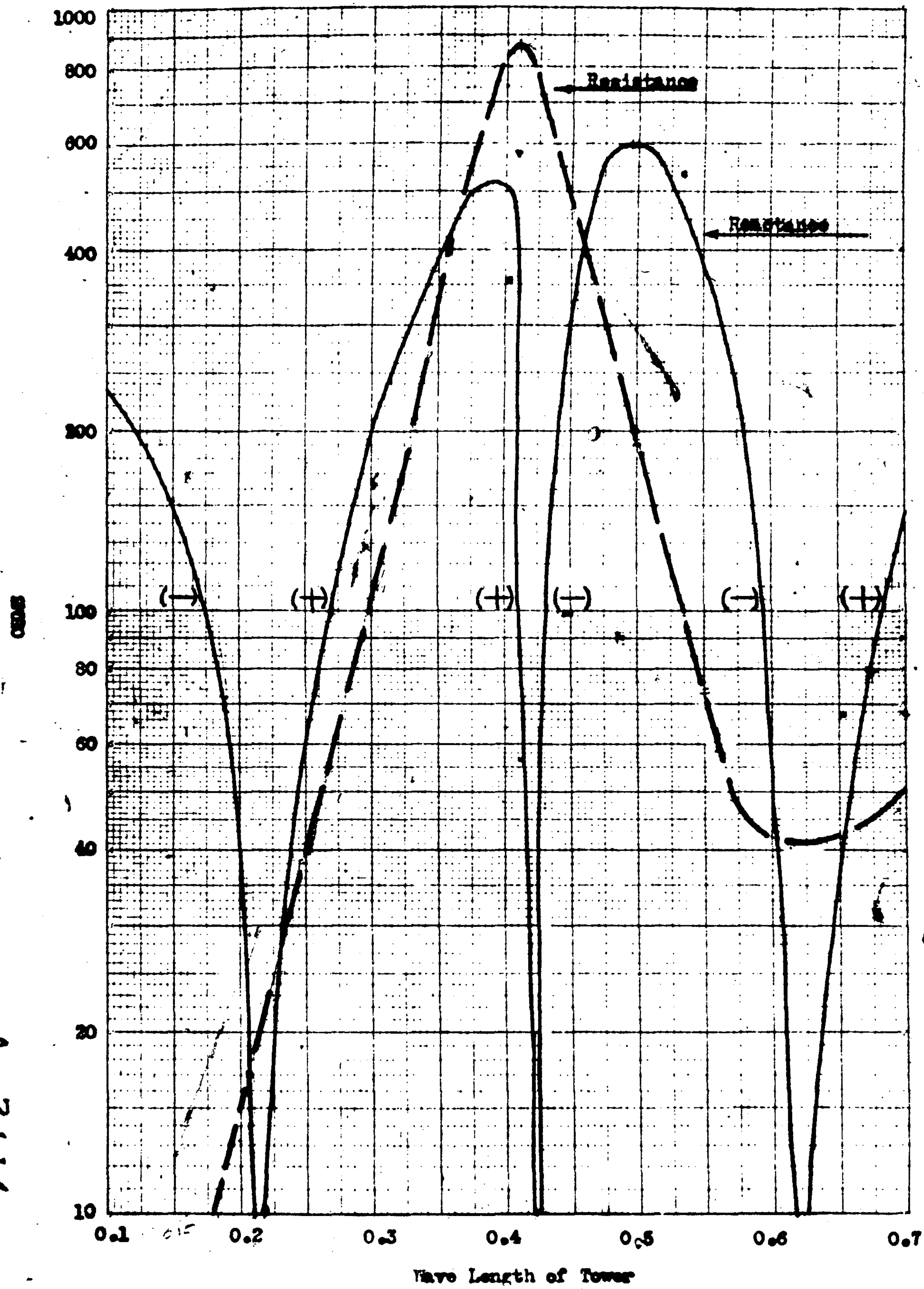
GRAPH OF RESISTANCE AND
REACTANCE VERSUS TOWER HEIGHT
(Based on I.R.E. Curves)

FIGURE 5

RADIATION RESISTANCE AND REACTANCE OF WINCHARGER RADIO TOWERS

HISTORICAL INFORMATION

A-3114



A-3114

Wincharger Corporation
Sioux City, Iowa

TABLE III

```
C       PROGRAM NAME:  AM.FOR
C       WRITTEN JULY  1987
C       EXPRESS THE ELECTRICAL HEIGHT OF AM ANTENNA RADIATORS
C       FROM BASE IMPEDANCE MEASUREMENTS.
C
C
C       NAME OF INPUT FILES:  IMPEDANCE.DAT -- IMPEDTWO.DAT
C               (THE IMPEDTWO.DAT FILE HAS BEEN ELIMINATED
C               OF QUESTIONABLE POINTS)
C       NAME OF OUTPUT FILES:  LINEFIT.DAT
C                              CANADIAN.DAT
C
C
C       VARIABLE LIST:
C
C               ARRAYS:
C               H(500) = ELECTRICAL HEIGHT IN DEGREES
C                        BASED ON FREE SPACE PROPAGATION
C               G(500) = ELECTRICAL HEIGHT IN DEGREES
C                        FROM BASE IMPEDANCE MEASUREMENTS
C              HM(500) = ELECTRICAL HEIGHT IN METERS - FREE SPACE
C           GM(500) = ELECTRICAL HEIGHT IN METERS - IMPEDANCE
C              GH(500) = RATIO OF G TO H (IN DEGREES)
C               R(500) = RESISTANCE (OHMS)
C              JX(500) = REACTANCE (OHMS)
C          COM(500) = ALPHANUMERIC ARRAY FOR TAGGING QUESTIONABLE POINTS
C               STRING = HEADER LINE OF INPUT FILE
C
C
C
C       VARIABLES USED FOR LEAST SQUARES:
C
C               XSUM, YSUM, XSQSUM, YSQSUM, XYSUM = SUMMATIONS OF
C                        X, Y, THEIR SQUARES AND CROSS PRODUCT
C                        CORR = CORRELATION COEFFICIENT
C                       SLOPE = SLOPE OF BEST-FIT LINE
C                      NTRCPT = Y-INTERCEPT OF BEST-FIT LINE
C                           D = INTERMEDIATE VARIABLE TO SIMPLIFY EQUATIONS
C
C                        Q = CONVIENCE VARIABLE FOR G(J)
C                        J = LOOP COUNTER
C                        N = # OF ELEMENTS IN ARRAY
C                       NR = NORMALIZED RESISTANCE
C                       NZ = NORMALIZED REACTANCE
C                        C = COUNTER FOR PRINTOUT
C                        P = COUNTER FOR PRINTOUT
C
C*****************************************************************
C
C       VARIABLE DECLARATION:
C
        DIMENSION R(500),JX(500),H(500),GH(500),HM(500),GM(500),G(500)
        REAL   NR, NX, XSUM, YSUM, XSQSUM, YSQSUM, XYSUM, D, SLOPE
      REAL   NTRCPT, CORR, G, JX

        INTEGER J, N, Z, C, P

        INTRINSIC ATAN2

        CHARACTER*72 STRING

        CHARACTER*1 COM(500)
C
```

```
C*****************************************************************
C
C         INPUT
C
C
        OPEN(1,FILE='IMPEDTWO.DAT')
                  READ(1,5) STRING
5                 FORMAT(A72)
C
C
C          NOTE:  SET UPPER LIMIT TO ONE LESS THAN # OF LINES IN FILE
           DO 10 J = 1, 248
                  READ(1,*,END=10,ERR=10)R(J), JX(J), H(J)
10         CONTINUE
C
           N = J - 1
C
C*****************************************************************
C
C
C         PROCESSING:  CALCULATING G
C                                (THE ELECTRICAL HEIGHT)
C
C
           DO 50  J = 1, N
                  COM(J) = ' '
                  NR =R(J)/200
                  NX = JX(J)/200
C
C
                  Q = 0.5 * (ATAN2((-2*NX),(NX*NX + NR*NR -1)))
                  G = Q * 180 / 3.14159
C
                  IF (G .LE. 0) THEN
                        Q=G+180
                  ENDIF
C
C
                  IF (NX.LT.0) THEN
C
                  IF (H(J).GE.111)  THEN
                        Q = Q + 180
                  ENDIF

                        IF(H(J).GE.72) THEN
                              IF(H(J).LE.144)  THEN
                              COM(J) = '*'
                              ENDIF
                        ENDIF
C
                  ELSE
30                IF (H(J).GE.192)  THEN
                        Q = Q + 180
                  ENDIF
                        IF(H(J).GT.144)  THEN
                              IF(H(J).LT.244)  THEN
                                COM(J) = '*'
                              ENDIF
                        ENDIF


                   ENDIF

          G(J) = Q

50        CONTINUE
```

```
C*******************************************************************
C
C  PROCESSING:  CALCULATE G / H RATIOS
                DO 100 J = 1, N
                        GH(J) = G(J) / H(J)
100          CONTINUE
C
C*******************************************************************
C
C        PROCESSING:  CALCULATE H(METERS) AND G(METERS)
          DO 200  J = 1, N

                HM(J) = H(J) / 360 * 181.27
C
C        NOTE:   181.27 = WAVELENHTH(METERS) AT 1655 kHz IN FREE SPACE
C
                GM(J) = GH(J) * HM(J)

200       CONTINUE
C
C
C*******************************************************************
C
C        PROCESSING:  BEST FIT LINE (LEAST SQUARES METHOD)
          DO 310  J = 1, N

                XSUM = XSUM + HM(J)
                YSUM = YSUM + GM(J)
              XSQSUM = XSQSUM + HM(J) * HM(J)
              YSQSUM = YSQSUM + GM(J) * GM(J)
               XYSUM = XYSUM + HM(J) * GM(J)

310       CONTINUE
C
C
C
          D = N*XSQSUM - (XSUM*XSUM)

          SLOPE = (N * XYSUM - XSUM * YSUM) / D

          NTRCPT = (XSQSUM * YSUM - XSUM * XYSUM) / D

          CORR = (XYSUM - XSUM*YSUM/N) / ((XSQSUM - (XSUM**2) / N)
     *  * (YSQSUM - (YSUM**2) / N )) ** 0.5

C
C
C*******************************************************************
C
C        OUTPUT:  WRITE RESULT OF LEAST-SQUARES TO FILE

          OPEN(1,FILE='LINEFIT.DAT',STATUS='NEW')

          DO 305  J = 1, 6
                WRITE(1,*)
305       CONTINUE

          WRITE (1,311)
311       FORMAT (1X,'RESULTS OF LINE-FIT ROUTINE')
          WRITE(1,*) 'NUMBER OF POINTS = ',N
          WRITE(1,312)  SLOPE, NTRCPT, CORR
312       FORMAT(1X,'SLOPE = ', F4.2,5X, 'Y-INTERCEPT = ', F6.2,5X,
     * 'CORRELATION COEFFICIENT =  ', F5.4)
          WRITE(1,*)'* -INDICATES POINT REQUIRES FURTHER INSPECTION'
```

```
        WRITE (1,*)
        WRITE (1,*)
        WRITE (1,315)
315     FORMAT(1X, 'H(DEGREES)', 4X, 'H(METERS)', 4X, 'G(METERS)',
     *   3X, 'BEST-FIT G(METERS)    DIFFERENCE(METERS)')

        WRITE (1,*)

        DO 330  J = 1, 46
                WRITE (1,335)COM(J),H(J),HM(J),GM(J),SLOPE*HM(J)+NTRCPT,
     *                  GM(J) - (SLOPE * HM(J) + NTRCPT)
335             FORMAT(2X,A1,1X,F5.1,8X,F5.1,8X,F5.1,11X,F5.1,14X,F5.1)
                C = C + 1
330     CONTINUE
C
C
C************** PAGE 2 AND FOLLOWING


340     DO 350  J = 1, 12
                WRITE(1,*)
350     CONTINUE

        WRITE(1,315)
        WRITE(1,*)
        P = C + 1
        DO 370  J = P, P + 51
                WRITE(1,335)COM(J),H(J),HM(J),GM(J),SLOPE*HM(J)+NTRCPT,
     *  GM(J) - (SLOPE * HM(J) + NTRCPT)
                C = C + 1
                IF (C.EQ.N) GOTO 380
370     CONTINUE

        GOTO 340

        WRITE(*,*) 'OUT OF BEST WRITE'

C*****************************************************************
C
C       OUTPUT:  WRITE TABLE 1 TO FILE

380     C = 0
        P = 0

        OPEN (1,FILE='CANADIAN.DAT',STATUS='NEW')

        DO 490  J = 1, 4
                WRITE(1,*)
490     CONTINUE

        WRITE (1,500)
500     FORMAT(1X, 17X, 'TABLE 1:  IMPEDANCE MEASUREMENT DATA,')
        WRITE (1,501)  'G1 AND H* VALUES IN METRES           '
501     FORMAT(1X, 27X, A35)
        WRITE (1,501) 'AND DEGREES, AND DERIVATION OF      '
        WRITE (1,501) 'G1 AND H VALUES AT 1655 KHZ         '
        WRITE (1,*)
        WRITE (1,501) '* --INDICATES CALCULATED G REQUIRES'
        WRITE (1,501) '     FURTHER INSPECTION             '
        WRITE (1,*)
        WRITE (1,*)
C
C************** PAGE 1 ***************
C
        WRITE (1,503)
503     FORMAT(1X,7X,'H',11X,'R',9X,'JX',10X,'G1',6X,'G1/H'
```

```
      *     , 8X, '(H(1455)', 5X, '(B1(1990)')
            WRITE (1,504)
504    FORMAT(1X,5X,'(DEGREES)', 5X, '(OHMS)', 4X, '(OHMS)', 4X,
      *  '(DEGREES)', 9X,'(METRES)',5X, '(METRES)')
            WRITE (1,*)
C
C

            DO 610  J = 1, 44
                   C = C + 1
                   WRITE(1,605) COM(J),H(J),R(J),JX(J),B(J),GH(J),HH(J),GM(J)
605                FORMAT(1X,2X,A1,4X,F5.1,7X,F5.1,5X,F6.1,6X,F5.1,5X,
      *  F4.2,4X, F5.1,7X, F5.1)

610         CONTINUE
C
C
C**************** PAGE 2 AND FOLLOWING ***
C

540         DO 545 J = 1,12
                   WRITE(1,*)
545         CONTINUE

            WRITE (1,503)
            WRITE (1,504)
            WRITE (1,*)

            P = C + 1
            DO 570  J = P, P + 50

                   WRITE(1,605) COM(J),H(J),R(J),JX(J),B(J),GH(J),HH(J),GM(J)
                   C = C + 1
                   IF (C.EQ.N) GOTO 580

570         CONTINUE

            GOTO 540
C
580    END

[C:\FORTRAN]
```

