

INSTRUCTION MANUAL
FOR
LOOP ANTENNA
MODEL 94608-1

Manual No. 1-500783-282 (REV. A)

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11-85

EATON CORPORATION
Electronic Instrumentation Division
Los Angeles Plant
5340 Alla Road
Los Angeles, California 90066

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Chargeable repairs: If requested, an estimate of charges will be made prior to repairs. Please provide us with the following information in order to expedite the processing of your instrument:

- | | |
|---|---|
| 1. Model or Type | 5. Approximate number of hours in use. |
| 2. Serial Number | 6. Maintenance action previously requested or performed |
| 3. Description of trouble ⁽¹⁾ | 7. Other comments. |
| 4. Approximate date instrument was placed in operation. | |

⁽¹⁾ Include data on symptoms, measurements taken, suspected location of trouble, maintenance action taken and any other relevant data

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Section I
INTRODUCTION

1.1 GENERAL DESCRIPTION

The **Eaton** Model 94608-1 is an electrostatically shielded loop antenna that operates over a frequency range of 20 Hz to 250 kHz. The loop antenna is 30 inches in diameter and is wound with 11 turns. The loop may be mounted on a standard tripod for remote measurements.

1.2 APPLICATIONS

The Model 94608-1 Loop Antenna may be used with any Electromagnetic Interference/Field Intensity (EMI/FI) Meter or calibrated receiver that tunes part or all of the 20 Hz to 250 kHz frequency range. The loop may be terminated by any known load impedance from 50 ohms to 100,000 ohms and accurate measurements can be made of Magnetic Flux Density or related Magnetic Fields; see Table 4-1.

1.3 ACCESSORIES

1.3.1 Supplied Accessories

The items listed in Table 1-1 are furnished with the Model 94608-1 Loop Antenna.

Table 1-1. Supplied Accessories

Quantity	Device	Eaton Part Number
1	Instruction Manual	1-500783-282

1.3.2 Optional Accessories

- a. Collapsible Tripod, Model 91933-2. Used for mounting the Loop Antenna for remote measurements.
- b. RF Transmission Line, Model 92191-1, 20 ft., BNC. Used for connecting the output receptacle of the Model 94605-1 Loop Antenna to the RF input receptacle of an EMI/FI Meter or calibrated receiver within a distance of 20 feet.

Section II

SPECIFICATIONS

2.1 SPECIFICATIONS

Table 2-1 contains specification data for the Model 94608-1 Loop Antenna.

Table 2-1. Specifications and Operating Characteristics

Parameter	Characteristic
Frequency range:	20 Hz to 250 kHz in one band
RF output load impedance:	50, 600 or 100 k ohms
Loop diameter:	76.2 cms (30")
Number of turns:	11
Shielding:	Electrostatic (Faraday) shield
Antenna effective height:	See Figure 4-1
Mechanical:	
Dimensions (including receptacles, loop antenna and base plate):	Height: 81.25 cm (32") Width: 79.15 cm (31.16") Depth: 8.89 cm (3.5")
Weight:	0.9 kg (2.0 lbs)
Mounting hole thread size:	1/4-20 UNC-2B
Environmental:	
Temperature:	Operational and non-operational: -50°C to +75°C (-58°F to +167°F)
Vibration:	Meets MIL-T-21200, Class 3 non-operating
Altitude:	Operational to at least 4570 m (15,000 ft) mean sea level

Section III

INSTALLATION

3.1 GENERAL

The Loop Antenna may be set in a vertical position on its base on a flat surface. Use a Model 92191-1 20 foot RF cable to connect the loop output receptacle to the RF input receptacle of the EMI/FI Meter or receiver.

3.2 TRIPOD MOUNTING

The Loop Antenna may be mounted directly on the tripod by tightening the 1/4-20 screw into the mounting hole in the antenna base by means of the tripod center knob. The antenna can be oriented in any desired position in the vertical axis by loosening the tripod center knob.

