

AD-A056 685

MEGATEK CORP SAN DIEGO CA

F/G 17/7

OMEGA NORWAY ANTENNA SYSTEM CHARACTERISTICS: MODIFICATION AND V--ETC(U)

MAY 78 A N SMITH, J C HANSELMAN

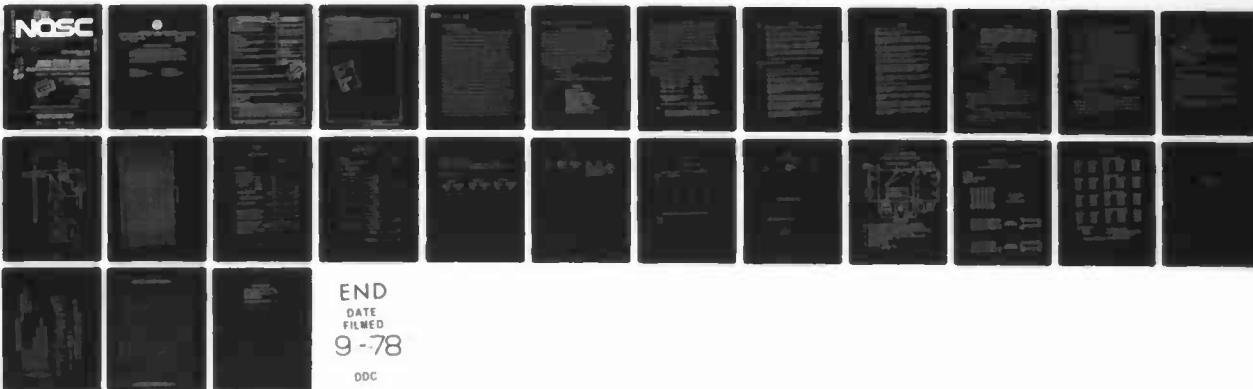
N00123-75-C-0328

UNCLASSIFIED

NOSC-TR-246-VOL-3

NL

1 OF 1
AD
A056685



AD A 056685

NOSC TR 246

A056631 **LEVEL II** *(12)*
NOSC

NOSC TR 246

(15) *N00123-75-C-0328*

(18) *NOSC*

(19) *TR-246-VOL-3*

Technical Report 246
Volume 3

AD No. _____
DDC FILE COPY

(6)
**OMEGA NORWAY ANTENNA
SYSTEM CHARACTERISTICS:
MODIFICATION AND VALIDATION TESTS.**

Volume 3. Test Plan for Base Impedance

DDC
RECEIVED
JUL 25 1978
RESERVED
F

(10) AN/Smith **NOSC Code 8112**
JC/Hanselman **Megatek**
(11) 8 May 1978

(9) Final Report
Prepared for
US Coast Guard

(12) *34p.*

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

NAVAL OCEAN SYSTEMS CENTER
SAN DIEGO, CALIFORNIA 92152

78 07 14 053
391 984

Yue



NAVAL OCEAN SYSTEMS CENTER, SAN DIEGO, CA 92152

AN ACTIVITY OF THE NAVAL MATERIAL COMMAND

RR GAVAZZI, CAPT USN

Commander

HL BLOOD

Technical Director

ADMINISTRATIVE INFORMATION

Electronic measurements were performed on the Bratland Omega Antenna System during the months of July and August 1977. The work was performed under NOSC project MP01537B10 with Megatek as contractor under NOSC Technical Agreement 7220-90, Contract N00123-75-C-0328.

Volume 1 of NOSC TR 246 is the report proper. Volume 2 contains data sheets. Volume 3 is the test plan for base impedance. Volume 4 is the test plan for field intensity measurements.

Released by
WE RICHARDS, Head
Communications Research and
Technology Division

Under authority of
RO EASTMAN, Head
Communications Systems and
Technology Department

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

12

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NOSC Technical Report 246 (TR 246)	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) OMEGA Norway Antenna System Characteristics: Modification and Validation Tests (Four Volumes)		5. TYPE OF REPORT & PERIOD COVERED Final
7. AUTHOR(s) AN Smith (NOSC) JC Hanselman (Megatek)		6. PERFORMING ORG. REPORT NUMBER
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Ocean Systems Center San Diego, CA 92111		8. CONTRACT OR GRANT NUMBER(s)
11. CONTROLLING OFFICE NAME AND ADDRESS US Coast Guard		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS NOSC MP01537B10
14. MONITORING AGENCY NAME & ADDRESS (If different from Controlling Office)		12. REPORT DATE 8 May 1978
		13. NUMBER OF PAGES 28
		15. SECURITY CLASS. (of this report) Unclassified
		16a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES Volume 1 is the report proper. Volume 2 contains data sheets. Volume 3 is the test plan for base impedance. Volume 4 is the test plan for field intensity measurements.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Omega vlf navigation system Antennas - configuration Monopole antenna Measurements - electrical Radiation resistance - efficiency		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Electronic measurements were performed on the Bratland Omega Antenna System during the months of July and August 1977. The work was performed under NOSC project MP01537B10 with Megatek as contractor under NOSC Technical Agreement 7220-90, Contract N00123-75-C-0328. The antenna height had been significantly lowered in 1975, therefore tests were conducted on antenna performance in three configurations, so that a curve of performance for each frequency of operation is now available as a function of antenna span height. A determination of geometry by means of an optical		

DDC
JUL 25 1978
F

DD FORM 1473

EDITION OF 1 NOV 58 IS OBSOLETE
S/N 0102-014-6801

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

survey was carried out by NOSC in the period 21 through 25 July 1977. Reference data for future comparison, in the event the antenna spans are raised, are thus available.

The electrical height of the antenna is 205 meters for 10.2 kHz when the span is in the so-called 1975 or intermediate elevation in which spans 1 and 3 are respectively paid out 14 and 10½ turns from the "high" or 1973 position. The effective height varies directly as the mean span height, so that the percent increases are the same for electrical and geometrical height. For the 1973 position the effective height is 229 meters. There is a small frequency variation which is very nearly proportional to the fifth root of the frequency ratio.

The antenna system efficiency in the 1975 configuration is 5.9%, and in the 1973 configuration is 7.3%; therefore with 150 kW antenna system input power the station will be able to radiate 10 kW when the spans are raised. For this mode of operation the spans are operating at about 70% of their design voltage limit or less; full 10 kW radiated can be obtained by raising the spans back to the full 1973 height.

ACCESSION for	
NTIS	White Section ☒
DDC	Buff Section ☐
UNANNOUNCED	
JUSTIFICATION	
BY DISTRIBUTION/AVAILABILITY: ☐ ☐	
Dist.	AVAIL. dist.
	

