SENSORS & SOFTWARE
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SPX

SPIDAR

Operations Manual

2018-00022-03

Warranty Confirmation

Return this card within 60 days of purchase to confirm your warranty. You can mail it to Sensors & Software, fax it to +1-905-624-9365, or register your product online at www.sensoft.ca/product-registration.

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City:	State/Province:	Zip Code:
Country:		email:
Phone:		Fax:

Component Serial Numbers (refer to packing list or the sticker on the component)

Comp:	Serial #	Comp:	Serial #
Comp:	Serial #	Comp:	Serial #
Comp:	Serial #	Comp:	Serial #
Comp:	Serial #	Comp:	Serial #
Comp:	Serial #	Comp:	Serial #
Vendor Name:		Date Received:	

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Product Warranty and Limited Liability

Please refer to the terms and conditions included as part of your order acknowledgement and/or invoice for full details of the product warranty and limited liability.

Important Safety Information

Read this manual in its entirety before attempting to operate the SPIDAR system. Note all safety notices in the preface and throughout this manual

The battery charger/AC adapter must only be connected to a power outlet which provides a protective earth (ground).

Connect the AC power cord only to designated power sources as marked on the battery charger/AC adapter.

The battery charger/AC adapter is rated for indoors use only.

Do not replace detachable MAINS supply cords for the battery charger/AC adapter by inadequately RATED cords.

The exterior of this product should be cleaned using a damp cloth.

Safety Symbols

Consult this documentation in all cases where this safety symbol appears. This symbol is used to inform you of any potential HAZARD or actions that require your attention.

Do not attempt to open or dismantle any part of this equipment unless directed specifically by this manual. Doing so may render the equipment faulty and may void the manufacturer's warranty.

Use authorized accessories only. Incompatible accessories may damage the equipment or give inaccurate readings.

Follow your company and national safety procedures and or requirements when operating this equipment in any environment or workplace. If you are unsure what policies or procedures apply, contact your company or site's occupational health and safety officer or your local government for more information.

Table of Contents

1. Introduction

Congratulations on your purchase of SPIDAR. The SPIDAR NIC-500s are a family of devices used to connect multiple GPR systems and create a custom platform to address a wide range of GPR applications. The variety of available configurations allow for a truly customizable multi-channel system.

There are two ways to configure SPIDAR for multi-channel applications:

- Connect the same frequency GPR antennas to create an array system and collect a wide swath of data in a single pass.
- Connect different frequency GPR antennas to create a multi-frequency system, and collect data at varying depths in a single pass

Both systems increase the speed of data collection, resulting in increased productivity.

There are three variations of the NIC-500 available:

- NIC-500N – used to run Noggin systems. Each NIC-500N can run 2 Noggin sensors simultaneously. Multiple NIC-500Ns can be connected together (daisy-chained) to run several Noggins simultaneously.
- NIC-500P – used to run pulseEKKO PRO antennas. Each NIC-500P can run 2 pairs of pulseEKKO PRO transmitters and receivers simultaneously. Multiple NIC-500Ps can be connected together (daisy-chained) to run several pulseEKKO PRO antennas simultaneously.
- NIC-500X – used to run pulseEKKO PRO antennas. Each NIC-500X can run any combination of pulseEKKO PRO transmitters and receivers totaling up to 8 simultaneously.

A key feature of SPIDAR is that the data acquisition software and storage reside on the NIC-500. As a result, any network capable device can be used to setup and control data acquisition on a NIC-500. Once data has been collected, it can be downloaded to a computer, post-processed and analyzed with the EKKO_Project software.

For those who would like to use GPR, but control it with their own data acquisition software, SPIDAR can be put into SDK (Software Development Kit) mode. Details of SDK can be found in Section 5.

This manual references NIC-500 firmware version V1 R5.

2. Overview of NIC-500s

This section explains the physical properties of the NIC-500s. Attributes common to all NIC-500s are explained, followed by differences between NIC-500N, NIC-500P and NIC-500X.

Figure 2-1: SPIDAR NIC-500

A NIC (short for Network Interface Controller) is a device that allows users to collect data with multiple GPR antennas simultaneously (Figure 2-1). Every NIC-500 contains:

- Wi-Fi – the NIC-500 broadcasts its own Wi-Fi signal. A user can connect their laptop or tablet to this Wi-Fi network to control the NIC-500. Alternatively, a user can connect an Ethernet cable directly from their device to the NIC-500 instead of connecting via Wi-Fi.
- SPIDAR software –the operational software that allows the user to setup parameters for data acquisition. The user can access this through a web browser such as Google Chrome on their device.
- Storage – a hard drive for data storage is built into the NIC-500.
- Voltage stabilizer – protects the system from spikes in the power supply and ensures an even and steady distribution of power to the antennas and any accessories, such as a GPS.

Each NIC-500 has several ports to connect antennas, power and accessories. Ports that are on the long side (opposite side to where the antennas connect) are common to all NIC-500s (Figure 2-2); these are described below. Ports unique to the NIC-500N, NIC-500P and NIC-500X are described in the subsequent sections:

- USB – there are two USB ports (one on the long side, one on the front). A USB stick can be inserted to download data off the machine. As well, the SPIDAR software can be updated by inserting a USB containing the upgrade file into one of these ports (Section 4.6.1)

- Ethernet– there are two Ethernet ports. If you are using a hardware connection to the NIC-500, then you must run an Ethernet cable between your device and the NIC-500. If you are daisy-chaining NIC-500s, you must plug an Ethernet cable from one NIC-500 to the other.
- Power – this port could be used by customers who have a pulseEKKO PRO power cable. However, it is recommended to power the system with the NIC-500 power cable plugged into the Link In port (explained below).
- Odometer – if the data acquisition is to be triggered by an odometer, plug the odometer cable into this port. An example of this is using a SmartCart platform to collect data.
- Link In – this port serves two purposes. For a single NIC-500 or the Master NIC-500 in a daisy-chained setup, the power supply will be plugged into this port. If this is a subordinate NIC-500, then the Sync cable will get plugged into this port coming from the Master NIC link out cable.
- Link Out – if you are running a single NIC-500, this port will not be used. If you are daisy-chaining two NIC-500s, then a NIC Sync cable will be plugged into the link out of the Master NIC and connect into the Link In port of the subordinate NIC-500.

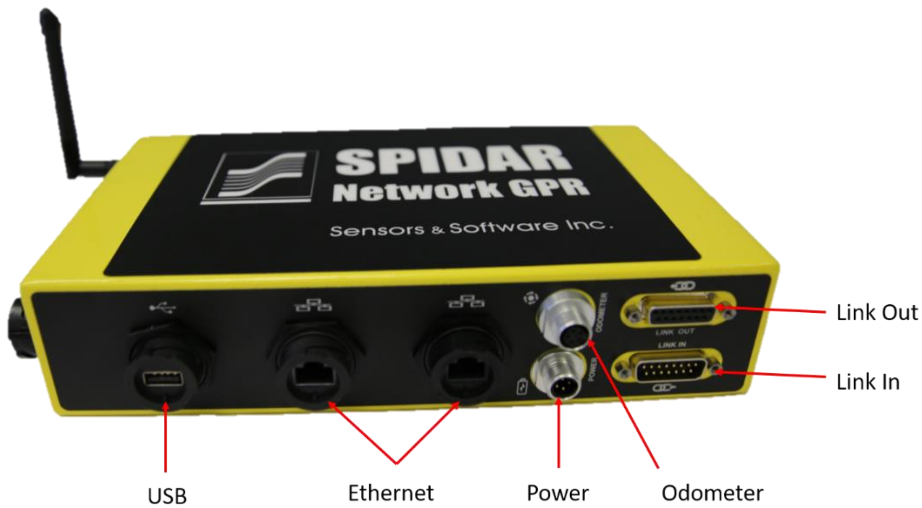


Figure 2-2: Connection ports common to all NIC-500s

The features & ports on the front (short) side of the NIC-500 (Figure 2-3) are described below:

- Power button – Press the Power button to turn on the NIC-500.
- LCD Display – Displays the name of the network and the IP address
- USB – there are two USB ports (one on the long side, one on the front). A USB stick can be inserted to download data off the machine. As well, the SPIDAR software can be updated by inserting a USB containing the upgrade file into one of these ports (Section 4.6.1)

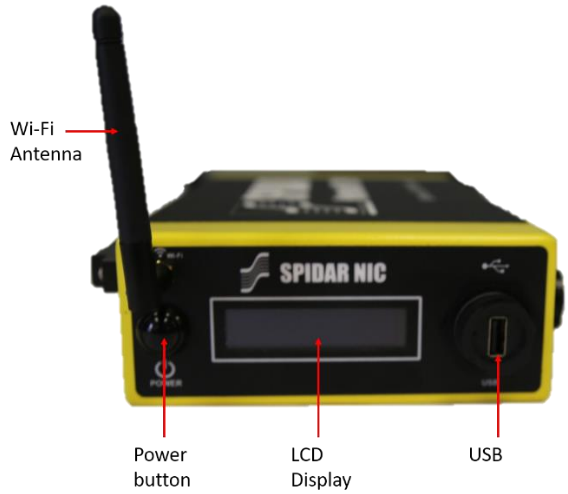


Figure 2-3: Showing the front (short) side of the NIC-500

2.1 NIC-500N

A NIC-500N is a variation of the NIC that can be used to run up to 2 Noggins simultaneously. Noggins are available in 4 center frequencies: 100, 250, 500 and 1000 MHz. Multiple NIC-500Ns can be connected together, to run any number of Noggin systems; this is called daisy-chaining.

On the long side of the NIC-500 (opposite side to the power and odometer connections), there are two Noggin ports and a serial port (Figure 2-4), described below:

- Serial port – used to connect a GPS receiver. The GPS receiver can receive power from this port, if power out is enabled. For more information, see Section 3.3.
- Noggin Ports – there are two numbered ports available to connect up to two Noggin sensors. The NIC-500N can be run with only one Noggin, which would be a single channel system.

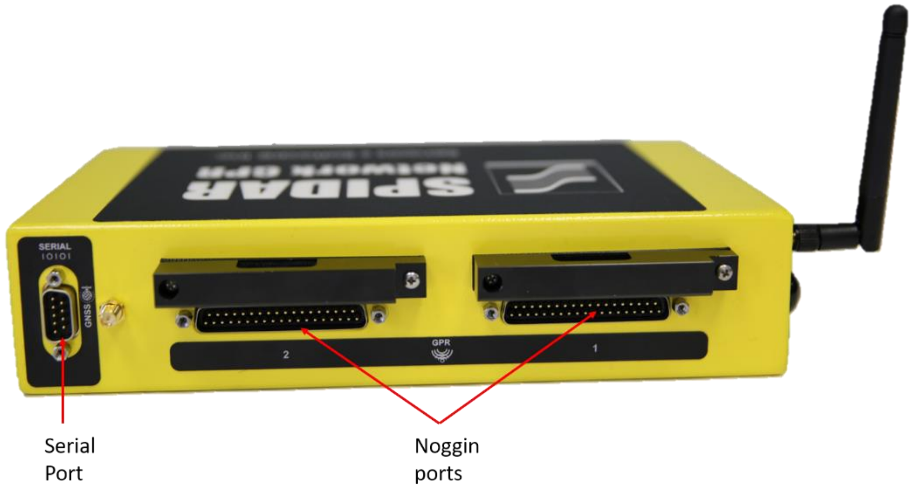


Figure 2-4: Long side of NIC-500N showing Noggin ports and serial port

2.2 NIC-500P

The NIC-500P can run up to 2 pairs of pulseEKKO PRO transmitters and receivers simultaneously. pulseEKKO PRO antennas are available in 8 center frequencies: 12.5, 25, 50, 100, 200, 250, 500 and 1000 MHz. Multiple NIC-500Ps together can be connected to run any number of pulseEKKO PRO antenna pairs; this is called daisy-chaining.

On the long side of the NIC-500 (opposite side to where the power and odometer connections are), you will find 4 pulseEKKO ports and a serial port (Figure 2-5), which are described below:

- Serial port – used to connect a GPS receiver. The GPS receiver can receive power from this port, if power out is enabled. For more information, see Section 3.3.
- pulseEKKO antenna ports – there are four numbered ports available to connect up to two pulseEKKO transmitter and receiver pairs. If you are using low frequency antennas, you will need to use fibre-optic converters to convert the fibre-optic cable to the 15-pin antenna port input (Figure 2-6). The other end of these cables will run to the respective transmitter or receiver. The NIC-500P can be run with a single transmitter/receiver pair if desired, which would be a single channel system.

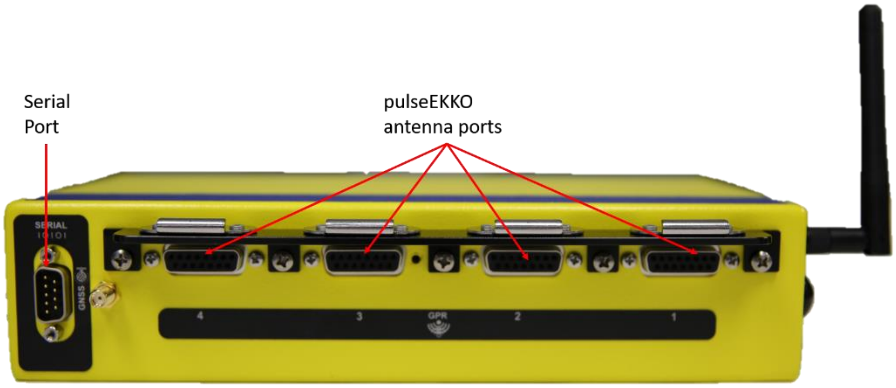


Figure 2-5: Long side of NIC-500P showing pulseEKKO antenna ports and serial port

Figure 2-6: Fibre optic converters

2.3 NIC-500X

The NIC-500X allows for the connection of up to eight pulseEKKO PRO transmitters and receivers simultaneously. The key distinction compared to the NIC-500P is that any combination of transmitters and receivers can be connected to the NIC-500X. For example, various configurations include 1 transmitter and 7 receivers, 1 transmitter and 5 receivers, and 4 transmitters and 4 receivers. Furthermore, the listening patterns of the transmitters and receivers respectively can be controlled.

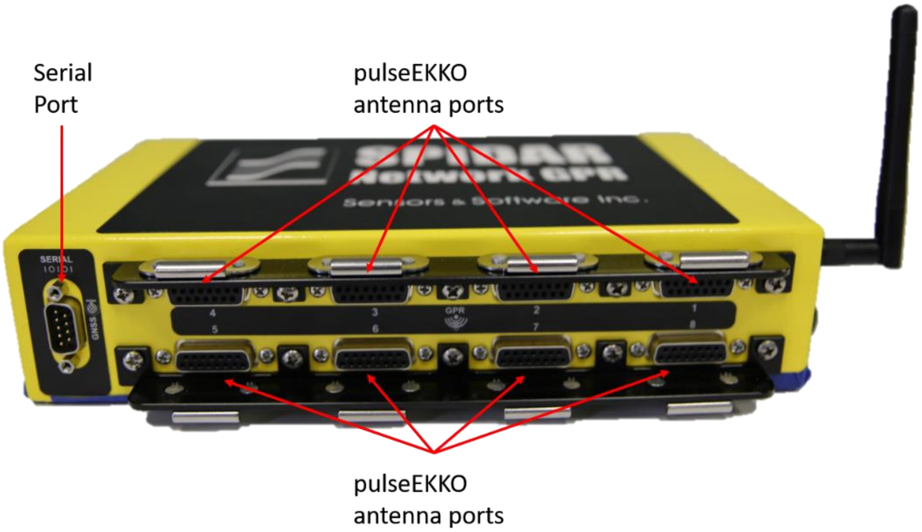


Figure 2-7: Long side of NIC-500X showing pulseEKKO antenna ports and serial port

On the long side of the NIC-500X (opposite side of the power and odometer connections), there are eight pulseEKKO ports and a serial port (Figure 2-7), described below:

- Serial port – used to connect a GPS receiver. The GPS receiver can receive power from this port, if power out is enabled. For more information, see Section 3.3.
- pulseEKKO antenna ports – there are eight numbered ports available to connect up to eight pulseEKKO PRO transmitters and receivers. If low frequency antennas are employed, fibre-optic converters are required to convert the fibre-optic cable to the 15-pin antenna port input (Figure 2-8). The other end of these cables will run to the respective transmitter or receiver.

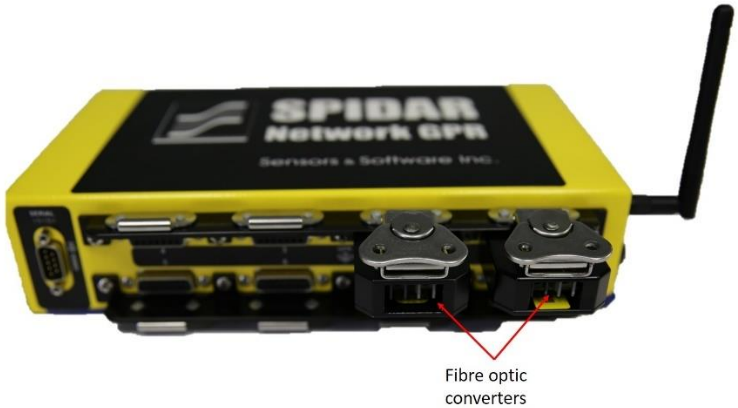


Figure 2-8: Fibre optic converters connected to the NIC-500.

3. Getting Started

This section explains how to connect all the components of the NIC-500 together. The first step is identifying the required cables. Depending on the setup, the cables displayed in Figure 3-1 may not all be needed.

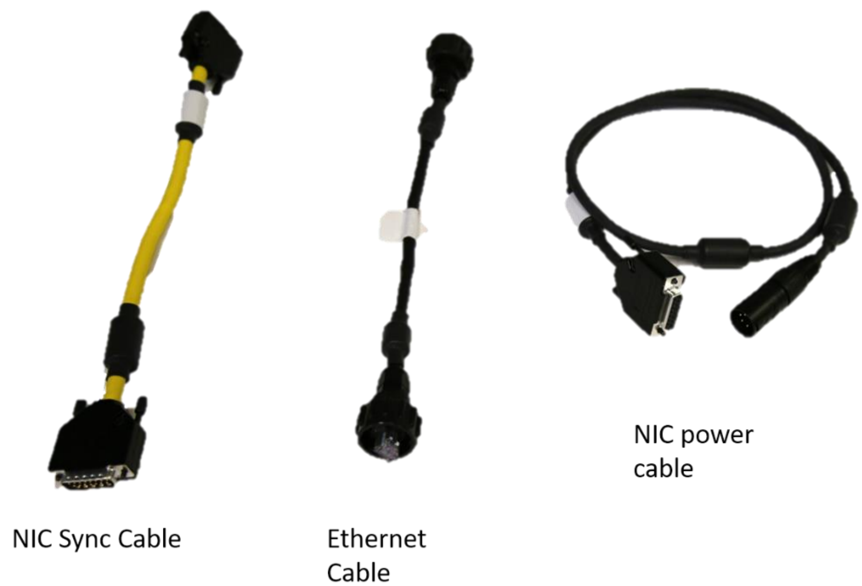


Figure 3-1: Common NIC cables

- NIC Sync Cable –required when connecting two NIC-500s together, regardless of the type of NIC-500. It will plug into the Link Out port on the Master NIC-500 and into the Link In port on the Subordinate NIC-500.
- NIC power cable – provides power to the NIC-500. One end plugs into the Link In port, the other end plugs into the power supply.
- Ethernet Cable –required when connecting two NIC-500s together. The ends connect to the Ethernet ports on the two NIC-500s. The cable pictured above has sealed ends, for a more secure connection. However, if this is not available, a standard Ethernet cable could be used.

Legacy pulseEKKO customers can also plug the pulseEKKO PRO power cable (Figure 3-2) into the round power port on the NIC-500.

> **NOTE:** If NIC-500s are daisy-chained, then the legacy power cable cannot be used. The NIC power cable must be used in this instance, as it provides adequate current to be drawn from the power supply.

pulseEKKO
power cable

Figure 3-2: pulseEKKO PRO power cable, not included with NIC-500s, but could be used to power a single NIC-500

3.1 Connecting all components – Single NIC-500

This section describes the cable connections to and from a NIC-500. Refer to Chapter 2 for information on NIC-500 ports.

> **NOTE:** Make sure all connections are made before plugging in the battery and powering up the system.

Odometer: Determine if an odometer will be used to trigger the system (from a SmartCart for example). If so, connect the odometer cable to the odometer port on the NIC-500 (Figure 3-3).

Ethernet: If a hardware connection (rather than Wi-Fi) is used to connect the device to the NIC-500, connect an Ethernet cable between the computer/tablet and the Ethernet port on the NIC-500 (Figure 3-3).

GPS: If a GPS is being used, the GPS must have a serial output cable. More information can be found in Section 3.3. Connect this serial cable from the GPS to the serial port on the NIC-500 (Figure 3-4).

Figure 3-3: Plugging in cables to a NIC-500

Figure 3-4: Connecting a GPS receiver to the serial port

The sections below explain the antenna cable connections for each type of NIC-500.

3.1.1 NIC-500N

Up to two Noggin systems can be plugged into the Noggin ports on a single NIC-500. The ports are numbered '1' and '2'. If you are running one Noggin, plug it into Port '1' on the NIC-500.

Plug the 37-pin Noggin cable into the Noggin port, and the other end into the Noggin device (Figure 3-5). See Section 8.1 on compatibility.

> **NOTE:** Do not connect the Noggin cable power connection to a power supply in Figure 3-5

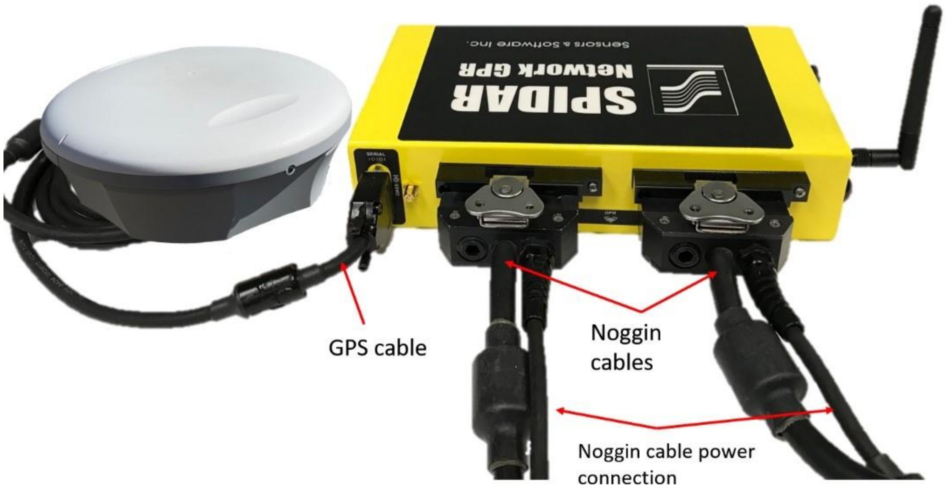


Figure 3-5: Connecting Noggin cables to the NIC-500N

Once completed, move on to Powering up in Section 3.4.

3.1.2 NIC-500P

Up to two pairs of pulseEKKO PRO antennas can be plugged into the pulseEKKO ports on the NIC-500. These ports are numbered '1', '2', '3' and '4'. Note that ports '1' and '3' should be used for transmitters and ports '2' and '4' for receivers. In addition, ports '1' and '2' must be used for a pair, before ports '3' and '4'.

If you are connecting a single pair of antennas, the Tx will connect to port '1' and the Rx will connect to port '2' (Figure 3-6). See Section 8.2 on compatibility.

Figure 3-6: Single pair of antennas connected to NIC-500P

Once completed, move on to Powering up in Section 3.4.

3.1.3 NIC-500X

The NIC-500X allows for the connection of up to eight pulseEKKO PRO transmitters and receivers simultaneously. The key distinction compared to the NIC-500P is that any combination of transmitters and receivers can be connected to the NIC-500X. For example, various configurations include 1 transmitter and 7 receivers, 1 transmitter and 5 receivers, and 4 transmitters and 4 receivers.

There are many combinations possible, but the following rules must be followed:

- Transmitter-Receiver pairs on ports '1' and '2' and ports '3' and '4' must have the same System Configuration settings under the GPR tab (Section 4.3.3). If the settings are different, then the second pair must be on ports '5' through '8'
- There must be at least one receiver in ports '1' to '4'

A fully loaded NIC-500X (with eight connections) is shown in Figure 3-7. See Section 8.2 on compatibility.

Once completed, move on to Powering up in Section 3.4.

Figure 3-7: NIC-500X with 4 pairs of transmitters and receivers

3.2 Connecting all components – multiple NIC-500s

If multiple NIC-500s are connected (daisy-chaining), one NIC-500 must be designated the "Master", and the other NIC-500s will be "subordinates". The Master NIC-500 will have the main power supply plugged into it. As well, if a GPS and/or an odometer are used, these must also be plugged into the Master NIC-500. When stacking NIC-500s on top of each other, the Master NIC-500 should be on the bottom. This way, the link cables will not cross over one another.

To connect multiple NIC-500s together:

- connect the Ethernet cable from the Ethernet port of one NIC-500 to the Ethernet port of the other NIC-500; it doesn’t matter which Ethernet port is used.
- connect the NIC Sync cable from the Link Out of the Master NIC-500 to the Link In of the subordinate NIC-500. If more NIC-500s are added, continue connecting Sync cables from Link Out of the previous NIC-500 to the Link In port of the newly added NIC-500

These connections are shown in Figure 3-8.

Figure 3-8: Daisy-chaining two NIC-500s

Connect appropriate antenna cables to the antenna ports, as described in the previous sections. Once all connections, move on to Powering up in Section 3.4.

3.3 GPS (optional)

A GPS can be connected to any NIC-500 to provide georeferenced data. Most GPS receivers with a standard thread can be screwed onto the top of the GPS mount (5/8-11 UNC-1A thread). Sensors & Software sells different mounts depending on the type of platform used.

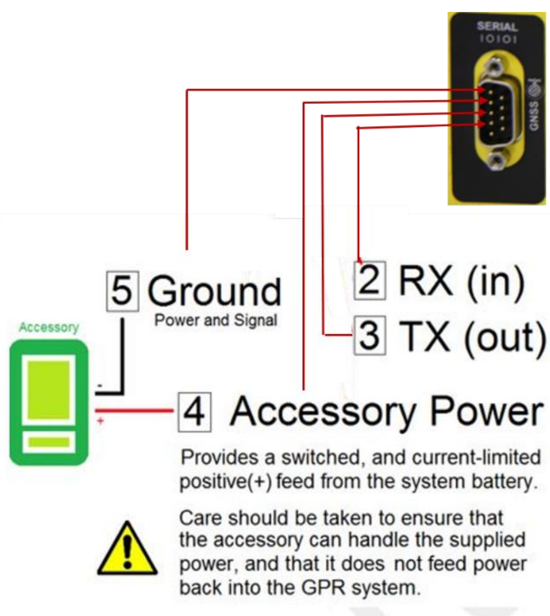
If the GPS was purchased from Sensors & Software, a single cable was provided that connects the GPS to the NIC-500; this cable supplies power to the GPS and sends data from the GPS to the NIC-500. Connect one end of the GPS cable to the GPS receiver, and the other end to the serial port on the NIC-500 (Figure 3-9). If the systems are daisy-chained, the GPS must be connected to the Master NIC-500.

Figure 3-9: Connecting cable at GPS end (L) and at NIC-500 end (R)

To connect and utilize a 3rd party GPS with the NIC-500, it must meet the following criteria:

- Be able to communicate over RS232 with a standard 9-pin serial output cable
- Output a NMEA GGA string in ASCII format, at a rate no faster than 20 Hz
- Support a baud rate of between 4800 and 115200
- If it cannot safely accept power via the serial port (as shown below), it must have its own battery or way of receiving power.
- GPS must not expect any handshaking from the NIC-500

NOTE: Since the serial port outputs power (current=1A, voltage=12V), it is the responsibility of the user to confirm with the GPS manufacturer that the serial cable does not provide power to the GPS <u>or</u> that the GPS will accept 12V power from our serial cable on the pins shown above. Sensors & Software is not responsible for damage caused to a GPS from using the serial port. Verify the pins on the drawing below.



3.4 Powering up

Once all connections are made, connect the NIC power cable to the battery. Press the Power button to turn on the NIC-500 (Figure 3-10).

Figure 3-10: Front of NIC-500 showing power button and LCD Display

Once the NIC-500 has powered up (about 30 seconds), the network name of the NIC-500 will be displayed on the top line of the LCD display; the bottom line will display the IP address (Figure 3-11). The first NIC-500 will always have the IP address 192.168.20.221. All the other NIC-500s will follow the same pattern: 192.168.20.XXX. The last three digits (XXX) are randomly assigned but will always be larger than 221

Figure 3-11: NIC-500 LCD Display

3.5 Connecting your device to the NIC-500

To setup and control data acquisition, connect to the NIC-500 using a computer, or tablet; the computer will be referred to as the “device” below. The minimum requirement for devices are listed below:

Operating System: Windows 7 or 10, Android or Linux
Web Browser: Google Chrome (version # 61.0.3163.100 or later)
Display Screen: 10-inch or larger is recommended
Resolution: 1920 x 1200 is recommended

Wireless Connection

To connect wirelessly from the device to the NIC-500, first obtain the name of the NIC-500 network from the LCD display. Then, on the device, search for this name among the Wi-Fi networks; the Wi-Fi networks may need to refresh once or twice for it to show up. When the NIC-500 network name appears, select this network and input the password. The default password is the name of the NIC-500 network. The password is case sensitive. The name and password can be changed in Network Settings 4.6.2.

