



SIR[®] 4000 Manual

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MN72-574 Rev B

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FCC Class B Compliance

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) the device may not cause harmful interference, and (2) this device must accept any interference received including interference that may cause undesired operation.

This Class B digital apparatus complies with Canadian ICES-003

Contains FCC ID: VRA-SG9011089E

Warning: Changes or modifications to this unit not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

Note: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment or residential installation. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the introduction manual, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation.

Shielded cables must be used with this unit to ensure compliance with the Class B FCC limits.

Canadian Emissions Requirements

This Class B digital apparatus complies with Canadian ICES-003.

Cet appareil numérique de la classe B est conforme à la norme NMB-003 du Canada.

Notice

Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Table Of Contents

Chapter 1: Introduction	1
1.1: Unpacking Your System	1
1.2: General Description	1
1.3 Cautions and Warnings	7
Chapter 2: Getting Started and Expert Mode Setup	9
2.1: Hardware Setup	9
2.2: Introduction Screen	11
2.3: Setup Collect/Playback Screen	20
2.4: The Toolbar	42
Chapter 3: Setting Up Your SIR 4000 for 2D Data Collection and Playback in Expert Mode	62
3.1: Setting Up Distance Mode Data Collection	62
3.2: Setup for Single Line 3D Collection in Expert Mode	67
3.3: Setting Up for Time Mode Data Collection	68
3.4: Setting Up for Point Mode Data Collection	73
3.5: Playing Back Collected Data	77
Chapter 4: Data Transfer and File Maintenance	78
4.1: Transfer to a PC via a USB Memory Stick	78
4.2: Deleting Data from the System	78
Chapter 5: Using a GPS with your SIR 4000	80
5.1: Attaching a GPS	80
5.2: Understanding GPS	81
5.3 What is WAAS?	82
5.4 What is NMEA?	82
Appendix A: SIR 4000 System Specifications	84
A.1: System Hardware	84
A.2: Data Acquisition and Software	85
A.3: System Includes	85
Appendix B: The How-To's of Field Survey	86
B.1: Site Selection	86
B.2: Targets	87
B.3: Data Collection Methods: 2D vs. 3D	89
Appendix C: Dielectric Values For Common Materials	92
Appendix D: Listing of Antenna Parameters	94
D.1: Preloaded Setups	94
D.2: Parameter Listing for Older/Specialty Antennae	97
Appendix E: Glossary of Terms and Suggestions for Further Reading	102

Chapter 1: Introduction

This manual is designed for both the novice and experienced user of ground penetrating radar. It is intended as both a reference and a teaching tool and it is recommended that you read the entire manual, regardless of your level of GPR experience. For information about GPR theory, please see the list of general geophysics references that can be found in Appendix F.

If you experience operation problems with your system, GSSI Technical Support can be reached Monday-Friday, 8:30 am - 5 pm EST, at 1-800-524-3011, or at (603) 893-1109 (International).

1.1: Unpacking Your System

Thank you for purchasing a GSSI SIR® 4000 (hereafter referred to as SIR 4000). A packing list is included with your shipment that identifies all of the items included in your order. You should check your shipment against the packing list upon receipt of your shipment. If you find an item is missing or was damaged during the shipment, please call or fax your sales representative to immediately report the problem.

Your SIR 4000 system contains the following items:

- 1- Digital Control Unit (DC-4000) with preloaded operating system
- 1 - Transit Case
- 2 - Batteries
- 1 - Charger
- 1 - Sunshade
- 1 - Operation Manual
- 1 - GSSI Manual CD
- 1 - USB Drive
- 1 - Universal Mounting Bracket

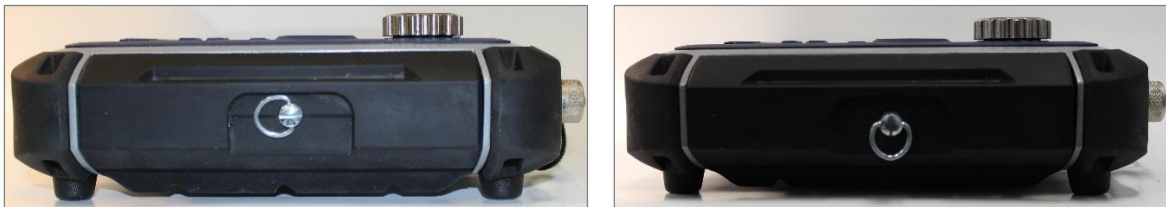
Your choice of antenna, cables, and post-processing software is available for an additional purchase.

1.2: General Description

The SIR 4000 is a lightweight, portable, ground penetrating radar system that is ideal for a wide variety of applications and designed to operate GSSI single digital antennas, single analog antennas, or dual frequency antennas. The system will not support operating both a digital and analog antenna at the same time. The various components of the SIR 4000 are described below.

The major features of the control unit are the keypad, control knob, 10.4 inch LED display with 1024 by 768 pixel resolution, connector panels (HDMI Video Out, USB 2.0, Ethernet, Serial Port I/O, digital and analog antenna connectors, power, GPIO Connector, micro-USB), battery slot, and indicator lights. The display screen allows you to view data in real time or in Playback mode. It is readable in bright sunlight, although a sunshade for the unit is available. Prolonged exposure to direct sunlight will cause the screen to heat up and may affect screen visibility.

There are two latching panels on the sides of the unit that contain the battery slot, Micro-USB port, and Ethernet port. To open the panels, rotate the locking pin until it is loose. To close the panel press it firmly, push the locking pin in, and rotate the pin until it tightens. See the figure below for further detail.



Left: Side panel when closed and locked. Right: Side panel when closed and unlocked.

The battery slot on the left side of the unit accepts the 10.8 V Lithium-Ion rechargeable battery provided. Survey time with a fully charged battery is approximately two and a half (2.5) hours. Batteries are recharged with the included battery charger or by simply leaving the battery in the unit and connecting the unit to a standard AC source using the optional AC adapter. Time to recharge a battery is approximately one and half to two (1.5-2) hours. Be sure to keep the right and left side panel covers on the unit closed and secured while in use to ensure that no dust or dirt enters the unit's interior.

Compatibility

The SIR 4000 is not compatible with the following GSSI software or systems.

StructureScan: When using either the black pad or the optical reader.

Terravision:

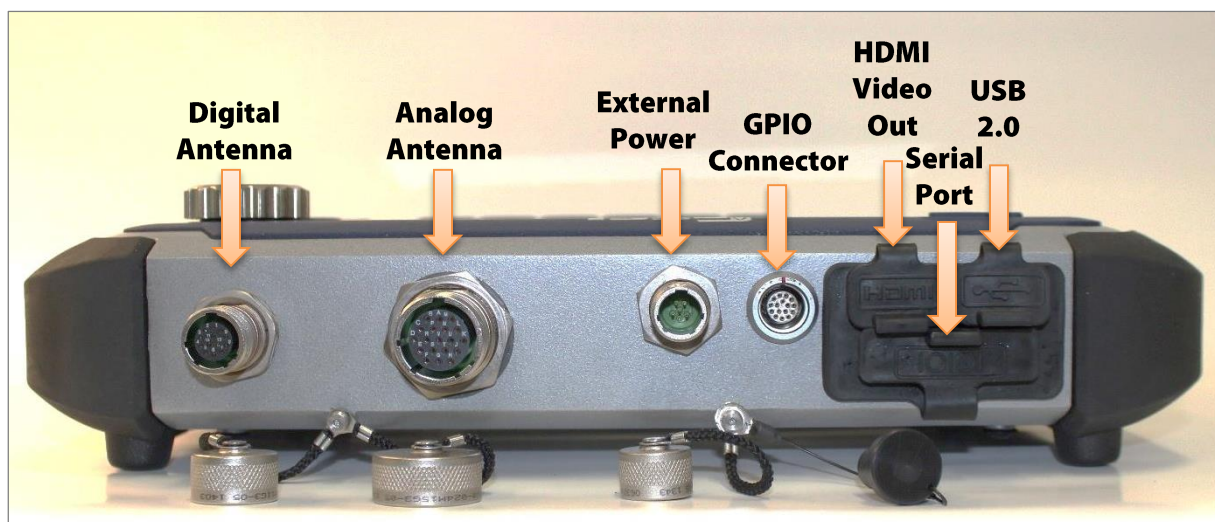
- Y Gain Equalization is not currently implemented in RADAN 7
- RADAN 7 will not properly import GPS for Terravision but will read Terravision files that have been opened in RADAN 6.

RADAN 5 or 6: Data collected with a SIR 4000 is also not compatible with RADAN 5 or 6. You will need RADAN 7 in order to view and process data collected with this system.

Orange Control Cables: The SIR 4000 will not work with the short, orange attenuated control cable that was sold with the SIR 2000. The SIR 4000 will only work with non-attenuated cables (blue or black in color).

Hardware Connections - Top

The SIR 4000 has seven connectors located on the top of the unit. Facing the unit from left to right the connectors are: 13 pin Digital Antenna Connection, 19 pin Analog Antenna Connection, External Power, GPIO Connector, HDMI Video Out, Serial Port, and USB 2.0.



Digital Antenna Connector: The protruding 13-pin connector at the back of the system is for a GSSI digital antenna control cable. You will notice the antenna connection on the SIR 4000 has five notches cut from the metal. These mate with the five raised nubs on the control cable to ensure that the pins line up properly.

- Screw the cable connector collar onto the SIR 4000 to make proper contact. The cable should only be *hand-tightened*. *Do not use a wrench* to tighten the connection as over-tightening will result in damage. The cable connector collar should be screwed down far enough to cover the red line on the SIR 4000 connector.
- The only proper time to attach or detach an antenna is with system power off. Be sure to unplug any external power and to remove the battery before attaching or detaching antennas.

Analog Antenna Connector: The large, protruding 19-pin connector at the back of the system is for the GSSI analog antenna control cable. You will notice the antenna connection on the SIR 4000 has five notches cut from the metal. These mate with the five raised nubs on the control cable to ensure that the pins line up properly.

- Screw the cable connector collar onto the SIR 4000 to make proper contact. The cable should only be *hand-tightened*. *Do not use a wrench* to tighten the connection as over-tightening will result in damage. The cable connector collar should be screwed down far enough to cover the red line on the SIR 4000 connector.
- The only proper time to attach or detach an antenna is with system power off. Be sure to unplug any external power and to remove the battery before attaching or detaching antennas.

External Power Adapter: Plug in the optional AC power adaptor to run the system from 110-240 V, 47-63 Hz power.

GPIO Connector: This is a General Purpose Input/Output connector. It will run a range of future accessories and peripherals available from GSSI. Output signals include power and GPS among others.

HDMI Video Out: This will allow you to duplicate the screen on the SIR 4000 when connected to an external monitor or projector.

Serial I/O (RS232): This is a standard serial connection that can be used to establish communication between the SIR 4000 and a GPS as well as supply power. Please see Chapter 5: Using a GPS with your SIR 4000 for additional information.

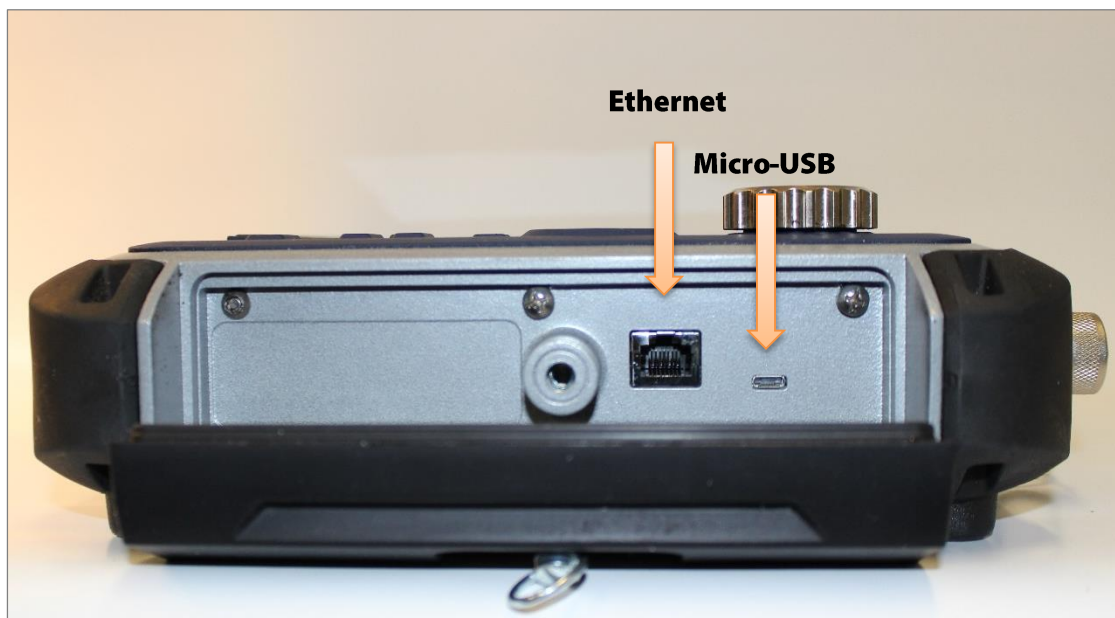
USB 2.0: This port is for connection to a variety of USB peripherals, including a mouse, keyboard, or memory device.

- The internal memory capacity is approximately 32 gigabytes. Please see Chapter 4: Data Transfer and File Maintenance for additional information on transfer.

Hardware Connections – Right Side

Micro-USB: The Micro-USB is used to connect an external USB memory device for data transfer.

Ethernet: The Ethernet connection is reserved for future functionality.



Hardware Connections – Left Side

Battery Slot: The battery slot features a release arm, or latch, to secure the battery when one is inserted. The slot has an eject spring to eject the battery when the latch is released.



Keypad

A built-in keypad, as well as the control knob, will control the SIR 4000. The keypad has sixteen (16) buttons, two (2) indicator lights, and a control knob. All of the keypad button functions will have alternative keyboard implementation, except the Power Button.



Power Button: This button turns the SIR 4000 on and off. To start up the system, insert a battery or connect the optional AC power adapter and push the power button.

To turn the system off press and hold the power button for approximately four (4) seconds until the screen turns black. Should a fault occur it may require ten (10) seconds for the system to respond.

Power Status LED: When the system is turned on the indicator light will flash red. When the system is ready the LED will remain a solid red.

Control Knob: This knob is used to cycle through the menu tree, quickly change numeric values, and make selections.

- Turning the knob clockwise moves down through a menu or numeric values. Turning the knob counter-clockwise moves up through a menu or numeric values.
- Pressing the knob either toggles between On/Off options or enables a secondary menu. After modifying the secondary option a second press of the knob locks-in the selection.

Directional Keypad: This grouping of five buttons is located right below the wheel. The Enter button is in the center. These buttons allow you to navigate through the menu tree and make selections.

- Move through the menus by pressing the Up or Down buttons.
- Pressing the Enter button either toggles between On/Off options or enables a secondary menu.
- Modify the menu setting by using either the Up, Down, Left, or Right buttons.
- After modifying the secondary option a second press of the Enter button locks-in the selection.

Back Button: Returns to the main screen from whichever menu is currently selected or open.

Start Button: Begin data collection.

- Short press begins data collection.
- Long press during data collection ends collection of the current file and immediately opens a new one or prompts you to save or discard the current file. The short press is disabled during data collection.

Stop Button: End data collection or playback.

- Short press stops data collection.
- Long press ends data collection or playback and return to the Main menu.

Marker Input Button: This button is located below the Stop button. Pressing this button while collecting or playing back data will place a User mark in the data. User marks are used in post-processing to evenly distribute the number of scans collected in Time Mode between two known points, or marks.

- User marks are helpful for noting distance traveled if you are not using a survey wheel and for noting the location of objects or obstacles such as columns, trees, pits, etc.
- User marks will appear as long, dashed, vertical red lines through the data window.
- Add user marks by pressing either the Marker Input button on the SIR 4000 keypad or by pressing the marker button on whichever cart or handle is connected to the system.

Software Control Buttons: Six (6) buttons are located below the display screen and change function depending upon the current mode in use on the SIR 4000. For a list of each function see Chapter 2: Getting Started and Expert Mode Setup.

1.3 Cautions and Warnings

- 1 The Display Screen:** Do not use alcohol to clean the display screen as this may damage the rubber gasket around the screen and impact the IP rating. GSSI recommends using warm water or Windex (or another ammonia-based) cleaner. There is not an anti-glare coating on this screen as there was with the acrylic SIR 3000 screen protector. The screen is protected by a non-removable chemically hardened glass.
- 2 Power off before connection/disconnecting an antenna:** GSSI recommends turning off the SIR 4000 before connecting or disconnecting an antenna. Failure to remove power may cause damage to the SIR 4000.
- 3 Weatherproofing:** When all of the doors are closed and connections are correctly made the SIR 4000 is IP65 rated. However, if it does get wet internally, immediately power down the system, open all of the doors and connections, and leave it for a minimum of 12 hours in a warm dry place. The SIR 4000 is factory sealed and no attempt should be made to open it.
- 4 USB Ports:** Do not plug two USB drives into the SIR 4000 at the same time. This includes the USB 2.0 Port and the Micro USM Port. You can have a USB device, such as a keyboard or mouse, plugged in at the same time as USB drive.

Unlike the SIR 3000, the USB ports must not be used to connect the SIR 4000 directly to a computer. This does not provide any additional functionality.

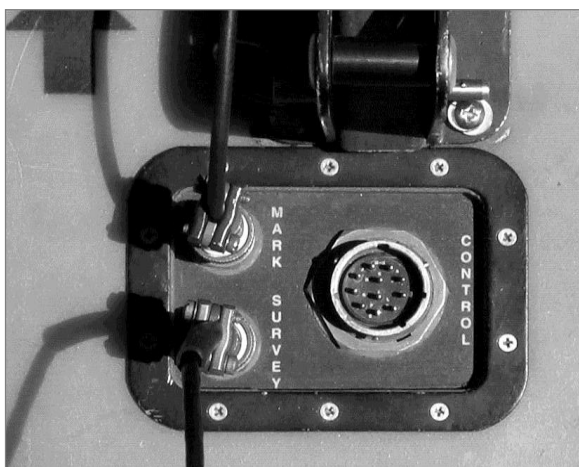
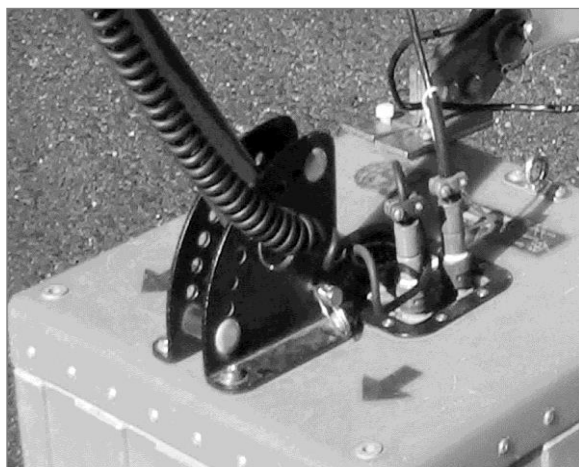
Chapter 2: Getting Started and Expert Mode Setup

In Chapter 2, you will find instructions for connecting all of the hardware inputs and an introduction to the different menus and functions that are available to you in Expert Mode. Expert Mode allows total control over all collection parameters and is the most versatile data collection method, usable for all GPR applications. If desired, 2D profiles can later be transferred to a PC for processing in GSSI's RADAN post-processing software.

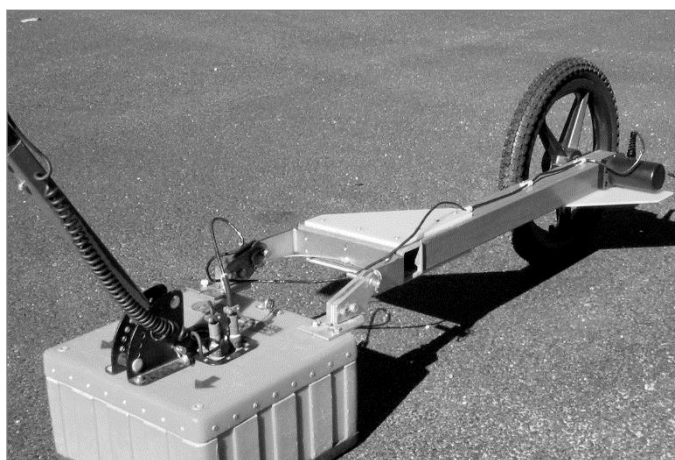
2.1: Hardware Setup

Hardware setup for the SIR 4000 is very simple. We will use the 400 MHz (Model 50400S) antenna with single survey wheel for this example. Follow the steps below.

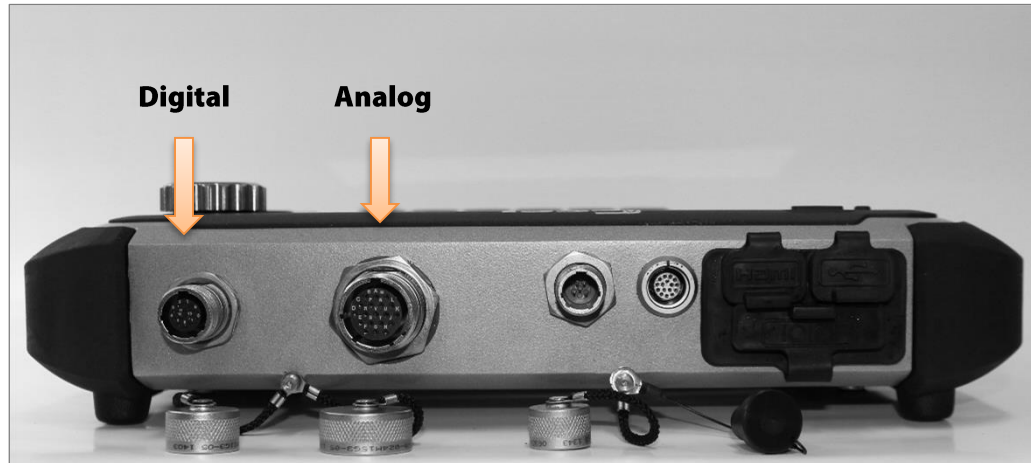
- 1 Single Survey Wheel Encoder:** Attach the survey handle between the two vertical mounting plates on the top of the antenna with the two removable pins, adjust the angle for comfort, and connect the marker cable from the handle to the antenna at the MARK port.



- 2 For Use with the Single Survey Wheel Encoder:** Attach the survey wheel to the brackets at the back of the antenna (as shown below) and connect the cable from the survey wheel to the SURVEY port on the top of the antenna. Be sure that the triangular plate protecting the survey wheel encoder faces down.



- 3 Analog Antennas:** Connect the female end of the antenna control cable to the antenna. Then connect the male end to the 19 pin analog antenna connection on the back of the SIR 4000. Connect the two protective caps together.
- 4 Digital Antennas:** Connect the female end of the antenna cable to the antenna. Then connect the male end to the 13 pin digital antenna connection on the back of the SIR 4000. Connect the two protective caps together.

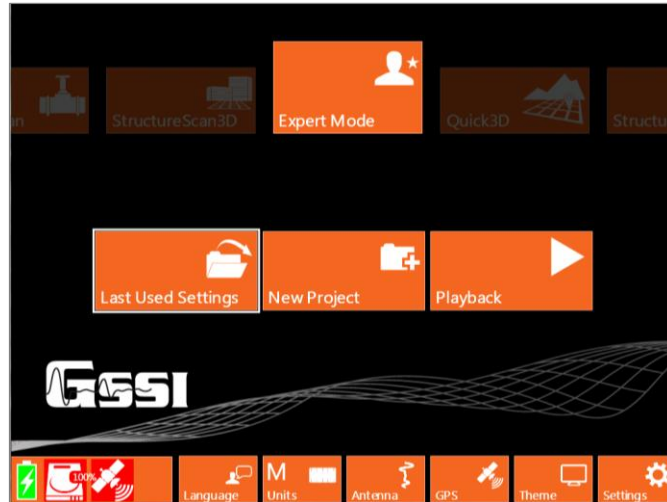


- 5** Connect power source (battery or optional AC power adapter) to the SIR 4000 and push the power button to turn on the system.
- 6** Existing carts may require mounting hardware to attach to the SIR 4000 universal mounting bracket included with SIR 4000.

Note: If you purchased a SIR® 4000 with a cart as in the UtilityScan System, or purchased the cart system separately, please see Appendix C: Mounting Your SIR® 4000 on a Cart. The cart also incorporates a survey wheel that is used in place of the survey wheel pictured here. For a StructureScan Standard system, please consult the hardware setup instructions in the small, laminated Quick Start Guide that came with the system.

2.2: Introduction Screen

After the SIR 4000 boots up and goes past the splash screen, you will see the Introduction screen. This screen allows you to select from the following options and modes. It also includes a toolbar at the bottom and status information.



Modes

The following modes have different options available in the subsequent Setup display based upon application and whether 2D or 3D data is being collected. Applications that are in development will be greyed out in the Introduction screen.

Expert Mode

With Expert Mode the user has complete control over all 2D data collection parameters. All parameters in this mode is customizable, whereas in an application specific mode some options are limited based on what is necessary and customary for successful data collection.

Quick 3D (tba)

In Quick 3D Mode the user has all of the same controls from Expert Mode with additional functionality to aid in 3D data collection.

StructureScan 2D (tba)

StructureScan 2D provides quick options for locating shallow structural features in concrete and marking their location directly on the survey surface. The mode is preconfigured for use with high frequency (high resolution) antennas.

UtilityScan (tba)

Similar to StructureScan 2D, UtilityScan provides quick 2D options for locating burial utilities in soils.

StructureScan3D (tba)

This mode is for collecting very high resolution 3D data over concrete. The data can be viewed in a 3D cube to identify targets at different depths to help note clear locations for cutting or coring.

Last Used Settings, New Project, and Playback

These options allow you to either collect or playback data starting from different points.

Last Used Settings

Starts the system in the last used application mode and project. These may be inappropriate settings if the antenna was changed.

New Project

Opens a new project in whichever application mode is currently selected and requires you to create a new Project Name.

Playback

Starts the system in the currently selected mode and prompts you to select a file or multiple files for playback from the last project selected.

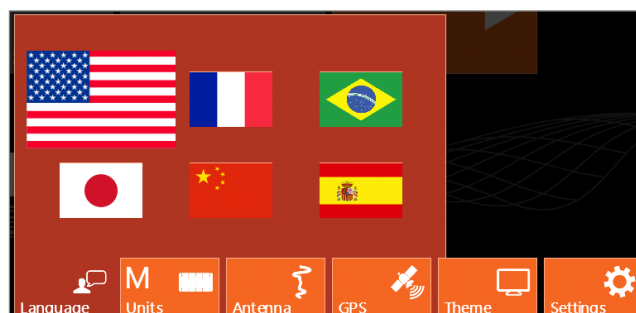
Toolbar

The bottom toolbar provides access to change system settings and universal setup options. Selecting any of the Software Control buttons, located immediately under each icon, will open and close each window.



Language

There are six (6) language options on the SIR 4000 including English, Japanese, French, Chinese, Portuguese, and Spanish. Use the Control Knob or the Arrow keys to move through the different languages. Once a language is selected using either the Control Knob or the Enter button the menu will automatically close. You can also back out of the menu by pressing the Back button.



Units

Select between Metric and English Units of measure. Once a unit of measure is selected using either the Control Knob or the Enter button the menu will automatically close. You can also back out of the menu by pressing the Back button.

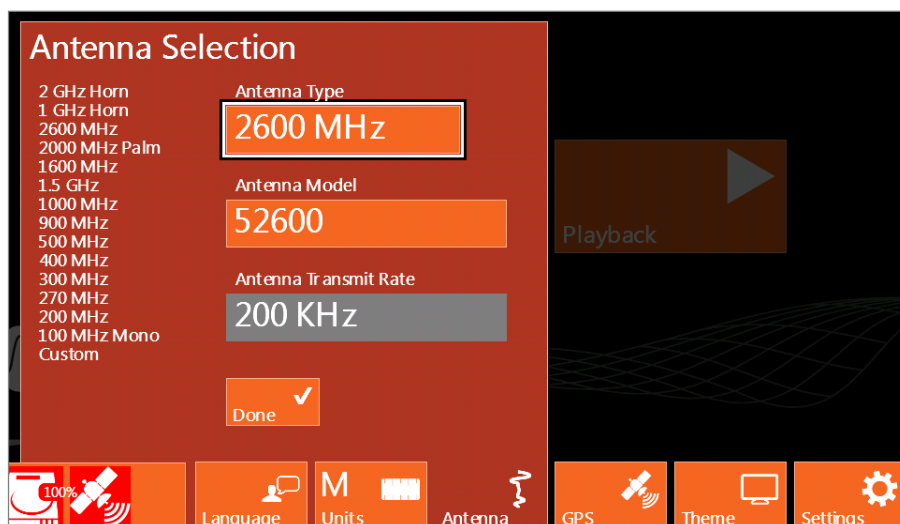


Antenna

This menu is available if you are using an older analog antenna without “Smart ID.” If a digital or “Smart ID” antenna is connected the system will auto detect the antenna and display the appropriate Antenna Model on the Antenna button and access to the menu will be disabled. This menu is also disabled when no antenna is connected.



