HI-3638

ELF / VLF
Electric Field Meter

User Manual

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An ESCO Technologies Company

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Revision	Description	Date
	Initial Release	July, 1994
A	Added CE	October, 1997
B	Added *Error Codes*	January, 1998
C	Updated area code	February, 2000
D	Rebrand	March, 2009
E	Updated electric field information, *Replacement and Optional Parts*, *Specifications*, *Operating Protocols*	February, 2011
F	Added *Operating Protocols* as appendix	April, 2011
G	Updated *Replacement and Optional Parts*	April, 2013
H	Updated *Calibration* and format	March, 2016

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Notes, Cautions, and Warnings

Note: Denotes helpful information intended to provide tips for better use of the product.

Caution: Denotes a hazard. Failure to follow instructions could result in minor personal injury and/or property damage. Included text gives proper procedures.

Warning: Denotes a hazard. Failure to follow instructions could result in SEVERE personal injury and/or property damage. Included text gives proper procedures.

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

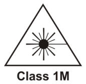
Safety Information

Refer to Manual: When product is marked with this symbol, see the instruction manual for additional information. If the instruction manual has been misplaced, download it from www.ets-lindgren.com, or contact ETS-Lindgren Customer Service.

High Voltage: Indicates presence of hazardous voltage. Unsafe practice could result in severe personal injury or death.

High Voltage: Indicates presence of hazardous voltage. Unsafe practice could result in severe personal injury or death.

Protective Earth Ground (Safety Ground): Indicates protective earth terminal. You should provide uninterruptible safety earth ground from the main power source to the product input wiring terminals, power cord, or supplied power cord set.



Laser Warning: Denotes a laser (class 1M) is part of the operating system of the device.

Waste Electrical and Electronic Equipment (WEEE) Directive: (European Union) At end of useful life, this product should be deposited at an appropriate waste disposal facility for recycling and disposal. Do not dispose of with household waste.

Recyclable Products: This product includes rechargeable batteries. At end of useful life, please recycle the used batteries, or dispose of them safely and properly. Many cities collect used batteries for recycling or disposal. You may contact your local waste disposal agency for information on battery recycling and disposal.

1.0 Introduction

The **ETS-Lindgren HI-3638 ELF/VLF Electric Field Meter** provides full ELF/VLF (extremely low frequency/very low frequency) capability.

The HI-3638 covers MPR bands I and II for Swedish low-emission standards, plus meets test requirements for IEEE 1140-1994 (IEEE standard for the measurement of electric fields from video display terminals).

(Tripod not included)

The HI-3638 is useful in low field intensity measurements such as video display terminals (VDTs) and computer monitors, as well as higher field environments such as power transmission lines and industrial locations.

The HI-4416 Digital Readout/Control Unit is included with the HI-3638 and provides an optically isolated, full control digital readout for quick and easy measurements in any sensor orientation. An optional HI-4413P Fiber Optic Modem allows for a serial interface.

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

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

Maintenance of the HI-3638 is limited to external components such as cables or connectors.

Warranty may be void if the enclosure is opened.

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.

Maintenance of Fiber Optics

Fiber optic connectors and cables can be damaged from airborne particles, humidity and moisture, oils from the human body, and debris from the connectors they plug into. Always handle connectors and cables with care, using the following guidelines.

Before performing any maintenance, disconnect the fiber optic cables from the unit and turn off power.

When disconnecting fiber optic cables, apply the included dust caps to the ends to maintain their integrity.

Before connecting fiber optic cables, clean the connector tips and in-line connectors.

Before attaching in-line connectors, clean them with moisture-free compressed air.

Failure to perform these tasks may result in damage to the fiber optic connectors or cables.

Replacement and Optional Parts

Following are the part numbers for ordering replacement or optional parts for the HI-3638 ELF/VLF Electric Field Meter.

Part Description	Part Number
Battery Pack, 12 VDC	H-491069
Universal 12 VDC Trickle Charger (110/240 V)	H-491063-06
Cable, Fiber Optic, Glass, Dual, 2-Meter	H-491106-02
HI-3638 Carrying Case	H-491100
Tripod	H-491009
Fiber Optic Modem	HI-4413P
Fiber Option to USB Converter, USB interface	HI-4413USB
Probeview II™ Software	H-491255

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

Instrument accuracy is derived from a field calibration using a 30 cm TEM cell creating a known electric field. A sinusoidal voltage impressed on the TEM cell is directly measured using a true RMS detector and used to calculate the electric field strength in V/m.

