Model 7604

Magnetic Field Pickup Coil

User Manual

ETS·LINDGREN™
An ESCO Technologies Company

Revision Record | MANUAL 7604 | Part #399063, Rev. E

Revision	Description	Date
A	Initial Release	February, 1991
B	Edits/updates	
C	Edits/updates	
D	Edits/updates	April, 1999
E	Rebrand	July, 2010

Table of Contents

Notes, Cautions, and Warnings

	Note: Denotes helpful information intended to provide tips for better use of the product.
CAUTION	**Caution**: Denotes a hazard. Failure to follow instructions could result in minor personal injury and/or property damage. Included text gives proper procedures.
WARNING	**Warning**: Denotes a hazard. Failure to follow instructions could result in SEVERE personal injury and/or property damage. Included text gives proper procedures.

See the ETS-Lindgren *Product Information Bulletin* for safety, regulatory, and other product marking information.

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1.0 Introduction

➔ A number enclosed in a square bracket corresponds to the numbered item in *References*.

The **ETS-Lindgren Model 7604 Magnetic Field Pickup Coil** is designed to measure magnetic emissions to the specification limits in MIL-STD-461 [1] in accordance with MIL-STD-462 [2], Method RE01. The design was originally specified in MIL-STD-461A [3] and is also used in tests for compliance to other specifications [4] and standards. The Model 7604 is normally connected to an EMI meter for the range 20 Hz to over 500 kHz.

The international system of units (SI) is used throughout this manual. See Appendix C on page 23 for the standard abbreviations, symbols, units, and their equivalents.

References

[1] MIL-STD-461 (MIL-STD-461C), *Military Standard Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference*, Department of Defense, 4 Aug 1986.

[2] MIL-STD-462, *Military Standard Electromagnetic Interference Characteristics, Measurement of,* Department of Defense, 31 Jul 1967. (with change notices 1 through 6, dated from 1 Aug 68 to 15 Oct 87).

[3] MIL-STD-461A, *Military Standard Electromagnetic Interference Characteristics Requirements for Equipment*, Department of Defense, 1 Aug 1968, pp 8 and 17.

[4] *Draft Space Station Electromagnetic Emission and Susceptibility Requirements for Electromagnetic Compatibility*, January 8, 1990.

[5] Bronaugh, E.L., and W.S. Lambdin, *Electromagnetic Interference Test Methodology and Procedures,* Vol 6 of A Handbook Series on Electromagnetic Interference and Compatibility, Interference Control Technologies, Inc., Gainesville, VA 22065, 1988, pp 4.22 and 11.2.

[6] ANSI/IEEE Std 268-1982, *American National Standard Metric Practice*.

[7] ANSI/IEEE Std 260-1978, *Standard Letter Symbols for Units of Measurement*, (reaffirmed 1985).

ETS-Lindgren Product Information Bulletin

See the ETS-Lindgren *Product Information Bulletin* included with your shipment for the following:

- Warranty information
- Safety, regulatory, and other product marking information
- Steps to receive your shipment
- Steps to return a component for service
- ETS-Lindgren calibration service
- ETS-Lindgren contact information

2.0 Maintenance

CAUTION

Before performing any maintenance, follow the safety information in the ETS-Lindgren *Product Information Bulletin* included with your shipment.

Maintenance of the Model 7604 is limited to external components such as cables or connectors.

If you have any questions concerning maintenance, contact ETS-Lindgren Customer Service.

Annual Calibration

See the *Product Information Bulletin* included with your shipment for information on ETS-Lindgren calibration services.

Service Procedures

For the steps to return a system or system component to ETS-Lindgren for service, see the *Product Information Bulletin* included with your shipment.

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3.0 Specifications

Electrical Specifications

Useful Frequency Range:	20 Hz to >500 kHz
Connector:	BNC receptacle
Coil	
Winding:	36 turns of 7-41 Litz wire electromagnetically shielded
Resistance:	10 Ohms, nominal
Inductance:	340 µH, nominal

Physical Specifications

Coil Diameter:	133 mm (5.24 in)
Weight:	0.91 kg (2 lb)