> **NOTE:** If the password for the network was forgotten, connect to the NIC-500 with an Ethernet cable and change the password at this time.

Once connected, open a Google Chrome browser window. In the address bar at the top of the Google Chrome browser page, type the NIC-500's IP address, which is displayed on the NIC-500 LCD display. If there are more than one NIC-500, type in the IP address of the Master NIC-500.

Once connected, the screen in Figure 3-12 will be displayed

> **NOTE:** If you are in SPIDAR SDK mode, you cannot connect wirelessly to the NIC-500. It must be a wired, Ethernet connect.

Wired Connection

To use a wired connection from the device to the NIC-500, connect an Ethernet cable from the Ethernet port on the device to one of the Ethernet ports on the NIC-500.
Open a Google Chrome browser window. In the address bar at the top, type the IP address, which is also found on the NIC-500 LCD display.

Once connected, you will see the screen in Figure 3-12.

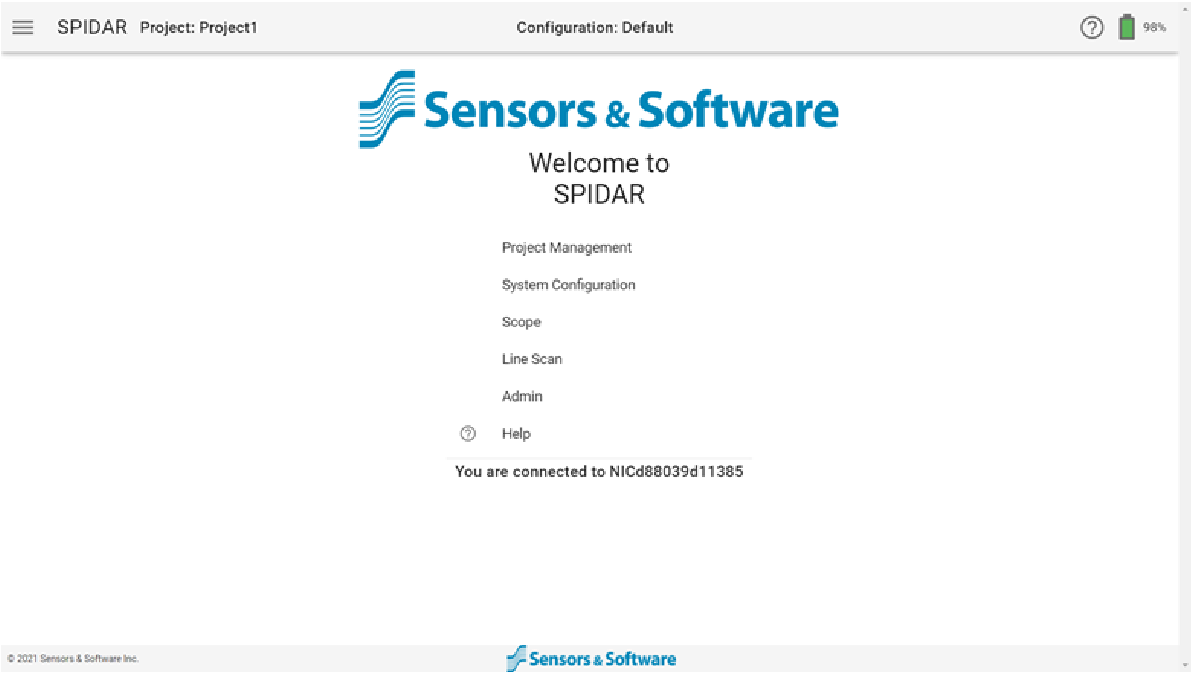


Figure 3-12: Welcome screen when you successfully connect to the NIC-500

If this screen does not appear or an error message appears (Figure 3-13), confirm that the device is indeed connected to the NIC-500 network, and not a different Wi-Fi network. In some rare cases, the device may need to be rebooted to ensure proper connectivity.

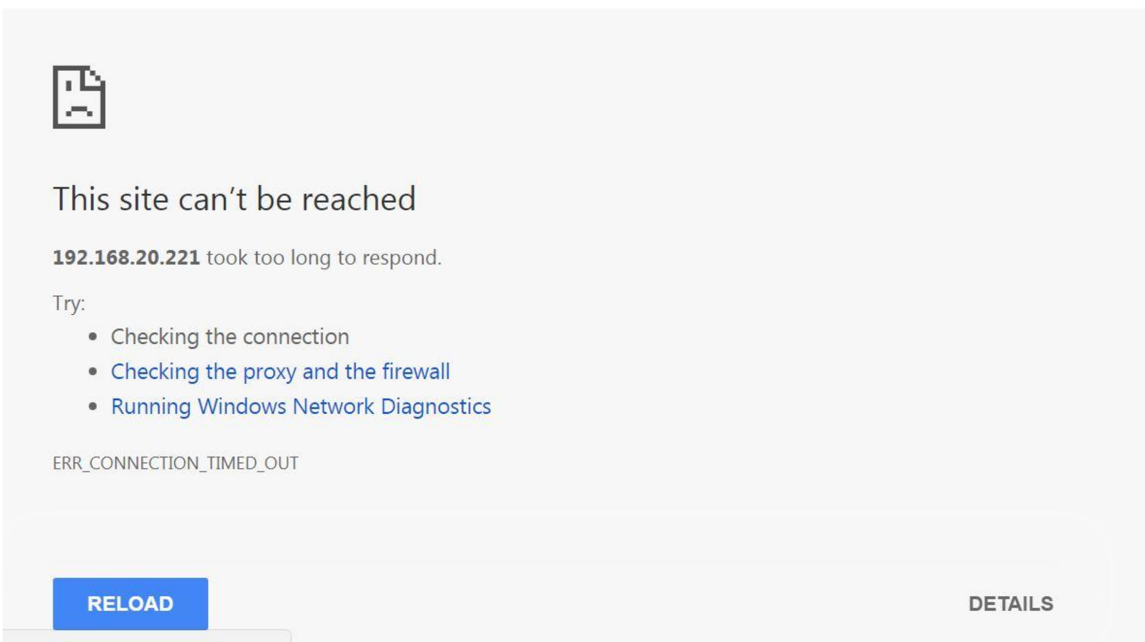


Figure 3-13: Trouble connecting to the NIC-500 from browser

3.6 Powering down NIC-500

It is recommended to power down the NIC-500 in the software (Section 4.6.1). This ensures that the system shuts down in the proper way.

In the event that the NIC-500 cannot be powered down in the software, press and hold the power button on the NIC-500 for a few seconds. The NIC-500 has shut down when the LCD display is blank. Only do this when absolutely necessary as this could lead to data loss and corruption.

4. SPIDAR Software

The SPIDAR Software allows the user to:

- Configure and setup data collection parameters
- Setup unique parameters for each antenna
- Control data acquisition
- Manage and export data from the NIC-500

During Line Scan operation, the data is displayed for the user to ensure that the system is running properly and collecting data. The software is not designed for reviewing, in-depth analysis or processing of data; this should be done in EKKO_Project.

4.1 Main screen

Once connected to the NIC-500, the Welcome screen will be displayed (Figure 4-1).

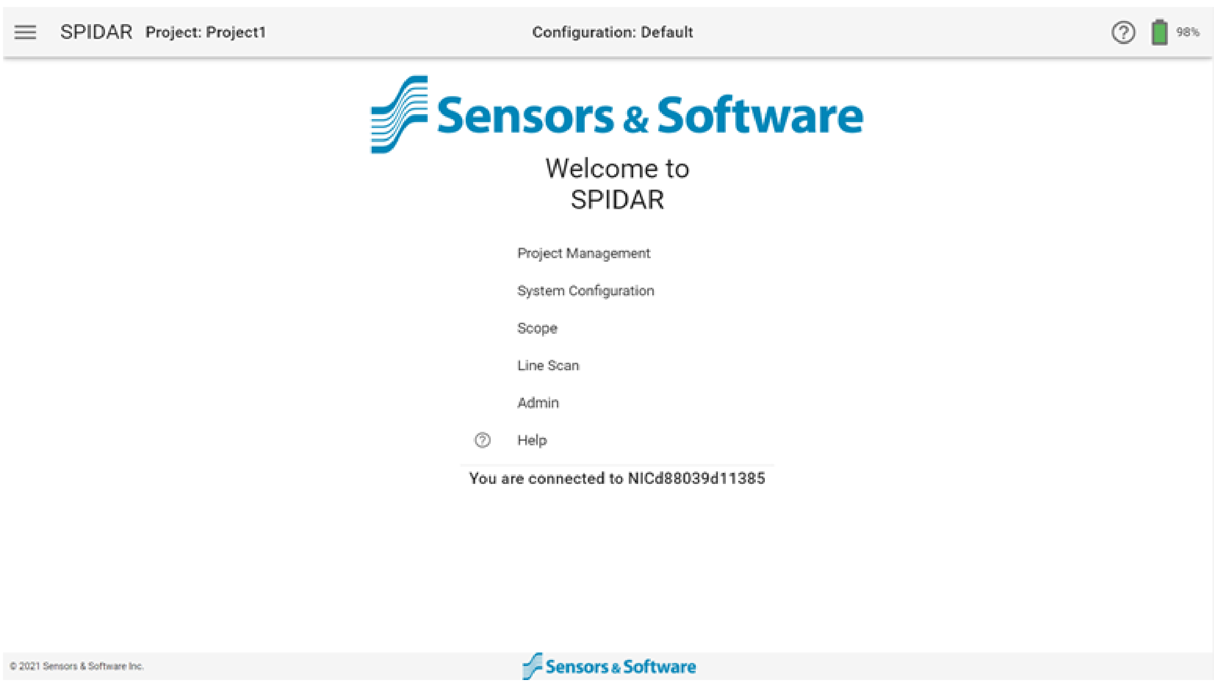


Figure 4-1: Welcome screen

On the left side of the top menu bar there is a button with three horizontal bars (often called a Hamburger button). Clicking on this button will produce a menu with 5 options, as well as a slider button for the background theme and shutdown button (Figure 4-2).

The 5 menu options correspond to the same options shown on the welcome screen. Clicking on an option (either on the menu, or on the Welcome screen) will change the main window display accordingly. Each option is explained in the following sections.

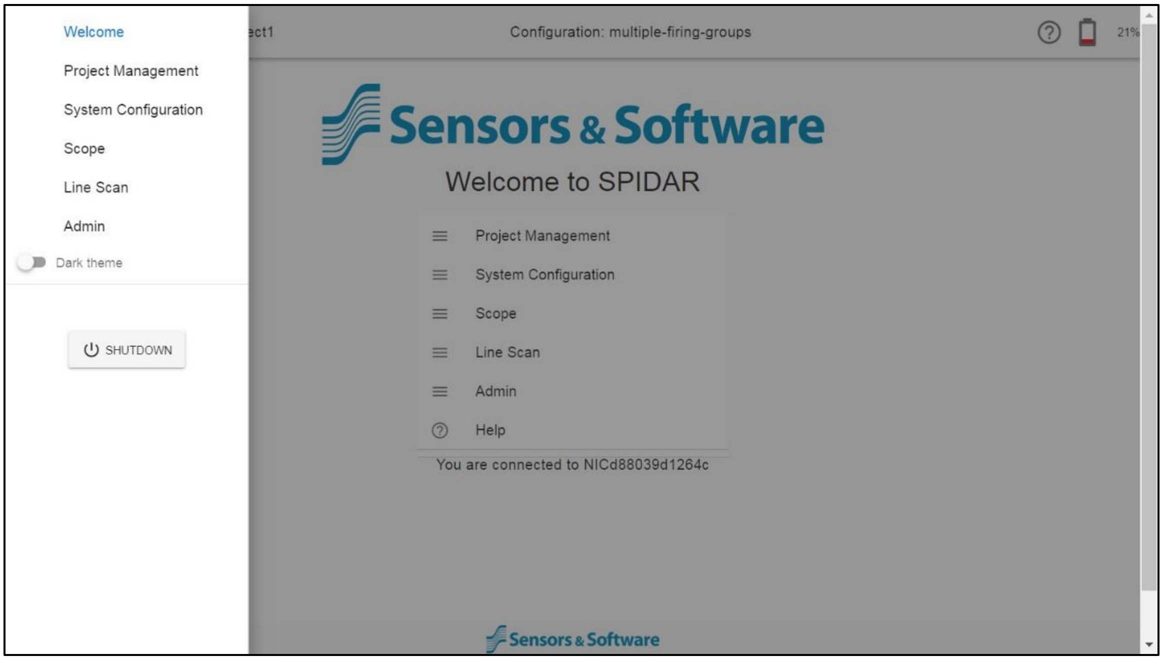


Figure 4-2: Available options from Hamburger button or Welcome screen

Below the menu options there is a slider to change the **Background Theme**. Using the slider, the background can be toggled between light and dark themes. This is a personal preference; however most users would likely find Dark Theme to be better suited for operation in direct sunlight.

Press the **Shutdown** button to power down the NIC-500.

On the top bar of every screen, the following information is displayed:

- Project (left side): Displays the name of the current project
- Configuration (center): Displays the name of the currently saved configuration
- Question mark icon (right side): click here to launch the User's Guide (as a .PDF file)
- Battery icon (right side): displays current battery power and the battery percentage remaining

4.2 Project Management

Selecting Project Management from the Menu on the left will display the screen in Figure 4-3. This screen shows all the projects that have been started. The active project is the one selected with a green dot.

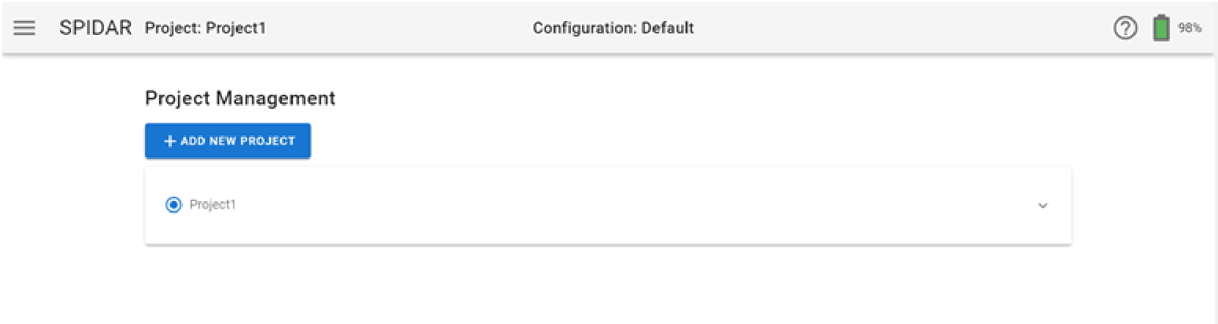


Figure 4-3: Project Management screen, showing just one active project

Click the **+** button to create a new project (you cannot use a name that already exists). A pop-up window will appear where the project name can be entered (Figure 4-4). Use letters and numbers only, special characters are not allowed. There is no limit for the number of characters in the name, however only the first 32 characters are shown in the pop-up window.

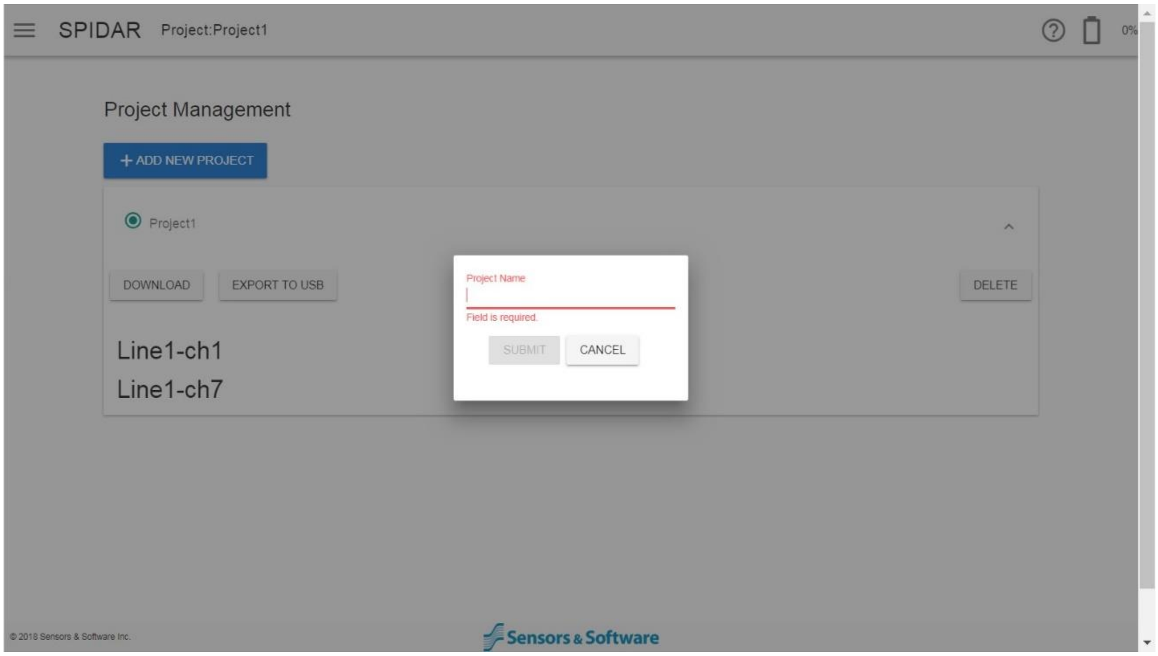


Figure 4-4: Entering the name for a new project

On the project page, click the drop-down arrow on the right of a project name to expand the window and display the number of lines collected for that project. Beside each line number is the channel (or port) that the receiver antenna was connected to. In the example in Figure 4-5, a single line was acquired with two receivers: one was connected to Port #1, the other to Port #7.

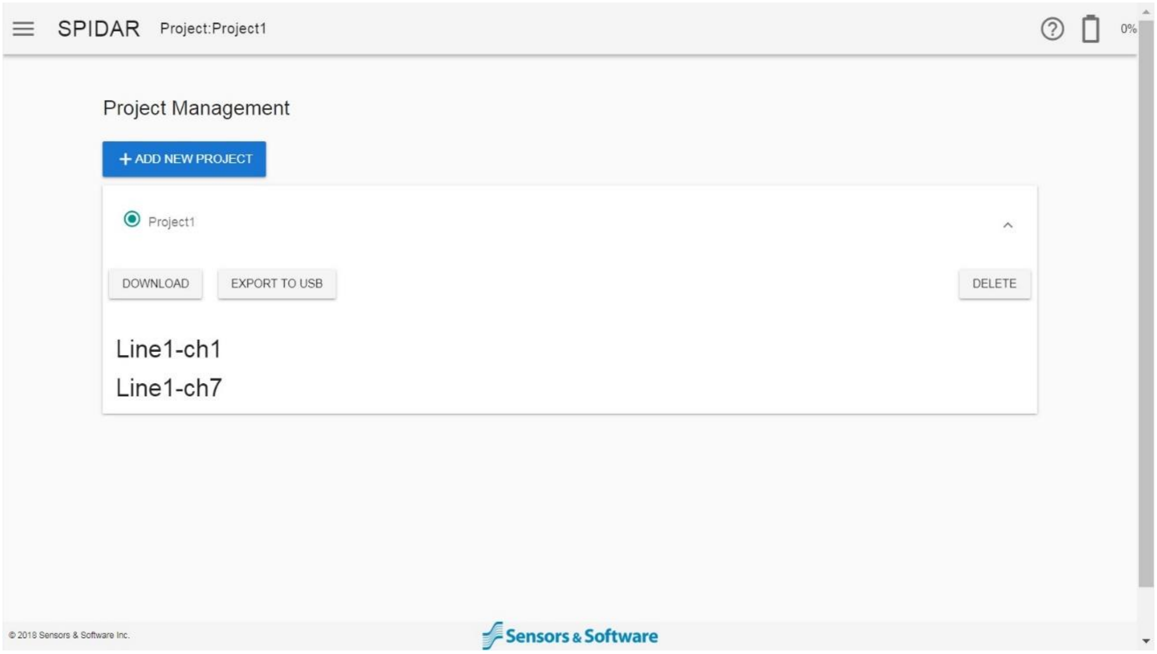


Figure 4-5: Expanded view showing the lines in a project

There are 3 buttons available when the project is expanded:

- Download – pressing this will copy the data from that Project to the device that is connected to the NIC-500. For large volumes of data, the software may produce an error message that it is unable to download. In this case, Export to USB method must be used.

  The data (a .GPZ file) will go into the Downloads directory, which is the default location your browser downloads files to. On most Windows PCs, it is typically C:\Users\<name>\Downloads, where name is the user who is logged in to that computer. The download directory can be changed by going into Settings in Google Chrome (Figure 4-6).

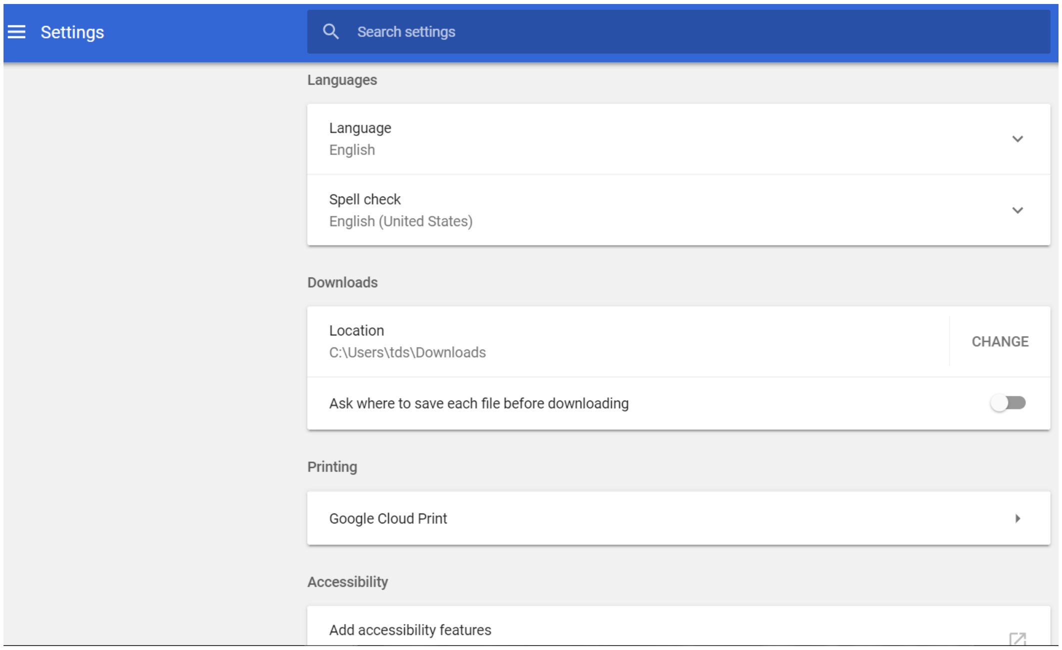


Figure 4-6: Changing downloads directory in Google Chrome

- Export to USB – provided a USB stick is inserted into one of the NIC-500 USB ports, pressing this button will copy the data (.GPZ file) for that project to the USB stick. A directory structure will be created on the USB stick.

  \GPR_Data\SPIDAR\Export01\<name>

  where <name> is the name of the Project on the NIC-500

  If the directory Export01 already exists, it will create another directory called Export02 and so on.

- Delete – pressing this button will delete ALL the data in this project, including the project itself. However, if there is only one project left, you won't be allowed to delete that project.

Multiple NIC-500s

If there is more than one NIC-500 connected, the screen in Figure 4-7 will be displayed. This allows the user to select one of the subordinate NIC-500s, and then click the blue plus button. This will open a new tab in your browser program for that NIC-500.

Data is stored locally on each NIC-500. As such, data management (download, export, deletion) is handled separately on each NIC-500.

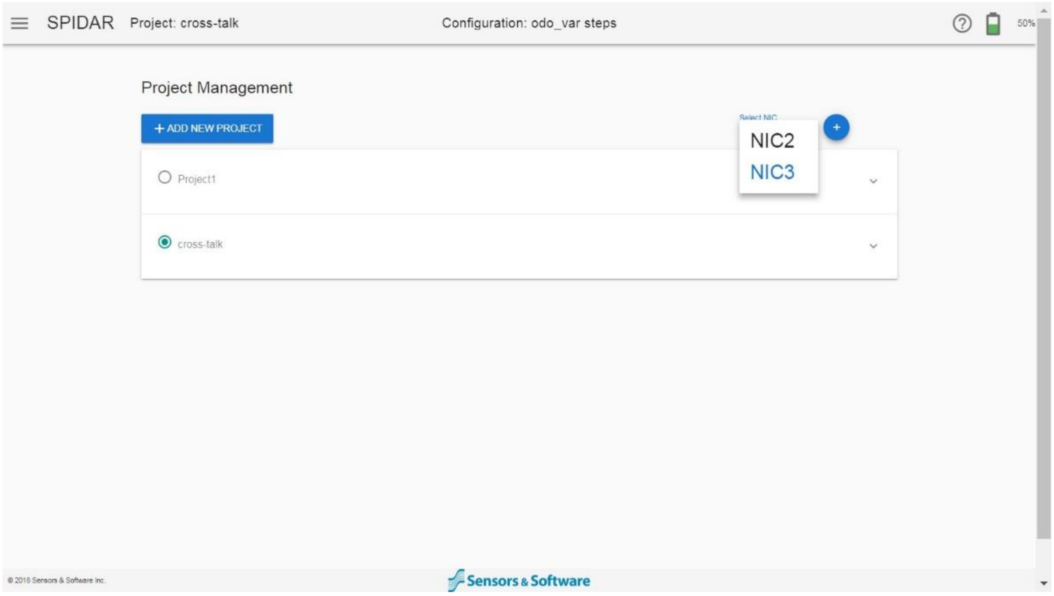


Figure 4-7: Project Management screen with multiple NIC-500s

Menu options are limited when connecting directly to a subordinate NIC-500 (Figure 4-8).

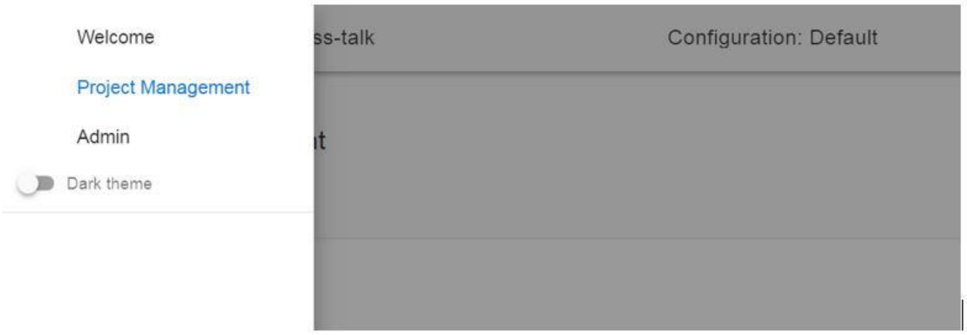


Figure 4-8: Menu options when connecting to a subordinate NIC-500

4.3 System Configuration

The System Configuration menu allows the user to configure the collection parameters and positions of each connected antenna. Since SPIDAR allows many different configurations and settings, it is useful to save and recall configurations to avoid having to input all the settings every time.

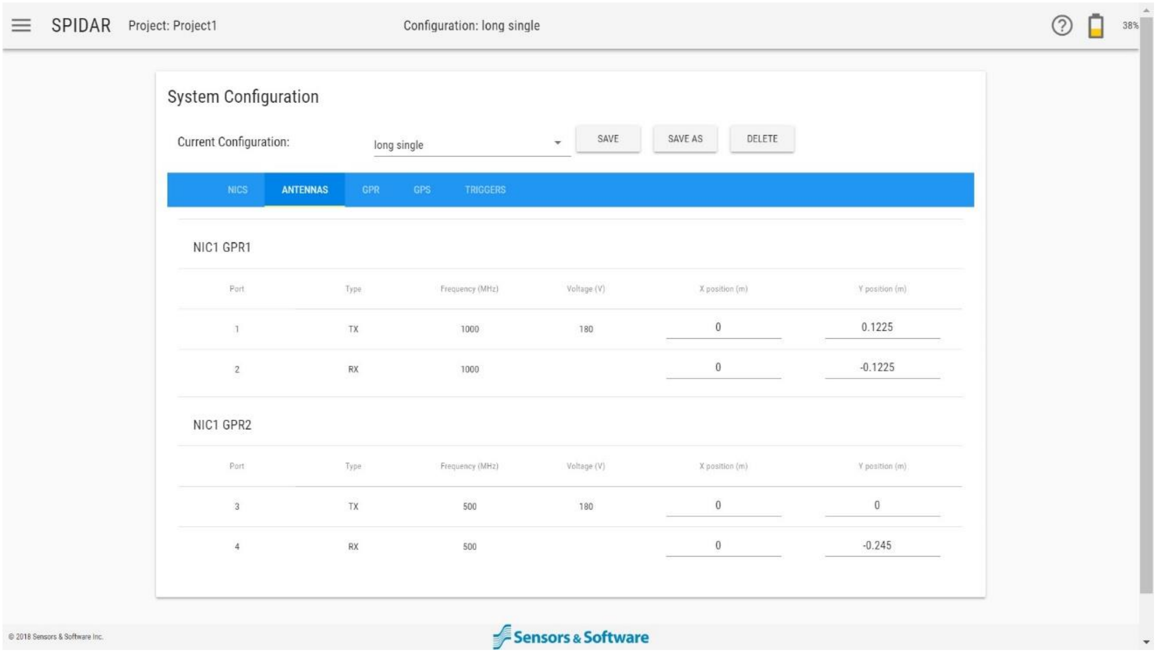


Figure 4-9: Creating, saving and deleting System Configurations

Above the blue bar are buttons that allow the user to create, save and delete system configurations (Figure 4-9). These are explained below:

- Current Configuration – the name of the current configuration is shown. To load a saved configuration, select it from the drop-down box. If nothing has been loaded, it will display Default. Note: the current physical setup (with antennas plugged into the same ports) must match the selected configuration or else an error message will be displayed.
- Save As – press this button to save a configuration under a new name. A pop-up window will appear where the name can be entered. A new unique name must be given, no duplication is allowed.
- Save – press this button to save the current configuration under the same name.
- Delete – press this button to delete the current configuration.

