



Güralp Radian

Post-hole & bore-hole

Technical Manual

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1 Preliminary Notes

1.1 Proprietary Notice

The information in this document is proprietary to Güralp Systems Limited and may be copied or distributed for educational and academic purposes but may not be used commercially without permission.

Whilst every effort is made to ensure the accuracy, completeness and usefulness of the information in the document, neither Güralp Systems Limited nor any employee assumes responsibility or is liable for any incidental or consequential damages resulting from the use of this document.

1.2 Warnings, Cautions and Notes

Warnings, cautions and notes are displayed and defined as follows:



Warning: A black cross indicates a chance of injury or death if the warning is not heeded.



Caution: A yellow triangle indicates a chance of damage to or failure of the equipment if the caution is not heeded.



Note: A blue circle indicates indicates a procedural or advisory note.

1.3 Manuals and Software

All manuals and software referred to in this document are available from the Güralp Systems website: www.guralp.com unless otherwise stated.

1.4 Conventions

Throughout this manual, examples are given of command-line interactions. In these examples, a fixed-width typeface will be used:

`Example of the fixed-width typeface used.`

Commands that you are required to type will be shown in bold:

Example of the fixed-width, bold typeface.

Where data that you type may vary depending on your individual configuration, such as parameters to commands, these data are additionally shown in italics:

Example of the fixed-width, bold, italic typeface.

Putting these together into a single example:

System prompt: user input with variable parameters

2 System Overview

Thank-you for purchasing a Güralp Radian digital seismometer system.

This section describes the key components of a full Radian system. The Radian instrument is the main standard product in the system; other components and accessories can be purchased optionally. Please check your order confirmation to see which components were purchased by your organisation.

2.1 Key features

- A slim-line, 55 mm diameter sonde with 750 mm length for rapid post-hole deployment.
- Bluetooth communication via Android App (available for mobile phone and tablet) confirms integrity of the installation without physical disturbance of site.
- State-of-the-art seismic sensor allows full operation over a full tilt range of $\pm 180^\circ$ by automatically centring the masses;
- Streaming and storage of instrument response and calibration parameters dramatically simplifies data management (RESP and Dataless SEED formats).
- Instrument orientation and inclination are measured using an internal magnetometer and MEMS accelerometer to store and stream geographically-aligned waveforms.
- Internal MEMS accelerometer extends the head-room (clip level) of the instrument to 4 g, to capture high-amplitude ground motion from local seismic events.
- Triaxial orthogonal (ZNE) instrument with high cross-axis rejection ratio (> 65 dB).
- Velocity and Acceleration responses available - selected at time of order.
- Retractable, three-jaw, motorised hole-locks for optimal coupling to bore-hole casings.
- Frequency response flat to either velocity or acceleration between 120 s and 200 Hz.
- Low-latency outputs available (approx. 0.01 s data packets).
- Robust and water-proof, encased in SAE 316 corrosion-resistant stainless steel to protect the instrument in extreme environments.
- Accurate time-base provided by either surface GNSS, Precision Time Protocol (PTP), Network Timing Protocol (NTP), or internal clock (< 1 ms drift per day without GNSS).

- No mass locking required; automatic mass centring.
 - Dual-redundant microSD card data storage.
 - Low power consumption (2.1 W): suitable for temporary deployments using batteries and solar panels.
-

2.2 Main benefits

2.2.1 Post-hole installations

- Faster deployment reduces total field-work costs and/or allows greater station density for high-resolution seismic monitoring.
 - Reduced transportation costs compared to traditional instrumentation.
 - Can be drilled/cored into bed-rock for exceptional coupling and noise performance.
 - Reduced material costs and footprint compared to traditional seismic vault installations.
 - High performance in areas of high cultural noise.
 - Dramatically improved noise performance (20 dB reduction compared to vault installations - horizontal components; IRIS figures).
-

2.2.2 Bore-hole installations

- Deep installations allow you to get closer to the source and farther from cultural noise, for better subsurface characterisation
 - Ultra-low noise performance at depth
 - Excellent coupling with bore-hole casing provided by three-jaw hole-locks
-

2.3 Typical applications

2.3.1 Post-hole deployments

- Rapid deployment for volcanic unrest monitoring: recording of long-period tremor events and volcanic-tectonic earthquakes using a single instrument.
 - Ultra-dense recording arrays for microseismic monitoring in noisy environments.
 - Legislative compliance: Suitable for use in "traffic-light" systems for energy extraction or storage.
-

- Accurate recordings of strong ground shaking caused by local events.
 - Fast installation for rapid-response aftershock deployments.
 - Permanent regional and global seismic networks.
 - Recording of ice-quakes in glaciers.
-

2.3.2 Bore-hole deployments

- Passive microseismic monitoring.
- Vertical seismic profiling (VSP).
- Monitoring of moderate-strong teleseismic earthquakes.
- Complement dense surface arrays.