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

890 21 40 82

1.0 BASE CHARACTERISTICS

1.1 Description of Requirements

1.1.1. The antenna for a VLF transmitting station operating on the OMEGA frequencies (10.2 kHz to 13.6 kHz) is electrically very short and is conveniently, but not accurately, represented by a small inductance, a large capacitance and a small resistance in series. The net reactance, at the operating frequencies, is capacitive. Measurements of the base reactances are made in terms of "apparent capacitance," ($C_{app.}$), by the substitute or auxiliary capacitor method. Since the reactance at the exit bushing is the value required to calculate the tuning network reactance, measurements are made at this point on all the OMEGA and unique frequencies. These values include the net reactance of the bushing and the net reactance of the antenna, expressed as an "apparent capacitance." The tuning network must supply a reactance, of the opposite sign, to resonate the antenna system. The tuning network consists of the Helix inductance (L_H), the variometer inductance (L_V), the inductance of the buswork and the various leakage inductances of the coupling transformers expressed as the tuning inductance (L_{tune}). The inductance of all items except the Helix is measured by substituting a capacitor for everything outside of a variometer room, measuring the resonant frequency and calculating the value of the sum of transformer leakage inductance, the buswork and the variometer. If the variometer is repositioned, to many points in its operating range, the inductance range of the variometer is obtained. The mid point of the relatively linear portion of the variometer is chosen as the optimum operating point and the total inductance is called L_V . From these values the Helix

inductance (L_H) required is obtained by subtraction:

$$L_H = L_{\text{tune}} - L_V$$

1.1.2. Measurements of the self-resonant frequency (f_0) of the antenna are made to determine the approximate values of the static capacitance (C_0) and the inductance of the structure. These approximate values are determined, by calculation, as if they were lumped into a single capacitance and a single inductance. Since both inductance and capacitance are in fact distributed along the structure, the calculation will show a variation depending on the frequency, below self-resonance, used in the calculation. Any variations of C_0 as indicated by variation of the self-resonant frequency, caused by aeolian forces, are used to estimate the required travel of the variometer.

1.2 APPARENT CAPACITANCE

1.2.1. Instrumentation

a. Test Equipment List

The following equipment is used in the measurement of Apparent Capacitance.

EQUIPMENT

Oscillator, H-P 651
Counter, H-P
Amplifier, McIntosh MC-100
Resistor "Z" (see Appendix I)
Variable Inductor, 2.2 to 25 mH
Decade Capacitor, G-R-1419B
Variable Capacitor, GR-1422N
Current Transducer, Pearson
Oscilloscope, H-P
Digital Voltmeter, Fluke 8600A
Auxilliary Capacitors, Mica, 0.05 mF
Knife Switch, DPDT
Transformer, Isolation, Topaz

b. Since this is a completed station it is impractical to measure the apparent capacitance and self-resonant frequency from the top of the Helix coil framework as done during the station installation. A table to support instruments similar to Figure 1, will be placed on the roof of the helix building near the exit bushing. The test equipment was connected as shown in the block diagram of Figure 2. An isolation transformer, if used, is placed on the platform, at the end of an extension cord, to provide power for the A.C. operated test equipment without producing a second ground path.

1.2.2. Procedure

a. Since the G-R type 1419-B Decade Capacitor has a maximum voltage limitation of 350 volts rms (500 V peak) it is necessary to limit the current through the resonant circuit of Figure 2 when the substitute capacitors are in use. The following parameters are given to illustrate the procedure used to measure and monitor the current flowing:

Lowest estimate of C apparent:	>0.025 μ F.
Lowest frequency of measurement:	>5000 Hz.
Highest reactance of measurement (C app):	<1275 ohms
Highest voltage across C:	<350 V rms 500 V peak
Maximum voltage from Pearson Current Transducer (0.01 V./A.)	<0.0027 V rms 0.0039 V peak

To calibrate the oscilloscope, use the following procedure:

<u>Step</u>	<u>Procedure</u>
1	Connect all the equipment together as shown in Figure 2. Use co-axial cable between the Pearson Current Transducer and the vertical amplifier of the oscilloscope.

<u>Step</u>	<u>Procedure</u>
2	Short the input terminal of the variable inductor to ground using a clip lead.
3	Connect the Fluke 8600A DVM to the Pearson Transducer using a "tee" in the co-axial cable to the oscilloscope.
4	Adjust the gain control of the McIntosh MC-100 amplifier to obtain a reading of 0.0027 V.A.C. on the DVM.
5	Verify that the oscilloscope indication is approximately 0.007 volts peak to peak. Remember this indication of maximum current for future use with Lissajous Figures.
6	Reduce the gain control of the amplifier to zero and remove the clip lead short from the input terminal of the variable inductor.

b. To measure the apparent capacitance of the antenna,

the following steps are performed:

<u>Step</u>	<u>Procedure</u>
1	Adjust the Variable Inductor, "L," to maximum.
2	Move the knife switch to the position that connects the antenna to L.
3	Increase the gain control of the amplifier to obtain a small Lissajous figure on the oscilloscope.
4	Sweep the oscillator frequency until resonance is indicated by a sloping straight line figure on the oscilloscope. Adjust the amplifier gain as necessary to keep the vertical component of the picture at, or slightly below, the value found in step a. 5.
5	Increase the horizontal and vertical gain of the oscilloscope to obtain the largest possible picture with the slope of the line approximately 45 degrees from the vertical.
6	Carefully adjust the oscillator frequency to a value which closes the picture to a straight line. (This indicates that the load, at that point, is at resonance and, therefore, a pure resistance).
7	Record the frequency reading from the counter on the line for "frequency" on Data Sheet 1. Note that there is a separate sheet for each frequency.

<u>Step</u>	<u>Procedure</u>
8	Reduce the gain of the amplifier.
9	Move the knife switch to the position that connects the variable capacitor package to L.
10	Adjust the capacitor package to produce a straight line. Adjust the amplifier gain as necessary to keep the vertical component of the picture at, or slightly below, the value found in step a. 5.
11	Increase the horizontal and vertical gain to obtain the largest possible picture with the slope of the line approximately 45 degrees from the vertical.
12	Carefully adjust the capacitor package to a value which closes the picture to a straight line.
13	Record the settings of the decade capacitor and the reading of the variable capacitor on data sheets.
14	Sum the corrected values of the decade capacitor settings and the residual capacitance, both taken from Table 1, with the reading of the variable capacitor. Record this value in the column of Table 2, labeled C apparent + bushing.
15	Subtract the bushing capacitance, of 150 pf, from the value in Step 13. Record this value in the column of Table 2, labeled C apparent.
16	Reduce the gain of the amplifier.
17	Repeat Step 2 through 16, for additional frequencies, below the normal operating range, with the following exceptions to Steps 4 and 6: The oscillator frequency is set to a value chosen for measurement. The variable inductor is adjusted to produce resonance.
18	Measurements may be made at several frequencies below the range and must be made at the OMEGA frequencies including the unique frequencies assigned to each station.
19	The value of X_C apparent + bushing is calculated from the value of C apparent + C bushing and the frequency then entered in Table 2.