TABLE IV : IMPEDANCE MEASUREMENT DATA,
G1 AND H* VALUES IN METRES
AND DEGREES, AND DERIVATION OF
G1 AND H VALUES AT 1655 KHZ

* --INDICATES CALCULATED G REQUIRES
FURTHER INSPECTION

	H (DEGREES)	R (OHMS)	JX (OHMS)	G1 (DEGREES)	G1/H	H(1655) (METRES)	G1(1655) (METRES)
	51.6	11.2	-53.0	75.1	1.46	26.0	37.8
	52.8	12.0	-115.6	59.9	1.13	26.6	30.2
	54.5	12.3	-114.0	60.2	1.11	27.4	30.3
	56.7	21.5	-164.5	50.4	.89	28.6	25.4
	57.6	16.7	-128.6	57.1	.99	29.0	28.8
	58.9	15.1	-90.0	65.7	1.11	29.7	33.1
	59.0	14.6	128.2	122.8	2.08	29.7	61.8
	60.9	16.5	-119.0	59.1	.99	30.2	29.8
	62.4	11.5	-87.0	66.4	1.06	31.4	33.5
	63.1	15.7	-63.5	72.3	1.15	31.8	36.4
	63.5	18.5	-125.9	57.7	.91	32.0	29.0
	64.0	21.0	-44.0	77.5	1.21	32.2	39.0
	65.0	28.9	20.7	96.0	1.48	32.7	48.4
	65.0	20.0	-69.3	70.7	1.09	32.7	35.6
	65.0	20.8	-65.0	71.9	1.11	32.7	36.2
	65.9	10.0	-28.8	81.8	1.24	33.2	41.2
	67.0	12.2	-58.0	73.8	1.10	33.7	37.1
	67.0	27.0	-72.5	69.8	1.04	33.7	35.1
	67.0	20.4	-23.9	83.1	1.24	33.7	41.9
	68.2	27.8	-22.6-	83.4	1.22	34.3	42.0
	69.0	29.5	-48.1	76.2	1.10	34.7	38.4
	69.3	26.1	-22.2	83.6	1.21	34.9	42.1
	69.4	16.7	-71.6	70.2	1.01	34.9	35.3
	69.8	19.3	-28.2	81.9	1.17	35.1	41.2
	70.0	25.0	-65.0	71.8	1.03	35.2	36.1
	70.0	23.1	-43.2	77.7	1.11	35.2	39.1
	70.5	23.8	-42.9	77.7	1.10	35.5	39.1
	70.7	21.8	-34.6	80.1	1.13	35.6	40.3
	70.8	25.0	-12.0	86.5	1.22	35.6	43.6
	73.0	24.9	-49.1	76.0	1.04	36.8	38.3
	73.0	27.5	-1.5	89.6	1.23	36.8	45.1
	73.4	27.3	7.9	92.3	1.26	37.0	46.5
	75.3	34.5	-23.9	83.0	1.10	37.9	41.8
	76.0	37.0	16.0	94.7	1.25	38.3	47.7
	76.1	29.0	3.3	91.0	1.20	38.3	45.8
	76.8	26.5	.8	90.2	1.17	38.7	45.4
	76.8	26.0	17.4	95.1	1.24	38.7	47.9
	77.8	29.0	-8.7	87.5	1.12	39.2	44.0
	77.8	26.8	-9.0	87.4	1.12	39.2	44.0
*	78.1	32.0	-13.0	86.2	1.10	39.3	43.4
*	78.1	34.0	-33.0	80.4	1.03	39.3	40.5
	78.4	54.0	37.8	101.5	1.29	39.5	51.1
*	78.5	31.8	-7.0	88.0	1.12	39.5	44.3
	79.4	30.5	1.0	90.3	1.14	40;0	45.5

	H (DEGREES)	R (OHMS)	JX (OHMS)	G1 (DEGREES)	G1/H	H(1655) (METRES)	G1(1655) (METRES)
	80.0	36.0	70.0	109.8	1.37	40.3	55.3
	80.0	37.5	40.4	101.8	1.27	40.3	51.3
	80.8	31.5	35.9	100.4	1.24	40.7	50.6
	81.0	32.3	27.0	97.9	1.21	40.8	49.3
	82.0	30.5	1.0	90.3	1.10	41.3	45.5
	82.3	33.8	18.0	95.3	1.16	41.4	48.0
	82.4	33.5	23.0	96.7	1.17	41.5	48.7
	82.5	34.0	53.9	105.5	1.28	41.5	53.1
	83.0	38.0	47.0	103.7	1.25	41.8	52.2
	83.3	39.5	36.0	100.6	1.21	41.9	50.7
	84.9	34.3	43.0	102.5	1.21	42.7	51.6
	85.0	38.3	32.6	99.6	1.17	42.8	50.2
	85.0	34.0	67.9	109.2	1.28	42.8	55.0
	86.9	43.0	49.7	104.6	1.20	43.8	52.7
	86.9	66.0	95.2	117.5	1.35	43.8	59.2
	87.5	43.5	56.3	106.4	1.22	44.1	53.6
	87.7	40.0	77.5	111.9	1.28	44.2	56.3
	88.0	38.5	46.0	103.4	1.18	44.3	52.1
	88.0	45.3	75.2	111.5	1.27	44.3	56.1
	88.4	55.0	69.6	110.4	1.25	44.5	55.6
	88.4	51.5	96.0	116.9	1.32	44.5	58.9
	88.5	49.5	74.2	111.4	1.26	44.6	56.1
	88.9	64.0	55.0	106.9	1.20	44.8	53.8
	89.0	44.5	92.1	115.6	1.30	44.8	58.2
	89.1	52.2	77.2	112.3	1.26	44.9	56.5
*	89.2	48.5	-113.0	59.4	.67	44.9	29.9
	89.3	46.8	69.2	110.0	1.23	45.0	55.4
	89.3	48.0	54.1	105.9	1.19	45.0	53.3
	89.4	55.0	93.0	116.4	1.30	45.0	58.6
	89.5	59.0	94.0	116.8	1.30	45.1	58.8
	89.6	49.0	79.2	112.7	1.26	45.1	56.7
	89.6	36.5	44.4	102.9	1.15	45.1	51.8
	89.6	39.0	43.0	102.6	1.14	45.1	51.7
	89.7	49.7	86.0	114.4	1.28	45.2	57.6
*	89.7	92.0	-220.0	39.6	.44	45.2	19.9
	89.8	50.0	84.0	113.9	1.27	45.2	57.4
	89.8	57.9	94.0	116.8	1.30	45.2	58.8
	89.9	46.3	76.8	111.9	1.25	45.2	56.4
	89.9	41.0	92.3	115.5	1.29	45.3	58.2
	90.0	46.5	71.8	110.7	1.23	45.3	55.7
	90.0	44.0	64.9	108.7	1.21	45.3	54.8
	90.0	49.0	70.0	110.3	1.23	45.3	55.5
	90.0	44.0	56.9	106.6	1.18	45.3	53.7
	90.0	49.1	60.0	107.6	1.20	45.3	54.2
	90.0	42.0	87.9	114.5	1.27	45.3	57.7
	90.0	47.0	92.0	115.7	1.29	45.3	58.3
	90.0	50.0	64.0	108.7	1.21	45.3	54.7
	90.0	38.0	118.3	121.3	1.35	45.3	61.1
	90.0	47.0	88.0	114.8	1.28	45.3	57.8
	90.0	47.0	57.0	106.7	1.19	45.3	53.7
	90.0	47.0	67.0	109.4	1.22	45.3	55.1

H (DEGREES)	R (OHMS)	JX (OHMS)	G1 (DEGREES)	G1/H	H(1655) (METRES)	G1(1655) (METRES)
90.0	62.0	118.8	122.6	1.36	45.3	61.7
90.0	48.0	72.0	110.8	1.23	45.3	55.8
90.0	48.0	107.0	119.2	1.32	45.3	60.0
90.0	55.5	67.0	109.8	1.22	45.3	55.3
90.0	46.0	52.0	105.3	1.17	45.3	53.0
90.0	50.0	70.0	110.3	1.23	45.3	55.6
90.0	52.0	75.0	111.7	1.24	45.3	56.3
90.0	49.1	72.0	110.8	1.23	45.3	55.8
90.0	55.0	94.9	116.8	1.30	45.3	58.8
90.0	48.5	104.3	118.7	1.32	45.3	59.7
90.0	49.0	88.0	114.8	1.28	45.3	57.8
90.0	46.4	64.5	108.7	1.21	45.3	54.7
90.0	55.0	87.0	114.9	1.28	45.3	57.9
90.0	62.5	105.0	119.6	1.33	45.3	60.2
90.0	46.0	76.0	111.7	1.24	45.3	56.3
90.0	47.0	75.2	111.6	1.24	45.3	56.2
90.0	56.0	96.0	117.1	1.30	45.3	59.0
90.0	59.0	88.9	115.6	1.28	45.3	58.2
90.0	52.0	106.0	119.2	1.32	45.3	60.0
90.0	44.0	50.4	104.8	1.16	45.3	52.8
90.0	52.0	72.9	111.2	1.24	45.3	56.0
90.0	55.0	98.0	117.5	1.31	45.3	59.2
90.0	60.5	113.5	121.3	1.35	45.3	61.1
90.0	58.0	107.2	119.8	1.33	45.3	60.3
90.0	55.2	85.3	114.5	1.27	45.3	57.6
90.0	56.8	82.0	113.3	1.26	45.3	37.3
90.0	123.0	130.6	130.7	1.45	45.3	65.8
90.0	55.0	107.0	119.6	1.33	45.3	60.2
90.0	51.0	76.2	112.0	1.24	45.3	56.4
90.3	46.0	66.0	110.1	1.22	45.5	55.4
90.4	48.0	71.0	110.5	1.22	45.5	55.6
90.5	50.0	110.0	120.0	1.33	45.6	60.4
90.5	52.0	87.0	114.7	1.27	45.6	57.8
90.8	61.0	69.0	110.6	1.22	45.7	55.7
91.0	56.5	76.0	112.2	1.23	45.3	56.5
91.0	57.5	80.0	113.3	1.24	45.8	57.0
91.0	58.3	83.2	114.1	1.25	45.8	57.5
91.0	58.0	75.0	112.0	1.23	45.8	56.4
91.5	64.2	109.3	120.7	1.32	46.1	60.8
91.7	62.0	117.7	122.3	1.33	46.2	61.6
91.9	51.0	90.1	115.5	1.26	46.3	58.1
91.9	63.5	114.4	121.7	1.32	46.3	61.3
92.0	68.0	116.0	122.4	1.33	46.3	61.6
92.3	48.5	78.8	112.5	1.22	46.5	56.7
92.2	45.0	94.9	116.3	1.26	46.5	58.6
92.5	54.0	68.0	110.0	1.19	46.6	55.4
92.5	50.5	147.1	127.5	1.38	46.6	64.2
93.0	60.0	96.8	117.5	1.26	46.8	59.2
93.0	94.0	111.0	123.5	1.33	46.8	62.2
93.1	68.0	121.0	123.4	1.32	46.9	62.1
93.2	61.0	99.0	118.1	1.27	46.9	59.5

