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IGS-2/EM-4 GENIE/HORIZONTAL LOOP ELECTROMAGNETIC RECEIVER

OPERATION MANUAL

785 700

Version R 1.0

March, 1986

ABOUT THIS MANUAL:

This manual describes the operation of the combined IGS-2/EM-4 GENIE/Horizontal Loop Electromagnetic Receiver.

Information pertaining to the operation of the IGS-2 System Control Console, TM-2 Transmitter, TF-2 Transmitter, MP-4 Proton Magnetometer Sensor Option and VLF-4 VLF EM Sensor Option which may be used in conjunction with the IGS-2/EM-4 Receiver may be found in the appropriate Scintrex manuals.

If the operator is not familiar with the "IGS-2 Integrated Geophysical System - Operation Manual", then it is highly recommended that the operator begin by becoming familiar with it.

IGS-2/EM-4 GENIE/HORIZONTAL LOOP ELECTROMAGNETIC RECEIVER

OPERATION MANUAL

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Figure EM:1
Operator wearing the IGS-2 System Console and MP-4/VLF-4/EM-4 Sensor Options.

1.0 INTRODUCTION

1.1 Electromagnetic Method

The electromagnetic (EM) method consists of measuring variations in the components of electromagnetic fields that are induced by an EM transmitter. The transmitter generates an electromagnetic moment sufficient to energize the ground and penetrate any conductive bodies that are present. Current will usually flow through a conductor, such as a massive sulphide body or fault, in response to the primary EM field emanating from the transmitter, in planes that are perpendicular to the lines of the primary EM field, unless restricted by the conductor's geometry. This secondary EM field at the conductor can be measured and compared with the primary EM field by an EM receiver.

Scintrex introduced a novel moving source electromagnetic system in 1981. Dubbed the GENIE, the instrument measures the ratio of vertical magnetic field amplitudes at two well separated frequencies. Transmitter and receiver coils are held in horizontal coplanar geometry as with conventional Horizontal Loop (HLEM) systems. The method has been used in place of HLEM systems in areas of moderate to rough terrain for conductors at shallow to moderate depths as it is relatively insensitive to errors in coil position and orientation.

Scintrex has more recently developed an improved receiver for use with either moving or fixed source transmitters. The new receiver, called the IGS-2/EM-4 GENIE/Horizontal Loop Electromagnetic Receiver, has been designed to carry out both GENIE type and traditional Horizontal Loop readings. Drillhole measurements may also be performed with the addition of an optional drillhole sensor.

The IGS-2/EM-4 Receiver, when used with an appropriate transmitter, is designed primarily for use in mineral prospecting for massive sulphide ore bodies. It may also be used for the detection of faults or shear zones and to give information about subsurface conductivity for geological mapping, sand and gravel or ground water exploration, or other geotechnical purposes.

The IGS-2/EM-4 Receiver is an electromagnetic sensor capable of making amplitude ratio (GENIE) and in-phase/quadrature (HLEM) measurements over several pairs of frequencies. It may be used in conjunction with either a dipolar moving source (Scintrex TM-2) or a large loop, fixed source (Scintrex TF-2) transmitter.

This manual specifically concerns the IGS-2/EM-4 Receiver. Any references regarding the IGS-2 System, accessory sensors, or complementary transmitters can be found in operation manuals dedicated to these various instruments.

1.2 EM-4 GENIE/HLEM Electromagnetic Sensor Option

When the EM-4 GENIE/Horizontal Loop Electromagnetic Sensor Option is used in conjunction with a Scintrex IGS-2 System Control Console, the result is the IGS-2/EM-4 GENIE/Horizontal Loop Electromagnetic Receiver. Other sensor options, such as the MP-4 Proton Magnetometer Sensor Option or the VLF-4 VLF Electromagnetic Sensor Option may also be used with the IGS-2 System Control Console to permit multiple measurements to be made during a single traverse of an area of geological interest.

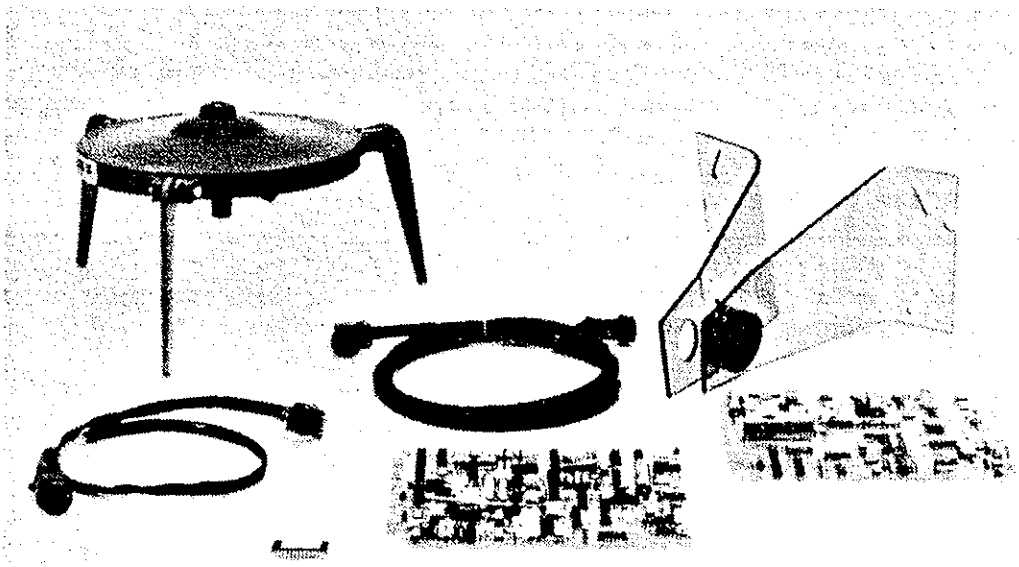

Figure EM:2
EM-4 Sensor Option

The EM-4 Sensor Option consists of the following:

1. Receive Coil Assembly
2. 2 Interconnecting Cables
3. 2 Electronic Circuit Boards
4. Program EPROM

Receive Coil Assembly:
The Receive Coil Assembly includes a 25 cm diameter non-magnetic air-cored receive coil that is packaged in a protective plastic case. Three retractable legs can be deployed for placing the receive coil on the ground. Alternatively, the receive coil may be mounted on a backplate assembly with the two backplate brackets supplied with the receive coil.

A bubble-level on the top of the receive coil case can be used to visually adjust the level of the sensor. The arrow imprinted on the case is used to align the receive coil in the direction of the survey so that the receive coil's built-in tiltmeter sensor will function correctly if enabled.

Interconnecting Cables:
The two Interconnecting Cables are used to connect the receive coil to either the IGS-2 System Control Console or the EM-4 GENIE/Horizontal Loop Expansion Module. The Short Interconnecting Cable is used when the receive coil is backplate mounted. The Long Interconnecting Cable is used when the receive coil is placed on the ground for measurements.

Electronic Circuit Boards:
The two Electronic Circuit Boards provide input amplification and signal processing of the receive coil signals. These signals are then utilized by the IGS-2 System Control Console for final data processing.

Program EPROM:
The Program EPROM (Electrically Programmable Read-Only Memory) contains the recorded instructions necessary for the correct computations to be performed by the IGS-2 System Control Console's microprocessor.

1.3 Modes of Measurement

The IGS-2/EM-4 Receiver may be used in conjunction with either the Scintrex TM-2 GENIE/Horizontal Loop Portable Electromagnetic Transmitter or the Scintrex TF-2 GENIE Fixed Source Electromagnetic Transmitter. Essentially, the TM-2 Transmitter contains two iron-cored, moment stabilized transmit coils permitting two frequencies in the range of 112.5 to 3037.5 Hz to be transmitted simultaneously. The motor-generator driven TF-2 Transmitter simultaneously energizes a large loop or grounded dipole with five frequencies in the range of 37.5 to 3037.5 Hz.

The TM-2 Transmitter and IGS-2/EM-4 Receiver combination can be used to make measurements in two modes - GENIE and Horizontal Loop. With the TF-2 Transmitter, only the GENIE measurement is made.

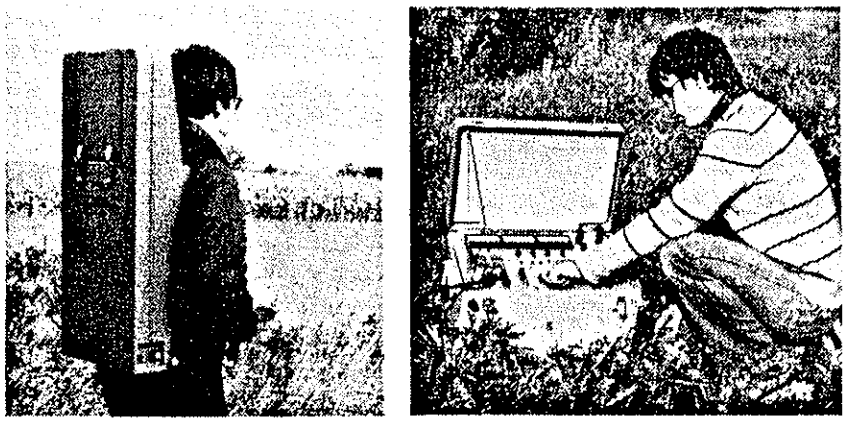

Figure EM:3
The TM-2 GENIE/Horizontal Loop Portable Electromagnetic Transmitter (left) and the TF-2 GENIE Fixed Source Electromagnetic Transmitter (right).

1.3.1 GENIE MODE

In this mode of operation the EM-4 Receive Coil picks up the two separate frequency signals, filters and amplifies them. The microprocessor normalizes these amplitudes by the free space amplitude for the selected transmitter-receiver separation and for the different transmitter moments. Then, the ratio of these amplitudes is calculated. All of these values may be displayed on the LCD display of the IGS-2 System Control Console and are recorded in the solid-state memory along with the time of day, grid coordinates and other information.

The amplitude ratio measurement, which does not require an interconnecting cable between the transmitter and receiver, is quite insensitive to errors in coil separation and orientation, permitting effective use in rough terrain.

1.3.2 Horizontal Loop Mode

This second mode of operation allows the standard in-phase and quadrature measurements normally associated with the Horizontal Loop (also known as HLEM or Slingram) method to be used. This measurement requires the use of a transmitter-receiver interconnecting cable which carries phase references permitting the vertical secondary field at the receiver to be resolved into in-phase and quadrature components. Two frequencies are measured simultaneously.

When the Horizontal Loop Mode is used, the GENIE Mode amplitude ratio is automatically measured, displayed and recorded in memory. In both modes the analog signal voltages are integrated for one second. The one second samples are then stacked and averaged to improve the signal-to-noise ratio. In addition, the statistical error is calculated and displayed. This permits the operator to judge when he has achieved the desirable accuracy. The error is also recorded to provide a permanent record of data quality. As a further check, the number of seconds required to achieve the reading are recorded in memory.

1.4 EM-4 GENIE/Horizontal Loop Expansion Module

This module is required when it is desired to use the IGS-2/EM-4 Receiver for performing HLEM measurements, or when the IGS-2 System Control Console is equipped with all of the EM-4, MP-4 and VLF-4 Sensor Options.