Step

Procedure

- 20 In order to measure C_{apparent} at frequencies lower than resonance of the variable inductor and C_{apparent} , additional capacity (C_{aux} , in Figure 2) is added in increments of approximately 0.05 μF . A maximum of 0.15 μF . is recommended if high quality mica capacitors are used. Since C_{aux} is in the circuit during resonance with both the antenna and the substitute capacitor assembly, the substitute capacitor will read C_{apparent} .

1.3 SELF RESONANT FREQUENCY

1.3.1. Instrumentation

a. The following equipment is used in the measurement of Self Resonant Frequency. The variance from those indicated in the test plan may be justified by the availability of equipment at the time of test execution.

EQUIPMENT

Oscillator, HP-651

Counter, H-P

Amplifier, McIntosh MC-100

Current Transformer, Pearson

Transformer, Isolation Topaz

b. The same platform and table that was used for the Apparent Capacitance measurements is employed. The test equipment is to be connected as shown in the block diagram of Figure 3. The same isolated power source that was used for the Apparent Capacitance measurements is employed.

1.3.2. Procedure

a. Adjust the oscillator frequency to a frequency well below the expected self-resonant frequency. Set the oscillator output level near one (1) volt r.m.s.

b. Adjust the amplifier gain to produce some small amount of current as indicated on the oscilloscope.

c. Sweep the oscillator frequency up to the first point of resonance indicated by a Lissajous figure showing zero (0) phase angle.

d. Adjust the amplifier gain high enough, within the capability of the equipment, to override noise or interfering signals.

e. Adjust the oscilloscope X and Y gain controls to provide the largest picture possible with the sloping straight line, of the Lissajous figure, at approximately 45 degrees from the vertical.

f. Carefully adjust the frequency of the oscillator to produce a straight line Lissajous figure, then read the frequency from the counter and record the value. Repeat the adjustment of frequency and record the values several times to produce a list that may be averaged. These values are summarized in Table 3.

g. If the wind is blowing, preferably at a variable speed and direction, follow the peak to peak excursions of resonant frequency and record them in Table 3, for an estimate of the variometer travel to be expected.

1.3.3. Calculation of C_0 and L_0

a. In the calculation of the static capacitance and inductance of the antenna it is convenient to assume lumped components. It can be shown that the apparent capacitance at a low frequency and the self resonant frequency may be placed in the following equation to derive the static capacitance:

$$C_o = C_{app} \left[1 - \left(\frac{\omega}{\omega_o} \right)^2 \right]$$

where: C_o = Static (D.C.) Capacitance
 C_{app} = Apparent Capacitance at ω
 ω_o = Self resonant frequency.

A graph of apparent capacitance and the derived C_o is given in Figure 4. Extrapolation of the two curves to zero frequency will help refine the calculated value of C_o .

L_o is derived from the expression:

$$L_o = \frac{1}{\omega_o^2 C_o}$$

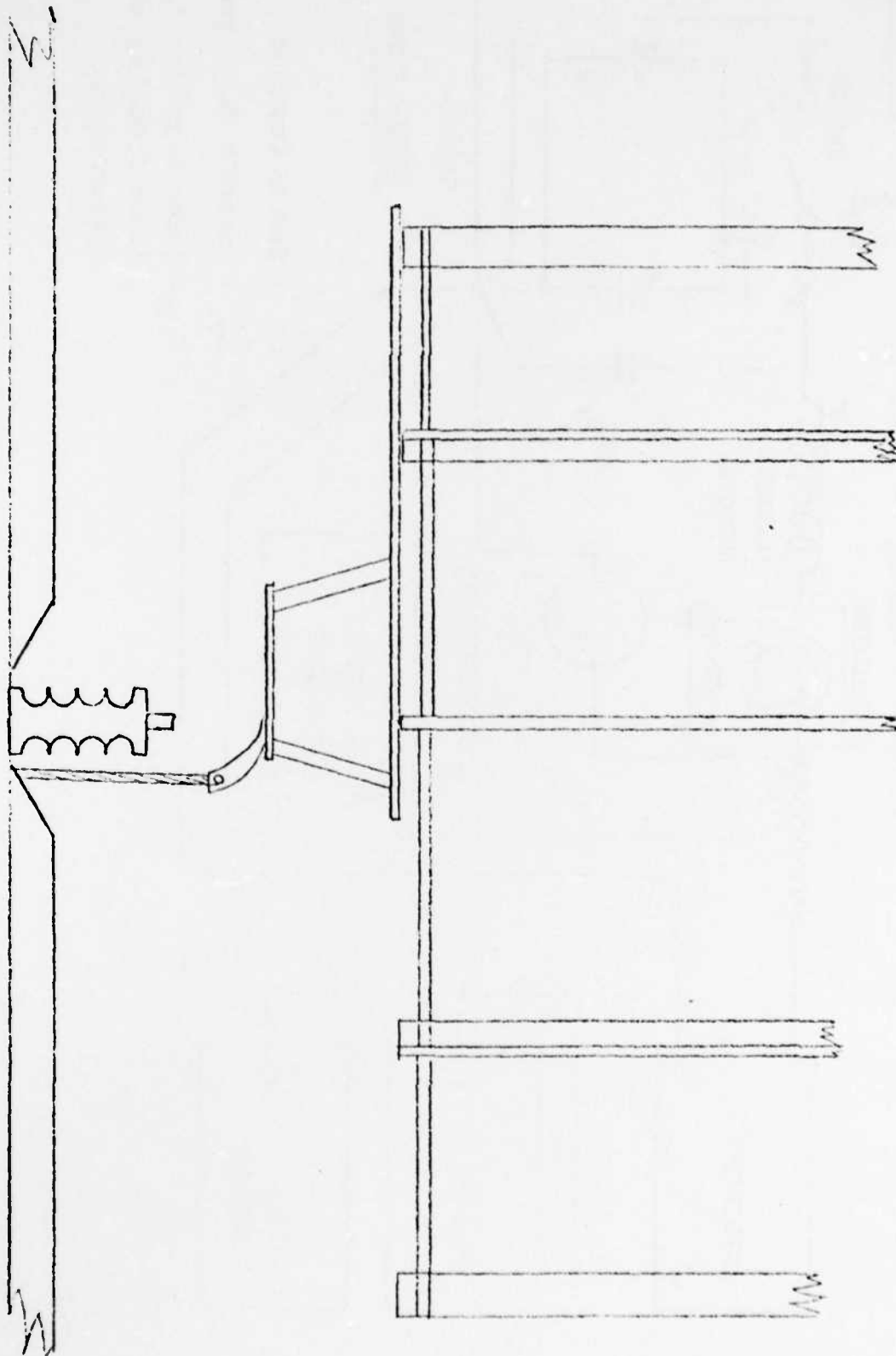
C_o , L_o and the calculations necessary to derive these values are shown in Table 4.