H (DEGREES)	R (OHMS)	JX (OHMS)	B1 (DEGREES)	B1/H	H(1655) (METRES)	B1(1655) (METRES)
93.3	59.5	90.0	115.9	1.24	47.0	58.4
93.8	66.1	105.0	119.8	1.28	47.2	60.3
93.9	57.9	84.0	114.3	1.22	47.3	57.6
94.0	37.5	71.0	110.1	1.17	47.3	55.4
94.6	64.0	61.9	108.8	1.15	47.6	54.8
94.7	44.0	28.0,	98.4	1.04	47.7	49.5
95.5	75.0	134.0	126.3	1.32	48.1	63.6
95.7	71.0	117.0	122.8	1.28	48.2	61.8
96.0	70.0	104.0	119.9	1.25	48.3	60.4
96.6	51.0	119.0	122.0	1.26	48.6	61.4
96.6	69.0	115.0	122.2	1.27	48.6	61.5
97.8	90.0	171.0	133.9	1.37	49.2	67.4
98.2	71.0	158.0	130.5	1.33	49.4	65.7
98.7	111.0	86.0	119.7	1.21	49.7	60.3
99.0	98.0	144.5	130.3	1.32	49.8	65.6
99.5	76.4	153.6	130.1	1.31	50.1	65.5
99.8	45.3	117.0	121.3	1.22	50.3	61.1
100.0	89.0	128.6	126.6	1.27	50.4	63.7
100.0	84.5	144.0	129.1	1.29	50.4	65.0
100.0	83.0	182.0	135.0	1.35	50.4	68.0
100.1	88.5	138.9	128.5	1.28	50.4	64.7
100.2	54.0	113.0	120.9	1.21	50.4	60.9
100.3	102.0	167.0	134.4	1.34	50.5	67.7
100.8	140.0	180.0	139.7	1.39	50.8	70.4
100.8	57.5	64.3	109.2	1.08	50.8	55.0
100.9	106.5	163.0	134.1	1.33	50.8	67.5
100.9	21.5	125.0	125.2	1.24	50.8	63.1
101.0	95.0	185.0	136.3	1.35	50.9	68.6
101.0	88.5	176.0	134.5	1.33	50.9	67.7
102.0	88.5	190.9	136.6	1.34	51.4	68.8
103.0	154.0	217.0	144.8	1.41	51.9	72.9
103.0	127.0	219.9	142.8	1.39	51.9	71.9
103.2	110.0	159.0	133.8	1.30	52.0	67.4
103.9	98.0	203.0	138.8	1.34	52.3	69.9
104.0	100.0	212.0	140.0	1.35	52.4	70.5
104.4	65.5	164.0	131.2	1.26	52.6	66.0
104.6	123.0	236.0	144.7	1.38	52.7	72.9
105.0	64.0	159.3	130.3	1.24	52.9	65.6
105.6	115.0	184.6	137.8	1.31	53.2	69.4
105.6	150.0	207.0	143.5	1.36	53.2	72.3
106.9	82.0	175.0	133.9	1.25	53.8	67.4
107.0	212.9	270.0	153.0	1.43	53.9	77.0
108.0	582.0	410.0	170.3	1.58	54.4	85.8
108.0	79.0	204.0	137.7	1.28	54.4	69.4
109.0	95.0	193.0	137.3	1.26	54.9	69.1
109.8	70.0	137.0	126.7	1.15	55.3	63.8
110.0	179.0	257.0	149.7	1.36	55.4	75.4
110.0	200.0	224.4	149.6	1.36	55.4	75.4
110.0	215.1	253.8	152.4	1.39	55.4	76.7
110.0	50.0	130.0	124.2	1.13	55.4	62.5
110.0	200.0	237.5	150.3	1.37	55.4	75.7

	H (DEGREES)	R (OHMS)	JX (OHMS)	G1 (DEGREES)	G1/H	H(1655) (METRES)	G1(1655) (METRES)
	110.5	193.0	205.0	147.8	1.34	55.6	74.4
	111.0	126.0	264.0	146.7	1.32	55.9	73.9
	113.2	234.0	277.0	154.8	1.37	57.0	77.9
	114.0	169.0	280.0	150.4	1.32	57.4	75.7
	114.2	117.3	232.3	143.3	1.25	57.5	72.2
	114.5	339.0	187.0,	162.9	1.42	57.7	82.0
	115.0	164.0	297.0	151.2	1.31	57.9	76.1
	116.0	227.0	288.0	154.7	1.33	58.4	77.9
	116.0	215.0	341.0	156.0	1.34	58.4	78.5
	119.3	242.0	412.0	159.4	1.34	60.1	80.3
	120.0	320.0	289.0	160.9	1.34	60.4	81.0
	121.2	187.0	298.0	152.5	1.26	61.0	76.8
	121.5	140.0	298.0	149.9	1.23	61.2	75.5
	121.7	128.0	268.0	147.1	1.21	61.3	74.1
	125.0	194.0	343.0	155.0	1.24	62.9	78.1
	130.0	155.0	302.0	151.0	1.16	65.5	76.0
*	130.0	340.0	-55.0	187.8	1.44	65.5	94.6
	130.3	530.0	292.0	170.1	1.31	65.6	85.7
	134.0	473.0	324.0	167.9	1.25	67.5	84.5
	136.8	113.7	311.5	149.7	1.09	68.9	75.4
	137.7	178.0	90.5	134.9	.98	69.3	67.9
	138.0	560.0	292.0	171.0	1.24	69.5	86.1
	142.0	134.8	22.0	101.2	.71	71.5	51.0
*	142.0	80.5	-150.0	230.2	1.62	71.5	115.9
	145.5	225.0	-350.0	203.2	1.40	73.3	102.3
*	146.0	245.0	924.0	168.5	1.15	73.5	84.9
*	146.0	248.7	418.0	159.8	1.09	73.5	80.5
	149.0	230.0	-475.0	199.2	1.34	75.0	100.2
*	149.0	50.0	121.9	122.5	.82	75.0	61.7
	150.0	130.0	-265.9	212.9	1.42	75.5	107.2
	150.0	842.0	-86.3	181.5	1.21	75.5	91.4
	152.0	710.0	-238.0	185.2	1.22	76.5	93.2
*	152.8	54.5	409.6	154.3	1.01	76.9	77.7
*	153.0	28.0	155.0	128.1	.84	77.0	64.5
*	153.0	800.0	315.0	174.9	1.14	77.0	88.1
	157.0	507.2	-458.0	191.6	1.22	79.1	96.5
	161.0	267.0	-390.0	200.2	1.24	81.1	100.8
	164.0	548.0	-210.0	187.7	1.14	82.6	94.5
	166.8	56.0	-297.0	213.3	1.28	84.0	107.4
	166.8	212.0	-405.0	201.9	1.21	84.0	101.7
	168.0	133.0	-286.0	211.3	1.26	84.6	106.4
	169.0	36.5	-21.0	263.8	1.56	85.1	132.8
	180.0	85.0	-202.0	222.2	1.23	90.6	111.9
	180.0	594.0	-270.0	187.8	1.04	90.6	94.5
	181.0	158.0	-222.0	214.5	1.18	91.1	108.0
	185.0	121.0	-541.0	199.5	1.08	93.2	100.5
	186.0	24.0	-214.0	222.9	1.20	93.7	112.2
	188.0	92.0	-249.0	216.5	1.15	94.7	109.0
	189.0	122.0	-306.0	210.4	1.11	95.2	105.9
	190.0	36.0	-142.0	234.0	1.23	95.7	117.8
	190.3	82.0	-218.0	220.4	1.16	95.8	111.0

	H (DEGREES)	R (OHMS)	JX (OHMS)	G1 (DEGREES)	G1/H	H(1655) (METRES)	G1(1655) (METRES)
	192.9	85.0	-189.2	223.9	1.16	97.1	112.7
	198.7	52.0	-113.0	239.2	1.20	100.1	120.5
	200.0	66.0	-196.0	224.0	1.12	100.7	112.8
	201.3	66.0	-249.0	217.6	1.08	101.4	109.6
	202.5	142.0	-268.0	212.1	1.05	102.0	106.8
	203.7	116.0	-865.0	192.8	.95	102.6	97.1
	210.0	100.0	-222.0	218.9	1.04	105.7	110.2
	210.0	56.0	-156.0	230.7	1.10	105.7	116.2
	212.0	51.5	-166.8	229.1	1.08	106.7	115.3
	219.5	32.2	-136.4	235.2	1.07	110.5	118.4
	225.0	31.5	-118.0	239.0	1.06	113.3	120.3
*	225.0	39.5	106.6	298.8	1.33	113.3	150.5
	225.0	36.0	-82.0	247.1	1.10	113.3	124.4
	226.0	47.5	-228.0	220.6	.98	113.8	111.1
	227.2	28.5	-53.0	254.9	1.12	114.4	128.3

[C:\FORTRAN]

TABLE V

RESULTS OF LINE-FIT ROUTINE
NUMBER OF POINTS = 249
SLOPE = 1.08 Y-INTERCEPT = 7.94 CORRELATION COEFFICIENT = .9517
* -INDICATES POINT REQUIRES FURTHER INSPECTION

H(DEGREES)	H(METERS)	G(METERS)	BEST-FIT G(METERS)	DIFFERENCE(METERS)
51.6	26.0	37.8	36.0	1.9
52.8	26.6	30.2	36.6	-6.5
54.5	27.4	30.3	37.5	-7.2
56.7	28.6	25.4	38.7	-13.4
57.6	29.0	28.8	39.2	-10.5
58.9	29.7	33.1	39.9	-6.9
59.0	29.7	61.8	40.0	21.8
60.0	30.2	29.8	40.5	-10.7
62.4	31.4	33.5	41.8	-8.4
63.1	31.8	36.4	42.2	-5.8
63.5	32.0	29.0	42.4	-13.4
64.0	32.2	39.0	42.7	-3.7
65.0	32.7	48.4	43.2	5.1
65.0	32.7	35.6	43.2	-7.6
65.0	32.7	36.2	43.2	-7.1
65.9	33.2	41.2	43.7	-2.5
67.0	33.7	37.1	44.3	-7.2
67.0	33.7	35.1	44.3	-9.2
67.0	33.7	41.9	44.3	-2.5
68.2	34.3	42.0	45.0	-3.0
69.0	34.7	38.4	45.4	-7.0
69.3	34.9	42.1	45.6	-3.5
69.4	34.9	35.3	45.6	-10.3
69.8	35.1	41.2	45.8	-4.6
70.0	35.2	36.1	45.9	-9.8
70.0	35.2	39.1	45.9	-6.8
70.5	35.5	39.1	46.2	-7.1
70.7	35.6	40.3	46.3	-6.0
70.8	35.6	43.6	46.4	-2.8
73.0	36.8	38.3	47.6	-9.3
73.0	36.8	45.1	47.6	-2.5
73.4	37.0	46.5	47.8	-1.3
75.3	37.9	41.8	48.8	-7.0
76.0	38.3	47.7	49.2	-1.5
76.1	38.3	45.8	49.3	-3.5
76.8	38.7	45.4	49.6	-4.2
76.8	38.7	47.9	49.6	-1.8
77.8	39.2	44.0	50.2	-6.1
77.8	39.2	44.0	50.2	-6.2
78.4	39.5	51.1	50.5	.6
79.4	40.0	45.5	51.1	-5.6
80.0	40.3	55.3	51.4	3.9
80.0	40.3	51.3	51.4	-.1
80.8	40.7	50.6	51.8	-1.2
81.0	40.8	49.3	51.9	-2.6
82.0	41.3	45.5	52.5	-7.0

H(DEGREES)	H(METERS)	G(METERS)	BEST-FIT G(METERS)	DIFFERENCE(METERS)
82.3	41.4	48.0	52.6	-4.6
82.4	41.5	48.7	52.7	-4.0
82.5	41.5	53.1	52.7	.4
83.0	41.8	52.2	53.0	-.8
83.3	41.9	50.7	53.2	-2.5
84.9	42.7	51.6	54.0	-2.4
85.0	42.8	50.2	54.1	-3.9
85.0	42.8	55.0	54.1	.9
86.9	43.8	52.7	55.1	-2.5
86.9	43.8	59.2	55.1	4.1
87.5	44.1	53.6	55.4	-1.9
87.7	44.2	56.3	55.6	.8
88.0	44.3	52.1	55.7	-3.7
88.0	44.3	56.1	55.7	.4
88.4	44.5	55.6	55.9	-.3
88.4	44.5	58.9	55.9	2.9
88.5	44.6	56.1	56.0	.1
88.9	44.8	53.8	56.2	-2.4
89.0	44.8	58.2	56.3	2.0
89.1	44.9	56.5	56.3	.2
89.3	45.0	55.4	56.4	-1.0
89.3	45.0	53.3	56.4	-3.1
89.4	45.0	58.6	56.5	2.1
89.6	45.1	58.8	56.6	2.2
89.6	45.1	56.7	56.6	.1
89.6	45.1	51.8	56.6	-4.8
89.6	45.1	51.7	56.6	-4.9
89.7	45.2	57.6	56.6	1.0
89.8	45.2	57.4	56.7	.7
89.8	45.2	58.8	56.7	2.1
89.8	45.2	56.4	56.7	-.3
89.9	45.3	58.2	56.8	1.4
90.0	45.3	55.7	56.8	-1.1
90.0	45.3	54.8	56.8	-2.1
90.0	45.3	55.5	56.8	-1.3
90.0	45.3	53.7	56.8	-3.1
90.0	45.3	54.2	56.8	-2.6
90.0	45.3	57.7	56.8	.9
90.0	45.3	58.3	56.8	1.5
90.0	45.3	54.7	56.8	-2.1
90.0	45.3	61.1	56.8	4.3
90.0	45.3	57.8	56.8	1.0
90.0	45.3	53.7	56.8	-3.1
90.0	45.3	55.1	56.8	-1.7
90.0	45.3	61.7	56.8	4.9
90.0	45.3	55.8	56.8	-1.0
90.0	45.3	60.0	56.8	3.2
90.0	45.3	55.3	56.8	-1.5
90.0	45.3	53.0	56.8	-3.8
90.0	45.3	55.6	56.8	-1.3
90.0	45.3	56.3	56.8	-.6
90.0	45.3	55.8	56.8	-1.0