	Band 1 ELF	**Band II VLF**
Frequency Range:	5 Hz–2000 Hz Bandwidth (-3dB)	2 kHz–400 kHz Bandwidth (-3dB)
Filter Attenuation:	• -80 dB/dec below 5 Hz • -40 db/dec above 2 kHz	• -80 dB/dec below 2 kHz • -40 dB/dec above 400 kHz

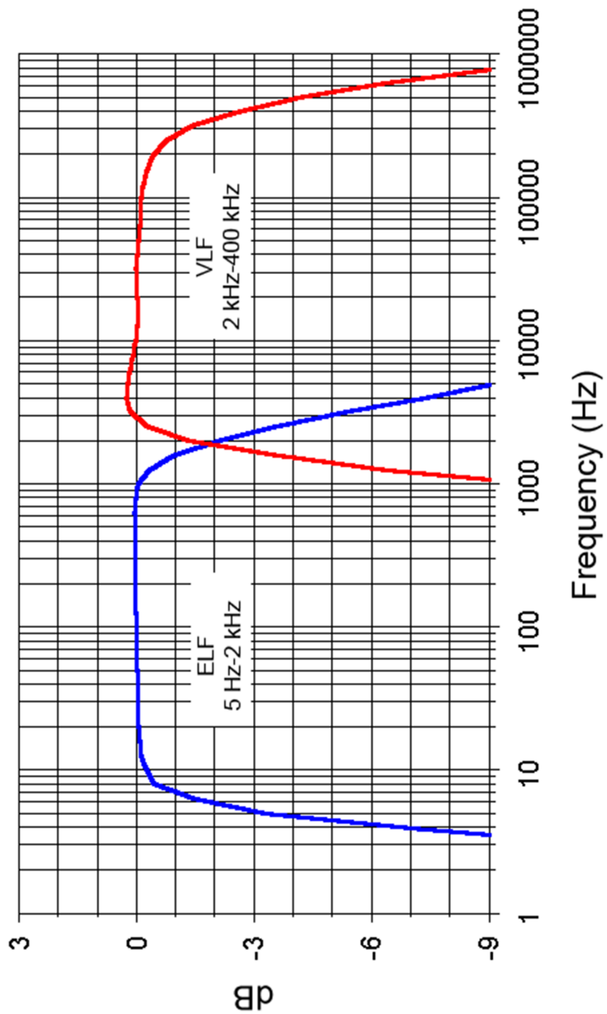
Bands I and II	
Measuring Ranges:	4, 40 V/m, 0.4, 4, 40 kV/m F.S.
Measuring Limit:	1 V/m
Linearity:	±0.5 dB + 1% of Full Scale
Calibration Accuracy:	±0.75 dB @ Calibration Points

Display Resolution:	• 3 1/2 Digit LCD • 0.01 V/m
Waveform Out	
Output Sensitivity:	1 Volt/Full Scale Range
Output Impedance:	1 Ω
Waveform Out Jack:	3.5 mm (0.14 in) Phone Jack
Grounding Jack:	Standard Banana Jack

Operating Temperature:	+10°C to +40°C +50°F to +104°F
Humidity:	5% to 95% Relative Humidity, Non-condensing
Isotropicity:	Single Axis
Fiber Optic Connectors:	Standard FSMA
Fiber Optic Cable:	200 Micron, Graded Index, Multimode
Readout:	HI-4416 Digital Readout/Control Unit
Probe Mount:	• 1/4–20 UNC tapped hole (internal thread) • Two, 90 degrees apart
Battery	
Battery Type	12 Volt DC, 1400 mAh Nickel-Cadmium (NiCd)
Current Consumption:	35 mA
Battery Life:	40 Hours (Nominal)
Battery Charger:	110/240 VAC, 16 Hour
Battery Charger Jack:	2.5 mm (0.1 in) Phone Jack
Physical Specifications	
Height:	102 mm (4 in)
Diameter	305 mm (12 in)
Weight:	0.91 kg (2 lb)

HI-3638 Typical Frequency Response

Measured at 20 V/m.