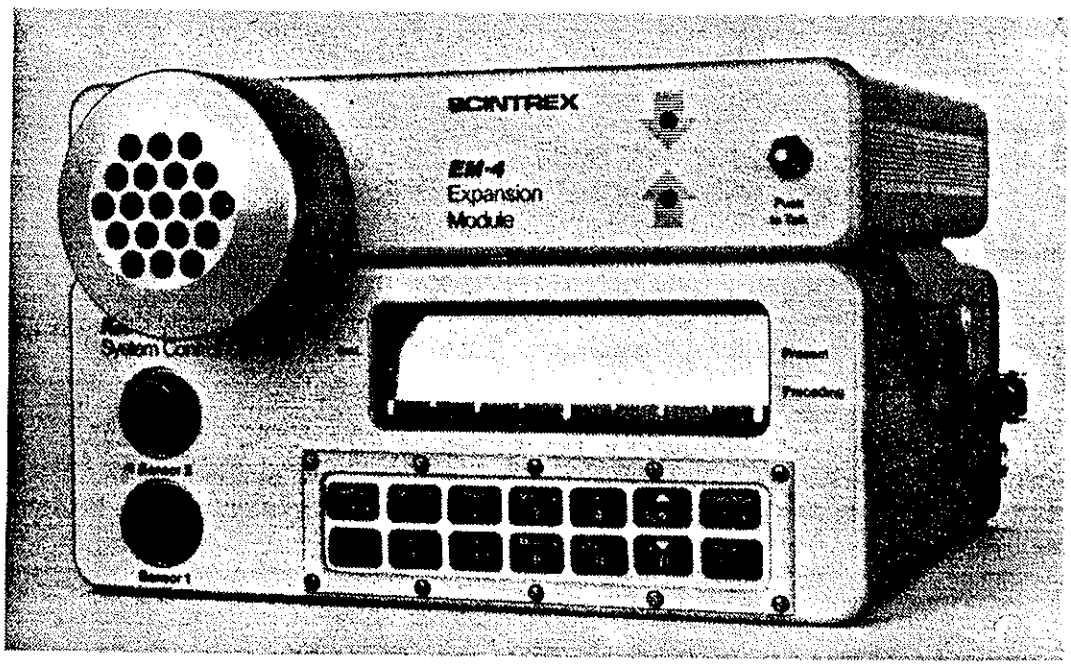

Figure EM:4
IGS-2 Console with EM-4 Expansion Module Attached.

The EM-4 Expansion Module is attached in piggyback fashion to the IGS-2 System Control Console. This unit permits the two EM-4 Sensor Option electronic circuit boards to be installed inside. This allows the three available electronic circuit board slots in the IGS-2 System Control Console to be used for one MP-4 and two VLF-4 electronic circuit boards, if three survey methods are to be employed concomitantly.

The EM-4 Expansion Module has a tiltmeter feature which is useful whenever it is desired to orient the transmit and receive coils to coplanarity in order to maximize the signal in GENIE measurements, or to ensure correct HLEM measurements in rough terrain. The electronics within the module accept the output of an electronic tiltmeter sensor installed in the EM-4 Receive Coil and compares it with a desired tilt keyed into the IGS-2 System Control Console. The positive or negative deviation from the desired tilt is displayed by two bright LEDs on the module's front panel. The tilt angle is automatically recorded with the electromagnetic data.

The EM-4 Expansion Module is fully described below:

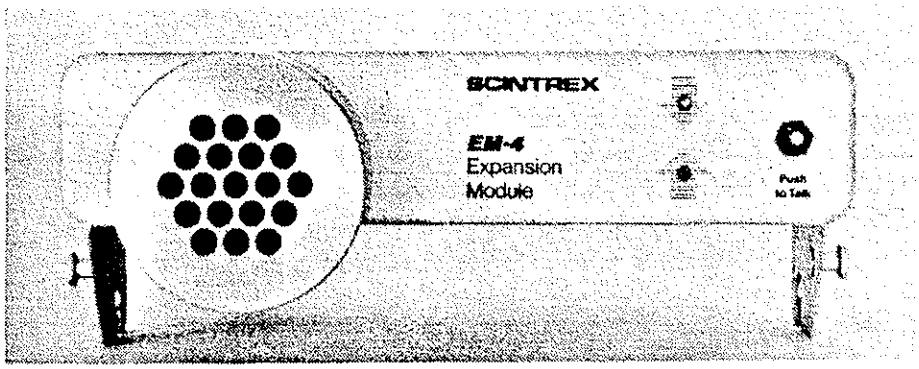

Figure EM:5
EM-4 Expansion Module Front Panel

Microphone/Speaker:
The front mounted Microphone/Speaker unit is permanently mounted to the front panel of the EM-4 Expansion Module. It is of non-magnetic design to prevent any interference with the MP-4 Sensor Option.

Tiltmeter Display:
The LED Tiltmeter Display indicates the positive or negative deviation from the desired tilt value that is entered through the keyboard. The tilt angle value is automatically recorded with the EM data.

Push to Talk:
The Push to Talk button is a momentary switch that activates the intercom system enabling the user to speak to his partner. The intercom functions only when connected via the transmitter-receiver interconnecting cable to the TM-2 Transmitter.

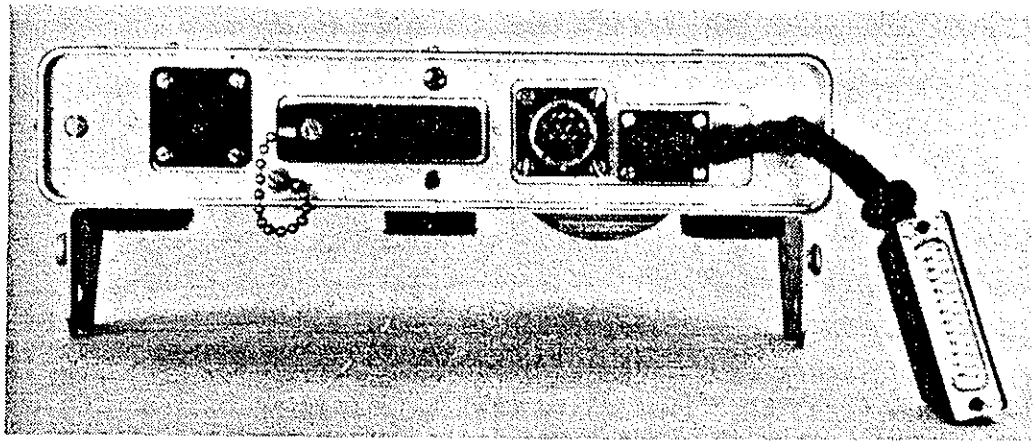

Figure EM:6
EM-4 Expansion Module Rear Panel

HLEM Input Socket:
A four pin socket accommodates the transmitter-receiver interconnecting cable.

RS-232C Port:
This port provides a serial output interface to external printers and other communication devices.

Receive Coil Socket:
A ten pin socket accommodates the receive coil cable.

IGS-2 CPU Interconnect:
A short, permanently attached cable with connector facilitates the transfer of processed EM-4 signals to the Central Processing Unit of the IGS-2 System Control Console, for final signal processing.

1.5 IGS-2/EM-4 Accessories

1.5.1 Transmitter-Receiver Interconnecting Cables

The Transmitter-Receiver Interconnecting Cables are made to order for the user. The cables come complete with connectors on both ends of the cable. The reference frequency signal from the transmitter to the receiver, as well as voice communication between operators, are transmitted via this cable.

Scintrex prepares Transmitter-Receiver Interconnecting Cables for Horizontal Loop measurements to order, in any lengths up to 300 m, or imperial measure equivalents.

1.5.2 DHEM-4 GENIE Electromagnetic Drillhole Logging Option

Drillhole GENIE Mode measurements can be performed by utilizing the DHEM-4 GENIE Electromagnetic Drillhole Logging Option with the TF-2 Transmitter. The DHEM-4 Drillhole Option consists of the following components:

1. Sonde
2. CLW Winch
3. Cable

Sonde:

The Sonde consists of an iron-cored sensor coil and preamplifier that is sealed in a protective plastic case. The Sonde can operate to depths of 1,000 metres at temperatures up to 60°C. It weights 1.8 kg and is 34 mm in diameter by 875 mm in length to fit standard boreholes.

CLW Winch:

Scintrex offers the CLW-1, CLW-2 and CLW-3 Winches that can carry up to 250, 500 and 1,000 metres of cable respectively. These winches are used in conjunction with the drillhole Sonde.

The standard version of all three models uses a two-speed, hand crank drive. For longer cable lengths and for winches to be used with a controller, the optional Power Drive Package including a motor-generator, AC drive motor and controls is recommended.

A special adaptor box for signal and supply voltage transfer between the winch and the IGS-2/EM-4 Receiver interfaces with the winch.

Cable:

The Cables are made to order for the user depending upon the winch that will be utilized.

1.6 Adding the EM-4 Option to the IGS-2 System

Complete information pertaining to the reconfiguration and upgrading of your IGS-2 System is located in Section 7.0 of the "IGS-2 Operation Manual".

1.7 EM Setup Menus

The EM Setup Menus are presented on the next page for easy reference as you read the next chapter, entitled "Enabling the Survey Methods".

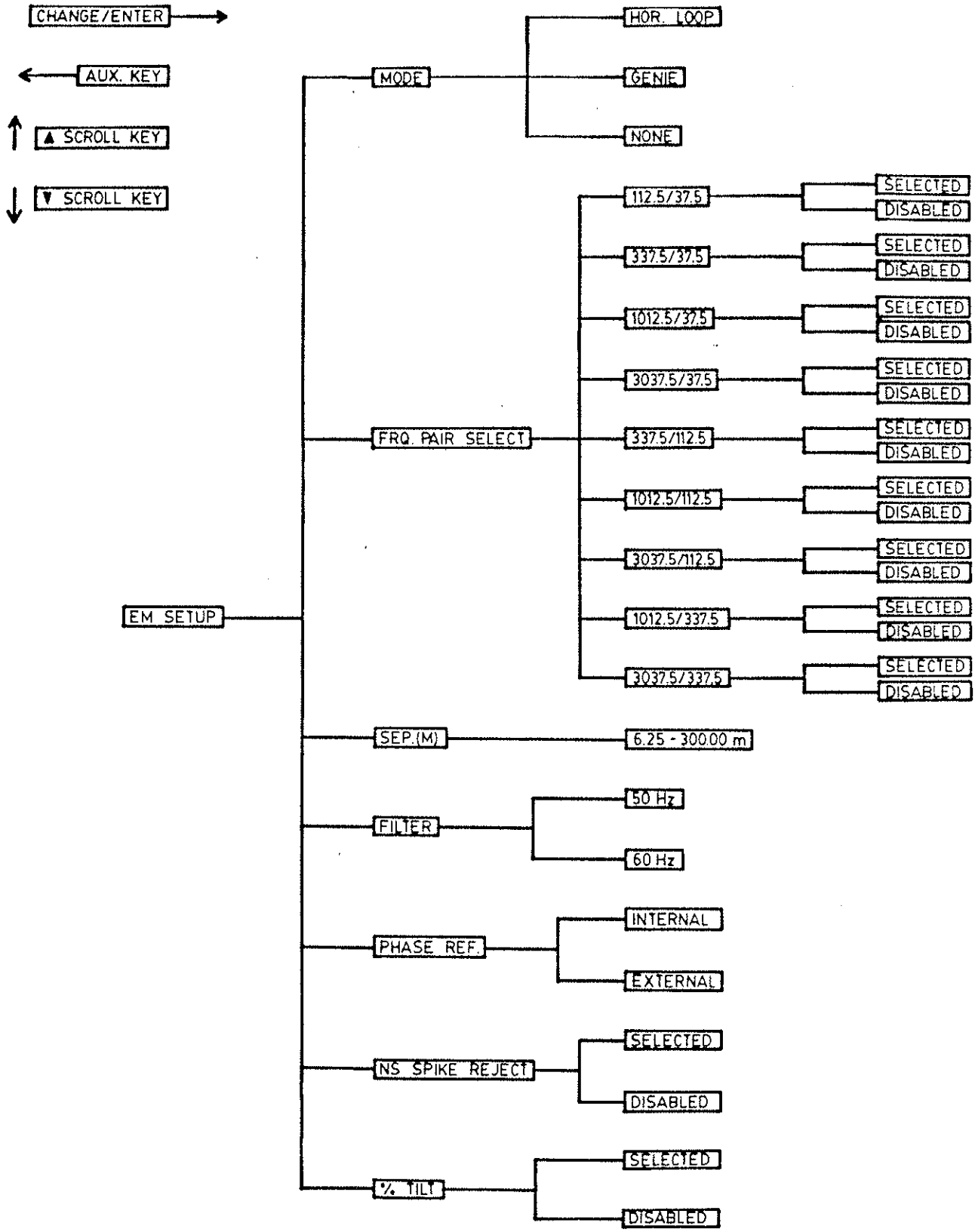

Table EM:1
EM Setup Menus

2.0 ENABLING THE SURVEY METHODS

2.1 Introduction

Two modes of operation are available with the IGS-2/EM-4 Receiver. They are:

1. Horizontal Loop (HLEM)
2. GENIE

2.2 Selecting the Mode

Selecting the mode of operation is performed in the following way:

1. In the AUX. mode, scroll to find EM SETUP.
2. Press CHANGE/ENTER to enter this item and scroll to find MODE.
3. One of the following will appear beside MODE:

HOR. LOOP	Horizontal Loop Mode
GENIE	GENIE Mode
NONE	Disables the Electromagnetic Receiver

4. Press CHANGE/ENTER in order to change a selection.
5. Scroll until the required mode appears on the display.
6. Press CHANGE/ENTER to complete the entry.