3 A note on the documentation

The Radian is delivered with a Surface Interface Unit (SIU) that acquires data from and allows control/configuration of the Radian. The Güralp Minimus or Minimus+ acts as the SIU for the Radian Post-hole and Bore-hole (in the case of shallow, single-instrument installations).

This document, **MAN-RAD-0001**, begins in Section 4 on page 10 by describing the main components of the Radian system. Further details on the SIU and its accessory pack are given in **MAN-MIN-0001**. Section 5 on page 17 partially duplicates the "Getting Started" section of the Minimus and Minimus+ manual, by describing a typical system set-up and providing details of viewing waveforms from the Radian.

Many operations and configuration options described in this document, **MAN-RAD-0001**, are carried out within Güralp Discovery software, which is described fully in **MAN-MIN-0001**. Therefore, it is highly recommended that the user fully familiarises themselves with **MAN-MIN-0001** prior to reading this document. It is also strongly recommended that this document is read in conjunction with the Minimus and Minimus+ manual.

4 System Description

Depending on your chosen deployment type and depth, the Güralp Radian seismometer can be delivered in two forms: the **Radian Post-hole** or the **Radian Bore-hole**. A Surface Interface Unit (SIU), accessories (cables and connectors etc.), and software will also be supplied to provide a fully operational system.

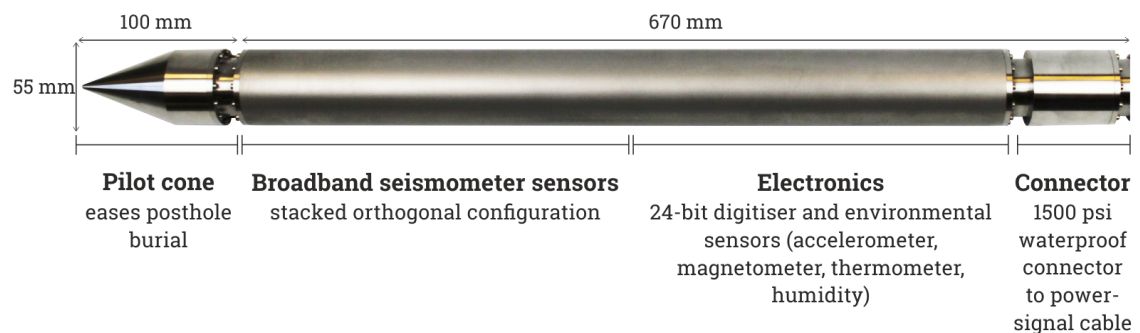
This Section describes the two main variants of Radian instrument and the primary components that constitute a full Radian system.



Note: Owing to the Radian's proprietary digital output, it can only be used in combination with a Surface Interface Unit (SIU), such as the Güralp Minimus.

4.1 Güralp Radian Post-hole Digital Seismometer

The Radian Post-hole instrument comprises a triaxial broadband seismometer and 24-bit digitiser (i.e. digital seismometer) inside a robust 55 mm diameter stainless steel casing. The main components of the Radian Post-hole are shown in the photo below; further description is given in the following text.



4.1.1 Pilot cone

The conical module at the bottom end of the Radian eases direct burial of the instrument into a post-hole.

4.1.2 Sensors

The broadband seismometer sensors are stacked vertically, allowing the instrument to have its very slim form factor. The sensors can be delivered with a frequency response (transfer function) that is flat to either velocity or acceleration. This option is decided by the customer upon ordering and normally depends on the anticipated seismic monitoring application. The sensors have a standard broadband frequency response of 120 s (0.0083 Hz) to 200 Hz. The unique sensor technology allows the

sensors' masses to fully centre regardless of orientation, allowing the Radian to be installed at any angle in the shallow sub-surface, facilitating rapid deployment.