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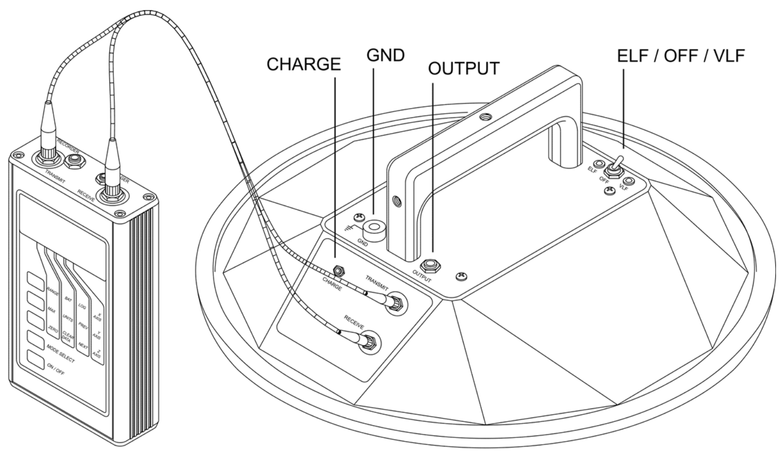
4.0 HI-3638 Controls and Connectors

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

Following is a description of the controls and connectors for the HI-3638 ELF/VLF Electric Field Meter.

Transmit / Receive



Attach fiber optic cables to
TRANSMIT and RECEIVE connectors,
matching white to white
and yellow to yellow

Plug the fiber optic cable from the HI-4416 Digital Readout/Control Unit into the TRANSMIT connector and RECEIVE connector on the HI-3638, matching white to white (for transmit) and yellow to yellow (for receive).

When the fiber optic cable is not connected, cover the cable and connectors with the protective plastic caps supplied. This prevents dirt or other contaminants from entering the connector and causing communication problems. See *Maintenance of Fiber Optics* on page 10 for more information.

ELF/OFF/VLF

This switch activates and deactivates the HI-3638 as well as the selection of ELF or VLF bands. LEDs indicate which band is selected.

In the ELF or VLF position the HI-3638 is powered by the internal 12 VDC nickel-cadminum (NiCd) battery. To prolong battery life, set the switch to OFF when not in use.

Charge

A 16-hour trickle battery charger is supplied with the HI-3638. The battery charger can charge the HI-3638 or the HI-4416.

Slight overcharging up to 24 hours will not harm the battery; however, charging the battery longer than 24 hours may degrade battery performance.

Ground

Connect GND to earth ground to establish a reference for the HI-3638.

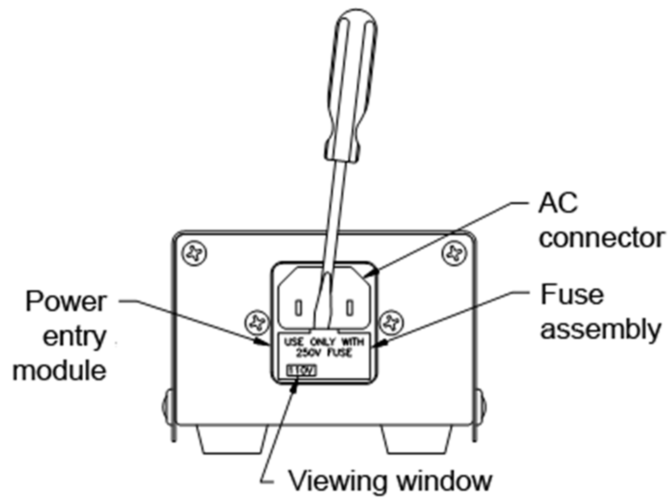
Output

Connect an oscilloscope to OUTPUT to observe the waveform of the signal driving the true RMS to DC converter circuit.

5.0 Battery Charger

Setting the Voltage

Disconnect the battery charger from power before changing the voltage setting.



Check the viewing window on the power entry module to verify that the battery charger is set to the proper voltage for your AC power source. To change the voltage setting:

1. Disconnect the battery charger from power.
2. Use a small screwdriver to loosen and remove the fuse assembly from the power entry module.
3. Slide the small board located on the back of the fuse assembly from right to left to remove it.

4. Rotate the board so the desired voltage is facing up, and then reinsert it into the fuse assembly. The desired voltage should be visible in the viewing window.
5. Firmly re-seat the fuse assembly back into the power entry module. The battery charger is ready to use.

Charging the Battery

The HI-3638 ELF/VLF Electric Field Meter contains a rechargeable nickel-cadmium (NiCd) battery. A fully-charged battery (nominal output voltage of 12 VDC) provides up to 40 hours of continuous operation.