There are 5 tabs in the System Configuration menu, each one is explained below. Some tabs may differ slightly, depending on whether it is a NIC-500N, NIC-500P or NIC-500X.

4.3.1 NIC-500s

This option displays each NIC-500 that is connected, along with its IP address. NIC-500s will be sequentially numbered, with NIC1 being the Master NIC-500 (Figure 4-10). As daisy-chaining is not available for the NIC-500X, this tab will only be displayed if using a NIC-500N or NIC-500P with multiple NIC-500s connected.

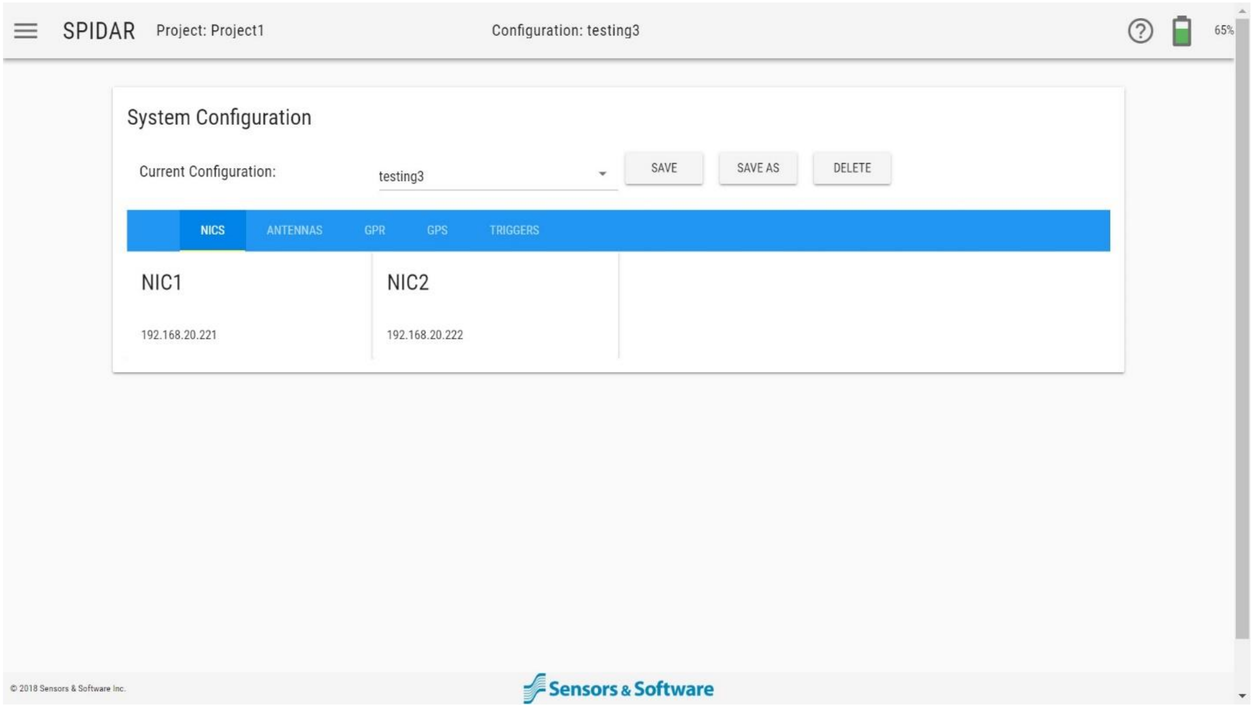


Figure 4-10: NIC-500 tab in System Configuration menu

4.3.2 Antennas

The antennas tab displays the transducers or antennas connected to the NIC-500s. The screen displayed will differ slightly depending on the type of NIC-500 used.

<u>Antenna Positions</u>

For all NIC-500 types, the relative position of each antenna must be entered, by inputting values for the X Position and Y Position. The X Position is measured from left to right when looking in the direction of travel. The Y Position is pointed along the direction of travel. These directions are indicated on the axis graphic at the top right of the antennas page.

The user must define an origin (0,0), however this point is completely arbitrary. For Noggin systems, it is usually the center of one of the Noggins (as shown in Figure 4-11) and every other system is relative to that. For pulseEKKO PRO antennas, it could be the center of a transmitter, with all other transmitters and receivers relative to that. Alternatively, it could be the geometric center of the cart. The choice is up to the user. Remember to follow a Cartesian coordinate system, so some numbers may be negative (i.e., to the left of the system or behind the system).

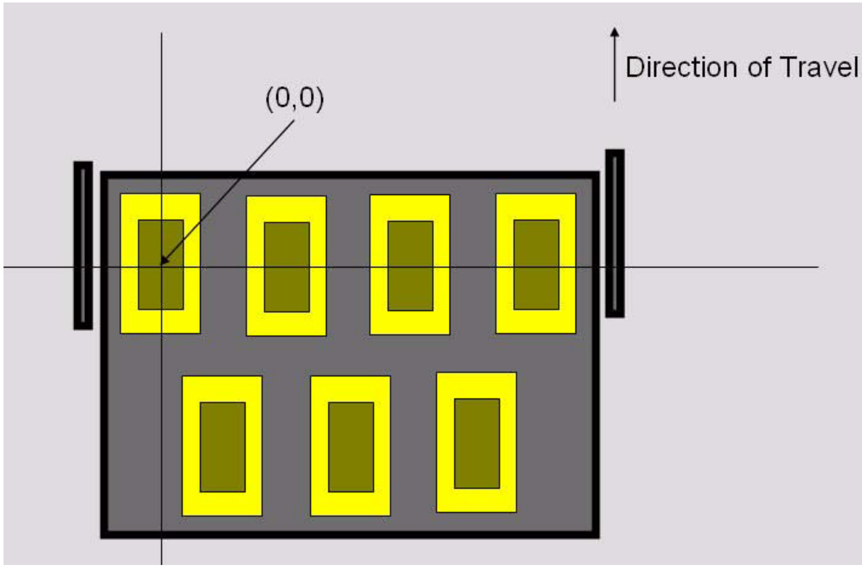


Figure 4-11: Example of setting the offsets for 7 Noggin GPR systems on a cart. The center of the Noggin in the top left position is x=0, y=0 and all other Noggins are positioned relative to the first one. The 3 Noggins to the right would have positive X coordinates and the three Noggins at the bottom would have negative Y coordinates.

NIC-500N – Single NIC

Each NIC-500N has two ports, to connect up to two Noggins to the system. Each Noggin frequency is automatically detected and identified under the frequency column. In the example in Figure 4-12, there is a Noggin 500 MHz and Noggin 1000 MHz system connected to it.

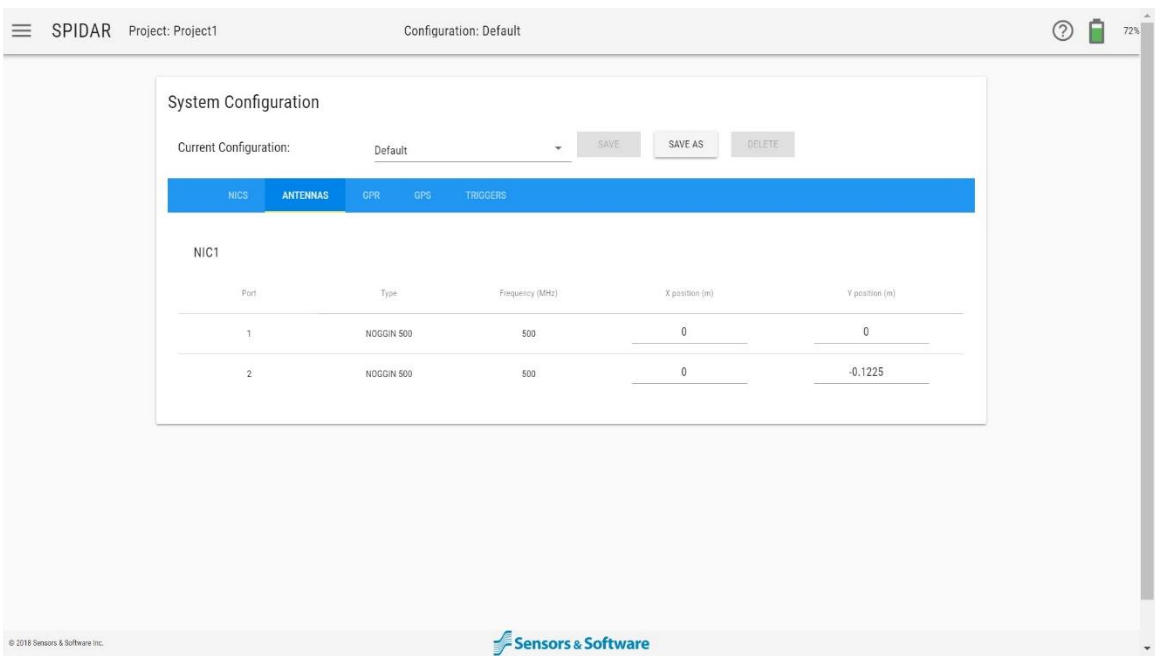


Figure 4-12: Antenna tab showing two Noggins connected to a single NIC-500

Based on the positions listed, the Noggin 1000 would be at the front centered on the origin (0,0), and the Noggin 500 behind it.

NIC-500N – Multiple NIC-500s

If the user has daisy-chained more than one NIC-500, it will list each NIC-500 and the Noggins connected to it; all else remains the same. In Figure 4-13, the master NIC-500 has a Noggin 1000 connected to it, and the subordinate NIC-500 has a Noggin 500 connected.

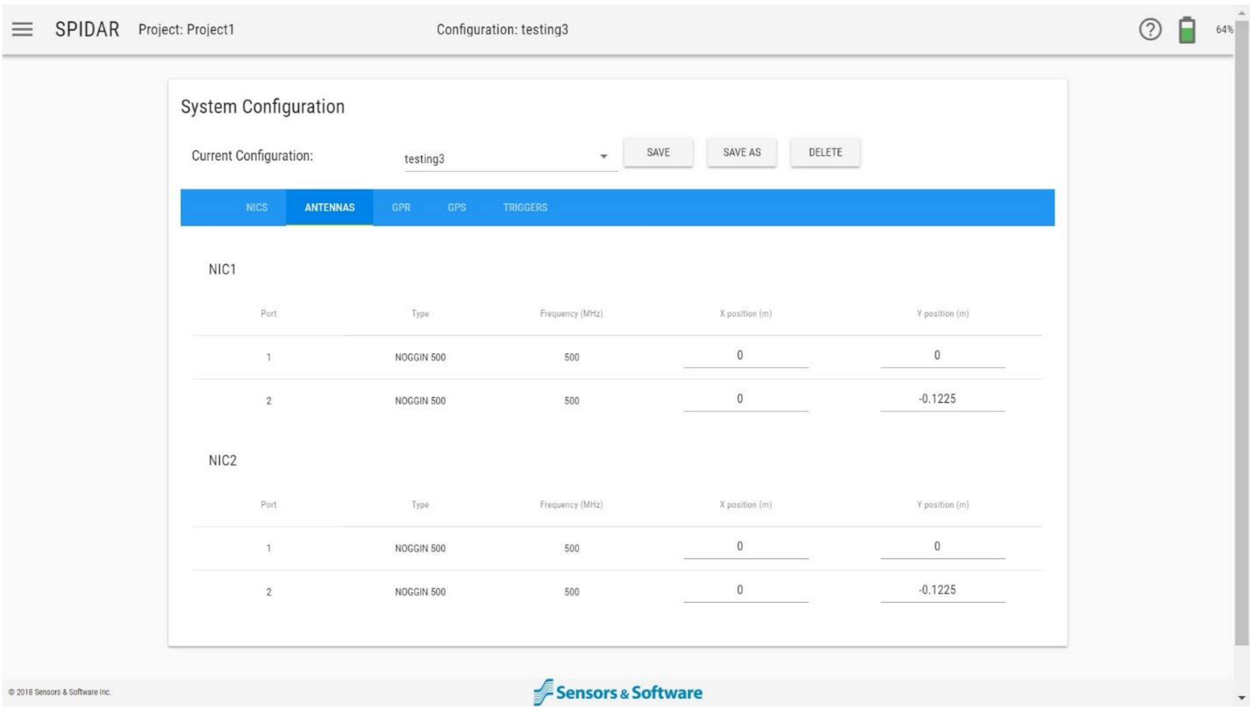


Figure 4-13: Antenna tab showing two NIC-500s, each with one Noggin

When daisy-chaining more than two NIC-500s, it is recommended to contact Sensors & Software support for advice on the port connections and physical placement of each Noggin to optimize data collection. Currently, a maximum of 4 NIC-500s can be daisy-chained.

NIC-500P – Single NIC

Each NIC-500P has four ports and can connect up to two pairs of transmitter and receivers. The higher frequency antennas (250 MHz, 500 MHz and 1000 MHz) will be automatically detected and listed. For lower frequency antennas, the user has to input the frequency in the frequency column. Note that ports ‘1’ and ‘3’ should be used for transmitters and ports ‘2’ and ‘4’ for receivers. The example below shows a NIC-500P connected to pulseEKKO 500 MHz and 1000 MHz

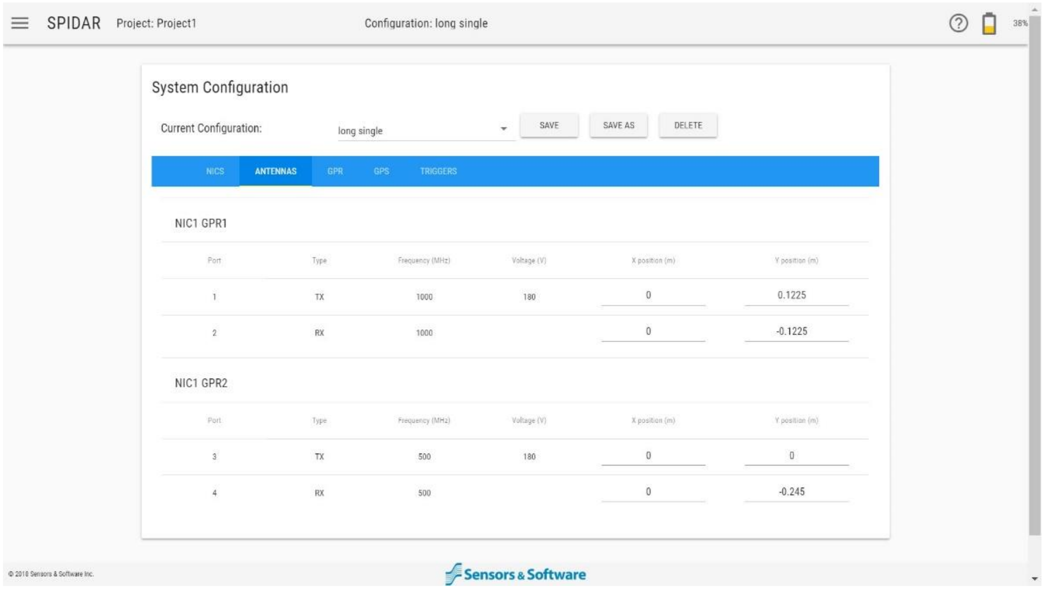


Figure 4-14: Antenna tab showing a single NIC-500, with two pairs of pulseEKKO antennas

<u>NIC-500P – Multiple NIC-500s</u>

If the user has daisy-chained NIC-500Ps, the page will list each NIC-500 and the pulseEKKO PRO antennas connected to it. Figure 4-15 shows two NIC-500s, where the first NIC-500 has two pairs of antennas connected, and the second NIC-500 only has one pair connected.

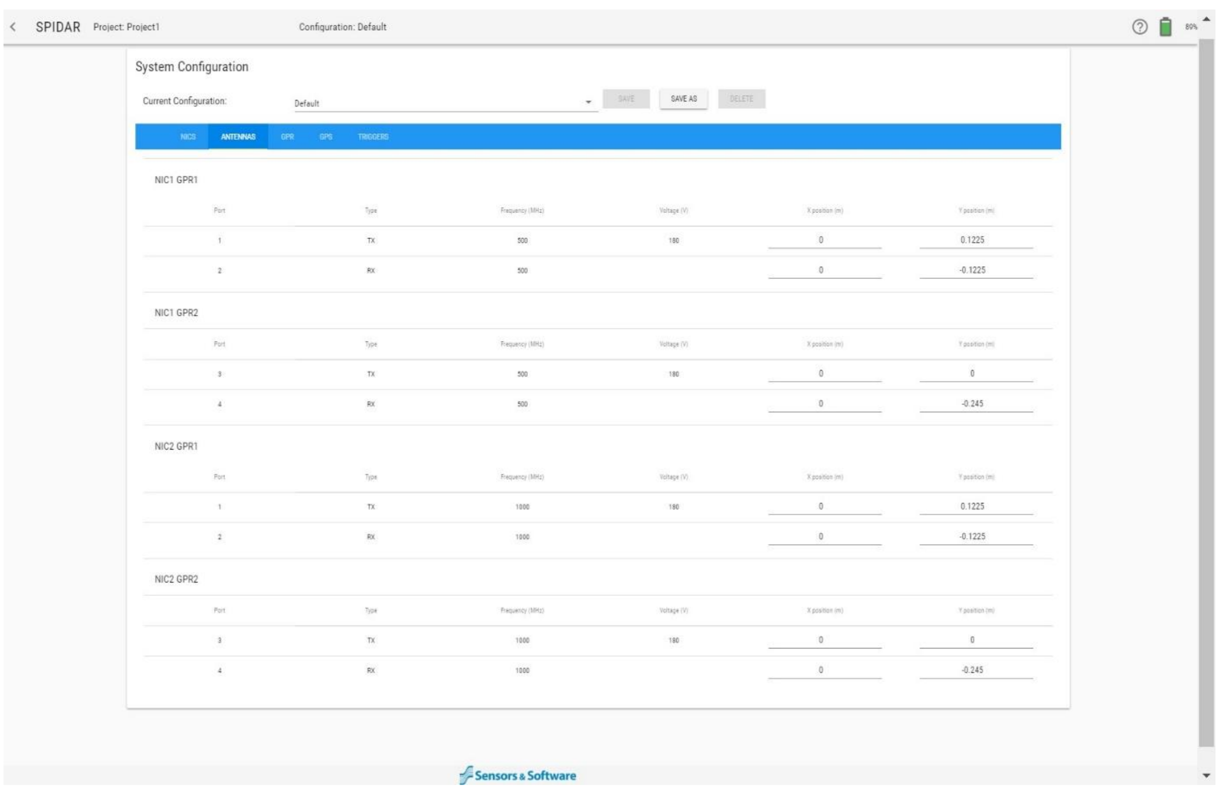


Figure 4-15: Antenna tab showing two NIC-500s and four pairs of pulseEKKO PRO antennas in total

When daisy-chaining more than two NIC-500s, it is recommended to contact Sensors & Software support for advice on the port connections and physical placement of each pulseEKKO to optimize data collection. Currently, a maximum of 4 NIC-500s can be daisy-chained.

NIC-500X

The NIC-500X allows up to eight transmitters and receivers to be connected.

The NIC-500X is unique in that the user can collect data from all transmitter and receiver pairings simultaneously. This is achieved through Sequencing, described in Appendix A. For a given NIC-500, there can be up to 4 Sequences. Firing groups are used to define which receiver is listening to which transmitter in each sequence.

It is useful to sketch a diagram to help visualize the sequencing. Consider the following example: a user has four transmitters and four receivers and for each transmitter firing, they would like to collect data at two different receivers. This is illustrated in Figure 4-16.

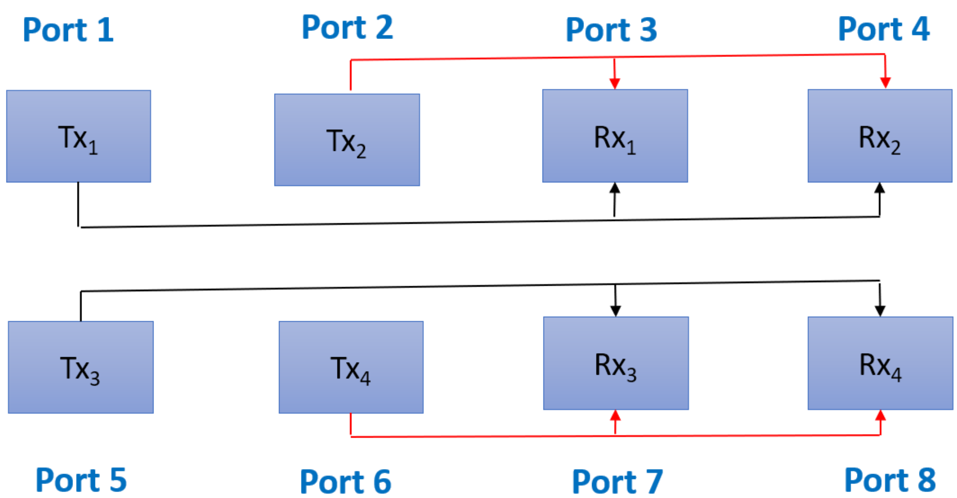


Figure 4-16: Conceptual diagram for four transmitters and four receivers connected to a NIC-500X; black lines illustrate sequence 1 and red lines illustrate sequence 2

This collection process requires two sequences to collect all desired transmitter-receiver combinations.

- Sequence 1 (arrows in black)
  - Tx_1 fires, Rx_1 & Rx_2 listen
  - Tx_3 fires, Rx_3 & Rx_4 listen
- Sequence 2 (arrows in red)
  - Tx_2 fires, Rx_1 & Rx_2 listen
  - Tx_4 fires, Rx_3 & Rx_4 listen

The firing groups must now be specified. A firing group consists of a single transmitter firing, and the receivers that listen to it. In this example, Tx_1 firing and Rx_1 & Rx_2 listening are assigned to firing group 1; Tx_3, Rx_3 and Rx_4 are assigned to firing group 3. These two events make Sequence 1.

For Sequence 2, Tx_2, Rx_1 & Rx_2 are assigned to firing group 1, and Tx_4, Rx_3 & Rx_4 are assigned to firing group 3. The table below illustrates this by showing the firing groups for each sequence:

Port	Antenna	Sequence 1	Sequence 2
1	Tx_1	1	-
2	Tx_2	-	1
3	Rx_1	1	1
4	Rx_2	1	1
5	Tx_3	3	-
6	Tx_4	-	3
7	Rx_3	3	3
8	Rx_4	3	3

Consider another example of two pairs of 500 MHz transmitter and receivers connected to a NIC-500X.This is graphically depicted in (Figure 4-17). Once again, Sequence 1 is shown in black, while Sequence 2 is shown in red.

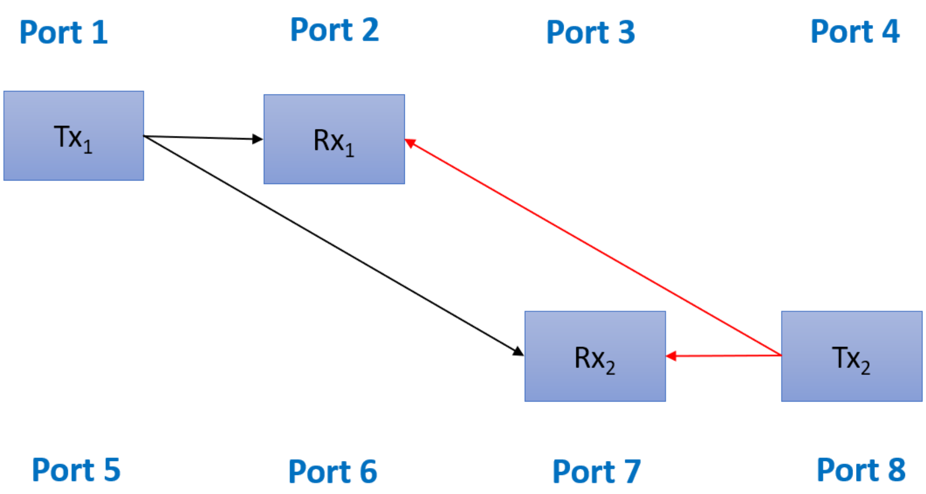


Figure 4-17: Diagram of two Sequences for two pairs of antennas

The SPIDAR screen display is shown in Figure 4-18.

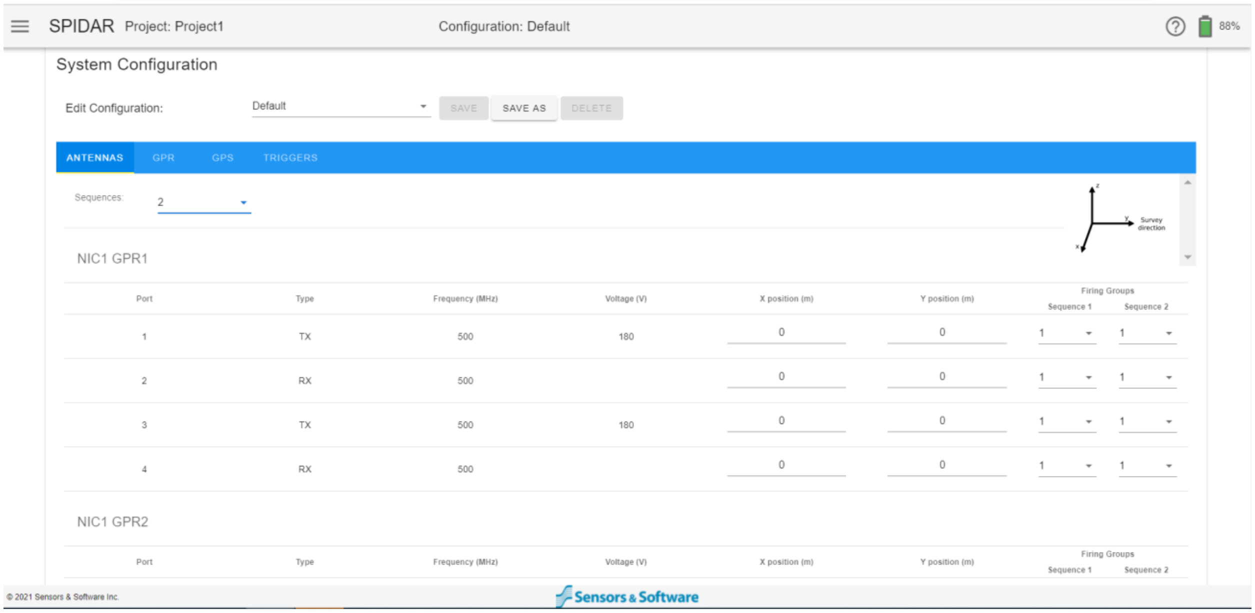


Figure 4-18: Two pairs of 500 MHz transmitters and receivers

The user must first select the number of sequences from the drop-down box under the blue bar. This will control the number of sequence columns displayed on the right of the screen. In this case, the user has selected 2 sequences, resulting in two columns (Seq1 and Seq2) being displayed. The first sequence has the Tx on port 1 firing and both receivers listening; this is firing group 1. The second sequence has the Tx on port 8 firing and both receivers listening again; this is firing group 3. Notice how the Tx on port 8 is OFF during Sequence 1, and the Tx on port 1 is OFF during Sequence 2.

There are some rules that must be adhered to when setting Sequences and firing groups:

1. Transmitters on Ports 1-4 can only use firing groups 1 and 2. Transmitters on Ports 5-8 can only use firing groups 3 and 4.
2. It is not possible to have more than one transmitter on a firing group.
3. Each element (transmitter and receiver) can only be used once per sequence.
4. A receiver can listen to a transmitter on any port. However, they must have the same system configuration settings (time window, sampling interval etc). If these settings differ, then receivers on Ports 1-4 can only listen to transmitters on Ports 1-4, and receivers on Ports 5-8 can only listen to transmitters on Ports 5-8. An application of this rule is the WARR machine, where the user could have 1 transmitter and 7 receivers. In this scenario, all receiver settings must be the same.

NOTE: At this time, it is not possible to connect multiple NIC-500X's together

4.3.3 GPR

The GPR tab allows the user to setup parameters specific to the connected antennas (Figure 4-19). This section describes the settings common to all NIC-500s.