H(DEGREES)	H(METERS)	G(METERS)	BEST-FIT G(METERS)	DIFFERENCE(METERS)
90.0	45.3	58.8	56.8	2.0
90.0	45.3	59.7	56.8	2.9
90.0	45.3	57.8	56.8	1.0
90.0	45.3	54.7	56.8	-2.1
90.0	45.3	57.9	56.8	1.0
90.0	45.3	60.2	56.8	3.4
90.0	45.3	56.3	56.8	-.6
90.0	45.3	56.2	56.8	-.6
90.0	45.3	59.0	56.8	2.2
90.0	45.3	58.2	56.8	1.4
90.0	45.3	60.0	56.8	3.2
90.0	45.3	52.8	56.8	-4.0
90.0	45.3	56.0	56.8	-.8
90.0	45.3	59.2	56.8	2.4
90.0	45.3	61.1	56.8	4.3
90.0	45.3	60.3	56.8	3.5
90.0	45.3	57.6	56.8	.8
90.0	45.3	57.3	56.8	.5
90.0	45.3	65.8	56.8	9.0
90.0	45.3	60.2	56.8	3.4
90.0	45.3	56.4	56.8	-.4
90.3	45.5	55.4	57.0	-1.5
90.4	45.5	55.6	57.0	-1.4
90.5	45.6	60.4	57.1	3.3
90.5	45.6	57.8	57.1	.7
90.8	45.7	55.7	57.2	-1.5
91.0	45.8	56.5	57.3	-.9
91.0	45.8	57.0	57.3	-.3
91.0	45.8	57.5	57.3	.1
91.0	45.8	56.4	57.3	-.9
91.5	46.1	60.8	57.6	3.1
91.7	46.2	61.6	57.7	3.9
91.9	46.3	58.1	57.8	.3
91.9	46.3	61.3	57.8	3.4
92.0	46.3	61.6	57.9	3.7
92.3	46.5	56.7	58.0	-1.4
92.3	46.5	58.6	58.1	.5
92.5	46.6	55.4	58.2	-2.8
92.5	46.6	64.2	58.2	6.0
93.0	46.8	59.2	58.4	.7
93.0	46.8	62.2	58.4	3.8
93.1	46.9	62.1	58.5	3.6
93.2	46.9	59.5	58.5	.9
93.3	47.0	58.4	58.6	-.2
93.8	47.2	60.3	58.9	1.5
93.9	47.3	57.6	58.9	-1.4
94.0	47.3	55.4	59.0	-3.5
94.6	47.6	54.8	59.3	-4.5
94.7	47.7	49.5	59.4	-9.8
95.5	48.1	63.6	59.8	3.8
95.7	48.2	61.8	59.9	1.9
96.0	48.3	60.4	60.1	.3

H(DEGREES)	H(METERS)	G(METERS)	BEST-FIT G(METERS)	DIFFERENCE(METERS)
96.6	48.6	61.4	60.4	1.0
96.6	48.6	61.5	60.4	1.1
97.8	49.2	67.4	61.0	6.4
98.2	49.4	65.7	61.3	4.5
98.7	49.7	60.3	61.5	-1.2
99.0	49.8	65.6	61.7	3.9
99.5	50.1	65.5	62.0	3.6
99.8	50.3	61.1	62.1	-1.1
100.0	50.4	63.7	62.2	1.5
100.0	50.4	65.0	62.2	2.7
100.0	50.4	68.0	62.2	5.7
100.1	50.4	64.7	62.3	2.4
100.2	50.4	60.9	62.3	-1.5
100.3	50.5	67.7	62.4	5.3
100.8	50.8	70.4	62.7	7.7
100.8	50.8	55.0	62.7	-7.7
100.9	50.8	67.5	62.7	4.8
100.9	50.8	63.1	62.8	.3
101.0	50.9	68.6	62.8	5.8
101.0	50.9	67.7	62.8	5.0
102.0	51.4	68.8	63.3	5.5
103.0	51.9	72.9	63.9	9.0
103.0	51.9	71.9	63.9	8.0
103.2	52.0	67.4	64.0	3.4
103.9	52.3	69.9	64.4	5.5
104.0	52.4	70.5	64.4	6.1
104.4	52.6	66.0	64.6	1.4
104.6	52.7	72.9	64.7	8.1
105.0	52.9	65.6	65.0	.7
105.6	53.2	69.4	65.3	4.1
105.6	53.2	72.3	65.3	7.0
106.9	53.8	67.4	66.0	1.4
107.0	53.9	77.0	66.0	11.0
108.0	54.4	85.8	66.6	19.2
108.0	54.4	69.4	66.6	2.8
109.0	54.9	69.1	67.1	2.0
109.8	55.3	63.8	67.6	-3.8
110.0	55.4	75.4	67.7	7.7
110.0	55.4	75.4	67.7	7.7
110.0	55.4	76.7	67.7	9.1
110.0	55.4	62.5	67.7	-5.1
110.0	55.4	75.7	67.7	8.0
110.5	55.6	74.4	67.9	6.5
111.0	55.9	73.9	68.2	5.6
113.2	57.0	77.9	69.4	8.5
114.0	57.4	75.7	69.8	5.9
114.2	57.5	72.2	69.9	2.2
114.5	57.7	82.0	70.1	11.9
115.0	57.9	76.1	70.4	5.7
116.0	58.4	77.9	70.9	7.0
116.0	58.4	78.5	70.9	7.6
119.3	60.1	80.3	72.7	7.5

H(DEGREES)	H(METERS)	G(METERS)	BEST-FIT G(METERS)	DIFFERENCE(METERS)
120.0	60.4	81.0	73.1	7.9
121.2	61.0	76.8	73.7	3.1
121.5	61.2	75.5	73.9	1.6
121.7	61.3	74.1	74.0	.1
125.0	62.9	78.1	75.8	2.2
130.0	65.5	76.0	78.5	-2.5
130.3	65.6	85.7	78.7	7.0
134.0	67.5	84.5	80.7	3.9
136.8	68.9	75.4	82.2	-6.9
137.7	69.3	67.9	82.7	-14.8
138.0	69.5	86.1	82.9	3.2
142.0	71.5	51.0	85.0	-34.1
145.5	73.3	102.3	86.9	15.4
149.0	75.0	100.3	88.8	11.5
150.0	75.5	107.2	89.4	17.8
150.0	75.5	91.4	89.4	2.0
152.0	76.5	93.2	90.5	2.8
157.0	79.1	96.5	93.2	3.3
161.0	81.1	100.8	95.4	5.4
164.0	82.6	94.5	97.0	-2.5
166.8	84.0	107.4	98.5	8.9
166.8	84.0	101.7	98.5	3.2
168.0	84.6	106.4	99.2	7.2
169.0	85.1	132.8	99.7	33.1
180.0	90.6	111.9	105.7	6.2
180.0	90.6	94.5	105.7	-11.1
181.0	91.1	108.0	106.2	1.8
185.0	93.2	100.5	108.4	-7.9
186.0	93.7	112.2	108.9	3.3
188.0	94.7	109.0	110.0	-1.0
189.0	95.2	105.9	110.6	-4.6
190.0	95.7	117.8	111.1	6.7
190.3	95.8	111.0	111.3	-.3
192.9	97.1	112.7	112.7	.0
198.7	100.1	120.5	115.8	4.6
200.0	100.7	112.8	116.5	-3.8
201.3	101.4	109.6	117.2	-7.7
202.5	102.0	106.8	117.9	-11.1
203.7	102.6	97.1	118.5	-21.5
210.0	105.7	110.2	122.0	-11.8
210.0	105.7	116.2	122.0	-5.8
212.0	106.7	115.3	123.1	-7.7
219.5	110.5	118.4	127.1	-8.7
225.0	113.3	120.3	130.1	-9.8
225.0	113.3	124.4	130.1	-5.7
226.0	113.8	111.1	130.7	-19.6
227.2	114.4	128.3	131.3	-3.0

[C:\FORTRAN]

TABLE VI

MEASURED NON-DIRECTIONAL RMS VALUES
OBTAINED FROM FCC FILES

Frequency kHz	Call	City/State	Listed Electrical Height (Deg.) ND	DA	RMS mV/m per 1 kW at 1 km Non-Directional Theo.	Meas.	Directional Theo.	Meas.	ND Impedance
1520	WEXY	Wiltonwoods Florida	86.8	86.8	304 [310]	305.7	327.8	296	37.5+j20.4(SS)
1500	KDFN	Doniphan Missouri	90	90	306 [314]	306	461.3	460	71+j151.8(G)
1600	KATZ	St. Louis Missouri	88	88	304 [313]	300.8	399	395	46.2+j75.2(G)
1600	KBBX	Clateville Utah	144.1	144.1*	343 [362]	334	286.1	285.1	332+j346.7(G)
1550	KVAN	Vancover Washington	147.6	147.6	346.1[367]	336.8	351.1	361.8	856-j72.1(G)
1510	WLKR	Norwalk Ohio	90	90	306 [315]	312	325.2	325.2	54+j82.8(G)
1520	KOMA+	Oklahoma City Oklahoma	181	181	383 [419]	385	371.9	403	158-j222(G)
1520	KOMA/	Oklahoma City Oklahoma	181	181	383 [419]	383	371.9	386.7	153.2-j218.9(G)
1540	WQCC	Charlotte North Carolina	70	70	292.8[300]	292.8	320.3	311.9	94+j162(G)
1580	WVKO	Columbus Ohio	128	unequal	332 [343]	325.4 Night	350 314.2	326.6 318.6	176-j53.7
1580	WPGC	Morningside Maryland	90	90	306 [315]	312.5	288.1	279.7	53+j76(G)

(SS) - Self-supporting
(G) - Guyed
* - 1 tower top-loaded - DA only
[ ] - Anticipated using Document 7E
KOMA+ - 1971
KOMA/ - 1987

APPENDIX A
OTHER METHODS OF ANALYSIS INVESTIGATED
JULY 1987

From the "National Association of Broadcasters Engineering Handbook - Fourth Edition", pp. 2-1-15 published 1949. A first order approximation of the self base impedance is derived from the theory of non-uniform transmission lines resulting in the following equation:[1]

$$Zb = Z_o \left[\frac{HSinG+j[(F-N)sinG+(M-2Z_o)cosG]}{[2Z_o+M)sinG+(F+N)cosG)]-jHcosG} \right]$$

Where:

$F = 60Si(2G)+30(Ci(4G)-lnG-\gamma)sin2G-30Si(4G)cos2G$
$H = 60(\gamma+ln2G-Ci(2G)$
$\quad +30(\gamma+lnG-2Ci(2G)+Ci(4G))cos(2G)$
$\quad +30(Si(4G)-2Si(2G)sin2G$
$M = 60(ln2G-Ci(2G)+\gamma-1+cos2G$
$N = 60(Si(2G)-sin2G)$
$\gamma = 0.5772$
Si = sine integral function
Ci = cosine integral function
G = antenna height (degrees or radians)

$$Z_o = 60(ln\frac{2G}{a} - 1)$$

Where:

Z_o = average characteristics impedance, ohms
ln = base of natural logarithms
G = antenna height, degrees or same units as a
a = antenna radius, degrees or same units as G

From the formula given on Page 793 of "Radio Engineering Handbook", by Frederick Emmons Terman, Sc.D., published by McGraw-Hill Book Company, Inc., 1943, it calculates the self-no-loss loop resistance of vertical radiatiors having a sinusoidal distribution of current.

$$\left.\begin{matrix}\text{Radiation}\\ \text{resistance}\\ \text{in ohms}\end{matrix}\right\} = 60\left\{S_1\left(4\pi\frac{H}{\lambda}\right)\cos^2\left(2\pi\frac{H}{\lambda}\right) - \frac{1}{4}S_1\left(8\pi\frac{H}{\lambda}\right)\cos\left(4\pi\frac{H}{\lambda}\right) - \frac{1}{2}\sin\left(4\pi\frac{H}{\lambda}\right)\left[Si\left(4\pi\frac{H}{\lambda}\right) - \frac{1}{2}Si\left(8\pi\frac{H}{\lambda}\right)\right]\right\}$$

where $Si(x) = \int_0^x \frac{\sin x}{x}\,dx$

H/λ = height (length) in wave lengths.