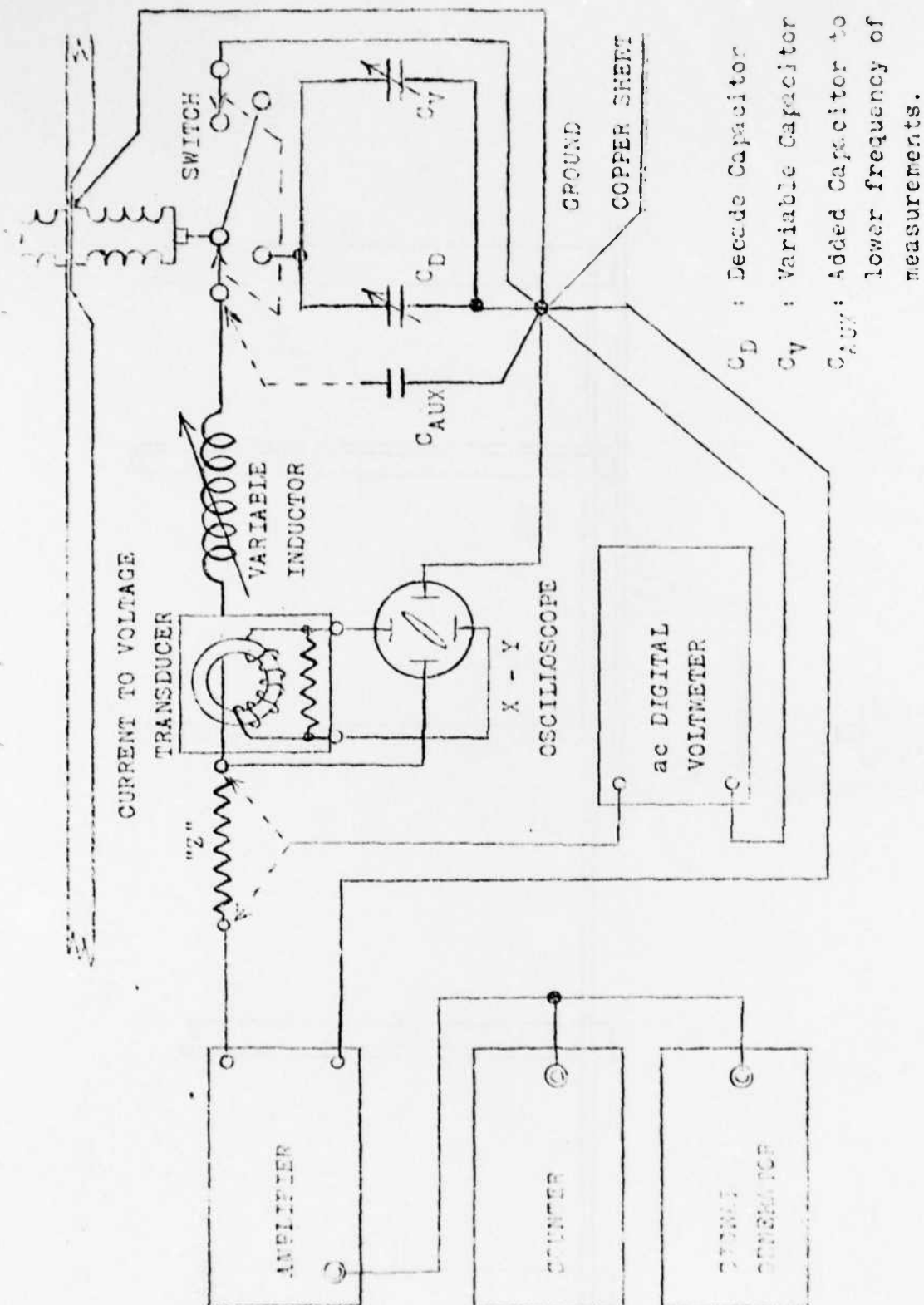
1.4 ANTENNA SYSTEM RESISTANCE, R_{as}

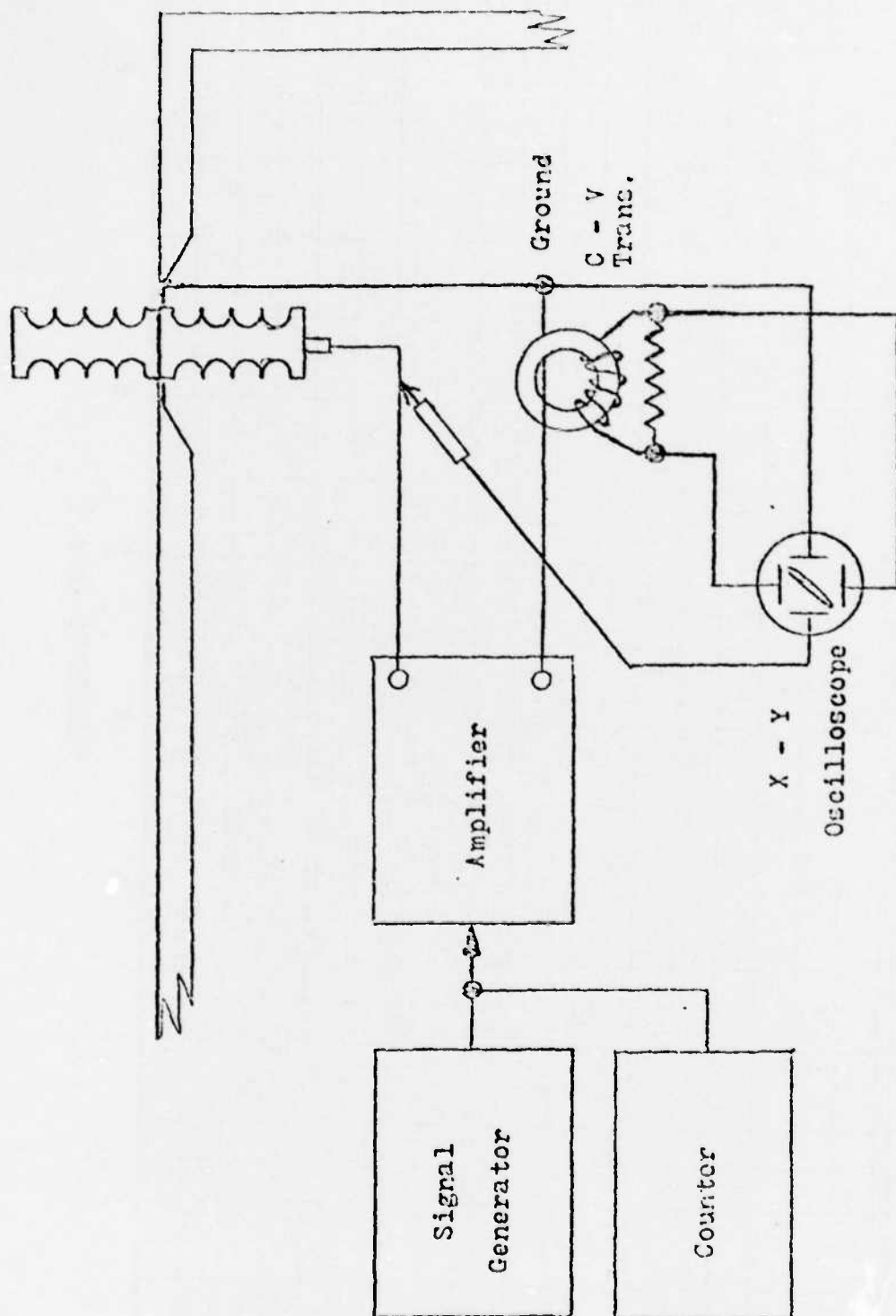
1.4.1. The procedure for performing this measurement has been previously reported as the "Incremental Voltage Method for Antenna System Resistance, (R_{as}). The method is described in Appendix I.