2.3 Enabling the GENIE Mode

When GENIE has been selected as the mode of operation, continue as follows:

1. Scroll down to see the next item in the menu: FRQ. PAIR SELECT.

2. The Frequency Pair Select feature is entered by means of the CHANGE/ENTER key. (See explanation of Frequency Pair selection in Section 2.5.1.)

3. Press AUX. to complete the selection(s) and to return to the previous menu.

4. Scroll down to the next item: SEP(M).

5. Press CHANGE/ENTER and enter the Separation value. (See explanation of Separation in Section 2.5.2.)

6. Press CHANGE/ENTER to complete the entry.

7. Scroll down to the next item: FILTER.

8. Press CHANGE/ENTER and scroll until the appropriate option appears. (See explanation of Filter in Section 2.5.3.)

9. Press CHANGE/ENTER to complete the entry.

10. Scroll down to the next item: PHASE REF.

11. Press CHANGE/ENTER and scroll until the appropriate option appears. (See explanation of Phase Reference in Section 2.5.4.)

12. Press CHANGE/ENTER to complete the entry.

13. Scroll down to the next item: NS. SPIKE REJECT.

14. The Noise Spike Rejection feature is enabled/disabled by means of the CHANGE/ENTER key. (See explanation of Noise Spike Rejection feature in Section 2.5.5.)

15. Scroll down to the next item: % TILT.

16. The % Tilt feature is enabled/disabled by means of the CHANGE/ENTER key. (See explanation of % Tilt in Section 2.5.6.)

2.4 Enabling the HLEM Mode

When HOR. LOOP has been selected as the mode of operation, continue as follows:

1. Scroll down to see the next item in the menu: FRQ. PAIR SELECT.

2. The Frequency Pair Select feature is entered by means of the CHANGE/ENTER key. (See explanation of Frequency Pair selection in Section 2.5.1).

3. Press AUX. to complete the selection(s) and to return to the previous menu.

4. Scroll down to the next item: SEP(M).

5. Press CHANGE/ENTER and enter the Separation value. (See explanation of Separation in Section 2.5.2).

6. Press CHANGE/ENTER to complete the entry.

7. Scroll down to the next item: FILTER.

8. Press CHANGE/ENTER and scroll until the appropriate option appears. (See explanation of Filter in Section 2.5.3.)

9. Press CHANGE/ENTER to complete the entry.

10. Scroll down to the next item: NS. SPIKE REJECT.

11. The Noise Spike Rejection feature is enabled/disabled by means of the CHANGE/ENTER key. (See explanation of Noise Spike Rejection feature in Section 2.5.5.)

12. Scroll down to the next item: % TILT.

13. The % TILT feature is enabled/disabled by means of the CHANGE/ENTER key. (See explanation of % Tilt in Section 2.5.6.)

2.5 EM-4 Survey Parameters

2.5.1 Frequency Pairs

There are nine frequency pairs that can be selected for use in measurements. They are:

112.5/ 37.5 Hz
337.5/ 37.5 Hz
1012.5/ 37.5 Hz
3037.5/ 37.5 Hz
337.5/112.5 Hz
1012.5/112.5 Hz
3037.5/112.5 Hz
1012.5/337.5 Hz
3037.5/337.5 Hz

All frequency pairs can be used with the TF-2 Transmitter. Frequency pairs that include 37.5 Hz cannot be used with the TM-2 Transmitter.

The frequency pairs are enabled/disabled as follows:

1. Press the CHANGE/ENTER key.

2. Scroll through the pairs to check status of each pair.

3. Press the CHANGE/ENTER key while viewing a frequency pair to either select or disable the pair.

4. Press the AUX. key to return to the previous menu.

Note: If all the frequency pairs are disabled then the EM METHOD is effectively disabled, regardless of the mode selection.

2.5.2 Separation

The separation value is the distance between transmitter and receiver coils. It is a value that is established and maintained during a moving source survey in either the HLEM or GENIE modes.

The separation value is utilized by the IGS-2 System Control Console microprocessor when performing calculations of the primary fields used for normalizing the received signals from the transmitter.

When using the TF-2 Transmitter an intermediate separation value is entered. A typical value selected is 100 metres. This is because during a fixed source survey the actual separation between transmitter and receiver is constantly changing.

IMPORTANT: If conducting a moving source survey the correct separation value must be entered, or the data generated by the IGS-2/EM-4 Receiver will not be correct.

The separation value can be between 6.25 and 300 metres. The separation value must be converted from imperial to metric with a two decimal place resolution.

The separation value is entered as follows:

1. Press the CHANGE/ENTER key.

2. Enter through the keyboard the correct separation value.

3. Press the CHANGE/ENTER key a second time to complete the entry.

Note: If the entered separation value is outside the range of 6.25 to 300.00 metres, then a message "INVALID SEP" will appear. The same message will appear if the operator attempts to make a measurement without entering a separation value that is inside the permissable range.

2.5.3 Filter

The IGS-2/EM-4 Receiver is equipped with a selectable power line filter. The filter suppresses the fundamental and third harmonics of either 50 or 60 Hz power line frequencies.

Depending upon the prevailing power line frequency at the survey location, the appropriate filter should be selected.

The filter is selected as follows:

1. Press the CHANGE/ENTER key.

2. Scroll until the appropriate filter frequency appears.

3. Press the CHANGE/ENTER key a second time to complete the entry.

2.5.4 Phase Reference

The IGS-2/EM-4 Receiver requires phase reference information. This information can be generated either internally or externally.

In Horizontal Loop Mode measurements an external phase reference is automatically selected by the IGS-2/EM-4 Receiver for use in signal processing. The external phase reference is supplied via the Transmitter-Receiver Interconnecting Cable.

In GENIE Mode measurements either internal or external phase references can be used, depending upon the application. Normally, for all GENIE surface measurements the internal phase reference is used. An internally generated phase reference is supplied by the EM-4 signal processing boards. When performing GENIE drillhole measurements, an external phase reference can be supplied from the TF-2 Transmitter.

NOTE: In the GENIE Mode the external phase reference is used only if phase information is required. If the external phase reference is used for surface GENIE measurements, then the normalized total field amplitude and phase will be measured instead of the normalized secondary field in-phase and quadrature components as in the HLEM Mode.

The phase reference, in GENIE Mode, is selected as follows:

1. Press the CHANGE/ENTER key.

2. Scroll until the appropriate phase reference appears.

3. Press the CHANGE/ENTER key a second time to complete the entry.

2.5.5 Noise Spike Rejection

The IGS-2/EM-4 Receiver is equipped with a noise spike rejection feature.

This feature, if selected, will eliminate noise spikes from the averaged signals obtained from the receive coil.

The noise spike rejection feature is enabled/disabled as follows:

1. Press the CHANGE/ENTER key once to select the noise spike rejection feature, if it is currently disabled, or

2. Press the CHANGE/ENTER key once to disable the noise spike rejection feature, if it is currently selected.

See Section 6.7.4, entitled "Noise Spike Rejection Filter", for further details.

2.5.6 % Tilt

The IGS-2/EM-4 Receiver is equipped with an optional tiltmeter feature that is part of the EM-4 Expansion Module. This feature is used whenever it is desired to orient the transmitter and receive coils to coplanarity in order to improve signal strength in GENIE measurements or to correctly align the transmitter and receive coils for measurements in rough terrain.

Electronics within the EM-4 Expansion Module accept the output of an electronic tiltmeter sensor installed in the receive coil and compare it with a desired tilt keyed into the IGS-2 System Control Console. This desired tilt must be established beforehand by an appropriate method (i.e. using an inclinometer). If the tilt of the receive coil is within detection range (±4% or ±2.5 degrees), of the desired tilt, both LEDs are off. If the tilt of the receive coil is outside the detection range then one or the other of the LEDs will indicate in which direction the receive coil has to be tilted in order to bring it into the desired tilt.

The tilt measuring range is -20% to +80% grade. Positive tilt is achieved by the operator bending forward if the receive coil is backplate mounted. If the receive coil is placed on the ground, lowering the coil side to which the arrow is pointed results in positive tilt.

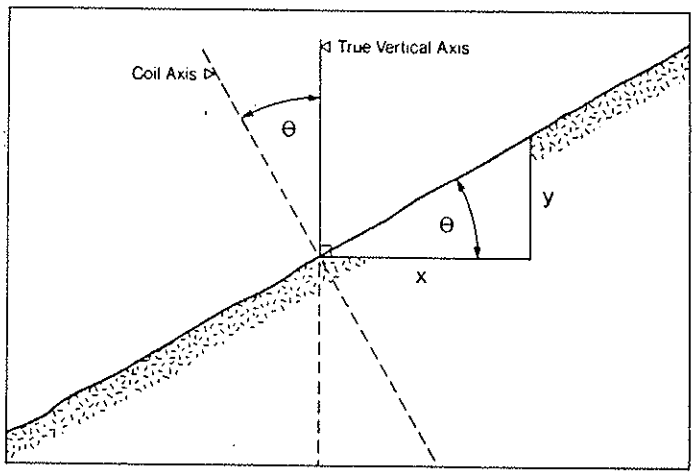

Figure EM:7
% Tilt Parameters

The equation expressing % TILT is stated as:

$$100\ (\text{TAN}\ \theta) = \%\ \text{TILT} \qquad (1)$$

The tilt measurement feature is enabled/disabled as follows:

1. Press the CHANGE/ENTER key to make the desired selection. If the % TILT is enabled, then at the beginning of the measurement the display will indicate the present tilt value. If it has to be changed, then proceed to step 2.

2. Enter through the keyboard the correct % Tilt value for that particular measurement station.

3. Press the CHANGE/ENTER key a second time to complete the entry.

4. Press the START/STOP key once again to start the measurement.

2.6 Disabling the EM-4 Sensor

In order to disable the IGS-2/EM-4 Receiver, do the following:

1. In EM SETUP, press CHANGE/ENTER and scroll to find MODE.

2. Press CHANGE/ENTER and scroll until NONE appears.

3. Press CHANGE/ENTER to complete the selection.

The message in the auxiliary mode will now read EM DISABLED instead of EM SETUP.

Note: If all the frequency pairs are disabled then the EM METHOD is effectively disabled, regardless of the mode selection.

3.0 PERFORMING A MEASUREMENT

3.1 Preliminary Check of Battery, Memory and Time

Examining the contents of INFO ensures that the survey can proceed:

Press INFO and scroll to confirm the following conditions:

1) memory is free 100%;
2) battery level is sufficiently high;
3) time and date are correct;
4) grid number is correct;
   Grid number can be changed here if necessary without going through the Initialise mode by pressing CHANGE/ENTER, changing the number, and pressing CHANGE/ENTER once again.

The items labelled INFO A - INFO H will appear next. They are used to store ancillary information, such as elevation, along with a measurement. The use of this feature is described in Chapter 4.0 of the IGS-2 Operation Manual in the section entitled "Adding Ancillary Data".

3.2 Surface Measurements

3.2.1 Moving Source GENIE and HLEM Measurements

Before starting a survey, ensure that the present line and station displays of the instrument correspond to the actual survey location. To do this, press the Line key, then the Station key and change the entries if necessary.

A typical survey would follow the sequence as outlined below:

1. **Orientation:** Both the IGS-2/EM-4 Receiver and the TM-2 Transmitter operators take their correct starting places.