If an older analog antenna is connected to the SIR 4000 you will be able to select from a list of antenna frequencies.



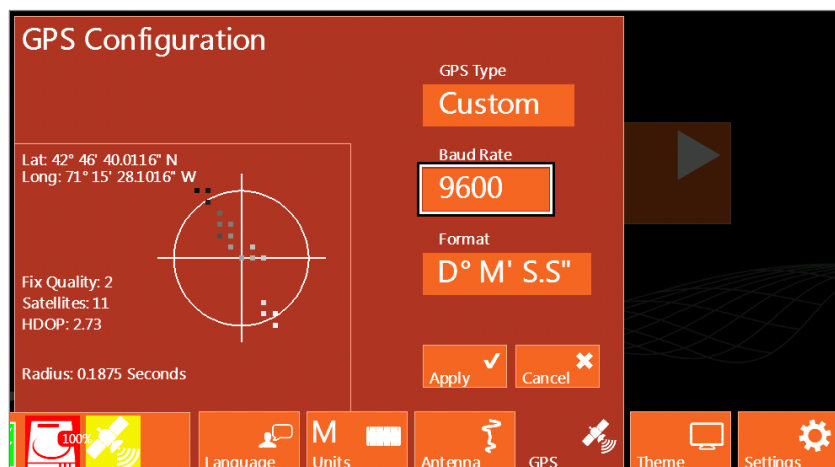
Antenna Type: Choose an antenna frequency from the list of available frequencies.

Antenna Model: If multiple models of the chosen Antenna Type are available, you can select which model of antenna is connected.

Antenna Transmit Rate: The antenna transmit rate is in KHz, with a Custom rate capped at 100 KHz. You can modify the antenna transmit rate if Antenna Type is set to Custom. A higher transmit rate enables faster data collection or more stacking to reduce random noise. Some older antennas are not capable of transmitting at high speeds and setting them at a high transmit rate may cause an error. Consult your antenna documentation or call GSSI Tech Support if you have any question about transmit rate. All GSSI 5100 and 52000 series antennas (2.6 GHz, 2.0 GHz Palm, 1.6 GHz, 1.5 GHz, 1.0 GHz, 400 MHz, 270 MHz, 200 MHz) can be operated at 100-200 KHz. Rates are limited per regulations of the region where the unit is operated. If you are using another GSSI antenna, consult Appendix E for the proper transmit rate.

GPS

Allows you to configure your SIR 4000 to collect GPS points during data collection. Make the following selections to enable GPS collection.



GPS Type: None is set when a GPS is not connected. Custom should be selected if a GPS is connected and needs to be configured.

Baud Rate: Match the baud rate with the one you are using on your GPS. Available baud rates range from 4800 up to 230400.

Format: Select which format to use when displaying point, Degrees Minutes Seconds, Degrees Minutes Decimal Minutes, and Decimal Degrees.

Lat/Long: Displays the current position in whichever format is currently selected.

Fix Quality: Shows whether or not a GPS or DGPS signal is recording.

Satellites: Displays the number of satellites that are currently in view of the GPS. These satellites are displayed on the plot in the middle of the GPS Configuration window.

HDOP: The Horizontal Dilution of Precision is the relative accuracy of the horizontal position. The system needs an HDOP of 2 or less in order to collect data.

Radius: This indicates the size of the Circular Error Probability which appears in the center of the GPS window as a bull's eye. This is the radius of a circle, which centers on the mean of the GPS accuracy in seconds.

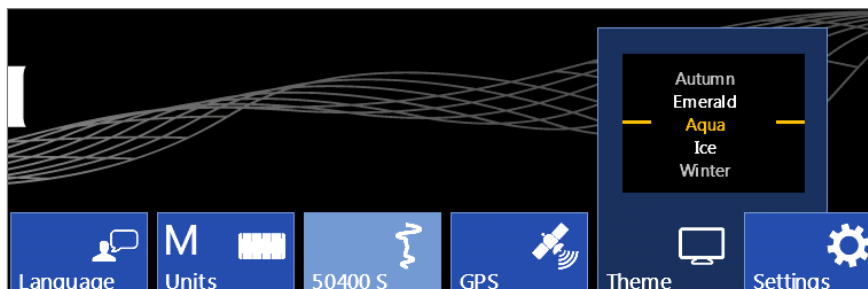
Steps to setup the SIR 4000 to match GPS Settings:

- 1** The external GPS needs to be pre-configured to operate with the allowable capabilities of the SIR 4000.
- 2** Connect your GPS to the SIR 4000 through the Serial Port.
- 3** Turn on your GPS.
- 4** Select Custom from GPS Type.
- 5** Select the Baud Rate that matches the one set on your GPS.
- 6** Press the green Start button on the right side of the SIR 4000.
- 7** Wait for the GPS to acquire enough satellites and accuracy so that the HDOP is 2 or less.
- 8** Select Apply to save the GPS configuration and exit the menu.

Theme

Select from preformatted color themes for the display on your SIR 4000. Once a theme is selected it will carry through to any of the modules and become the default for the next time you turn the system on. Scroll through the

different theme options using either the Control Knob or the Up and Down Arrows. Select a Theme by pushing the Control Knob or the Enter key.



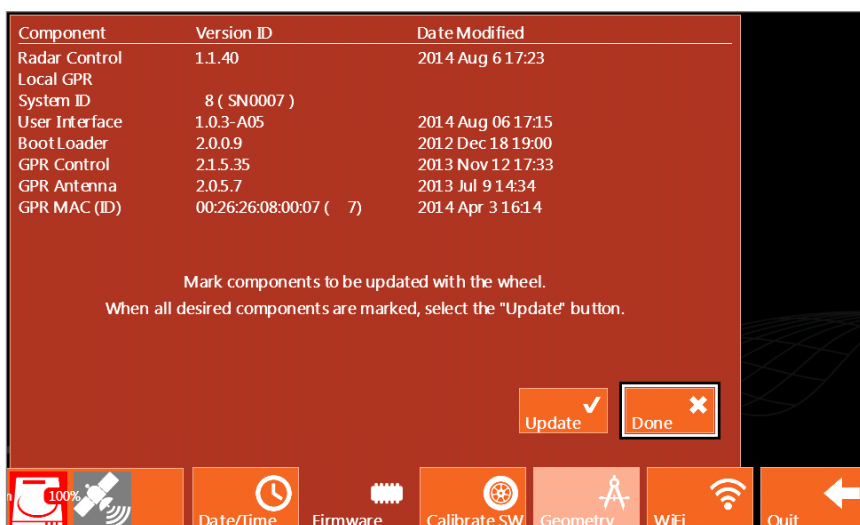
Settings

This button opens additional calibration and configuration options. The functions of the Software Control buttons change to include the following:



Date/Time: Modify the current Date and Time on the system. Use the Control Knob to select and modify the fields. Select Apply using either the Control Knob or Arrow keys to accept any changes.

Firmware: View the current software and firmware installed on the SIR 4000. You can also update the software and firmware from this menu by selecting Update.



Software Update

- 1 Download the latest version of software from the GSSI support website.
<https://support.geophysical.com>.

- 2 Save the downloaded files to the GSSI 2GB USB drive supplied with your SIR 4000.

- 3 Plug the USB drive into your SIR 4000.

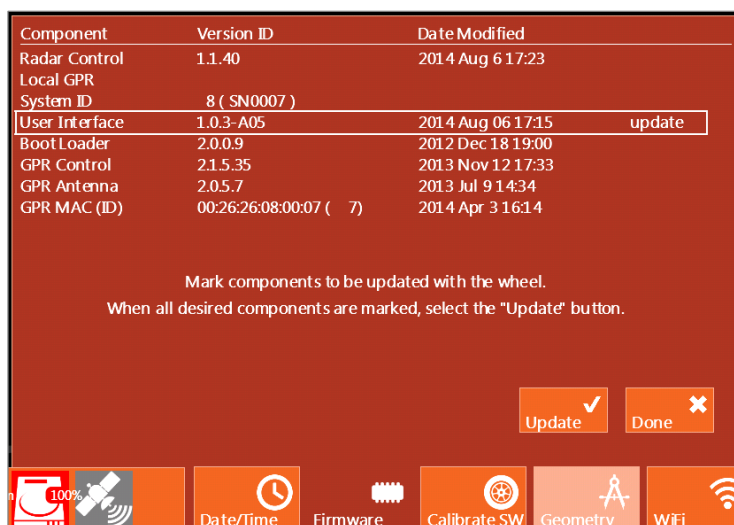
- 4 Open the Firmware menu from the Settings Screen.

- 5 Use the Control Knob or the arrow keys to navigate through the list of Components.

- 6 Select the User Interface Component by pushing the Control Knob or the Enter key.

- 7 Once it reads Update next to the User Interface Component select Update at the bottom of the window.

Note: GSSI recommends using the provided USB as not all USB drives are formatted the same and some may interfere with the system's ability to do automatic updates.



- 8 This will launch the SIR 4000 UI Updater. This window shows the current version of the software, the version it's being updated to, and a list of any major changes between the two versions.

- 9 Press the green Start button on the right side of the SIR 4000 to begin the software update.

- 10 Once the update is complete the SIR 4000 UI Updater will automatically close.



Firmware Update

- 1 Repeat Steps 1-5 from the Software Update instructions.

- 2 Select the firmware components to update: Boot Loader, GPR Control, GPR Antenna, and/or GPR MAC (ID). It is recommended to update the firmware one component at a time.

- 3 Once it reads Update next to the selected firmware select Update at the bottom of the window.

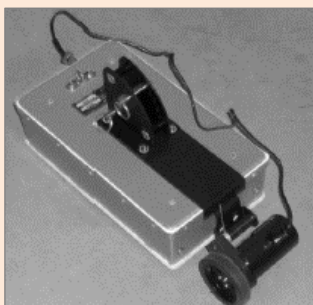
- 4 Select Done when the update is complete to exit the Firmware Menu.

Calibrate SW: You should calibrate the survey wheel when you change wheels or the ground surface changes. Begin by selecting a Survey Wheel Mode, Quadrature or Pulse, and then following the instructions. Quadrature Mode is intended for dual channel type encoders and will track the direction the encoder turns and the number of rotations. Pulse Mode is intended for single channel encoders and tracks the number of rotations of the encoder and not the direction. Once you've completed the calibration steps select Apply to save the New Calibration Value or cancel to exit the Calibrate SW menu without saving.

- 1** Select calibration distance – The default distance is 10 meters or feet. However this distance can be changed. The longer the calibration distance the more accurate the calibration should be.
- 2** Position Antenna on the Start mark – The antenna or system can be positioned anywhere at the start as long as you use the same point on the antenna or system when you stop.
- 3** Press the Start button – This is the green Start button located on the keypad of the SIR 4000.
- 4** Move antenna to the stop mark – This should match the same location on the antenna or system where you started.
- 5** Press the Stop button – This is the red Stop button located on the keypad of the SIR 4000.
- 6** Select Apply to save the current calibration setting.

Survey Wheel Factory Default Calibration Settings

Note: These default values are provided for convenience, but it is always advisable to calibrate your survey wheel to obtain a more accurate value.



Model 611 (3 5/8" wheel)

Single survey wheel designed for the 3101 Series (900 MHz) antenna

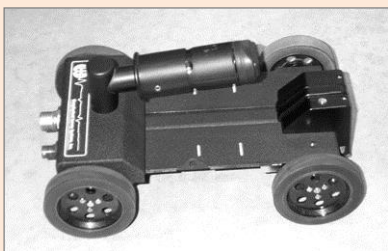
- 2000 ticks



Model 613 StructureScan Cart

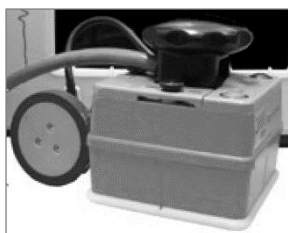
- 2000 ticks

Note: These default values are provided for convenience, but it is always advisable to calibrate your survey wheel to obtain a more accurate value.

**Model 614/615 Survey Handcart**

Blue metal StructureScan Cart with or without bar code reader

- 4030 ticks

**Model 62000 Palm Antenna**

2 GHz Palm Antenna with attached single survey wheel

- 22146 ticks

**Model 620 (16" wheel):**

400 MHz and 200 MHz tow-behind

- 417 ticks

**Model 623/624/625 Survey Cart**

2-Wheel or 3-Wheel UtilityScan Cart:

- -1785 ticks

**Model 643/644 Survey Cart**

Large 4-Wheel UtilityScan Cart:

- 3140 ticks

Note: These default values are provided for convenience, but it is always advisable to calibrate your survey wheel to obtain a more accurate value.



Model 652/653/654/655 Survey Cart

Small 4-Wheel UtilityScan Cart:

- 3850 ticks

Geometry: This menu option is not available with the initial release of the SIR 4000, but will be part of a later software upgrade.

WiFi: The WiFi configuration is reserved for future functionality.

Quit: Exits the current Settings menu and returns to the Introduction screen.

Status

This real-time monitor is always visible during both setup and data collection. It shows power, storage, and GPS status.



Battery

Shows the current status of the SIR 4000 battery.

AC Power Supply: 255 or more minutes of average run time remaining. This occurs when the SIR 4000 is plugged into AC power.

Green Battery: 30-255 minutes of average run time remaining.

Yellow Battery: 15-29 minutes of average run time remaining. At this level the Battery status icon will begin to pulse.

Red Battery: Less than 15 minutes of average run time remaining. Battery status icon will continue to pulse and the battery should be immediately replaced.

Storage

This status icon indicates the amount of used memory on the SD card. The SIR 4000 comes with 32 GB of internal memory.

GPS

The GPS monitor indicates whether or not a GPS is connected and the quality of the GPS signal.

Green GPS Icon: The GPS is enabled, detected, and the data has an HDOP of 2 or less.

Yellow GPS Icon: The GPS is enabled, detected, and the data has an HDOP greater than 2.

Red GPS Icon: The GPS is enabled, but not detected.

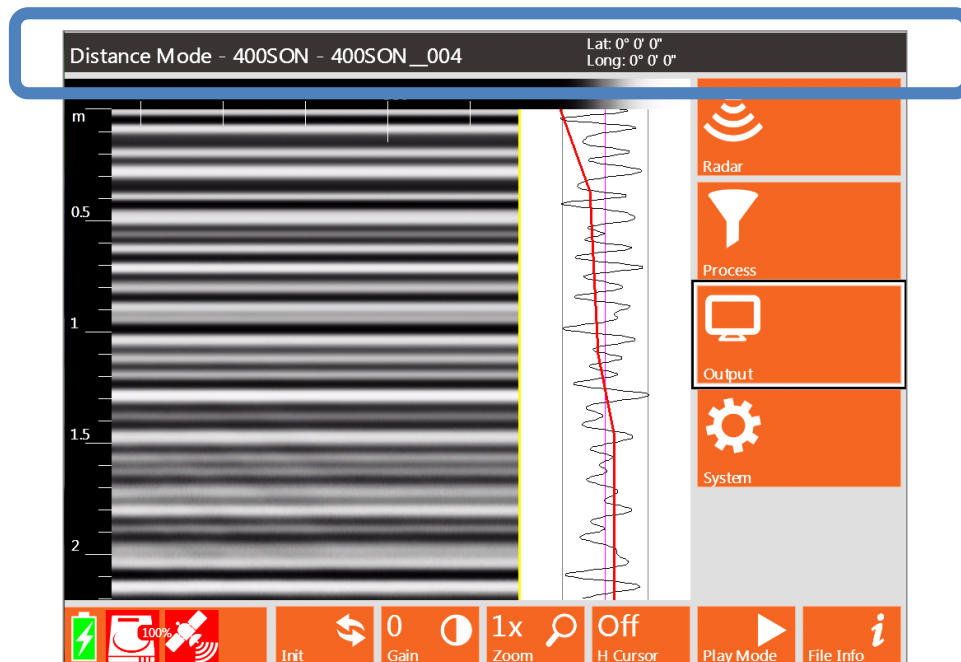
Grey GPS Icon: The GPS is either not enabled in the GPS menu or it is not detected.

2.3: Setup Collect/Playback Screen

The SIR 4000 Setup Screen displays a preview of the data, an Information Bar, Setup Menu, and Toolbar.

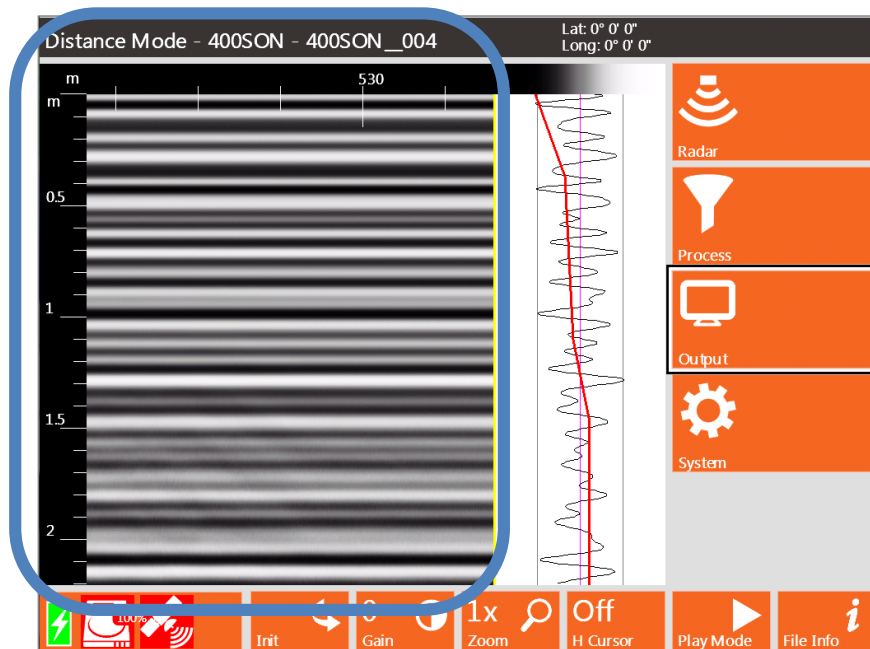
Information Bar (top): An information bar appears at the very top of the screen and is updated based on whether the SIR 4000 is currently in Collect or Playback Mode.

- The left-hand side displays the current mode (Distance, Time, Point, or Playback) and file information (Project Folder – File Name).
- The middle displays GPS coordinates if the system is configured to collect GPS points.
- During collection the right-hand side displays either the scan number if in Time or Point Data Collection mode or distance if the Collection Mode is set to Distance.



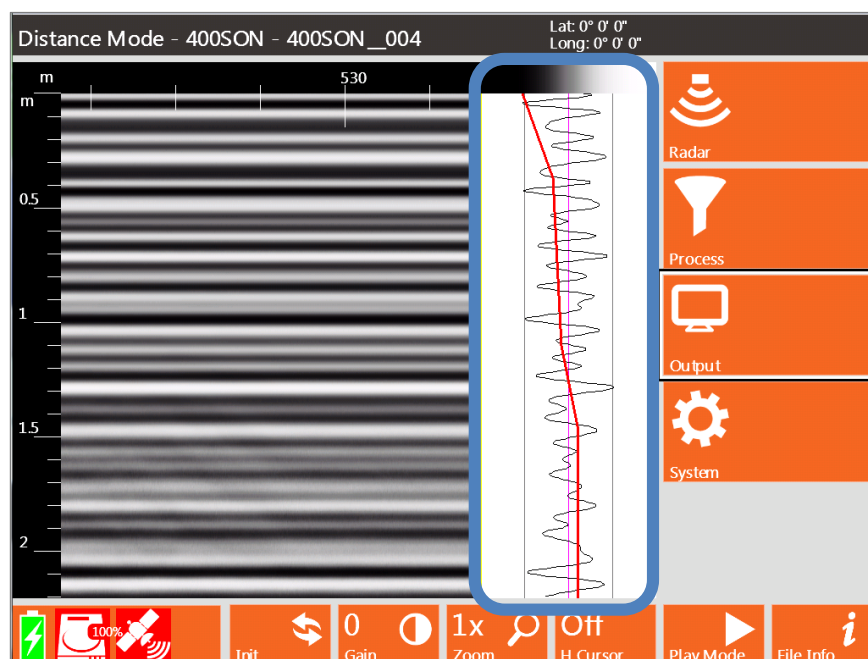
Main Data Display (left): The main data display window shows a radar profile in linescan format. Successive single scans are assigned color values based on amplitude change and displayed next to each other in sequence to form a continuous image.

- The vertical scale on the left of this data display window shows time, depth, or height.
- New scans will be placed at the right side of the window and data will scroll from right to left.
- The horizontal scale will be in the units of measure selected in the Introduction Screen and with the density set in the Setup Menu.

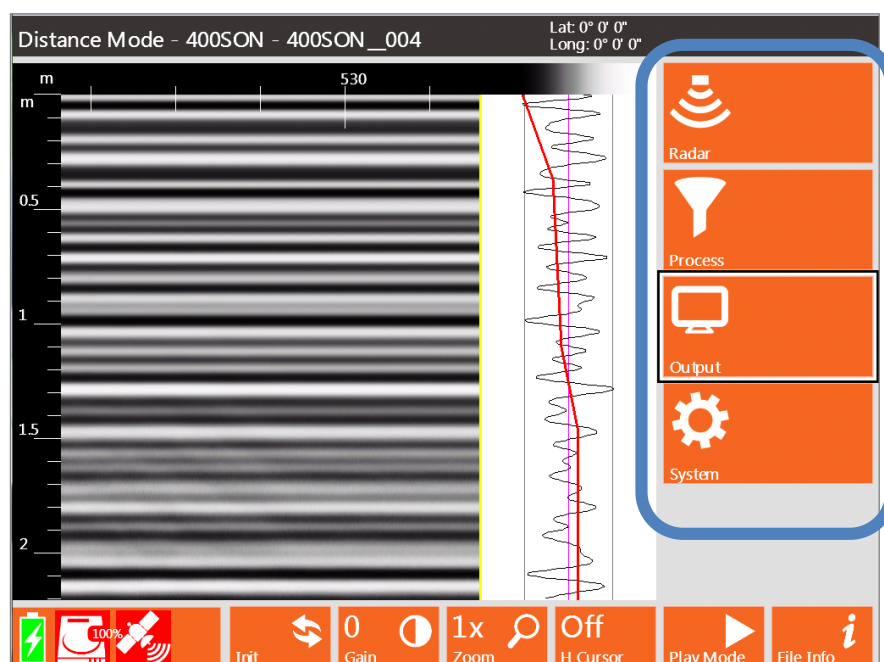


O-Scope (middle): In the middle of the screen you will see a window that shows a single radar scan in an oscilloscope-style (O-scope) depiction. This will show successive single scans as you move your antenna across an area while in the Setup Screen.

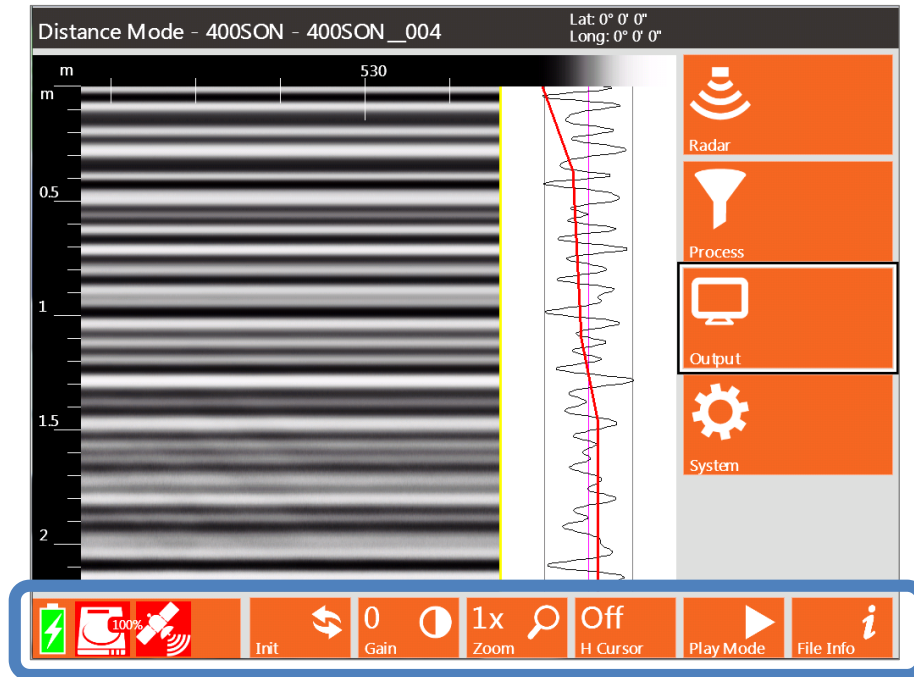
- Time or depth increases down the screen at the same vertical scale that is selected from the Setup Menu to the right of the Main Data Display.
- At the top of the window you will see a color bar. This shows you the distribution of colors across the range of reflection amplitudes from negative, on the left, to positive, on the right. The exact color and distribution depends on your choice of Colormap, Color Stretch, and Color Slide selected from the Setup Menu.
- The red line that travels the length of the O-Scope is the Time Variable Gain Curve. Refer to the section on Gain Mode under Setup Menu – Process for more information on modifying the gain curve.



Setup Menu (right): To the right of the O-Scope display is the Setup Menu. This window is where you will navigate through the various commands, set system parameters, data paths, colors, and how to save data. There are four (4) main menu options, Radar, Process, Output, and System. For more information on each see the sections Setup Menu – Collect Mode or Setup Menu – Playback Mode.



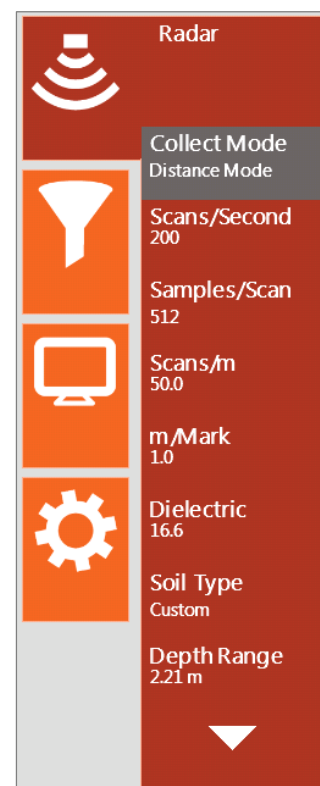
Toolbar (bottom): The bar across the bottom of the screen is the Setup or Playback Toolbar and provides different options for modifying how the data appears during setup, collection, or playback. Different Applications will have partially customized or completely redefined Toolbars based upon necessity. In Expert Mode the Toolbar includes Init(ialize), Gain (Display Gain), Zoom (Horizontal Zoom), Run Mode, Play Mode, and File Info. These commands are each explained in more detail later on in this chapter when each button is defined.



Setup Menu – Radar

Under Radar, there are fourteen (14) settings that can each be accessed by rotating the Control Knob or using the Directional Keypad. The settings are:

Menu Option	Collect Mode	Playback Mode
Collect Mode	X	
Scans/Second	X	
Samples/Scan	X	
Scans/Unit	X	
Units/Mark	X	
Static Stacking		
Dielectric	X	X
Soil Type	X	X
Depth Range	X	
Time Range	X	
Position Mode	X	
Offset	X	
Surface (%)	X	
Exit	X	X



Collect Mode

Collect Mode allows you to collect either distance-, time-, or point-based data.

Distance Mode: Distance-based collection is performed with a survey wheel. The system records a certain number of scans per unit of distance. Distance Mode is more accurate than Time Mode and it is strongly recommended that you collect data in this mode if possible. To calibrate the survey wheel refer to Section 2.2 Introduction Screen – Settings – Calibrate SW.

Note: Distance-based data is required for 3D files.