Always check the condition of the battery prior to making any measurements.

Never attempt to charge a non-rechargeable battery.

1. Verify that the battery charger is set to the proper voltage for your AC power source. See *Voltage Setting* on page 19 for more information.
2. Connect the battery charger to a power source.
3. Switch the HI-3638 to OFF.
4. Insert the charging plug into the CHARGE connector on the HI-3638.

   When the charging plug is connected, the LED on the battery charger illuminates. It remains illuminated until the charging plug is disconnected.

5. A full charge will be completed after approximately 16 hours of charging. Disconnect the charging plug after this amount of time.

Charging the battery longer than 24 hours could damage the battery cells and reduce battery life.

Battery Tips

If the battery exhibits low terminal voltage during charging or if it appears unable to acquire or maintain an appreciable charge, individual cells in the battery may be shorted or damaged. If your battery needs replacement, contact ETS-Lindgren Customer Service.

Operating Temperature

Although NiCd batteries are rated for operation in temperatures from -20°C to +65°C (-4°F to +140°F), operating the HI-3638 in extreme temperatures significantly reduces operating time. The optimum operating temperature range is +20°C to +30°C (+68°F to +86°F).

Charging

The HI-3638 battery does not require periodic deep discharges to reverse the capacity-depleting memory effect caused by repeated shallow discharges; however, undercharging can reduce battery capacity. Therefore, after the charging procedure is complete, verify that the battery is fully charged before resuming field operation.

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6.0 Application

Meter

The HI-3638 ELF/VLF Electric Field Meter is a single axis meter (responsive to one polarization component at a time) designed to be responsive to electric fields, including non-sinusoidal waveforms, from 5 Hz to 400 kHz.

When the HI-3638 is immersed in an electric field, the sensor generates a current. An input op-amp then generates a voltage which correlates to this sensor current. This voltage is fed into a filter which isolates the ELF and VLF ranges and discards the out of band signals. The output of the selected filter stage, ELF or VLF, is passed to a software controlled gain stage with selectable gains of x1, x10, x100, x1k, x10k. The output of the gain stage is converted to its RMS DC equivalent which is then converted to a digital number. This digital number is then converted to a displayable value and sent through fiber optic cable to the HI-4416 Digital Readout/Control Unit.

Sensor Theory

Electric fields are measured through the employment of a *displacement current sensor*. A displacement current sensor operates on the principle that two parallel conductive flat-plate electrodes, when electrically connected together, will exhibit a displacement current which flows between the two plates when immersed in an electric field. This can be visualized by remembering that the electric field between two such plates must be zero when they are connected together; because they are at the same potential there can be no electric field between them (an electric field exists when the potential on the two electrodes is different).

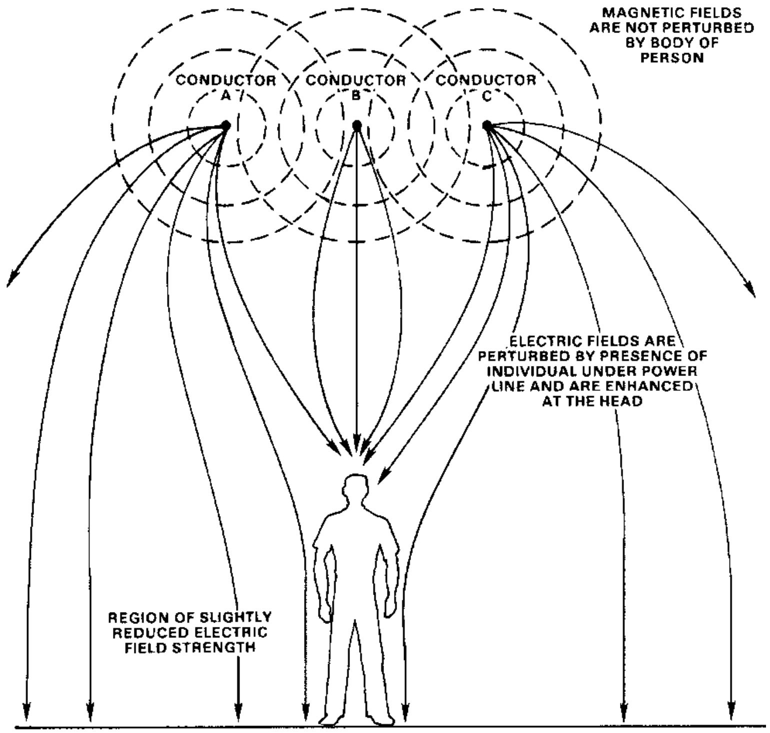
Another way of viewing this phenomenon is to understand that when immersed in an electric field, the external field causes a redistribution of electric charge on the two electrodes and this redistribution, or charge, is just flow of current, a displacement current between the two plates.