   For reconnaissance exploration surveys, in areas without a properly chained grid, the autoranging feature of the IGS-2/EM-4 Receiver can be utilized provided that only GENIE and not HLEM measurements are made. Please refer to Section 6.4.1, entitled "Autoranging Feature" for complete details.

2. **Method Check:** Before starting a measurement the METHOD key can be pressed to see what method or frequency pair is about to be measured.

3. **Tilt Correction:** If the tiltmeter function has been selected, a "% TILT" prompt will appear after pressing the START/STOP key. If a correction is required at this particular station, a new value can be entered by pressing the CHANGE/ENTER key and entering a new value.

   With the tilt function enabled, the tiltmeter's LED display will indicate when the tilt angle is correct. Deviation from the desired tilt is indicated when a particular LED is illuminated. When the receive coil has been oriented correctly with respect to tilt both LED's will NOT be illuminated.

   With the transmitter operator using his tiltmeter, he should verify that his tilt angle corresponds with the receiver operator's tilt angle. Failure to do this could result in non-coplanarity between the transmitter and receive coils. This condition can cause inaccurate data to be generated.

   IMPORTANT: The tilt angle of the transmitter and receive coils must be correctly established before entering the averaging mode.

   If the IGS-2 Console should automatically turn itself off (i.e. after 60 secs) while in the % TILT correction, then the measurement must be initiated again from the beginning.

4. **Reading:** By pressing the START/STOP key once, the instrument will tune itself to the selected frequency pair, measure the output offsets, set the gain controls and commence reading. The message "READING" will be displayed and individual one second signal readings will be indicated. These readings are not recorded.

   IMPORTANT: Ensure that the transmitter is ON before starting the reading sequence.

5. **Averaging:** By pressing the START/STOP key a second time, the subsequent samples will be averaged together. The message "DUR xxxx" will be displayed indicating the present duration time (in seconds) of the averaging process.

   IMPORTANT: The receive coil must not change orientation during averaging because motion noise and signal level variations will corrupt the measurement.

6. **Recording Measurement:** By pressing the START/STOP key once during the averaging of samples, the averaging will be terminated. If the measurement is to be recorded, the RECORD key is pressed once. If the operator prefers to disregard that particular measurement, the START/STOP key can be pressed twice to repeat the measurement at that particular station location.

7. **Subsequent Measurements:** If more than one pair of frequencies have been selected for measurement, or other optional sensor measurements have been selected, the instrument will upon recording the present measurement automatically sequence itself through those selected measurements before automatically incrementing to the next station number.

8. **Station Incrementation:** If Auto Station Incrementation has been selected, the instrument will automatically increment the Station Number by the value entered as Station Separation. Otherwise, station incrementation must be done manually by the operator. (See Section 4.3.11 in the "IGS-2 - Operation Manual" for further details.)

9. **Next Measurement:** Both operators move to their next set of positions to proceed with their survey.

3.2.2 Fixed Source GENIE Measurements

Before starting a survey, ensure that the present line and station displays of the instrument correspond to the first survey location. To do this, press the Line key, then the Station key and change the entries if necessary.

A typical survey would follow the sequence as outlined below:

1. **Transmitter Setup:** The TF-2 Transmitter is setup as per the instructions in the "TF-2 Operation Manual".

2. **Method Check:** Before starting a measurement the METHOD key can be pressed to see what method is about to be measured. It should be the EM GENIE method.

3. **Separation Value:** For fixed source measurements an intermediate separation value is entered. A typical value selected is 100 metres. This is because during a fixed source survey the actual separation between the fixed source transmitter and receiver is constantly changing. Primary field cannot be calculated due to the uncertainty of loop current, loop dimensions and other variable factors.

Please refer to Section 2.5.2 of this manual, entitled "Separation", for details regarding separation initialization.

4. **Tilt Correction:** This feature is not usually employed during fixed source measurements.

   IMPORTANT: During fixed source measurements it is strongly recommended that the receive coil be placed on the ground if frequency pairs involving 37.5 Hz are measured, to avoid noise induced by moving the receive coil in the Earth's magnetic field.

5. **Reading:** By pressing the START/STOP key once, the instrument will tune itself to the selected frequency pair, measure the output offsets, set the gain controls and commence reading. The message "READING" will be displayed and individual one second signal averages will be indicated. These readings are not recorded.

   IMPORTANT: Ensure that the transmitter is ON before starting the reading sequence.

6. **Averaging:** By pressing the START/STOP key a second time, the subsequent samples will be averaged together. The message "DUR xxxx" will be displayed indicating the present duration time (in seconds) of the averaging process.

   IMPORTANT: The receive coil must not change orientation during averaging because motion noise and signal level variations will corrupt the measurement.

7. **Recording Measurement:** By pressing the START/STOP key once during the averaging of samples, the averaging will be terminated. If the measurement is to be recorded, the RECORD key is pressed once. If the operator prefers to disregard that particular measurement, the START/STOP key can be pressed twice to repeat the measurement at that particular station location.

8. **Subsequent Measurements:** If more that one pair of frequencies have been selected for measurement, or other optional sensor measurements have been selected, the instrument will automatically sequence itself upon receiving the present measurement through those selected measurements before automatically incrementing to the next station number.

9. **Station Incrementation:** If Auto Station Incrementation has been selected, the instrument will automatically increment the Station Number by the value entered as Station Separation. Otherwise, station incrementation must be done manually by the

operator. (See Section 4.3.11 in the "IGS-2 - Operation Manual" for further details.)

10. **Next Measurement:** The IGS-2/EM-4 Receiver operator moves to his next station to proceed with the survey.

3.3. Drillhole Measurements

Before starting a survey, ensure that the following are performed:

A. Determine that the borehole is clear using a dummy probe.

B. Setup the transmitter and receiver with the Sonde at the surface.

C. Measure all frequency pairs of interest with the Sonde at the surface - held vertically.

D. Lower the Sonde to just below any metal casing to begin measurements.

Before taking measurements, ensure that the present line and station (depth) displays of the instrument correspond to the first survey location. To do this, press the Line key, then the Station key and change the entries if necessary.

A typical survey would follow the sequence as outlined below:

1. **Transmitter Setup:** The TF-2 Transmitter is setup as per the instructions in the "TF-2 Operation Manual".

2. **Method Check:** Before starting a measurement the METHOD key can be pressed to see what method is about to be measured. It should be the EM GENIE method.

3. **Depth Incrementation:** The drillhole Sonde is lowered to its appropriate depth.

4. **Reading:** By pressing the START/STOP key once, the instrument will tune itself to the selected frequency pair, measure the output offsets, set the gain controls and commence reading. The message "READING" will be displayed and individual one second signal readings will be indicated. These readings are not recorded.

5. **Averaging:** By pressing the START/STOP key a second time, the subsequent samples will be averaged together. The message

"DUR xxxx" will be displayed indicating the present duration time (in seconds) of the averaging process.

If phase information is required a Phase Reference Interconnecting Cable can be connected from the TF-2 Transmitter via an isolation transformer to the EM-4 Expansion Module.

IMPORTANT: The Sonde depth must not be changed during a measurement.

6. **Recording Measurements:** By pressing the START/STOP key once during the averaging of samples, the averaging will be terminated. If the measurement is to be recorded, the RECORD key is pressed once. If the operator prefers to disregard that particular measurement, the START/STOP key can be pressed twice to repeat the measurement at that particular station (depth) location.

7. **Subsequent Measurements:** If more than one pair of frequencies have been selected for measurement, the instrument will automatically sequence itself upon receiving the present measurement through those selected measurements before automatically incrementing to the next station (depth) number.

8. **Station Incrementation:** If Auto Station Incrementation has been selected, the instrument will automatically increment the Station Number by the value entered as Station Separation. Otherwise, station incrementation must be done manually by the operator. (See Section 4.3.11 in the "IGS-2 - Operation Manual" for further details.)

9. **Next Measurement:** The drillhole Sonde is lowered to the next depth level that corresponds to the next survey station location.

3.4 Common Operating Procedures

3.4.1 Aborting a Measurement

By pressing the AUX. key once during an IGS-2/EM-4 Receiver measurement, that particular measurement will be aborted. This is useful for immediate termination during either reading or averaging of the received signals.

3.4.2 Viewing Data

Press the Data key to view the data that has been measured for the measurement just completed. Scroll to see the items listed. They are:

A) For the HLEM Mode
   1) IN-PHASE 1
   2) QUADR. 1 (Quadrature 1)
   3) IN-PHASE 2
   4) QUADR. 2 (Quadrature 2)
   5) % RATIO (GENIE Ratio)
   6) SD.1 (Standard Deviation 1)
   7) SD.2 (Standard Deviation 2)
   8) DUR (Averaging Duration)
   9) SEP (Separation)
   10) % TILT (Tilt Value)
   11) # REJECTED (Measurements Rejected)
   12) TIME

B) For the GENIE Mode
   1) % RATIO (GENIE Ratio)
   2) AMPL. 1 (Amplitude 1)
   3) AMPL. 2 (Amplitude 2)
   4) PHASE 1 (Ext. Reference Only)
   5) PHASE 2 (Ext. Reference Only)
   6) SD.1 (Standard Deviation 1)
   7) SD.2 (Standard Deviaton 2)
   8) DUR (Averaging Duration)
   9) SEP (Separation)
   10) % Tilt (Tilt Value)
   11) # REJECTED (Measurements Rejected)
   12) TIME

Notes:

1. Number 1 refers to the lower frequency of the frequency pair selected.

2. Data can be viewed during measurement, as well as after a measurement, by pressing the SCROLL key. It may take up to one second for the display to change after the SCROLL key is pressed.

3. During a measurement SEP, % TILT, # REJECTED and TIME are not displayed, as they are of no particular interest at that time. The averaging duration (DUR) is displayed during a measurement on the lower display line, along with the other data parameters.

3.4.3 Ancillary Data

The IGS-2 System Control Console has a data storage capacity for eight pieces of coded information (INFO A - INFO H) to be recorded with each measurement that is taken.

The use of this feature is fully discussed in the "IGS-2 - Operation Manual", Chapter 4.0, under "Adding Ancillary Data".

4.0 EM-4 WARNING MESSAGES

Display	Meaning
NO REFERENCE (GENIE-Int.Ref.)	The internal phase reference is not being generated. This condition will occur under extremely noisy conditions or when expected transmitted signals are not present.
NO REFERENCE (HLEM or GENIE-Ext. Ref.)	The external phase reference is not present. This can be caused by: 1) Transmitter-Receiver Interconnecting Cable not connected properly. 2) Transmitter-Receiver Interconnecting Cable is broken or the wrong cable is installed. 3) Isolation Transformer is not present or malfunctioning.
OUT OF RANGE	The separation value entered is invalid. The SEP value must be between 6.25 and 300 metres.
OVERLOAD AC	Indicates a saturation of the AC amplifier due to an improper gain setting. The IGS-2/EM-4 Receiver normally adjusts the internal gain to prevent this condition. However, it could occur under one of the following conditions: 1) Excessive receive coil motion noise. 2) Local power line noise increases greatly after gain setting. 3) Atmospheric noise increases greatly after gain setting. 4) Receive coil less than 6.25 metres from transmitter coils.

Display	Meaning
OVERLOAD AC	5) Receiver-Transmitter separation reduced greatly after gain setting. 6) Transmitter off during gain setting, then switched on. This overload condition can normally be corrected by terminating and then restarting the measurement.
OVERLOAD DC	Indicates a saturation of the DC amplifier due to an improper gain setting. The IGS-2/EM-4 Receiver normally adjusts the internal gain to prevent this condition. However, it could occur under one of the following conditions: 1) Excessive receive coil motion noise. 2) Receive coil less than 6.25 metres from transmitter coils. 3) Receiver-Transmitter separation reduced greatly after gain setting. 4) Transmitter off during gain setting, then switched on. This overload condition can normally be corrected by terminating and then restarting the measurement.
REJECTED	This message is displayed if the noise spike rejection feature is selected and a one second sample is rejected during averaging because it was too noisy. The total number of such rejected samples is displayed as # REJECTED. The rate of rejection depends upon local atmospheric conditions.