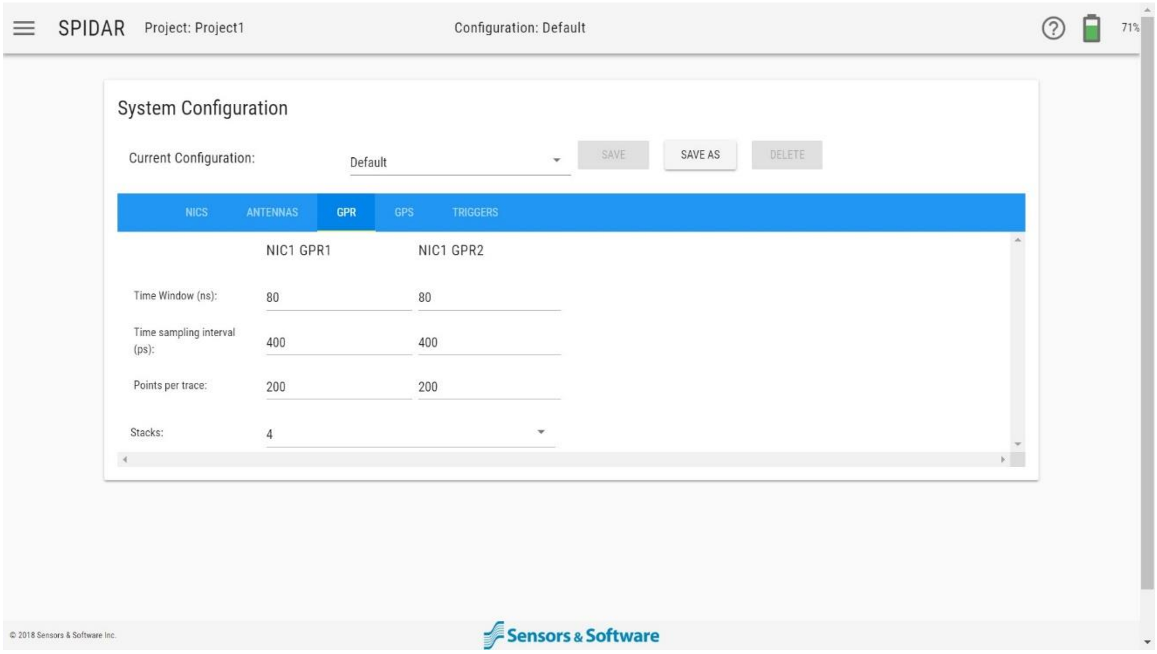


Figure 4-19: Setting parameters under the GPR tab

Note: When using a single NIC-500 with multiple GPR units, there are some settings that must be same for the GPR units (such as step size, points per trace and stacks); these are detailed in the paragraphs below. In particular, the step size required for the highest frequency GPR is what determines the spatial sampling for both GPR systems. This results in spatial over-sampling of any lower frequency GPR units connected.

<u>Time Window</u>

The Time Window setting determines how long (and therefore how deep) the GPR will collect data. It is important that it is set to a value appropriate for the depth of the survey target. An entire survey could fail if the window is not sufficiently long enough to sample to the depth of the target. Conversely, too long a time window increases the data volume, can make data hard to interpret and increases collection time.

For users that are more comfortable working with depth, rather than time, the following equation relates time to depth

Time = (Depth x 2) / Velocity

Assuming a velocity of 0.1 m/ns, if the targeted depth is 2m deep, then set the time window to approximately 40 ns. Remember that Time Window also includes time before time-zero.

The table below lists some default time windows and their associated depth of penetration, assuming a velocity of 0.1 m/ns (or 0.328 ft/ns).

Frequency (MHz)	Time Window (ns)	Approx. Depth (m)	Approx. Depth (ft)
12.5	1600	80	260
25	800	40	130
50	400	20	65
100	200	10	33
200	100	5	16
500	50	2.5	8
1000	25	1.25	4

Changing the time window will correspondingly change the points per trace (described below).

<u>Points per trace</u>

A trace is collected each time the GPR pulses and records new data at a specified location. The trace contains all the data (as data points) from the top of the scan to the bottom of the time window.

The points per trace is related to the Time Sampling Interval as per the equation below:

Points per trace = Time Window / Time Sampling Interval

Changing the points per trace will make a corresponding change in the time sampling interval, such that the value for time window is maintained.

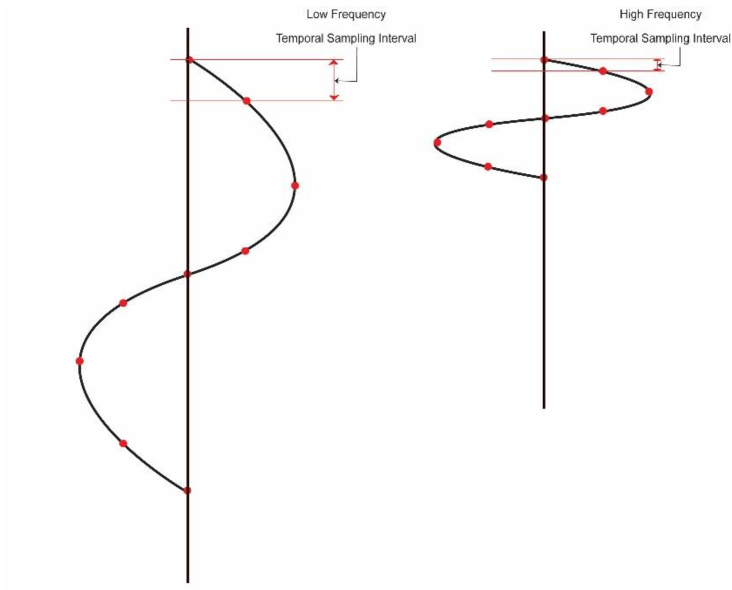
The value for points per trace must be between 70 and 30,000.

It is more common for the user to change the time sampling interval (below) than it is to change the points per trace. Changing the sampling interval will automatically adjust the points per trace.

> **Note**: Points per trace must be set the same for the GPRs on a single NIC-500. Points per trace can be different between NIC-500s on a daisy chained system.

Time Sampling Interval

Also known as Temporal Sampling, this defines how often the GPR wave is sampled at the GPR receiver, to accurately capture the resulting signal waveform. It is expressed as a time interval, in picoseconds, between points on a trace (1000ps = 1ns). Antenna frequency affects the sampling interval; higher frequencies should be sampled at a finer time interval than lower frequencies to accurately capture the resulting waveform.



The following table displays recommended temporal sampling interval for different frequencies:

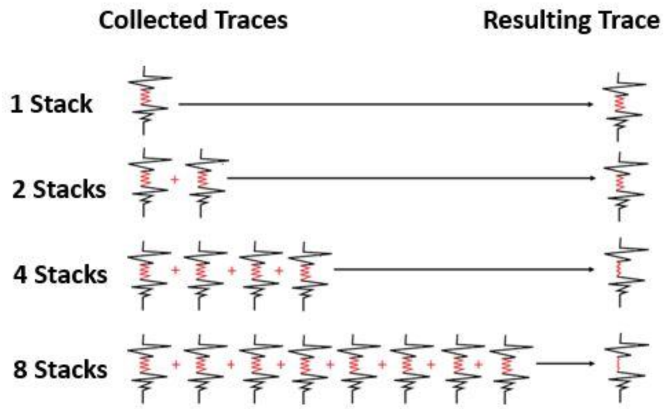
Center Frequency (MHz)	**Recommended Sampling Interval (ps)**
12.5	6400
25	3200
50	1600
100	800
200	400
250	400
500	200
1000	100

The minimum value that can be set is 50 ps.

Stacks

In noisy environments, one way to improve the signal to noise ratio is to collect more than one trace at each position, average them, and then record the average trace; this is known as "stacking". Stacking improves data quality because noise, which is usually a random addition to the trace, tends to zero when averaged.

The following diagram displays how data is stacked. At each data collection point, the trace is collected multiple times. Traces are averaged to calculate the resulting data trace, which is saved.



Stacking improves data quality but may slow down survey time. The more stacks, the longer it takes to collect data at each survey position. It is important to find the ideal number of stacks that adequately detect the target. Select the number of stacks from the drop-down box. Stacks values will always be 2^n, where n=1 to 15. This translates to a minimum value of 2 to a maximum value of 32,768.

> **Note**: Stacks must be set the same for the GPRs on a single NIC-500. Stacks can be different between NIC-500s on a daisy chained system.

<u>NIC-500X</u>

There are some restrictions when using a NIC-500X, with antennas connected to GPR1 and GPR2:

- Both GPRs must have the same number of stacks
- Both GPRs must have the same number of points per trace (time window / sampling interval). See Figure 4-20.
- Points per trace must be an integer

If the above restrictions are not followed, a warning message will pop up with the user tries to save the configuration.

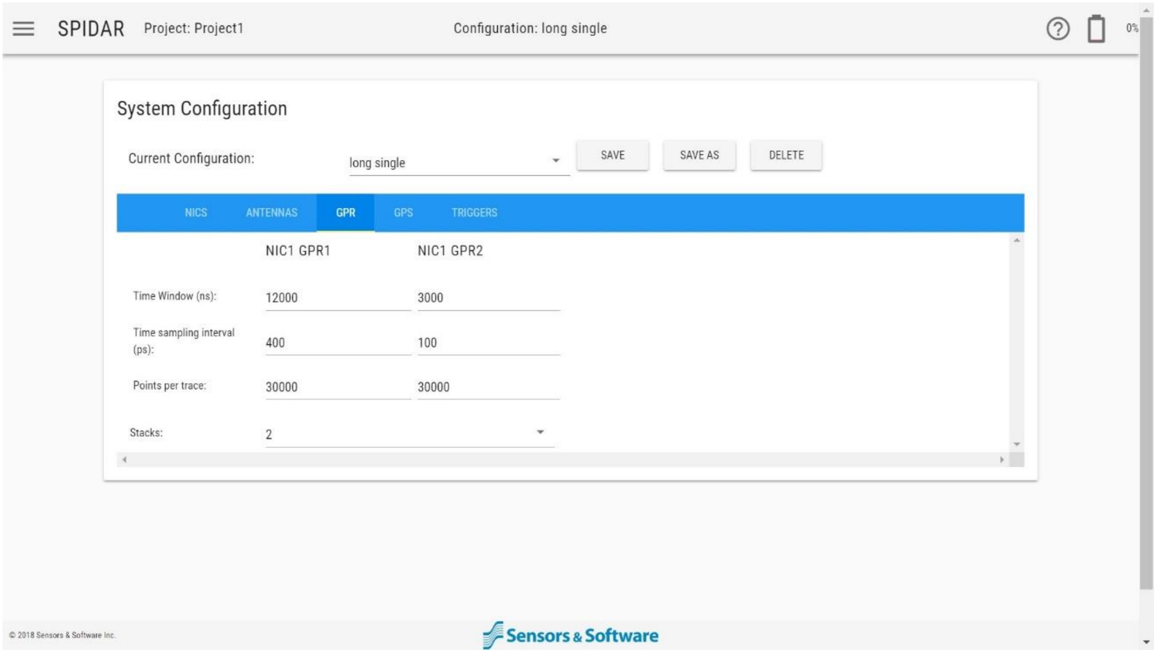


Figure 4-20: GPR1 & GPR2 must have the same points per trace

4.3.4 GPS

The user has the following options for configuring the GPS parameters (Figure 4-21):

- GPS Device – Use this dropdown to select the External GPS or turn GPS off. If the user selects External, they can attach an optional GPS to the system via the serial cable.
- Baud rate – This option only appears if External GPS is selected. The baud rate is the speed that data is sent from the GPS receiver to the serial port of the NIC-500, specific to the GPS manufacturer. Using the dropdown box, it can be set to one of the following values: 4800, 9600, 19200, 57600 or 115200.
- External Power - This option only appears if External GPS is selected. The serial port on NIC-500 can also output power, thereby enabling a single cable to be used for the GPS (for power and data). This is specific to the GPS that is sold by Sensors & Software.
- Positions – input the coordinate of the GPS relative to the origin of your configuration as set in Section 4.3.2. The 'Z' position will be the height of your GPS receiver from the ground.
- Latency - The GPS latency time is the time difference between when the GPS receiver obtains its position and when it is logged by the NIC-500. If GPS latency time is not corrected for, the GPS position of targets and features of interest in the GPR line is less accurate. GPS latency is not a large problem when GPR data are collected on slow-moving platforms such as the SmartCart or SmartTow; it has the largest effect when trying to determine the true position of a fast-moving platform such as the SmartChariot.

For example, at 25 km/h, you are moving 6.94m per second. If the GPS has 1.00 second latency, your data position would be off by 6.94m. Details on calculating GPS Latency can be found in Appendix B. The latency will be saved in the data for use in EKKO_Project. It could also be adjusted at that time, if it's unknown at the time of acquisition.

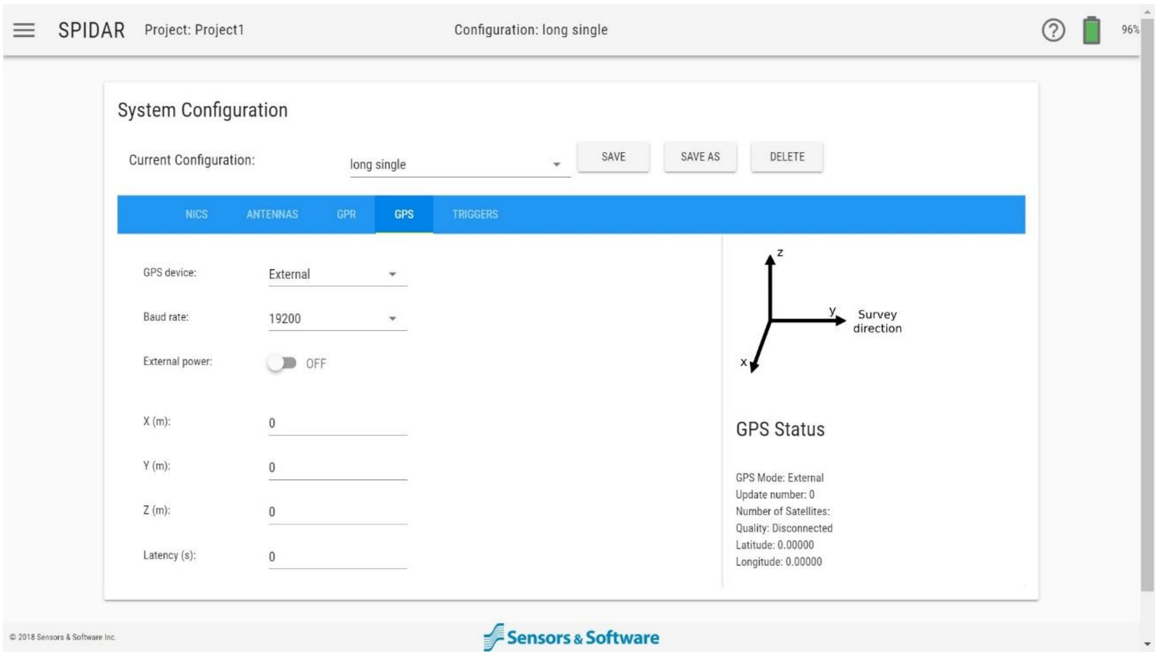


Figure 4-21: Setting options under the GPS tab

Note: In a daisy-chained configuration, GPS data is only recorded on the Master NIC-500. For the subordinate NIC-500s, the user must copy the .GP2 files from the Master NIC-500 and rename them to match the subordinate NIC-500(s). Then the appropriate GPS offset must be applied in the EKKO_Project software (see the EKKO_Project manual for details).

4.3.5 Triggers

A trigger is used to fire, or pulse, the GPR system to collect a trace of data. There are three ways to trigger the GPR system: using an Odometer, Manually or Free Run mode. These are set by selecting Trigger method and configuring the appropriate settings.

Note: If there are multiple NIC-500s, the same Trigger Method must be used for all of them.

Odometer

Used most often if the configuration has a wheel encoder. When the odometer wheel moves one step size, it will cause the transmitter to fire. This is the easiest mode to operate in, as you don't have to worry about collecting data at equally spaced intervals.

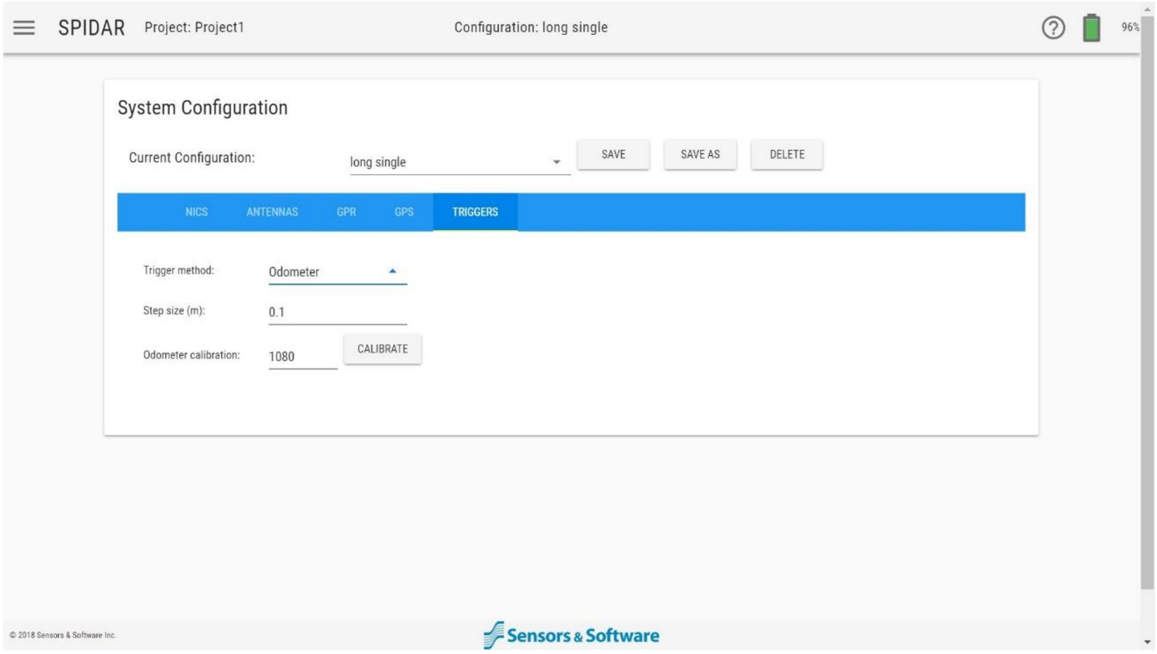


Figure 4-22: Setting trigger to Odometer (single NIC-500)

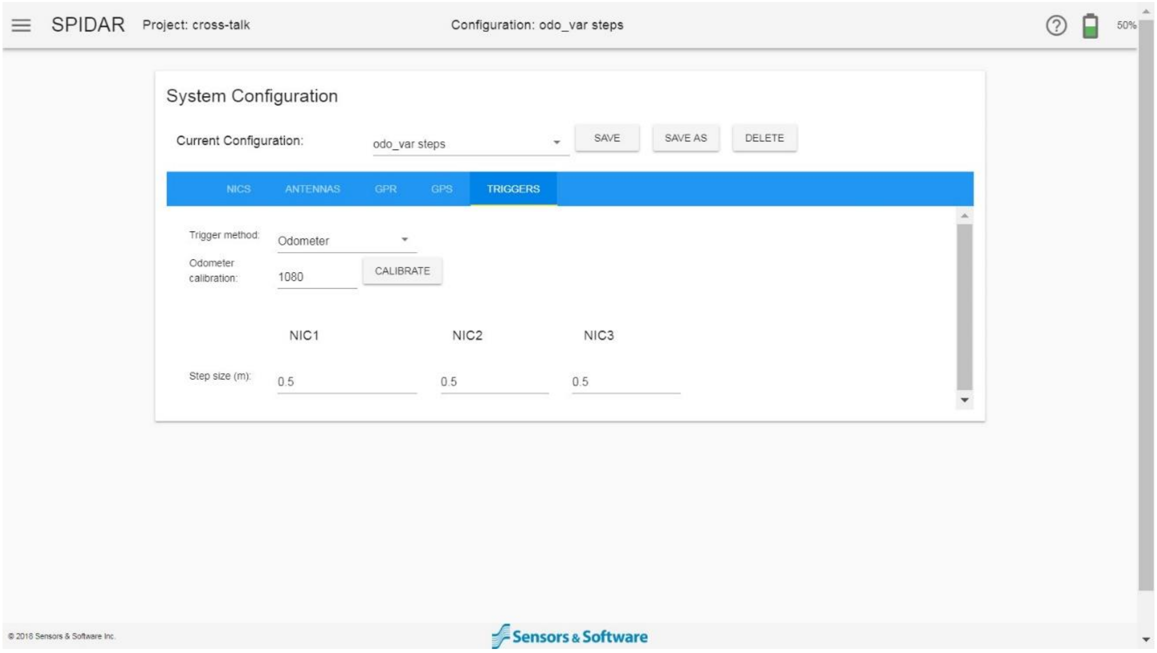


Figure 4-23: Setting Trigger to Odometer (multiple NIC-500s)

Regardless of whether there is a single NIC-500 (Figure 4-22) or multiple NIC-500s (Figure 4-23), the following options will appear beneath it:

- Odometer Calibration – this is the numerical value for the calibrated odometer, unique to each site and conditions. This can be directly input if it's known. When an odometer is calibrated, this value is automatically updated.
- Step Size – used to specify the distance the GPR will move before collecting a new trace. It is important to set the correct step size to resolve subsurface targets. A step size that is too coarse may result in missed subsurface targets. A step size that is too fine may result in large data volumes, skipped traces and slow survey productivity.

  If there are multiple NIC-500s connected, the step size can be set for each NIC-500 (Figure 4-23). Otherwise, the same step size must be used for all GPR transducers/antennas connected to that NIC-500. For a multi-frequency application, you will want to use the recommend step size for the highest frequency system.
- Calibrate Odometer – pressing this button, will navigate the user to a page where the odometer is calibrated by moving the system a known distance (Figure 4-24). Press **Start** and then move the system that exact distance, using a measuring tape or other known distance indicator (Figure 4-25). Upon completion, either accept the new value or revert back to the old one.

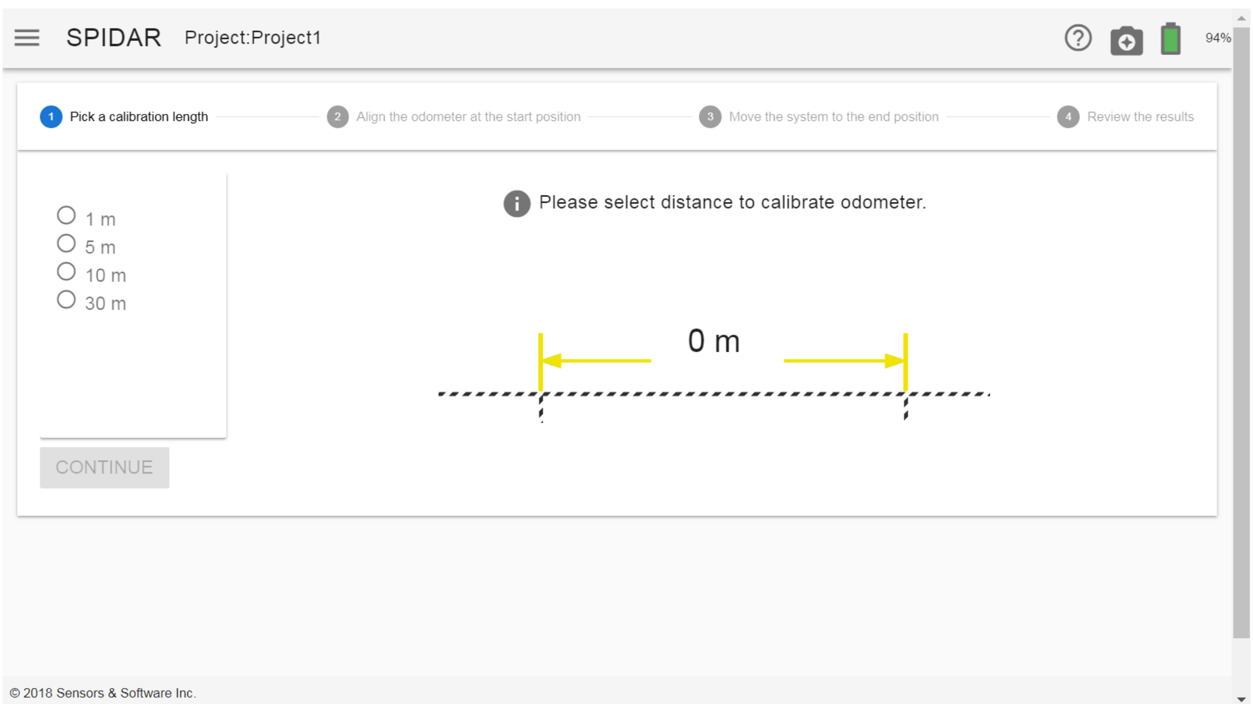


Figure 4-24: Select distance to calibrate odometer

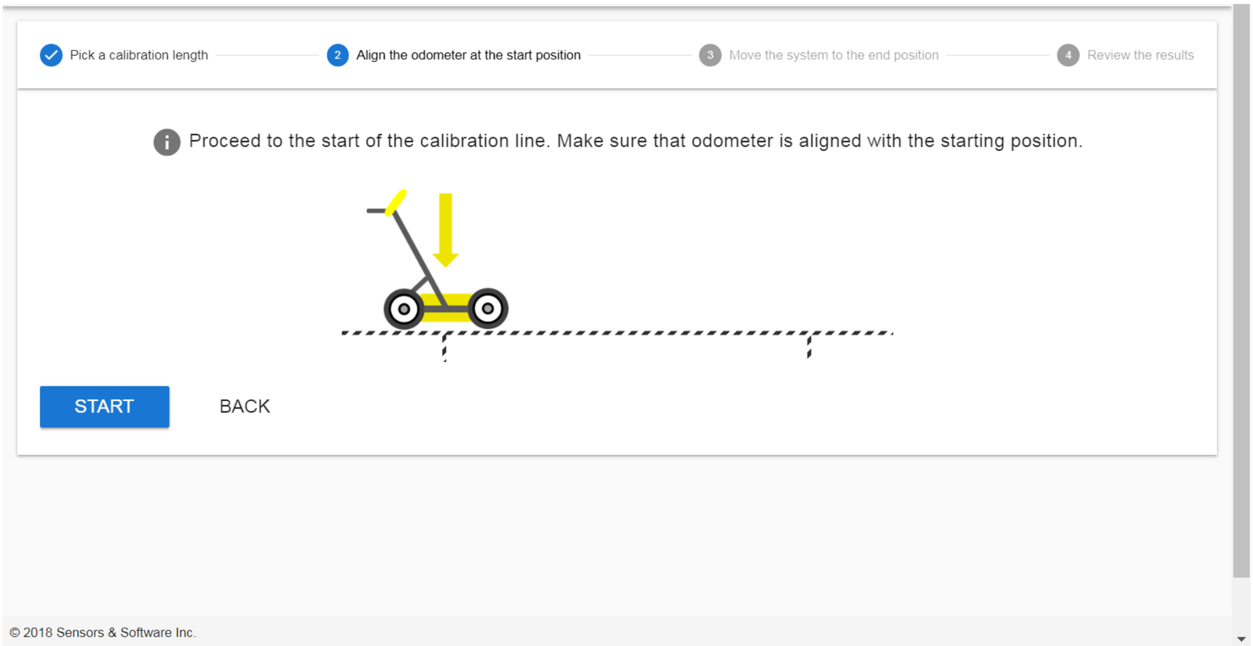


Figure 4-25: Begin odometer calibration by pushing system the selected distance

<u>Free Run</u>

Free run mode allows the system to pulse based on a specified time interval. This is best for survey conditions not suited to using an odometer wheel. For the position of each measurement point, the system assumes the operator has moved the antennas one step size along the survey line. Data is collected even when the system is not moving, so proper data collection relies on the operator moving the system at a consistent speed.