Time Mode: In time-based data collection, the system is recording a certain number of scans per second. The data density over an area depends on the speed at which the antenna is moved over the ground. The rate is set in the Scans/Second setting option. The option is often used when it is not feasible to use a survey wheel during data collection.

Point Mode: Point-based data collection is commonly selected only for very deep applications or very difficult terrain. The system will record one scan every time the external marker or Start button is pressed. The antenna is then moved to the next location and the next scan is collected.

Scans/Second

Scans/second is the number of scans the system will collect per second. The SIR 4000 will collect minimum of 4 and maximum of 400 scans/second.

- If you are collecting data based on time, this is the number of scans that will be saved each second.
- If you are collecting data based on distance with a survey wheel, this number represents the maximum possible collect rate. If you exceed this maximum rate the over-speed beeps will sound. It is recommended that the scans/second be set lower as lower scan rates will auto stack and improve the signal to noise ratio.

For example if your Scans/Second is set to 60 and you have configured the system to collect 60 scans a foot, and you move more than one foot per second, the system is going to attempt to collect scans which are not available. Assuming your Antenna Transmit Rate is 200 KHz, the scans/second should be at least 240 whenever you are collecting with a survey wheel and are collecting a max of 512 Samples/Scan.

If you set scans/second higher than possible given the selected transmit rate and the number of samples/scan, the SIR 4000 will automatically lower it to the maximum possible. However, it is recommended that the scans/second be set lower than the maximum. This will allow the system to stack points thereby improving the signal to noise ratio.

Samples/Scan

Each scan curve is made up of a set number of individual data points, called Samples. The more samples you collect, the smoother the scan curve and the better your vertical resolution will be. The more points collected, the lower the maximum scans/second is set.

- You can choose from a preset list of 256, 512, 1024, 2048, 4096, 8192, or 16384 samples/scan. FIR filters should only be used with 256-2048 samples/scan.
- As sample number increases, maximum scan rate drops and file size increases.
- GSSI recommends sampling at 512 or 1024 samples/scan for most applications. More samples will be required for deep geologic or polar ice thickness applications. Below is the equation to use when choosing a sample rate.

Samples/Scan > (Time Range/Pulse Duration)

Antenna Model	Frequency (MHz)	Pulse Duration (ns)
4200S	2 GHz Horn	0.5
4100SA	1 GHz Horn	1
52600S	2.6 GHz	0.4
62000	2 GHz Palm	0.5
51600S	1.6 GHz	0.7
5101	1 GHz	1
3101A	900 MHz	1.1
50400S	400 MHz	2.5
50270S	270 MHz	3.7
5106	200 MHz	5
3207	100 MHz	10

Scans/Unit

Scans/unit allows you to adjust the number of scans/unit of horizontal distance. This parameter is the scan spacing when you are collecting with the survey wheel. A unit of measure will appear based on the Units selected from the Introduction Screen and the Horizontal Units selected from the Output Menu.

- Smaller scan spacing produces higher resolution data, but larger file sizes, and may require slower data collection. For example, if you see a 12 here and the system is set to English feet, rather than Metric units, you will collect 12 scans per foot, or 1 per inch.
- Scan spacing will vary based on application. For example, 5-10 scans/inch (60-120 scans/foot) is the optimal range for shallow structural features in concrete, but with lower frequency antennas, like a 400 MHz, a coarser scan density of 12-24 scans/foot is typical.

Units/Mark

You can also set how many units (i.e., feet or meters) will be collected between system marks. These marks will appear at the top of the data display along the horizontal scale.

Static Stacking

This option is only available in Point Mode. It takes the number of scans entered and averages them together to output a single scan at each collection location. This is done to minimize high-frequency or random noise.

Dielectric

Dielectric constant represents the velocity at which radar energy moves through a material.

- If you know the dielectric value of the material that you are surveying through, you can enter it here and get an in-field time to depth calculation.
- Values range between 1 and 81.
- Higher dielectric values mean slower travel time and shallower penetration. For example, in air, which has a dielectric constant of 1, radar energy will travel at 12 inches per ns. Since the time range is in two-way travel time, 1 ns on the vertical scale translates to 6 inches if the DIEL is set to 1. The distance traveled per ns is reduced by the square root of the dielectric constant. The dielectric constant of water is 81, so that water slows down the radar wave by a factor of 9 ($\sqrt{81}=9$). The range in water is thus 6/9 inches per ns.
- Generally speaking, water raises a material's dielectric constant, and surveys should be performed on dry material whenever possible.
- Please see Appendix C for a chart of dielectric values of common materials and a deeper discussion of dielectrics.

Soil Type

Several different Soil Type options are included on the SIR 4000. Selecting a Soil Type will automatically update the Dielectric with a value that is representative of that soil.

Material	Dielectric Constant
Snow/Ice	3.0
Dry Sand	4.0
Pavement	6.0
Rock	8.0
Dry Soil	9.0
Ave. Soil	14.0
Wet Soil	20.0
Wet Sand	25.0
Custom	

Custom: Will automatically appear if the Dielectric Constant is manually changed or if either a hyperbola fitting or ground truth are performed during data collection. For more information on hyperbola fitting and ground truth see section 2.4 The Command Bar – Output in Collect Mode.

Depth Range

Depth Range is the vertical scale displayed in whichever units are selected under the Output > Vertical Units menu.

- Depth Range can be set from 1-10000 cm (0.4-3900 in).
- Modifying Time Range will automatically update the Depth Range.

Time Range

Time Range is the vertical scale in nanoseconds (ns) within which the SIR 4000 will record reflections. It is proportional to depth viewed because a higher Time Range will allow the energy to penetrate deeper and return deeper reflections.

- It is important to remember that the Time Range is two-way travel time, so that a range of 50 ns means that the deepest possible reflector is at 25 ns.
- A very long range may require a greater number of samples in order to create enough data dots for the scan curve. Refer to the section above about how to determine the appropriate number of samples/scan.
- Time Range can be set from 1-20000 ns.
- Please see Appendix D for a list of common ranges for individual antennas.
- Modifying Depth Range will automatically update the Time Range.

Position Mode

This option controls the position of Time-Zero. Time-Zero is the location of the beginning of the time range, and thus the beginning of the scan. In ground-coupled applications this also corresponds with the ground-surface reflection. Typically, having the system auto locate itself is sufficient to adequately set the position during data collection. However, you can also manually adjust the location of Time-Zero. Toggle between the two options, Manual or Auto, by pushing the Control Knob or the Enter button.

Manual: Allows you to set an Offset and Surface %. Offset is the time lag between the initial pulse and when the signal first leaves the antenna. Surface % is a visual shift in the scan to begin at the initial reflection. When switching from Manual back to Auto the system will automatically reset Time-Zero based on the Surface % selected.

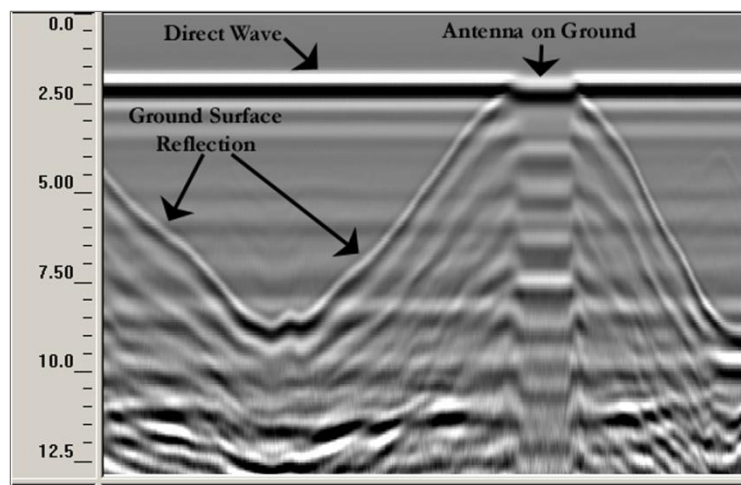
Auto: Anytime the antenna is re-initialized, as when pressing the Init button or first entering the Setup Collect Screen, the SIR 4000 will set the Position automatically.

- For most applications and surveys the antenna should be placed on the ground surface or surface to be scanned prior to entering the Setup Collect Screen in order to acquire an accurate Position using Auto Mode.
- This choice is automatically set to Manual if you are using sample densities of 4096, 8192, or 16384.

Offset

This is an internal system parameter that describes the time lag (in ns) from the SIR 4000 triggering the pulse inside of the control unit until we consider it to have transmitted from the antenna itself. Since there is no way to accurately measure the exact moment the pulse leaves the antenna, we use the antenna's direct wave to determine the appropriate point to set the offset.

- The direct wave is the pulse that travels inside of the antenna housing, directly from the transmitter to the receiver, and it is generally considered to be the first response in the data. As long as the antenna dipoles are not very far apart, as is the case with a separated bistatic antenna pair, the direct wave occurs sooner than any reflections from the ground. So if we make sure that we have the direct wave visible in the data, we can be sure that we have 100% of our data and most importantly, the ground surface to perform a depth calculation. The value is in nanoseconds from trigger pulse inside the SIR 4000. If you need to adjust this parameter, use caution not to lose the direct wave.
- Adjusting the Offset is only available when Position Mode is set to Manual. When it is set to Auto, the SIR 4000 auto calculates the Offset.
- In the associated image, the antenna was moved up and down over the ground surface. Notice how the surface reflection moves up to join the direct wave.



Surface (%)

This is a display option that allows you to visually ‘cut out’ the flat part of the scan and begin at the direct wave, thereby only showing the scan from the first reflected target, which should be the ground surface.

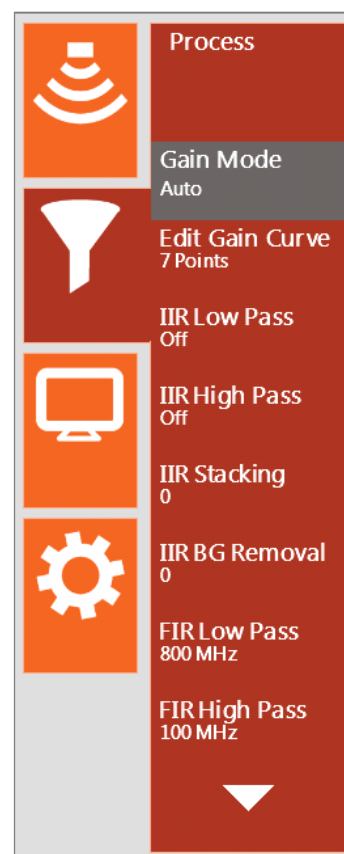
- The entire scan is still collected and saved, but not displayed during data collection. This allows you to set the display to show an in-field time to depth calculation.
- It is set as a percentage of the total vertical window. The SIR 4000 will examine the offset and the antenna type selected from the Introduction Screen to find the proper surface automatically. It will set near to the first positive peak of the direct wave.

Setup Menu - Process

None of the filters used during data collection or playback with the SIR 4000 will be saved with the data. When data is opened in the processing software RADAN it will come in without any applied filters.

Under Process, there are fourteen (14) settings that can each be accessed by rotating the Control Knob or using the Directional Keypad. These settings are listed below as well as which modes they are available in:

Menu Option	Collect Mode	Playback Mode
Gain Mode	X	X
Edit Gain Curve	X	X
FIR Low Pass	X	X
FIR High Pass	X	X
FIR Stacking	X	X
FIR BG Removal	X	X
Custom Filter	X	X
IIR Low Pass	X	X
IIR High Pass	X	X
IIR Stacking	X	X
IIR BG Removal	X	X
Signal Floor	X	X
Exit	X	X



Gain Mode

Gain is the artificial addition of signal in order to counteract the natural effects of attenuation. As a radar scan travels into the ground, some of the scan is reflected, some of it is absorbed, and the remaining signal continues penetrating until it is completely absorbed in the media. Therefore as the scan gets deeper, it also becomes weaker. Gain is applied to the scan to make the subtle variations in weaker data more visible. It is applied using a Time-Variable Gain Curve, visually represented by a red line in the O-Scope window on the Setup screen. Values increase from left to right and the location of gain points is shown by a change in the slope of the curve.

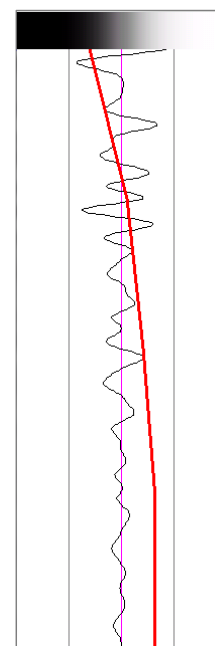
There are two Gain options to choose from and you push either the Control Knob or Enter button to toggle between them.

Manual: Selecting Manual Gain allows you to change the number of gain points and to add strength to the signal at your own discretion.

- Manual Gain is not recommended for inexperienced users as it is possible to 'create' features in the data by over-gaining areas.

Auto: Selecting Auto Gain causes the system to re-initialize and adjust the time-variable gain curve based on the quality of the current scan and the selected number of gain points.

- This is useful if you find that your data is clipped (over-gained) or too weak to see (under-gained) over a particular section of your survey area. Just place the antenna on the area where the data is clipped or weak and either toggle the gain to Manual, and then back to Auto, or press the Init button at the bottom of the SIR 4000 keypad. This will cause the system to reset the gains to a lower level to prevent clipping or a higher level to strengthen weak reflections.



Edit Gain Curve

This menu option allows you to modify the number of gain points along the time-variable gain curve and, if in Manual Gain, strengthen or weaken individual points.

Pressing Edit Gain Curve with either the Control Knob or Enter button will activate the time-variable gain curve for editing and open new button functions for the bottom of the keypad.

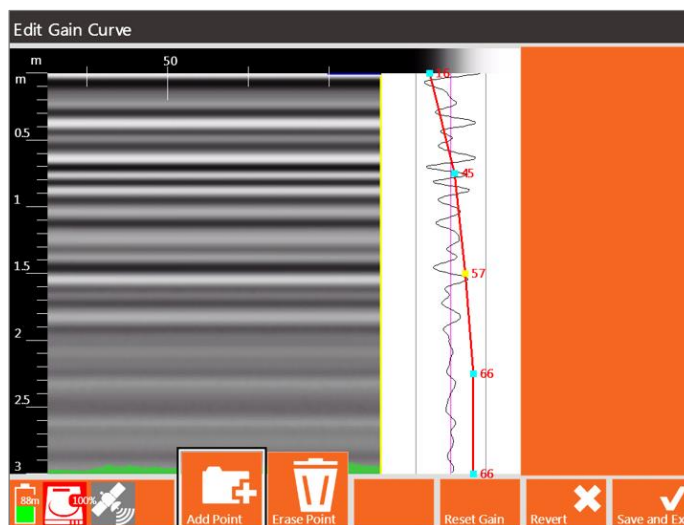
- With the time-variable gain curve activated, use the Control Knob or arrow keys to move between different gain points.

Add Point: Use this button to add up to eight (8) gain points to the gain curve. These points will be evenly spaced throughout the data scan.

Erase Point: Use this button to remove gain points from the gain curve. The minimum number of gain points is two (2). As points are removed, the remaining gain points are evenly redistributed throughout the data scan.

Revert: Returns to the main Setup Screen without saving any changes to the time-variable gain curve.

Save and Exit: Saves changes to the time-variable gain curve and returns to the Setup Screen.



When using Manual Gain you can modify the individual gain points using the following steps. Use caution when manually adjusting gain point values to not add too much gain to a single point because you may create what will look like a layer in the data.

Note: The SIR 4000 is only displaying about 25% of the actual amplitude range. This means that even if your data appears slightly clipped, the SIR® 4000 is likely still recording the full amplitude range of the reflection. If you use a -12 dB display gain, you will see an accurate representation of the recorded scan. This also means that when you view your data in RADAN, it will appear under-gained and you will need to add some display gain.

- 1** Press the Control Knob or Enter key to select a gain point and then use the knob or arrow keys to adjust to strengthen or weaken the point.
- 2** Press the Control Knob or Enter key a second time to save and deselect the modified gain point.

FIR Low Pass and IIR High Pass

These options, and the following seven (7) allow you to set data collection filters to either remove interference or smooth noise. A Low or High Pass filter is an antenna-specific frequency filter and should be modified each time a different antenna is connected. These filters are used to downplay external interference, and clean up the signal.

FIR filters have a finite-duration impulse response and, when encountering a feature in the data, are guaranteed to output a finite filtered version of that feature. These filters will produce symmetrical results so reflections will not be shifted in time or position.

By setting these at different ends of the antenna's bandwidth, you are determining the range of frequencies that the antenna is filtering out. Pressing FIR Low/High Pass with either the Control Knob or Enter button will allow you to scroll through different frequencies.

- FIR Filters should not be used with 4096 samples/scan or higher.
- The maximum Low and High Pass filter values are 5000 MHz.
- Select Off to disable either filter.

FIR Low Pass: The selected frequency in MHz is the upper limit of the filter. Any frequency lower than selected Low Pass frequency will be allowed to pass through the filter and be recorded by the system.

FIR High Pass: The selected frequency in MHz is the lower limit of the filter. Any frequency higher than selected High Pass frequency will be allowed to pass through the filter and be recorded by the system.

FIR Stacking

In addition to FIR frequency filters, another option is Stacking. Stacking is a high-frequency noise reduction filter which operates in the horizontal direction. Each new scan has a $1/n$ influence in the data, so this filter has a tendency to smooth high frequency targets and accentuate low frequency horizontal features, such as layers. As the number of scans you stack (n) increases, the influence of each new scan drops.

The FIR Stacking filter input is in number of scans. Pressing FIR Stacking with either the Control Knob or Enter button will allow you to select a number of scans.

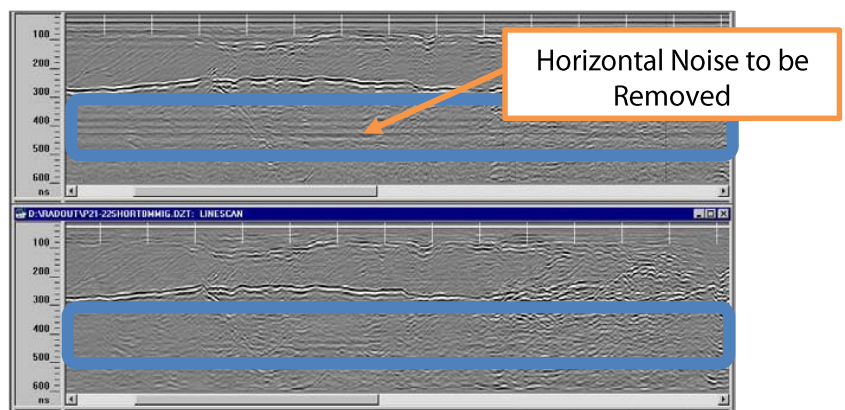
- High frequency noise generally has a 'snowy' appearance.
- The larger the number you put in here, the smoother the data will be. It is possible to over smooth and 'smudge' out real data.
- A larger number also means that the system is performing a great deal of extra calculations and data collection speed may be reduced.
- The Stacking filter maximum value is 1023 scans.

FIR BG Removal

Background Removal is a filter which removes horizontal bands of noise similar to those seen in the image below. Sometimes these bands are caused by 'real' horizontal reflectors, but they can also be caused by low frequency noise such as antenna ringing. These layers can obscure other 'real' horizontal or point source reflectors.

Filter length should be set to the number of scans equal to the feature length to be removed. Any continuous feature within the data, such as a water table reflector or a stratigraphic boundary between two soil types, may also be filtered out by performing Background Removal. Be careful to not filter out desired reflectors.

The FIR Background Removal filter input is in number of scans. Pressing FIR BG Removal with either the Control Knob or Enter button will allow you to select a number of scans.



- Determine the length in scans of the feature or noise that you want to remove from the data and input that number in to the SIR 4000. Features, or horizontal reflections, of this size or larger will be removed.
- The Background Removal filter maximum value is 1023 scans.

- It is recommended that this filter be set last. When Background Removal is turned on the previewed linescan data and individual scan will gradually be averaged out by the filter and only noise will be visible. This makes it impossible to preview the effects of other filters.

Custom Filter

This filter overrides the FIR Low/High Pass filters with a custom filter provided with the attached antenna. Custom Filters are only available with certain antennas and are sent with the antenna when it is purchased.

IIR Low Pass and IIR High Pass

IIR filters are a holdover from analog circuits. It is a simpler and potentially cruder type of filter than the FIR filter. The IIR filter is used to remove noise, but may change the waveform shape. When an IIR filter encounters a feature in the radar data, it produces an output that decays exponentially towards zero but never reaches it, hence the name “infinite.” IIR filters are not necessarily symmetrical and while they achieve excellent amplitude response, their phase response is non-linear and so they can cause slight phase shifts in the data.

By setting these at different ends of the antenna’s bandwidth, you are determining the range of frequencies that the antenna is filtering out. Pressing IIR Low/High Pass with either the Control Knob or Enter button will allow you to scroll through different frequencies.

- IIR Filters should not be used with 4096 samples/scan or higher.
- The maximum Low and High Pass filter values are 5000 MHz.
- Select Off to disable either filter.

IIR Low Pass: The selected frequency in MHz is the upper limit of the filter. Any frequency lower than selected Low Pass frequency will be allowed to pass through the filter and be recorded by the system.

IIR High Pass: The selected frequency in MHz is the lower limit of the filter. Any frequency higher than selected High Pass frequency will be allowed to pass through the filter and be recorded by the system.

IIR Stacking

In addition to IIR frequency filters, another option is Stacking. Stacking is a high-frequency noise reduction filter which operates in the horizontal direction. Each new scan has a 1/n influence in the data, so this filter has a tendency to smooth high frequency targets and accentuate low frequency horizontal features, such as layers. As the number of scans you stack (n) increases, the influence of each new scan drops.

The IIR Stacking filter input is in number of scans. Pressing IIR Stacking with either the Control Knob or Enter button will allow you to select a number of scans.

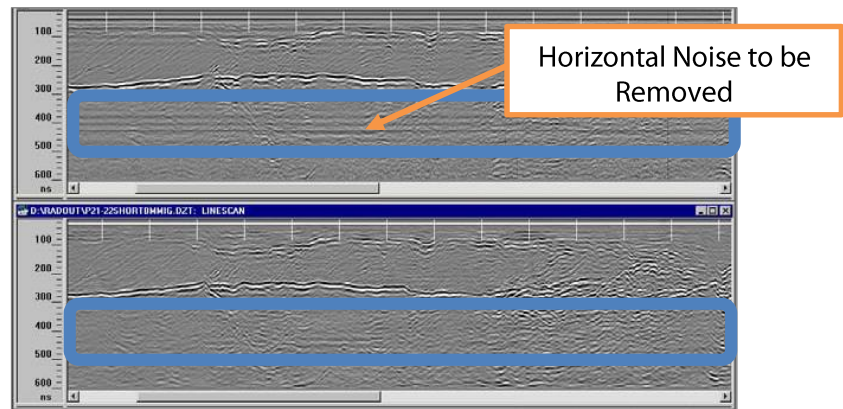
- High frequency noise generally has a ‘snowy’ appearance.
- The larger the number you put in here, the smoother the data will be. It is possible to over smooth and ‘smudge’ out real data.
- A larger number also means that the system is performing a great deal of extra calculations and data collection speed may be reduced.
- The Stacking filter maximum value is 1023 scans.

IIR BG Removal

Background Removal is a filter which removes horizontal bands of noise similar to those seen in the image below. Sometimes these bands are caused by ‘real’ horizontal reflectors, but they can also be caused by low frequency noise such as antenna ringing. These layers can obscure other ‘real’ horizontal or point source reflectors.

Filter length should be set to the number of scans equal to the feature length to be removed. Any continuous feature within the data, such as a water table reflector or a stratigraphic boundary between two soil types, may also be filtered out by performing Background Removal. Be careful to not filter out desired reflectors.

The IIR Background Removal filter input is in number of scans. Pressing IIR BG Removal with either the Control Knob or Enter button will allow you to select a number of scans.



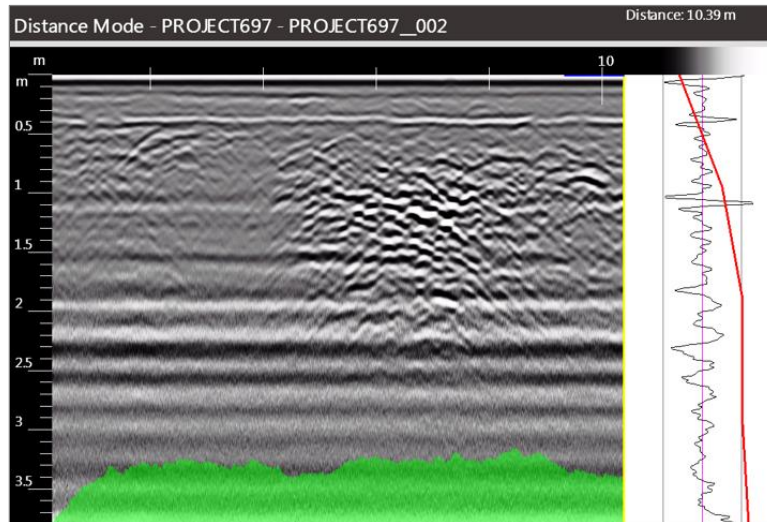
- Determine the length in scans of the feature or noise that you want to remove from the data and input that number in to the SIR 4000. Features, or horizontal reflections, of this size or larger will be removed.
- The Background Removal filter maximum value is 1023 scans.
- It is recommended that this filter be set last. When Background Removal is turned on the previewed linescan data and individual scan will gradually be averaged out by the filter and only noise will be visible. This makes it impossible to preview the effects of other filters.

Signal Floor

When Signal Floor is turned on it overlays a green field on the Linescan display. This green field is an estimate of the effective depth of each scan based on an analysis of the noise to signal loss (attenuation). Real reflectors may still be located beneath the Signal Floor if they are strong enough.

Press the Control Knob or Enter key to toggle Signal Floor On or Off.

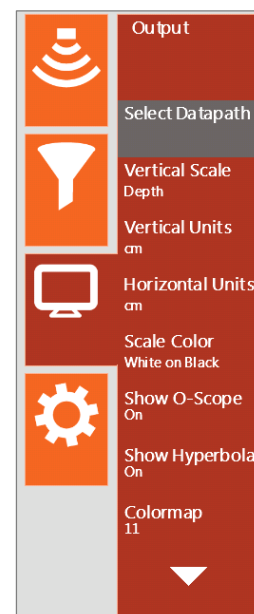
This process does not affect the data being collected. It is a visual indication only.



Setup Menu - Output

This menu controls the data display and file maintenance. There are eleven (11) sub-menus to the Output menu depending upon which collection mode is selected:

Menu Option	Collect Mode	Collect/Playback Point Mode	Playback Mode
Select Datapath	X	X	X
Vertical Scale	X	X	X
Vertical Units	X	X	X
Horizontal Units	X	X	X
Scale Color	X	X	X
Show O-Scope	X	X	X
Show Hyperbola	X		X
Colormap	X		X
Color Stretch	X		X
Color Slide	X		X
Spacing		X	
Amplitude		X	
Fill		X	
Exit	X	X	X



Select Datapath

This is the location in which your files are stored on the SIR 4000. There are two basic types of paths: Common and User-defined.

- Common is the default file path and files in this directory will be named with the word FILE and then a number. For example, the first data file will be FILE__001, then FILE__002, and so on.
- User-defined paths allow you to change the location of your data. This is useful if you are surveying multiple areas or if you prefer to name your files during collection with a site name instead of doing it later after download. Files will be named after the data path. For example a data path named GRID will contain files named GRID__001, GRID__002, and so on.



When Select Datapath is pressed using either the Control Knob or the Enter key it opens a list of the different project folders saved on the SIR 4000. Use the Control Knob or Enter key to scroll the list and select a new project folder by pressing the Control Knob or Enter key. After a new selection is made you'll return the Collect Setup Screen.

- You can only choose from existing data paths. In order to create a new data path, return to the Introduction Screen and select New Project.
- When New Project is selected the Edit Project Name menu opens allowing you to change the name of the data path. This name will also be used as the default filename.

You can also delete old project folders through this menu. To do so scroll through the list of project names and when the project folder you wish to delete is highlighted press the Delete Path control button.

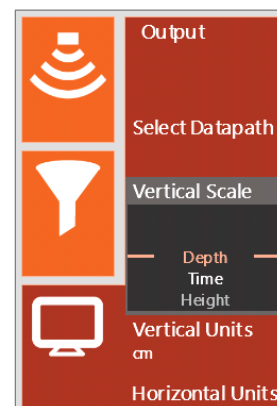
Vertical Scale

The Vertical Scale menu options allows you to choose how the vertical scale on the left-hand side of the data display appears. It can be set to either Depth, Time, or Height.