Section IV

OPERATING INSTRUCTIONS

4.1 GENERAL

Magnetic Flux Density in Picotesla (pT) or Electric Field Strength (E vector) in microvolts-per-meter ($\mu\text{V}/\text{m}$) can be determined by applying the factors of Figures 4-1 and 4-2 to the signal induced voltage at the loop antenna terminals. Several related radiated emission terms are shown in Table 4-2 and conversion values are given for easy changing from one term to another. Figure 4-3 provides power gain versus frequency information. Table 4-1 gives RF field strength information when using the loop as a signal source. The direction or bearing of a signal source can be determined by rotating the Loop Antenna for a null output on the signal, an advantageous use of the Figure 8 radiation pattern of a loop antenna.

4.2 PICOTESLA MEASUREMENTS

- a. Orient the Loop Antenna for maximum EMI/FI Meter or calibrated receiver indication.
- b. Measure the signal level in $\text{dB}\mu\text{V}$ at the input to the measuring instrument.
- c. Algebraically add the Conversion Factor in dB at the test frequency as indicated in Figure 4-1 to obtain the magnetic flux density in dB relative to one picotesla (dBpT).

NOTE

Use the Figure 4-1 graph curve that corresponds to the input impedance of the measuring instrument. Use the lowest input impedance available on the measuring instrument for best overall signal-to-noise ratio (applies when a transformer input design is used).

Example:

Assume a measuring instrument reading of 55 dB μ V at a frequency of 50 kHz. Assume the input impedance of the measuring instrument to be 50 ohms. From Figure 4-1 the conversion factor is 4 dB. The Magnetic Flux Density (B) in dB above one picotesla is:

$$B = 55 \text{ dB}\mu\text{V} + 4 \text{ dB} = 59 \text{ dBpT}$$

4.3 MICROVOLT-PER-METER MEASUREMENTS

This term is used in the "free-space" sense where the electric and magnetic fields are equal. This is seldom true at low frequencies, and when measuring close to the signal source and in confined areas. However, the microvolts-per-meter term is occasionally used and the following measurement procedure is suggested.

- a. Orient the loop antenna for maximum EMI/FI Meter or calibrated receiver indication.
- b. Measure the signal level in dB μ V at the input to the measuring instrument.
- c. Algebraically subtract the effective height of the Loop Antenna in dB above one meter at the test frequency as indicated in Figure 4-2 to obtain the radiation level or RF field intensity in dB above one microvolt-per-meter.

NOTE

Use the Figure 4-2 graph curve that corresponds to the input impedance of the measuring instrument. Use the lowest input impedance available on the measuring instrument for best overall signal-to-noise ratio (applies when a transformer input design is used).

Example:

Assume a measuring instrument reading of 25 dB μ V at a frequency of 30 kHz. Assume the input impedance of the measuring instrument

to be 50 ohms. From Figure 4-2 the effective height is -55 dB. Then the Electric Field Intensity (E) in dB above one micro-volt-per-meter is:

$$E = 25 \text{ dB}\mu\text{V} - (-55 \text{ dB}) = 80 \text{ dB}\mu\text{V}/\text{m}$$

4.4 SIGNAL BEARING

The Loop Antenna is rotated for a null indication of the signal on the measuring instrument. The plane of the loop is now normal to the direction of the signal. A magnetic bearing of the signal source may be made with the aid of a compass. Since bilateral bearings are obtained with a loop (by virtue of the figure 8 pattern), ambiguity can be resolved by triangulation (plotting bearings taken at two or more sites on a map - the point of intersection indicating the location of the signal source).

4.5 POWER GAIN

Refer to Figure 4-3 for power gain in dB versus frequency. Refer to Paragraph 5-3 for information on determining power gain.