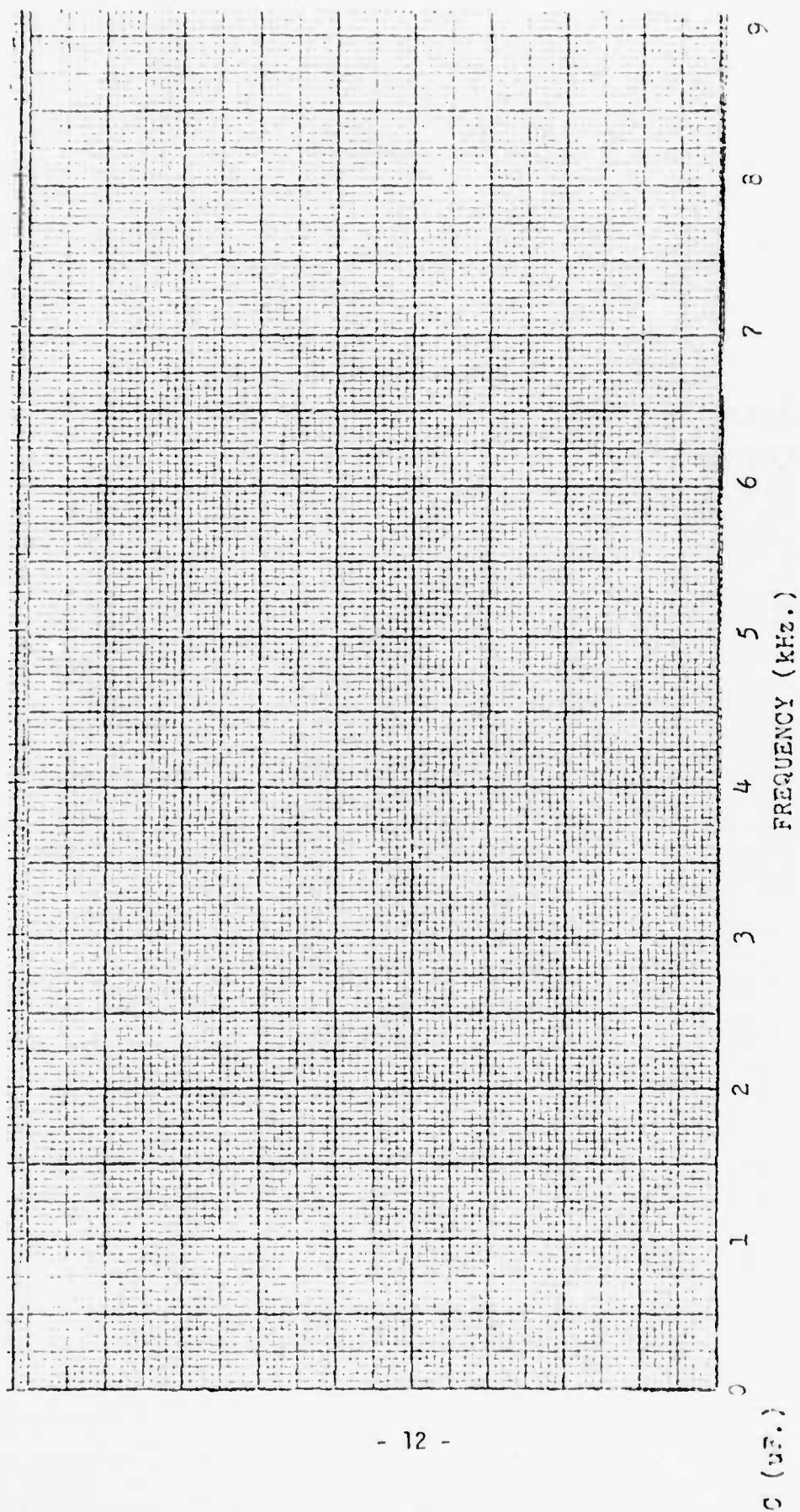
1.4.2. The actual resistor (Z) may be one of two available. In either case the value of R will be corrected for frequency to become the impedance " Z ".

1.4.3. Measurements will be made at the four (4) OMEGA frequencies and the remaining unique frequency if applicable.









- 12 -

Figure 4

DATA SHEET 1

APPARENT CAPACITANCE

Date _____

1. Frequency _____ Hz.

2. Decade Capacitor

Indicated Reading: 0 . _____ $\mu\text{F.}$

Corrected Values : 0.0X . 0 . _____ $\mu\text{F.}$

(Table 1) 0.00X . 0 . _____ $\mu\text{F.}$

0.000X . 0 . _____ $\mu\text{F.}$

Residual Capacitance: _____ $\mu\text{F.}$

Add

TOTAL Decade Capacitance: 0 . _____ $\mu\text{F.}$

3. Variable Capacitor:

Add 0 . _____ $\mu\text{F.}$

4. Apparent Capacitance, $C_{app.}$:
(Includes Exit Bushing)

0 . _____ $\mu\text{F.}$

5. Reactance, X_C (Calculated)

_____ Ohms

6. Exit Bushing Capacitance
(Manufacturer's Data)

Subtract 0 . 0 0 0 1 5 0 . _____ $\mu\text{F.}$

7. Apparent Capacitance, $C_{app.}$,
(Antenna only)

0 . _____ $\mu\text{F.}$

DATA SHEET 2
ANTENNA SYSTEM RESISTANCE

R_{as}

Date _____

1. Frequency _____ Hertz
2. Fixed Resistor, Z (Impedance) _____ Ohms

3. $R_{as} = \frac{E_1 Z}{E - E_1}$ (Ohms)