Depth: When Depth is selected the SIR 4000 performs a time to depth conversion based on the dielectric value that you have set in Radar > Dielectric or Radar > Soil Type. It will then display the vertical scale in depth based on the units of measure chosen under Output > Vertical Units.

Time: Measured in nanoseconds (ns). When set to time, the vertical scale displays two way travel time (TWTT).

Height: Inverts the screen so that time-zero is at the bottom. This can be a useful display if you are scanning upside-down.



Vertical Units

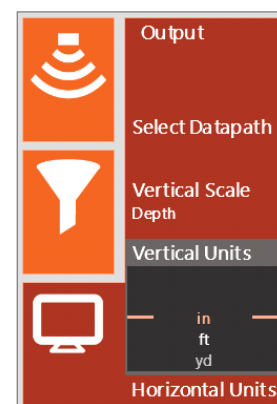
Sets which units of measure are displayed based on which Vertical Scale is currently selected.

- As an example if you are using a very high frequency antenna to scan 18 inches into concrete, you may choose to display depth in inches instead of feet.

Time: Nanoseconds (ns) is the only option available.

Distance: Which units are available is based on the units of measure set in the Introduction > Units menu. If Metric, then centimeters (cm) and meters (m) are available. If English, then inches (in), feet (ft), and yards (yd) are available.

Height: Which units are available is based on the units of measure set in the Introduction > Units menu. If Metric, then centimeters (cm) and meters (m) are available. If English, then inches (in), feet (ft), and yards (yd) are available.



Horizontal Units

Sets which units of measure are displayed based on the Units selected from the Introduction Screen.

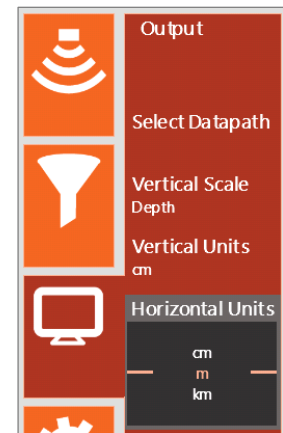
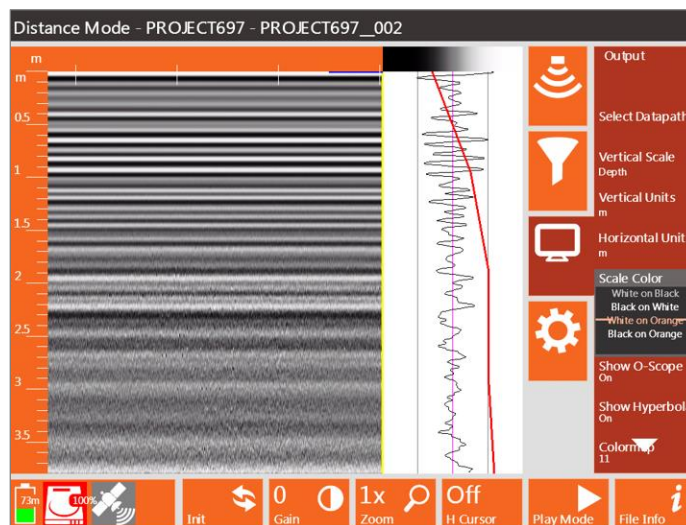
- As an example if you are collecting a long geologic profile you can display the distance in kilometers instead of meters.

Metric: Horizontal units of measure available for Metric are centimeters (cm), meters (m), or kilometers (km).

English: Horizontal units of measure available for English are inches (in), feet (ft), yards (yd), or miles (mi).

Scale Color

Change the color of the text and background for the vertical and horizontal scales in data display. The choices are either white or black text on a white, black, or orange background. This will change the display in both the Setup Screen, during data collection, and during playback.

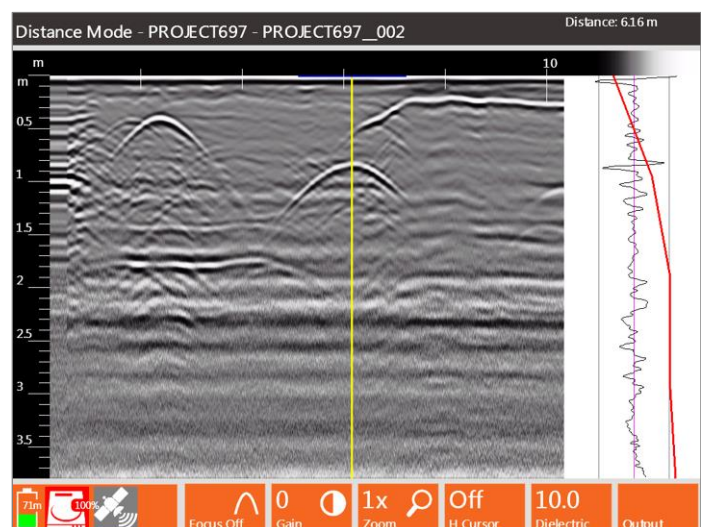


Show O-Scope

Toggles the O-Scope display On or Off for use during data collection. Selecting Off will not turn off the O-Scope display in the Setup Screen.

- During data collection you will not have the option to turn the O-Scope display On or Off. This choice is only made while in the Setup Screen.

Toggle Show O-Scope On or Off by pressing the Control Knob or the Enter key.

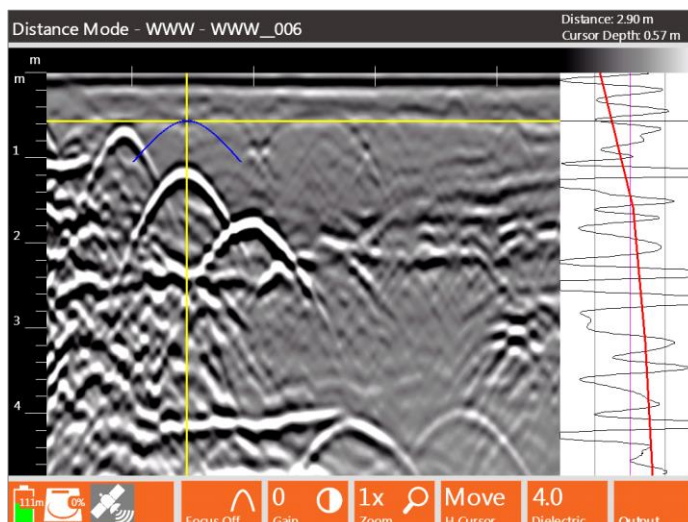


Show Hyperbola

Toggles a hyperbola On or Off while in setup or during collection. The hyperbola appears at the intersection of the vertical and horizontal cursor. By default the horizontal cursor is placed at the top of the data display.

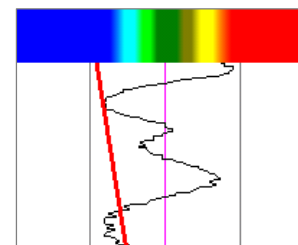
- The hyperbola is used during data collection to do real-time hyperbola fitting. Hyperbola fitting measures the geometry of visible hyperbolas in the data to generate an estimated Dielectric Constant.
- During data collection you'll also have the option to turn the hyperbola On or Off.

Toggle Show Hyperbola On or Off by pressing the Control Knob or the Enter key.



Colormap

This menu option offers 30 available Colormap options (i.e. color tables). Select the menu by pressing the Control Knob or Enter key and then scroll through Colormap #0-29. The currently selected Colormap appears at the top of the O-Scope display and indicates how colors are distributed between negative (left) and positive (right) amplitude changes.



Color Stretch

Selecting Color Stretch allows you to adjust how the selected Colormap is distributed over a scan's amplitude range. A Color Stretch greater than one (1) compresses the colors towards zero (0). A Color Stretch less than one (1) expands the colors towards the maximum negative and positive amplitudes.



Left Color Stretch = 0; Middle Color Stretch = 1; Right Color Stretch = 3

Color Slide

Selecting Color Slide allows you to shift the center point of the selected Colormap over a scan's amplitude range (amplitude zero crossing). A negative number shifts towards the positive amplitudes and positive number shifts towards the negative amplitudes.

- Adjusting the Color Slide over a particular value range allows you to see more subtle variations in the data.



Left Color Slide = -0.20; Middle Color Slide = 0; Right Color Slide = 0.20

Spacing – Point Mode Only

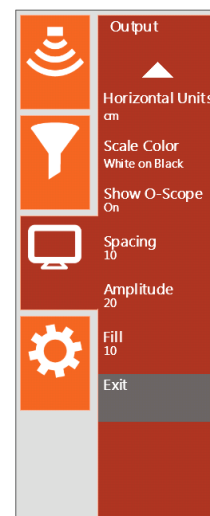
This is the number of pixels displayed between each individual scan collected using Point Mode. Values range from 1-50. You can select different spacing using the Control Knob or the arrow keys.

Amplitude – Point Mode Only

Similar to Display Gain, Amplitude increases the amplification of each scan to bring out the weaker reflections. It is in decibels (db) and can range from 1-100. You can select different spacing using the Control Knob or the arrow keys.

Fill – Point Mode Only

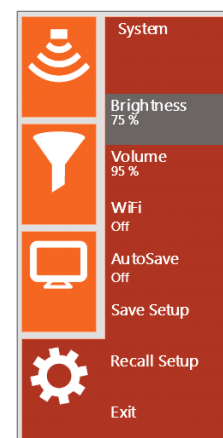
This is the percent of the scan's positive peaks that are filled in and will appear black during data collection and playback.



Setup Menu – System

This menu includes general settings such as how files are saved and default setups. There are seven (7) options under the System menu:

Menu Option	Collect Mode	Playback Mode
Brightness	X	X
Volume	X	X
WiFi	X	X
AutoSave	X	X
Save Setup	X	X
Recall Setup	X	X
Exit	X	X



Brightness

This controls screen brightness. The scale runs from 0-100% with 100% being the brightest and the screen will be black when set at zero (0). The darker the screen is, the longer the battery will last because the screen consumes more power when the brightness is increased.

Volume

This controls the volume of the control unit. The system makes noise at certain points during setup, data collection, and playback. The scale runs from 0-100% with 100% being the loudest and the sound entirely turned off when set at zero (0).

WiFi

This menu option toggles the SIR 4000 WiFi On and Off. The WiFi configuration is reserved for future functionality.

AutoSave

You can toggle AutoSave to On or Off. When AutoSave is set to On each time you end data collection the profile is automatically saved in the project folder under the filename shown at the top of the screen. If AutoSave is set to Off you will be prompted each time you end data collection to either save or delete the current file. If you choose to save the file it saves in the project folder under the filename shown at the top of the screen.

- When collecting a manual 3D grid without using the SIR 4000 3D Grid mode you should set AutoSave to Off. When you finish collecting a transect of data, the file save prompt pauses data collection so that you can reposition to start collecting the next transect.

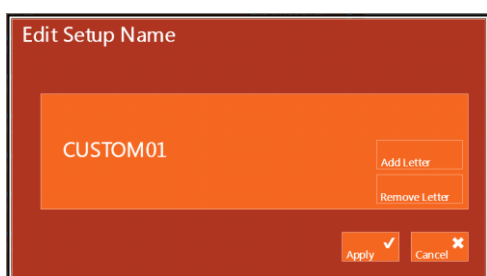
Toggle AutoSave On or Off by pressing the Control Knob or the Enter key.

Save Setup

You can save all of the settings from the Radar, Process, and Output menus to be recalled at a later date. When Save Setup is pressed using either the Control Knob or the Enter key a menu opens with sixteen (16) available setups, Setup01 – Setup16. Setup00 is the current setup, which is automatically saved anytime data is collected.

You can also create a New Setup from the control button at the bottom of the screen. Pressing this button opens the Edit Setup Menu where you can customize the name.

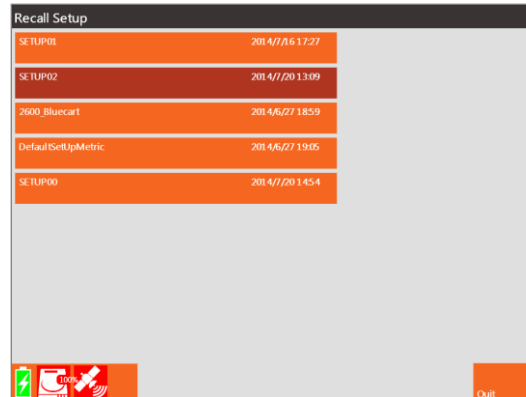
- Use the Control Knob or arrow keys to select and modify letters.
- You can Add Letters to or Remove Letters from the end of the Setup Name.
- To save the custom setup select Apply.



Recall Setup

You can recall a setup that was saved by selecting Recall Setup. When Recall Setup is selected by either pressing the Control Knob or the Enter key, a list of available setups will appear.

- Setup00 is always available and represents the current settings whether or not they've been saved.



2.4: The Toolbar

The six keys across the bottom of the data display window have different functions depending on whether you are in Setup Collect/Playback Mode, data collection, or data playback.

In Setup Collect Mode

In Setup Collect Mode, the Toolbar will appear like this:



Init(ialize)

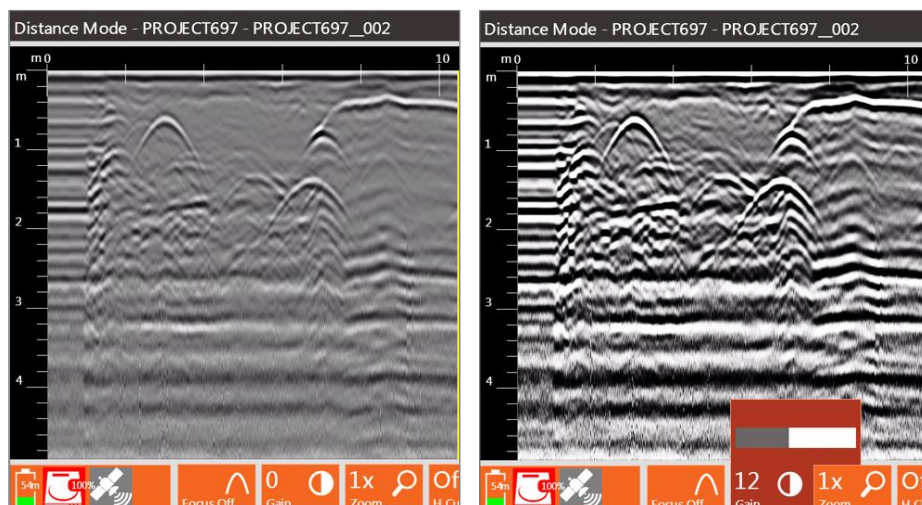
This button stops and instantly restarts the transmitter. Through the Initialization process all settings that are set to Auto, such as Gain or Position, will reset based on the current quality of the scan trace.

- To Initialize the system just press the Init control button one time.

Gain

This Gain option is also referred to as display gain. It increases the amplitude of your data by multiplying every sample throughout your scan by a constant value. The result is that you will be able to better see weaker reflections, but those already strong reflections may be over-gained. This function is useful for a quick viewing of data that is attenuated or otherwise under-gained to guarantee that it was not clipped.

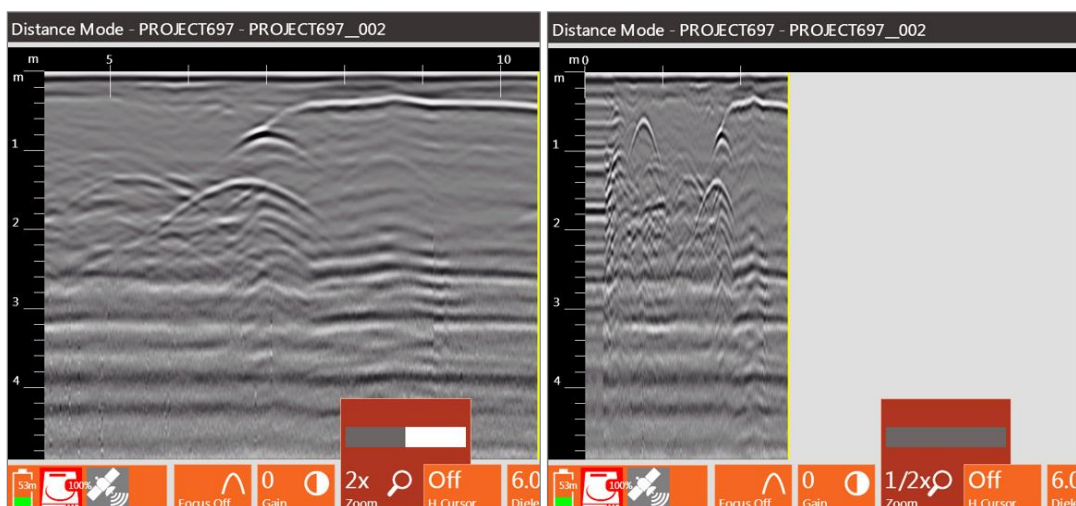
- You can change Gain from -12 to 60, with negative values weakening the entire signal and positive values strengthening the signal by the value shown.
- To modify Gain press the Gain control button and use either the Control Knob or Right/Left Arrow keys to adjust the gain amount.
- Display Gain is only for display and is not saved with the data.



Zoom

This option allows you to modify the horizontal scale by zooming in or out by factors of $\frac{1}{2}x$, 1x, 2x, 4x, or 8x.

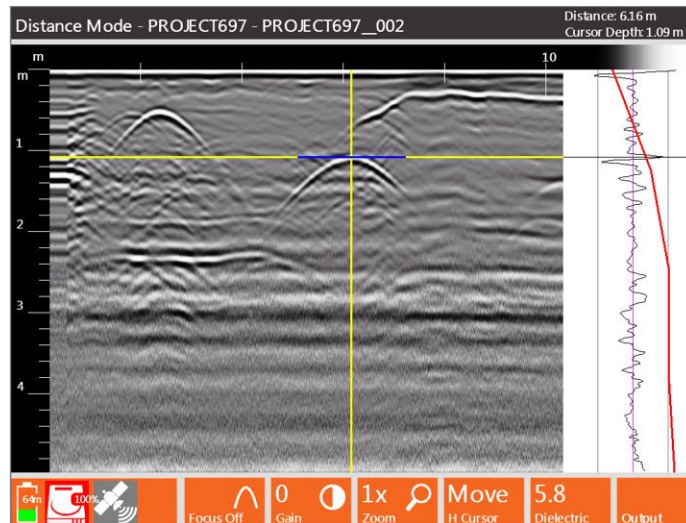
- The system defaults to 1x Zoom on initial startup and when data collection begins.
- This does not affect how the data are saved.



H Cursor

You can add a horizontal cursor to the screen during setup and data collection. The yellow line can be toggled On or Off and moved.

- To position H Cursor press the H Cursor control button to change the H Cursor to Move. Then use the Control Knob to adjust its position. Rotate the knob left (counter-clockwise) to move the cursor down the time range. Rotate the knob right (clockwise) to move the cursor up the time range.
- To set the H Cursor press the Control Knob or press Enter. The H Cursor control button will say On.
- To turn the H Cursor off press the H Cursor control button until it says Off.



Play Mode

Clicking this button while in the Setup Collect Mode the system will prompt you for a file to open from the current project folder to playback. Use the Control Knob or arrow keys to select a saved file to playback. You can select multiple files to playback in sequence.

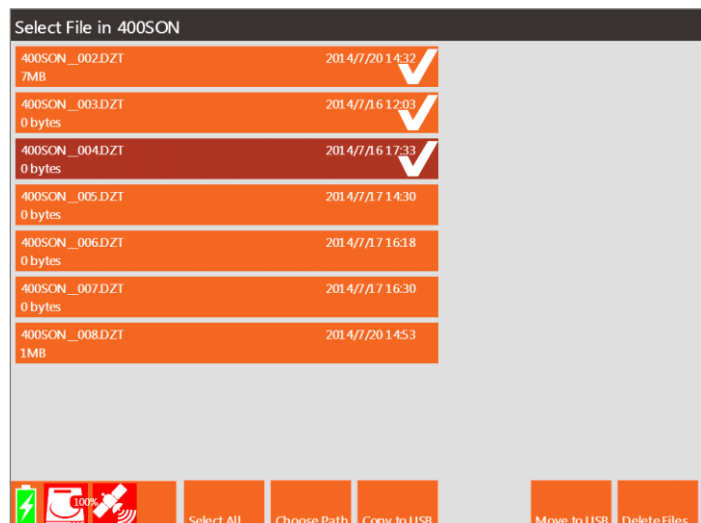
Select All: Selects all of the files in the current project folder to playback in sequence.

Choose Path: Allows you to select a different project folder for playback.

Copy to USB: A way to transfer the files currently selected to a USB drive. The files will be copied, maintaining a copy on the SIR 4000.

Move to USB: A way to transfer the files currently selected to a USB drive. The files will be removed from the SIR 4000.

Delete Files: Deletes the currently selected files from the project folder. If all of the files are selected it maintains the project folder.



File Info

This control button opens a window showing the current settings including Radar Parameters, Positioning information, and Processing History.

File Information - PROJECT697__002					
Radar Parameters		Positioning		Processing History	
Transmit Rate	230 KHz	GPS Type	None	Gain Points	
Samples/Scan	512	Scan Step	75.00 Scans/m	13 47 73 77 79	
Scan Rate	350	Mark Step	50.00 m/Mark	FIR Low Pass	800
Dielectric	9.96			FIR High Pass	100
Antenna	50400S				
Time Range	80.00 ns				
Position Offset	-14.81 ns				

In Setup Playback Mode

In Setup Playback Mode, the Toolbar will look like this:



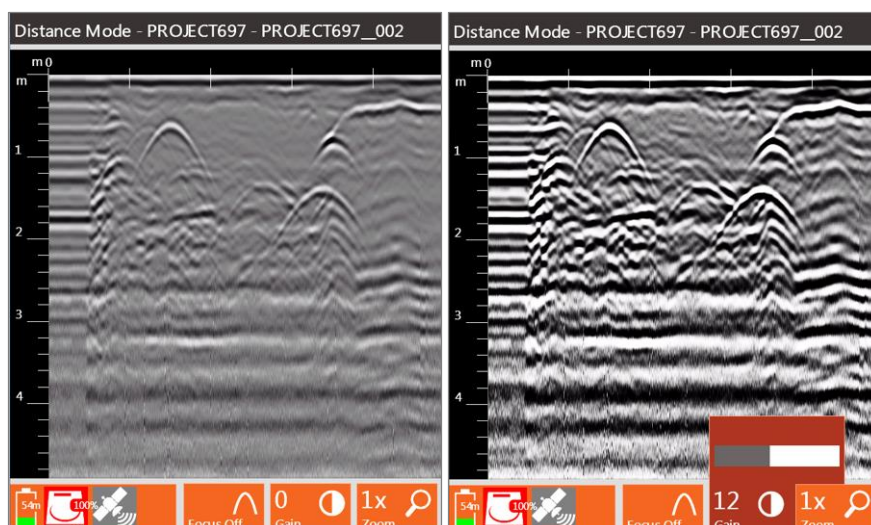
Init(ialize)

This button initiates the auto gain, which will reset the gain curve based on the quality of the saved data.

Gain

This Gain option is also referred to as display gain. It increases the amplitude of your data by multiplying every sample throughout your scan by a constant value. The result is that you will be able to better see weaker reflections, but those already strong reflections may be over-gained. This function is useful for a quick viewing of data that is attenuated or otherwise under-gained to guarantee that it was not clipped.

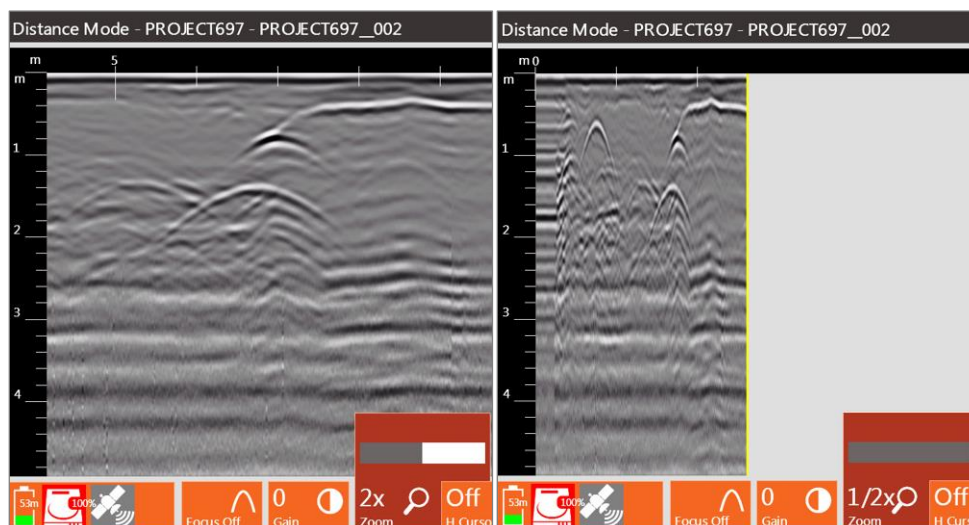
- You can change Gain from -12 to 60, with negative values weakening the entire signal and positive values strengthening the signal by the value shown.
- To modify Gain press the Gain control button and use either the Control Knob or Right/Left Arrow keys to adjust the gain amount.



Zoom

This option allows you to modify the horizontal scale by zooming in or out by factors of $\frac{1}{2}x$, 1x, 2x, 4x, or 8x.

- The system defaults to 1x Zoom on initial startup and when data collection begins.
- This does not affect how the data are saved.



Select File

Opens a list of files within the current project folder to open into Playback Mode. You can navigate through the list using either the Control Knob or the arrow keys. Select a file to open by pressing the Control Knob. Then open the file by pressing the Enter key.

If two or more files are selected it will open the files in sequence from the lowest file number to the highest.

Select All: Selects all of the files in the current project folder to playback in sequence.

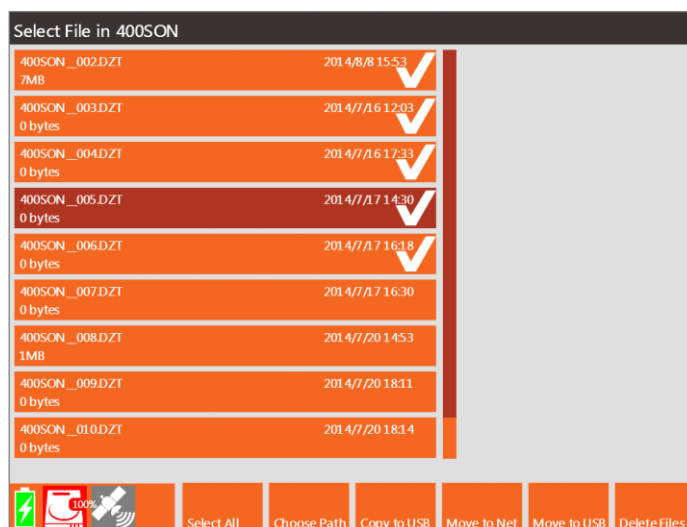
Choose Path: Allows you to select a different project folder for playback.

Copy to USB: A way to transfer the files currently selected to a USB drive. The files will be copied, maintaining a copy on the SIR 4000.

Move to Net: A way to transfer the files currently selected to a location on the network. The files will be removed from the SIR 4000.

Move to USB: A way to transfer the files currently selected to a USB drive. The files will be removed from the SIR 4000.

Delete Files: Deletes the currently selected files from the project folder. If all of the files are selected it maintains the project folder.



Collect Mode

Clicking the Collect control button will bring you back to Setup Collect Mode. You'll know which mode you're in by the text displayed in the top left corner of the screen.

Playback Mode: Playback Mode – [Folder] – [File name]

Collect Mode: Distance/Time/Point Mode – [Folder] – [File name]

File Info

This Command Key opens a window showing the current settings including Radar Parameters, Positioning information, and Processing History.

File Information - PROJECT697_002					
Radar Parameters		Positioning		Processing History	
Transmit Rate	230 KHz	GPS Type	None	Gain Points	
Samples/Scan	512	Scan Step	75.00 Scans/m	13 47 73 77 79	
Scan Rate	350	Mark Step	50.00 m/Mark	FIR Low Pass 800	
Dielectric	9.96			FIR High Pass 100	
Antenna	50400S				
Time Range	80.00 ns				
Position Offset	-14.81 ns				

In Collect Mode

In Collect Mode, the Command Bar will change based on the method of data collection; Distance, Time, or Point. To begin Collect Mode press on the green Start button while in the Setup Collect Mode. After the Start button is pushed data will start to fill in from the left moving to the right at a rate dependent upon the type of collection mode chosen.