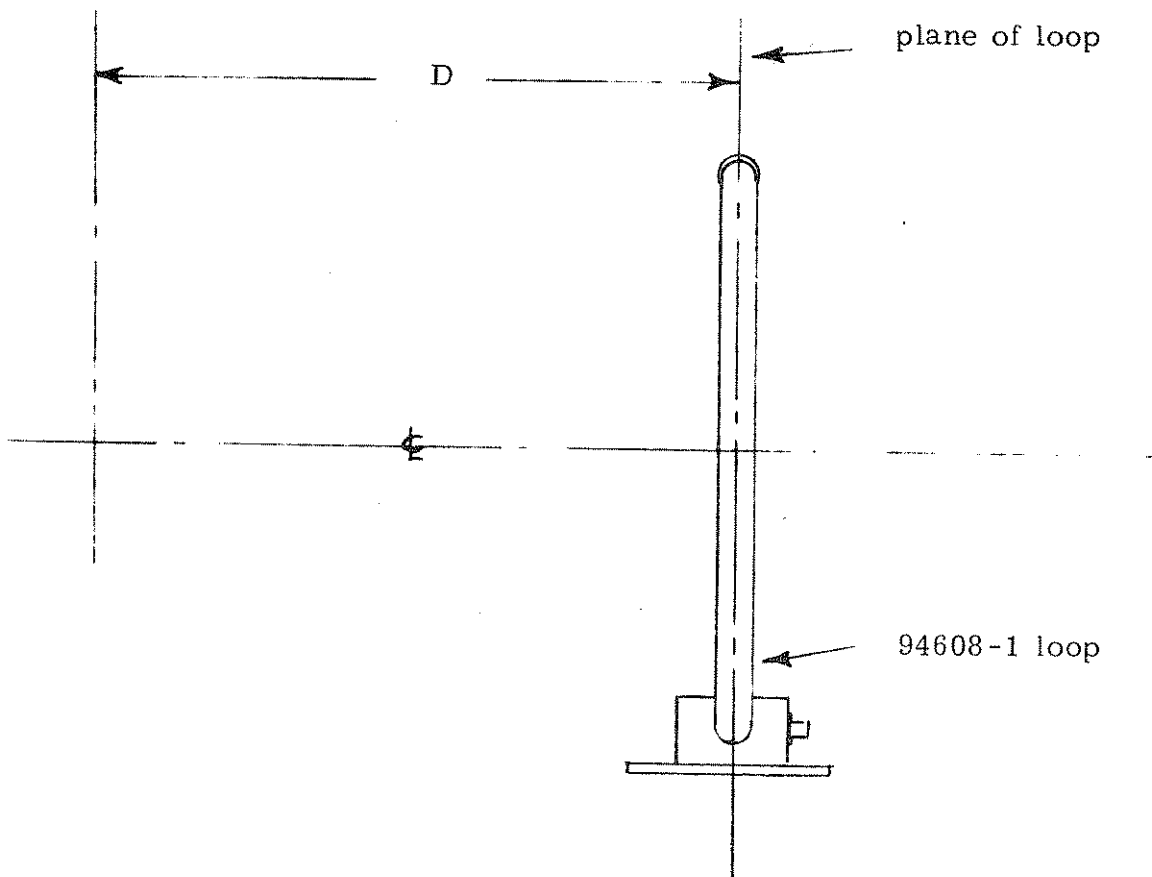
4.6 RF FIELD GENERATION

The loop impedance varies from less than one ohm at low frequencies to well above 50 ohms at resonance (≈ 350 kHz). Computing RF field strength based on power input to the loop is difficult because of the variables involved. It is better to measure and adjust the RF current through the loop winding and not be concerned with the impedance.

4.6 RF FIELD GENERATION (Cont'd.)

The 94608-1 loop antenna is wound with 11 turns of #29 AWG insulated copper wire. Maximum continuous current is 620 mA. Two or three times this current level is permitted for a short time, allowing sufficient time between current applications for cooling of the wire. The RF field strength in volts/meter versus RF current in milliamperes through the loop winding versus distance from the loop in meters is given in Table 4-2.

The RF field strength values given in Table 4-2 are only accurate near to and along a line that is coaxial with the transmitting loop as follows:



Algebraically add the indicated value to convert from ↓ to →	dBuV/m	dBGauss	dBpT	dBuA/m	dBWb/m ²	dBgamma
0 dB microvolts-per-meter =	0	-209.5	-49.5	-51.5	-289.5	-109.5
0 dB Gauss ⁽¹⁾ =	+209.5	0	+160	+158	-80	+100
0 dB pico Tesla =	+49.5	-160	0	-2	-240	-60
0 dB microampere-per-meter =	+51.5	-158	+2	0	-238	-58
0 dB Weber-per-square meter ⁽²⁾ =	+289.5	+80	+240	+238	0	+180
0 dB gamma =	+109.5	-100	+60	+58	-180	0