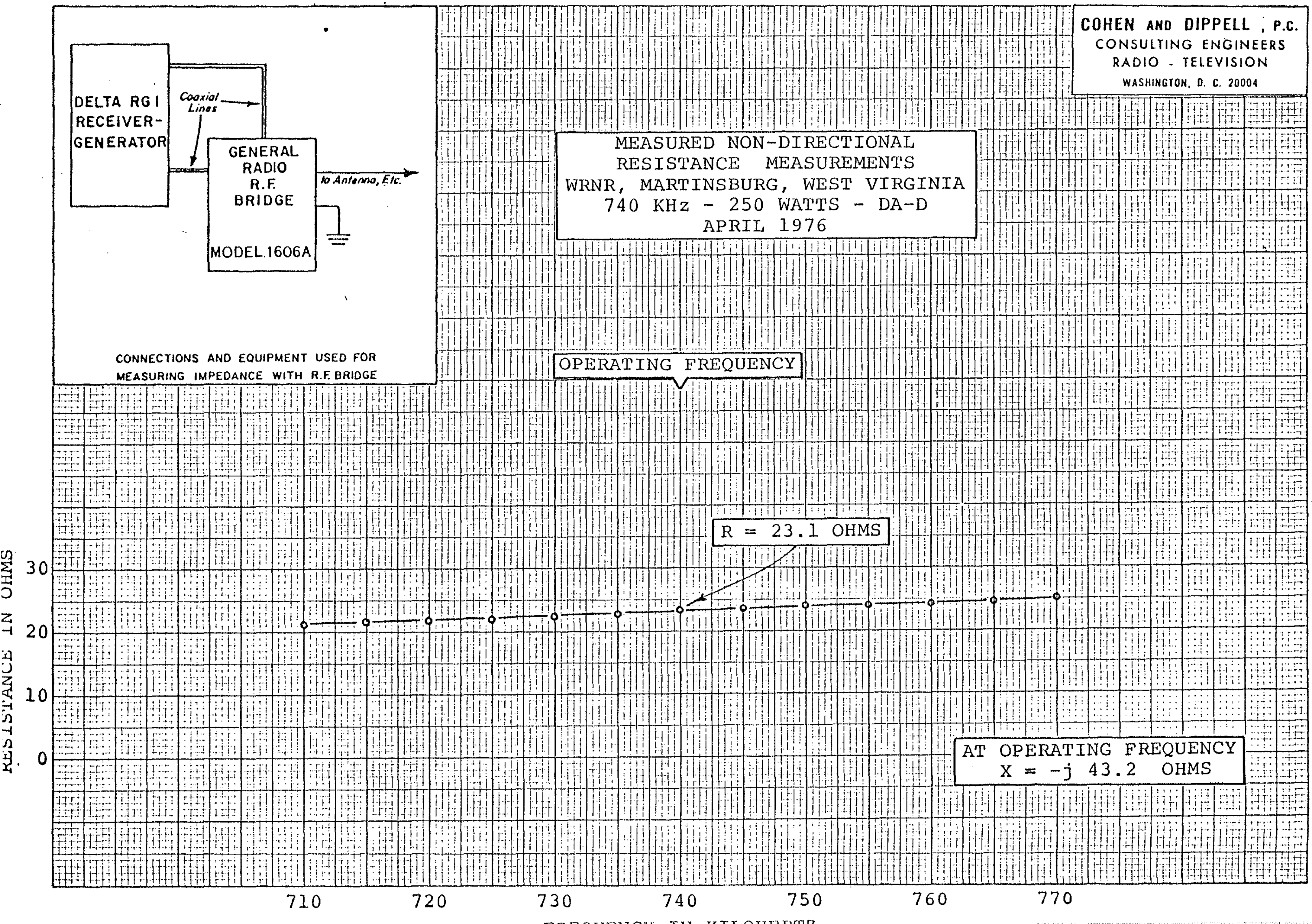
[1] S. A. Schelkunoff, "Theory of Antennas of Arbitrary Size and Shape", Proc. I.R.E., Vol. 29, pp. 493-521; September, 1941

TABULATION OF
NON-DIRECTIONAL RESISTANCE MEASUREMENTS
WRNR, MARTINSBURG, WEST VIRGINIA
740 kHz 250 WATTS ND-D
APRIL 1976

Frequency kHz	Resistance ohms
710	21.1
715	21.4
720	21.7
725	21.9
730	22.2
735	22.6
740	23.1
745	23.5
750	23.9
755	24.0
760	24.3
765	24.6
770	25.0

Reactance at operating frequency -j43.2

H = 258'



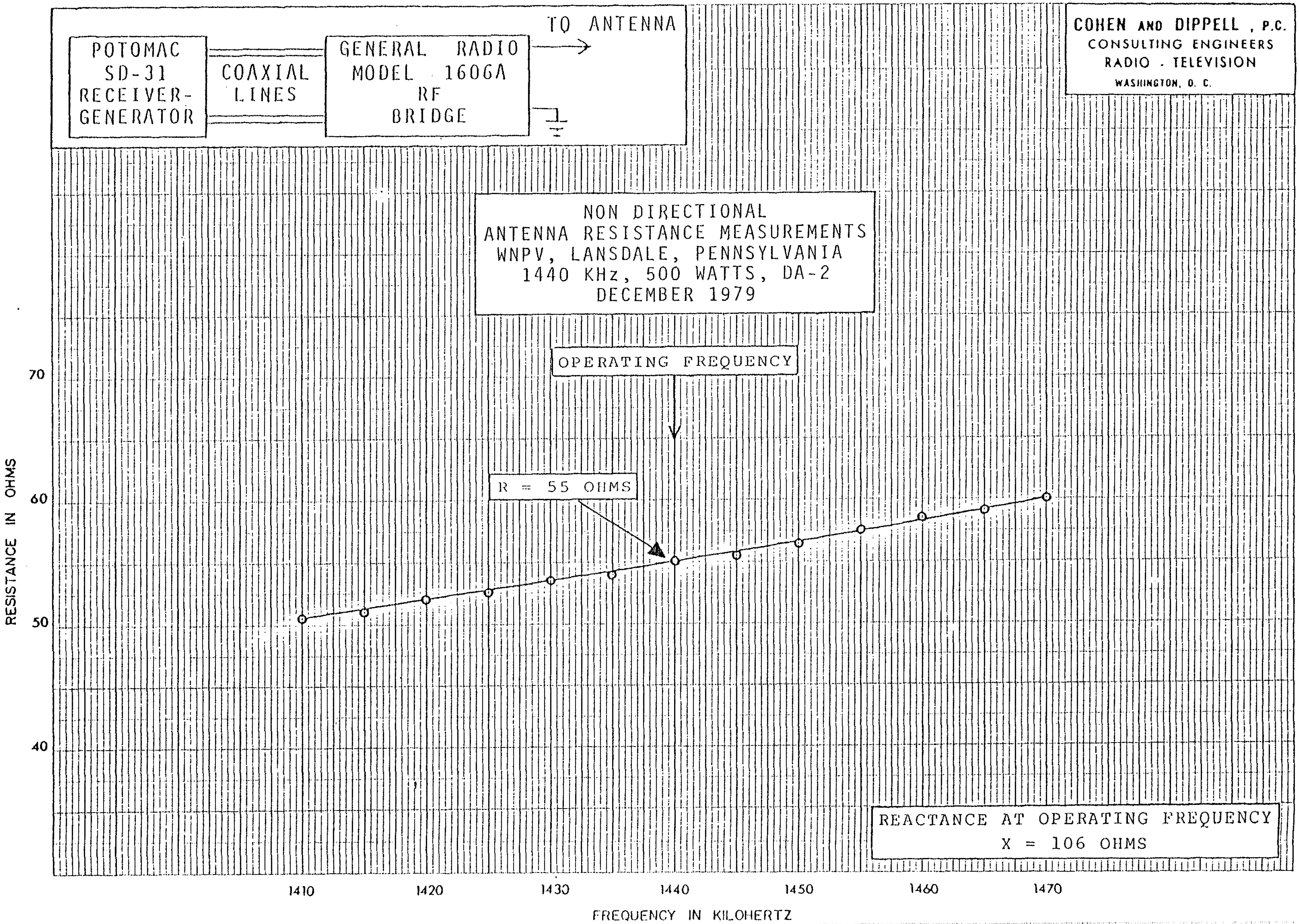
COHEN AND DIPPELL, P.C.
CONSULTING ENGINEERS
RADIO - TELEVISION
WASHINGTON, D. C. 20004
DELTA RG1 RECEIVER-GENERATOR
Coaxial Lines
GENERAL RADIO R.F. BRIDGE
MODEL 1606A
To Antenna, Etc.
CONNECTIONS AND EQUIPMENT USED FOR MEASURING IMPEDANCE WITH R.F. BRIDGE
MEASURED NON-DIRECTIONAL
RESISTANCE MEASUREMENTS
WRNR, MARTINSBURG, WEST VIRGINIA
740 KHz - 250 WATTS - DA-D
APRIL 1976
OPERATING FREQUENCY
R = 23.1 OHMS
AT OPERATING FREQUENCY
X = -j 43.2 OHMS
RESISTANCE IN OHMS
30
20
10
0
710
720
730
740
750
760
770

TABULATION OF NON-DIRECTIONAL RESISTANCE MEASUREMENTS WNPV, LANSDALE, PENNSYLVANIA 1440 kHz 500 WATTS DA-2 DECEMBER 1979

Frequency kHz	Resistance ohms
1410	50.5
1415	51.0
1420	51.8
1425	52.5
1430	53.5
1435	54.0
1440	55.0
1445	55.5
1450	56.5
1455	57.5
1460	58.5
1465	59.0
1470	60.0

Reactance at operating frequency = +j106

H = 171'

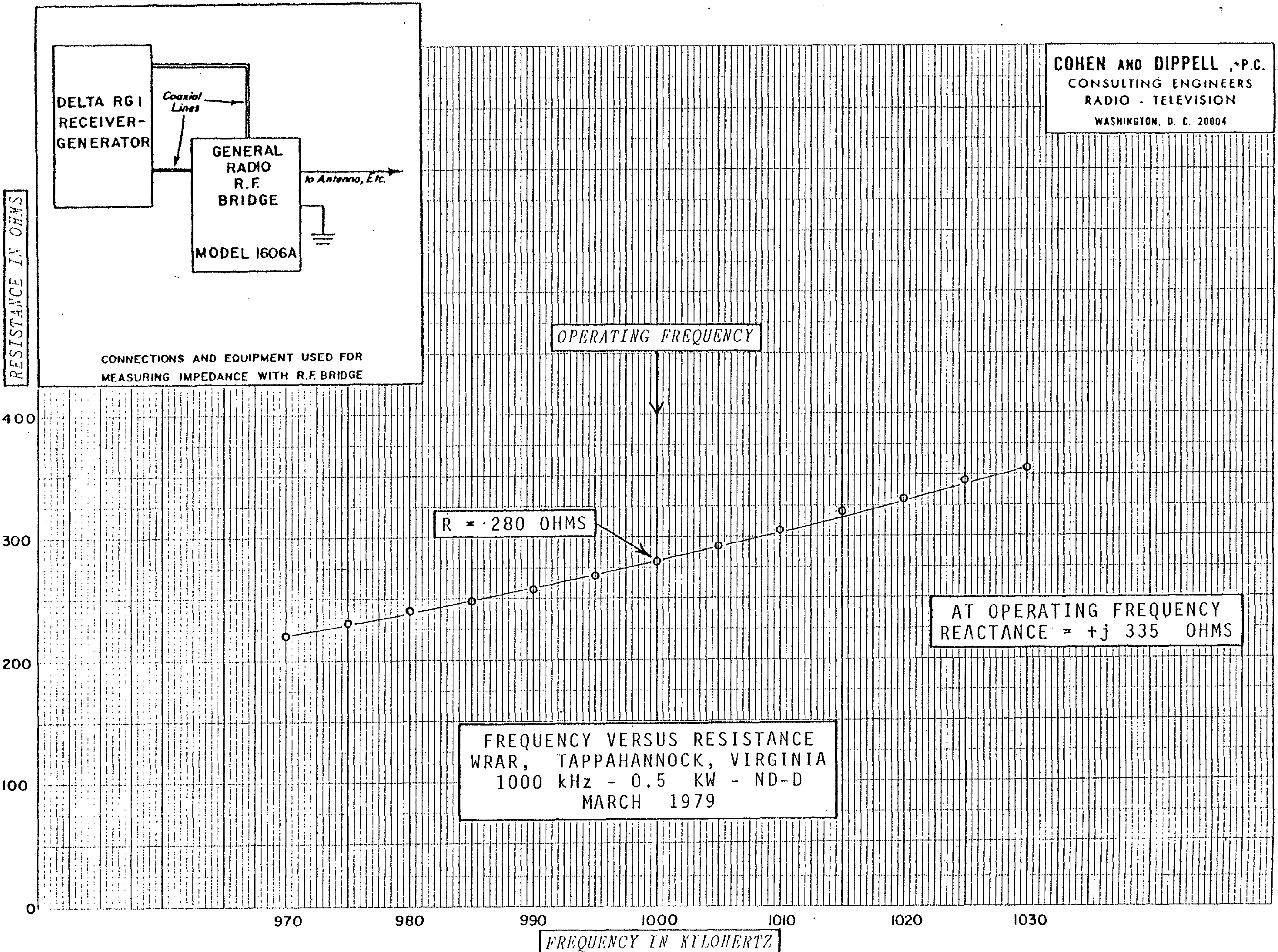

POTOMAC SD-31 RECEIVER-GENERATOR
COAXIAL LINES
GENERAL RADIO MODEL 1606A RF BRIDGE
TO ANTENNA
COHEN AND DIPPELL, P.C.
CONSULTING ENGINEERS
RADIO - TELEVISION
WASHINGTON, D. C.
NON DIRECTIONAL
ANTENNA RESISTANCE MEASUREMENTS
WNPV, LANSDALE, PENNSYLVANIA
1440 KHz, 500 WATTS, DA-2
DECEMBER 1979
OPERATING FREQUENCY
R = 55 OHMS
REACTANCE AT OPERATING FREQUENCY
X = 106 OHMS
RESISTANCE IN OHMS
70
60
50
40
1410
1420
1430
1440
1450
1460
1470
FREQUENCY IN KILOHERTZ