Distance Mode Control Buttons



Time Mode Control Buttons



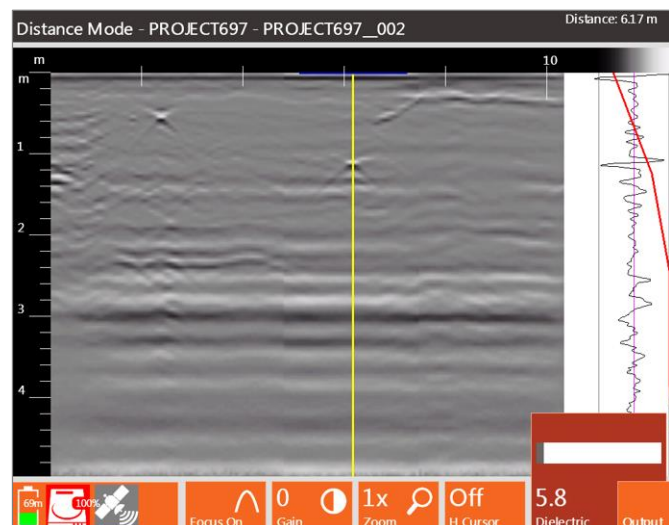
Point Mode Control Buttons

Focus On - Distance Mode Only

Focus On performs a migration, which is a processing procedure that reduces or eliminates hyperbolic diffraction patterns in the data. It removes the tails of the hyperbolas to more accurately represent the center location of a target. This makes the identification of point reflectors much easier.

Migration also offers a simple and accurate way of estimating the radar velocity (and thus dielectric) of the material your target is in from the shape of the hyperbolas.

- If the dielectric constant is too high when Focus is turned on, hyperbolic reflections will still appear as hyperbolas.
- If the dielectric constant is too low when Focus is turned on, hyperbolic reflections will appear in a “U” shape.
- Adjusting the dielectric, using the Dielectric control button, will change how hyperbolic reflections appear during data collection. The goal is for all hyperbolic reflections to appear as dots.
- If you are on a homogenous material, like concrete, this calibration is good for all like material. If you are on soils, know that the Dielectric Constant of the soils can change drastically with depth and across an area, so this is only an approximation.





Pause/Resume - Time Mode Only

Temporarily pauses data collection when collecting in Time Mode. Press it once to Pause collection. The Pause control button will change to a Resume control button when the system is paused. Press Resume to continue data collection.

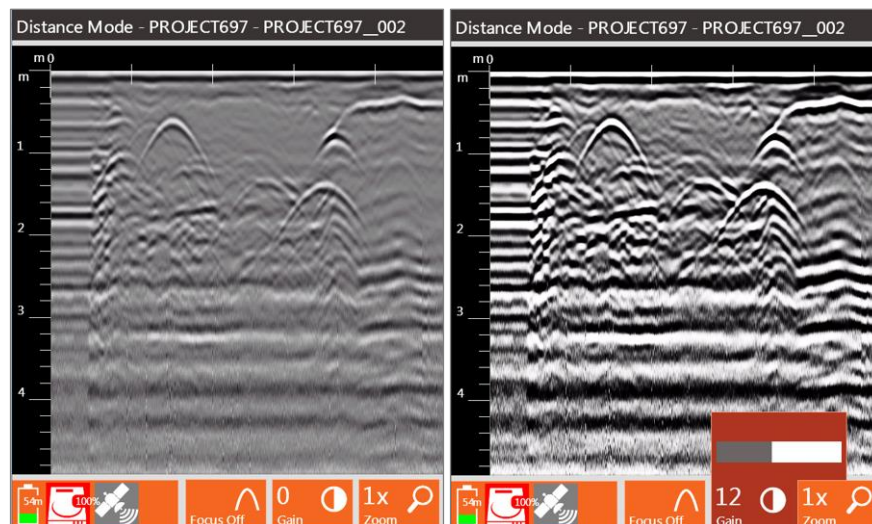
Next Point - Point Mode Only

This is the control button that allows you to collect multiple scans in one file when collecting data in Point Mode. When the Next Point control button is pressed a subsequent scan will be added to the data display starting from the left and progressing to the right.

Gain

This Gain option is also referred to as display gain. It increases the amplitude of your data by multiplying every sample throughout your scan by a constant value. The result is that you will be able to better see weaker reflections, but those already strong reflections may be over-gained. This function is useful for a quick viewing of data that is attenuated or otherwise under-gained to guarantee that it was not clipped.

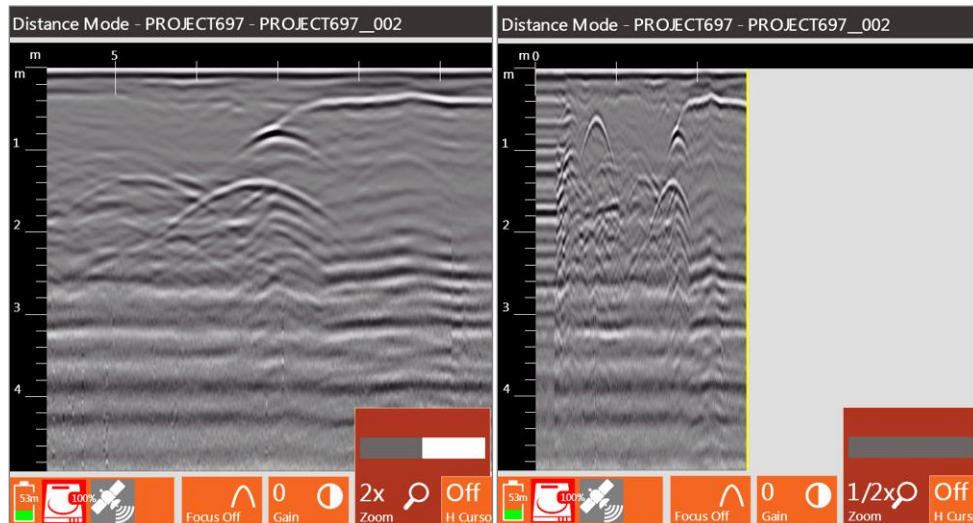
- You can change Gain from -12 to 60, with negative values weakening the entire signal and positive values strengthening the signal by the value shown.
- To modify Gain press the Gain control button and use either the Control Knob or Right/Left Arrow keys to adjust the gain amount.
- Display Gain is only for display and is not saved with the data.



Zoom

This option allows you to modify the horizontal scale by zooming in or out by factors of $\frac{1}{2}x$, $1x$, $2x$, $4x$, or $8x$.

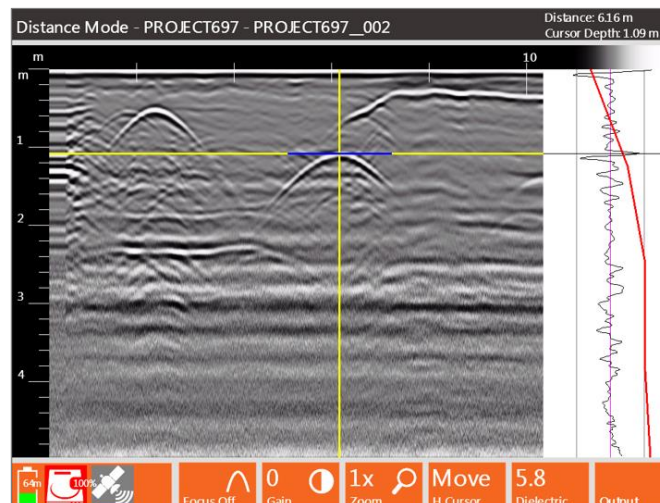
- The system defaults to $1x$ Zoom on initial startup and when data collection begins.
- This does not affect how the data are saved.



H Cursor

You can add a horizontal cursor to the screen during data collection. The yellow line can be toggled On or Off or moved.

- To position H Cursor press the H Cursor control button to change the H Cursor to Move. Then use the Control Knob to adjust its position. Rotate the knob left (counter-clockwise) to move the cursor down the time range. Rotate the knob right (clockwise) to move the cursor up the time range.
- To set the H Cursor press the Control Knob or press Enter. The H Cursor control button will say On.
- To turn the H Cursor off press the H Cursor control button until it says Off.



Dielectric

You can adjust the Dielectric Constant during data collection from a value of one (1) to eighty-one (81).

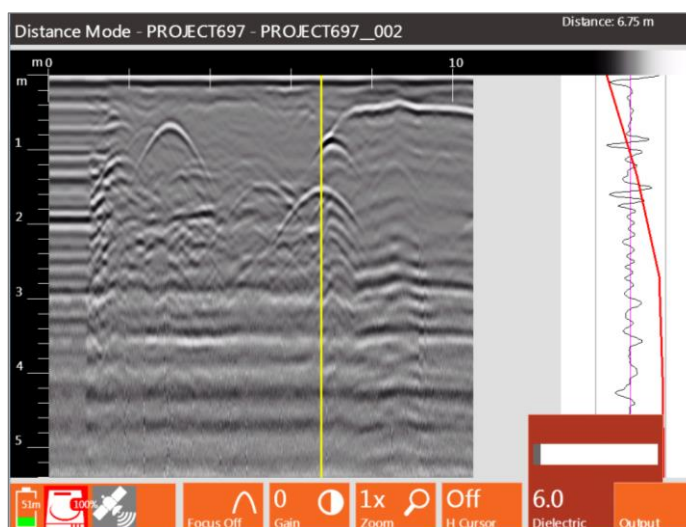
- Changing the Dielectric Constant will change the vertical scale if it is displayed in depth based on the Time Range selected during setup.

Distance Mode: Dielectric can be modified during distance-based collection when data are not actively being collected, as when the survey wheel is stopped or backing up. Adjust the Dielectric Constant by pressing the Dielectric control button and using the Control Knob or arrow keys to adjust the value. Save the selected Dielectric by pressing the control button again, the Control Knob, or the Enter button.

Time Mode: Dielectric can only be adjusted when data collection is paused while collecting in Time Mode.

- Press the Pause control button to pause data collection. Then press the Dielectric control button. Use the Control Knob to adjust the Dielectric Constant between one (1) and eighty-one (81). The vertical scale will update as the Dielectric Constant is changed.
- Save the selected Dielectric by pressing the control button, the Control Knob, or the Enter button.

Point Mode: Dielectric can be modified at any time during Point Mode collection. Adjust the Dielectric Constant by pressing the Dielectric control button and using the Control Knob or arrow keys to adjust the value. Save the selected Dielectric by pressing the control button again, the Control Knob, or the Enter button.



Set Depth

This control button allows you to enter the depth of a known target and automatically adjust the Dielectric Constant. This option is only available when Show Hyperbola is turned off. This can either be done from Setup or while collecting through the Output control button.

- 1 Collect a file over a target with a known depth.
- 2 Back up so the vertical cursor is in line with the target.
- 3 Set Horizontal Cursor (H Cursor) to Move, and the Set Depth button appears. Position the H Cursor at the top of the known target.

- 4 Press the Set Depth control button and the depth value for the position of the H Cursor appears above Set Depth.
- 5 Adjust the depth value using either the Control knob or arrow keys to match the known value.

The vertical scale will change as you adjust the depth value and once the known depth is saved the Dielectric Constant is adjusted.



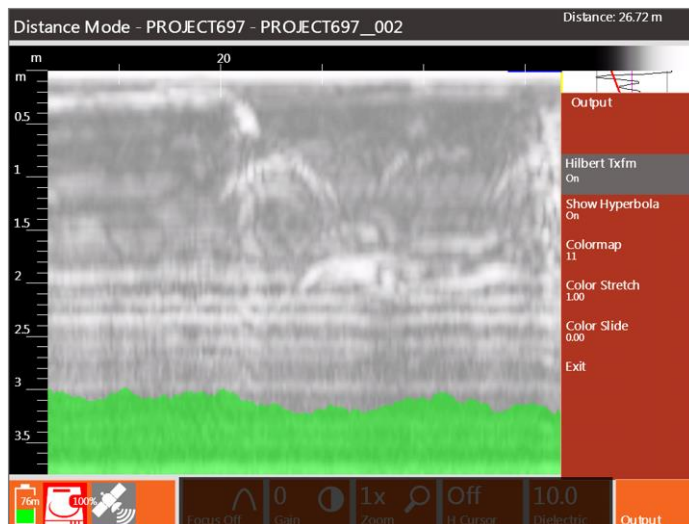
Output - Distance or Time Mode

This control button opens a menu with options for modifying the data display during collection.

Hilbert Txfm: A Hilbert Transform is used to display subtle properties of the subsurface. Reflector amplitude and time are the primary types of information in GPR data used to make interpretations. Another way of defining the data is by transforming it into frequency and phase (positive or negative changes in the scan trace). This information is sometimes more sensitive to important subsurface (dielectric) changes in the amplitude or geometric information.

A Hilbert Transform will change a radar signal represented as a time series into its magnitude (via envelope detection) phase). The Hilbert Transform expresses the relationship between the phase and magnitude of the signal, or between its real and imaginary parts. It allows the phase of a signal to be reconstructed from its amplitude.

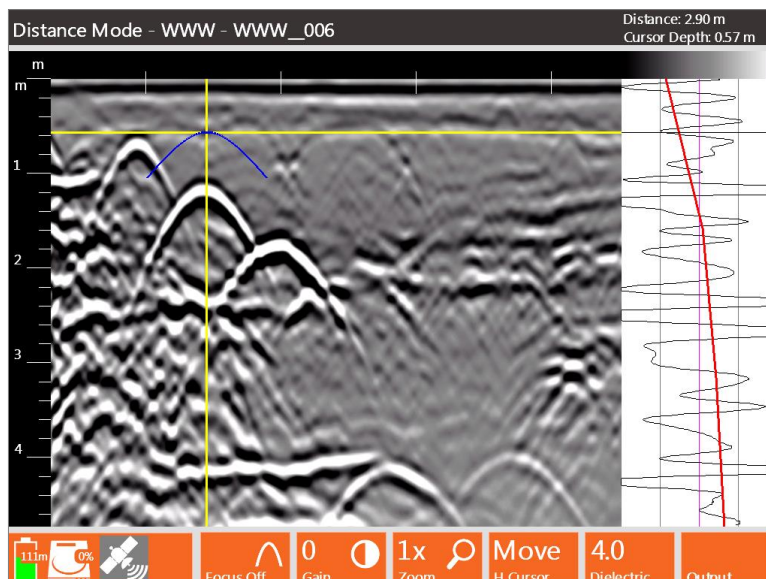
Toggle Hilbert Transform On or Off by pressing the Control Knob or the Enter key.



Show Hyperbola: Toggles a hyperbola On or Off while in setup or during collection. The hyperbola appears at the intersection of the vertical and horizontal cursor. By default the horizontal cursor is placed at the top of the data display.

- The hyperbola is used during data collection to do real-time hyperbola fitting. Hyperbola fitting measures the geometry of visible hyperbolas in the data to generate an estimated Dielectric Constant.
- During data collection you'll also have the option to turn the hyperbola On or Off.

Toggle Show Hyperbola On or Off by pressing the Control Knob or the Enter key.



Colormap: This menu option offers 30 available Colormap options (i.e. color tables). Select the menu by pressing the Control Knob or Enter key and then scroll through Colormap #0-29. To preview the different Colormaps, if the O-Scope is not displayed during data collection, return to the Setup Screen > Output Menu.

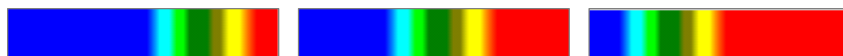
Color Stretch: Selecting Color Stretch allows you to adjust how the selected Colormap is distributed over a scan's amplitude range. A Color Stretch greater than one (1) compresses the colors towards zero (0). A Color Stretch less than one (1) expands the colors towards the maximum negative and positive amplitudes. To preview Color Stretch, if the O-Scope is not displayed during data collection, return to the Setup Screen > Output Menu.



Left Color Stretch = 0; Middle Color Stretch = 1; Right Color Stretch = 3

Color Slide: Selecting Color Slide allows you to shift the center point of the selected Colormap over a scan's amplitude range. A negative number shifts towards the positive amplitudes and positive number shifts towards the negative amplitudes. To preview Color Slide, if the O-Scope is not displayed during data collection, return to the Setup Screen > Output Menu.

- Adjusting the Color Slide over a particular value range allows you to see more subtle variations in the data.



Left Color Slide = -0.20; Middle Color Slide = 0; Right Color Slide = 0.20

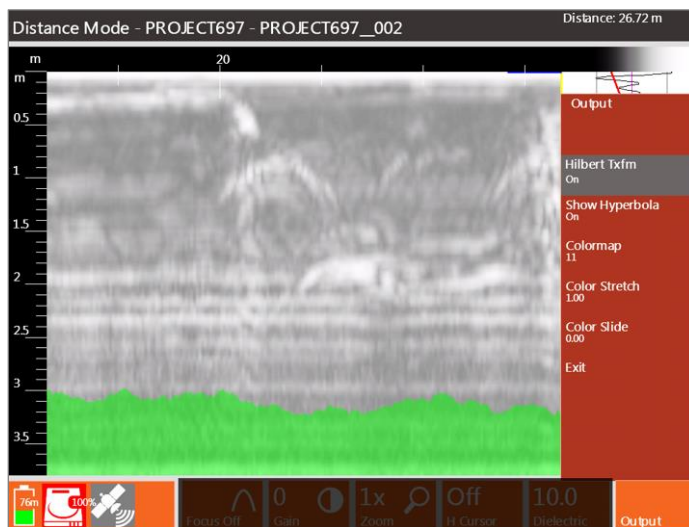
Output - Point Mode

This control button opens a menu with options for modifying the data display during collection.

Hilbert Txfm: A Hilbert Transform is used to display subtle properties of the subsurface. Reflector amplitude and time are the primary types of information in GPR data used to make interpretations. Another way of defining the data is by transforming it into frequency and phase (positive or negative changes in the scan trace). This information is sometimes more sensitive to important subsurface (dielectric) changes in the amplitude or geometric information.

A Hilbert Transform will change a radar signal represented as a time series into its magnitude (via envelope detection) phase). The Hilbert Transform expresses the relationship between the phase and magnitude of the signal, or between its real and imaginary parts. It allows the phase of a signal to be reconstructed from its amplitude.

Toggle Hilbert Transform On or Off by pressing the Control Knob or the Enter key.



In Playback Mode

This is what the Toolbar will look like in Playback Mode. This mode is accessible from the Playback Setup screen by pressing the green Start button. After clicking Start button the data file will scroll to the end of the file and stop.



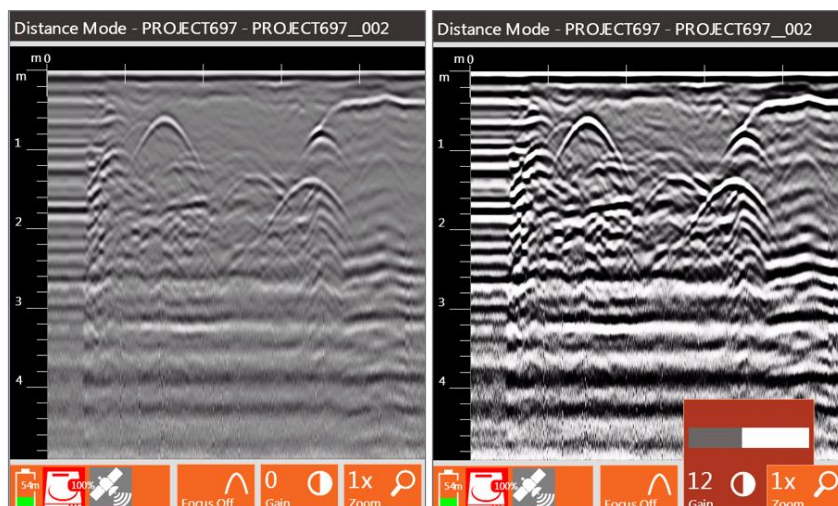
Pause/Resume

Pauses the data as it is being displayed on the SIR 4000. When the Pause control button is pressed once it stops playback and the control button changes to Resume. The Resume control button can then be pressed to continue playing back the selected data.

Gain

This Gain option is also referred to as display gain. It increases the amplitude of your data by multiplying every sample throughout your scan by a constant value. The result is that you will be able to better see weaker reflections, but those already strong reflections may be over-gained. This function is useful for a quick viewing of data that is attenuated or otherwise under-gained to guarantee that it was not clipped.

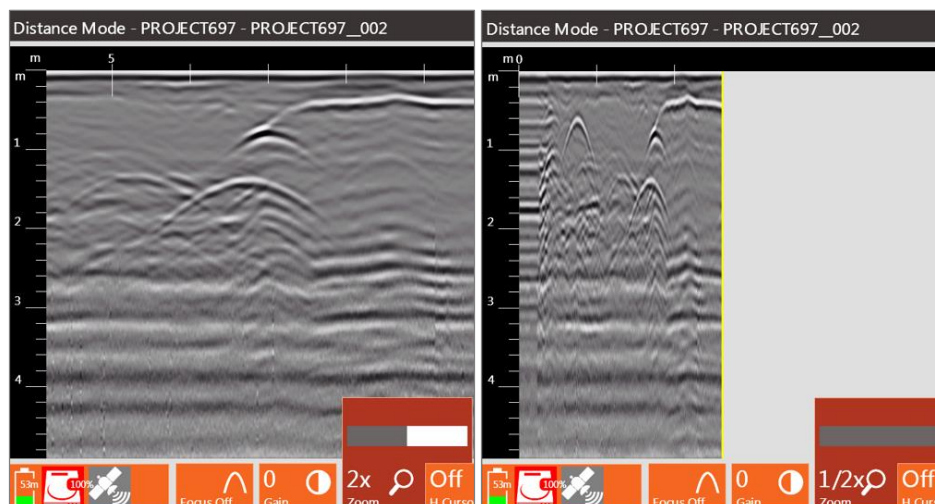
- You can change Gain from -12 to 60, with negative values weakening the entire signal and positive values strengthening the signal by the value shown.
- To modify Gain press the Gain control button and use either the Control Knob or Right/Left Arrow keys to adjust the gain amount.
- Display Gain is only for display and is not saved with the data.



Zoom

This option allows you to modify the horizontal scale by zooming in or out by factors of $\frac{1}{2}x$, $1x$, $2x$, $4x$, or $8x$.

- The system defaults to $1x$ Zoom on initial startup and when data playback begins.
- This does not affect how the data are saved.



H Cursor/Cursor Dir

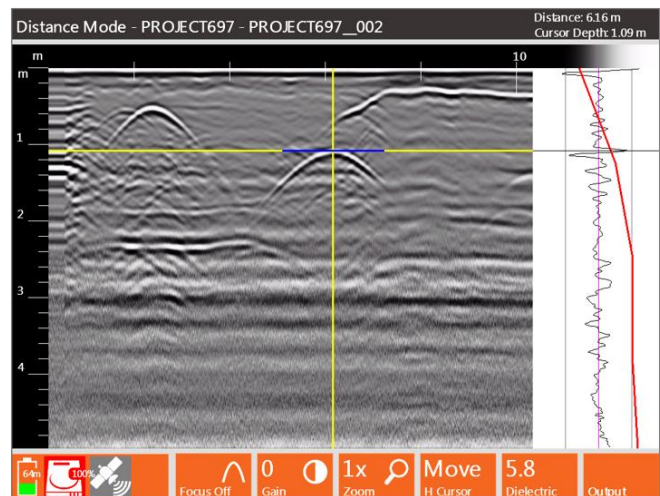
You can add a horizontal cursor to the screen during data collection. The yellow line can be toggled On or Off or moved. When Playback is paused the control button changes to Cursor Dir. This option allows you to use the Control Knob or arrow keys to move either the horizontal or vertical cursors. If repositioned, the cursors will stay in place once playback is resumed.

Positioning the H Cursor during Playback:

- To position H Cursor press the H Cursor control button to change the H Cursor to Move. Then use the Control Knob to adjust its position. Rotate the knob left (counter-clockwise) to move the cursor down the time range. Rotate the knob right (clockwise) to move the cursor up the time range.
- To set the H Cursor press the Control Knob or press Enter. The H Cursor control button will say On.
- To turn the H Cursor off press the H Cursor control button until it says Off.

Positioning the Vertical or Horizontal Cursor during paused Playback:

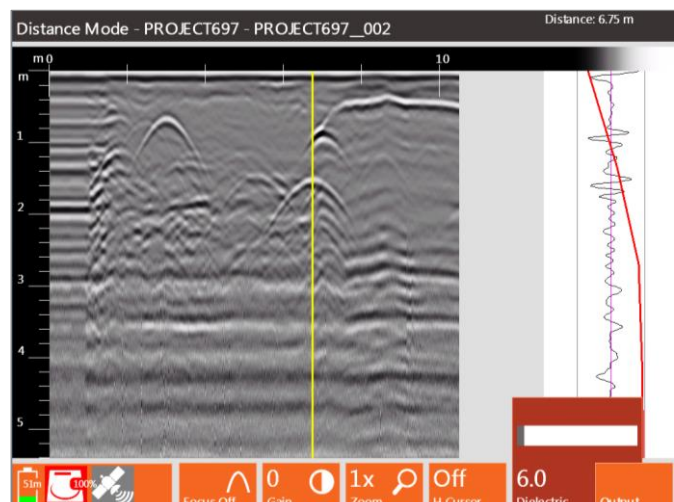
- To position cursors press the Cursor Dir control button to change the cursor to either Vert(ical) or Horiz(ontal). Then use the Control Knob to adjust its position.
- Rotate the knob left (counter-clockwise) to move vertical cursor to the left. Rotate the knob right (clockwise) to move the vertical cursor to the right.
- Rotate the knob left (counter-clockwise) to move the horizontal cursor down the time range. Rotate the knob right (clockwise) to move the cursor up the time range.
- To turn the H Cursor off press the H Cursor control button until it says Off.



Dielectric

You can adjust the Dielectric Constant during playback from a value of one (1) to eighty-one (81).

- Changing the Dielectric Constant will change the vertical scale if it is displayed in depth based on the Time Range selected during setup.

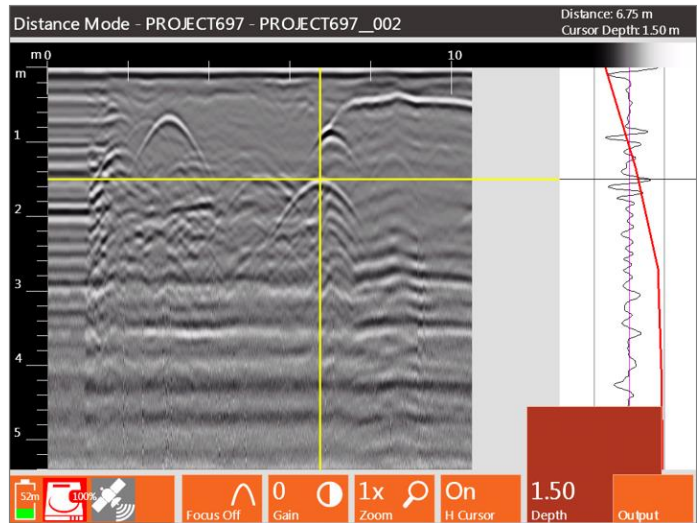


Set Depth

This control button allows you to enter the depth of a known target and automatically adjust the Dielectric Constant. This option is only available when Show Hyperbola is turned off. This can either be done from Setup or while data playback through the Output control button.

- 1** Set Horizontal Cursor (H Cursor) to Move, and the Set Depth button appears. Position the H Cursor at the top of the known target.
- 2** Press the Set Depth control button and the depth value for the position of the H Cursor appears above Set Depth.
- 3** Adjust the depth value using either the Control knob or arrow keys to match the known value.

The vertical scale will change as you adjust the depth value and once the known depth is saved the Dielectric Constant is adjusted.



Output – Distance or Time Mode

This control button opens a menu with options for modifying the data display during playback.