Multiply by the indicated value to convert from ↓ to →	uV/m	Gauss	pT	uA/m	wB/m ²	gamma
1 microvolt-per-meter =	1	3.33×10^{-11}	3.33×10^{-3}	2.65×10^{-3}	3.33×10^{-15}	3.33×10^{-6}
1 Gauss ⁽¹⁾ =	3×10^{10}	1	1×10^8	7.96×10^7	1×10^{-4}	1×10^5
1 picotesla =	3×10^2	1×10^{-8}	1	7.96×10^{-1}	1×10^{-12}	1×10^{-3}
1 microampere-per-meter =	3.77×10^2	1.26×10^{-8}	1.26	1	1.26×10^{-12}	1.26×10^{-3}
1 Weber-per-square meter ⁽²⁾ =	3×10^{14}	1×10^4	1×10^{12}	7.96×10^{11}	1	1×10^9
1 gamma =	3×10^5	1×10^{-5}	1×10^3	7.96×10^2	1×10^{-9}	1

NOTES:

- (1) One Gauss and One Oersted are equivalent and may be interchanged.
- (2) One Weber-per-square meter and one Tesla are equivalent and may be interchanged.
- (3) Decibel values are "rounded off" to the nearest 0.5 dB.

Table 4-1. Equivalent Magnetic Field Measurement Units and Conversion Chart

Table 4-2. RF Field Strength vs. RF Current vs. Distance from Loop

Distance from Loop in meters	RF Field Strength						
	1v/m mA	5v/m mA	10v/m mA	20v/m mA	50v/m mA	100v/m mA	200v/m mA
1	3.3	16.5	33	66.1	165	331	661
2	26.5	132	264	529	1,322		
3	89	446	892	1,785			
4	211.6	1,056	2,112				
5	413	2,066					
6	714						
7	1,134						
8	1,693						

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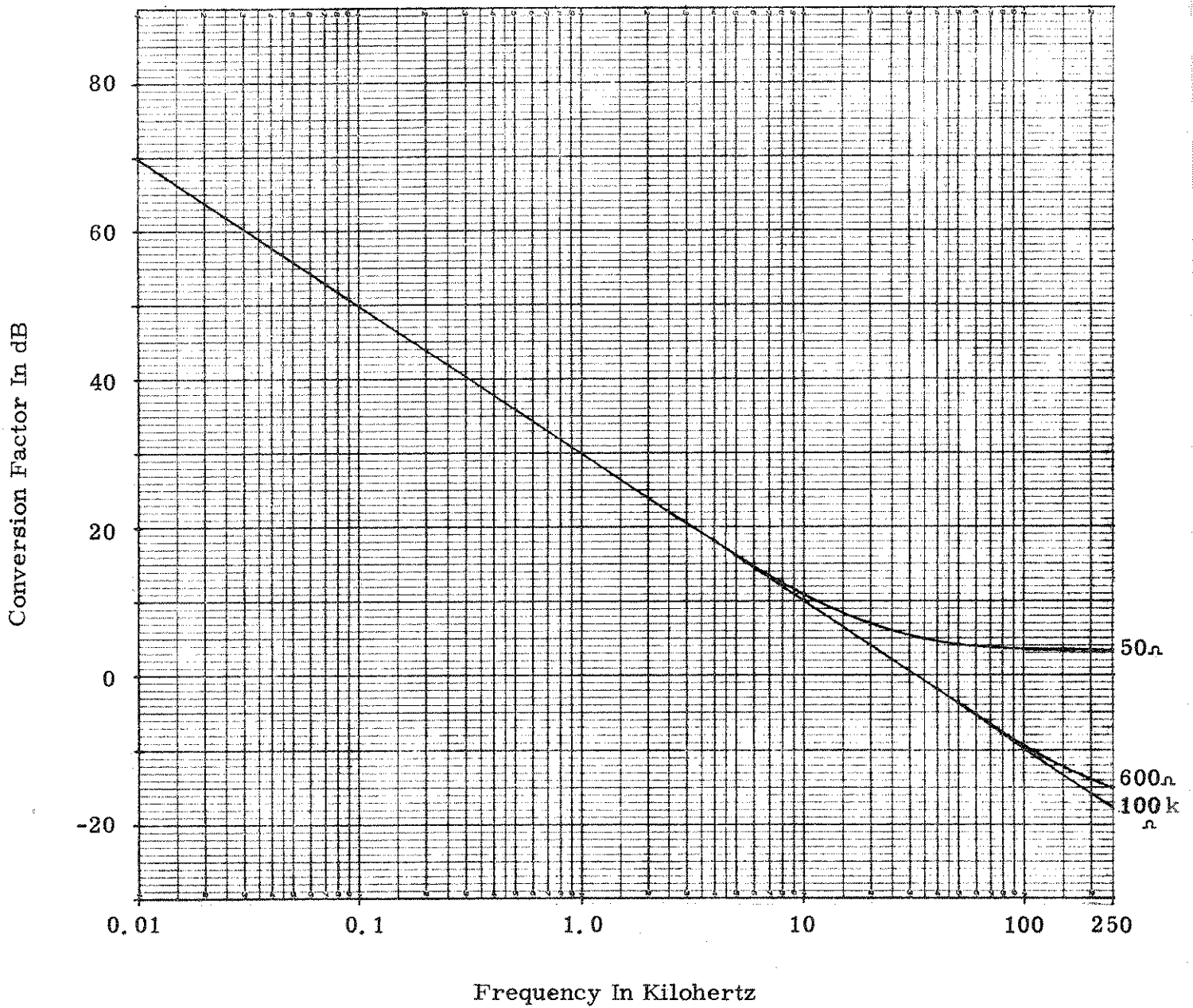