Regardless of whether there is a single NIC-500 (Figure 4-26) or multiple NIC-500s (Figure 4-27), the following options will appear beneath it:

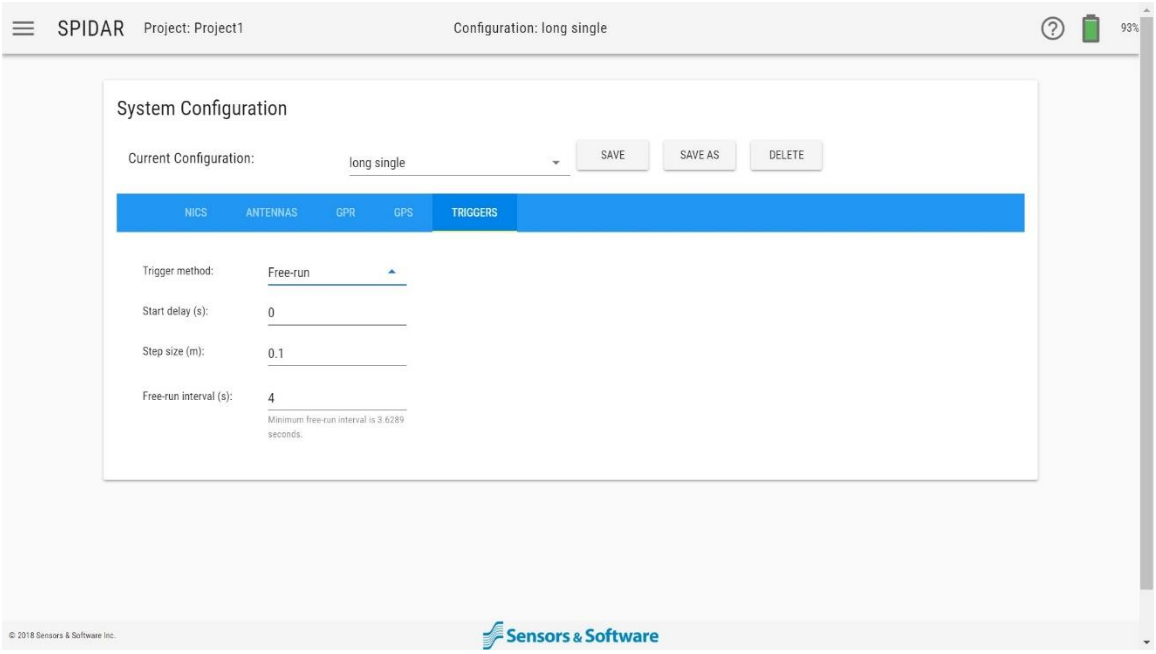


Figure 4-26: Trigger set to Free Run (single NIC-500)

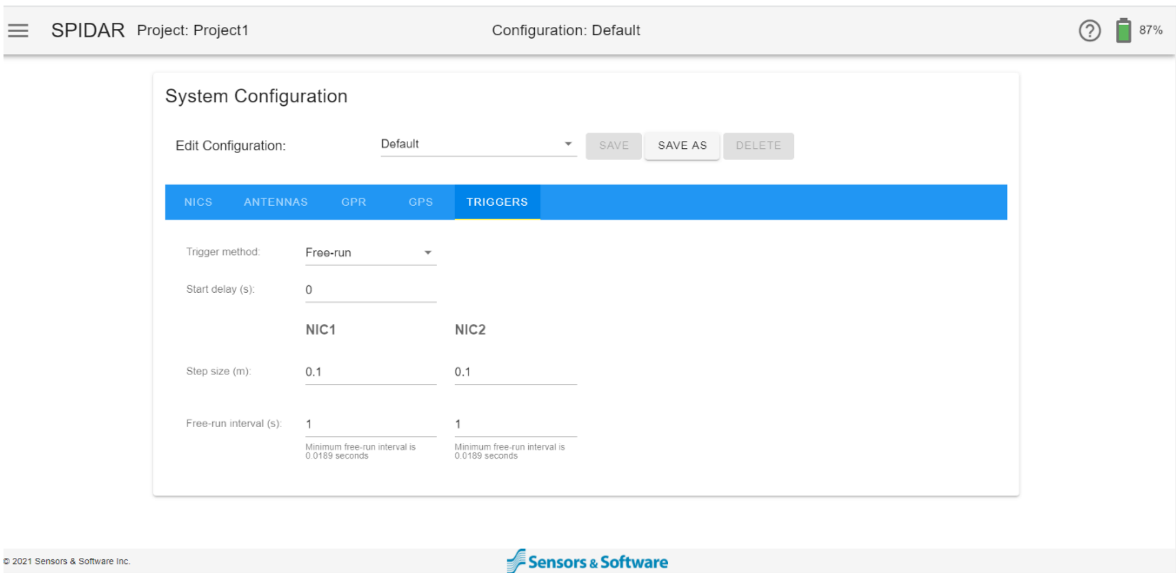


Figure 4-27: Trigger set to Free Run (multiple NIC-500)

- Free-run interval – the time between GPR traces.
- Start delay (s) - the user can set an initial time delay in seconds, to allow time to get setup and start the survey line. If there are multiple NIC-500s, the Start Delay must be the same for all NIC-500s.
- Step size – set individually per NIC-500, the free-run interval and speed together will be used to maintain the desired step size, as per the following equation:

Step Size = Travel Speed x Trace Interval

It is important to aim for a reasonable step size to resolve subsurface targets. A step size that is too coarse may result in missed subsurface targets. A step size that is too fine may result in large data volumes, skipped traces and slow survey productivity.

In the case of a single NIC-500, the same step size must be used for all GPR transducers/antennas connected to that NIC-500. For a multi-frequency application, you will want to use the recommend step size for the highest frequency system.

Recommended step sizes for different frequencies are shown below:

Frequency (MHz)	**Recommended Step Size (m)**
12.5	2
25	1
50	0.5
100	0.25
200	0.1
250	0.05
500	0.02
1000	0.01

Manual

This is typically used when surveying in difficult terrain where antennas cannot be moved easily. The screen display is shown in Figure 4-28 for a single NIC-500 and in Figure 4-29 for multiple NIC-500s.

The user specifies a step size, which is the distance between measurement points. For the position of each measurement point, the system assumes the operator has moved the antennas one step size along the survey line. A trace is collected every time the user presses a button in the line scan screen (Section 4.2)

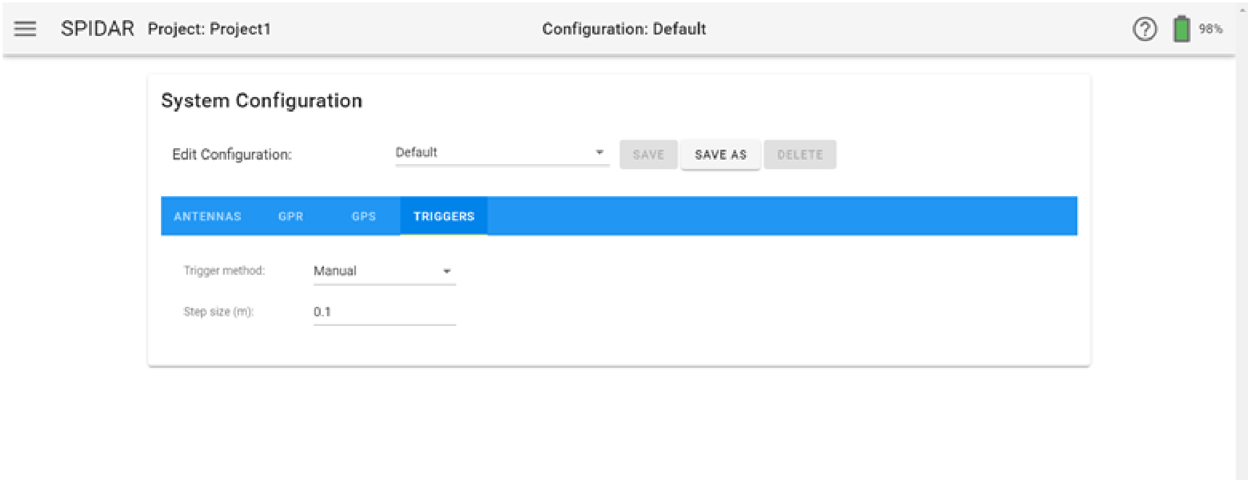


Figure 4-28: Setting trigger to Manual (single NIC-500)

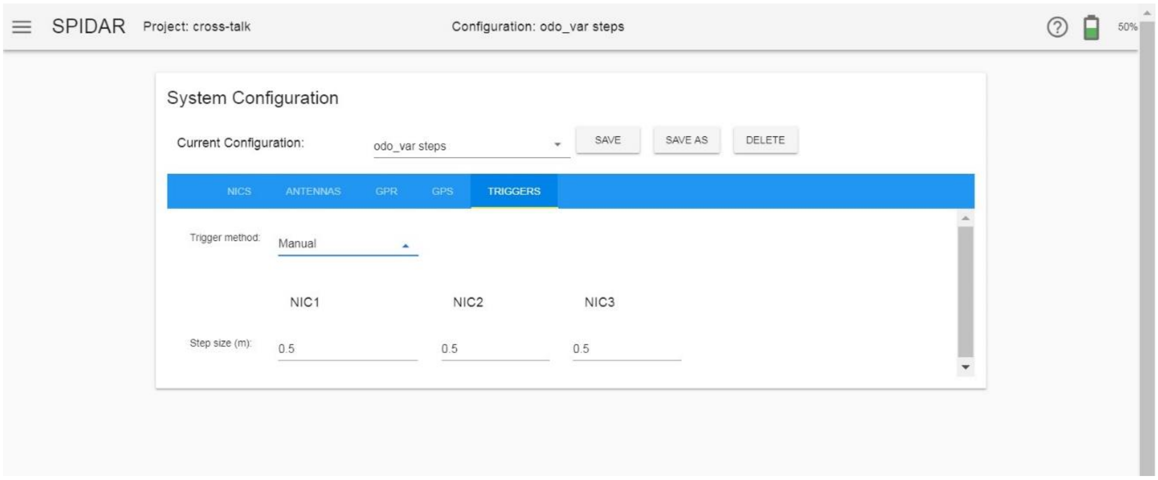


Figure 4-29: Setting trigger to Manual (multiple NIC-500s)

4.4 Scope (NIC-500P and NIC-500X)

Scope mode only applies when working with pulseEKKO antennas, therefore it is only available when using a NIC-500P or a NIC-500X. Accessing Scope mode allows the user to confirm that cable connections are correct, and the system is working properly. A major component of this is correctly setting up the system, primarily setting the Window Time Shift and First Break. Window Time Shift is the delay between the transmitter firing and the receiver beginning to record and is strongly influenced by cable length. First Break is the first arrival of the radar wave and is used as a reference point in later processing.

Entering Scope mode displays a window (Figure 4-30) where the Window Time Shift and First Break are set. On the left side of the screen, the Ports (or firing groups for NIC500-X) are listed with the associated channels. The Window Time Shift is set for the selected Ports, framed by a blue border, and the First Break is set for the selected channel, framed by a red border. If there is more than one NIC-500, select the first NIC-500 from the drop-down menu at the bottom of the screen

At the top of the screen is an icon with the letter 'i' in a circle. The text beside this icon displays useful information about what is happening at each step, and which channels it's affecting. Below that is a dialog box titled "Channel Information"; this describes the details for the transmitter-receiver pair currently being scoped.

On the main scope window, the + and – buttons can be used to zoom in and out on the vertical scale. Below this window, the Time Window value is displayed. The maximum Time Window that can be displayed in Scope Mode is 500ns, even if the actual Time Window is longer. Despite seeing a shorter time window, the entire time window is still being scoped.

Figure 4-30: Scope mode for NIC-500P

Auto is generally the preferred method of setting both the Window Time Shift and First Break. Use **Start** to skip the automated search and set Window Time Shift and First Break manually.

Note: Auto may fail if high frequency transducers are being employed, the antenna separation is large, or there is a large amount of external noise. In that case, try raising the antennas or transducers slightly off the ground to allow a stronger air wave to travel between the units.

For the NIC500-P (Figure 4-30):

1. Select Ports 1&2.
2. Press Auto. The system will initiate a search to attempt to set the Window Time Shift and the First Break for Ports 1&2.
3. If there is a need to manually adjust, select the radio button for Window Time Shift or First Break and use the arrows above the scope window to adjust their positions. More

arrows mean a larger (or coarser) movement of the waveform in that direction. For Window Time Shift, align the start of the waveform with the gray vertical line. For First Break, line up the start of the waveform with the red vertical line.

4. Press Stop
5. Repeat Steps 1-3 for Ports 3&4
6. Press Save
7. If there is more than one NIC-500, select the next NIC-500 from the drop-down menu at the bottom of the screen and repeat Steps 1-6.

Figure 4-31: Scope mode for NIC-500X

For the NIC500-X (Figure 4-31):

The process to Scope the NIC500-X will depend on the system configuration (number of sequences and number of firing groups).

1. Select the first firing group and the first channel.
2. Press Auto. The system will initiate a search to attempt to set the Window Time Shift for the selected firing group and the First Break for the selected channel. The Window Time Shift will align the start of the waveform with the gray line. The First Break will line up the start of the waveform with the red vertical line.

3. If there is a need to manually adjust, select the radio button for Window Time Shift above the scope window, and use the arrows to adjust the position for that firing group. More arrows mean a larger (or coarser) movement of the waveform in that direction
4. If there is a need to manually adjust, select the radio button for First break above the scope window, and use the arrows to adjust the position for that channel.
5. Select the next channel in that firing group
6. Check the Window Time Shift. The Window Time Shift for a firing group must be set so that the waveform for all channels is near the start of the displayed time window. If the Time Window Shift needs adjustment, select the Window Time Shift radio button and use the arrows to adjust the position.
7. Select the First Break radio button and use the arrows to align the red vertical line with the start of the waveform (Figure 4-32).
8. Repeat Steps 5-7 for all channels in a Firing Group.
9. Press Stop
10. Repeat Steps 1-9 for all Firing Groups.
11. Press Save

Figure 4-32: Setting First Break using Auto

If you are not able to set the Window Time Shift and First Break using Auto, these values can be set manually (Figure 4-33). Select the Window Time Shift option, using the radio button, below the Channel Information box. Press **Start** and search for the waveform by moving the pulse left and right using the arrows. The number of arrows on the left and right buttons, correspond to the movement of the waveform. More arrows mean a larger (or coarser) movement of the waveform in that direction. If your application dictates otherwise, adjust manually for more or less time prior to recording data.

Figure 4-33: Manually setting Window Time Shift

Next, select the First Break option below the Channel Information box. Selecting the left and right arrow buttons will move the red vertical line correspondingly. Position the start of the waveform to line up with the red vertical line, near the 10% mark shown on the screen. The correct placement of the waveform is shown in Figure 4-32.

Once complete, press **Stop** then **Save** to set these values in the NIC-500. Repeat for other firing groups on this NIC-500, then repeat for other NIC-500s if present.

> **NOTE:** If the pulse cannot be found, and all connections are made, check the batteries in the Low Frequency transmitter. If the batteries are OK, there could be a problem with the transmitter.

4.5 Line Scan

Selecting this option will open the Line Scan acquisition screen (Figure 4-34). There are several windows displayed on the screen.

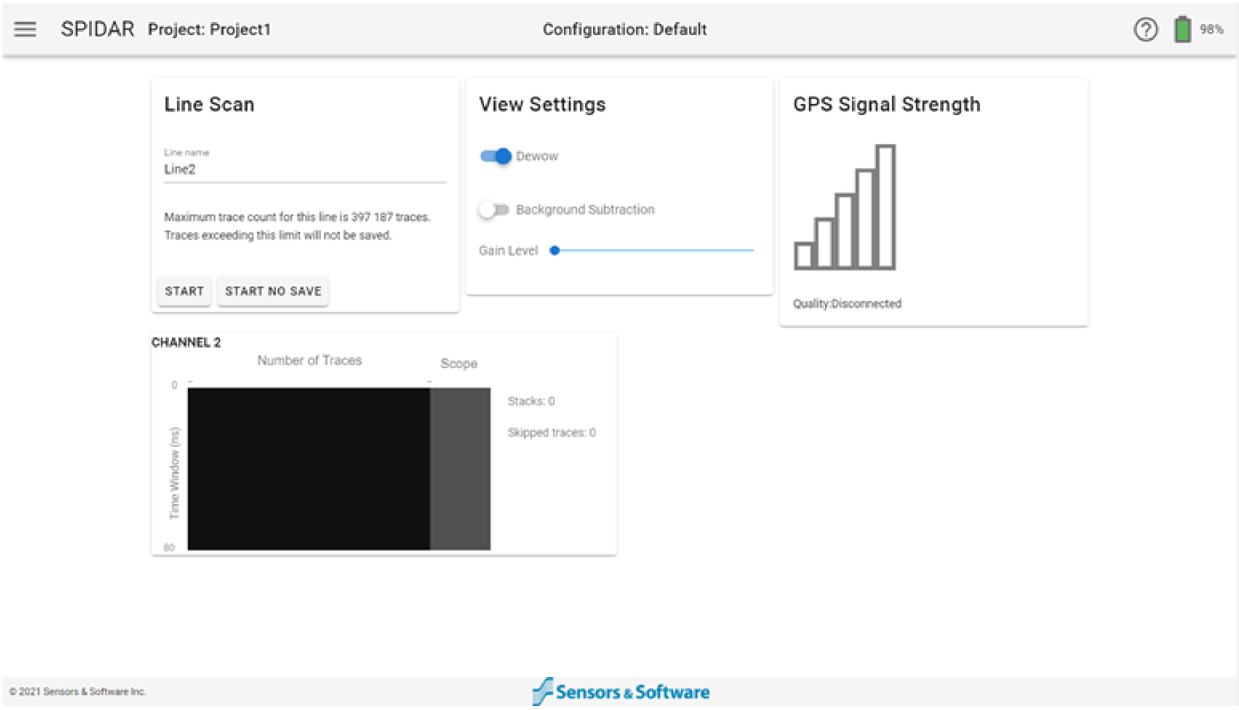


Figure 4-34: Line Scan setup and acquisition window

<u>Line Scan window</u>

The Line Scan window displays the name of the line and controls data acquisition. To change the name of the line, click in the field below Line name and type your preferred line name. If you pick a name that already exists, it will confirm if you want to overwrite an existing line. To begin data collection, press Start. The data will be saved in the project specified in the top bar.

To collect data without saving it, press Start No Save.

After pressing Start, the line number automatically increments to the next available line number.

If the Trigger is set to Manual, the Line Scan window will now have a Trigger button (Figure 4-35). Press this button to fire the GPR and collect data each time the system is moved one step size.

Once a line is started the Stop button will now appear in this window. Press Stop to end data collection. The line name will remain the same, but will automatically increment the last digit (or add a ‘1’ if there wasn’t any prior).

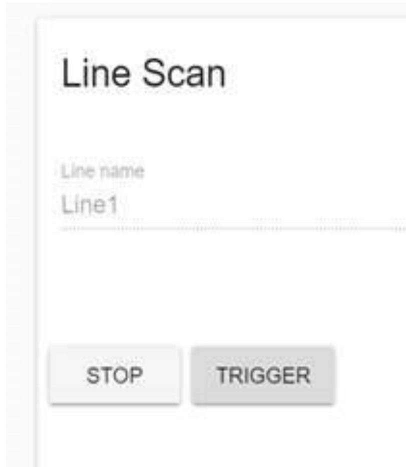


Figure 4-35: Trigger button appears only if Trigger mode is set to Manual

View Settings

Basic settings can be set to control how data is displayed. These can be set prior to data collection and changed during data collection. Note that if changed during collection, the new settings will only take effect from that point on. That is, they are not retroactively applied to the data already collected.

- Dewow – turning dewow ON applies a high pass filter to suppress the low frequency "wow" in the data.
- Background Subtraction – a background subtraction filter is used for removing flat-lying responses in the data. Filtering helps identify shallow targets that might be masked by the strong signals at the top of the section, as well as possibly enhancing the visibility of hyperbolas further down in the data. However, it will also filter out other flat-lying responses, such as soil boundaries, so be careful when using the filter option if your target is flat. Move the slider bar to the right to turn ON the background subtraction filter.
- Gain Level - Since the material being scanned absorbs the GPR signal, deeper targets return weaker signals. Gain acts like an audio volume control, amplifying signals and making deeper targets appear stronger in the image. Gain values vary from 0 to 9 where 0 means no amplification has been applied and 10 means that maximum amplification has been applied. As the slider bar is moved, the gain level will be displayed above the bar.

GPS Signal Strength

This window displays the strength of the GPS signal, which is a function of how many satellites it is seeing. The bars are coloured in green.

The Quality describes the type of fix the GPS is obtaining (e.g., DGPS, RTK).

GPR Windows

There will be a window displayed for each GPR channel (port) used. For example, if there are 2 NIC-500s, each with 2 Noggin systems, then four channels of data will be displayed. The NIC-500 and channel will be indicated for each window. Section 4.4.1 explains the data presented in these windows.

4.5.1 Collecting data

Press **Start** in the Line Scan window to begin acquisition. Press **Stop** in that same window to end the line.

Once data acquisition begins, the data scrolls from right to left for each window. Data is plotted as distance traveled along the horizontal axis, and time window on the vertical axis. The waveform is also displayed to the right of the GPR data. To the right of that, the following information is displayed:

- Stacks – shows the number of stacks for the last GPR trace.
- Skipped traces - indicates the number of traces that were not collected, or skipped, usually due to speed of movement. Each trace takes a certain amount of time to collect (which increases as the time window or number of stacks increase). If the user attempts to collect another trace (that is, by moving fast) before the first is completed, the first trace will be skipped. This number adds up during the line acquisition. Knowing this, the user can then change parameters of their survey to minimize skipped traces.

NOTE: Maximum number of traces for one line is limited to the lesser of either 1,000,000 traces or 200 MB individual file size.

4.6 Admin

The Admin section describes updating software, setting time/date, and system information. Each tab is described in detail below.

4.6.1 System Admin

The system admin tab displays an overview of version numbers for the SPIDAR software, as well as the version and serial numbers for connected antennas (Figure 4-36).

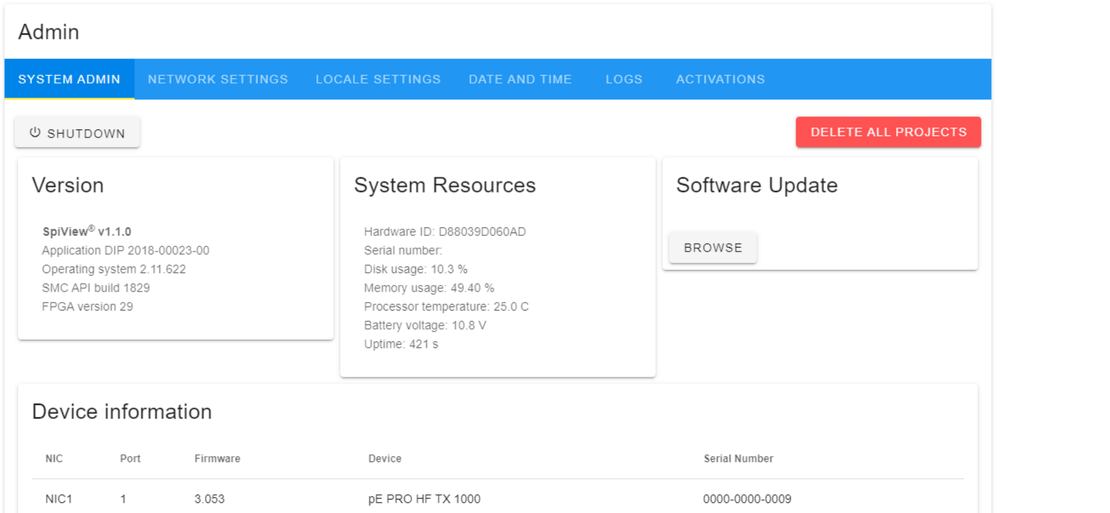


Figure 4-36: System admin tab

There are several buttons available on this page, described below:

- Shutdown – press this button to shutdown all NIC-500s.
- Delete All Projects – press this button to delete all projects on the NIC-500
- Browse – pressing this button in the Software Update window will open a window allowing you to browse your local hard drive for the upgrade package, to upgrade the SPIDAR software. After selecting the appropriate file, the screen in Figure 4-37 will be displayed. The file has already been uploaded to the NIC-500 and will be installed after rebooting the NIC-500.
- Clear – if a software update is loaded, it displays a message that the software will be installed on the next reboot. Press Clear to cancel the software update

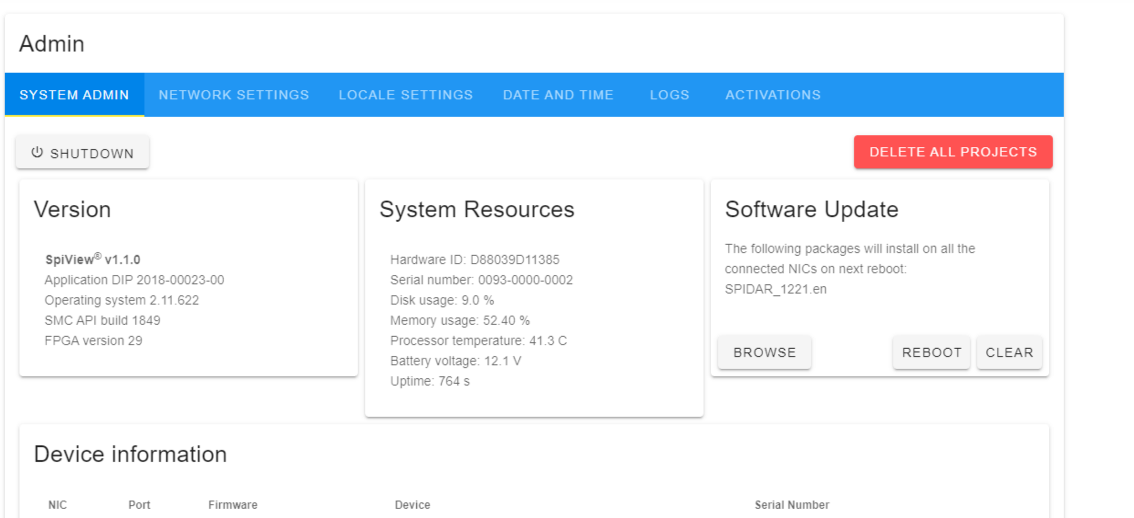


Figure 4-37: Message displayed in the Software Update window, after browsing for a file

The Device information section lists all the antennas/transducers connected to the NIC-500, the port they are connected to, as well as their serial numbers.

When using a NIC-500N only, the firmware on a Noggin must be at a certain level. If the firmware on a connected Noggin is below that level, it will display an exclamation mark after the number in the firmware column. Contact Sensors & Software to have the software updated.

<u>Multiple NIC-500s</u>

In the case of daisy-chained NIC-500s, when a software update is uploaded to the Parent NIC-500, it will automatically be uploaded to the sub-ordinate NIC-500s. The user should open the subsequent NIC-500 pages by pressing the plus button at the top right of the screen (Figure 4-38). This will spawn a new browser window for the sub-ordinate NIC-500. Check that the app has been applied by verifying the version number after reboot is complete.

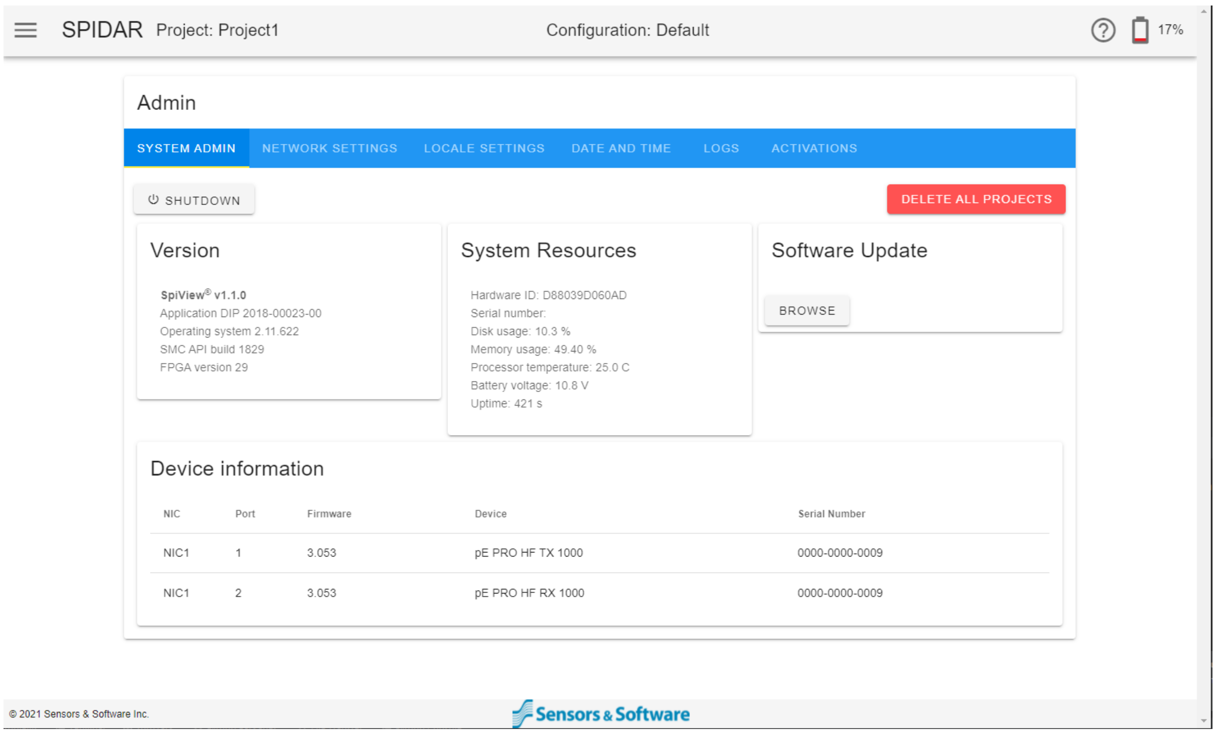


Figure 4-38: Admin screen with NIC-500s daisy-chained

4.6.2 Network Settings

Displays settings related to the NIC-500 network. The user has the option to customize the network name (SSID) and the password (WPA Passphrase). Press **Submit** to apply username/password changes. This will alert the user that the system requires a reboot and prompts them to reboot the system.