Focus - Distance Mode Only

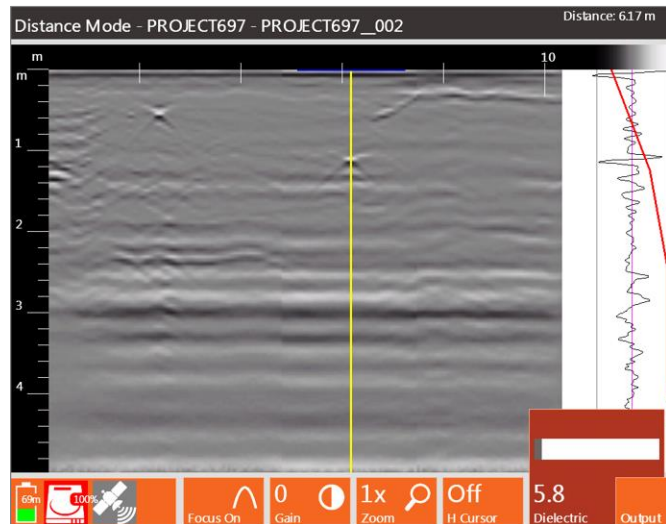
Focus On performs a migration, which is a processing procedure that reduces or eliminates hyperbolic diffraction patterns in the data. It removes the tails of the hyperbolas to more accurately represent the center location of a target. This makes the identification of point reflectors much easier.

Migration also offers a simple and accurate way of estimating the radar velocity (and thus dielectric) of the material your target is in from the shape of the hyperbolas.

- If the dielectric constant is too high when Focus is turned on, hyperbolic reflections will still appear as hyperbolas.
- If the dielectric constant is too low when Focus is turned on, hyperbolic reflections will appear in a “U” shape.
- Adjusting the dielectric, using the Dielectric control button, will change how hyperbolic reflections appear during data collection. The goal is for all hyperbolic reflections to appear as dots.



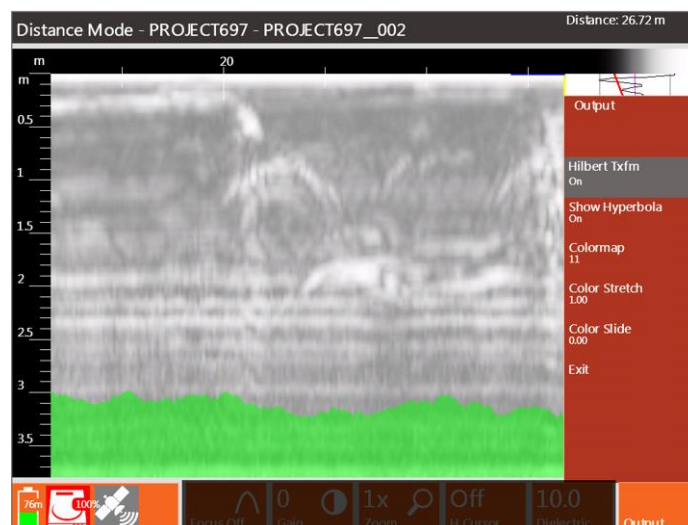
- If you are on a homogenous material, like concrete, this calibration is good for all like material. If you are on soils, know that the Dielectric Constant of the soils can change drastically with depth and across an area, so this is only an approximation.



Hilbert Txfm: A Hilbert Transform is used to display subtle properties of the subsurface. Reflector amplitude and time are the primary types of information in GPR data used to make interpretations. Another way of defining the data is by transforming it into frequency and phase (positive or negative changes in the scan trace). This information is sometimes more sensitive to important subsurface (dielectric) changes in the amplitude or geometric information.

A Hilbert Transform will change a radar signal represented as a time series into its magnitude (via envelope detection) phase). The Hilbert Transform expresses the relationship between the phase and magnitude of the signal, or between its real and imaginary parts. It allows the phase of a signal to be reconstructed from its amplitude.

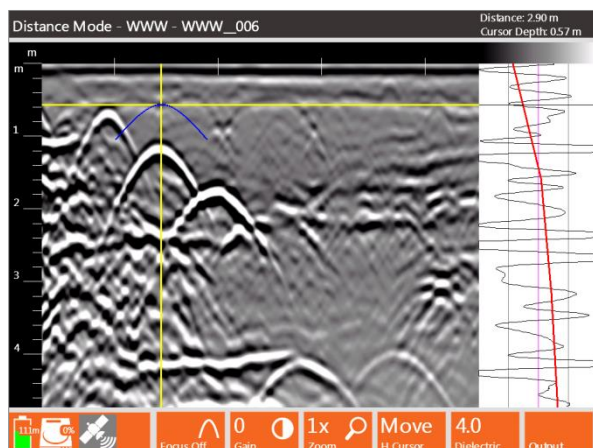
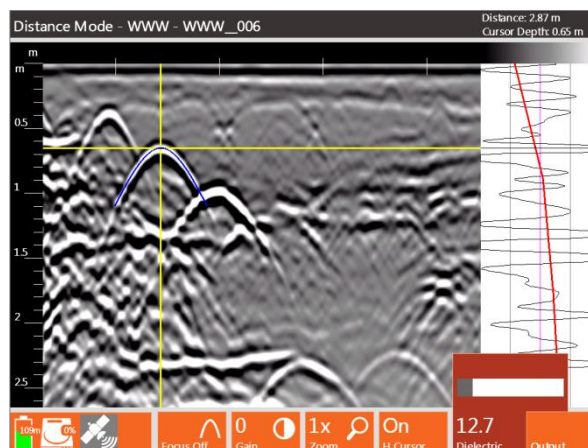
Toggle Hilbert Transform On or Off by pressing the Control Knob or the Enter key.



Show Hyperbola: Toggles a hyperbola On or Off while in setup or during playback. The hyperbola appears at the intersection of the vertical and horizontal cursor. By default the horizontal cursor is placed at the top of the data display.

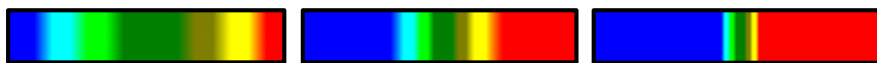
- The hyperbola is used during data collection to do real-time hyperbola fitting. Hyperbola fitting measures the geometry of visible hyperbolas in the data to generate an estimated Dielectric Constant.
- During data collection you'll also have the option to turn the hyperbola On or Off.

Toggle Show Hyperbola On or Off by pressing the Control Knob or the Enter key.



Colormap: This menu option offers 30 available Colormap options (i.e. color tables). Select the menu by pressing the Control Knob or Enter key and then scroll through Colormap #0-29. To preview the different Colormaps, if the O-Scope is not displayed during data collection, return to the Setup Screen > Output Menu.

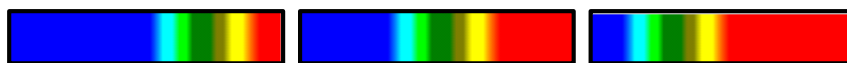
Color Stretch: Selecting Color Stretch allows you to adjust how the selected Colormap is distributed over a scan's amplitude range. A Color Stretch greater than one (1) compresses the colors towards zero (0). A Color Stretch less than one (1) expands the colors towards the maximum negative and positive amplitudes. To preview Color Stretch, if the O-Scope is not displayed during data collection, return to the Setup Screen > Output Menu.



Left Color Stretch = 0; Middle Color Stretch = 1; Right Color Stretch = 3

Color Slide: Selecting Color Slide allows you to shift the center point (point of zero amplitude) of the selected Colormap over a scan's amplitude range. A negative number shifts towards the positive amplitudes and positive number shifts towards the negative amplitudes. To preview Color Slide, if the O-Scope is not displayed during data collection, return to the Setup Screen > Output Menu.

- Adjusting the Color Slide over a particular value range allows you to see more subtle variations in the data.



Left Color Slide = -0.20; Middle Color Slide = 0; Right Color Slide = 0.20

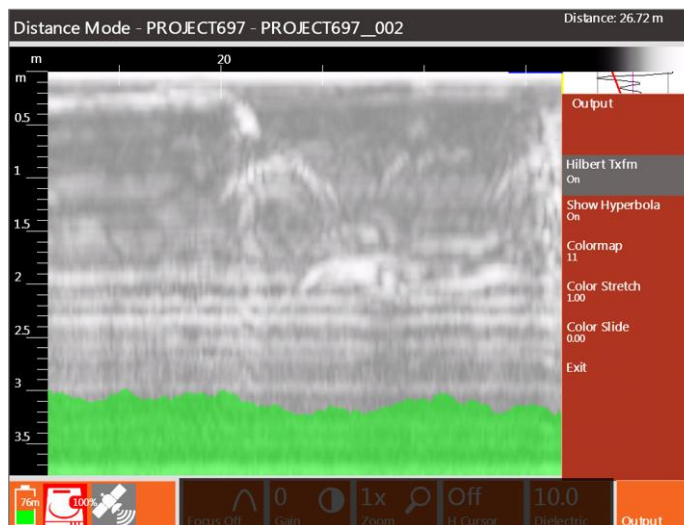
Output - Point Mode

This control button opens a menu with options for modifying the data display during collection.

Hilbert Txfm: A Hilbert Transform is used to display subtle properties of the subsurface. Reflector amplitude and time are the primary types of information in GPR data used to make interpretations. Another way of defining the data is by transforming it into frequency and phase (positive or negative changes in the scan trace). This information is sometimes more sensitive to important subsurface (dielectric) changes in the amplitude or geometric information.

A Hilbert Transform will change a radar signal represented as a time series into its magnitude (via envelope detection) phase). The Hilbert Transform expresses the relationship between the phase and magnitude of the signal, or between its real and imaginary parts. It allows the phase of a signal to be reconstructed from its amplitude.

Toggle Hilbert Transform On or Off by pressing the Control Knob or the Enter key.



Chapter 3: Setting Up Your SIR 4000 for 2D Data Collection and Playback in Expert Mode

In this chapter you will find instructions for configuring your SIR 4000 to collect single 2D profiles of data that can be interpreted by themselves or stacked together in software to produce a 3D image.

The first section of this chapter includes a step-by-step checklist to set up your system. This refers to the software setup only, not the hardware setup. If you are using a survey cart, please see Appendix C for a hardware example, otherwise see section 2.1.

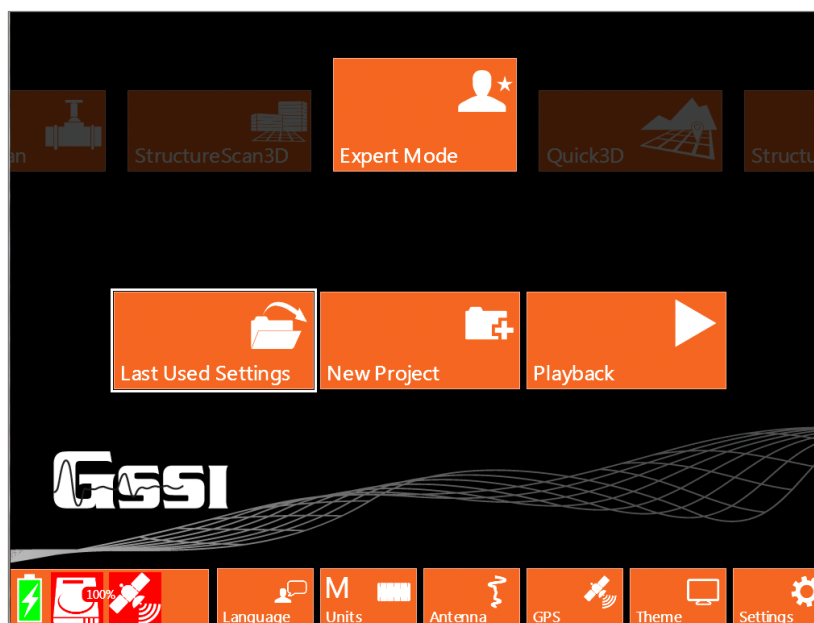
These first two parts also assume that you are collecting distance-based data with a survey wheel. If you are collecting data where the scan spacing is based on time (Time-based), see section 3.3, and if you are collecting single Point data, please see section 3.4.

Note: The largest single profile you can collect is 2 GB.

3.1: Setting Up Distance Mode Data Collection

Step 1 - Introduction Screen

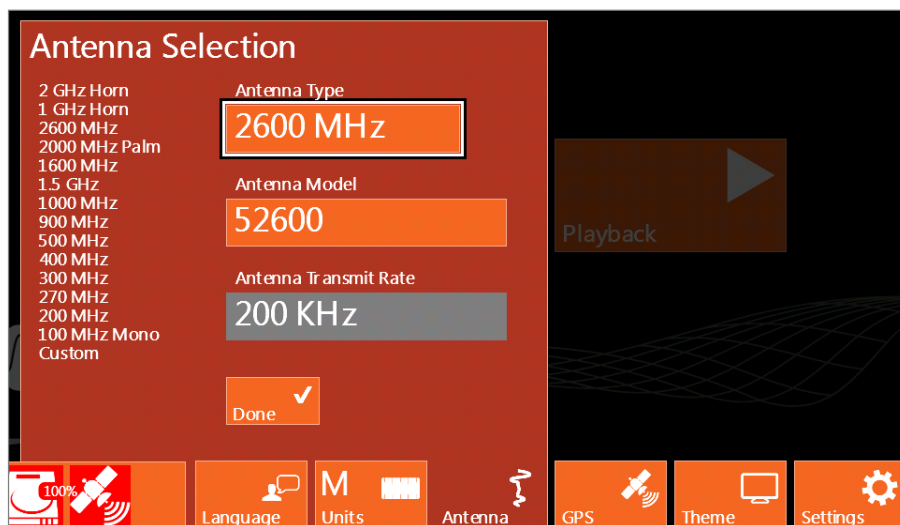
Press the green power button and wait for the SIR 4000 Introduction Screen to appear.



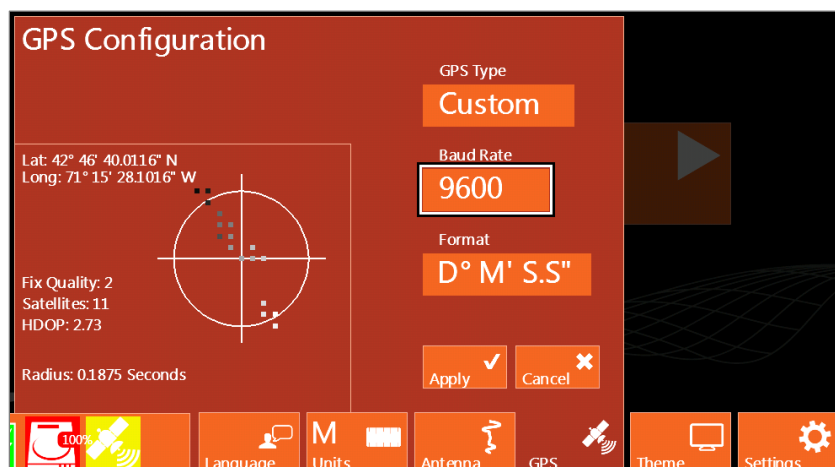
General Settings: Once the Introduction Screen loads verify that you are using the appropriate Language, Units of Measure, and Theme. These options are available in the Toolbar at the bottom of the screen.

Antenna: If an analog antenna without “Smart ID” is connected to the SIR 4000 you can select Antenna from the Toolbar and select the appropriate antenna frequency. If a digital or “Smart ID” antenna is connected that antenna frequency will appear in the Toolbar and you will not have access to the Antenna menu.

- **Select Antenna Type:** Choose an antenna frequency from the list of available frequencies.



GPS: If you want to also collect GPS data, then you'll need to configure the GPS from the Toolbar. Ensure that the GPS is connected to the SIR 4000 and set the baud rate so that the GPS and the SIR 4000 are using the same one. For more information on configuring and trouble-shooting your GPS connection see Chapter 5: Using a GPS with your SIR 4000.



- 1 Select GPS Type:** None is set when a GPS is not connected and Custom if a GPS is connected and needs to be configured.
- 2 Select Baud Rate:** Match the baud rate with the one you are using on your GPS. Available baud rates range from 4800 up to 230400.
- 3 Start:** Press the green Start button on the right side of the SIR 4000 control panel.
- 4 Select Format:** Select which format to use when displaying point, Degrees Minutes Seconds, Degrees Minutes Decimal Minutes, and Decimal Degrees.

Survey Wheel Calibration: If you're switching between different carts or moving from one type of terrain to another you should recalibrate the survey wheel in order to accurately track distance. In order to manually calibrate the antenna, you will need to lay out a measured line on your survey surface. It can be of any length, but the longer the line, the more accurate the calibration.

- 1** Begin by selecting a Survey Wheel Mode: Quadrature or Pulse.
- 2** Select calibration distance – The default distance is 10 meters or feet. However this distance can be changed. The longer the calibration distance the more accurate the calibration should be.
- 3** Position Antenna on the Start mark – The antenna or system can be positioned anywhere at the start as long as you use the same point on the antenna or system when you stop.
- 4** Press the Start button – This is the green Start button located on the keypad of the SIR 4000.
- 5** Move antenna to the stop mark – This should match the same location on the antenna or system where you started.
- 6** Press Stop button – This is the red Stop button located on the keypad of the SIR 4000.

If desired you can enter the calibration value in manually.

- 1** Use either the Control Knob or Arrow keys to navigate to the New Calibration Value box.

- 2** Press the Control Knob of the Enter key to highlight the New Calibration Value box.
- 3** Rotate the Control Knob or use the up and down arrows to enter in the correct value.
- 4** Click the right arrow to save and exit.

Once the desired survey wheel calibration is achieved select Apply. The current value will be saved and the Calibrate SW menu will close. Press the Quit Toolbar key to return to the main Introduction Screen.

Expert Mode: Select Expert Mode from the rotating list at the top of the Introduction Screen.

New Project: Select New Project and enter in a new Project Name. This will be the name of the folder where all of your files will be stored and the default name of the files as well. Once you provide a name and press Apply you will automatically leave the Introduction Screen and enter the Collect Setup Screen.

Step 2 – Expert Mode Setup

Once a new project is created you will see a split screen with the main data display window on the left, the O-Scope window in the center, and the Setup menu on the right.

There are four (4) main menus in the Setup Menu: Radar, Process, Output, and System. To get started collecting data you'll need to check or adjust settings in all four (4) menus.

Recall Setup

If you've previously saved a setup that you want to use then you should recall it first before making any changes. Otherwise when you do recall the setup it will overwrite any of your changes with those that were saved. Setups can either be uniquely named or you can use one of the sixteen (16) available setup names.

- 1 Open the System Menu and select Recall Setup.
- 2 Select your saved setup from the list using either the Control knob or arrow keys. Once the desired setup is highlighted press either the Control knob or Enter button.

Radar Menu

- 1 **Collect Mode:** Set to Distance.
- 2 **Dielectric/Soil Type:** Choose a Dielectric Constant or Soil Type that best represents the area you are surveying. For a list of Dielectric Constants see Appendix D: Dielectric Values for Common Materials.
- 3 **Depth/Time Range:** There are two options for setting the depth or time range.
 - **Full Range:** With the system in Collect Setup mode and data scrolling across the screen, drag the antenna over the area. As you do so watch the scan trace displayed in the O-Scope window. When the scan trace gets to a depth/time where there is more noise, or interference, than signal strength, you'll see the scan trace jump from negative to positive and appear craggy. To setup the system so that you're collecting the maximum range of data possible you'll want to see some of that noise in the scan trace. If no noise is apparent then you should increase your depth or time range until about 25% of the scan trace consists of noise. The noise to signal ratio will change as you move across your survey area. So keeping some noise on the screen will help ensure that you always collect the full range of quality signal.
 - **Target Specific:** With the system in Collect Setup mode and data scrolling across the screen, drag the antenna over the area and find a target that you want to image. Note its position on the screen and at what time/depth it occurs. Ideally, it should be halfway down the screen so that you can image targets above and below it. If it is not properly located, change the depth or time range.
- 4 **Scans/Unit:** Generally you need a minimum of 10 scans to draw a recognizable hyperbola. The rule of thumb is to have 10 scans divided by the depth of the shallowest object. So if you want to image something 10 feet deep, $10 \text{ scans} / 10 \text{ feet} = 1 \text{ scan/foot}$. For 5 feet deep, $10 \text{ scans} / 5 \text{ feet} = 2 \text{ scans/foot}$.
 - For locating structural features in concrete with the 1.5/1.6 GHz antenna, we usually recommend 90 scans/ft. For utility and tank location, we usually recommend 6-24 scans/ft. While this is more than the minimum rule of thumb, GSSI has found these densities work well in the widest variety of situations.

Process Menu

- 1 **Gain Mode and Edit Gain Curve:** The thin, red line superimposed over the scan in the O-Scope window is the gain curve. The centerline of the scan is zero and to the left of it is negative (decreasing gain) and the right is positive (increasing gain). Gain is applied in dB along an exponential function to model signal loss. Your goal should be to have a gain curve that creates a scan trace with balanced amplitude changes from top to bottom.

- **Select Auto Gain Mode:** If Auto Gain Mode is already selected you can press the Init control button at the bottom of the screen to apply an automatic gain curve to the current scan trace. This will cause the system to re-initialize and add/subtract gain to produce a visible signal. Drag the antenna over the area and look for evidence of clipping. If your data becomes clipped, leave the antenna over the area where it is occurring and re-initialize by pressing the Init control button. This will decrease the gains so that the data will not clip.
- If you plan to collect multiple profiles and wish to compare them, it is usually best to set the gain to Manual Gain Mode, once you find gain settings which are workable (you can see targets and the signal does not clip).
- If you are performing real-time locating, then leaving the Gain Mode set to Auto will allow you to use Init when your signal quality changes between profiles.
- **Edit Gain Curve:** If portions of the signal are under- or over-gained after using Auto Gain Mode, you can try increasing or decreasing the number of gain points. The number of gain points selected are evenly distributed along the scan trace and changing the number of points can change where along the scan trace amplification is increased or decreased.
 - Select Edit Gain Curve.
 - Add or erase points to modify the gain curve.
 - Save and Exit to return to the Collect Setup screen.

Output Menu

- 1 Scale and Units:** Verify that you are using the appropriate vertical scale, vertical units, and horizontal units.
- 2 Colormap, Color Stretch, and Color Slide:** Check that you are using your preferred color scale settings.

System Menu

- 1 AutoSave:** How you set this is based upon whether or not you want to save all of the files you collect or be selective. With AutoSave turned on you'll automatically save every profile.
 - If performing real-time locating turning this to On may be beneficial as it will decrease the number of selections you have to make to clear your screen.
 - If collecting individual profiles to build into a 3D grid using the software it is recommended to turn AutoSave Off. As you finish collecting one line this pauses data collection while you get in position to start the next line.
- 2 Save Setup:** Once you've made all of the modifications to the settings listed above it's a good idea to save your setup. This way you can recall it later if you have to restart the system or if you know you'll use these settings on a regular basis.

Step 3 – Data Collection

- 1** To begin data collection press the green Start button one time.
- 2** At the end of your profile, press the red Stop button one time or press and hold the green Start button. This halts the collection of the current data file; you now won't be able to scroll across the profile or perform any of the functions on the command bar.

- If AutoSave is set to On the file will automatically be saved. And a new file will immediately begin using the same collection parameters as the previous file.
 - If AutoSave is set to Off a system prompt will pop up giving you the option to save or discard the file. Choose to save or discard using the Control knob or the Directional Keys.
- 3** To continue data collection after choosing to save or discard a file, position yourself at the beginning of your next profile. Then press the green Start button one time to begin the next data file. The previous data will be cleared and a new file opened. New files will be collected with the same collection parameters as the previous file.
- 4** To return to the Collect Setup screen if AutoSave is set to On, push and hold down the red Stop button for two seconds. The current file will automatically be saved and you will return to the Collect Setup screen. If AutoSave is set to Off, press the red Stop button one time. A system prompt will pop up giving you the option to save or discard the current file. Once an option has been selected push and hold down the red Stop button for two seconds and you will return to the Collect Setup screen.

3.2: Setup for Single Line 3D Collection in Expert Mode

Follow these instructions if you want to build a 3D area out of multiple individual survey profiles. You will save each profile as a different file and create the 3D project in RADAN's 3D Module.

Step 1 – Distance Mode Setup

Follow all the above steps for 2D Distance Mode setup in order to set your SIR 4000 to local conditions and antenna choice. The following setup options are also recommended for single line 3D collection.

Position: Set Position to Manual under the Radar Menu. This will ensure that you do not accidentally auto-position over different ground surface conditions while collecting, which makes it impossible to compare depth or time between multiple profiles.

Gain: After you have set the gains so that you are not clipping, set Gain under the Process Menu to Manual. This will ensure that you do not accidentally auto-gain over a different area while collecting. Gaining over a different area will produce data that is 'mosaicked.' Gain differences will mask features and create edge-effects.

Select Datapath: It is recommended to create separate datapaths if collecting a bi-directional 3D grid. Create a folder for files collected in the X-direction and a new folder when you start to collect files in the Y-direction.

AutoSave: Set AutoSave to Off. This will pause the system between profiles allowing you to reposition the antenna to start the next profile.

Step 2 – Grid Setup

You must lay out your survey grid so that you can cross your targets with at least 3 profiles. Three profiles will allow you to tell the difference between a point target and a linear target. For example, if you are looking for graves 2 meters in length, your survey profiles should be spaced no more than 0.5 m apart, and try to orient your survey grid so that you cross the graves perpendicular to their long axis in order to have the greatest possibility of hitting them. If you have targets moving in multiple directions then you should plan to survey the grid twice; once in the X-direction and once in the Y-direction.

Your grid length should be evenly divisible by your line spacing. For example, for a 30 m by 30 m grid your lines in either the X- or Y-directions can be 0.5 m, 1 m, or 2 m apart, but they cannot be 4 m apart.

Step 3 – Takes Notes

In order for your data to be properly positioned in RADAN, you must be able to tell the software your survey grid origin, line direction, and line orientation. You may begin your survey in any corner of the grid and survey either in one direction, or zig-zig (i.e., back and forth). Be sure to keep accurate notes showing the location of each file in relation to other files and immovable objects. You will assemble the 3D project in RADAN with the 3D Module after downloading the data to a PC.

Step 4 – Data Collection

Collect each survey profile as a separate file.

- 1** Position the antenna so that the center of the antenna is located on the baseline of your grid. The antenna has black lines on it that mark the center or if you're using one of the 4-wheel carts there are lines on the black frame of the cart marking the center.
- 2** To begin data collection, press the green Start button one time.
- 3** At the end of each profile, press the red Stop button one time. You will be prompted to save the file. Before saving the file. Reposition your antenna so that it is in place to begin collecting the next profile. Once the antenna is in position select Save.
- 4** Repeat steps 1-3 until finished with the first direction of the grid.
- 5** At the end of your last profile in each direction, push and hold down the red Stop button to stop data collection and return to the Collect Setup screen. The profile will be saved and can be viewed in Playback mode.
- 6** If collecting a bi-directional 3D grid, create a new datapath and then repeat steps 1-5 in the new direction.

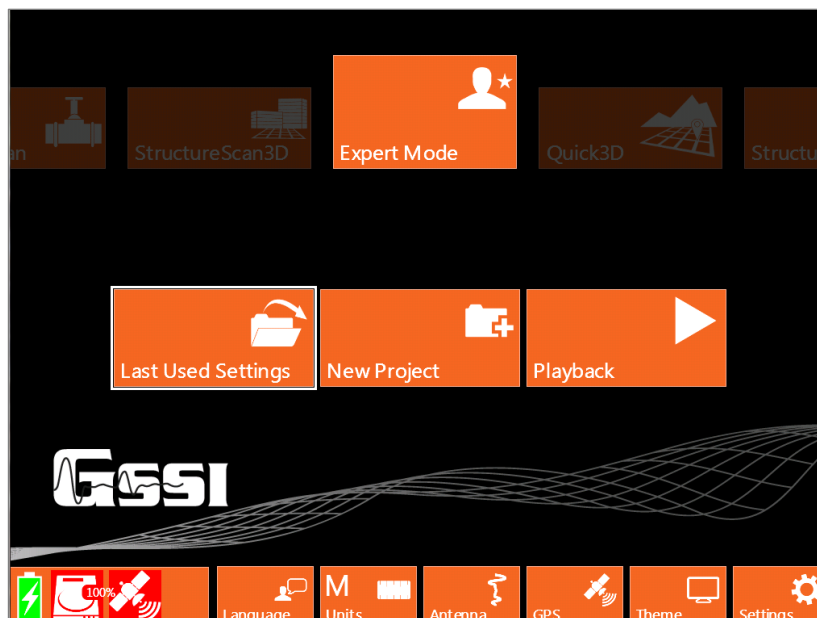
3.3: Setting Up for Time Mode Data Collection

The scan spacing (horizontal resolution) of Time-based data profiles is a function of the speed that the system is collecting data (Scans/Second) and the rate the antenna is moving over the survey surface. The higher you set the Scans/Second and the slower you move the antenna, the denser the data will be.