Figure 4-1
 Conversion Factors for Picotesla Terms
 Model 94608-1 Loop Antenna

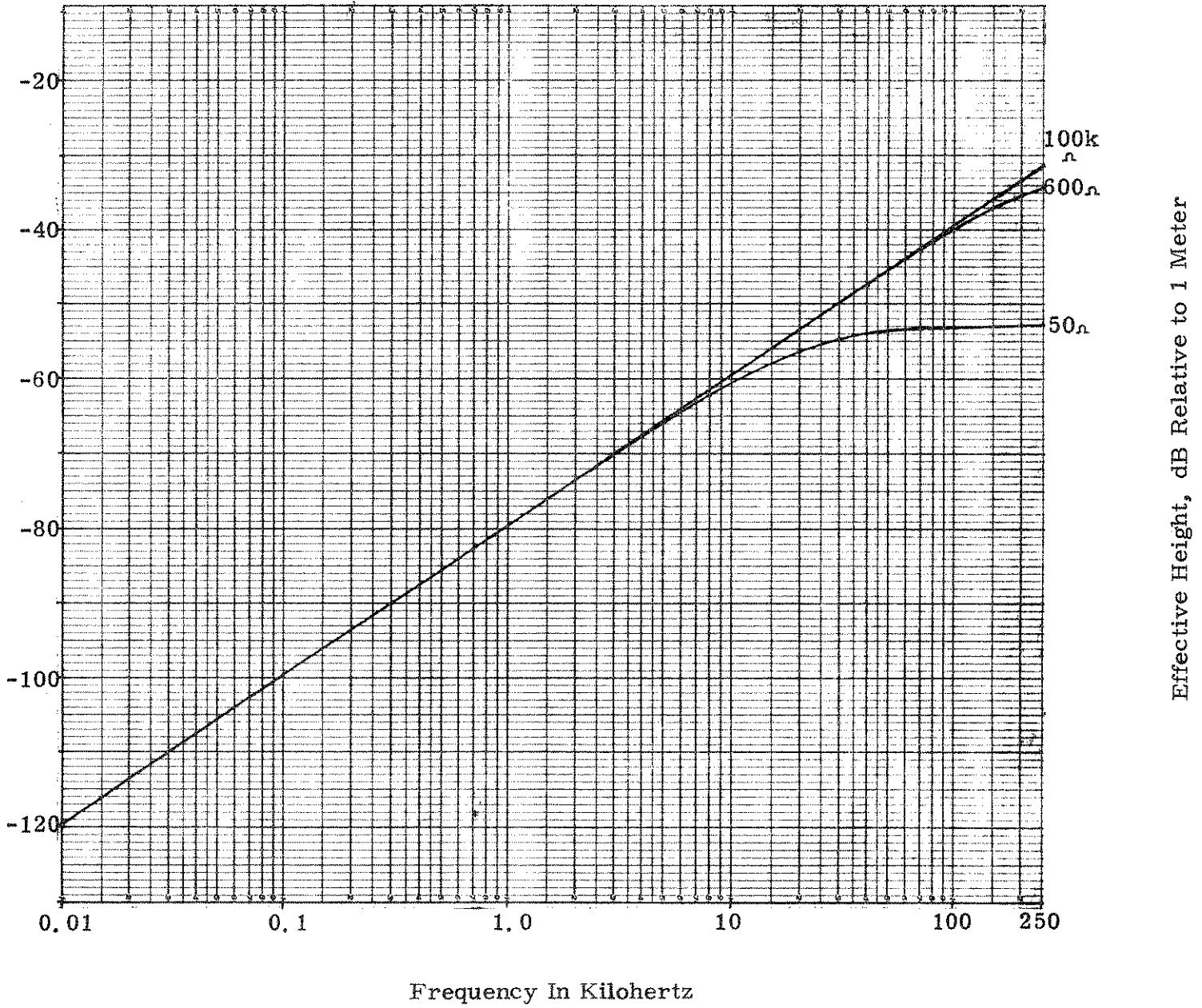


Figure 4-2
Effective Height of Model 94608-1 Loop Antenna

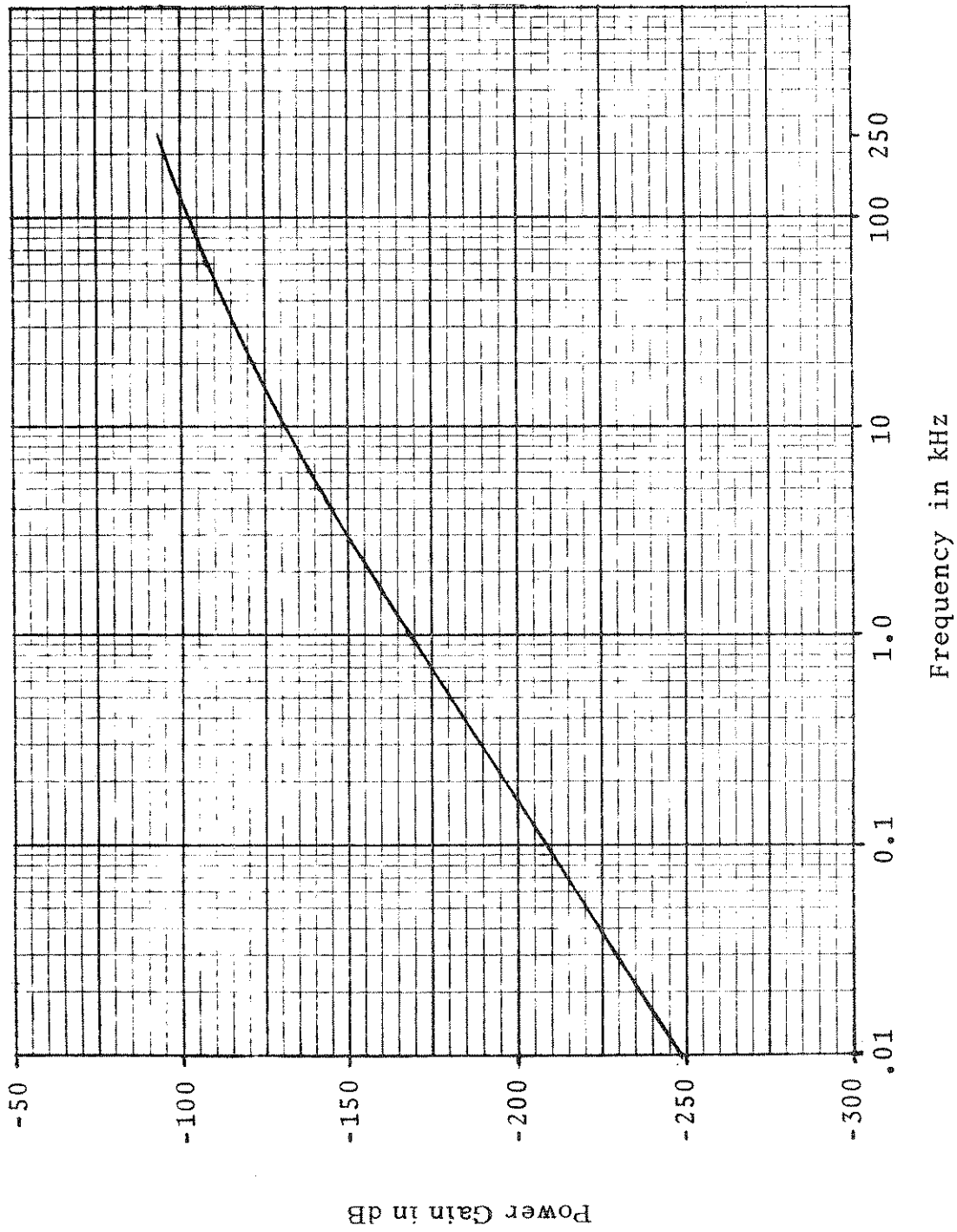


Figure 4-3. Power Gain Versus Frequency

Section V

THEORY OF OPERATION

5.1 GENERAL

The Loop Antenna can be considered as a coil. The dimensions of the Loop Antenna coil are made small with respect to the wavelength of the highest frequency at which it will be used. Consequently, the current induced in the Loop Antenna coil wires is essentially constant throughout (i. e. no standing waves).

The radiation pattern of the Loop Antenna is a figure 8 with maximum response in the plane of the loop. However, when the loop is positioned close to grounded surfaces, distributed capacities between ground and opposite sides of the loop are unequal and will cause unequal currents to flow in the coil, distorting the radiation pattern. To minimize this condition, the loop coil is enclosed within a conductive (Faraday) shield, thus providing equal capacities to ground. The gap in the shield (at the top of the loop) prevents