REJECTED	If the Transmitter-Receiver coil separation is changed during averaging and the reading differs by more than 3% from the previous reading, it will be rejected as well.
TUNING FAILED	This message indicates a failure to tune the internal phase reference. It will also occur if the % Tilt information is not entered and/or the START key is not pressed within one minute after the tilt prompt appears. The display will go blank. Pressing the START key will result in the above message appearing. Press START key again. Persistent failure indicates instrument malfunction.

5.0 SETTING UP THE EQUIPMENT

5.1 Introduction

This chapter describes how to physically set up the equipment for an electromagnetic survey using the IGS-2/EM-4 Receiver.

5.2 Sensors

5.2.1 Portable Receive Coil

The EM-4 Receive Coil may be deployed in two separate manners:

1) Backplate Method
2) Tripod Method

Figure EM:8
Backplate Mounted Receive Coil with VLF-4 Sensor below.

Backplate Method:
Two plexiglass backplate brackets are attached to the receive coil by means of a threaded stud that protrudes from the bottom of the receive coil. The knurled nut on the lower strut is tightly fastened to secure the entire assembly together. The straps of the backplate are then passed through slots on the other end of the struts. Buckles on the straps secure the struts to the backplate.

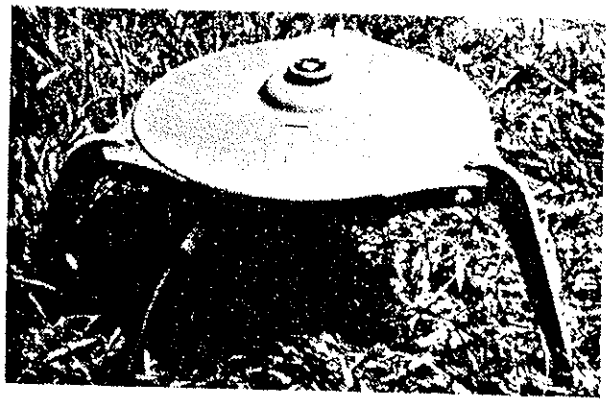

Figure EM:9
Retractable Receiver Coil with Legs Extended

Tripod Method:
The receive coil comes with three retractable legs. The legs can be extended for placing the receive coil on the ground. A "bubble-level" on the top of the receive coil case can be used for horizontal orientation.

The built-in tiltmeter measures positive tilt if the coil side to which the arrow points is lowered. The arrow imprinted on the top of the receive coil case should be oriented in-line with the direction of the survey.

The EM-4 Receive Coil Interconnect Cable is used to link the receive coil to either:

1) IGS-2 Console, or
2) EM-4 Expansion Module

1. If the EM-4 Electronic Circuit boards are installed in the IGS-2 System Control Console, then the receive coil interconnect cable is connected to either of the two sensor sockets located on the front panel of the IGS-2 Console.

2. If the EM-4 Electronic Circuit boards are installed in the EM-4 Expansion Module, then the receive coil interconnect

cable must be connected to the receive coil socket located on the rear panel of the EM-4 Expansion Module (see Figure EM:6).

NOTE: For HLEM and GENIE (external reference) measurements, the EM-4 Electronic Circuit boards must be installed in the EM-4 Expansion Module. For GENIE (internal reference) measurements the boards can be installed in the IGS-2 System Control Console or the EM-4 Expansion Module.

The other end of the receive coil interconnect cable is connected to the socket located on the underside of the receive coil case.

5.2.2 Drillhole Sonde

The Sonde, which is part of the DHEM-4 GENIE Electromagnetic Drillhole Logging Option, is designed for use down drillholes. It is connected to the IGS-2/EM-4 Receiver as outlined in the "DHEM-4 Operation Manual".

5.3 EM-4 Expansion Module

A complete description pertaining to the installation of the EM-4 Expansion Module is located in the "IGS-2 - Operation Manual", Chapter 7.0.

5.4 Setting Up For Surface Measurements

5.4.1 GENIE Mode Measurements

The steps outlined below should be followed in setting up the IGS-2/EM-4 Receiver for GENIE Mode measurements:

1. Setup the portable receive coil as discussed in Section 5.2.1 of this manual.

2. The IGS-2/EM-4 Receiver can be enabled as per the steps outlined in Section 2.3 of this manual, entitled "Enabling the GENIE Mode".

NOTE: 1) If the GENIE method is to be used along with the VLF-4 Sensor Option, then the EM-4 Electronic Circuit Boards must be installed in the EM-4 Expansion Module.

2) If the tiltmeter feature is required with the GENIE method or the external phase reference is used, then the EM-4 Electronic Circuit Boards must be installed in the EM-4 Expansion Module.

3) If the tiltmeter feature and the VLF-4 Sensor Option are not used, then the EM-4 Expansion Module is not required for the GENIE method and the EM-4 Electronic Circuit Boards can be installed in the IGS-2 System Control Console.

5.4.2 HLEM Mode Measurements

The steps outlined below should be followed in setting up the IGS-2/EM-4 Receiver for HLEM Mode measurements:

1. Set up the portable receive coil as discussed in Section 5.2.1 of this manual.

2. Select a Transmitter-Receiver Interconnecting Cable of the appropriate length for your survey requirements.

3. Attach the end of the Transmitter-Receiver Interconnecting Cable with the black plastic connector to the HLEM Input Socket on the rear panel of the EM-4 Expansion Module (see Figure EM:6).

4. Fasten the strain relief strap of the Transmitter-Receiver Interconnecting Cable to the strap tabs that are provided on the side of the IGS-2 System Control Console.

5. Attach the other end of the Transmitter-Receiver Interconnecting Cable with the metal connector to the Isolation Transformer of the TM-2 Transmitter, and secure the strain relief strap to the TM-2 Transmitter. The Isolation Transformer is attached to the Transformer and Reference Cable Connector on the TM-2 Transmitter.

   Complete information discussing the setup of the TM-2 Transmitter can be found in the "TM-2 Operation Manual".

6. The IGS-2/EM-4 Receiver can be enabled as per the steps outlined in Section 2.4 of this manual, entitled "Enabling the HLEM Mode".

5.5 Setting Up For Drillhole Measurements

Complete information pertaining to the setup of the DHEM-4 GENIE Electromagnetic Drillhole Logging Option is contained in the "DHEM-4 Operation Manual".

5.6 Setting Up Peripheral Equipment

Detailed information pertaining to peripheral equipment related to the EM-4 Receiver, that is offered by Scintrex, is generally contained within operation manuals for each piece of equipment (e.g. TM-2 Transmitter - "TM-2 Operation Manual").

6.0 OPERATIONAL NOTES

6.1 HLEM and GENIE Response Comparisons

The traditional Horizontal Loop Electromagnetic (HLEM) method measures the in-phase and quadrature components at a selected frequency of the secondary vertical magnetic field, normalized by the primary field. The primary field is the field which would be seen at the receiver in free space, and is a calculated quantity.

The in-phase or quadrature HLEM response to a vertical half-plane conductor in free space has the familiar form seen in Figure EM:10. A number of curves are shown for different h (depth of burial) versus L (coil separation) ratios. Such responses are characterized by a large negative anomaly over the target, crossovers at ±L/2 from the negative peak and small positive side lobes. In terms of the location, dip, depth of burial and conductance, HLEM responses are interpreted as follows:

Location: The uppermost edge of the conductor is located directly below the negative peak of the anomaly. Flat lying (or broad) conductors can produce double negative peaks.

Dip: The down-dip (hanging-wall) positive peak is larger than the up-dip (foot-wall) peak. The difference in positive peaks is more pronounced as the conductor moves away from the vertical. This is most pronounced for h/L less than 0.25.

Depth of Burial: Response amplitudes (negative peak or positive shoulders) decreases as the depth of burial increases. This is true over the depth to coil separation ratios of interest (0 less than h/L less than 0.5).

Conductance: This is determined by the relative amplitudes of the in-phase and quadrature components at one or more frequencies. The interpretation is based on the response curves shown in Figure EM:11 wherein the quadrature peaks at some intermediate value of the response parameter and the in-phase increases up to its inductive limit.

Conventional HLEM systems permit a variety of operating frequencies from approximately 100 to 4000 Hz (37.5 to 3037.5 Hz in GENIE Mode and 112.5 to 3037.5 Hz in HLEM Mode for the IGS-2/EM-4). Frequency and coil separation selections are optimized for particular exploration problems. Coil separations as large as 300 metres are possible. The most common type of "noise" is that due to inexact coil positioning. If the receive coil, for example, is 99 metres from the transmitter coil (where L should = 100 m), the in-phase component will be in error by +3% (absolute error).

All of the above should be familiar to the HLEM user. The GENIE is defined somewhat differently.

The GENIE Mode measures the amplitude of the vertical magnetic fields at two frequencies. The higher frequency (f_2) is called the signal frequency and the lower one (f_1) is called the reference frequency. The receiver computes and displays:

$$\% \text{ RATIO} = \left[\frac{\text{AMPL.2}}{\text{AMPL.1}} - 1\right] \times 100 \quad \% \qquad (2)$$

where

% RATIO = GENIE reading in %
AMPL.1 = Amplitude of vertical magnetic field at the reference frequency f_1
AMPL.2 = Amplitude of vertical magnetic field at the signal frequency f_2

The values of % RATIO, AMPL.1 and AMPL.2 are all recorded in the memory of the IGS-2 System Control Console.

The GENIE mode reading may be expressed as well in terms of the in-phase and quadrature readings of HLEM systems.

$$\% \text{ RATIO} = \left[\frac{\left[100 + \text{IN-PHASE 2})^2 + (\text{QUADR. 2})^2\right]^{\frac{1}{2}}}{100 + \text{IN-PHASE 1})^1 + (\text{QUADR. 1})^2} - 1\right] \times 100\% \qquad (3)$$

where

% Ratio = GENIE reading in %
In-Phase 1 = In-phase HLEM response at f1 (reference frequency)
In-Phase 2 = In-Phase HLEM response at f2 (signal frequency)
Quadr. 1 = Quadrature HLEM response at f1 (reference frequency)
Quadr. 2 = Quadrature HLEM response at f2 (signal frequency)

In an area with no conductors or conductive overburden, the GENIE Mode will give a reading of zero percent regardless of coil separation, transmitter or receiver orientation. This is because both signal and reference fields behave identically in such environments and explains why the GENIE Mode has been labelled as "geometry-invariant". This is approximately correct. Systematic coil orientation and separation are important, however, for other reasons.

Over a conductor, the GENIE Mode will describe an anomaly very similar in shape to that seen from the traditional in-phase and quadrature HLEM systems. Anomaly behaviour with variations in target location, dip and depth of burial will be much the same for both systems. A number of GENIE response profiles are shown in Figure EM:10.

The variation of anomaly amplitude with target conductance is a different matter and some time should be taken to understand this aspect of the GENIE mode. The reader is referred to Figures EM:11 and EM:12 for the discussion which follows.

The GENIE Mode response curve shown in Figure EM:11 is typical. The response curve shown is, in essence, determined by the differences of in-phase amplitudes at the signal and reference frequencies. The GENIE response curve is bell shaped and conductors outside a certain range of conductances will go undetected. A number of common EM systems (e.g. INPUT, Transient EM) behave in a similar manner.

The conductance range limits are a function of a number of factors, most critically the frequency pair selected. As the signal and reference frequencies get closer together, the aperture decreases. The GENIE response amplitude decreases as well (see Figure EM:12). Note that at low conductance values, the GENIE response curve follows the in-phase curve at the signal frequency.

To illustrate this characteristic, assume a vertical thin plate target of 400 m strike length and 200 m depth extent at 25 m depth of burial in a non-conducting host. Assume a coil separation of 100 metres. The conductance window is thereafter determined by the smallest detectable anomaly. Table EM:2 below defines the conductance range for targets producing GENIE responses of 5% or greater.