Time-based data has no real distance tag, so the software has no idea how far you actually traveled. It is extremely important to move the antenna at a constant speed and to add user marks (by clicking the mark button) at consistent intervals. Time-based data requires additional processing in RADAN to create a 3D image. If 3D imaging is your goal, it is ideal to collect Distance based data with a survey wheel.

Step 1 – Introduction Screen

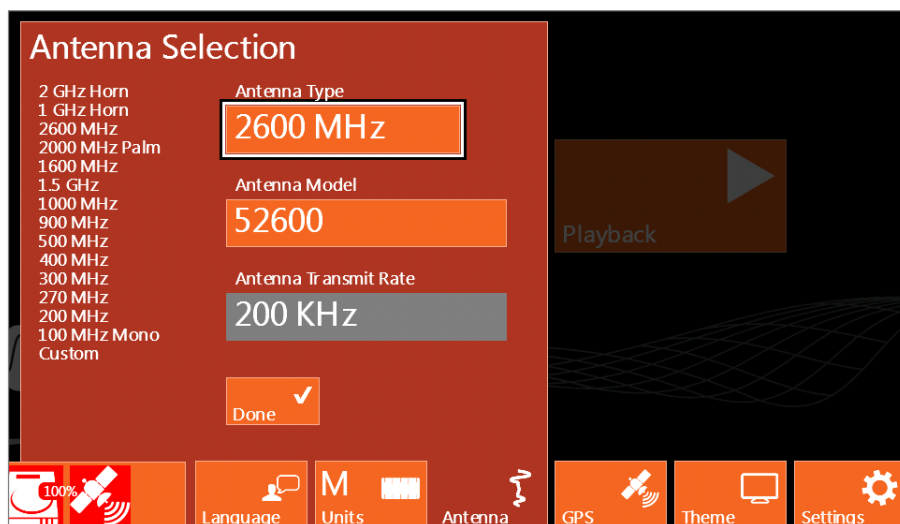
Press the green power button and wait for the SIR 4000 Introduction Screen to appear.



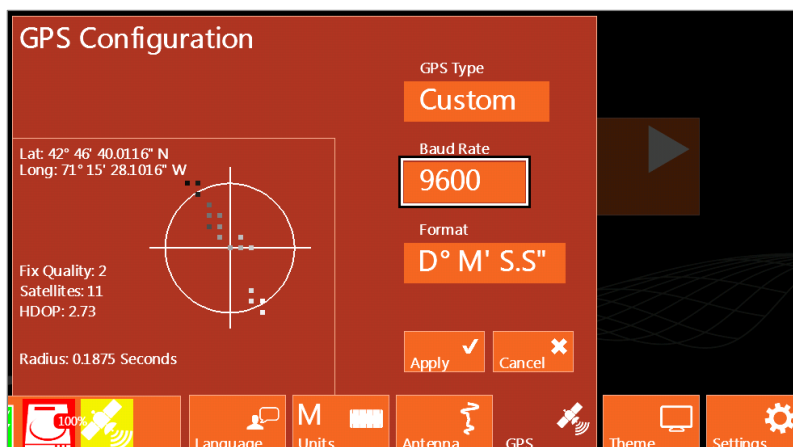
General Settings: Once the Introduction Screen loads verify that you are using the appropriate Language, Units of Measure, and Theme. These options are available in the Toolbar at the bottom of the screen.

Antenna: If an older analog antenna is connected to the SIR 4000 you can select Antenna from the Toolbar and select the appropriate antenna frequency. If a digital or “Smart ID” antenna is connected that antenna frequency will appear in the Toolbar and you will not have access to the Antenna menu.

- **Select Antenna Type:** Choose an antenna frequency from the list of available frequencies.



GPS: If you want to also collect GPS data, then you'll need to configure the GPS from the Toolbar. Ensure that the GPS is connected to the SIR 4000 and set the baud rate so that the GPS and the SIR 4000 are the same. For more information on configuring and trouble-shooting your GPS connection see Chapter 5: Using a GPS with your SIR 4000.



- 1 Select GPS Type:** None is set when a GPS is not connected and Custom if a GPS is connected and needs to be configured.
- 2 Select Baud Rate:** Match the baud rate with the one you are using on your GPS. Available baud rates range from 4800 up to 230400.
- 3 Select Format:** Select which format to use when displaying point, Degrees Minutes Seconds, Degrees Minutes Decimal Minutes, and Decimal Degrees.
- 4 Expert Mode:** Select Expert Mode from the rotating list at the top of the Introduction Screen.
- 5 New Project:** Select New Project and enter in a new Project Name. This will be the name of the folder where all of your files will be stored and the default name of the files as well. Once you provide a name and press Apply you will automatically leave the Introduction Screen and enter the Collect Setup Screen.

Step 2 – Expert Mode Setup

Once a new project is created you will see a split screen with the main data display window on the left, the O-Scope window in the center, and the Setup menu on the right.

There are four (4) main menus in the Setup Menu: Radar, Process, Output, and System. To get started collecting data you'll need to check or adjust settings in all four (4) menus.

Recall Setup

If you've previously saved a setup that you want to use then you should recall it first before making any changes. Otherwise when you do recall the setup it will overwrite any of your changes with those that were saved. Setups can either be uniquely named or you can use one of the sixteen (16) available setup names.

- 1** Open the System Menu and select Recall Setup.
- 2** Select your saved setup from the list using either the Control knob or arrow keys. Once the desired setup is highlighted press either the Control knob or Enter button.

Radar Menu

- 1 Collect Mode:** Set to Time.
- 2 Dielectric/Soil Type:** Choose a Dielectric Constant or Soil Type that best represents the area you are surveying. For a list of Dielectric Constants see Appendix D: Dielectric Values for Common Materials.
- 3 Depth/Time Range:** There are two options for setting the depth or time range.
 - **Full Range:** With the system in Collect Setup mode and data scrolling across the screen, drag the antenna over the area. As you do so watch the scan trace displayed in the O-Scope window. When the scan trace gets to a depth/time where there is more noise, or interference, than signal strength, you'll see the scan trace jump from negative to positive and appear craggy. To setup the system so that you're collecting the maximum range of data possible you'll want to see some of that noise in the scan trace. If no noise is apparent then you should increase your depth or time range until about 25% of the scan trace consists of noise. The noise to signal ratio will change as you move across your survey area. So keeping some noise on the screen will help ensure that you always collect the full range of quality signal.
 - **Target Specific:** With the system in Collect Setup mode and data scrolling across the screen, drag the antenna over the area and find a target that you want to image. Note its position on the screen and at what time/depth it occurs. Ideally, it should be halfway down the screen so that you can image targets above and below it. If it is not properly located, change the depth or time range.
- 4 Scans/Second:** Your data density depends on the rate you move the antenna over the survey surface. Typically this value is set much lower than the maximum.
- 5 Units/Mark:** You can also set how many units (feet or meters) will be collected between system marks.

Process Menu

- 1 Gain Mode and Edit Gain Curve:** The thin, red line superimposed over the scan in the O-Scope window is the gain curve. The centerline of the scan is zero and to the left of it is negative (decreasing gain) and the right is positive (increasing gain). Gain is applied in dB along an exponential function to model signal loss. Your goal should be to have a gain curve that creates a scan trace with balanced amplitude changes from top to bottom.
 - **Select Auto Gain Mode:** If Auto Gain Mode is already selected you can press the Init control button at the bottom of the screen to apply an automatic gain curve to the current scan trace. This will cause the system to re-initialize and add/subtract gain to produce a visible signal. Drag the antenna over the area and look for evidence of clipping. If your data becomes clipped, leave the antenna over the area where it is occurring and re-initialize by pressing the Init control button. This will decrease the gains so that the data will not clip.
 - If you plan to collect multiple profiles and wish to compare them, it is usually best to set the gain to Manual Gain Mode, once you find gain settings which are workable (you can see targets and the signal does not clip).
 - If you are performing real-time locating, then leaving the Gain Mode set to Auto will allow you to use Init when your signal quality changes between profiles.

- **Edit Gain Curve:** If portions of the signal are under- or over-gained after using Auto Gain Mode, you can try increasing or decreasing the number of gain points. The number of gain points selected are evenly distributed along the scan trace and changing the number of points can change where along the scan trace amplification is increased or decreased.
 - Select Edit Gain Curve.
 - Add or erase points to modify the gain curve.
 - Save and Exit to return to the Collect Setup screen.

Output Menu

- 1 Scale and Units:** Verify that you are using the appropriate vertical scale, vertical units, and horizontal units.
- 2 Colormap, Color Stretch, and Color Slide:** Check that you are using your preferred color scale settings.

System Menu

- 1 AutoSave:** How you set this is based upon whether or not you want to save all of the files you collect or be selective. With AutoSave turned on you'll automatically save every profile.
 - If performing real-time locating turning this to On may be beneficial as it will decrease the number of selections you have to make to clear your screen.
 - If collecting individual profiles to build into a 3D grid using the software it is recommended to turn AutoSave Off. As you finish collecting one line this pausing data collection while you get in position to start the next line.
- 2 Save Setup:** Once you've made all of the modifications to the settings listed above it's a good idea to save your setup. This way you can recall it later if you have to restart the system or if you know you'll use these settings on a regular basis.

Step 3 – Data Collection

- 1** To begin data collection, press the green Start button one time. The SIR 4000 will instantly begin collecting scans at the rate specified during setup. Scans will fill the screen from left to right.
- 2** If adding user marks during collection to correct distance in RADAN, press the Mark button at the appropriate interval.
 - For example, if collecting single lines to build a 3D grid in RADAN, add a user mark when the antenna crosses the baselines to indicate the beginning and end of each line.
- 3** At the end of your profile, press the red Stop button one time or press and hold the green Start button. This halts the collection of the current data file; you now won't be able to scroll across the profile or perform any of the functions on the command bar.
 - If AutoSave is set to On the file will automatically be saved. And a new file will immediately begin using the same collection parameters as the previous file.
 - If AutoSave is set to Off a system prompt will pop up giving you the option to save or discard the file. Choose to save or discard using the Control knob or the Directional Keys.

- 4** To return to the Collect Setup screen if AutoSave is set to On, push and hold down the red Stop button for two seconds. The current file will automatically be saved and you will return to the Collect Setup screen. If AutoSave is set to Off, press the red Stop button one time. A system prompt will pop up giving you the option to save or discard the current file. Once an option has been selected push and hold down the red Stop button for two seconds and you will return to the Collect Setup screen.

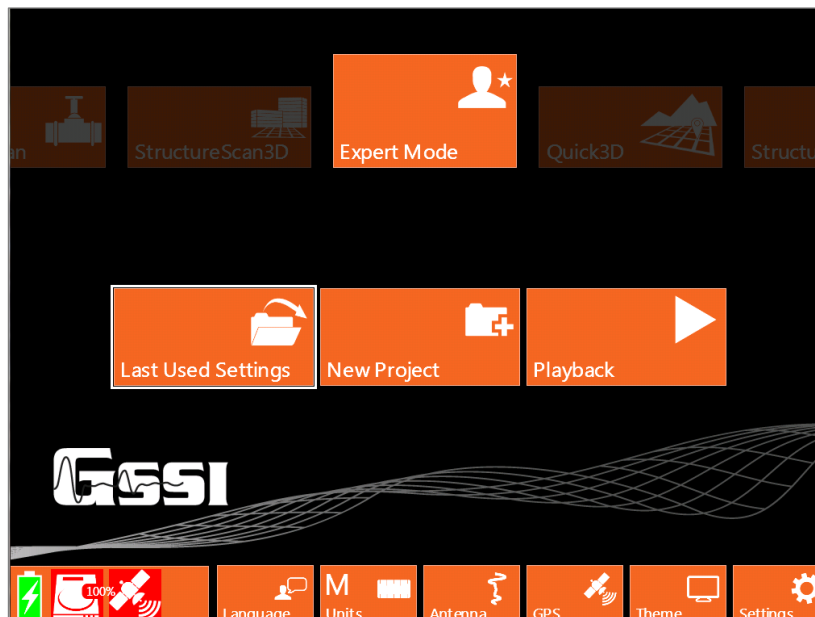
3.4: Setting Up for Point Mode Data Collection

The third data collection mode on the SIR 4000 is for Point mode data collection. This mode is most useful for deep geophysical investigations or data collection over difficult, broken terrain.

In Point mode, we are recording single scans over an area. The scan spacing (horizontal resolution) of Point-based data profiles is a function of how far apart you set your collection points.

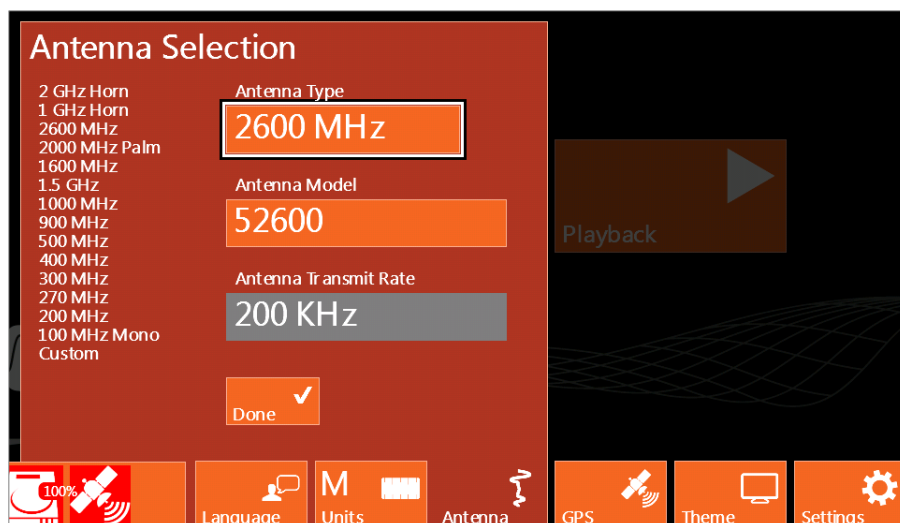
Step 1 – Introduction Screen

Press the green power button and wait for the SIR 4000 Introduction Screen to appear.



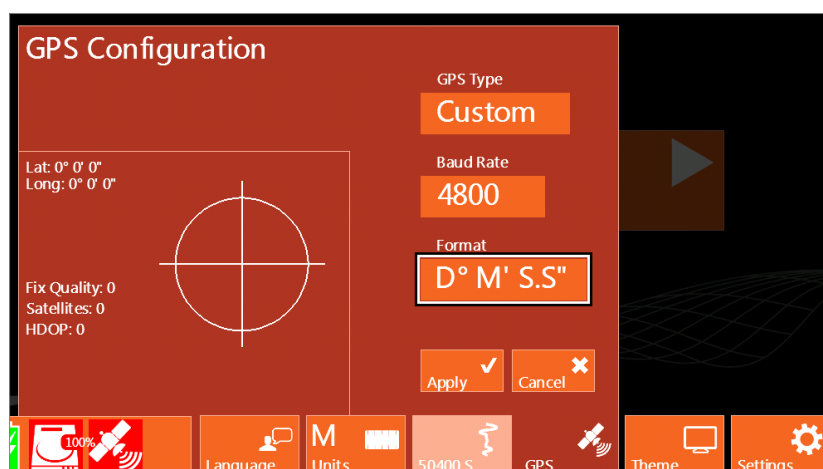
General Settings: Once the Introduction Screen loads verify that you are using the appropriate Language, Units of Measure, and Theme. These options are available in the Toolbar at the bottom of the screen.

Antenna: If an older analog antenna is connected to the SIR 4000 you can select Antenna from the Toolbar and select the appropriate antenna frequency. If a digital or “Smart ID” antenna is connected that antenna frequency will appear in the Toolbar and you will not have access to the Antenna menu.



Select Antenna Type: Choose an antenna frequency from the list of available frequencies.

GPS: If you want to also collect GPS data, then you'll need to configure the GPS from the Toolbar. Ensure that the GPS is connected to the SIR 4000 and set the baud rate so that the GPS and the SIR 4000 are the same. For more information on configuring and trouble-shooting your GPS connection see Chapter 5: Using a GPS with your SIR 4000.



- 1 Select GPS Type:** None is set when a GPS is not connected and Custom if a GPS is connected and needs to be configured.
- 2 Select Baud Rate:** Match the baud rate with the one you are using on your GPS. Available baud rates range from 4800 up to 230400.
- 3 Select Format:** Select which format to use when displaying point, Degrees Minutes Seconds, Degrees Minutes Decimal Minutes, and Decimal Degrees.
- 4 Expert Mode:** Select Expert Mode from the rotating list at the top of the Introduction Screen.
- 5 New Project:** Select New Project and enter in a new Project Name. This will be the name of the folder where all of your files will be stored and the default name of the files as well. Once you provide a name and press Apply you will automatically leave the Introduction Screen and enter the Collect Setup Screen.

Step 2 – Expert Mode Setup

Once a new project is created you will see a split screen with the main data display window on the left, the O-Scope window in the center, and the Setup menu on the right.

There are four (4) main menus in the Setup Menu: Radar, Process, Output, and System. To get started collecting data you'll need to check or adjust settings in the first three (3).

Recall Setup

If you've previously saved a setup that you want to use then you should recall it first before making any changes. Otherwise when you do recall the setup it will overwrite any of your changes with those that were saved. Setups can either be uniquely named or you can use one of the sixteen (16) available setup names.

Radar Menu

- 1 Collect Mode:** Set to Point.
- 2 Dielectric/Soil Type:** Choose a Dielectric Constant or Soil Type that best represents the area you are surveying. For a list of Dielectric Constants see Appendix D: Dielectric Values for Common Materials.
- 3 Depth/Time Range:** There are two options for setting the depth or time range.
 - **Full Range:** With the system in Collect Setup mode and data scrolling across the screen, drag the antenna over the area. As you do this watch the scan trace displayed in the O-Scope window. When the scan trace gets to a depth/time where there is more noise, or interference, than signal strength, you'll see the scan trace jump from negative to positive and appear craggy. To setup the system so that you're collecting the maximum range of data possible you'll want to see some of that noise in the scan trace. If no noise is apparent then you should increase your depth or time range until about 25% of the scan trace is made up of noise. The noise to signal ratio will change as you move across your survey area. So keeping some noise on the screen will help ensure that you always collect the full range of quality signal.
 - **Target Specific:** With the system in Collect Setup mode and data scrolling across the screen, drag the antenna over the area and find a target that you want to image. Note its position on the screen and at what time/depth it occurs. Ideally, it should be halfway down the screen so that you can image targets above and below it. If it is not properly located, change the range under the Scan menu.
- 4 Scans/Unit:** This is the number of scans that will be collected every foot or meter. This number will affect how the horizontal scale is displayed during data collection.

Process Menu

- 1 Gain Mode and Edit Gain Curve:** The thin, red line superimposed over the scan in the O-Scope window is the gain curve. The centerline of the scan is zero and to the left of it is negative (decreasing gain) and the right is positive (adding gain). Gain is applied in dB along an exponential function to model signal loss. Your goal should be to have a gain curve that creates a scan trace with balanced amplitude changes from top to bottom.

- **Select Auto Gain Mode:** If Auto Gain Mode is already selected you can press the Init Command key at the bottom of the screen to apply an automatic gain curve to the current scan trace. This will cause the system to re-initialize and add/subtract gain to produce a visible signal. Drag the antenna over the area and look for evidence of clipping. If your data becomes clipped, leave the antenna over the area where it is occurring and re-initialize by pressing the Init Command key. This will decrease the gains so that the data will not clip.
- If you plan to collect multiple profiles and wish to compare them, it is usually best to set the gain to Manual Gain Mode, once you find gain settings which are workable (you can see targets and the signal does not clip).
- If you are performing real-time locating, then leaving the Gain Mode set to Auto will allow you to use Init when your signal quality changes between profiles.
- **Edit Gain Curve:** If using Auto Gain Mode still leaves portions of the signal under-gained, you can try increasing or decreasing the number of gain points. The number of gain points selected are evenly distributed along the scan trace and changing the number of points can change where along the scan trace amplification is increased or decreased.
 - Set Gain Mode to Manual.
 - Select Edit Gain Curve.
 - Add or erase point to modify the gain curve.
 - Save and Exit to return to the Collect Setup screen.

2 Static Stacking: Point data is typically collected with some static stacking. A good default value here is 64. The system will take 64 scans at each scan location and average them together to output a single scan. This is done to minimize high-frequency, random noise.

Output Menu

- 1 Scale and Units:** Verify that you are using the appropriate vertical scale and units. The horizontal scale will appear in number of scans during collection.
- 2 Spacing, Amplitude, and Fill:** Check that you are using your preferred display settings for Point Mode.

Step 3 – Data Collection

- 1** To begin data collection press the green Start button one time.
- 1** The screen will appear with one scan trace already collected on the left side of the data display screen and the rest of the data display will be blank.
- 2** Press the Next Point control button to collect subsequent scans. The Scan number will update in the Information Bar at the top of the screen as additional scans are added.
- 3** At the end of your profile, press and hold the red Stop button for two seconds. If AutoSave is set to On the profile will be saved and you will return to the Collect Setup menu. If AutoSave is set to Off a system prompt will pop up giving you the option to save or discard the current file. Once an option has been selected press and hold down the red Stop button again and you will return to the Collect Setup screen.

3.5: Playing Back Collected Data

You can playback and review data collected in either Distance, Time, or Point Mode. Playback can be accessed either from the Introduction Screen by selecting Playback or from the Collect Setup screen by pressing the Play Mode control button. Either method will open a list of files stored in the currently selected folder.

- 1** Use the Control Knob or Arrow keys to navigate through the list.
- 3** Select a file or files to Playback by pressing with the Control Knob.
- 4** Once you've made your selections press the Enter key to open the selected files. The selected files will scroll across the screen in numerical order.
- 5** When the file scrolls across that you wish to view in full screen, press the green Start button. This will open the Playback Screen with only the current file displayed.
- 6** The file will scroll across to the end and you can pause and resume the scroll using the Pause/Resume control buttons.

Chapter 4: Data Transfer and File Maintenance

This section describes how to transfer data from the SIR 4000 to a PC for processing and interpretation, and also how to clear unwanted data from the system's memory. These functions are all accomplished under the Play Mode control button.

4.1: Transfer to a PC via a USB Memory Stick

- 1** Turn on SIR 4000 or if already running stop all collection and playback functions prior to continuing.
- 2** Insert USB memory stick.
- 3** Select Playback from either the Introduction or Setup screens. This opens whichever folder was last used during data collection. If the data you want to transfer is in a different folder press the Choose Path control button and select a different project folder.
- 4** Select the files you wish to transfer using the Control knob to navigate and by pressing the Control Knob to select a file. You can select multiple files from the list.
- 5** To copy the files select the Copy to USB control button. This will place a copy of the selected files onto the USB memory stick and maintain a copy on the SIR 4000 internal memory. A progress bar will appear on the screen showing the status of the copied files.
- 6** To copy the files to the USB memory stick and remove them from the SIR 4000 press the Move to USB Command key. A progress bar will appear on the screen showing the status of the copied files.

4.2: Deleting Data from the System

While it is always advisable to keep the data on your system until you have transferred it (if desired) and checked the integrity of the data, eventually the memory may fill up or you may simply want to do some 'housecleaning.'

Deleting Individual Files

- 1** In order to delete files you need to open up the file list. You can do this from three places.
 - a)** From the Introduction Screen select Playback. This opens whichever folder was last used during data collection. To select a different datapath you'll need to select Last Project and change the Datapath under the Output Menu.
 - b)** From the Collect Setup Screen select the Play Mode Command key. This opens the current folder and displays files available for playback or that you can delete.
 - c)** From the Playback Setup Screen select Select File. This opens the current folder and displays files available for playback or that you can delete.
- 2** Select the files you wish to delete.
- 3** Press the Delete Files control button. A progress bar will appear on the screen showing the status of the copied files.

Deleting Project Folders

- 1** From either the Collect or Playback Setup screen open Output > Select Datapath.
- 2** Select the data path you wish to delete.
- 3** Press the Delete Path control button. A progress bar will appear on the screen showing the status of the copied files.

Chapter 5: Using a GPS with your SIR 4000

Your SIR 4000 is capable of attaching GPS coordinates to individual data profiles. This will allow you to place your survey lines into a larger, real-world coordinate system provided that you have a GPS with sufficient accuracy for your application. RADAN 7 will then be able to show coordinates with a GPR X, Y, and Z.

GSSI has specific integration information as a series of Technical Notes available on the GSSI Technical Support website at <http://support.geophysical.com>.

The GPS you do choose must have the following:

1. Provide data output through a serial (RS232) port.
2. Output data at a baud rate ranging from 4800 to 230400.
3. Output the NMEA GGA data string.

East vs. West. The SIR 4000 is set to capture Latitude and Longitude coordinates rather than UTM. It does not however tag a North/South or East/West to those numbers. If you are west of the Prime Meridian, the Longitude will be negative and if you are south of the Equator, the Latitude will be negative.

5.1: Attaching a GPS

- 1** Try your GPS to determine if you are getting a good position and an adequate number of satellites.
- 2** Power up your SIR 4000 and connect the GPS to the serial port on the control unit.
- 3** From the Introduction Screen select GPS from the Toolbar and check the following settings. Once a GPS connection is verified Apply the settings.
 - **GPS Type:** Select Custom as the GPS Type.
 - **Baud Rate:** Choose a Baud Rate that matches the one set on the GPS unit.
 - **Start:** Press the green Start button on the right side of the control unit.
 - **Format:** Choose a format for viewing the data during collection and playback.
- 4** When you start collecting a file, the SIR 4000 will capture a GPS coordinate and place it in the file header. It will do the same every three (3) seconds as long as you are collecting data and the HDOP (Horizontal Dilution of Precision) is two (2) or less. These coordinates will be visible in the Tables Pane of RADAN 7.

5.2: Understanding GPS

This is a brief description of GPS and how to use it with our SIR 4000. GPS information gets attached to the data as a *.DZG file, which RADAN 7 incorporates into its database automatically when the *.DZT file is opened.

This section gives a quick GPS overview and then describes what you need to know in order to effectively use the SIR 4000 with a GPS.

What is it?

GPS is a satellite navigation system (provided free by the USDoD) designed to provide instantaneous position, velocity and time information almost anywhere on the globe at any time, and in any weather. It typically provides positioning accuracies ranging from 3 meters (costing \$150) to 1cm (\$15,000). Since it needs to see much of the sky, it works poorly indoors, in woods and in “concrete canyons” like Manhattan.



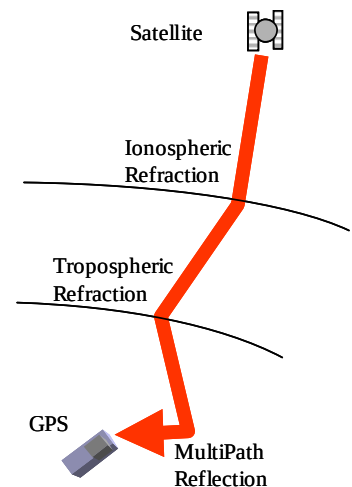
Why do I need it?

You probably don't! In fact for many Ground Penetration Radar applications you can just use a survey wheel to measure your distance and take simple notes about your start and stop locations. And since digging or drilling often requires more precision than 3meters, knowing “sort of” where you are is not helpful.

However, as surveys become larger and as technologies improve, GPS can be very helpful in telling you where you are on a map, or what road you turned onto, or what section of the avalanche you have already covered, or even where you were in the middle of a lake. And of course if you actually need expensive survey-grade GPS accuracy, we want to give you the hooks you need to place our RADAR data correctly. Increasingly GPS is claiming a legitimate place in the ever increasing size and variety of GPR applications.

How does it work?

GPS works by triangulating the distance from satellites in space. Like our RADARs, these satellites just transmit time very accurately and estimate the distance using the speed of light. Getting the travel-time from just three satellites is enough to know where you are on the earth. Getting the travel-time from 12 satellites greatly decreases the uncertainty of your position. Typically around buildings and trees you might “see” six satellites, plenty to know where you are to within 3 meters. The degree of precision depends on many things, like how well distributed the satellites are in the sky, or the travel path the signal took to get to your receiver.



Main sources of error

GPR and GPS share a lot in common. The travel times and paths are directly affected by the medium. For GPS, this means the signal from the satellites to your receiver can get slowed down and bent by changes in the Ionosphere, the Troposphere and even nearby objects. These sources of error can be reduced using expensive tricks like dual frequency, Klobuchar modeling and Real-Time Kinematic (RTK) solutions.