the shield from becoming a short-circuited turn. The shield also greatly reduces the response of the loop to the electric field; therefore, the loop is predominately responsive to the magnetic field.

5.2 EFFECTIVE HEIGHT

The effective height (h) of the Loop Antenna is given by:

$$h = \frac{2\pi N A F}{C} \text{ meters}$$

where:

N = number of turns

A = area of loop in square meters

F = frequency in megahertz

C = velocity of light in megameters per second

The effective height of the Model 94608-1 Loop Antenna at 10 kHz is:

$$h = \frac{2\pi \times 11 \times \pi (0.381)^2 \times 0.01}{300} = 0.0010506 \text{ meters}$$

Figure 4-2 graph was developed using the above effective height formula. Figure 4-2 shows "h" to be linear with frequency to 250 kHz when the load impedance is 100,000 ohms or greater. The Model 94608-1 Loop Antenna internal impedance is very low compared to 50 ohms at frequencies below 5 kHz. Therefore, a Loop Antenna terminal loading of 50 ohms provides essentially open-circuit voltage. Above 5 kHz the loop internal impedance increases in value with frequency and the external loading increasingly affects the loop output voltage. The loop output departs from the unloaded condition by the amount that the "apparent" effective height departs from the straight line (depending on value of load). The same situation applies to the Figure 4-1 graph.

5.3 POWER GAIN

Loop antenna correction factor (ACF) is derived from the Conversion Factor (K) in dB from Figure 4-1 plus 49.5 dB, see o dBpT Table 4-1.

$$K \text{ dB} + 49.5 \text{ dB} = \text{ACF in dB}$$

Antenna power gain (Figure 4-3) is derived from the ACF using the following formula:

$$\text{ACF} = \frac{9.76 *}{\lambda \sqrt{G}}$$

and

$$G = \left(\frac{9.76}{\lambda \text{ ACF}} \right)^2$$

where: G = power ratio (numeric)
λ = wavelength in meters
ACF = numeric factor value (not dB)

and where: ACF dB = 20 Log₁₀ ACF (numeric)
G dB = 10 Log₁₀ G (numeric)

Example:

At 10 kHz (Figure 4-1) the conversion factor is +11 dB for 50 ohm loop loading. The ACF is:

$$\text{ACF} = +11 \text{ dB} + 49.5 \text{ dB} = 60.5 \text{ dB} = 1059.25$$

$$\text{and } G = \left(\frac{9.76}{30,000 \times 1059.25} \right)^2 = -130.25 \text{ dB}$$

* Refer to SAE Aerospace Recommended Practice ARP 958