Frequency Pair f_2/f_1	Conductance Range (mhos)
337.5/112.5	150 - 275
1012.5/112.5	45 - 290
3037.5/112.5	1.4 - 300
1012.5/337.5	50 - 90
3037.5/337.5	1.5 - 100

Table EM:2
Conductance ranges for a vertical thin plate target with L = 100 m and an anomaly threshold of -5%.

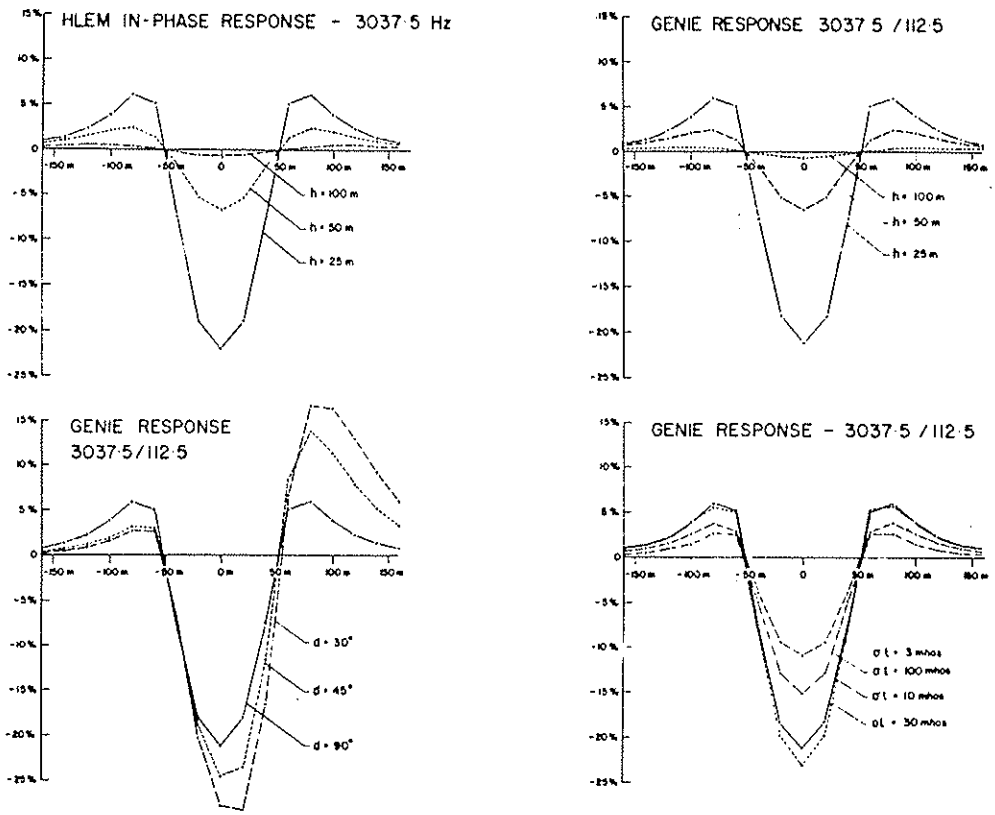

Figure EM:10
Horizontal Loop electromagnetic in-phase response profiles at 3037.5 Hz, and GENIE response profiles at the 3037.5/112.5 Hz frequency pair, for variable depth of burial (h), dip and conductance. Target is a vertical thin plate of 400 m (strike length) to 200 m (depth extent). Unless varying, dip = 90°, depth of burial = 25 m and conductance = 10 mhos. Traverse is normal to and over the centre of the plate. L = 100 m.

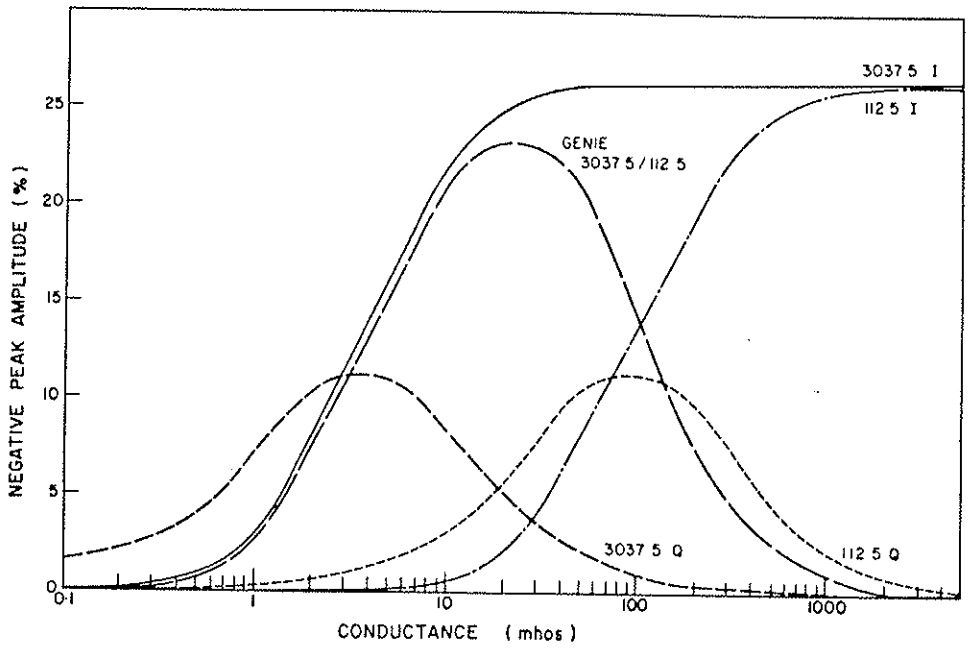

Figure EM:11
Response curves for HLEM and GENIE modes. A vertical thin plate conductor of 400 m (strike length) and 200 m (depth extent) at 25 m below surface is assumed. L=100 m. In-phase (I) and quadrature (Q) response amplitudes at 3037.5 and 112.5 Hz are plotted against conductance. The 3037.5/112.5 Hz GENIE response curve is superimposed.

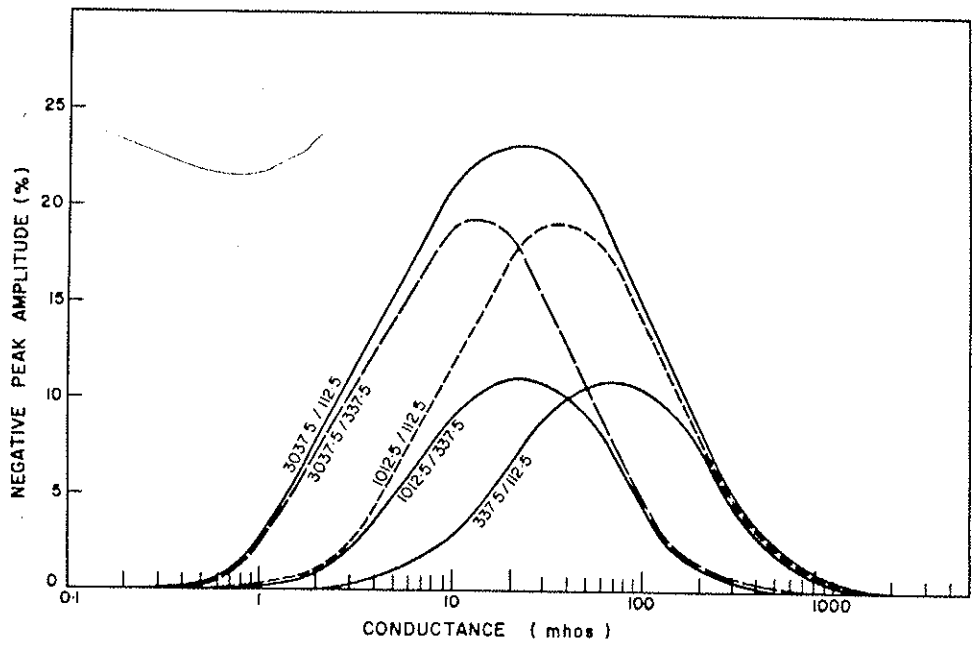

Figure EM:12
GENIE response diagrams for the five possible frequency pairs. Target model is as used in Figure EM:11, viz a 400x200 m vertical plate at 25 m below surface.

6.2 Normalization Based Upon Coil Separation

During a moving source measurement all amplitude parameters at a given frequency (Amplitudes 1 & 2, In-Phase 1 & 2, and Quadrature 1 & 2) are normalized by a primary field computed by the IGS-2/EM-4 Receiver. This is the vertical magnetic field that would exist at a separation distance (SEP), in metres, from a vertical axis transmitter (TM-2) coil in free space:

$$Hp = \frac{M}{4 \pi (SEP)^3} \qquad (4)$$

In a moving source measurement, the actual transmitter-receiver separation and the entered SEP value are equal, or approximately equal, depending upon whether the distance was measured with a chain or with the autoranging feature.

In a fixed source measurement, the relationship between primary magnetic field and separation from the current carrying transmitter loop is unknown, because the shape and size of the loop and current in the loop are arbitrary. This is not a concern for GENIE Mode measurements because the ratio of the primary magnetic fields is the same as with the moving source TM-2 Transmitter.

It is recommended that only one SEP value be used in fixed source (surface or drillhole) GENIE surveys and that the SEP value be changed only if the AMPL. 1 or AMPL. 2 display overflows (e.g. AMPL. > 99,999.99%), of if measurement resolution suffers (e.g. AMPL. < 10.00%).

A reasonable separation value to choose is SEP = 100 metres for fixed source measurements.

All amplitude parameters can be denormalized to MKS units by multiplying by Hp/100 to give units of A/m RMS

6.3 Frequency Pair and Coil Separation Selection

Moving Source Surface Survey:

Given that the 3037.5/112.5 frequency pair gives the widest conductance range, it is recommended as the standard for field surveys. In anomalous areas the 1012.5/112.5 and the 337.5/112.5 data is collected as well. This extra information will be

required for interpretation. The 337.5/112.5 pair is useful as a measure of target conductance. If an applicable 337.5/112.5 response is seen the target is quite conductive.

The general rule is that the maximum depth of exploration is approximately one-half the coil separation used. An experienced operator on a day of low noise in a resistive environment, can detect steeply dipping targets at a depth of burial almost equal to the coil separation.

The maximum useable coil separation is a function of "noise" which, in turn, is a function of transmitter moment, operator care, atmospheric noise, etc.

Note: Measurements taken with only two frequency pairs are sufficient to obtain data at all four frequencies (i.e. 3037.5/112.5 and 1012.5/337.5). In GENIE Mode measurements, the ratio data for the other three frequency pairs can be computed from the amplitude readings after the survey.

Fixed Source Surface Survey:

In fixed source surface surveys it is recommended that measurements be made with the 112.5/37.5, 337.5/37.5, 1012.5/37.5 and 3037.5/37.5 frequency pairs. Station incrementation values are normally 25 metres taken moving away from the loop's near edge. The distance which one can operate away from the loop's edge is primarily a function of the averaging time an operator would tolerate. For normal transmitter loops and currents, averaging times are in the order of 30 seconds at a four loop width distance. The IGS-2/EM-4 Receive Coil should be placed on the ground to minimize motion noise.

Fixed Source Drillhole Survey:

In fixed source drillhole surveys it is recommended that measurements be made with the 112.5/37.5, 337.5/37.5, 1012.5/37.5 and 3037.5/37.5 frequency pairs. Station (depth) incrementation values are normally in the order of 5 metres. The Sonde should not be moved during a measurement.

6.4 GENIE Survey Techniques

6.4.1 Autoranging Feature

In the GENIE Mode, the autoranging capability of the IGS-2/EM-4 Receiver keeps the transmitter and receiver at a separation that you select. Accuracy of separation is very good over neutral ground and relatively flat topography. However, steep topography or the presence of large conductors will shorten the separation. In very steep terrain, the reduction in spacing may become large. This is because the transmitter and receive coils are no longer maximally coupled. To maintain accurate spacing use either flagging or, for small separations, have the receiver operator drag a hip chain.