The least expensive way to correct for these errors is through Differential GPS (DGPS), where data from a second stationary “Base” GPS is subtracted from a Roving GPS. Compared to the distance from the satellite, distance between Base and Rover is insignificant, which means the travel paths through the

ionosphere and troposphere are basically identical. So the difference between the two positions subtracts out atmospheric effects, leaving just the Rover position.

5.3 What is WAAS?

The Wide Area Augmentation System (WAAS) is a form of differential GPS that uses geostationary satellites to transmit an error correction estimate back down to your receiver. The measured positions of ground reference stations, strategically positioned across the country, are sent up to the WAAS satellites. Your receiver reads the reference station closest to you.

“WAAS testing in September 2002 confirmed accuracy performance of 1 – 2 meters horizontal and 2 –3 meters vertical throughout the majority of the continental U.S. and portions of Alaska.”

(<http://gps.faa.gov/Programs/WAAS/waas.htm>) This is with a clear view of the sky. Typically WAAS can improve your error from less than 5 meters 95% of the time to less than 3 meters. WAAS is now available even in the less expensive GPS units and is recommended.

5.4 What is NMEA?

The National Marine Electronics Association ([NMEA](#), pronounced “NEE’ma”) has generated a standard set of messages for communicating GPS information. We use the NMEA 0183 version 2.1 protocol.

Appendix A: SIR 4000 System Specifications

A.1: System Hardware

Antennas: Compatible with all GSSI Antennas

Number of Channels: 1 (one)

Data Storage: Internal memory 32 GB

Processor: NVidia Tegra 3

Display: Enhanced 10.4" LED, 1024 by 768 resolution and 32-bit color
Linescan, Linescan plus O-Scope, and Wiggle trace display modes
Full 3D, 256 color bins are used to represent the amplitude and polarity of the signal

IP Rating: IP-65

GPS Support: Internal data logging

Video Output: HDMI

Input/Output:

- 19 pin analog antenna input (control cable)
- 13 pin digital antenna input (control cable)
- AC power adapter
- GPIO connector
- HDMI video out
- RS232 Serial I/O (GPS port)
- USB 2.0
- Micro USB
- RJ45 100BT Ethernet
- WiFi 802.11 B/G

Mechanical:

- Dimensions: 14x10x2.75 in (36x25x7 cm)
- Weight: 10 lbs (4.53 kg) with battery
- Relative Humidity: <95% non-condensing
- Storage Temperature: -40°C to 60°C external (-40°F to 140°F)

Operating:

- Temperature: -20°C to 40°C external (-4°F to 104°F)
- Charging Power Requirements: 19V DC, 3.42 amps
- Battery: 10.8V Lithium Ion rechargeable, Inspired Energy Ni2020ED
- Transmit Rate: Up to 800 KHz (International), US/Canada and CE rates depend on antenna model

A.2: Data Acquisition and Software

Data Format: RADAN™ (.dzt)

Output Data Format: 32 bit

Scan Rate: Maximum 400 scans/sec at 256 samples/scan

Scan Interval: User-selectable

Number Of Samples Per Scan: 256, 512, 1024, 2048, 4096, 8192, 16,384

Operating Modes: Time- (Continuous), Distance- (Survey Wheel), or Point-Based Collection

Time Range: 1-20,000 nanoseconds full scale, user selectable

Gain: Manual or automatic gain, 1-8 points, (-40 to +120 dB)

Standard Real-Time Filters:

- Vertical: FIR Low-Pass, FIR High-Pass, IIR Low-Pass, and IIR High-Pass
- Horizontal: FIR Stacking, FIR Background Removal, IIR Stacking, and IIR Background Removal

Advanced Real-Time Filters: Migration, Surface Position Tracking, Signal Noise Floor Tracking, and Hilbert Transform.

Automatic System Setups: Storage of an unlimited number of system setup files for different survey conditions and/or antenna deployment configurations.

Automatic Antenna Recognition: Automatic recognition of Smart Antennas to allow maximum compliant transmit rate.

A.3: System Includes

Digital Control Unit (DC-4000) with preloaded operating system (1)

Transit Case (1)

Batteries (2)

Charger (1)

Sunshade (1)

Operation Manual (1)

GSSI Manual CD (1)

Fully FCC , RSS-220, and CE Compliant.

Appendix B: The How-To's of Field Survey

As the old saying goes: “Garbage in, Garbage out”. The biggest single factor affecting the quality of your data and your ability to make decisions based on it, is the accuracy of your data collection. This appendix has instructions and helpful hints to get you into the habit of collecting quality data from the beginning. While many of these points are only relevant to data collection over the ground, as opposed to concrete structures, you may find this section helpful no matter what your application.

B.1: Site Selection

Radar is not the proper technique for every situation. If you are unable to inspect the site, have prospective clients send a photograph of the area. As you gain experience, you will find it easy to judge an area's or an application's suitability. In the meantime, consider the four following issues before deciding whether you should conduct work at an area:

- Topography

- Ground Cover

- Subsurface Conditions

- Site Accessibility

Topography

One of the first things you should consider about a new survey area is the topography. In the first place, you need to be able to physically move the antenna over the ground surface in a fairly smooth fashion. Areas that are full of trenches or extreme slopes are not ideal. You can still survey an area of broken terrain, but it may require collecting point data rather than continuous data profiles.

Radar energy travels into the ground perpendicular to the surface. This means that if the antenna is flat on the ground, and level, you are reading right under the antenna. This forward-scanning of the antenna could lead to serious position errors.

Ground Cover

If your antenna is floating on top of thick grass or a layer of gravel, you may get errors in your data because the signal is taking too long to couple (penetrate) with the ground. When this happens, more of the signal than was intended bounces off of the ground surface instead of going into the ground. Always try to keep your antenna flat on the ground surface. The systems will have no problem penetrating carpeting or low grass. A good rule of thumb for the 1500 MHz is no thicker than low carpet, and for the 400 MHz, no more than 1 inch. NEVER survey through standing water, no matter how shallow the puddle.

Subsurface Conditions

If you are working with concrete, try to make sure that the concrete has had some curing time. Three months is usually adequate for a standard slab on grade, while a suspended slab may cure faster. The best solution is to practice on slabs of different ages so that you have a first-hand feel of the way they will look. Concrete that is not well cured will be difficult to see into.

Try and find out some information about the area's soil and water content. Generally speaking, clay and water cause attenuation and impede penetration. Finding out the soil grain size (sand, silt, clay) will help you to guess the dielectric constant of the material to help you set up survey parameters and make time to depth estimations. If you have never worked with soils before, you should consult the US Department of Agriculture soils website at <http://soils.usda.gov/>. The site has a number of free and low cost resources including soil maps of most of the United States and guides to help you understand soils.

Site Accessibility

Simply put, can you feasibly work in the proposed area? Is the site in the middle of a dense thicket of trees, or is it the outside of a tall building, or a tight elevator shaft? Remember that GPR and geophysics depends on your ability to see contrasts in the data. The area has to be large enough for you to collect enough data to be able to make an interpretation. For example, if you need to survey an area in advance of an 18" utility trench, you want to make sure that you have some coverage over areas outside of that trench so you can see normal conditions. Always give yourself some elbow room.

B.2: Targets

The type of targets you are trying to find will govern your choice of antennas, setup parameters, or even the feasibility of radar for the application. There are two main criteria to consider:

- Target Size

- Target Composition

Target Size

All things being equal, antenna choice determines how deeply you are able to penetrate and the minimum size of the targets that you are able to see. Lower frequency antennas see deep, but the minimum target size that they can see is larger. Rather than focus on what each antenna can see, the table below lists the appropriate antenna by application and depth range.

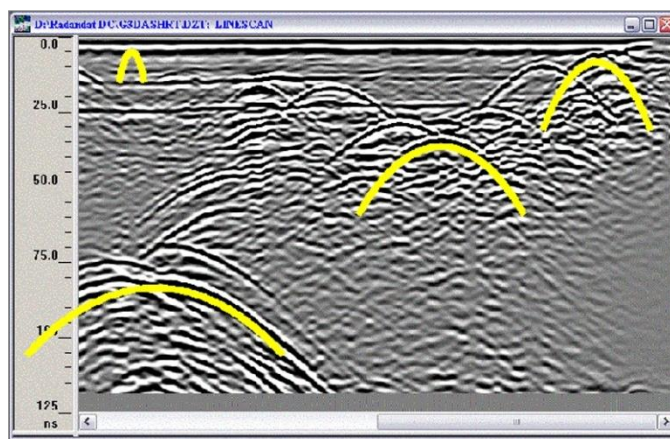
Frequency	Sample Applications	Typical Max Depth Feet (meters)	Typical Range (ns)
2.6 GHz	Structural Concrete, Roadways, Bridge Decks	1 (0.3)	10
1.6 GHz	Structural Concrete, Roadways, Bridge Decks	1.5 (0.5)	10-15
900 MHz	Concrete, Shallow Soils, Archaeology	3 (1)	10-20
400 MHz	Shallow Geology, Utility, Environmental, Archaeology	9 (3)	20-100
200 MHz	Geology, Environmental	25 (8)	70-300
100 MHz	Geology, Environmental	60 (20)	300-500

Antennas by Application

Radar is also not a continuous measurement along a survey line. The system takes readings (scans) at a set spacing. If your scan spacing is too wide, you risk not hitting your target with enough scans to draw a recognizable hyperbola, or worse, missing the target altogether.

Generally you need a minimum of 10 scans to draw a recognizable hyperbola. The rule of thumb is to have 10 scans divided by the depth of the shallowest object. So if you want to image something 10 feet deep, $10 \text{ scans} / 10 \text{ feet} = 1 \text{ scan/foot}$. For 5 feet, $10 \text{ scans} / 5 \text{ feet} = 2 \text{ scans/foot}$.

For locating structural features in concrete with the 1.6 GHz antenna, we usually recommend 60-90/ft. For utility and tank location, we usually recommend 6-24/ft. While this is more than the minimum rule of thumb, GSSI has found these densities to work well in the widest variety of situations.



The image above shows hyperbolas from objects of similar size. The hyperbolas vary in size because, due to the spreading of the radar signal, a deeper target shows reflections in more scans than a shallow one.

Lower frequency antennas, like the 200 MHz and 400 MHz, will sometimes not image targets close to the surface very well. While not strictly a ‘dead zone’ you should be aware that it may be difficult (but not impossible!) to see targets in this area. As a general rule of thumb, this zone is equal to the spacing between the transmitter and receiver dipoles, but this can vary with soil composition. See the chart at right for a general idea. If your application requires you to see deep and shallow, consider surveying the area with two different antennas.

Frequency	“Hazy” Zone Inches (cm)
2.6 GHz	0.5 (1)
1.6 GHz	1 (2.5)
900 MHz	4 (10)
400 MHz	6 (15.25)
200 MHz	12 (30.5)

Target Composition

Your ability to see a target depends on the contrast between the dielectric values of the target’s material and the material that the radar energy was traveling through just before it hit the target. The greater the contrast between the dielectric values, the more visible the target is. For applications which involve finding metal targets like rebar, pipes, and drums, this is not a great issue because there will always be a great contrast. The dielectric of metals is so high that the actual number is meaningless. You will always have a visible contrast where metals are concerned.

Composition can affect your ability to see things in different ways. For example, the contact between a dry sand (3-6) and a water table (water being 81) will be easy to image, while the contact between sandstone (6) and limestone (7-8) will be much more difficult. Also remember that it is the electrical property of the material that most governs dielectric. Even though concrete and grade are qualitatively very different, they are made of similar materials and react to radar energy similarly. It is usually extremely difficult to tell the top of grade from the bottom of the slab. You should practice trying to image different materials so that you can build up a body of experience. See Appendix D for a chart of the dielectric constants of different materials.

B.3: Data Collection Methods: 2D vs. 3D

Time is money. Whether you are a university-based researcher working off a grant or performing NDT work for pay, the faster you can get the survey done the better off you will be. Those charging by the hour understand the fine balance between a price that reflects a realistic estimate of how long it will take to get the job done, and padding the cost with unnecessary work. The point of this discussion is to get you to think about how much information you really need to make a decision.

2D

Two-dimensional data collection means that you will be collecting and interpreting single profiles of data. This is useful for quickly following a pipe by scanning over an area, noting the location of the pipe hyperbola on the ground, then moving some distance away and scanning again for the pipe. The real benefit of 2D data collection is speed and ease of use. Processing is certainly possible on 2D data to clean up the image, but most clients will only use it for visually noting the presence/absence of targets in the field. 2D data collection is also useful for geologic applications such as bedrock and water table mapping.

3D

Collecting data for 3D imaging obviously takes more time than 2D collection. While the SIR(R) 4000 makes it faster and easier than it has ever been before, it can still add significant time (and cost) to a job. It also requires some software processing to produce an interpretable image. These two issues may frighten some users away from 3D data collection, but like GPR in general, it only requires some practice to gain confidence.

Three-dimensional data can be a great aid in interpretation. The question many people ask is “When do I use 3D?” Aside from producing a 3D map for its own sake, there are really only three main reasons: a complicated area, prospecting, or dangerous targets in the subsurface. A complicated area might be a city street with many different types of pipes running in different directions. In a situation like that, the best option is usually to do 3D data collection so that you are able to visually track targets as they twist and turn around other targets. Prospecting is mainly what those doing Archaeology will face. In this case, you don’t have any concrete information about the subsurface so you will need to do 3D over the area and look for human-made patterns that could be targets. An example of the final reason would be coring or cutting into an area that has live high-voltage in the floor. When the safety of your crew is at stake, the more information, the better.

Appendix C: Dielectric Values For Common Materials

Material	Dielectric Constant	Material	Dielectric Constant
Air	1	Wet Granite	6.5
Snow Firn	1.5	Travertine	8
Dry Loamy/Clayey Soils	2.5	Wet Limestone	8
Dry Clay	4	Wet Basalt	8.5
Dry Sands	4	Tills	11
Ice	4	Wet Concrete	12.5
Coal	4.5	Volcanic Ash	13
Asphalt	5	Wet Sands	15
Dry Granite	5	Wet Sandy Soils	23.5
Frozen Sand & Gravel	5	Dry Bauxite	25
Dry Concrete	5.5	Saturated Sands	25
Dry Limestone	5.5	Wet Clay	27
Dry Sand & Gravel	5.5	Peats (saturated)	61.5
Potash Ore	5.5	Organic Soils (saturated)	64
Dry Mineral/Sandy Soils	6	Sea Water	81
Dry Salt	6	Water	81
Frozen Soil/Permafrost	6		
Syenite Porphyry	6		
Wet Sandstone	6		

Meter to English conversion factor: 2.54 cm in 1 inch.

Table of Dielectric values adapted from: Reynolds, John M., 1997
An Introduction to Applied and Environmental Geophysics, John Wiley & Sons, New York.

Appendix D: Listing of Antenna Parameters

The SIR 4000 comes with preloaded setups to fit the system's data collection parameters and filters to the most commonly used, currently available GSSI antennas. Settings for additional antennae are also provided below to assist you in creating a setup for an older or specialized antenna. Please note that these are only generalized setups, and it may be necessary to alter these to your particular situation. For example, deeper penetration can be set by increasing the range in the Radar menu during setup. Please note that this is not an exhaustive list and you should consult the antenna documentation saved on the Manual CD Compendium or on the GSSI Support Website: www.support.geophysical.com.

D.1: Preloaded Setups

2.6 GHz (Model 52600S)

2.6 GHz ground coupled antenna. Depth of viewing window is approximately 10 inches in concrete. Setting is optimized for scanning of structural features in concrete.

- Range: 8 ns
- Samples per Scan: 512
- Resolution: 16 bits
- Number of gain points: 4
- Vertical High Pass Filter: 500 MHz
- Vertical Low Pass Filter: 4000 MHz
- Scans per second: 100
- Vertical IIR High Pass $N=2F=10$ MHz
- Transmit Rate: 100 KHz

2 GHz Palm (Model 62000)

2 GHz ground coupled antenna. Depth of viewing window is approximately 10 inches in concrete. Setting is optimized for scanning of structural features in concrete.

- Range: 8 ns
- Samples per Scan: 512
- Resolution: 16 bits
- Number of gain points: 2
- Vertical High Pass Filter: 400 MHz
- Vertical Low Pass Filter: 5000 MHz
- Scans per second: 100
- Vertical IIR High Pass $N=2F=10$ MHz
- Transmit Rate: 100 KHz

1.5/1.6 GHz (Model 5100S)

1.5 GHz ground coupled antenna. Depth of viewing window is approximately 18 inches in concrete. Setting is optimized for scanning of structural features in concrete.

Range: 12 ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 250 MHz
Vertical Low Pass Filter: 3000 MHz
Scans per second: 100
Vertical IIR High Pass $N=2F=10$ MHz
Transmit Rate: 100 KHz

900 MHz (Model 3101A)

900 MHz ground coupled antenna. Depth of viewing window is approximately 1 m assuming a dielectric constant of 5.

Range: 15 ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 2
Vertical High Pass Filter: 225 MHz
Vertical Low Pass Filter: 2500 MHz
Scans per second: 120
Transmit Rate: 100 KHz

400 MHz (Model 50400S)

400 MHz ground coupled antenna. Depth of viewing window is approximately 3m assuming a dielectric constant of 5.

Range: 50 ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 3
Vertical High Pass Filter: 100 MHz
Vertical Low Pass Filter: 800 MHz
Scans per second: 120
Transmit Rate: 100 KHz

270 MHz (Model 50270S)

270 MHz ground coupled antenna. Depth of viewing window is approximately 4m assuming a dielectric constant of 5.

Range: 75 ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 3
Vertical High Pass Filter: 75 MHz
Vertical Low Pass Filter: 700 MHz
Scans per second: 120
Transmit Rate: 100 KHz

200 MHz (Model 5106)

200 MHz ground coupled antenna. Lower frequency antenna optimized for mid-range profiling.

Range: 100ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 50 MHz
Vertical Low Pass Filter: 600 MHz
Scans per second: 64
Transmit Rate: 100 KHz

100 MHz (Model 3207)

100 MHz ground coupled antenna. Low frequency for deeper profiling.

Range: 500ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 25 MHz
Vertical Low Pass Filter: 300 MHz
Scans per second: 16
Transmit Rate: 50 KHz

D.2: Parameter Listing for Older/Specialty Antennae

The following list of antenna setups is provided to assist you in using the SIR(R) 4000 with additional antennae. To use this list, you must enter the correct parameters. You may wish to save any special parameters in a separate setup (under the System menu) to help you easily recall them. Some of these are no longer commercially available, but the system does function with all older antennas. They are designated by their center frequency, and in some cases a D or S which noted whether that setup is for Deep or Shallow prospecting. Please note that many of these antennae have a different listed transmit rate than the default one on the SIR 4000. The transmit rate listed here is the rate that the antenna was tested and rated at. It may function correctly at a higher transmit rate and allow you to collect data faster, but you must pay careful attention to your data to decide if the antenna is functioning correctly at the different rate.

If your system is beeping, it indicates that your T_RATE is too high for this antenna.

500-MHz (Model 3102)

500 MHz antenna. Not Model 3102 HP or 3102 DP

Data Collection Mode: Continuous
Range: 60ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 3
Vertical High Pass Filter: 125 MHz
Vertical Low Pass Filter: 1000 MHz
Scans per second: 120
Transmit Rate: 100 KHz

300-Shallow

Old 300 MHz antenna.

Data Collection Mode: Continuous
Range: 150ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 100 MHz
Vertical Low Pass Filter: 1000 MHz
Scans per second: 32
Horizontal Smoothing: 5 scans
Transmit Rate: 50 KHz

300-Deep

Old 300 MHz antenna.

Data Collection Mode: Continuous
Range: 300ns
Samples per Scan: 1024
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 100 MHz
Vertical Low Pass Filter: 1000 MHz
Scans per second: 32
Horizontal Smoothing: 5 scans
Transmit Rate: 50 KHz

120-Deep-Unshielded

120 MHz standard antenna.

Data Collection Mode: Continuous
Range: 400ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 30 MHz
Vertical Low Pass Filter: 240 MHz
Scans per second: 32
Horizontal Smoothing: 5 scans
Transmit Rate: 50 KHz

120-Shallow-Unshielded

120 MHz standard antenna.

Data Collection Mode: Continuous
Range: 200ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 30 MHz
Vertical Low Pass Filter: 240 MHz
Scans per second: 32
Horizontal Smoothing: 5 scans
Transmit Rate: 50KHz

100 High Power

100 MHz antenna with high power transmitter.

Data Collection Mode: Continuous
Range: 500ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 25 MHz
Vertical Low Pass Filter: 200 MHz
Scans per second: 16
Horizontal Smoothing: 5 scans
Transmit Rate: 12 KHz

100 Very High Power

100 MHz antenna with very high power transmitter.

Data Collection Mode: *Continuous*
Range: 500ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 25 MHz
Vertical Low Pass Filter: 200 MHz
Scans per second: 16
Horizontal Smoothing: 5 scans
Transmit Rate: 6 KHz

Subecho 70

70 MHz antenna with high power transmitter.

Data Collection Mode: Continuous
Range: 500ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 15 MHz
Vertical Low Pass Filter: 150 MHz
Scans per second: 16
Horizontal Smoothing: 5 scans
Transmit Rate: 12 KHz

Subecho 40

40 MHz antenna with high power transmitter.

Data Collection Mode: Continuous
Range: 1000ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 10 MHz
Vertical Low Pass Filter: 80 MHz
Scans per second: 32
Transmit Rate: 12KHz

80 MHz

80 MHz folded bow-tie antenna. Note: The 80 MHz antenna is unshielded.

Data Collection Mode: Continuous
Range: 500ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 25 MHz
Vertical Low Pass Filter: 200 MHz
Scans per second: 32
Stacking: 32 scans
Transmit Rate: 50 KHz

MLF 120 cm

Low Frequency antenna 1.2m length. Note: The MLF antennas are unshielded.

Data Collection Mode: Point
Range: 250ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 30 MHz
Vertical Low Pass Filter: 160 MHz
Scans per second: 32
Stacking: 32 scans
Transmit Rate: 12 KHz

MLF 240 cm

Low Frequency antenna length 2.4m

Data Collection Mode: Point
Range: 500ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 15 MHz
Vertical Low Pass Filter: 90 MHz
Scans per second: 32
Stacking: 32 scans
Transmit Rate: 12 KHz

MLF 360 cm

Low Frequency antenna length 3.6m

Data Collection Mode: Point
Range: 750ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 10
Vertical Low Pass Filter: 60
Scans per second: 32
Stacking: 32 scans
Transmit Rate: 12 KHz

MLF 480 cm

Low Frequency antenna set to a length of 4.8m

Data Collection Mode: Point
Range: 1000ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 6
Vertical Low Pass Filter: 40
Scans per second: 32
Stacking: 32 scans
Transmit Rate: 12KHz

MLF 600 cm

Low Frequency antenna set to a length of 6.0m

Data Collection Mode: Point
Range: 1000ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 1
Vertical Low Pass Filter: 50
Scans per second: 32
Stacking: 32 scans
Transmit Rate: 12 KHz

Borehole 120 MHz

Borehole antenna frequency 120 MHz. Note: The borehole antennas are unshielded.

Data Collection Mode: Point
Range: 500ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 30 MHz
Vertical Low Pass Filter: 240 MHz
Scans per second: 32
Stacking: 32 scans
Transmit Rate: 64 KHz

Borehole 300 MHz

Borehole antenna frequency 300 MHz.

Data Collection Mode: Point
Range: 300ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 38 MHz
Vertical Low Pass Filter: 600 MHz
Scans per second: 32
Stacking: 32 scans
Transmit Rate: 64 KHz

Appendix E: Glossary of Terms and Suggestions for Further Reading

Antenna: a paired transmitter and receiver that sends electromagnetic energy into a material and receives any reflections of that energy from materials in the ground. Also called a transducer. Antennae are commonly referred to by their center frequency value (i.e. 400 MHz, 1.5 GHz). This frequency determines the depth of penetration and the size of the objects or layers visible.

Attenuation: the weakening of a radar pulse as it travels through different materials.

Center Frequency: the median transmit frequency of an antenna. The antenna will also transmit energy at a frequency range of 0.5-2 times its center value. For example, a 400 MHz antenna may actually transmit at a range from 200-800 MHz.

Clipping: occurs when the amplitude of a reflection is greater than the maximum recordable value. The system disregards the true value of the reflection and writes in the maximum allowable value. Clipping appears in the O-Scope as signal that “goes off the scale” at the sides of the window.

Dielectric permittivity: the capacity of a material to hold and pass an electromagnetic charge. Varies with a material’s composition, moisture, physical properties, porosity, and temperature. Used to calculate depth in GPR work.

EM: Acronym for electro-magnetic.

FCC: Acronym for Federal Communications Commission. The United States governmental body that oversees the UWB industry of which GPR is a part.

Gain: amplifying the signal to certain section of a radar pulse in order to counteract the effects of attenuation and make features more visible.

GHz: Acronym for Gigahertz. A measurement of frequency equal to one billion cycles per second.

GPR: Acronym for Ground Penetrating Radar.

Ground-coupling: the initial entry of a radar pulse into the ground.

Hyperbola: an inverted “U.” The image produced in a vertical linescan profile as the antenna is moved over a discrete target. The top of the target is at the peak of the first positive (white in a grayscale color table) wavelet.

Interface: the surface separating materials with differing dielectric constants or conductivity values.

KHz: Acronym for Kilohertz. A measurement of frequency equal to one thousand cycles per second.

Linescan: commonly used method of depicting a radar profile. Linescans are produced by placing adjacent scans next to each other and assigning a color scheme to their amplitude values.

Macro: a preset list of processing options that may be applied to perform repetitive functions on an entire dataset. Macros may be created and edited to include different functions (see RADAN manual for addition information).

Mark: point inserted along a survey line manually by the operator or at preset intervals.

MHz: Acronym for Megahertz. A measurement of frequency equal to one million cycles per second.

Migration: mathematical calculation used to remove outlying tails of a hyperbola and to accurately fix the position of a target.

Nano-second: unit of measurement for recording the time delay between transmission of a radar pulse and reception of that pulse's reflections. Equal to one one-billionth of a second.

Noise: unwanted background interference that can obscure true data.

nS: see Nano-Second.

Oscilloscope: device used to view and measure the strength and shape of energy waves. Common term in GPR industry for a method of data display showing actual radar wave anatomy.

Passband: the frequency range at which the antenna is emitting energy. It is roughly equivalent to 0.5-2 times the center frequency.

RAM: Acronym for random access memory. Temporary memory in which a computer stores information used with a running program, or temporarily stored data before it is written to a hard drive.

Range: the total length of time (in nanoseconds) for which the control unit will record reflections. Note: indicates two-way travel time.

RF: Acronym for radio frequency.

Sample: a radar data point with two attributes: time and reflection amplitude. A third attribute, position, is assigned by the user. Under-sampling will produce a scan wave that does not contain enough information to draw a smooth curve. It may miss features. Over-sampling will produce a larger data file.

Samples/Scan: the number of samples recorded from an individual radar scan. Commonly set to 512.

Scan: one complete reflected wave from transmission to reception, sometimes called a trace.

Signal Noise floor: time depth at which the noise makes target identification impossible.

Survey wheel: wheel attached to an antenna and calibrated to record precise distances. Necessary for accurate data collection.

Time-slice: a horizontal planview of amplitude values drawn from adjacent vertical profiles. The time-slice is produced for a particular time-depth and is vital for understanding the horizontal positions of features in a survey area.

Time window: the amount of time, in nano-seconds, that the control unit will count reflections from a particular pulse. Set by the operator.

Transect: a line of survey data. An area is systematically surveyed by recording transects of data at a constant interval. The transects are then placed in their correct position relative to each other in a computer and horizontal time-slices are produced.

UWB: Acronym for Ultra-Wide Band. Refers to the wide frequency band of emissions put out by a GPR device.

Wiggle trace: method of GPR data display showing oscilloscope trace scans placed next to each other to form a profile view. Commonly used method in seismic studies.

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Useful Websites:

- 1** Geophysical Survey Systems, Inc.:
www.geophysical.com
- 2** United States Department of Agriculture Soils Website:
<http://soils.usda.gov/>
- 3** USDA-Natural Resources Conservation Service, Ground Penetrating Radar Program:
<http://nesoil.com/gpr/>
- 4** USDA – Natural Resources Conservation Service, GPR Soil Suitability
http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/use/maps/?cid=nrcs142p2_053622
- 5** USDA-Natural Resources Conservation Service, Web Soil Survey
<http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm>
- 6** North American Database of Archaeological Geophysics:
www.cast.uark.edu/nadag