4. Voltage Readings:

Trial 1 $E =$ _____ Volts
 $E_1 =$ _____ Volts
 $R_{as(1)} =$ _____ Ohms

Trial 2 $E =$ _____ Volts
 $E_1 =$ _____ Volts
 $R_{as(2)} =$ _____ Ohms

Trial 3 $E =$ _____ Volts
 $E_1 =$ _____ Volts
 $R_{as(3)} =$ _____ Ohms

Trial 4 $E =$ _____ Volts
 $E_1 =$ _____ Volts
 $R_{as(4)} =$ _____ Ohms

Trial 5 $E =$ _____ Volts
 $E_1 =$ _____ Volts
 $R_{as(5)} =$ _____ Ohms

5. Average $R_{as} =$ _____ Ohms

TABLE 1

Polystyrene Decade Capacitor

General Radio, Type 1419-B

Serial Number (Unknown) Calibration data supplied by
NAVELEXSYSENGCEN, Great Lakes, Ill.

Residual Capacitance:

DECADE 1		DECADE 2		DECADE 3	
Switch Dial	Corrected Value	Switch Dial	Corrected Value	Switch Dial	Corrected Value
uF	uF	uF	uF	uF	uF
_____	_____	_____	_____	_____	_____

TABLE 2

FREQUENCY (Hz.)	C _{apparent} + bushing (uF)	C _{apparent} antenna only (uF)	R' _{as} (Ohms)	R' _{tune} (Ohms)	R _a (Ohms)
_____	_____	_____	R' _{as} and R' _{tune} too large to measure accurately enough to subtract for R _a .		

TABLE 3

SELF-RESONANT FREQUENCY

a. Taken during clear dry weather and low surface wind.

TRIAL	FREQUENCY (Hz.)	E	E ₁	R _a
1	_____	_____	_____	_____
2	_____	_____	_____	_____
3	_____	_____	_____	_____
4	_____	_____	_____	_____
5	_____	_____	_____	_____
6	_____	_____	_____	_____
7	_____	_____	_____	_____
$\bar{x}$	_____	_____	_____	_____
s	_____	_____	_____	_____

b. Largest noted peak to peak excursion during slight wind.

f_{high} _____

f_{low} _____

TABLE 4

 C_o , Static (DC) Capacitance

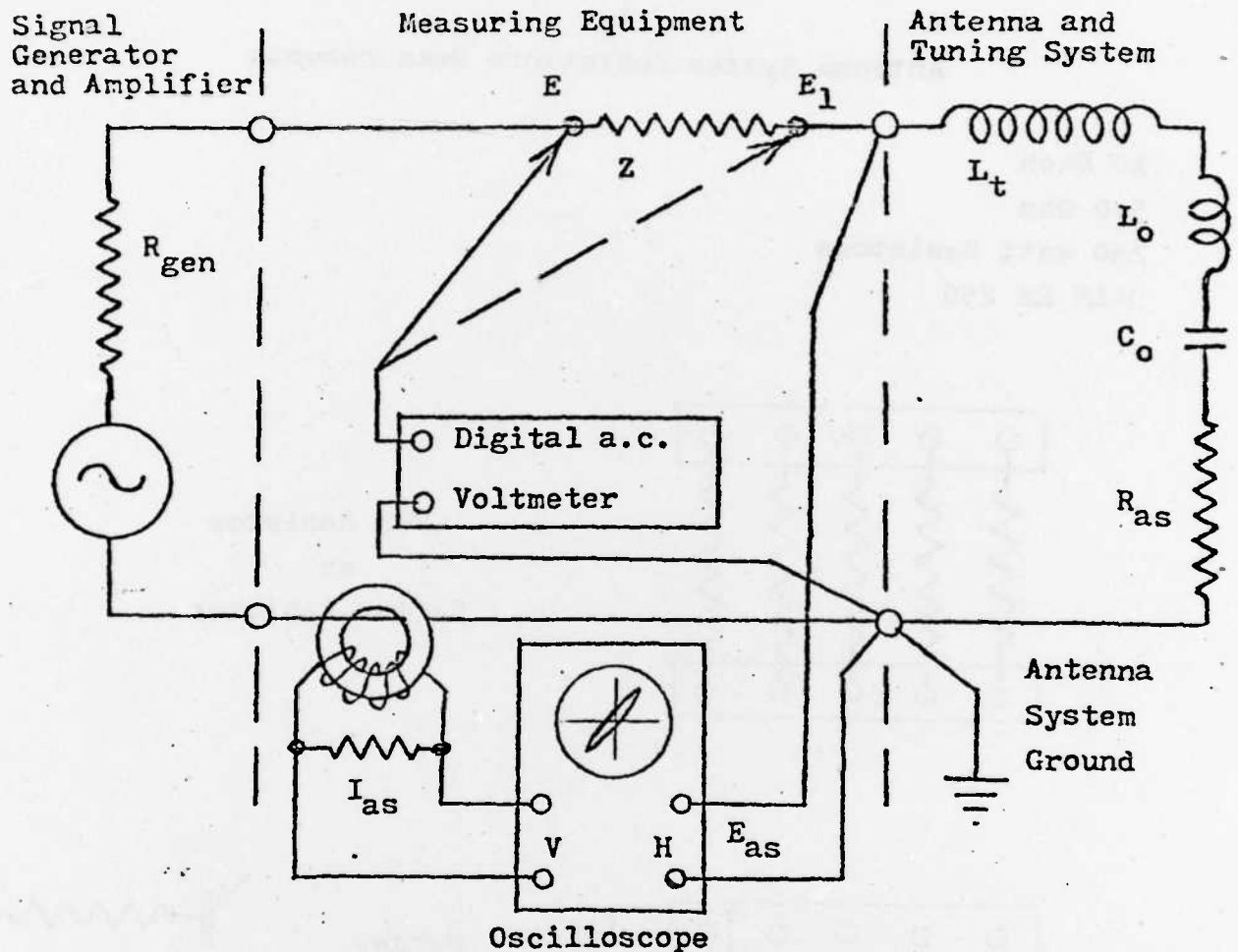
Frequency (Hz.)	$C_{app.}$ Antenna only. (uF.)	C_o (uF.)
--------------------	--------------------------------------	----------------

ANTENNA INDUCTANCE (L_o) f_o C_o (Extrapolated in Figure 4.)

$$L_o = \frac{1}{(\omega_o)^2 C_o} =$$

APPENDIX I

INCREMENTAL VOLTAGE METHOD for ANTENNA SYSTEM RESISTANCE (R_{as})