The transmitter operator takes his correct position. The IGS-2/EM-4 Receiver operator then walks away from the transmitter until he reaches what he believes to be his correct location. At this point both the transmitter and receiver are activated. The IGS-2/EM-4 Receiver operator proceeds to take a reading of the low frequency amplitude (AMPL.1) from the transmitter. If the operator is at the correct location, the instrument gives an AMPL.1 reading equal to 100%. If the indicated value is greater than 100%, then the operator has not yet reached his intended station. If the indicated value is less than 100%, then the operator has probably passed his intended station.

IMPORTANT: Due to the change in signal strength with distance, a new measurement should be initiated by the operator each time he alters the transmitter-receiver separation. This will permit the correct gain factor to be selected. Failure to do so could result in incorrect data.

Atmospheric noise and movement of the receive coil in the natural magnetic field will cause reading fluctuations. Keep the transmitter and receive coils vertical and steady during a measurement. At large separations signal averaging is required to reduce error due to atmospheric noise.

6.4.2 Cut and Flagged Lines

As mentioned in the previous section, flagging or the use of a hip chain is recommended in very steep terrain or when good station accuracy is desired on detailed surveys.

Either operator may lead along a flagged traverse. Both operators switch on their equipment when on station. The appropriate station separation setting may be preselected on the receiver.

6.5 Moving Source Genie Survey Methods

Having decided coil separation and frequency pairs, three situations will normally be encountered:

1. **Normal In-Line:** areas of low to moderate topographic relief.
2. **Steep In-Line:** areas of moderate to high topographic relief.
3. **Broadside:** Transmitter and Receiver coils advance parallel to target.

Distinction with regard to terrain slope is important for the following reason. Assume the TM-2 Transmitter and IGS-2/EM-4 Receiver are held vertically but one is displaced up or down due to the non-zero slope. A problem arises because as the slope increases, the vertical separation of the transmitter and receiver increases and the vertical primary field at the receiver decreases. At a 35 degree slope, the vertical primary field is zero and the IGS-2/EM-4 Receiver in GENIE Mode will not work.

The Broadside technique involves the transmitter and receiver advancing in parallel down adjacent survey lines. This is possible in the GENIE Mode because of the lack of any interconnecting cable.

6.5.1 Normal In-Line Survey (Slingram)

For areas of low relief, the GENIE field procedure is much the same as the traditional HLEM method. Transmitter and receiver advance down a line which runs normal to the geologic strike. Coil separation is fixed. Stations are occupied at a station spacing equal to half of the coil separation used (or one-quarter of same if in an anomalous area).

Where reconnaissance data is required over an unchained line, the autoranging feature may be used. This involves the use of the reference frequency AMPL. 1. This can produce an error relative to the expected separation of up to +2% over conductive overburden or -5% right over steeply dipping targets. Over resistive ground the autoranging feature should be accurate to ±1%.

6.5.2 Steep In-Line Survey

In areas of moderate to high relief, it is recommended that both the transmitter and receiver axes be oriented perpendicular to the average plane of the slope. This ensures that coils are at least roughly coplanar so that primary fields measured at the receiver are maximized and the interpretation is unaffected.

Noise levels should in general be similar to those seen when operating in flat terrain. Movement is much simpler in the GENIE Mode than in the HLEM Mode due to the lack of an interconnecting cable. In the presence of a conductor, the orientation noise may increase as secondary fields are a function of frequency. In such situations, as the receive coil is tipped relative to the coplanar geometry, unwanted secondary fields are measured. In the presence of large conductors, a tilt of 1 degree can produce a GENIE Mode excursion of as much as 0.5%.

In the absence of accurate orientation controls, repeatability may suffer near prominent conductors. The re-occupation of such stations may produce different results without an accurate record of transmitter and receiver coil orientations used.

Note: The above approach for steep terrain does not include the use of tiltmeters to achieve a better level of orientation agreement.

6.5.3 Broadside Survey

Because the GENIE Mode has no interconnecting cables and is largely independent of intercoil geometry, it can be used in a broadside reconnaissance technique. The transmitter and receiver move, in parallel, on adjacent lines, usually up to a 100 metre separation. Measurements are made with the transmitter and receiver at stations with equivalent numbers (latitude) on adjacent lines. The results are plotted against the receiver coil location, but with due notation of the corresponding transmitter location (line).

The rate of reconnaissance coverage of properties may be doubled by the broadside technique, as compared with the in-line (i.e. single line traverse) technique which is traditional with Horizontal Loop systems. This is because the electromagnetic responses observed using the broadside technique may equally reflect conductors located near the receiver or near the transmitter (or both). It is therefore only necessary for the

transmitter to traverse one profile and the receiver to traverse the other profile, rather than both of them traversing each profile. The possible ambiguity of the interpretation of conductor location may be resolved thereafter by running the appropriate short sections of both lines with the in-line technique, and thereby determining the various conductor parameters required, viz, location, dip, depth and conductance, on each line.

6.6 Noise Sources

6.6.1 Electromagnetic Noise

When the IGS-2/EM-4 Receiver is in the reading mode, the one second readings (average values during one second) of the observed parameter will be seen to vary randomly about some constant value. This random fluctuation is due to electromagnetic noise.

During the averaging mode, at each frequency, all electromagnetic parameters are computed from the average value of "n" one second readings of the received signal, where "n" is the displayed duration (DUR) of the average in seconds. The received signal is resolved into two orthogonal components, which are measured. The standard deviation of the "n" one second readings of both of these components are computed at each frequency and normalized by the primary field. As statistically, the standard deviation of these two components should not differ greatly, standard deviation of one component for each frequency is displayed (SD.1, SD.2). However, they are both used in determining whether a reading is to be rejected if the noise spike rejection feature is enabled.

$$SD = \left[\frac{\sum_{i=1}^{n} (Xi - \overline{Xn})^2}{n-1} \right]^{\frac{1}{2}} \times 100\ \%\ \text{Primary Field} \qquad (5)$$

where

Xi = A one second reading of one field component, for the "i"th second, normalized by the primary field.

$\overline{Xn}$ = Average of Xi for an averaging time of "n" seconds.

The SD values can also be expressed as a function of separation, noise, and transmitter moment.

$$SD = \frac{400\ \pi\ Hn\ (SEP)^3}{M}\ \%\ \text{Primary Field} \qquad (6)$$

where

Hn =	Electromagnetic Noise Spectral Density	$Am^{-1}\ Hz^{-\frac{1}{2}}$
SEP =	Transmitter-Receiver Separation (as entered into the EM-4 by operator)	m
M =	TM-2 Transmitter Moment	Am^2

As seen from this formula, the SD value increases rapidly with increasing separation (third power).

The main source of electromagnetic noise is atmospheric noise. Other sources include motion noise (due to coil movement in the Earth's magnetic field) and local power line currents.

Typical SD levels as a function of SEP are shown at different signal frequencies in Figure EM:13.

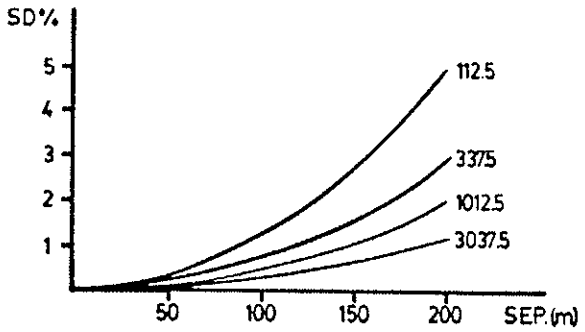

Figure EM:13
SD versus SEP. Data collected during quiet conditions at Timmins, Ontario, Canada, test site, in September, 1985.

For a given frequency and separation, the standard deviation is proportional to atmospheric noise. Standard deviation is a measure of the signal-to-noise ratio and it quantitatively describes the signal quality. Smaller SD values correspond to signals with less noise. An increase in SD values indicate a deterioration of the signal due to local storms (lightning discharges) or gusting winds. Large variations in atmospheric noise are possible, depending upon season, latitude, and local thunderstorm activity.

Measurement Frequency	112.5 Hz	337.5 Hz	1012.5 Hz	3037.5 Hz
SD (No Local Storms)	4.9%	2.9%	2.0%	1.2%
SD (Local Storms)	5.7%	4.6%	4.6%	10.8%

Table EM:3
Example of SD values recorded with a 200 metre separation at Timmins, Ontario, Canada, test site, in September 1985.

From the measured SD values, the standard deviation of the one second readings of any IGS-2/EM-4 parameters can be determined:

$$\text{SD (AMPL.1)} = \text{SD1\%} \quad (7)$$
$$\text{SD (AMPL.2)} = \text{SD2\%} \quad (8)$$
$$\text{SD (\% RATIO)} = (\text{SD1}^2 + \text{SD2}^2)^{\frac{1}{2}} \quad (9)$$
$$\text{SD (IN-PHASE 1)} = \text{SD (QUADR.1)} = \text{SD1\%} \quad (10)$$
$$\text{SD (IN-PHASE 2)} = \text{SD (QUADR.2)} = \text{SD2\%} \quad (11)$$
$$\text{SD (PHASE 1)} = 0.57\ \text{SD1 degrees} \quad (12)$$
$$\text{SD (PHASE 2)} = 0.57\ \text{SD2 degrees} \quad (13)$$

The importance of knowing the SD values is that the SD values determine the standard error of a measurement consisting of a "n" second average of the parameters of interest:

$$\text{ERROR} = \frac{\text{SD}}{(n)^{\frac{1}{2}}} = \frac{\text{SD}}{(\text{DUR})^{\frac{1}{2}}} \quad (14)$$

If one were to keep repeating the measurements while remaining at the same station, 68% of the readings averaged over "n" seconds would be in the limits of ±ERROR around the true value. 95% of the readings would be in the limits of ±2ERROR.

Also, the averaging time required to reduce the measurement error to a desired value can be determined:

$$\text{DUR} = \left[\frac{\text{SD}}{\text{ERROR}}\right]^2 \quad (15)$$

EXAMPLE:

GENIE Measurement

f_1 = 112.5 Hz f_2 = 3037.5 Hz

SEP = 200 m SD1 = 4.9%
DUR = 30 sec SD2 = 1.2%

AMPL.1 = 105%
AMPL.2 = 120% % RATIO = 14.3%

$$\text{ERROR (AMPL.1)} = \frac{\text{SD.1}}{(\text{DUR})^{\frac{1}{2}}} = \frac{4.9}{(30)^{\frac{1}{2}}} = 0.9\%$$

$$\text{ERROR (AMPL.2)} = \frac{\text{SD.1}}{(\text{DUR})^{\frac{1}{2}}} = \frac{1.2}{(30)^{\frac{1}{2}}} = 0.2\%$$

$$\text{ERROR (\%RATIO)} = \frac{(\text{SD.1}^2 + \text{SD.2}^2)^{\frac{1}{2}}}{(\text{DUR})^{\frac{1}{2}}} = \frac{5.04}{(30)^{\frac{1}{2}}} = 0.92\%$$

To determine the averaging time required to reduce ERROR (%RATIO) to 0.5%, the method is as follows:

$$\text{DUR} = \left[\frac{\text{SD}}{\text{ERROR}}\right]^2 = \left[\frac{5.04}{0.5}\right]^2 = 102 \text{ sec} \qquad (16)$$

In theory, the ERROR can be reduced to arbitrarily small values by using a sufficiently large averaging duration. However, a practical limit is quickly reached as SEP is increased, or the required ERROR is reduced, because the necessary DUR becomes excessive:

$$\text{DUR} = \left[\frac{\text{SD}}{\text{ERROR}}\right]^2 \propto \frac{\text{SEP}^6}{\text{ERROR}^2} \qquad (17)$$

Reasonable limits should be set for ERROR and SEP depending upon the noise conditions, in order to prevent the duration of the measurement from becoming unnecessarily long.

During a survey, the operator should regularly observe the SD measurements, as large values or wide variations may indicate problems (i.e. local thunderstorms, motion noise, power line noise, or excessively large separations).

6.6.2 Receive Coil Motion Noise

Receive coil motion noise is most troublesome at low frequencies. When the receive coil is mounted on the backplate, the operator should take care not to move during signal averaging. In windy conditions, or when operating at large transmitter-receiver separations, it is recommended that the receive coil be placed on the ground.