4.1.3 Digitiser and electronics

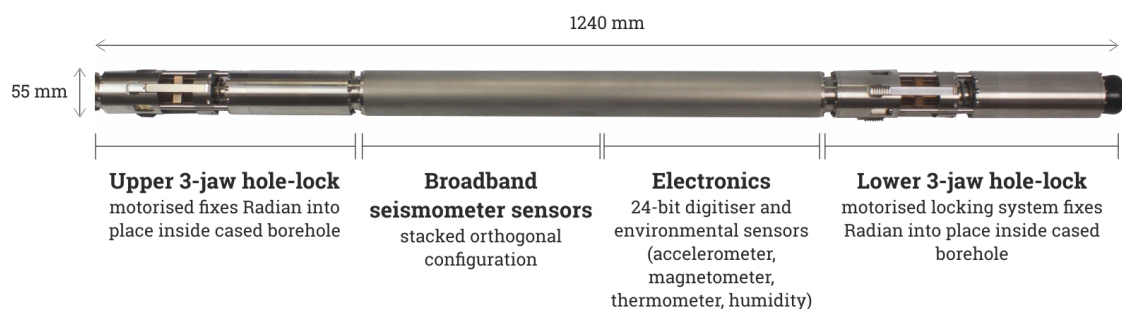
The electronics module inside the Radian contains a 24-bit analogue-to-digital converter (ADC) that supports recording rates up to 5000 samples per second. The electronics system also stores instrument calibration parameters that can be transmitted across a network and/or recorded at the SIU.

4.1.4 Connector

The connector module comprises a 10-way female plug that is used to connect to the power/signal cable (see Section 4.3 on page 12). The module is threaded on the outside to mate with the plug on the power/signal cable. The connector is rated waterproof to 10 MPa, 100 Bar or 1500 psi.

4.2 Güralp Radian Bore-hole Digital Seismometer

The Radian Bore-hole is designed for installations in cased bore-holes up to 2000 m depth. Apart from not having a pilot cone, the instrument consists of the same modules as the Radian Post-hole (Section 4.1 on page 10), with two three-jaw hole-lock systems.



Main features of the Radian bore-hole digital seismometer

4.2.1 Three-jaw hole-lock system

The Radian's hole-lock system is designed to maintain a positive pressure on the bore-hole casing over a prolonged period of time and to fix the instrument in place whilst avoiding the transmission of any stresses.

Hole-locks are located at the top and bottom of the Radian bore-hole instrument. Each three-jaw hole-lock provides excellent grip on the bore-hole casing; it can be installed in bore-holes with diameters of between 60 mm and 100 mm.

Each hole-lock consists of a set of three active clamp arms attached to a compression spring, which forces them to swing out from the instrument and wedge themselves against the bore-hole wall. Serrated steel jaws at the end of each arm provide maximum grip against the bore-hole casing. This configuration ensures that the sonde body is held parallel to the axis of the bore-hole and prevented from twisting or slipping under the influence of ground vibrations.

The hole-locks can be easily controlled using the Discovery software (see Section 4.6 on page 16) using a PC or laptop (see Section 5.5 on page 19).

4.3 Power/signal cable

The supplied power/signal cable connects the SIU with the Radian Post-hole instrument.

At the instrument end of the cable, there is a waterproof (10 MPa or 1500 psi) 10-way military-specification connector. This connector must be connected and attached firmly by hand-tightening the screw cover. At the SIU end, there is a standard 10-way military-specification bayonet connector which should be attached to the port labelled "DIGITAL".

4.4 Surface Interface Unit for post-hole and shallow bore-hole installations

Please refer to Sections 3.1 and 3.2 of **MAN-MIN-0001** for full details of the Surface Interface Unit (SIU) / Minimus and its Accessory Pack.

4.4.1 Connectors

The Surface Interface Unit has a total of five connectors that are clearly labelled as follows:



Caution: Use attached dust-caps where possible to prevent ingress of any dirt, dust or fluids. Any such foreign bodies may compromise the operation of the connectors.

- **Sensor ("ANALOGUE") connector**

The 26-pin military-specification "ANALOGUE" connector allows the SIU to be connected to a standard analogue seismic seismometer or accelerometer with three primary channels and one auxiliary channel; e.g. Güralp Fortis, 5TC, 3T, 3ESPC, 40T, 6T or a third-party sensor.

- **Network (“ETHERNET”) connector**

The 8P8C Ethernet connector allows use of 10BASE-T, 100BASE-TX or 1000BASE-T networks.

- **Power supply (“POWER”) connector**

The SIU accepts power from lines in its “POWER” connector. This is a Güralp standard 4-pin bayonet plug conforming to MIL-DTL-26482.