TABULATION OF NON-DIRECTIONAL RESISTANCE MEASUREMENTS WRAR, TAPPAHANNOCK, VIRGINIA MARCH 1979

Frequency kHz	Resistance ohms
970	220
975	230
980	240
985	249
990	258
995	269
1000	280
1005	292
1010	305
1015	320
1020	330
1025	345
1030	355

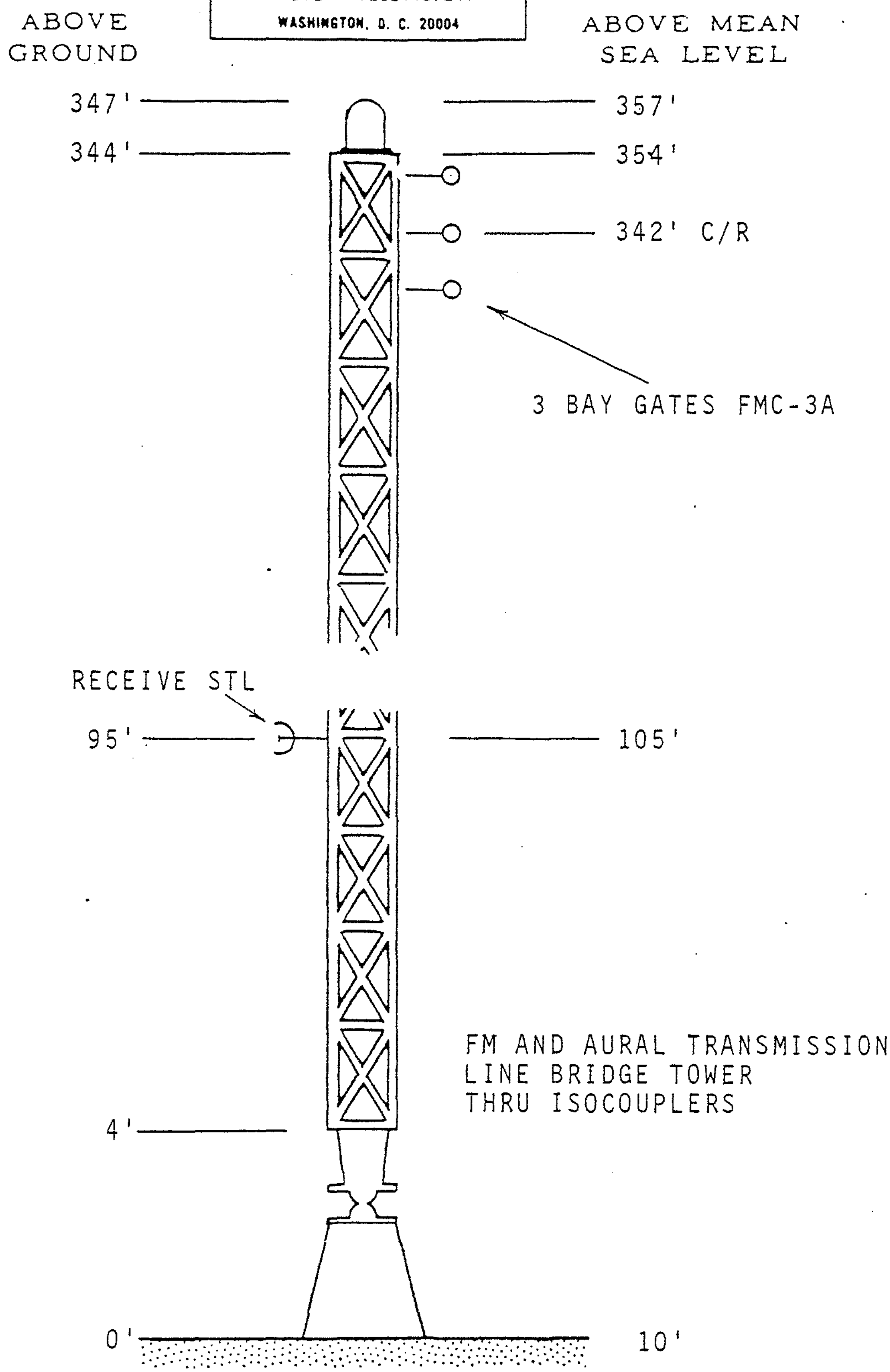
Reactance at the operating frequency = +j335 ohms

H = 340'



COHEN AND DIPPELL, P.C.
CONSULTING ENGINEERS
RADIO - TELEVISION
WASHINGTON, D. C. 20004
DELTA RG1 RECEIVER-GENERATOR
Coaxial Lines
GENERAL RADIO R.F. BRIDGE
MODEL 1606A
to Antenna, Etc.
CONNECTIONS AND EQUIPMENT USED FOR MEASURING IMPEDANCE WITH R.F. BRIDGE
RESISTANCE IN OHMS
400
300
200
100
0
OPERATING FREQUENCY
R = 280 OHMS
AT OPERATING FREQUENCY
REACTANCE = +j 335 OHMS
FREQUENCY VERSUS RESISTANCE
WRAR, TAPPAHANNOCK, VIRGINIA
1000 kHz - 0.5 KW - ND-D
MARCH 1979
970
980
990
1000
1010
1020
1030
FREQUENCY IN KILOHERTZ

COHEN AND DIPPELL, P.C.
CONSULTING ENGINEERS
RADIO - TELEVISION
WASHINGTON, D. C. 20004



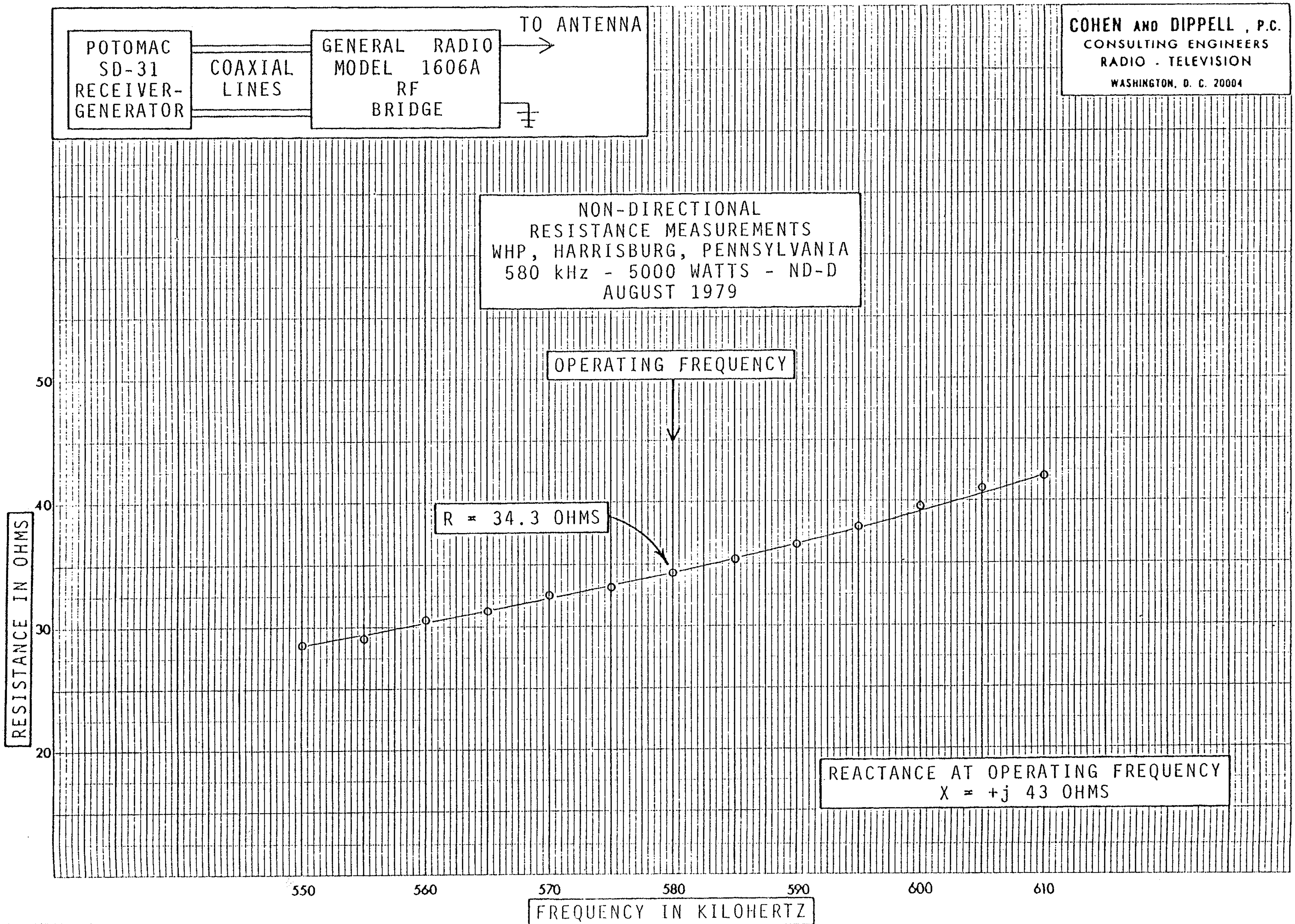
ELEVATION
OF EXISTING STRUCTURE
WRAR, TAPPAHANNOCK, VIRGINIA
MARCH 1979

TABULATION OF NON-DIRECTIONAL RESISTANCE MEASUREMENTS WHP, HARRISBURG, PENNSYLVANIA 580 kHz 5000 WATTS ND-D AUGUST 1979

Frequency kHz	~~Reactance~~ Resistance ohms
550	28.5
555	29
560	30.5
565	31.2
570	32.5
575	33.1
580	34.3
585	35.3
590	36.5
595	38
600	39.5
605	41
610	42

Reactance at operating frequency = +j43

H = 400'



POTOMAC SD-31 RECEIVER-GENERATOR
COAXIAL LINES
GENERAL RADIO MODEL 1606A RF BRIDGE
TO ANTENNA
COHEN AND DIPPELL, P.C.
CONSULTING ENGINEERS
RADIO - TELEVISION
WASHINGTON, D. C. 20004
NON-DIRECTIONAL
RESISTANCE MEASUREMENTS
WHP, HARRISBURG, PENNSYLVANIA
580 kHz - 5000 WATTS - ND-D
AUGUST 1979
OPERATING FREQUENCY
R = 34.3 OHMS
REACTANCE AT OPERATING FREQUENCY
X = +j 43 OHMS
RESISTANCE IN OHMS
50
40
30
20
550
560
570
580
590
600
610
FREQUENCY IN KILOHERTZ