The HI-3638 uses this principle to detect electric fields by measuring the displacement current caused by the ambient field between two closely spaced circular disks. By placing such a detector in a known electric field, the displacement current can be related directly to the magnitude of the field causing it, permitting calibration. A circular sensing plate surrounded by a *guard ring* is used in the HI-3638 and the displacement current developed between this 100 mm diameter disk and a closely spaced 300 mm circular disk electrode is sensed and converted to equivalent electric field strength. Because the larger electrode is used as a reference in the measurement process, for accurate measurements of electric fields the sensor must be oriented perpendicular to the incident field lines for maximum readings.

7.0 Power Frequency Fields

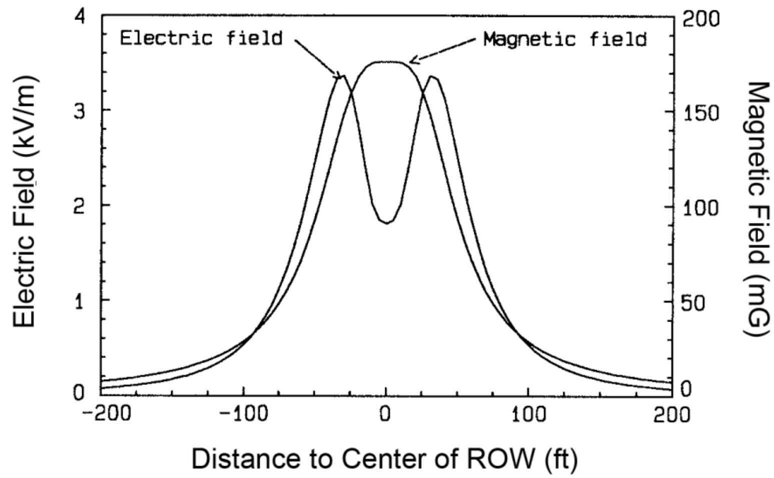
Before connecting or operating any component, follow the safety information in the ETS-Lindgren *Product Information Bulletin* included with your shipment.

Use care when operating this instrument near energized conductors.



The previous illustration portrays an electric field environment surrounding a typical power transmission line. It illustrates a single-circuit, three phase power line consisting of three separate electrical conductors, each having an impressed voltage which is 120 degrees out of phase with its neighboring conductors. A shield wire may be present above the three phases of the line; this grounded wire acts as a preferred point for lightning strikes which could, if unprotected, strike the current carrying conductors, potentially damaging and removing the line from service for repairs. A double circuit line would consist of two sets of the three phase conductors.

Electric and magnetic fields produced by the power line originate because of the voltages impressed on the conductors and the magnitude of current (electricity) flowing through the conductors. The previous illustration depicts the approximate spatial orientation of these fields; electric field lines are shown to be directed such that they terminate at perpendicular angles to the surface of the earth and magnetic field lines are shown as lines encircling the conductors. At any particular point in space, the field can be determined by the superposition of the fields associated with each conductor; because the voltage and current of each conductor is out of phase with that in any of the others, and the conductors have some finite spacing between them, the resulting electric and magnetic fields are calculated on the basis of the vector sum of fields caused by each of the three conductors. At some points the fields can constructively add together causing a relatively elevated field strength. At other points the fields from the conductors may destructively add leading to minima in the fields. Thus, power line fields can have rather complex spatial distributions about the line.



Spatial distribution of electric and magnetic field strength beneath a 345 kV transmission line

This illustration shows the field distribution for a typical double circuit 345 kV transmission line carrying 1000 A. The field strengths have been computed for a height of one meter above the ground from one side of the line to the other and indicate that the maximum electric field strength beneath the 345 kV line is expected to be about 3.4 kV/m. The maximum magnetic field strength will be dependent on the magnitude of current flowing in the line. If the line was carrying a current of 1000 A, the magnetic fields indicate an expected maximum value of 175 mG (equivalent to 14 A/m).