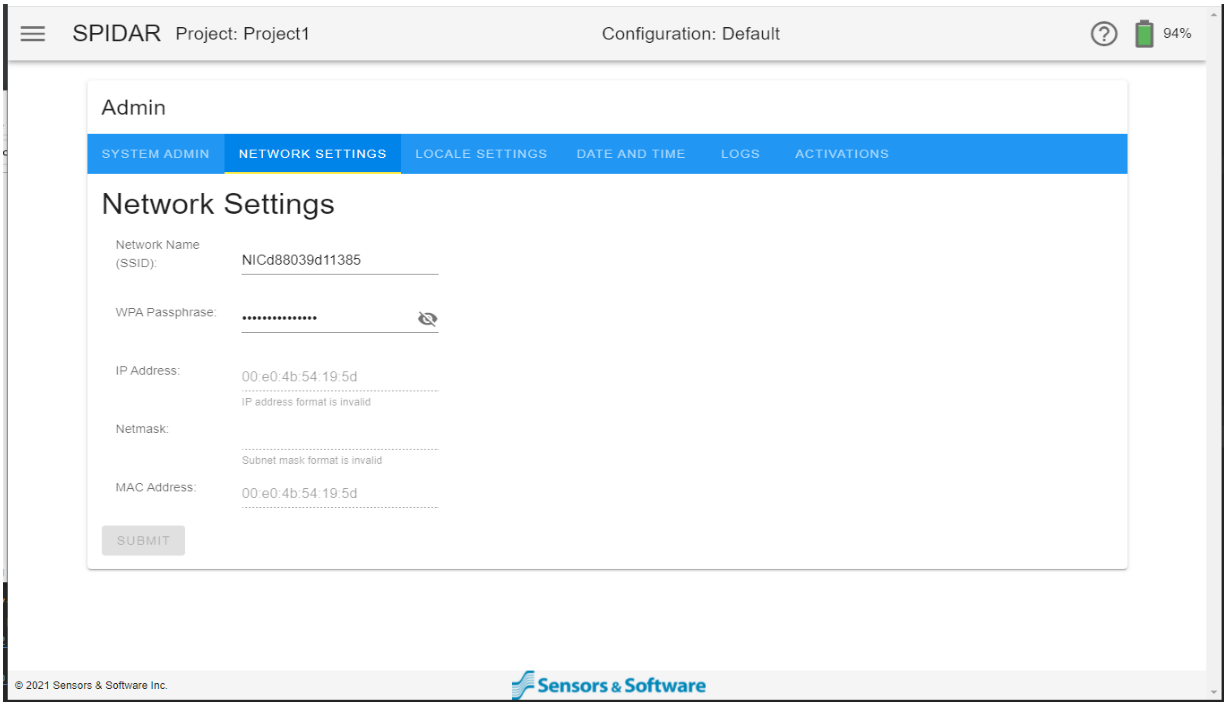
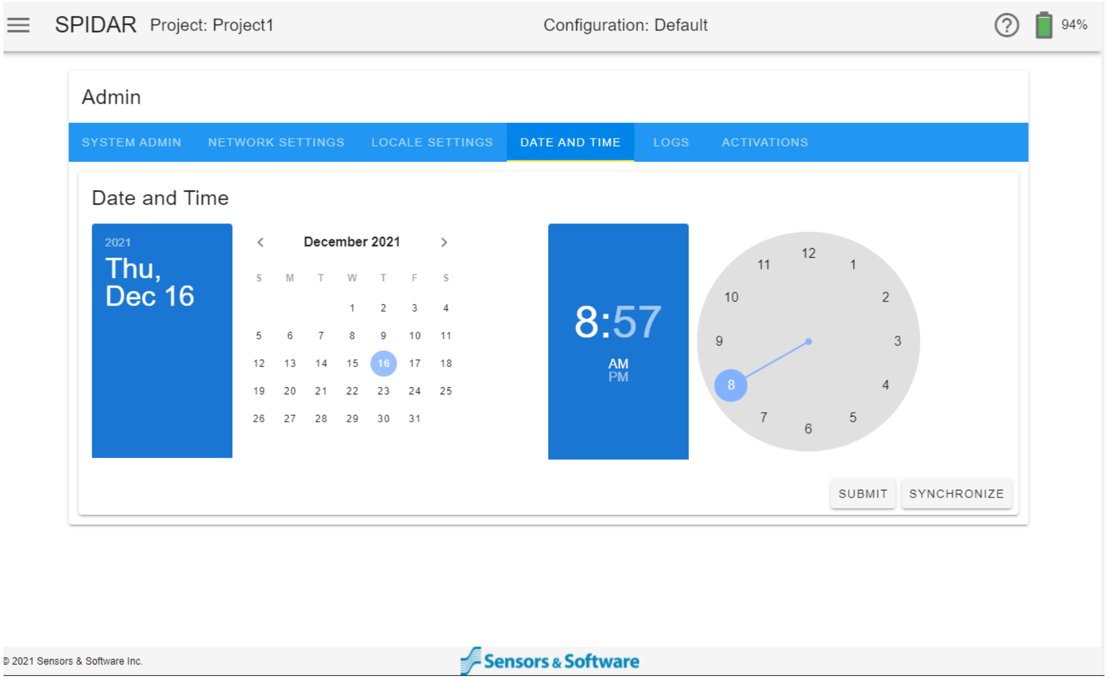


Figure 4-39: Network settings window

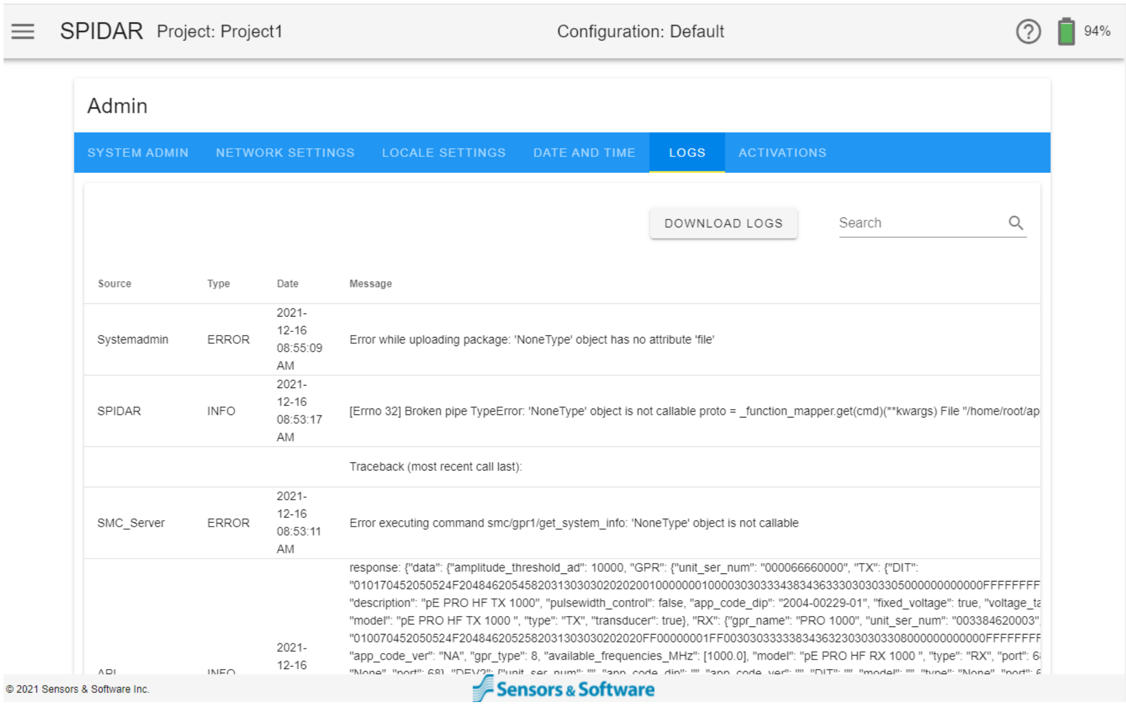
4.6.3 Date and Time

The Time and Date tab displays the current time and date on the NIC-500. Pressing **Synchronize** will set the time on the NIC-500 as the same time on the device (computer/tablet. Pressing **Submit** will upload the changes to the NIC-500.



4.6.4 Logs

This tab displays a run-time log of the NIC-500. Pressing the **Download** button will download the logs to your device, wirelessly or via the Ethernet connection.



5. SPIDAR SDK

SPIDAR SDK (Software Development Kit) is designed for customers who would like to control a GPR system with their own data acquisition software. SPIDAR SDK allows users to control a Noggin or pulseEKKO GPR connected to a NIC-500, using specific software commands sent over an ethernet connection. The user can develop their own software to control data acquisition. A computer is required, however it doesn't matter what operating system is running on the computer (Windows, Mac, Linux). SPIDAR SDK will work with NIC-500N, NIC-500P and NIC-500X.

5.1 Activating SDK

To activate SPIDAR SDK mode, you must connect a laptop or tablet computer to the NIC-500 using an Ethernet cable (Wi-Fi is not supported in SDK mode).

Open a web browser and connect to SPIDAR (Section 3.5). You will see the screen in Figure 5-1.

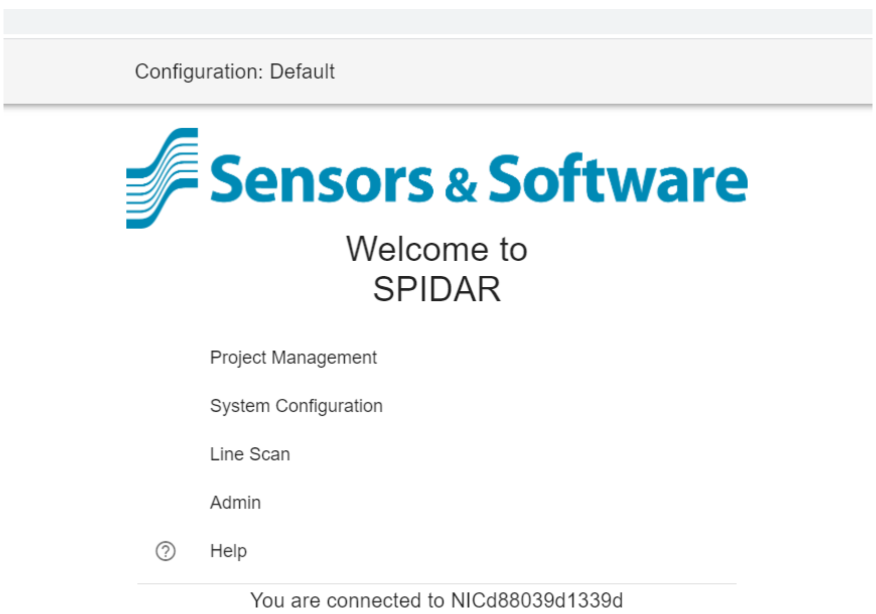


Figure 5-1: Main SPIDAR screen

Click on **Admin**, which will take you to the admin screen (Figure 5-2).

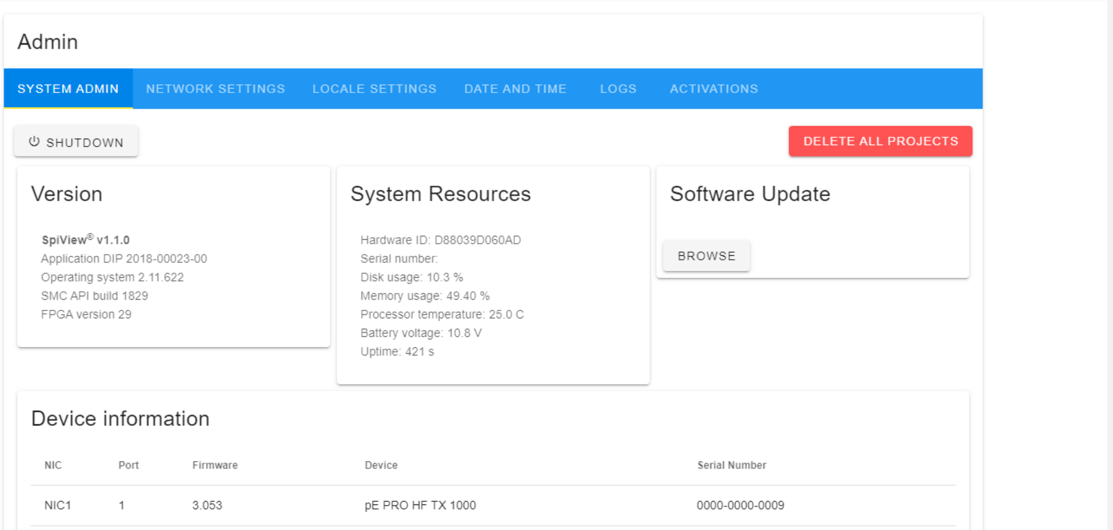


Figure 5-2: Admin section

Click on the Activations tab. This tab, shown in Figure 5-3, contains the Hardware ID and a text box for entering the SPIDAR SDK activation code. Activation codes are tied to a NIC-500's hardware ID and are unique to each NIC-500. When you purchase an activation code, the Serial Number and Hardware ID of your NIC-500 must be sent to Sensors & Software, and we will provide you with an Activation Code.

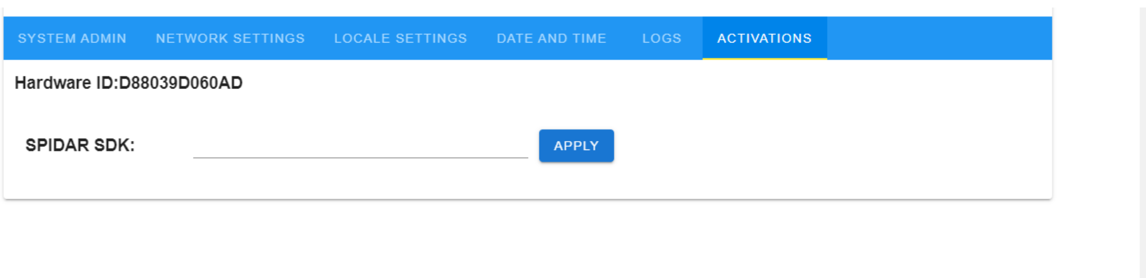


Figure 5-3: Activations tab

Enter the Activation Code provided by Sensors & Software, then click the **Apply** button. You will see a terms and conditions window. Full details of this use agreement can be found at: https://www.sensoft.ca/sdk_accessanduseagreement/

Upon accepting, you will see the confirmation message that a code has been added (Figure 5-4). You will only have to do this once; SDK is now activated on the NIC.

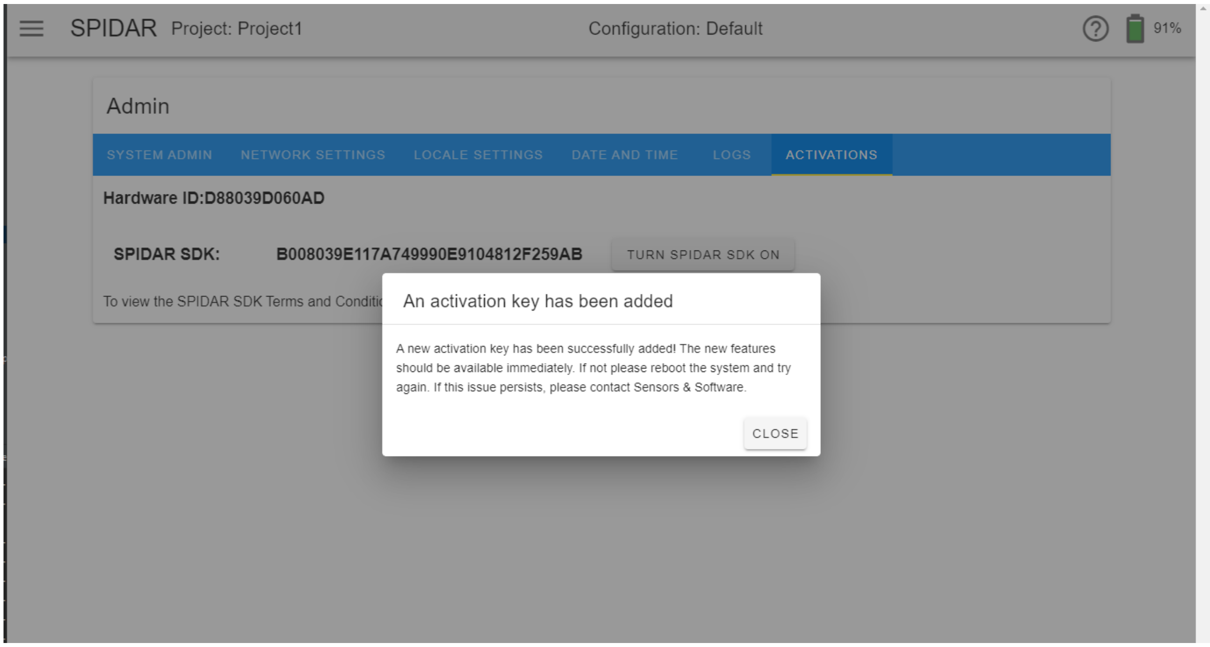


Figure 5-4: SDK has been activated

To put the SPIDAR into SDK mode, click the **TURN SPIDAR SDK ON** button (Figure 5-5)

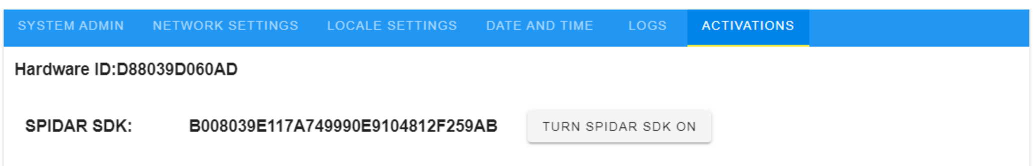


Figure 5-5: Button to turn SDK on

To complete the change, you must reboot the NIC-500 for SDK mode to take effect (Figure 5-6). Click **Yes** to reboot SPIDAR into SDK mode.

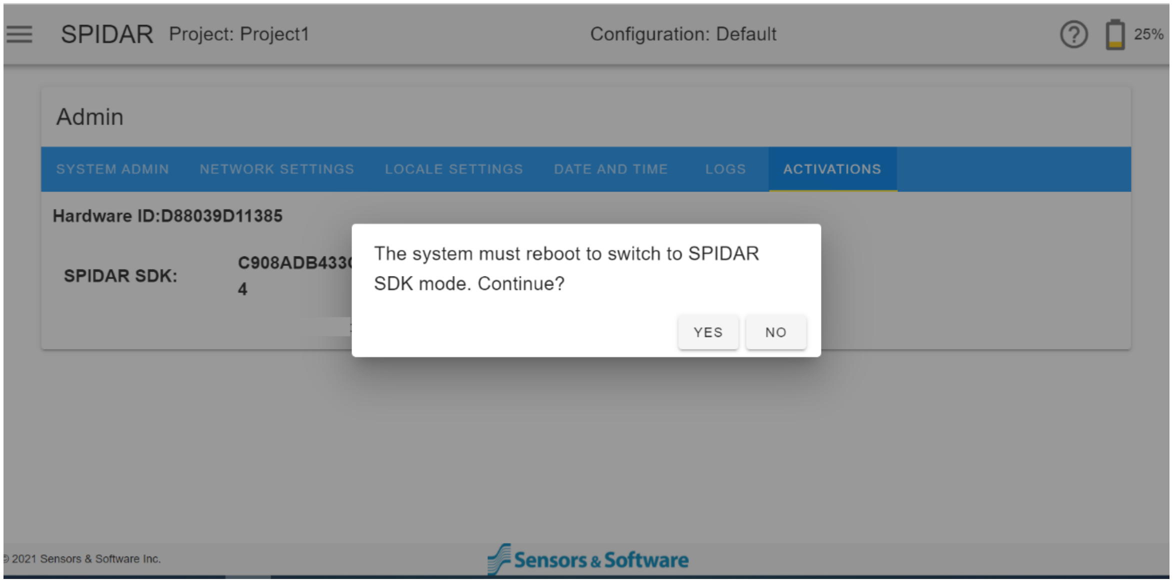


Figure 5-6: Notice that system must be rebooted

To return to regular SPIDAR mode, return to the above screen, and click **TURN SPIDAR SDK OFF** (Figure 5-7). Once again, the system will reboot for the change to take effect.

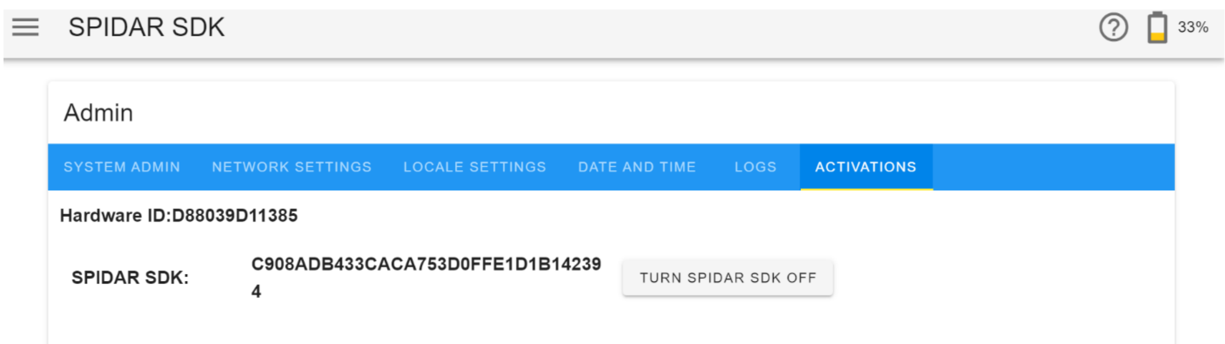


Figure 5-7: Button to turn SDK off

5.2 Configuring the Ethernet connection

You will need to configure your computers' Ethernet connection for SDK, to use a static IP address on the same subnet as the NIC-500. The example below illustrates this on a PC running Windows 10.

On your computer, launch the Network and Internet settings. Near the bottom, under Advanced network settings, click Change Adapter Options (Figure 5-8).

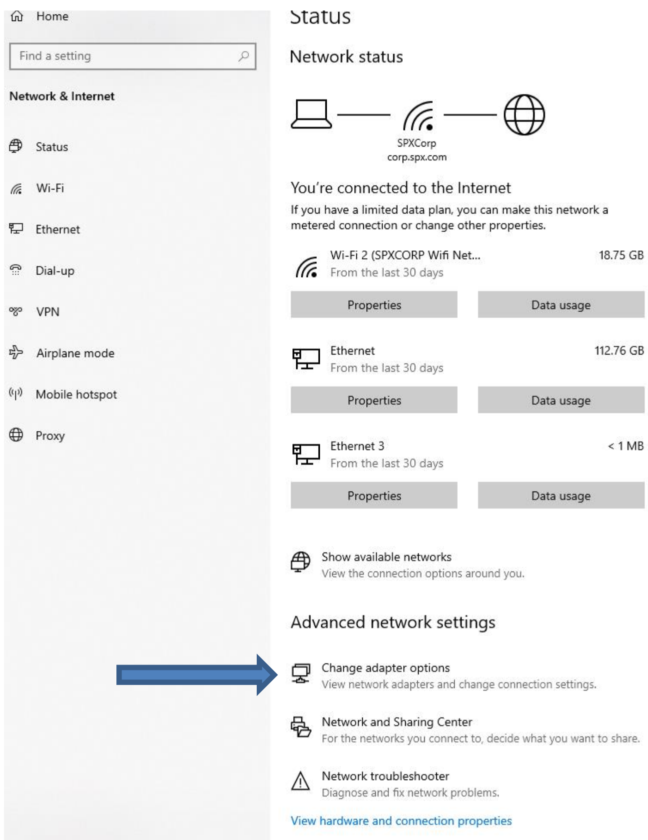


Figure 5-8: Network & Internet Settings

You will see the image in Figure 5-9.

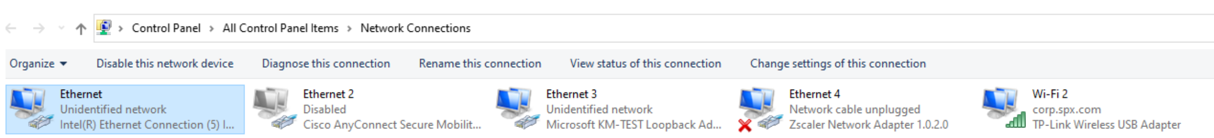


Figure 5-9: Configuring Ethernet connection

Determine which network connection will be used to communicate with the NIC-500. Most laptop computers will have a wired and a wireless connection.

Right-click on the connection you would like to use to communicate with the NIC-500 and choose **Properties → Internet Protocol Version 4 (TCP/IPv4) → Properties**, then select the option “Use the following IP address” (Figure 5-10). Assign the computer an IP address on the same subnet as the NIC-500. By default, the NIC-500s IP address is 192.168.20.221 so using an IP address of the form 192.168.20.X where X is any host ID (i.e., a number between 1 and 254) will allow you to communicate with the NIC-500. Note that you cannot set X to 221 as that Host ID is already in use by the NIC-500. Set the subnet mask to 255.255.255.0.

These steps assume that the NIC-500 is left with its default IP address. If the user wishes to add SDK to an existing network, they can change the IP address following the steps outlined in Section 5.3.1.

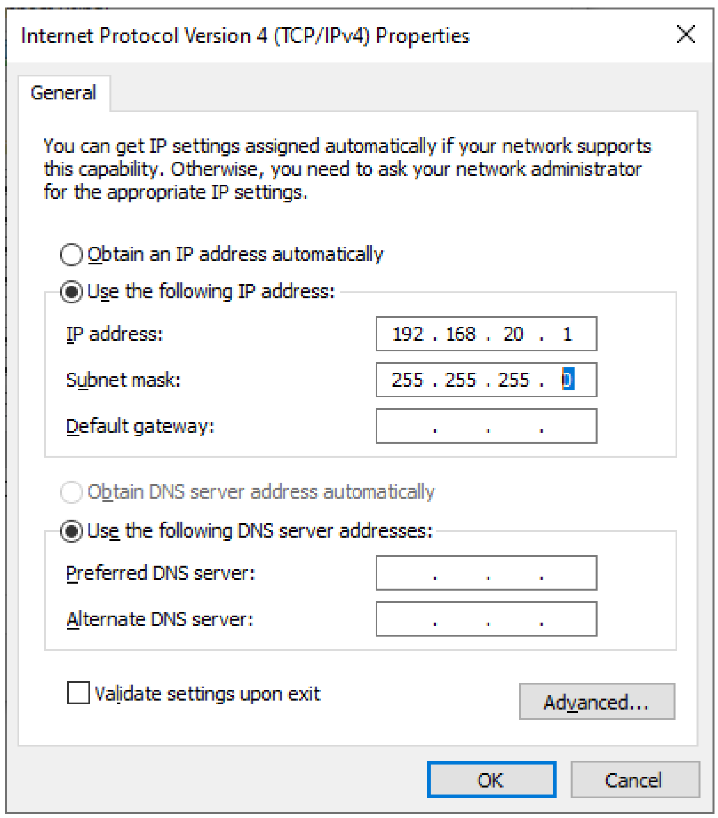


Figure 5-10: IP Properties

5.3 Changes in SDK mode

When the NIC-500 boots up into SDK mode, type in the NIC-500’s IP address (usually 192.168.20.221) in a supported browser. You will see the screen in (Figure 5-11).

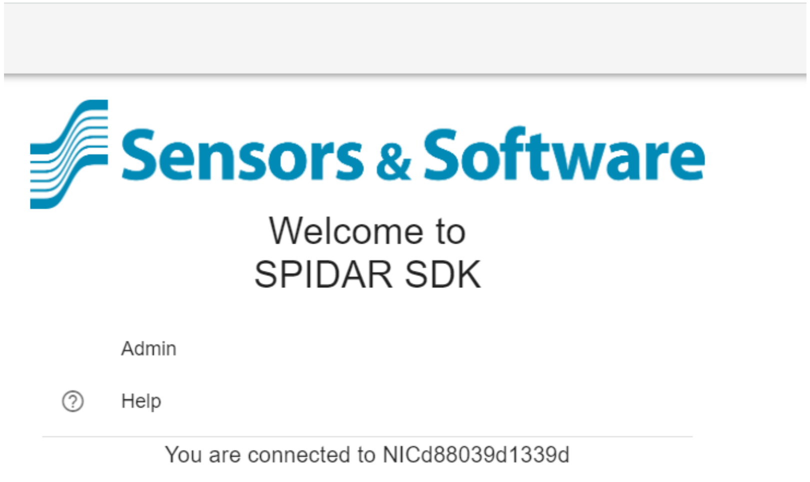


Figure 5-11: Main screen in SDK mode

Since you are controlling data acquisition from your software, there are no options for Project Management, System Configuration or Line Scan (which are usually available in regular SPIDAR mode). Additionally, the following functions do not work in SDK mode:

- Wireless mode
- Odometer
- Scope mode
- GPS
- Multi-channel including daisy chaining NIC-500s

However, some of the NIC-500 ports are active so it is possible for data collection to be triggered by sending an electronic pulse to the Link In port (Section 5.3.2).

SDK mode only supports the use of a single Noggin or a single pulseEKKO Transmitter-Receiver (Tx-Rx) pair. When connecting a Noggin to a NIC-500N, the Noggin must be connected to **port 1** on the NIC-500.

When connecting a pulseEKKO Tx-Rx pair to a NIC-500P or a NIC-500X, the Tx-Rx must be connected to **port 1 and 2** (it doesn't matter if the Tx or Rx is port 1 or 2, as they are interchangeable)

5.3.1 Changing the IP Address and Netmask

You can add SPIDAR SDK to an existing network to support integrating multiple sensors. On the Network Settings tab of the Admin page (Figure 5-12), change the IP address and Netmask to the appropriate values. Clicking submit will restart the NIC-500 with the updated IP address. The LCD screen on the NIC-500 will display the new IP address.