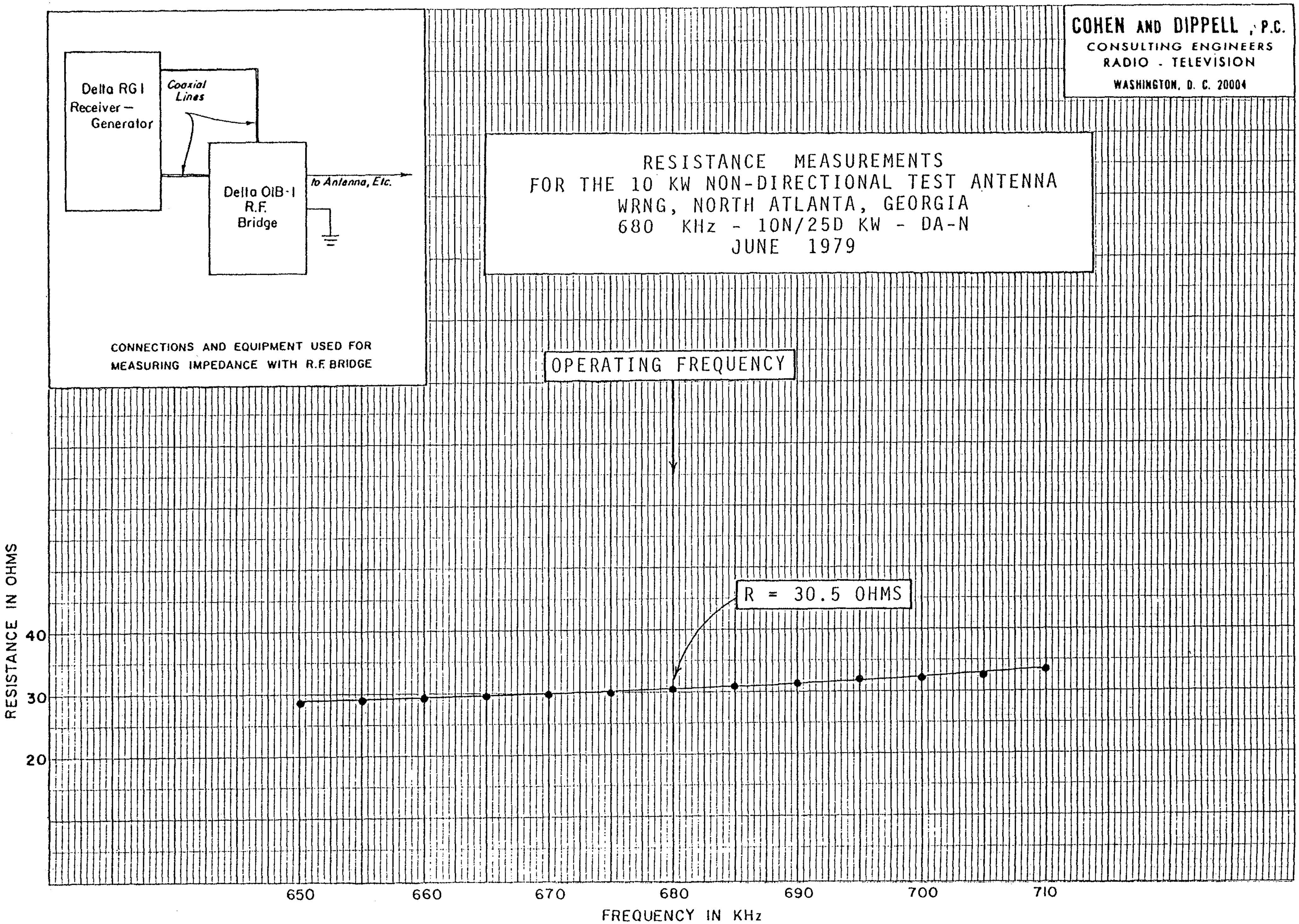
TABULATION OF RESISTANCE MEASUREMENTS FOR THE 10 KW NON-DIRECTIONAL TEST ANTENNA WRNG, NORTH ATLANTA, GEORGIA 680 kHz 10n/25d KW DA-N JUNE 1979

Tower #3 (NWC)

Frequency kHz	Resistance ohms
650	28.8
655	29.0
660	29.2
665	29.5
670	29.8
675	30.0
680*	30.5
685	31.0
690	31.5
695	32.0
700	32.2
705	32.8
710	33.5

*Operating frequency
Reactance at 680 kHz +j1.0 ohm

H = 319'


COHEN AND DIPPELL, P.C.
CONSULTING ENGINEERS
RADIO - TELEVISION
WASHINGTON, D. C. 20004
RESISTANCE MEASUREMENTS
FOR THE 10 KW NON-DIRECTIONAL TEST ANTENNA
WRNG, NORTH ATLANTA, GEORGIA
680 KHz - 10N/25D KW - DA-N
JUNE 1979
Delta RG I
Receiver — Generator
Coaxial Lines
Delta OIB-I R.F. Bridge
to Antenna, Etc.
CONNECTIONS AND EQUIPMENT USED FOR MEASURING IMPEDANCE WITH R.F BRIDGE
OPERATING FREQUENCY
R = 30.5 OHMS
RESISTANCE IN OHMS
40
30
20
650
660
670
680
690
700
710
FREQUENCY IN KHz

MAIN TRANSMITTER

Broadcast Application — FEDERAL COMMUNICATIONS COMMISSION — Section II-A

LICENSE APPLICATION ENGINEERING DATA
STANDARD BROADCAST

Name of applicant: Ring Radio Company

Purpose of authorization applied for: (Check one)

		Answer paragraphs
[X]	Station license	1-13
[ ]	Direct measurement of power	2,6,7,8,9,14

1. Facilities authorized in construction permit

Call Sign	File No. of construction permit		
WRNG	BP-20252		
Frequency	Hours of operation	Power in kilowatts Night	Day
680 kHz	Nighttime	10	25*

2. Station location

State: Georgia — City or town: North Atlanta

3. Transmitter location

State: Georgia — County: Gwinnett

City or Town: Near Norcross — Street Address (or other identification): Spalding Drive at Crooked Creek

4. Main studio location

State: Georgia — County: DeKalb

City or Town: North Atlanta — Street and number: 3954 Peachtree Rd. N.E.

5. Remote control point location (only if authorized)

State: Georgia — City or town: North Atlanta

Street Address (or other identification): 3954 Peachtree Road, N.E.

6. Transmitter Installed

Make: Harris — Type No.: BC-10H — Rated Power: 10 KW

Last radio stage

	Total unmodulated plate current	Plate voltage
Night	2.16	5610
Day		

Manufacturer's recommended operating efficiency for the last radio frequency amplifier stage in percent. 87%

Is inverse feedback utilized? Yes [ ] No [X]
If "Yes", to what value of feedback power is transmitter adjusted (in db)

Efficiency of the last radio frequency amplifier stage as now adjusted (use formula $\left[\frac{I_a^2 R_a (100)\%}{E_p I_p}\right]$)

DA-N = 86.6%

7. Operating constants: (If directional system, give current at point of resistance measurement.)

RF common point or antenna current without modulation for night power in amperes: 14.5

RF common point or antenna current without modulation for day power in amperes:

Actual measured antenna or common point resistance (in ohms) at operating frequency: Night 50 Day ____

Actual measured antenna or common point reactance (in ohms) at operating frequency: Night +j0 Day ____

Currents, and phases for directional operation

Tower	Phase reading in degrees Night	Day	Antenna base current Night	Day	Remote indication of antenna current Night	Day
SW #1	- 83.1		5.20		0.573	
SWC #2	0		8.90		1.000	
NWC #3	+108.4		6.35		0.716	
NW #4	-136.7		3.90		0.426	
SE #5	+ 23.5		5.95		0.655	
SEC #6	+109.1		9.30		1.045	
NEC #7	-146.1		6.40		0.701	
NE #8	- 36.4		3.58		0.392	

Manufacturer and type of antenna monitor: Delta DAM-1

Describe equipment used for remote indication of antenna currents (antenna monitor or other method)

Antenna Monitor

8. Description of antenna system

(If directional antenna is used, the information requested below should be given for each element of the array. Use separate sheets if necessary. Height figures should not include obstruction lighting.)

Type radiator: Triangular, uniform cross-section, guyed

Height in feet of complete radiator above base insulator, or above base if grounded: 319 feet

Overall height in feet above ground. (without obstruction lighting) 322 feet

If antenna is either top loaded or sectionalized, describe fully as EXHIBIT N/A.

Excitation: Series [X] Shunt [ ]

Geographic coordinates to nearest second.
For directional antenna give coordinates of center of array.
For single vertical radiator give tower location.

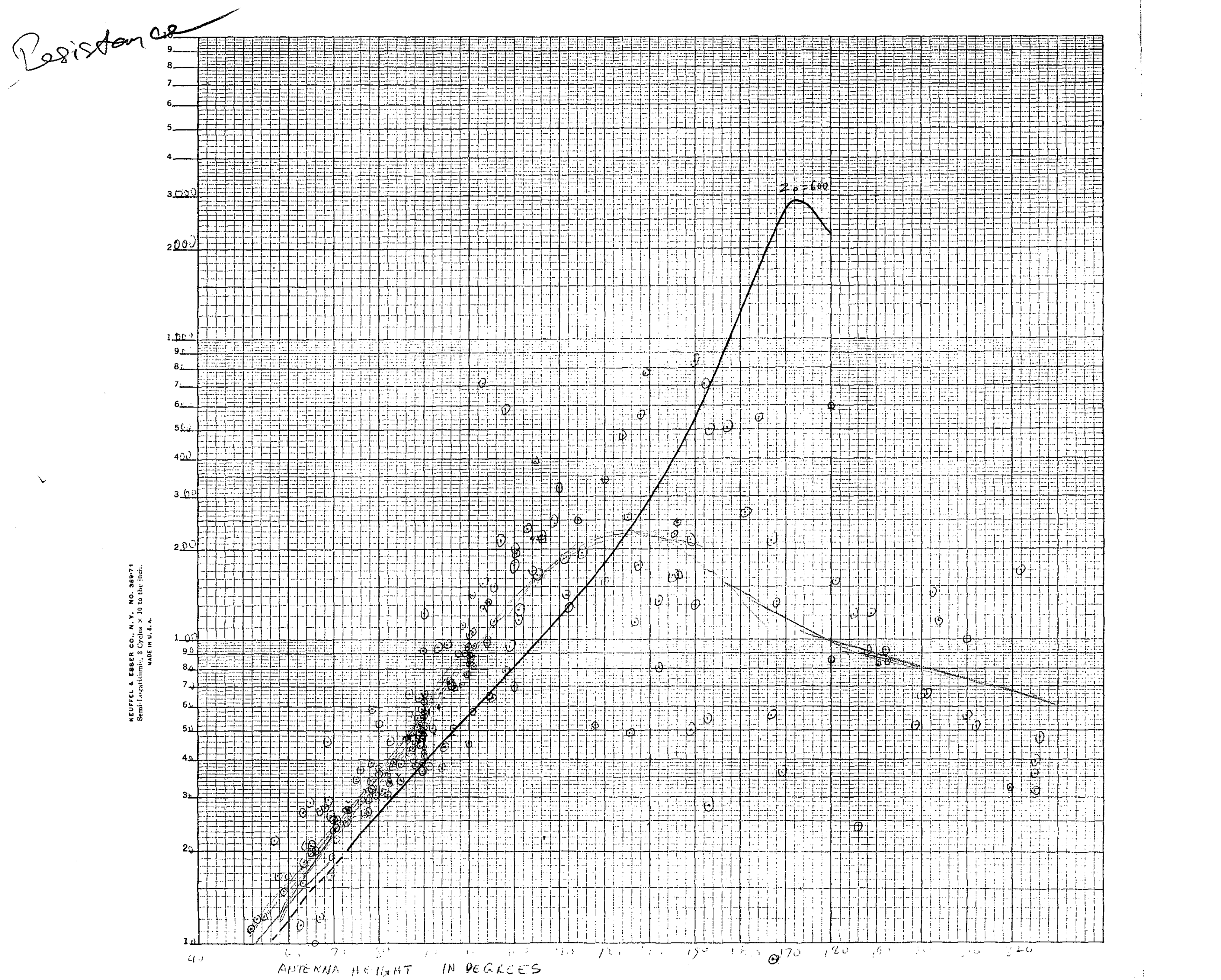
North latitude 33° 57' 42" — West longitude 84° 15' 48"

If not fully describe above, give further details and dimensions including any other antennas mounted on tower and associated isolation circuits as EXHIBIT ____.

Details and dimensions of ground system: (Attach sketch as EXHIBIT ____ if necessary for complete description).

120 buried copper radials 362 feet in length, except where shortened and bonded to transverse copper strap or terminated at property boundary. In addition to a 48 x 48 foot ground screen at the base of each tower.