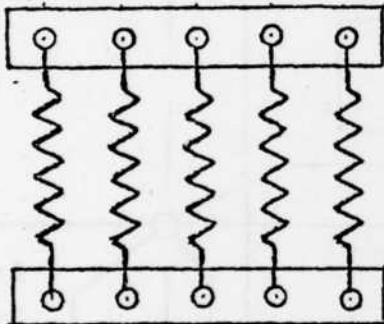


1. Select Z approximately equal to R_{as} (Estimated)
2. Set the Generator to the frequency of measurement.
3. Tune the Antenna to resonance as indicated by zero (0) degrees phase angle between I_{as} and E_{as} .
4. Adjust Antenna current (I_{as}) to the maximum value allowable through Z .
5. Measure E and E_1 .
6. Solve for:
$$\frac{E_1 Z}{E - E_1} = R_{as}$$

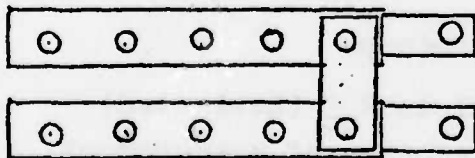
APPENDIX I

Resistor Assembly for Antenna System Resistance Measurements

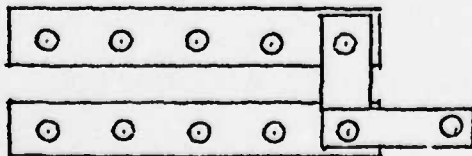
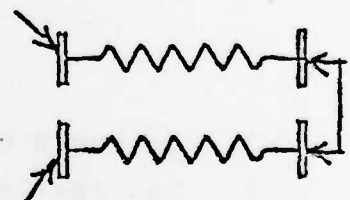
10 Each
5.0 Ohm
250 Watt Resistors
DALE RH 250



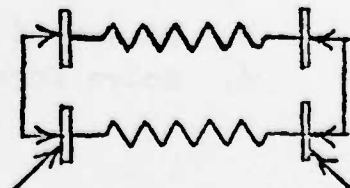
Top Resistor
or
Bottom Resistor



Series
Connection



Parallel
Connection



APPENDIX I

Bottom Resistor				
f(kHz)	R(Ohms)	L(uH)	X_L (Ohms)	Z(Ohms)
10.0	0.993	0.38	0.0239	0.9933
15.0	0.994	0.37	0.0349	0.9946
20.0	0.993	0.37	0.0465	0.9941

Top Resistor				
f(kHz)	R(Ohms)	L(uH)	X_L (Ohms)	Z(Ohms)
10.0	0.992	0.36	0.0226	0.9923
15.0	0.993	0.36	0.0339	0.9936
20.0	0.994	0.36	0.0452	0.9950

Series Connection				
f(kHz)	R(Ohms)	L(uH)	X_L (Ohms)	Z(Ohms)
10.0	1.984	0.42	0.0264	1.9842
15.0	1.983	0.42	0.0396	1.9834
20.0	1.983	0.42	0.0528	1.9837

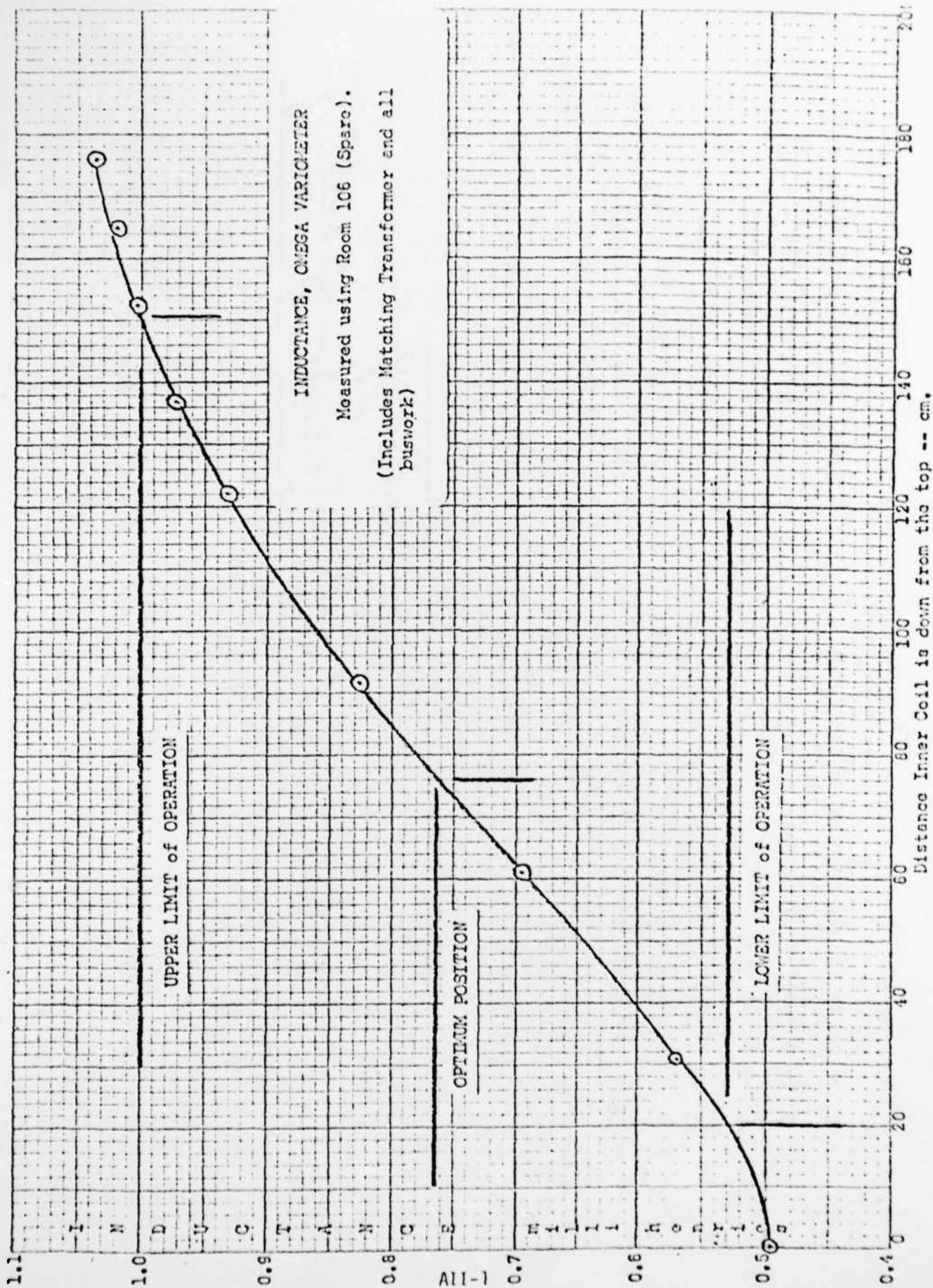
Parallel Connection				
f(kHz)	R(Ohms)	L(uH)	X_L (Ohms)	Z(Ohms)
10.0	0.496	0.24	0.0151	0.4962
15.0	0.496	0.24	0.0226	0.4965
20.0	0.497	0.24	0.0302	0.4975