In addition to the normal variation in field strength which is observed along a line transverse to the power line, electric fields beneath power lines are perturbed by the local surroundings. This illustration shows the phenomenon of electric field concentration which occurs above the head of a person standing under the line. Localized enhancement of the electric field will lead to decreased field strength in other nearby areas. Because electric field lines have a tendency to terminate on grounded objects, and because the human body is conductive and is electrically near ground potential, there tends to be a concentration of field lines at the top of the head. This same phenomenon occurs with virtually any grounded object immersed in the electric field environment of a power line and can be confirmed through field measurements.

This inherent shielding effect of the body, unless the body is sufficiently distant from the instrument, can lead to inaccurate measures of the electric field strength. Depending on the proximity and orientation of the body, the perturbation effect of the body can lead to either enhanced electric field strength readings or reduced readings when compared to the true unperturbed field strength. While in some cases it may be desirable to determine the enhanced fields near objects, in general, most field measurements should be directed toward assessing the unperturbed values. For example, unperturbed field strengths or *free space values*, are more easily related to internal induced currents in the body. Induced currents represent one potential dosimetric measure of electric field exposure.

The illustration on page 25 also suggests that the electric field lines which terminate on the earth are essentially purely vertically oriented directly beneath the conductors, but at extended lateral distances from the line there can be some horizontal component to the field. Thus, in measurements of electric fields near power lines, it may be important to explore different polarization components of the field to assess the resultant electric fields at points above the earth.

Measurement of electric field strength under a power line or near any other source of electric fields may be accomplished by supporting the HI-3638 ELF/VLF Electric Field Meter on a non-conductive tripod. Because of the physical asymmetry in the displacement current sensor it is imperative that the front side of the sensor be directed toward the electric field source. In this position, the electric field lines which are directed downward toward the earth will strike the correct side of the displacement current sensor resulting in an accurate measurement of the field strength. In addition, the presence of the operator will tend to perturb the electric field that is being measured. The operator should remain approximately one to two times their height away from the HI-3638 sensor.

8.0 Guidelines for EMF Exposure

To provide a means for judging the significance of measured electromagnetic field emissions found near a VDT, the scientific literature can be examined for information on suggested exposure or emission limits. The exposure standards used for the content presented in this manual apply to humans for the purpose of establishing safe working or living environments where electromagnetic fields exist. The exposure limits in this manual are those found that correspond most closely to the predominant frequency range of VDTs. In some cases, the standards apply to occupational exposure environments and in other cases, to the general living environment; often standards for this latter case are referred to as general population or public exposure limits.

Traditional approaches to radiation protection, principally derived from ionizing radiation protection practices, usually differentiate between occupational and public exposure. Generally, occupational exposure limits are higher (more permissive) than public limits. This is because of the greater uncertainties associated with the general public; in the work place, employees are generally healthier, and possible exposure to potentially hazardous physical agents is usually under much better control. For example, employers can inform workers of situations which should be avoided; this is not the case for the general population as a whole. Regardless of these considerations, it is informative to examine some of the recommended exposure guides that apply to different organizations and/or countries.

Radio Frequency Exposure / Emission Standards Pertinent to VDT Frequency Range

Many RF exposure standards are under development or revision. The following table should be used only as an orientation to existing standards.

Standard/ Reference	Frequency (kHz)	E (V/m) RMS	H (gauss) RMS
ACGIH	0–0.1 0.1–4 4–30	25000 2500/f * 625	— 0.6/f * —
IEEE C95.1-1991	3–100	614	2.05
IRPA (gen. pop. 24 hr)	50/60 Hz	5000	1.0
Swedish Guidelines **	0.005–2 2–400	25 2.5	0.0025 (0.25μT) 0.00025 (0.25nT)
UK(1986)(occ)	750 Hz–50 kHz	2000	1.25
UK(1986)(public)	750 Hz–50 kHz	800	0.05
USSR(public) (Slesin, 1985)	0.03–0.3	25	—

* Frequency in kHz

** Guidelines based on what was technically possible, not biological effects

This table summarizes the electromagnetic field exposure standards found in the literature that either directly apply to the frequency range appropriate to VDT emissions or pertain to a frequency range close to that of interest. As can be seen, the primary difficulty in applying many RF exposure standards to VDT emission levels is that the applicable frequency range of the standards does not extend down low enough. From the literature searched, only one reference was found that offered a quantitative emission limit as a guideline specific to VDTs (Telecom, 1984). This Occupational Health Policy Guideline for screen-based equipment was developed by Telecom Australia for internal use until such time as there is a national standard for VDTs in Australia. The guide specifies that the levels of radiation emitted from cathode-ray VDTs in the frequency range of 50 Hz to 0.3 MHz shall be as low as possible, and should not at any time exceed an electric field strength of 50 V/m, measured 30 cm from the terminal.