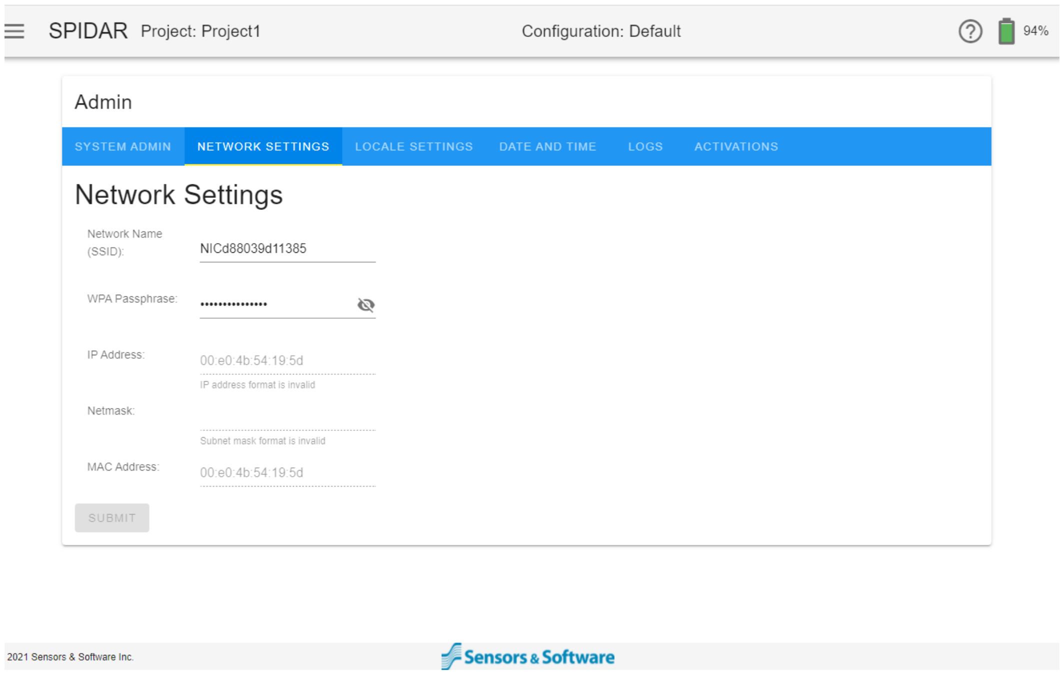


Figure 5-12: Network Settings tab

5.3.2 Data Collection with Pulse Trigger

When the Trigger Mode setting is set to “Pulse” (see 5.4.2), a device that sends out an electronic pulse can be used to trigger data collection. The SPIDAR SDK enabled NIC-500 collects a GPR trace on every pulse. This is done using the Link In port 15-socket D-connector shown in Figure 5-13.

Figure 5-13: NIC-500 showing the Link In port

The Link In port can also be used to control the power to the NIC-500 from your device, mimicking a press of the power button.

The details of this port are described in Appendix E.

5.4 Communication

The commands sent to the NIC-500 are in the form of HTTP request strings. There are two methods used to communicate with the NIC-500: GET and PUT:

- GET requests are used to query the NIC-500 to get the current status/value.
- PUT requests are used to set a state/value or execute an action.

These methods are performed on different endpoints (URL address available on SDK mode) to perform the following action commands in SDK mode:

1) Power up the GPR
2) Setting up GPR survey parameters:
    a. Antenna frequency
    b. Time sampling interval
    c. Number of points per trace (related to time window and depth)
    d. Number of stacks
    e. Trigger mode
    f. Window time shift
3) Start and stop data collection including using your own triggering device
4) Check for errors
5) Set/check date and time
6) Read system information (e.g., version numbers, serial numbers)

SDK does not apply any processing (e.g., gain, background subtraction filter) to the collected data.

Commands used to control the NIC-500 can be written in any programming language that supports basic networking. For the purposes of this manual, we are illustrating examples using Python.

Full example code showing the use of each of these functions is available at GitHub: https://github.com/sensoftinc/spidar-sdk.

Below is a brief example of common commands and their uses. The example code is written in Python, but any API capable of executing HTTP methods can be used. These examples use the following Python packages:

- Requests
- Json
- Socket
- Struct
- Numpy

5.4.1 Turning On/Off

Before collecting you must turn on the sensor. This is done through the power endpoint. The following code turns on the sensor:

```
power_state = {'data': json.dumps({"state": 2})}
ret = requests.put("http://192.168.20.221:8080/api/nic/power",
data=power_state)
```

5.4.2 Setting Parameters

The collection parameters must then be set through the setup endpoint. For example, if the user wanted to collect a 20 ns trace at 4 stacks and a 100 ps sampling interval at a rate of 1 trace/s, they would run the following command:

```
gpr_param = {'data': json.dumps({"gpr0": {"parameters": {
      "points_per_trace": 200,
      "point_stacks": 4,
      "time_sampling_interval_ps": 100,
      "trigger_mode": "Free"}},
      "timer": {"parameters": {"period_s": 1}}})}
ret = requests.put(("http://192.168.20.221:8080/api/nic/setup",
data=gpr_param)
```

Note that you cannot set the time window directly, you must calculate the appropriate number of points per trace (time window = points per trace × sampling interval).

5.4.3 Beginning and Ending Collection

You must issue the command to start the collection through the acquisition endpoint. The “state” parameter decides if collection should start or stop. For example:

```
acq_param = {'data': json.dumps({'state': 1})}
ret = requests.put((("http://192.168.20.221:8080/api/nic/acquisition",
data=acq_param)
```

Ending the acquisition is done through a similar command:

```
acq_param = {'data': json.dumps({'state': 0})}
ret = requests.put((("http://192.168.20.221:8080/api/nic/acquisition",
data=acq_param)
```

5.4.4 Reading Data

In SDK mode, data is not saved on the NIC-500. Data is pushed over a network socket to the client which must read the data from the buffer. If power to the NIC-500 is lost then all of the data in the buffer is forgotten, and if the buffer is filled, the earliest traces will be overwritten. For these reasons we strongly recommend running a script to read data from the system while the system is collecting.

The first thing you must do is open the data socket:

```
ret=requests.get("http://192.168.20.221:8080/api/nic/gpr/data_socket")
```

This command will return information on the data socket including the port number. You must then open a socket on this port, the following example uses Python socket library:

```
data_channel = socket.socket(socket.AF_INET, socket.SOCK_STREAM)

data_channel.connect((“192.168.20.221”, 8090))
```

Once the data channel is connected the data must be received. The data is sent from the buffer in bytes so it must be converted to be readable. Each trace consists of a 20-byte header followed by the trace data, which writes each sample point as a 4-byte floating point amplitude in mV. The header contains information such as a time stamp, the trace number, number of stacks etc. The total length of a single trace (in bytes) then is 4 × points per trace + 20. In our example one trace is 820 bytes. The following code reads in a single trace and converts it to a readable format:

```
data = data_channel.recv(820)

(tv_sec, tv_nsec, trace_num, status, stacks, header_size), s =
struct.unpack('<LLLLHH', data[0:20]),data[20:]

trace = numpy.frombuffer(s, dtype=numpy.float32)
```

The first line receives the bytes from the buffer over the data channel. The second and third lines split the received data into the header (in brackets, from left to right: the time of collection in seconds, time of collection in ns, the trace number, the status of the trace, the number of stacks in the trace and the size of the header) and the trace amplitude data (held in the variable s). The final line converts the trace amplitude data from bytes to an array of numbers.

5.5 Troubleshooting

Refer to the sample code provided when programming SDK, this may give you a starting point, and something to build on.

If you believe the system is not operating properly, turn off SDK mode and see if normal operation resumes. If it does, then there is possibly something in your SDK commands which is affecting operation.

6. Building a System

The SPIDAR systems allow the design of custom systems to meet unique needs. A major aspect of designing a system is how to physically mount and layout all the antennas. Aspects to consider include weights, maneuverability, cable connections, NIC-500 mounting, cart designs and power requirements.

Often a cart-based platform is used as a starting point. A cart is convenient and productive to maneuver and allows for easy odometer triggering to collect data. Custom platforms can be built using fiberglass poles to minimize RF interference. Contact Sensors & Software to discuss specific requirements.

Some photos of configurations are shown below:

Figure 6-1: NIC-500X with 3 sets of pulseEKKO 500 MHz antennas

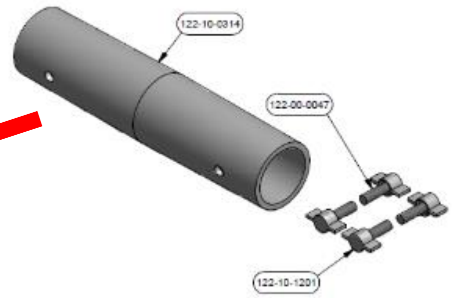
Figure 6-2: NIC-500N with a Noggin 250 MHz & 1000 MHz

Figure 6-3: Two NIC-500Ps with pulseEKKO 250 MHz & 500 MHz

6.1 Couplers

To extend a SmartCart to accommodate more transducers/antennas, couplers can be attached.

Note there are two sets of holes drilled into each coupler. Each side has a different spacing between the holes. This is to accommodate different types of separation bars for the Noggin and pulseEKKO carts. The position of the couplers is shown on an “extended” SmartCart below.



6.2 NIC-500 Mounting

NIC-500s can be mounted to the standard 30mm fiberglass tubes used on all Sensors & Software carts, chariots and tow systems. The user need only purchase the clamps shown to fasten to a fiberglass pole.

Figure 6-4: Clamps, pointed to with the red arrows, can be used to secure the NIC-500 to fibreglass frame

6.3 NIC-500 Stacking Hardware

When daisy-chaining NIC-500s, the stacking hardware allows the NIC-500Ns and NIC-500Ps to be stacked on top of each other, allowing for the NIC-500s to be securely fastened together and take up less space. The stacking hardware is shown below.

The picture below shows the stacking kit with 2 NIC-500s.

6.4 Odometer Extension Cable

If a SPIDAR NIC-500 is being attached to SmartCart, SmartTow or SmartChariot platform using an odometer trigger, the odometer cable must now be directly connected to the NIC-500. This will necessitate the use of an odometer extension cable, pictured below. The cable coming off the odometer must now be connected to this extension cable. The other end of this extension cable will be connected to the NIC-500.

6.5 Power Requirements

As more NIC-500s and antennas are added to a platform, the power requirements increase and may require a larger capacity battery. The best way to estimate the total power consumption is to add up the total components in a platform, using the guidelines below:

- Each pulseEKKO antenna or transducer = 1 component
- Each Noggin = 2 component
- Each NIC-500 = 1 component

Take the total number of components and multiply by the current draw. Each component draws about 0.25A. This gives an estimate of the total number of Amps the system requires to run.

For example:

- Scenario 1: 10 pulseEKKO antennas + 3 NIC-500s = 13 components x 0.25A = 3.25A required
- Scenario 2: 4 Noggins + 2 NIC-500s = 10 components x 0.25A = 2.5A required

Batteries capacities are measured in Amp-hours (Ah). The grey battery in the Pelican case sold by Sensors & Software is rated for 9 Ah.

For example, using this 9 Ah battery:

- Scenario 1: the system would run approximately 9 / 6.5 = 1.4 hours
- Scenario 2: the system would run approximately 9 / 5 = 1.8 hours

Please note that this formula is meant to provide an *approximate* calculation and may not be exact.

A higher capacity battery might be more beneficial for longer surveys. The 3m heavy duty cable below is available from Sensors & Software:

7. Exported Data

For every Project exported, a single .GPZ file will be created. For example, if there are 3 Projects on a single NIC-500 and all the data is exported, there will be 3 directories, each containing a .GPZ File. The directory structure will look as follows:

- GPR Data
  - SPIDAR
    - Export01
      - Project1
        - Project1.GPZ file
      - Project2
        - Project2.GPZ file
      - Project3
        - Project3.GPZ file

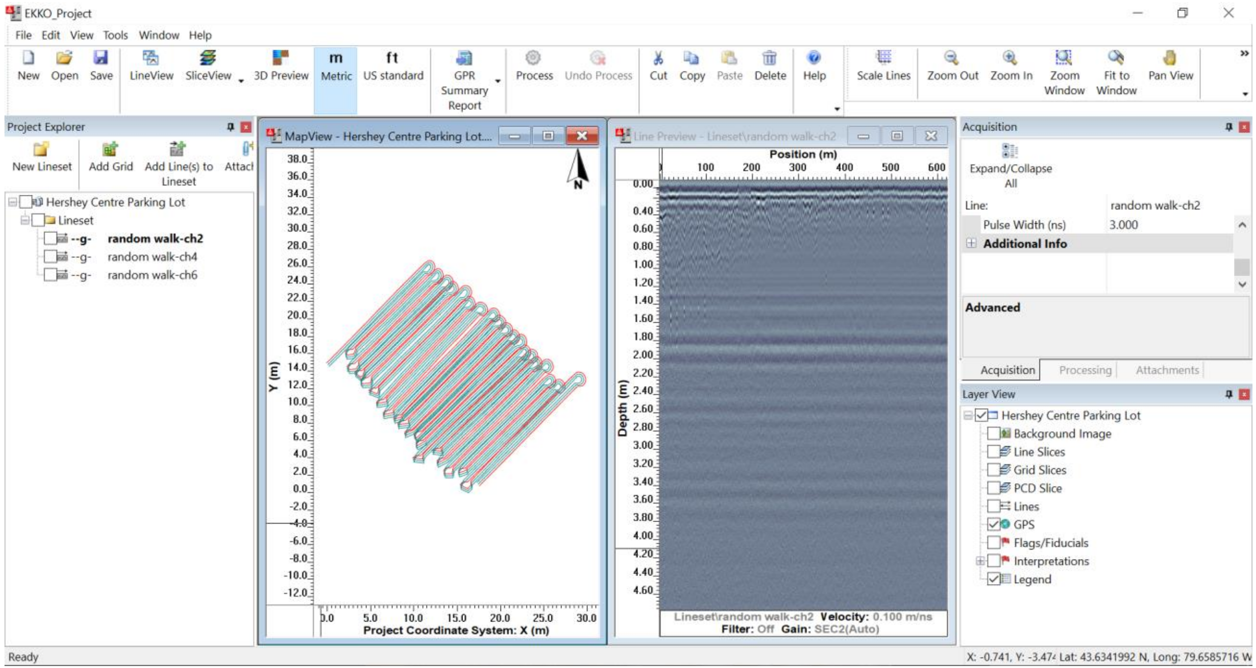
Project# may be replaced with the unique name of the Project.

Remember that data is stored on each NIC-500. In the case of multiple NIC-500s, data must be downloaded from each NIC-500 separately (Section 4.2).

7.1 EKKO_Project

The .GPZ files can be opened with the EKKO_Project software. EKKO_Project is powerful software that allows you to view, edit, process and ultimately create reports from your GPR data.

When a .GPZ file is opened in EKKO_Project, the left side of the screen will display all the individual lines/channels that were collected. For example, if you collected data with 3 x Noggin 500 systems, there will be 3 lines of data (as in the picture below). If you had 3 pairs of pulseEKKO 500 MHz transducers, and a NIC-500X was used to sequence the data, you could have up to 9 lines of data (3 transmitters firing separately and all 3 receivers listening each time).



For more information, consult your EKKO_Project manual or contact Sensors & Software (www.sensoft.ca).

8. Compatibility

Many customers who purchase SPIDAR will have existing Noggin and pulseEKKO systems. Some older systems may not be compatible with SPIDAR.

8.1 Noggins

At minimum, Noggin sensors must be a Noggin Gold. Older Noggin Sensors (for example, Noggin Plus) will not work with the NIC-500.

In addition, the firmware on the Noggin Gold sensor may need to be updated to run with the NIC-500N. If the Noggin sensor is connected to the NIC-500 with an older version of the firmware, there will be an exclamation mark beside the firmware number on the System Admin page, under Device Information (Section 4.6.1)

Contact Sensors & Software to determine if your Noggin sensor will require a field update.

Noggin cables must have a green LED on the Noggin end (Figure 8-1). If the LED is red, this cable is not compatible with the NIC-500.

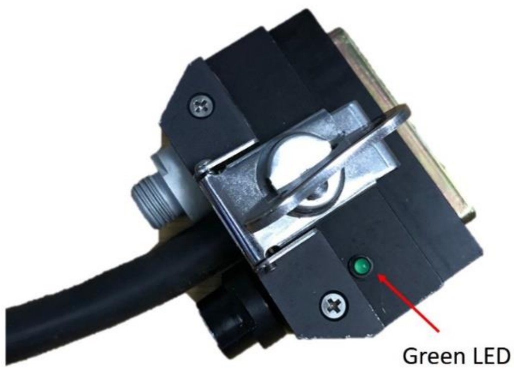


Figure 8-1: Noggin compatible cable, showing green LED

8.2 pulseEKKO

The NIC-500P and NIC-500X are compatible with pulseEKKO Pro Transducers, Transmitters and Model 1600 Receiver. It is possible that new versions of the fibre optic cables may be required if connecting the NIC-500 to an older pulseEKKO transmitter. Contact Sensors & Software for specific details on compatibility to legacy pulseEKKO systems.

9. Technical Specifications

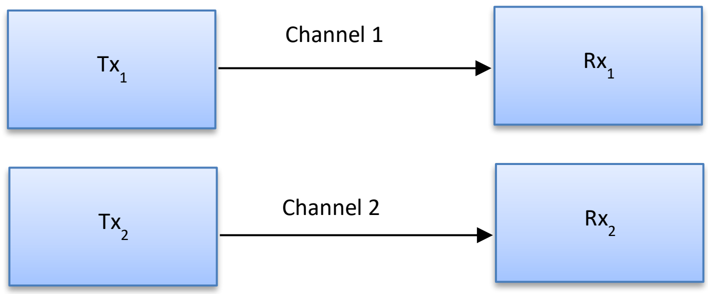
Dimension	28.6cm x 17.1cm x 6.4cm (11.25” x 6.75” x 2.5”)
Weight	NIC-500N: 2.0 kg (4.4 lbs) NIC-500P: 2.1 kg (4.6 lbs) NIC-500X: 2.2 kg (4.8 lbs)
Operating voltage	Wide voltage input range with built in stabilizer (10V to 28V)
Power Consumption (single NIC only)	6 W (0.5A @ 12V)
Power Source	Battery operated
Operating temperature	-40ºC to 50ºC
Environmental	IP65
Internal memory	8 GB
Wi-Fi connectivity	Yes (IEEE 802.11 b,g,n)
LCD text display	Non-Graphic OLED text display (32 characters) to indicate status
Ethernet ports	2
Odometer input port	1
Serial port	1
USB port	2

Appendix A: Data Collection Modes

The NIC-500 data collection modes are described below.

1) Interleaved Transmitter Operation

With Interleaved Transmitter Operation, multiple transmitters can be fired simultaneously. This enables multiple Transmitter-Receiver pairs (channels) to have concurrent data acquisition when time windows are shorter than 10,000 ns.

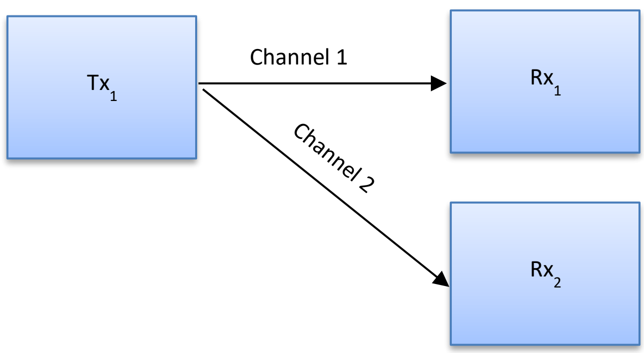


Channel 1 and Channel 2 are collected simultaneously.

The GPR data is captured per channel, so the data is stored into two DT1 data files. The channels are synchronized to avoid interference. Data is collected in parallel so there is no reduction in speed no matter how many channels are connected.
Interleaved Transmitter Operation is the default mode for the NIC-500N and NIC-500P. It is also available for the NIC-500X.

2) Concurrent Receiver Operation

With Concurrent Receiver Operation, multiple receivers can collect signals from one transmitter simultaneously.

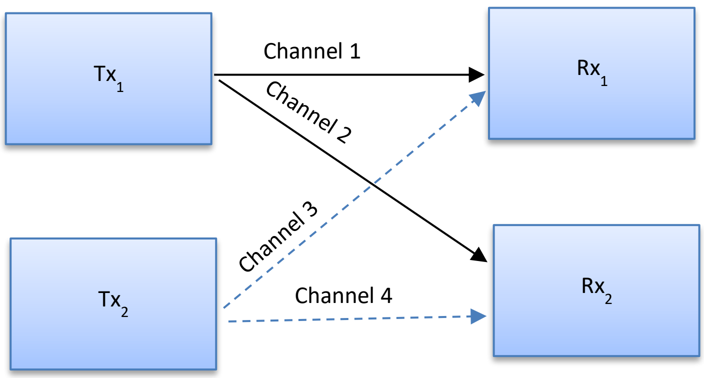


Channel 1 and Channel 2 are collected simultaneously.

In this configuration, there are still two channels and data is captured into two DT1 data files. The receivers are listening at the same time, so data collection is in parallel and there is no reduction in speed no matter how many receivers are connected.
Concurrent Receiver Operation mode is only available in the NIC-500X.

3) Sequencing

An extension of Concurrent Receiver Operation is the ability to provide dynamic transmitter-receiver pairing. The transmitter-receiver pairs can follow a specific sequence, thus allowing additional data channels with no additional hardware. In this example, channels 2 and 3 are created with no additional hardware when compared to the Interleaved Transmitter Operation above.



In this configuration, there are 4 channels and data is captured into four .DT1 data files. This is a mixture of concurrent and sequencing mode.

A sequence is similar to a series of events, which gets repeated over and over. In the example above, there would be 2 Sequences: the first Sequence would feature Tx_1 firing, and the second Sequence would feature Tx_2 firing.

Firing groups are used to define which receivers are listening to which transmitters in each sequence. In the example above, there would be two firing groups. Tx_1, Rx_1 & Rx_2 would be on one firing group, and Tx_2, Rx_1 and Rx_2 would be on another firing group.

The table below illustrates this by showing the firing groups for each sequence:

Antenna	Sequence 1	Sequence 2
Tx_1	1	-
Tx_2	-	2
Rx_1	1	2
Rx_2	1	2

Data collection speed is 1/n, the total number of transmitters in the system, n.
Sequencing is only available in the NIC-500X.

Appendix B: Components

The tables below list some components that can be purchased for your SPIDAR NIC-500 platform. For specific details and requirements, contact Sensors & Software.

NIC-500-Specific Accessories

Item	Description	Item Code
NIC-to-PC Communications Cable (1m)	Environmentally-protected ethernet cable to connect computer to NIC (instead of Wi-Fi)	100-52-0126
NIC-to-PC Communications Cable (5m)	Environmentally-protected ethernet cable to connect computer to NIC (instead of Wi-Fi)	100-52-0127
NIC-500 Power Cable (1m)	Cable from a Sensors & Software's battery to the primary NIC.	100-52-0130
NIC-500 Power Cable – Heavy Duty (3m)	Cable from an automotive battery (+ and – terminals) to the primary NIC.	100-52-0131
NIC-500 to NIC-500 Synchronization cable	When daisy-chaining NICs, must be used in conjunction with Network cable.	100-52-0129
NIC-500 to NIC-500 Network Cable	When daisy-chaining NICs, must be used in conjunction with Synchronization cable.	100-52-0128
SPIDAR Custom Noggin Cable	Cable to connect Noggin to SPIDAR, without the Y connection to the batter	100-52-0136A & 100-52-0136B
Couplers	Used to extend a SmartCart frame to accommodate more transducers	100-53-0099
Stacking Kit	Stacking NICs on top of each other	100-53-0114

General Accessories

Item	Item Code
Black battery (18 Ah) in Pelican Case	100-55-0014
Grey battery (9 Ah) in Pelican Case	100-55-0021
Belt battery (9 Ah)	100-55-0012
Odometer Extension Cable (0.45m)	100-52-0091
Odometer Extension Cable (1m)	100-52-0078
pulseEKKO PRO Transducer Cable (2m)	100-52-0069
pulseEKKO PRO Transducer Cable (3m)	100-52-0063
pulseEKKO PRO Transducer Cable (10m)	100-52-0065
pulseEKKO PRO Transducer Cable (30m)	100-52-0067
pulseEKKO PRO Dual Fibre-Optic FO Cable (2.5m)	100-52-0073
pulseEKKO PRO Dual Fibre-Optic FO Cable (5m)	100-52-0060
pulseEKKO PRO Dual Fibre-Optic FO Cable (20m)	100-52-0052
pulseEKKO PRO Fibre-Optic Converter	100-22-0028
Noggin Cable (2.5m)	100-52-0051
Noggin Cable (5m)	100-52-0049
Noggin Cable (7m)	100-52-0053

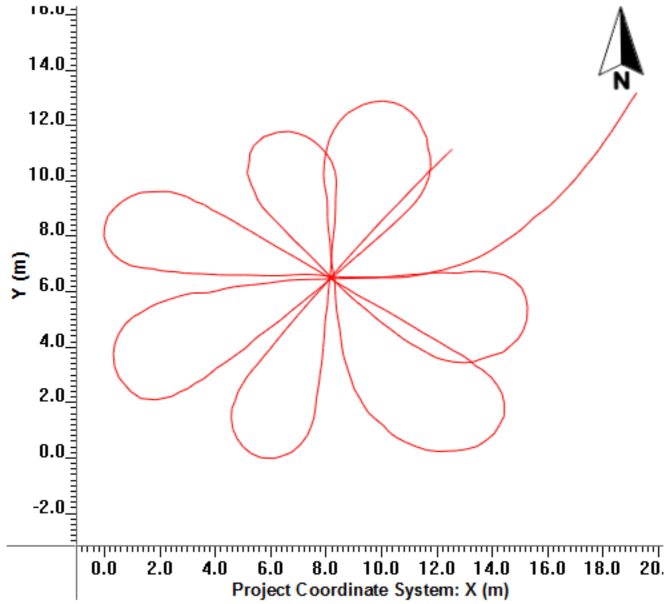
Item	Item Code
Noggin Cable (10m)	100-52-0050
Noggin Cable (30m)	100-52-0062

Appendix C: Calculating GPS Latency

This section explains how to calculate the GPS latency. Remember this only applies when collecting data on a fast-moving platform.

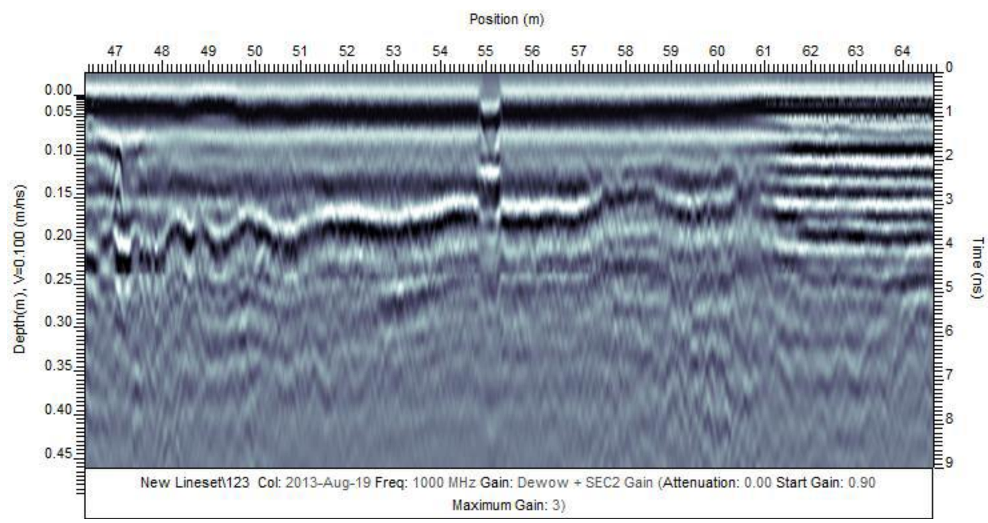
1. Choose a large outdoor area with a clear view of the sky, like a parking lot.
2. In the center of the area, place a metallic disk, roughly 1 ft in diameter. You can use a foil covered piece of cardboard. It is advised that the disk be taped down so that it does not move.
3. Set up your GPR to collect GPS data as well. Make sure that the GPS is centered directly over top of the GPR unit (as shown below).
4. Set GPR recording Depth to 0.50m (10.1ns) so that data can be collected quickly without skipping traces.
5. Start a new line and collect data running over the disk in a flower pattern (see figure below). Try to run over the disk in as many different directions and as many different speeds as you can. The faster the data are collected over the plate, the more accurate the latency value will be. ** Make sure no traces are skipped. **

6. Export the GPZ data from the flash memory card and open it in the EKKO_Project software. MapView should display your GPS path like this:

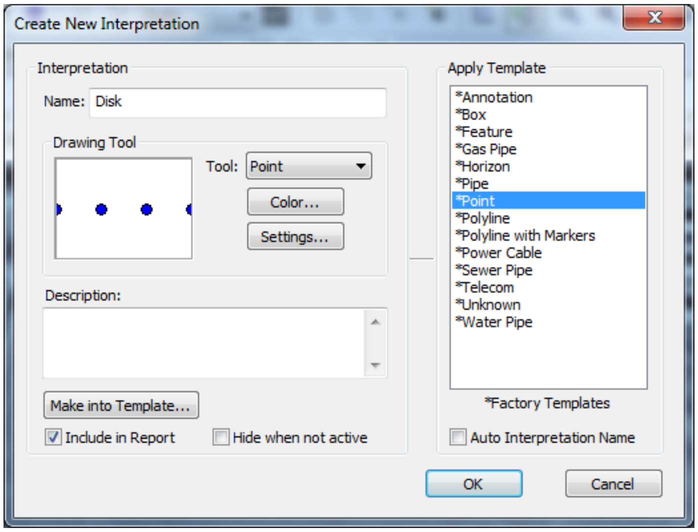


7. Double click the line name in the Project Explorer to open in LineView. Each time you ran over the disk you should see a disturbance in the direct wave like this:

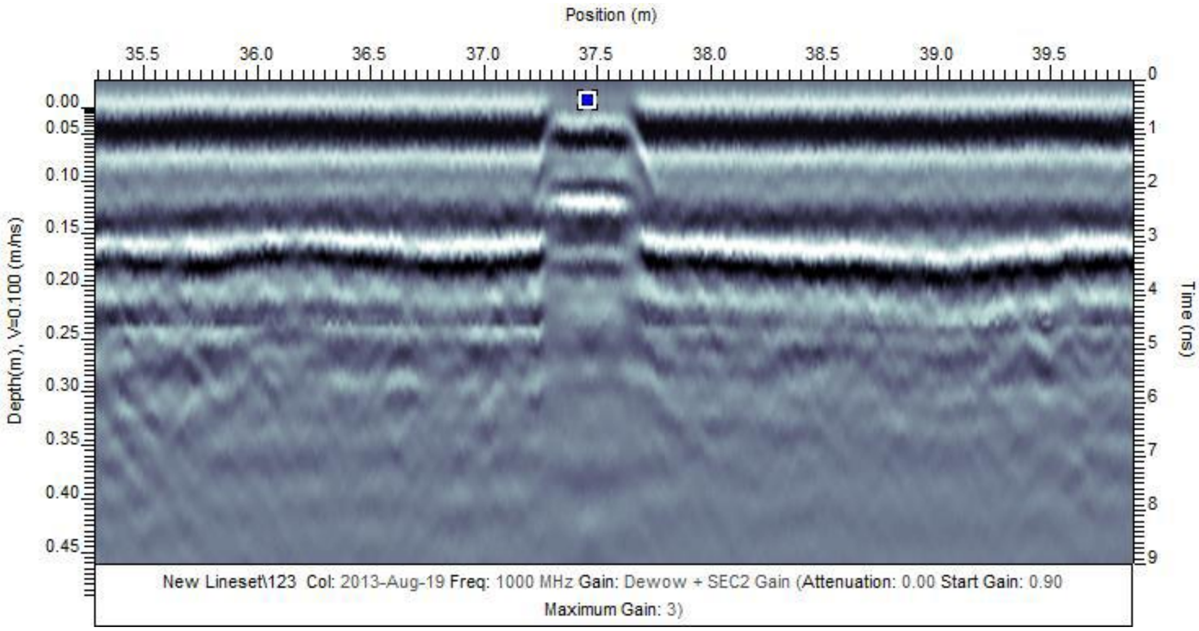
8. Create a new Point type interpretation.