MEASUREMENTS:

Type: 4 terminal bridge
 Bridge: Wayne Kerr, Universal Bridge,
 Model B221, Mk III
 External Generator: H-P 200CD Oscillator

REFERENCE INFORMATION

APPENDIX II



INDUCTANCE EQUATIONS *

C	-- center to center spacing of wire (cm.)	*	From: "The Theory and Design of Inductance Coils",
d	-- diameter of wire (cm.)		V. G. Welsby, 1960,
ℓ	-- length of coil (cm.)		Second Edition, p. 42,
N	-- number of turns in the coil		Equations (40), (41),
r	-- radius of coil (cm.)		(42), (43) and (44).
L ₀	-- inductance of coil in free space		

$$K_N =$$

$$\frac{1}{1 + 0.9\left(\frac{r}{\ell}\right) - 0.02\left(\frac{r}{\ell}\right)^2}$$

$$K_C = 1 - \ell \left\{ \left[\ln 1.73 \frac{d}{c} \right] + \left[0.336 \left(1 - \frac{2.5}{N} + \frac{3.8}{N^2} \right) \right] \right\}$$

$$\pi r N K_N$$

$$L_0 = \frac{4 \pi^2 r^2 N^2}{\ell}$$

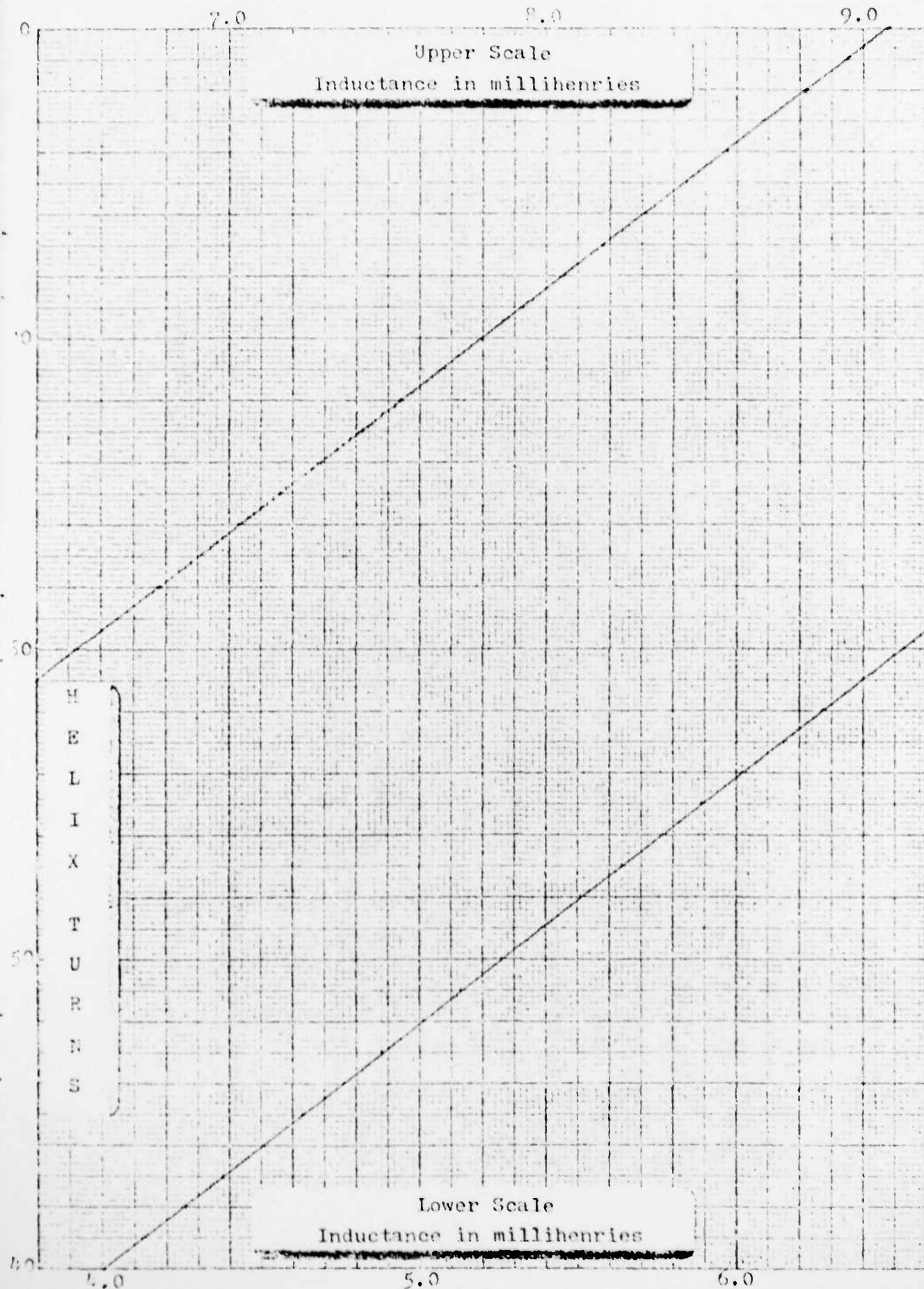
$$K_N K_C \times 10^{-6} \text{ (mh.)}$$

SHIELDING, Effect on Inductance *

- b -- radius of shield (cm.) * From: "Radiotron Designer's Handbook", Fourth Edition, p. 439, (D).
- r -- radius of coil (cm.)
- ℓ -- length of coil (cm.)
- L_0 -- inductance of coil in free space
- L_0' -- inductance of coil in a shielded enclosure
- ℓ_s -- length of shielded enclosure (along axis of the coil)
- g -- $b-r$ (spacing between coil and shield)

$$L_0' = L_0 \left\{ 1 - \left[\frac{1}{1 + 1.55 \frac{r}{\ell} \left(\frac{b}{r} - 1 \right)} \left(\frac{r}{b} \right)^2 \right] \right\}$$

- Notes: 1. Valid for: $\frac{g}{\ell} \gg 1$
2. When $\ell_s > \ell + 2g$, the effect on L_0' caused by closing the ends of the shielded enclosure is negligible.



INITIAL DISTRIBUTION

OMEGA NAVIGATION SYSTEM OPERATIONS
DETAIL (G-ONSOD) (20)
HEADQUARTERS, US COAST GUARD
2100 2ND STREET, SW
WASHINGTON, DC 20590

DEFENSE DOCUMENTATION CENTER (12)