6.6.3 Transmitter-Receiver Coil Orientation

When used with the TM-2 Transmitter, ratio accuracy in the IGS-2/EM-4 Receiver is maintained as long as both transmitting coils remain equidistant from the receive coil. The transmitter operator should therefore position himself so that he faces either direction of the survey line. The equidistance criteria is then satisfied. Small departures from this position become insignificant as the transmitter-receiver separation increases. Table EM:4 below gives the ratio error as a function of separation and angular departure from the ideal transmitter position. This error may be positive or negative depending upon the direction along the line in which the operator faces and in which direction he turns.

Angular Position Error	Separation				
	12.5 m	25 m	50 m	100 m	200 m
0°	0.0%	0.0%	0.0%	0.0%	0.0%
10°	1.3%	0.6%	0.3%	0.2%	0.1%
30°	3.7%	1.8%	0.9%	0.5%	0.2%
90°	7.5%	3.7%	1.8%	0.9%	0.5%

Table EM:4
Ratio Error (%) as a function of separation and angular transmitter position error.

6.7 Noise Attenuation

6.7.1 Power Line Filter

The IGS-2/EM-4 Receiver is equipped with a selectable power line filter. The initialization of the filter is outlined in Section 2.5.3, of this manual. The purpose of the filter is to suppress the first and third harmonics of either 50 Hz or 60 Hz power line frequencies.

6.7.2 Isolation Transformer

When taking HLEM Mode measurements, an isolation transformer is used in-line with the transmitter-receiver interconnecting cable. The purpose of the isolation transformer is to prevent transmitter signal frequencies from coupling into the transmitter-receiver interconnecting cable and offsetting the measurements.

The isolation transformer is also required for fixed source drillhole measurements with phase reference.

The isolation transformer is included as part of the TM-2 HLEM Upgrade Option, available for the TM-2 Transmitter.

6.7.3 Tiltmeter

The optional tiltmeter feature is utilized in order to achieve coplanarity between the transmitter and receive coils. The purpose of which is to improve signal strength in GENIE Mode measurements, or to correct in-phase HLEM Mode data. Use of the tiltmeter option is discussed in Section 2.5.6, of this manual.

6.7.4 Noise Spike Rejection Filter

Atmospheric electromagnetic noise is caused mainly by electrical activity in storms. Distant lightning discharges occurring worldwide generate a steady background noise. Electromagnetic impulses (spikes) due to lightning in nearby storms can cause

deviations in the one second amplitude readings of much greater magnitude than the standard deviation (SD) due to background noise.

When the noise spike rejection algorithm is enabled (see Section 2.5.5), the magnitudes of the difference between each one second reading of signal components, at both frequencies, and their running averages are computed. If any one of these four magnitudes is greater than,

$$4SD + 0.03\ AMPL. \qquad (18)$$

where:

SD = Standard Deviation
AMPL. = Computed Normalized Amplitude value for frequency 1 or 2.

then the one second reading of both signal components, at both frequencies, is rejected.

The addition of the term 0.03 AMPL. to the rejection criteria is needed to prevent rejection of the readings due to changes in receiver or transmitter coil orientation when the SD values are close to zero, as they may be at short separations.

Any rejected reading is excluded from the computation of running averages for all measurement parameters, and the averaging duration (DUR) time is not incremented until the next reading is accepted. The total number of rejected readings is displayed and recorded as # REJECTED, at the completion of a measurement.

No readings are rejected during the first ten seconds of averaging. This is because a reasonable estimate of the SD value must be established before any rejection criteria can be applied. The occurrence of a large noise spike during the first ten seconds of averaging will increase the SD value considerably and prevent the rejection of subsequent noise spikes. It is therefore suggested that the operator monitor the SD.2 value which is usually more affected by the lightning discharges. If a large SD.2 value is observed during the first ten seconds of averaging, it is suggested that the measurement be aborted and restarted.

6.8 Operational Hints

Observe the following hints to obtain consistent readings:

1. Keep the receive coil steady during a measurement. At large separations where the received signal may be weak, place the receive coil on the ground.

2. Receive coil motion noise may be caused by mechanical coil vibration. Do not tap the coil during a measurement.

3. Do not wear an electrical analog watch while operating the IGS-2/EM-4 Receiver. The small motor inside the watch creates enough electromagnetic disturbance to increase measurement error.

4. When the transmitter and receiver are at different elevations the GENIE ratio values need no correction. However, because of this positioning, the signal strength is zero on a slope equal to 35°.

5. To maximize the signal at the receiver for accurate measurements, in the absence of a tiltmeter, follow this procedure while in the reading mode:

   a) Have the transmitter operator incline the transmitter forward until AMPL. 1 reaches a maximum. When it is reached, tell the transmitter operator to hold that position.

   b) Next, tilt the receive coil away from the vertical until a maximum AMPL. 1 is measured.

   c) No corrections are required and only small inaccuracies are introduced with this procedure.

6. When using the transmitter-receiver interconnecting cable at large separation distances, stray coupling effects are a potential problem. Electric fields near the transmitter induce a AC voltage into the cable with respect to ground which causes a small current to flow through the cable. The magnetic field associated with this current is normally negligible. However, at large transmitter-receiver separations some measurement error may be detected at 3037.5 Hz if the transmitter-receiver interconnecting cable is near the receive coil. To minimize this effect, keep the cable away from the receive coil and do not coil excess cable at the receiver end.

6.9 Operator Intercommunication

When operating in the HLEM Mode the intercom is used to provide communication between transmitter and receiver operators. The intercom system can be used when the TM-2 Transmitter and the IGS-2/EM-4 Receiver are connected via the isolation transformer and the transmitter-receiver interconnecting cable.

When the TM-2 Transmitter and the IGS-2/EM-4 Receiver are both turned off (i.e. measurement not in progress), either operator can talk to the other by pressing the "Push To Talk" button and speaking into his microphone/speaker.

When the TM-2 Transmitter and the IGS-2/EM-4 Receiver are both turned on (i.e. measurement in progress), the intercom is disabled.

After the IGS-2/EM-4 Receiver operator has terminated his measurement, he can signal the TM-2 Transmitter operator by pressing the "Push To Talk" button. The TM-2 operator will then hear a beeping signal from his tiltmeter/intercom module. The operator then turns off the TM-2 Transmitter and two-way voice communication can resume.

For all other cases, a relatively low power transceiver set or a good walkie-talkie will be adequate. Very High Frequency (VHF) FM Sets are preferable because of their short antenna length and therefore more convenient handling. The receiver operator should refrain from transmitting with his set while taking measurements to avoid possible interference with the receiver.

When using transceiver sets, check with your local Communications Authority about licensing requirements.

6.10 Outputting Data

Complete information regarding the outputting of data is presented in the "IGS-2 Operation Manual", in Section 4.10, entitled "Outputting Data".

7.0 TROUBLESHOOTING

Problem	Cause	Solution
No Reference (GENIE-INT. Ref.)	1) Transmitter off or malfunctioning.	Check transmitter.
	2) Receive coil or sonde not connected.	Check connections.
	3) Frequency pair incorrectly selected.	Check EM set-up menu.
	4) Poor signal-to-noise due to excessive Tx-Rx separation and/or high levels of EM noise.	Reduce separation, ensure no motion noise, wait until atmospheric noise levels improve and move away from power lines.
	5) Broken sensor cable.	Check cable continuity and/or replace cable.
	6) Defective receive coil or sonde.	Repair/replace receive coil or sonde.
No Reference (GENIE-Ext. of or HLEM)	1) Transmitter off or malfunctioning.	Check Transmitter.
	2) Phase reference cable not connected or broken.	Check cable continuity and/or replace cable.
	3) Isolation transformer not installed or broken.	Check isolation transformer.
	4) EM-4 circuit boards not installed in EM-4 Expansion Module.	Check circuit board installation.
	5) HLEM electronics not installed in the TM-2 Transmitter.	Check circuit board installation.

Problem	Cause	Solution
Overload AC and Overload DC	1) Signal levels increased after receiver set gain, because:	
	a) Transmitter turned on after IGS-2/EM-4 set gain.	Check transmitter and restart measurement.
	b) Tx-Rx separation reduced after gain was set.	Maintain Tx-Rx separation when taking a measurement.
	c) Receive coil connected after gain was set.	Connect receive coil and restart measurement.
	d) Receive coil orientation was changed after gain was set.	Maintain receive coil orientation when taking a measurment.
	e) EM noise increased after gain was set.	Restart measurement.
	f) Separation less than 6.25 metres.	Increase separation and restart measurement.
	2) Failure of gain setting algorithm.	Restart measurement.

8.0 SPECIFICATIONS

Receive Coil Assembly	Air-cored coil, packaged in protective case, 25 cm in diameter. Can be backplate mounted or set on the ground.
GENIE Frequency Pairs	Nine pairs keyboard selected from the following frequencies: 37.5, 112.5, 337.5, 1012.5 and 3037.5 Hz. The 3037.5/1012.5 pair is not available.
HLEM Frequency Pairs	Any pair may be selected for simultaneous measurement from the following four frequencies: 112.5, 337.5, 1012.5 and 3037.5 Hz, except for the 3037.5/1012.5 pair.
Separation Selection	Keyboard selectable between 6.25 and 300 m with two decimal place resolution.
Power Line Filtering	Keyboard selectable at 60 or 50 Hz and third harmonic.
Signal Averaging Time	1.0 second sample interval. As many as 2^{16} samples can be stacked to improve measurement accuracy.
Resolution of Amplitude Measurements	0.01%
Resolution of Phase Measurement	0.1%
Reading Resolution	0.1% for both GENIE amplitude ratio and in-phase and quadrature Horizontal Loop components.
Power Requirement	The EM-4 Sensor Option draws an additional 0.15 A from +12 V

	supplied via the IGS-2 during measurement.
Memory Requirements	340 measurements can be stored per each 16K RAM of IGS-2 internal solid-state memory for either GENIE or Horizontal Loop Mode.
EM-4 Expansion Module	For Horizontal Loop measurements or when VLF is also required. EM-4 Expansion Module: 240 x 50 x 230 mm, 1.2 kg.
Transmitter-Receiver Interconnecting Cables	For Horizontal Loop measurements, made to order in any length up to 300 m. Cable weights are: 100 m, 3.0 kg; 200 m, 5.9 kg; 300 m, 8.8 kg.

9.0 EM-4 PARTS LIST

PART	PART NUMBER
EM-4 GENIE/HLEM Sensor Option	785 010
IGS-2/EM-4 Operation Manual	785 700
IGS-2/EM-4 GENIE Interpretation Manual	785 701
Carrying Case	785 024
Accessories	
EM-4 GENIE/HLEM Expansion Module	785 012
Backplate Assembly	785 022
Long Interconnecting Cable	785 071
Short Interconnecting Cable	783 520
Memory Expansion EPROM	481 203
Spare Parts Kit	785 023

10.0 WARRANTY AND REPAIR

All Scintrex equipment, with the exception of consumable items, is warranted against defects in materials and workmanship for a period of one year from the date of shipment from our plant. Should any defects become evident under normal use during this warranty period, Scintrex will make the necessary repairs free of charge.

This warranty does not cover damage due to misuse or accident and may be voided if the instrument consoles are opened or tampered with by persons not authorized by Scintrex Limited.

To validate the warranty, the warranty card supplied with the instrument must be returned to Scintrex within 30 days of shipment from our plant.

Instruments shipped for repair from outside Canada should be addressed to Scintrex Limited, care of: Murray and Robinson, Customs Brokers, Lester B. Pearson International Airport, Canada. Since Scintrex instruments are manufactured in Canada there is no customer delay or duty payable in Canada. It is advisable to state on customs documents "Canadian Goods Returned to Canada for Repair". Shipments should be made by air. Within Canada, ship by air directly to Scintrex Limited, 222 Snidercroft Road, Concord, Ontario, Canada, L4K 1B5. No instrument will be accepted for repair unless it is shipped prepaid. After repair it will be returned collect.

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