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4.0 Operation

CAUTION

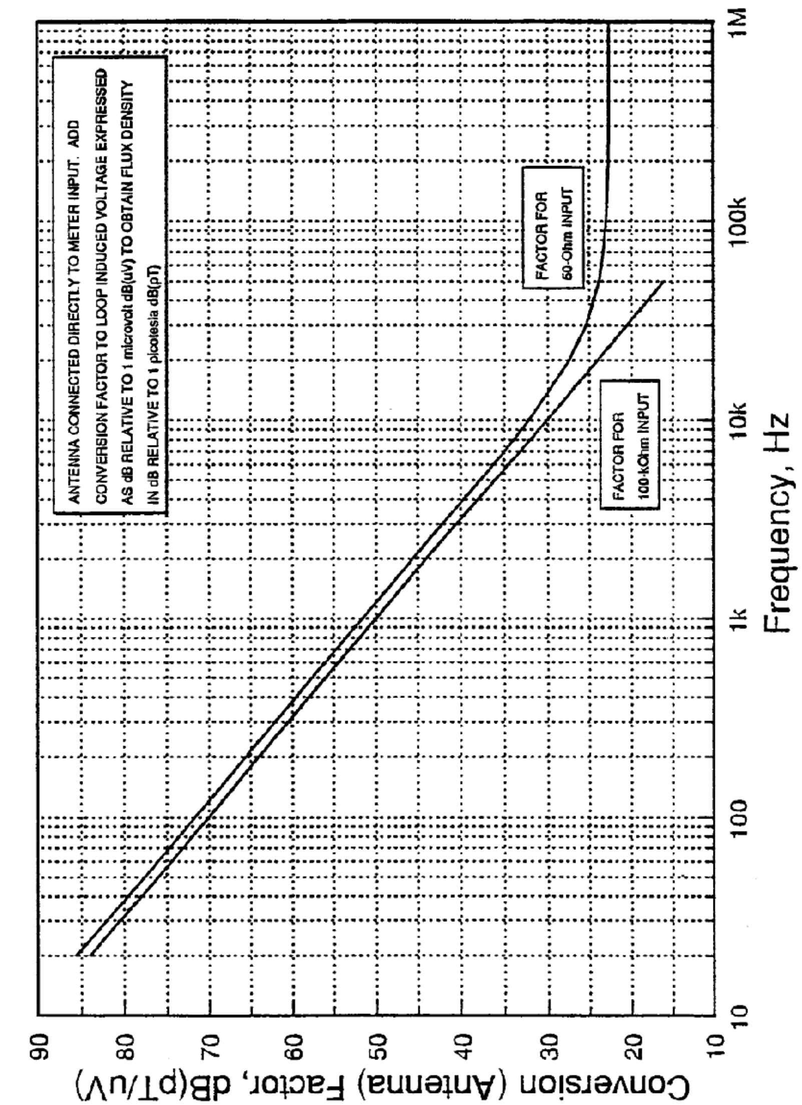
Before connecting any components, follow the safety information in the ETS-Lindgren *Product Information Bulletin* included with your shipment.

The reception pattern of the Model 7604 Magnetic Field Pickup Coil is directional, having a shape essentially of a dipole. Maximum pickup of alternating magnetic field occurs when the field vector is aligned with the coil axis.

1. Connect the Model 7604 to the input connector of an EMI meter using a coaxial cable fitted with a BNC plug. The EMI meter may have an input impedance that is either high (500 ohms or greater) or 50 ohms.
2. Make the measurements of the Equipment Under Test (EUT) in accordance with the applicable standard using the appropriate measurement method; for example, MIL-STD-462 [2], Method RE01. Methods of measurement may be found in [2] and [3], and further information on the measurements and a discussion of how to make them may be found in [5].
3. Reduce the data to flux density by applying the conversion factor at each frequency where an emission from the EUT is found. The conversion factors for the Model 7604 are illustrated in the graph on page 14; these factors are also tabulated in the table on page 16. They are provided in decibels referenced to one picotesla per microvolt: dB(pT/µV).

Graph of Conversion Factors

See *Table of Conversion Factors* on page 16.



The graph provides two conversion factors:

- The top curve is for a 50-ohm load and is valid to 1 MHz.
- The bottom curve is for an unloaded condition and is not valid above 50 kHz. Since the coil impedance is approximately 110 ohms at 50 kHz, the EMI meter input impedance must be 500 ohms or higher to use the unloaded conversion.

The two curves are provided to allow for the use of both 50-ohm EMI meters and certain audio or VLF EMI meters. These EMI meters cover frequencies ranging from 20 Hz at the low end; at the high end they cover from 15 kHz to 50 kHz. They usually have input impedances ranging from 500/600 ohms to 100 kilohms or higher.