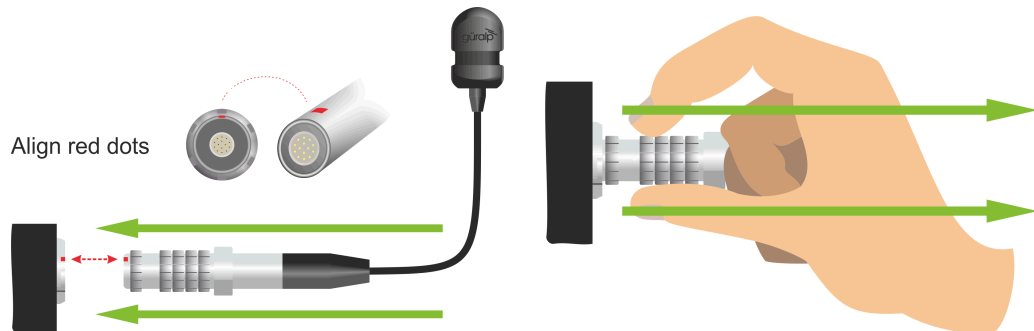
- **Radian (“DIGITAL”) connector**

This connector mates with the down-hole cable to the first or only Radian in a bore-hole string.

- **GNSS / GPS and Serial (“GPS”) connector**

This is a LEMO connector that connects either to the GNSS cable and receiver or to a LEMO-to-Serial adapter for debugging purposes.

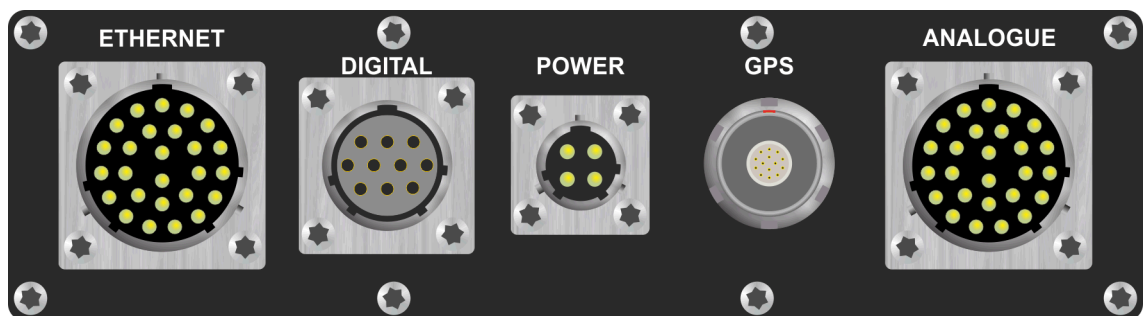
LEMO connectors use an innovative latching mechanism which is different to the bayonet connectors used elsewhere. To mate, simply line up the red marks and gently push the connector into place. To disconnect (un-mate), grasp the outer sleeve of the connector and pull gently.



Caution: Do not twist the connector.



Top-down view of the SIU shallow variant



Side connector-panel of the SIU shallow variant2

4.5 Surface Interface Unit for deep multi-instrument bore-hole installations

For multiple-instrument bore-hole installations (i.e. vertical array / VSP tool applications) and/or at installation depths greater than 100 m, the deep variant of the SIU must be used.

The deep SIU is similar to the shallow version and contains almost identical internal electronics. The main difference between the variants is the size of the enclosure; this difference is because of the larger voltage output required for deep, multi-

instrument bore-hole installations and the incorporation of fibre optic media converters.

4.5.1 Connectors



Caution: Use dust-caps where possible to prevent ingress of any dirt, dust or fluids. Any such foreign bodies may compromise the operation of the connectors.

- **Serial (“DEBUG”) connector**

This is a standard DE9m serial port which can be connected to a terminal emulator using either a standard serial cable or an RS232-to-USB converter.

- **Network (“ETHERNET”) connector**

The 8P8C Ethernet connector allows use of 10BASE-T, 100BASE-TX or 1000BASE-T networks.

- **Power/signal connector (“DIGITAL”)**

This connector mates with the down-hole cable to the first or only Radian in a bore-hole string.