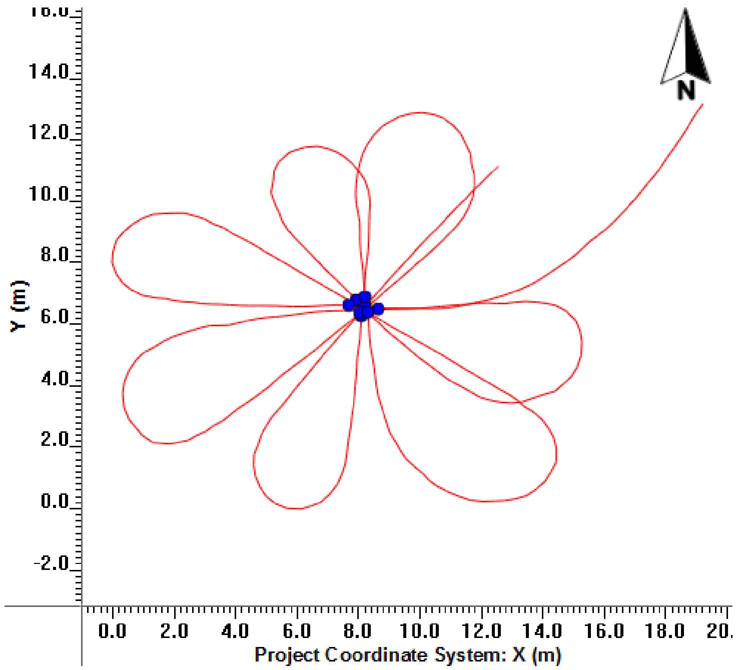
Note: If the Interpretation module is not enabled, use the mouse cursor and the F8 key for steps 8 to 13. Pressing the F8 key with the mouse cursor on the disk response in the GPR line saves the position information to the Clipboard. Copy the position information of each disturbance to a csv file.



9. Scroll through the line and enter and add an observation at the center of each of the disturbances. The vertical placement of the observation is not important.



10. Close LineView. Now you should see all of the observations clustered near the center of the flower pattern in MapView.



11. Run the Project Report under **File > Report > Project Report**, make a new folder called **0s_latency** and save the report inside.

12. Go to **Tools > GPS > Latency** and set it to 1 second, click **OK**.

13. Run the Project Report again under **File > Report > Project Report**, make a new folder called **1s_latency** and save the report inside.

14. Open a new spreadsheet in Excel. Copy and paste the UTM coordinates from the two project reports into the columns of the new spreadsheet.

0s Latency Set		1s Latency Set	
Easting	Northing	Easting	Northing
609895.67	4831925.06	609895.1	4831924.38
609895.55	4831924.67	609895.69	4831926.31
609895.36	4831925.25	609897.68	4831923.17
609896.07	4831924.94	609892.26	4831924.66
609895.51	4831924.85	609896.8	4831925.95
609895.65	4831925.42	609896.04	4831922.3
609895.77	4831924.83	609894.77	4831925.44
609895.1	4831925.07	609899.3	4831925.17

15. In the column to the right, calculate the speed in each axis by differencing the Eastings and the Northings. So Speed in Easting is Easting at 0s latency – Easting at 1s latency

0s Latency Set		1s Latency Set		Speed	
Easting	Northing	Easting	Northing	Easting	Northing
609895.67	4831925.06	609895.1	4831924.38	0.57	0.68
609895.55	4831924.67	609895.69	4831926.31	-0.14	-1.64
609895.36	4831925.25	609897.68	4831923.17	-2.32	2.08
609896.07	4831924.94	609892.26	4831924.66	3.81	0.28
609895.51	4831924.85	609896.8	4831925.95	-1.29	-1.1
609895.65	4831925.42	609896.04	4831922.3	-0.39	3.12
609895.77	4831924.83	609894.77	4831925.44	1	-0.61
609895.1	4831925.07	609899.3	4831925.17	-4.2	-0.1

16. In the next two columns calculate a corrected Easting and Northing based on some defined latency value. So the Corrected Easting is Easting at 0s latency – Speed_Easting * Latency_s (0s,1s)

CONCATENATE | =A3-E3*H1

	A	B	C	D	E	F	G	H
1	0s Latency Set		1s Latency Set		Speed		Latency	0
2	Easting	Northing	Easting	Northing	Easting	Northing	Corrected Easting	Corrected Northing
3	609895.67	4831925.06	609895.1	4831924.38	0.57	0.68	=A3-E3*H1	
4	609895.55	4831924.67	609895.69	4831926.31	-0.14	-1.64		
5	609895.36	4831925.25	609897.68	4831923.17	-2.32	2.08		
6	609896.07	4831924.94	609892.26	4831924.66	3.81	0.28		
7	609895.51	4831924.85	609896.8	4831925.95	-1.29	-1.1		
8	609895.65	4831925.42	609896.04	4831922.3	-0.39	3.12		
9	609895.77	4831924.83	609894.77	4831925.44	1	-0.61		
10	609895.1	4831925.07	609899.3	4831925.17	-4.2	-0.1		

17. Calculate the standard deviation of each of the corrected axes (Easting and Northing) and then calculate the average standard deviation:

0s Latency Set		1s Latency Set		Speed		Latency	0
Easting	Northing	Easting	Northing	Easting	Northing	Corrected Easting	Corrected Northing
609895.67	4831925.06	609895.1	4831924.38	0.57	0.68	609895.67	4831925.06
609895.55	4831924.67	609895.69	4831926.31	-0.14	-1.64	609895.55	4831924.67
609895.36	4831925.25	609897.68	4831923.17	-2.32	2.08	609895.36	4831925.25
609896.07	4831924.94	609892.26	4831924.66	3.81	0.28	609896.07	4831924.94
609895.51	4831924.85	609896.8	4831925.95	-1.29	-1.1	609895.51	4831924.85
609895.65	4831925.42	609896.04	4831922.3	-0.39	3.12	609895.65	4831925.42
609895.77	4831924.83	609894.77	4831925.44	1	-0.61	609895.77	4831924.83
609895.1	4831925.07	609899.3	4831925.17	-4.2	-0.1	609895.1	4831925.07
				Standard Deviation:		0.286256628	0.242100186
				Avg Standard Deviation:		0.264178407	

18. Now adjust the Latency value (in red) to minimize the Avg Standard Deviation

0s Latency Set		1s Latency Set		Speed		Latency	0.125
Easting	Northing	Easting	Northing	Easting	Northing	Corrected Easting	Corrected Northing
609895.67	4831925.06	609895.1	4831924.38	0.57	0.68	609895.5988	4831924.975
609895.55	4831924.67	609895.69	4831926.31	-0.14	-1.64	609895.5675	4831924.875
609895.36	4831925.25	609897.68	4831923.17	-2.32	2.08	609895.65	4831924.99
609896.07	4831924.94	609892.26	4831924.66	3.81	0.28	609895.5938	4831924.905
609895.51	4831924.85	609896.8	4831925.95	-1.29	-1.1	609895.6713	4831924.988
609895.65	4831925.42	609896.04	4831922.3	-0.39	3.12	609895.6988	4831925.03
609895.77	4831924.83	609894.77	4831925.44	1	-0.61	609895.645	4831924.906
609895.1	4831925.07	609899.3	4831925.17	-4.2	-0.1	609895.625	4831925.083
				Standard Deviation:		0.043527495	0.069991828
				Avg Standard Deviation:			0.056759662

19. Once you have found the minimum Average Standard Deviation, this is the latency value to use for this GPS unit.

Appendix D: GPR Knowledge

While this manual explains operation of your SPIDAR NIC-500 system, knowing GPR theory and principles will help in making your survey successful. Our website (www.sensoft.ca) contains a wealth of information, case studies and support.

Click here to visit the FAQ (Frequently Asked Questions) page on our website to learn more topics, such as:

1. Basic GPR Theory
2. How deep can GPR see?
3. What creates GPR Reflections
4. How do I select a GPR frequency?
5. How can velocity be extracted from hyperbolas?

Click here to see a Glossary of GPR terms and mathematical symbols.

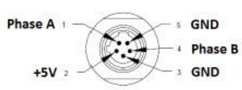
Appendix E: Port Specifications

Odometer Port

The connector that is used on SSI devices is Brad Harrison p/n 7R504A19A120.

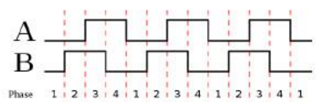
The connector/cable that is used to connect to SSI devices is Brad Harrison p/n 705002D02F060.
These are available from Westburne Electric, among others.

Pinout



1- red - white trace
2- red
3- green - gnd
4- red - yellow trace
5- red - black trace

Encoding



The odometer interface uses quadrature encoding at 5 Volt levels. The transition of one phase relative to the level of the other phase determines direction. Direction can easily be reversed by swapping connections to the Phase A/B inputs.

Link In Port

For pulse trigger mode: +5V input (with integrated 10K pullup)

Low level: 0-0.6V

High Level: 2.5-5V

Rise/fall time: < 10 ms

Minimum pulse width: 500 ns

Maximum rate: 1000 pulses/s

The pinout table is shown below:

Pin	**Function**	**Description**
1	GND	Ground
2	GND	Ground
3	Reserved	Do not connect.
4	Reserved	Do not connect.
5	Reserved	Do not connect.
6	ODO_Q0	For odometer mode, uses quadrature encoding with ODO_Q1. For pulse trigger mode, pull low then release (triggered on falling edge).
7	Power	10 -24 VDC, power input. Approx 14W. At 12V, current consumption 1.2A.
8	Power	10 -24 VDC, power input. Approx 14W. At 12V, current consumption 1.2A.
9	GND	Ground
10	Reserved	Do not connect.
11	GND	Ground
12	nPwrOn	Momentarily pull to ground for >10ms <1sec to power on. To power off, pull to ground for > 6sec.
13	ODO_Q1	For odometer mode, uses quadrature encoding with ODO_Q0. Not used in pulse trigger mode.
14	Power	10 -24 VDC, power input. Approx 14W. At 12V, current consumption 1.2A.
15	Power	10 -24 VDC, power input. Approx 14W. At 12V, current consumption 1.2A.

Appendix F: Health & Safety Certification

Radio frequency electromagnetic fields may pose a health hazard when the fields are intense. Normal fields have been studied extensively over the past 30 years with no conclusive epidemiology relating electromagnetic fields to health problems. Detailed discussions on the subject are contained in the references and the web sites listed below.

The USA Federal Communication Commission (FCC) and Occupational Safety and Health Administration (OSHA) both specify acceptable levels for electromagnetic fields. Similar power levels are mandated by corresponding agencies in other countries. Maximum permissible exposures and time duration specified by the FCC and OSHA vary with excitation frequency. The lowest threshold plane wave equivalent power cited is 0.2 mW/cm^2 for the general population over the 30 to 300 MHz frequency band. All other applications and frequencies have higher tolerances as shown in graphically in Figure B-1.

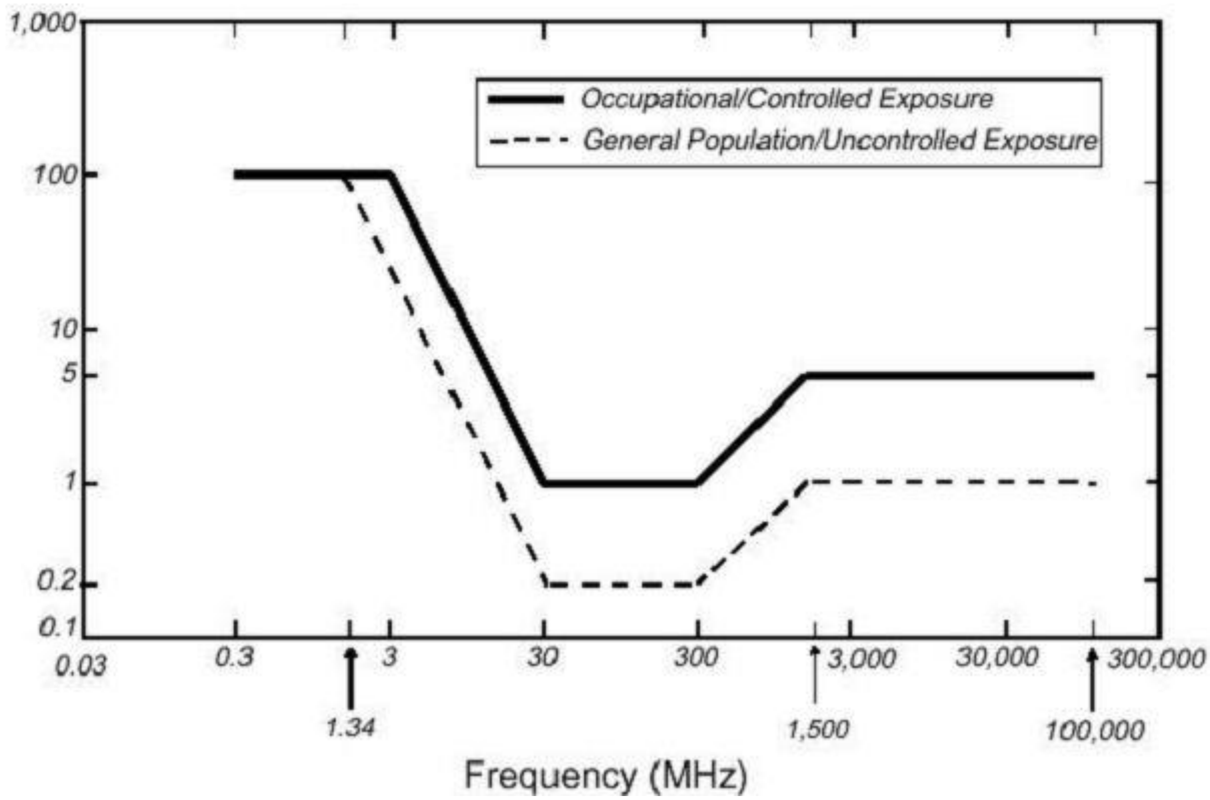


Figure B-0-1: FCC limits for maximum permissible exposure (MPE) plane-wave equivalent power density mW/cm^2.

All Sensors & Software Inc. GPR products are normally operated at least 1 m from the user and as such are classified as “mobile” devices according to the FCC. Typical power density levels at a distance of 1 m or greater from any Sensors & Software Inc. products are less than 10^{-3} mW/cm^2 which is 200 to 10,000 times lower than mandated limits. As such, Sensors & Software Inc. products pose no health and safety risk when operated in the normal manner of intended use.

Appendix G: GPR Emissions, Interference and Regulations

All governments have regulations on the level of electromagnetic emissions that an electronic apparatus can emit. The objective is to assure that one apparatus or device does not interfere with any other apparatus or device in such a way as to make the other apparatus non-functional.

The manufacturer tests their GPR products using independent professional testing houses and comply with latest regulations of the USA, Canada, European Community, and other major jurisdictions on the matter of emissions.

Electronic devices have not always been designed for proper immunity. If a GPR instrument is placed in close proximity to an electronic device, interference may occur. While there have been no substantiated reports of interference to date, if any unusual behavior is observed on nearby devices, test if the disturbance starts and stops when the GPR instrument is turned on and off. If interference is confirmed, stop using the GPR.

Where specific jurisdictions have specific GPR guidelines, these are described below.

F-1 FCC Regulations

This device complies with Part 15 of the USA Federal Communications Commission (FCC) Rules. Operation in the USA is subject to the following two conditions:

this device may not cause harmful interference and

this device must accept any interference received, including interference that may cause undesired operation.

Part 15 – User Information

This equipment has been tested and found to comply with the limits for a Class A digital device, where applicable, and for an ultra-wide bandwidth (UWB) device where applicable, 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. This equipment uses and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his/her own expense.

WARNING

Changes or Modifications not expressly approved by the manufacturer could void the user's authority to operate the equipment.

Certification of this equipment has been carried out using approved cables and peripheral devices. The use of non-approved or modified cables and peripheral devices constitutes a Change or Modification outlined in the warning above.

Operating Restrictions

Operation of this device is limited to purposes associated with law enforcement, firefighting, emergency rescue, scientific research, commercial mining, or construction. Parties operating this equipment must be eligible for licensing under the provisions of Part 90 of this chapter.

FCC Interpretation of Operation Restrictions issued July 12, 2002

(FCC Order DA02-1658, paragraph 9)

The regulations contain restrictions on the parties that are eligible to operate imaging systems (See 47 C.F.R. 5.509(b), 15.511(b), and 15.513(b)). Under the new regulations, GPRs and wall imaging systems may be used only by law enforcement, fire and emergency rescue organizations, by scientific research institutes, by commercial mining companies, and by construction companies. Since the adoption of the *Order*, we have received several inquiries from the operators of GPRs and wall imaging systems noting that these devices often are not operated by the users listed in the regulations but are operated under contract by personnel specifically trained in the operation of these devices. We do not believe that the recent adoption of the UWB rules should disrupt the critical safety services that can be performed effectively only through the use of GPRs and wall imaging systems. We viewed these operating restrictions in the broadest of terms. For example, we believe that the limitation on the use of GPRs and wall imaging systems by construction companies encompasses the inspection of buildings, roadways, bridges and runways even if the inspection finds no damage to the structure and construction does not actually result from the inspection; the intended purpose of the operation of the UWB device is to determine if construction is required. We also believe that the GPRs and wall imaging systems may be operated for one of the purposes described in the regulations but need not be operated directly by one of the described parties. For example, a GPR may be operated by a private company investigating forensic evidence for a local police department.

FCC Permitted Mode of Usage

The GPR antenna must be kept on the surface to be in compliance with FCC regulations. Use of the antenna is not permitted if it is lifted off the surface. Use as a through-the-wall imaging device is prohibited.

GPR Use Coordination

FCC regulation 15.525(c) (updated in February 2007) requires users of GPR equipment to coordinate the use of their GPR equipment as described below:

TITLE 47--TELECOMMUNICATION
CHAPTER I--FEDERAL COMMUNICATIONS COMMISSION
PART 15_RADIO FREQUENCY DEVICES
Subpart F_Ultra-Wideband Operation Sec.
15.525 Coordination requirements.

(a) UWB imaging systems require coordination through the FCC before the equipment may be used. The operator shall comply with any constraints on equipment usage resulting from this coordination.

(b) The users of UWB imaging devices shall supply operational areas to the FCC Office of Engineering and Technology, which shall coordinate this information with the Federal Government through the National Telecommunications and Information Administration. The information provided by the UWB operator shall include the name, address and other pertinent contact information of the user, the desired geographical area(s) of operation, and the FCC ID number and other nomenclature of the UWB device. If the imaging device is intended to be used for mobile applications, the geographical area(s) of operation may be the state(s) or county(ies) in which the equipment will be operated. The operator of an imaging system used for fixed operation shall supply a specific geographical location or the address at which the equipment will be operated. This material shall be submitted to:

Frequency Coordination Branch, OET
Federal Communications Commission
445 12th Street, SW, Washington, D.C.
20554

Attn: UWB Coordination
(**Sensors & Software Inc. Note**: The form given on the following page is a suggested format for performing the coordination.)

(c) The manufacturers, or their authorized sales agents, must inform purchasers and users of their systems of the requirement to undertake detailed coordination of operational areas with the FCC prior to the equipment being operated.

(d) Users of authorized, coordinated UWB systems may transfer them to other qualified users and to different locations upon coordination of change of ownership or location to the FCC and coordination with existing authorized operations.

(e) The FCC/NTIA coordination report shall identify those geographical areas within which the operation of an imaging system requires additional coordination or within which the operation of an imaging system is prohibited. If additional coordination is required for operation within specific geographical areas, a local coordination contact will be provided. Except for operation within these designated areas, once the information requested on the UWB imaging system is submitted to the FCC no additional coordination with the FCC is required provided the reported areas of operation do not change. If the area of operation changes, updated information shall be submitted to the FCC following the procedure in paragraph (b) of this section.

(f) The coordination of routine UWB operations shall not take longer than 15 business days from the receipt of the coordination request by NTIA. Special temporary operations may be handled with an expedited turn-around time when circumstances warrant. The operation of UWB systems in emergency situations involving the safety of life or property may occur without coordination provided a notification procedure, similar to that contained in Sec. 2.405(a) through (e) of this chapter, is followed by the UWB equipment user.[67 FR 34856, May 16, 2002, as amended at 68 FR 19751, Apr. 22, 2003]

Effective Date Note: At 68 FR 19751, Apr. 22, 2003, Sec. 15.525 was amended by revising [[Page 925]] paragraphs (b) and (e). This amendment contains information collection and recordkeeping requirements and will not become effective until approval has been given by the Office of Management and Budget.

FCC GROUND PENETRATING RADAR COORDINATION NOTICE
NAME:
ADDRESS:
CONTACT INFORMATION [CONTACT NAME AND PHONE NUMBER]:
AREA OF OPERATION [COUNTIES, STATES OR LARGER AREAS]:
FCC ID: Refer to FCC label on the GPR sensor you are using for FCC ID

Send the information to:
Frequency Coordination Branch., OET
Federal Communications Commission
445 12th Street, SW
Washington, D.C. 20554
ATTN: UWB Coordination
Fax: 202-418-1944

INFORMATION PROVIDED IS DEEMED CONFIDENTIAL

F-2 ETSI Regulations for the EC (European Community)

In the European Community (EC), GPR instruments must conform to ETSI (European Technical Standards Institute) standard EN 302 066-1 v1.2.1. Details on individual country requirements for licensing are coordinated with this standard. For more information, contact Sensors & Software's technical staff.

All Sensors & Software ground penetrating radar (GPR) products offered for sale in European Community countries or countries adhering to ETSI standards are tested to comply with EN 302 066 v1.2.1.

For those who wish to get more detailed information, they should acquire copies of the following documents available from ETSI.

ETSI EN 302 066-1 V1.2.1 (February 2008) Electromagnetic compatibility and Radio spectrum Matters (ERM); Ground and Wall- Probing Radar applications (GPR/WPR) imaging systems; Part 1: Technical characteristics and test methods

ETSI EN 302 066-2 V1.2.1 (February 2008) Electromagnetic compatibility and Radio spectrum Matters (ERM); Ground and Wall- Probing Radar applications (GPR/WPR) imaging systems; Part 2: Harmonized EN covering essential requirements of article 3.2 of the R&TTE Directive

ETSI TR 101 994-2 V1.1.2 (March 2008) Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Technical characteristics for SRD equipment using Ultra Wide Band technology (UWB); Part 2: Ground- and Wall- Probing Radar applications; System Reference Document

F-3a Industry Canada Regulations - English

Industry Canada published it regulations for ground penetrating radar (GPR) on Mar 29 2009 as part of the RSS-220 titled 'Devices Using Ultra-Wideband (UWB) Technology'.
Industry Canada has made a unique exception for GPR by not requiring user licensing. The user does have to comply with the following directives:
This Ground Penetrating Radar Device shall be operated only when in contact with or within 1 m of the ground.
This Ground Penetrating Radar Device shall be operated only by law enforcement agencies, scientific research institutes, commercial mining companies, construction companies, and emergency rescue or firefighting organizations.
Should the ground penetrating radar be used in a wall-penetrating mode then the following restriction should be noted by the user:
This In-wall Radar Imaging Device shall be operated where the device is directed at the wall and in contact with or within 20 cm of the wall surface.
This In-wall Radar Imaging Device shall be operated only by law enforcement agencies, scientific research institutes, commercial mining companies, construction companies, and emergency rescue or firefighting organizations.
Since operation of GPR is on a license-exempt basis, the user must accept the following:
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.

F-3b Règlement d'Industrie Canada - Français

Industrie Canada a publié des règlements pour les appareils géoradar (GPR) le 29 mars 2009, dans le cadre du RSS-220 intitulé "Dispositifs utilisant la bande ultra-large (UWB)".
Industrie Canada a faite une exception unique pour GPR en n'exigeant pas de licence par utilisateur. L'utilisateur doit se conformer aux directives suivantes:
Ce géoradar périphérique doit être utilisé que lorsqu'il est en contact avec ou moins de 1 m du sol.
Ce géoradar périphérique doit être utilisé que par les organisations d'application de la loi, les instituts de recherche scientifique, des sociétés minières commerciales, entreprises de construction et de secours d'urgence ou des organisations de lutte contre les incendies.
Si le géoradar est utilisé dans un mode de pénétration au mur, la restriction suivante est à noter par l'utilisateur:
Ce dispositif d'imagerie radar doit être utilisé lorsque l'appareil est orienté vers le mur et en contact avec ou dans les 20 cm de la surface du mur.
Ce dispositif d'imagerie radar doit être utilisé que par les organisations d'application de la loi, les instituts de recherche scientifique, des sociétés minières commerciales, entreprises de construction et de secours d'urgence ou des organisations de lutte contre les incendies.
Parce que l'exploitation de GPR est sur une base exempte de licence, l'utilisateur doit accepter le texte suivant:
La fonctionnement est soumis aux deux conditions suivantes: (1) cet appareil ne peut pas provoquer d'interférences et (2) cet appareil doit accepter toute interférence, y compris les interférences qui peuvent causer un mauvais fonctionnement du dispositive

Appendix H: Instrument Interference

Immunity regulations place the onus on instrument/apparatus/device manufacturers to assure that extraneous interference will not unduly cause an instrument/apparatus/device to stop functioning or to function in a faulty manner.

Based on independent testing house measurements, Sensors & Software Inc. systems comply with such regulations in Canada, USA, European Community and most other jurisdictions. GPR devices can sense electromagnetic fields. External sources of electromagnetic fields such as TV stations, radio stations and cell phones, can cause signals detectable by a GPR which may degrade the quality of the data that a GPR device records and displays.

Such interference is unavoidable but sensible survey practice and operation by an experienced GPR practitioner can minimize such problems. In some geographic areas emissions from external sources may be so large as to preclude useful measurements. Such conditions are readily recognized and accepted by the professional geophysical community as a fundamental limitation of geophysical survey practice. Such interference being present in the GPR recordings is not considered as an equipment fault or as a failure to comply with immunity regulations.

Appendix I: Safety around Explosive Devices

Concerns are expressed from time to time on the hazard of GPR products being used near blasting caps and unexploded ordnance (UXO). Experience with blasting caps indicates that the power of Sensors & Software Inc.'s GPR products is not sufficient to trigger blasting caps. Based on a conservative independent testing house analysis, we recommend keeping the GPR transmitters at least 5 feet (2m) from blasting cap leads as a precaution. Some customers do experimental trials with their particular blasting devices to confirm with safety. We strongly recommend that GPR users routinely working with explosive devices develop a systematic safety methodology in their work areas.

The UXO issue is more complex and standards on fuses do not exist for obvious reasons. To date, no problems have been reported with any geophysical instrument used for UXO. Since proximity and vibration are also critical for UXO, the best advice is to be cautious and understand the risks.

Appendix J: Wi-Fi Module

FCC Notice:
NOTE: This equipment has been tested and found to comply with the limits for a Class A 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. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his/her own expense.

Industry Canada Notice:
This device complies with Industry Canada's license-exempt RSSs. 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.