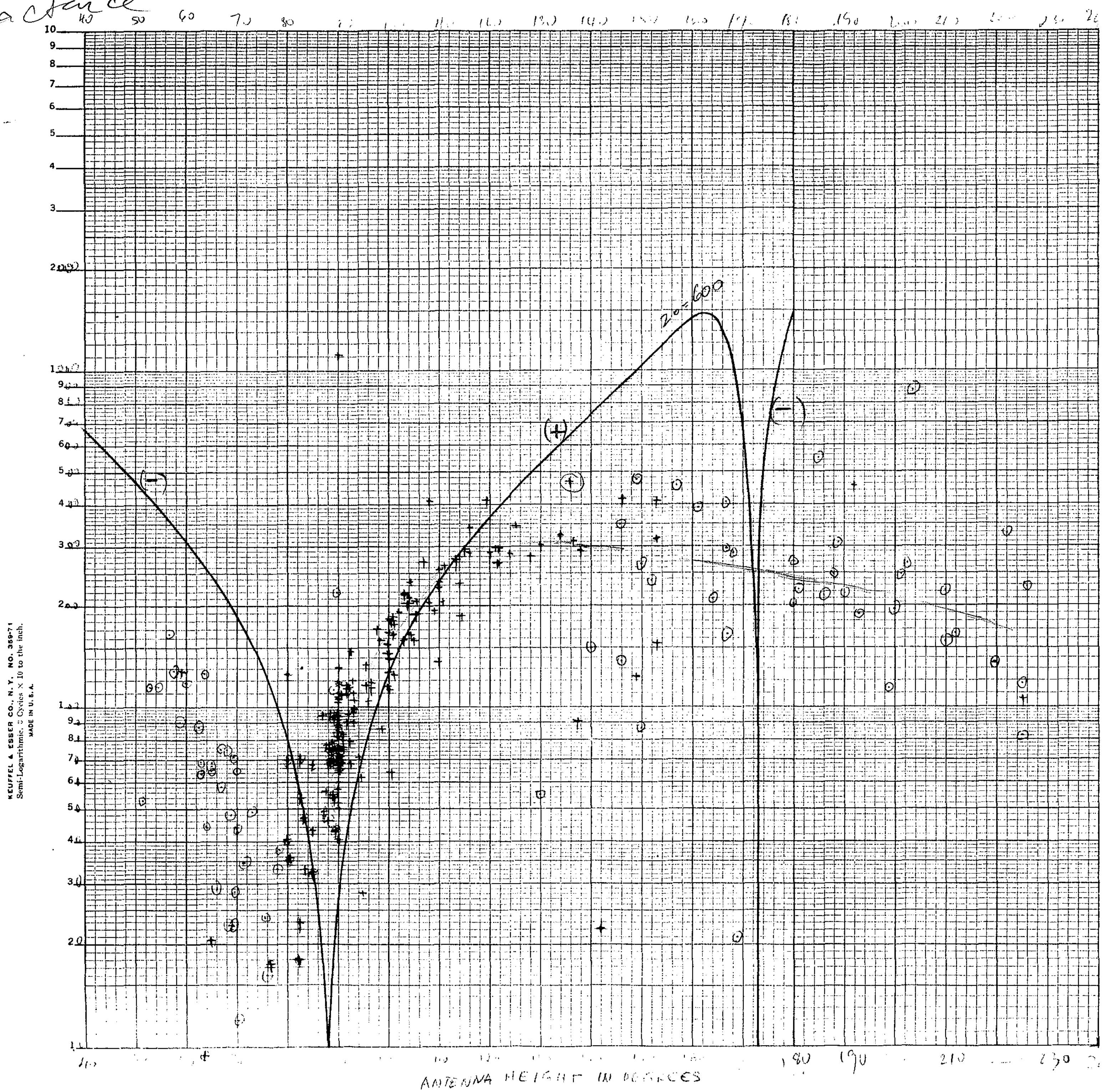
*licensed operation at different site


Resistance
Z₀=600
ANTENNA HEIGHT IN DEGREES
KEUFFEL & ESSER CO., N. Y. NO. 359-71
Semi-Logarithmic, 3 Cycles × 10 to the inch.
MADE IN U.S.A.

Reactance

+

∘ −ve



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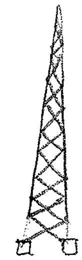
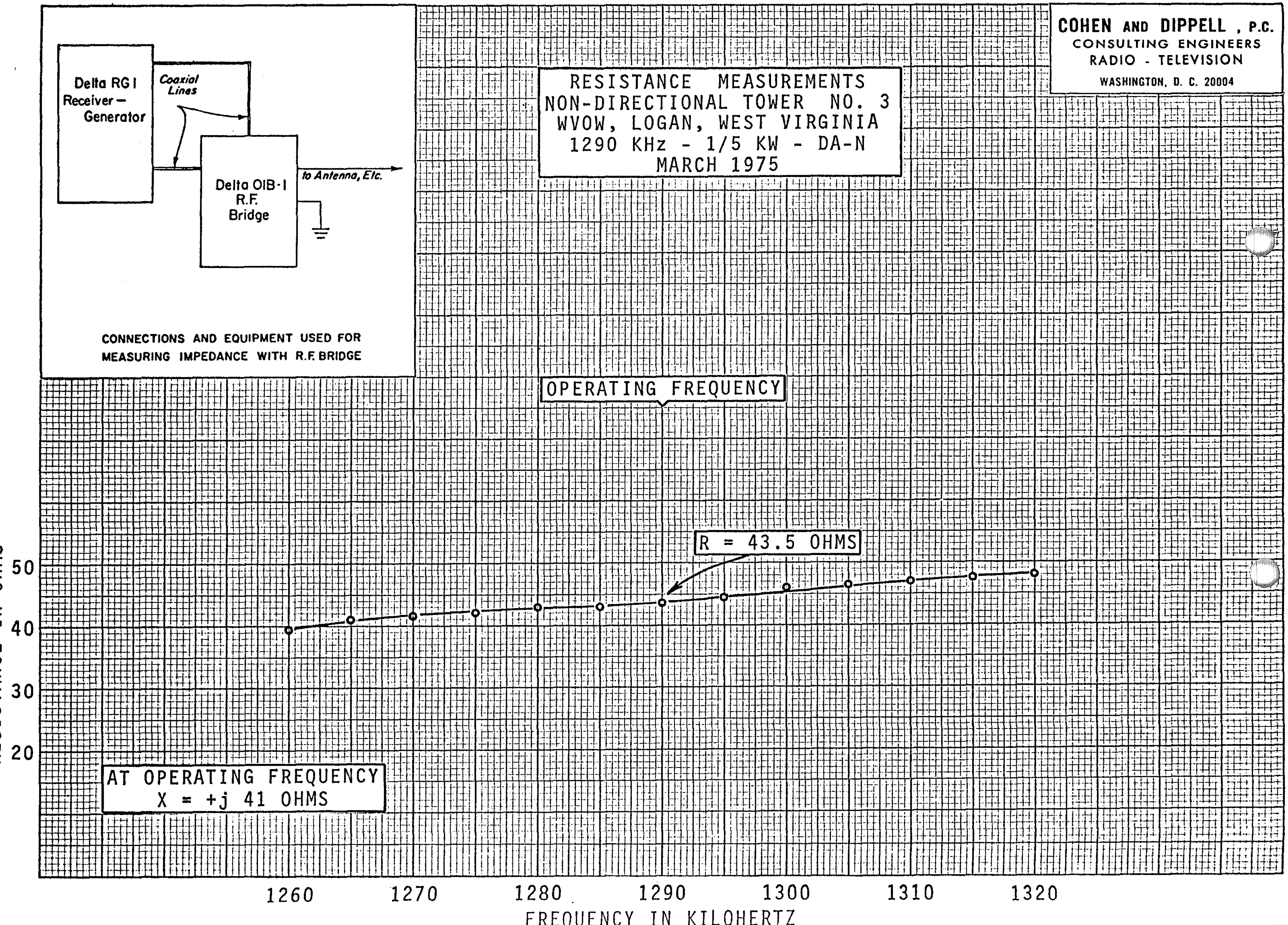


96.8° @ 1290 kHz

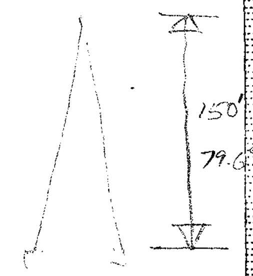
TABULATION OF RESISTANCE MEASUREMENTS FOR NON-DIRECTIONAL TOWER (#3) 1290 kHz - 1/5 KW - DA-N MARCH 1975

Frequency kHz		Resistance Ohms
1260		39.5
1265		41.0
1270		41.5
1275		42.0
1280		43.0
1285		43.0
1290	(Operating Frequency)	43.5
1295		44.5
1300		46.0
1305		46.5
1310		47.0
1315		47.5
1320		48.0

Reactance at 1290 kHz = +j41 Ohms


COHEN AND DIPPELL, P.C.
CONSULTING ENGINEERS
RADIO - TELEVISION
WASHINGTON, D. C. 20004
RESISTANCE MEASUREMENTS
NON-DIRECTIONAL TOWER NO. 3
WVOW, LOGAN, WEST VIRGINIA
1290 KHz - 1/5 KW - DA-N
MARCH 1975
Delta RG I Receiver — Generator
Coaxial Lines
Delta OIB-1 R.F. Bridge
to Antenna, Etc.
CONNECTIONS AND EQUIPMENT USED FOR MEASURING IMPEDANCE WITH R.F. BRIDGE
OPERATING FREQUENCY
R = 43.5 OHMS
AT OPERATING FREQUENCY
X = +j 41 OHMS
RESISTANCE IN OHMS
50
40
30
20
1260
1270
1280
1290
1300
1310
1320
FREQUENCY IN KILOHERTZ

TABULATION OF
RESISTANCE MEASUREMENTS
WFTR, FRONT ROYAL, VIRGINIA
1450 KHZ - 0.25/1 KW LS - ND-U
JANUARY 1979



FREQUENCY KHZ	RESISTANCE OHMS
1420	32.5
1425	33.0
1430	33.5
1435	33.8
1440	34.0
1445	34.0
1450	34.5
1455	36.0
1460	36.5
1465	37.5
1470	37.0
1475	38.0
1480	38.0

REACTANCE AT OPERATING FREQUENCY = +j3 OHMS

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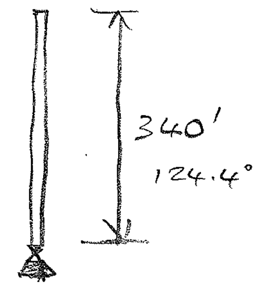
TABULATION OF RESISTANCE MEASUREMENTS WRAR, TAPPAHANNOCK, VIRGINIA OCTOBER 1975



Frequency KHz	Resistance ohms
970	180
975	186
980	195
985	202
990	214
995	221
1000	230
1005	240
1010	250
1015	260.5
1020	271
1025	286
1030	301

Reactance at the operating frequency = +j325 ohms

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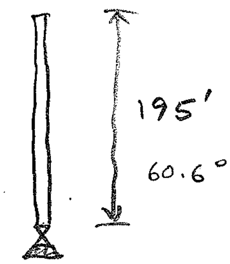
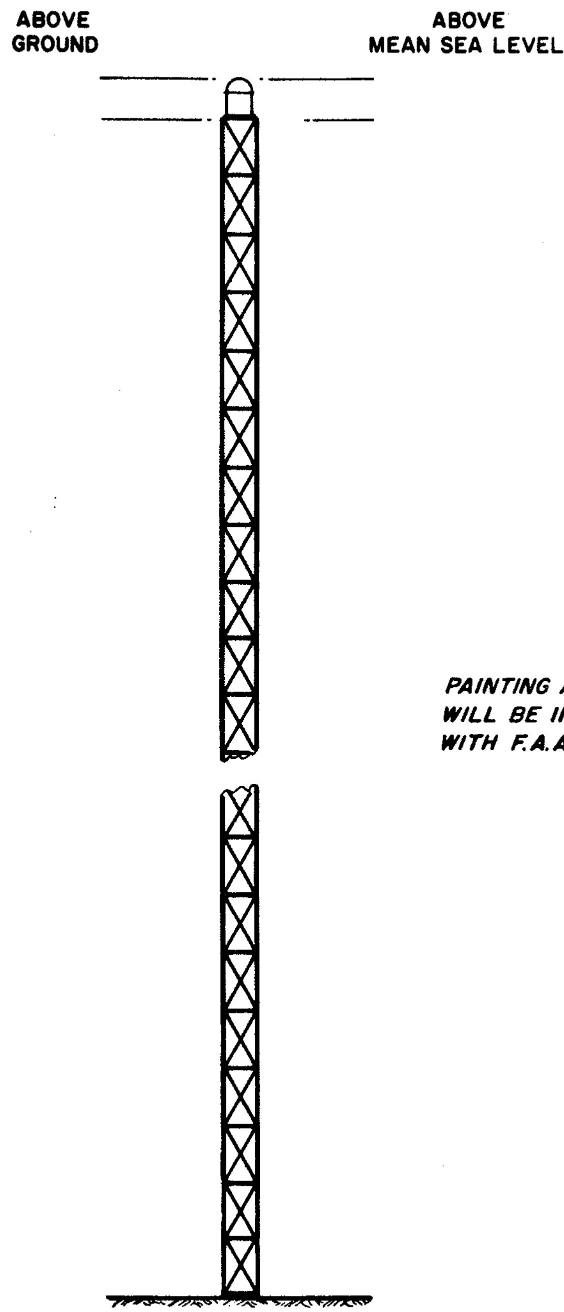


RESISTANCE MEASUREMENTS
NON-DIRECTIVE DAYTIME ANTENNA (NO. 2 TOWER)
WEEU, READING, PENNSYLVANIA
850 KHz 1 KW DA-N
JUNE 1973

Frequency KC	Resistance Ohms
820	18.9
825	18.9
830	19.0
835	19.0
840	19.1
845	19.1
850	19.1
855	19.2
860	19.3
865	19.3
870	19.5
875	19.6
880	19.8

Reactance at 850 KHz = -j99.5 ohms.

COHEN AND DIPPELL, P.C.
CONSULTING ENGINEERS
RADIO - TELEVISION
WASHINGTON, D. C. 20004



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