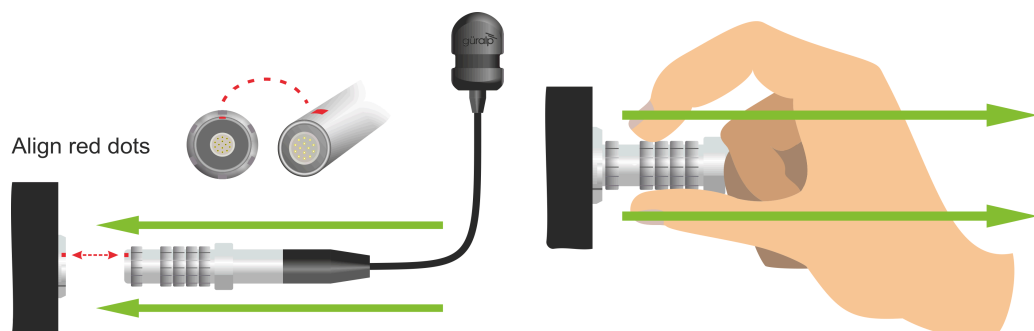


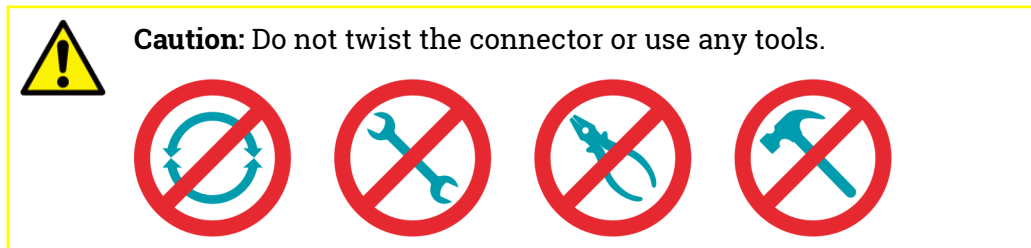
Warning: The “DIGITAL” connector can present voltages in excess of 200 Volts. Take extreme care not to touch this connector and to ensure that water does not enter this connector when the Surface Interface Unit receives power.

- **GNSS / GPS (“GPS”) connector**

This is a ten-pin, military-specification bayonet connector that connects to the GNSS cable and receiver.

LEMO connectors use an innovative latching mechanism which is different to the bayonet connectors used elsewhere. To mate, simply line up the red marks and gently push the connector into place. To disconnect (un-mate), grasp the outer sleeve of the connector and pull gently.





- **"ANALOGUE" connector**

This allows the connection of an analogue instrument, the output of which will be digitised by the ADC of the internal Minimus. For specifications, please see **MAN-MIN-0001**.

4.6 Güralp Discovery software and GüVü app

Please refer to Sections 3.3 and 3.4 of **MAN-MIN-0001** for full details on Güralp Discovery and Güralp GüVü.

5 Getting Started

5.1 Unpacking

Güralp Radian Post-hole systems are most commonly delivered inside rugged Peli™-cases with wheels, measuring 96 x 40 x 15 cm. This packaging is specifically designed for the Radian Post-hole system and should be re-used whenever you need to transport the instrument.



Warning: The Radian Radian Post-hole system weighs in excess of 12 kg. Improper storage or handling may cause injury, disability or death. Always follow recognised safety procedures for heavy equipment handling.



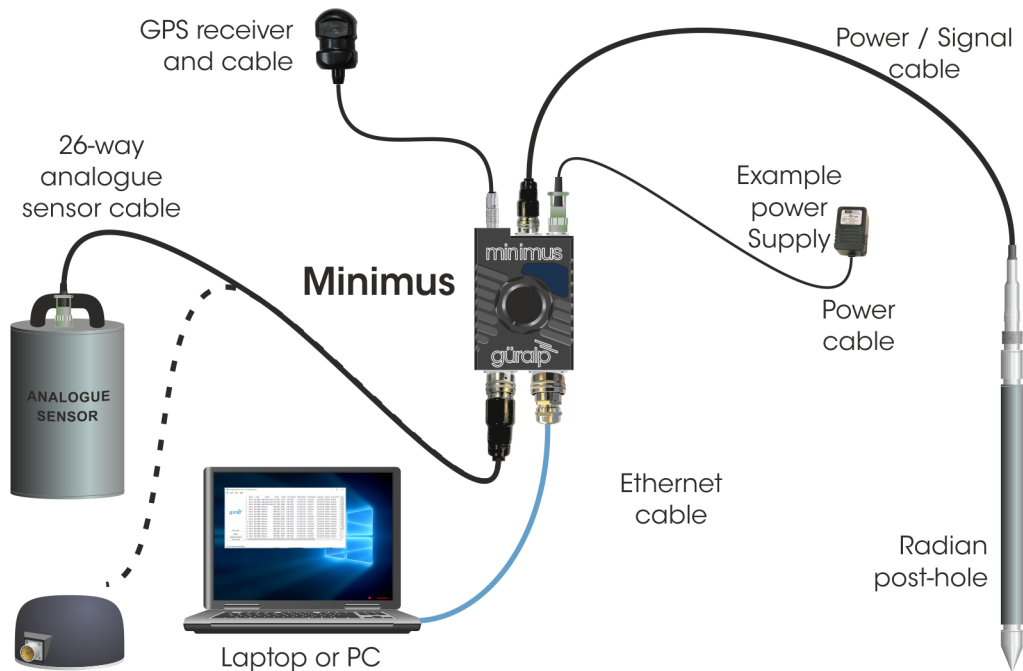
Caution: The Radian Post-hole system contains sensitive mechanical components which can be damaged by mishandling. If you are at all unsure about the handling or installation of the device, you should contact Güralp Systems for assistance.