Table of Conversion Factors

Frequency kHz	Conversion Factor (100-kOhm), dB(pT/µV)	Conversion Factor (50-Ohm), dB(pT/µV)
0.1	70.1	71.6
0.5	56.1	57.7
1.0	50.1	51.6
5.0	36.1	37.8
10.0	30.1	32.2
20.0	24.0	27.4
30.0	20.5	25.4
50.0	16.1	23.9
70.0		23.3
100.0		23.0
500.0		22.7
700.0		22.7
1000.0		22.7

To determine the measured magnetic flux density (sometimes called the B-Field), take the conversion factor from the graph on page 14 or from the table at the measurement frequency and add it to the signal level in dB(µV) indicated by the EMI meter. The result of this addition is the B Field strength in dB(pT).

EXAMPLE

Frequency: 5 kHz, 50-ohm EMI meter	
Indicated signal level	26 dB(µV)
Conversion factor	+ 36 dB(pT/µV)
Measured B-Field strength:	62 dB(pT)

If the EMI meter is a 50-ohm instrument calibrated in dBm, add 107 to the indicated signal level in dBm to convert it to dB(µV). Subtract 2 dB from result to obtain magnetic field strength *H* in dB(µA/m).

5.0 Theory of Operation

For the Model 7604 Magnetic Field Pickup Coil the voltage induced in the coil e_i is proportional to the area of the coil, the number of turns, the frequency, and the average flux density within the area of the coil. Equation (1) gives this relationship.

EQUATION (1)

$$e_i = 2\pi NAfB, \text{ V}$$

where: e_i is the open-circuit coil-terminal induced voltage in volts;
N is the number of turns on the coil;
A is the area of the coil in square metres;
f is the frequency in hertz; and,
B is the magnetic flux density in tesla.

For the Model 7604, the open-circuit coil-terminal induced voltage in microvolts for a magnetic field strength B in picotesla is given in (2).

EQUATION (2)

$$e_i = 3.14 \times 10^{-6} \text{ f B}$$

The general equation for the conversion factor is given by (3) and (4), and includes the effects of coil impedance and load impedance.

EQUATION (3)

$$AF_B = 20 \text{ Log } |B/V_L|, \ \text{dB(pT/}\mu\text{V)}$$

EQUATION (4)

$$|B/V_L| = \frac{\sqrt{(1+R_C/R_L)^2 + (2\pi fL/R_L)^2}}{2\pi fAN} 10^6$$

where: L is the coil inductance in henries;
Rc is the coil resistance in ohms; and,
R_L is the load impedance in ohms.

Equation (4) is derived in Appendix B on page 21. For the Model 7604, (4) becomes (5).

EQUATION (5)

$$|B/V_L| = \frac{\sqrt{(1+10/R_L)^2 + 4.57\text{x}10^{-6}(f/R_L)^2}}{3.14f} 10^6$$

The transition region between the near and far fields around a typical magnetic field source is centered at a distance equal to the wavelength divided by 2π. The near field thus extends out to a distance of about 100 m at 500 kHz, 1 km at 50 kHz, and 2500 km at 20 Hz.

It is important to understand that the Model 7604, like any loop antenna, responds to the average density of the magnetic flux enclosed within the coil. The importance of this is that two loop antennas of different size will produce different responses to the same source at the same position. This is because the measurements are made in the near field of the source, and the flux density in the near field is a non-linear function of the distance from the source. The varying flux density causes the integral of the flux in two differently-sized areas centered at the same point to be different, resulting in a different average flux density and thus a different response from each loop.

Appendix A: Warranty

See the *Product Information Bulletin* included with your shipment for the complete ETS-Lindgren warranty for your Model 7604.

DURATION OF WARRANTIES FOR MODEL 7604

All product warranties, except the warranty of title, and all remedies for warranty failures are limited to two years.

Product Warranted	Duration of Warranty Period
Model 7604 Magnetic Field Pickup Coil	2 Years

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Appendix B: Derivation of General Equation

Following is an explanation of the derivation of the general equation for conversion factor.

From magnetic loop theory the open circuit voltage induced in the coil is:

EQUATION (A1)

$$e_i = 2\pi NAfB, \text{ V}$$

where: e_i is the open-circuit coil-terminal induced voltage in volts;
N is the number of turns on the coil;
A is the area of the coil in square metres;
f is the frequency in hertz; and,
B is the magnetic flux density in tesla.

When the coil is loaded the voltage V_L across the load R_L is proportional to the induced voltage across the coil impedance and the load: $R_c + jX_c$.

EQUATION (A2)

$$\frac{e_i}{R_L + R_c + jX_c} = \frac{V_L}{R_L}$$

where: R_c is the coil resistance;
$X_c = 2\pi fL$ is the coil reactance; and,
L is the coil inductance.