Appendix A: Warranty

See the *Product Information Bulletin* included with your shipment for the complete ETS-Lindgren warranty for your HI-3638.

DURATION OF WARRANTIES FOR HI-3638

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

Product Warranted	Duration of Warranty Period
Model HI-3638 ELF/VLF Electric Field Meter	1 Year

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Appendix B: Operating Protocols

The information in this section is subject to change, and is included for reference only.

The following information assumes that the HI-4413P Fiber Optic Modem or HI-4413USB Fiber Optic to USB Converter was purchased and is communicating directly with the probe.

Communication Protocol

Data Type:	RS-232 Serial
Data Mode:	Asynchronous
Word Length:	7 bit
Parity:	Odd
Stop Bits:	1
Data Rate:	9600 baud

Information Transfer Protocol

The probe responds to commands from another device; it transmits no data without first receiving instructions to do so.

Probe Command Structure	Probe Response Structure
A command to a probe consists of: • A command letter • Parameters (if required) • <CR> (a carriage return)	When the probe completes the command, it responds with a string consisting of: • A start character (":") • The command letter • Data (if required) • <CR> (a carriage return)

If an error occurs, the probe responds with an error code. See page 35 for error codes.

Probe Commands

Probe Command	Description	Probe Response
B	Read battery voltage	*:Bxx.xx<CR>* • *xx.xx*=battery voltage
D1	Read probe data • *1* enables short form output	*:Dxx.xxuuu<CR>* • *xx.xx*=reading; the position of the decimal point depends on the range setting of the probe • *uuu*=units; for example, *_V_*=V/m *mW2*=mW/cm^2
R*x*	Set range • *x*=1, 2, 3, 4, or N (next range)	:*Rx*<CR> • *Rx*=range currently in use
U*x*	Set unit type • *x*=1, V/m • *x*=2, mW/cm^2	*:Ux<CR>* • *U1*=set to V/m • *U2*=set to mW/cm^2

Error Codes

If an error occurs, the probe will respond with one of the following strings. These strings begin with a colon and end with a carriage return.

E1	Communication error (for example, overflow)
E2	Buffer full error; too many characters contained between the start character and carriage return sequence
E3	Received command is invalid
E4	Received parameter is invalid
E5	Hardware error (for example, EEPROM failure)
E6	Parity error

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Appendix C: References

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Appendix D: EC Declaration of Conformity

ETS-LINDGREN
An ESCO Technologies Company

CE 96

Declaration of Conformity

We, ETS-Lindgren, L.P., 1301 Arrow Point Drive, Cedar Park, TX, 78613, USA, declare under sole responsibility that the:

Model/Part Number: HI-3638

Model/Part Name: ELF/VLF Electric Field Meter

Date of Declaration: 23 July, 1996

to which this declaration relates, meets the requirements and is in conformity with the relevant EC Directives listed below using the relevant section(s) of the following EC harmonized standards and other normative documents;

Applicable Directive(s):

Electomagnetic Compatibility Directive (EMC), 89/336/EEC and its amending directives

Applicable harmonized standard(s) and/or normative document(s):

EN 50082-1:1992 Electromagnetic compatibility - Generic immunity standard Part 1: Residential, commercial and light industry

EN 55011:1991- Group 1 Class B, Limits and methods of measurement of radio disturbance characteristics of industrial, scientific, and medical (ISM) radio-frequency equipment

Authorized Signatories:

ETS-Lindgren L.P.
Bryan Sayler, General Manager

ETS-Lindgren L.P.
James C. Psencik, Vice President of Engineering

The authorizing signatures on this Declaration of Conformity document authorizes ETS-Lindgren, L.P. to affix the CE mark to the indicated product. CE marks placed on these products will be distinct and visible. Other marks or inscriptions liable to be mistaken with the CE mark will not be affixed to these products.

ETS-Lindgren, L.P. has ensured that technical documentation shall remain available on premises for inspection and validation purposes for a period ending at least 10 years after the last product has been manufactured.