Rearranging (A2):

EQUATION (A3)

$$\frac{e_i}{V_L} = 1 + \frac{R_c}{R_L} + j\frac{X_c}{R_L}$$

Finding the magnitude of the voltage ratio:

EQUATION (A4)

$$\left|\frac{e_i}{V_L}\right| = \sqrt{\left(1+\frac{R_C}{R_L}\right)^2 + \left(\frac{X_C}{R_L}\right)^2}$$

Substituting e_i from (A1) and solving for $|B/V_L|$:

EQUATION (A5)

$$\left|\frac{B}{V_L}\right| = \frac{\sqrt{\left(1+\frac{R_C}{R_L}\right)^2 + \left(\frac{2\pi fL}{R_L}\right)^2}}{2\pi fAN}, \ \text{T/V}$$

Multiply by 10^6 to convert the units from tesla per volt to more convenient units of picotesla per microvolt:

EQUATION (A6)

$$\left|\frac{B}{V_L}\right| = 10^6 \frac{\sqrt{\left(1+\frac{R_C}{R_L}\right)^2 + \left(\frac{2\pi fL}{R_L}\right)^2}}{2\pi fAN}, \ \text{pT/}\mu\text{V}$$

Appendix C: Abbreviations, Symbols, Units

Following are the abbreviations, symbols, and units used in this manual, including their equivalents in obsolete systems.

U.S. National Standard and SI Abbreviations and Symbols

Ampere per metre:	A/m
Henry:	H
Microampere per metre:	μA/m
Tesla:	T
Nanotesla:	nT
Picotesla:	pT
Weber:	Wb

List of Equivalent SI Magnetic Units and Obsolete Units

➔ **Gauss** and **gamma** are obsolete terms and should not be used in engineering and science.

$(\mu = \mu_o = 4\pi \times 10^{-7}$ H/m)

1 T = 1 Wb/m^2
1 T = 7.96 x 10^5 A/m
1 T = 10^4 gauss
1 T = 10^9 gamma

1 nT = 796 µA/m
1 nT = 10^3 pT
1 nT = 10^{-5} gauss

1 µA/m = 1.256 x 10^{-3} nT
1 µA/m = 1.256 pT
1 µA/m = 1.256 x 10^{-8} gauss
1 µA/m = 1.256 x 10^{-3} gamma

1 pT = 0.796 µA/m
1 pT = 10^{-3} nT
1 pT = 10^{-8} gauss
1 pT = 10^{-3} gamma

1 gamma = 796 µA/m
1 gamma = 1 nT
1 gamma = 10^3 pT
1 gamma = 10^{-5} gauss

0 dB(µA/m) = +2 dB(pT)

Appendix D: Performance, Theory, Measurement

Following is a comparison of loop performance, theory, and measurement.

The Model 7604 Magnetic Field Pickup Coil performs as predicted in *Theory of Operation* by (5) on page 18. To verify this, a calibration of the antenna was performed. The calibration setup consisted of:

- A transmit loop;
- The Model 7604 as a receive loop;
- An HP8116A Pulse Function Generator;
- An HP7478A Multimeter; and
- An HP4194A Gain/Phase Analyzer.

The transmit loop was a single turn center conductor of 215 mm in diameter with a thermocouple having a k-factor of 650. The separation between the loop antennas was 500 mm. The thermocouple converts the current on the transmit loop to a DC voltage value that can be read on the multimeter. The antenna factor in dB(pT/µV) is computed as follows:

$$AF_B = 120 + 20\,\mathrm{Log}(B/V)$$

where: V (V) is read from HP4194A.

B (T) is computed as: $$B = 4\pi x 10^{-7}\,\frac{AI}{2\pi R_o^3}\sqrt{1+\left(\frac{2\pi R_o f}{3x10^8}\right)^2}$$

A (m^2) is the area of the Model 7604.

I (A) is current through the loop given by: $I = \sqrt{\frac{E_{th}}{k}}$

E_{th} (mV) is the dc voltage reading of the 7478A multimeter.

k is the calibration k-factor of the thermocouple.

R_o (m) is given by: $$R_o = \sqrt{D^2 + R_1^2 + R_2^2}$$

D (m) is the distance between the loops.

R_2 (m) is the radius of the Model 7604.

R_1 (m) is the radius of the transmit loop.

The following graph shows the computed versus theoretical conversion factor for the Model 7604. The data obtained by measurement is within 0.5 dB of theoretical values computed. Because of the probable amount of measurement inaccuracy, especially at the lower frequencies, the computed conversion factors are more accurate and are therefore preferred.