- Do not bump or jolt any part of the equipment when handling or unpacking.
- Do not kink or walk on any cables (especially on rough surfaces such as gravel), nor allow the cables to become trapped under the heavy items.
- Do not connect the instrument to power sources except where instructed.
- Never ground any of the output signal lines from the sensor.
- Take care with the connector pins and plugs. Pins can be delicate and may bend/break easily.

5.2 System set-up

Güralp highly recommends testing and gaining familiarity with the Radian system at your lab before installation in an outdoors environment.

A typical set-up for the Radian system (including an optional analogue sensor) is shown in the figure below.



To get started, connect the cables as shown and as described in Section 4.1.4 on page 11, Section 4.4.1 on page 12, Section 4.5.1 on page 15 and Section 4.1 of **MAN-MIN-0001**.

Connect the Minimus/Surface Interface Unit (SIU) to a 10-36 V DC power supply which will, in turn, provide power to the Radian.

5.3 Software installation and set-up

To view live waveforms and to control and configure the Radian, SIU and other connected sensors, you will need to use Güralp Discovery software. Using a web browser, visit

<http://www.guralp.com/sw/download-discovery.shtml>

and download the appropriate file for your PC. Run the file and follow the instructions on screen.

Full details of installation and upgrading are in Appendix 4 of **MAN-MIN-0001**.

When you open Discovery, it displays a main window which shows both locally and remotely connected instruments. If you close this main window, Discovery will quit.

Discovery will initially “listen” for connected instruments on your local network. This mode can be refreshed by selecting the “Scan Locally” button or by keying



The screenshot shows the 'Güralp Systems - Discovery' application window. It features a table with columns: Status, Label, System, Name, Serial#, Firmware Ver, WAN Address, LAN Address, Uptime, Latitude, and Longitude. Five rows of instrument data are visible, with the third row (Label: NO LABEL, Name: Minimus, Serial#: 37717) highlighted in blue. Below the table are buttons for 'Scan Locally' and 'Registry', and a text input field containing '52.34.40.123'. Annotations with arrows point to these elements: 'Scan the local network for locally-connected instruments and digitisers' points to 'Scan Locally'; 'Load list of registered systems from a central registry and attempt to contact them' points to 'Registry'; and 'Specify here the I.P address of the central registry (cloud server)' points to the IP address field. A bracket on the right side of the table is labeled 'Connected instruments'.

Instruments are referred to in Discovery as follows:

- Minimus: an analogue sensor directly attached to the SIU and the SIU's internal sensors are all referred to as Instrument 0, whereas Instruments connected through the digital port (i.e. Radian) are defined as Instruments 1, 2, 3... etc.
- Minimus+: the first analogue sensor directly attached to the SIU and the SIU's internal sensors are all referred to as Instrument 0. The second analogue sensor directly attached to the SIU is referred to as Instrument 1. Digital instruments connected through the digital port (i.e. Radian) are defined as Instruments 2, 3, 4... etc.

5.4 Viewing waveforms and system state-of-health


Please refer to Section 4.3 of **MAN-MIN-0001** for full details on viewing waveforms and state-of-health information from the Radian.

5.4.1 Using Güralp GüVü app on Android and iOS devices

Please refer to Section 6 of **MAN-MIN-0001** for full usage details on Güralp GüVü.

5.5 Radian bore-hole: control of hole-locks

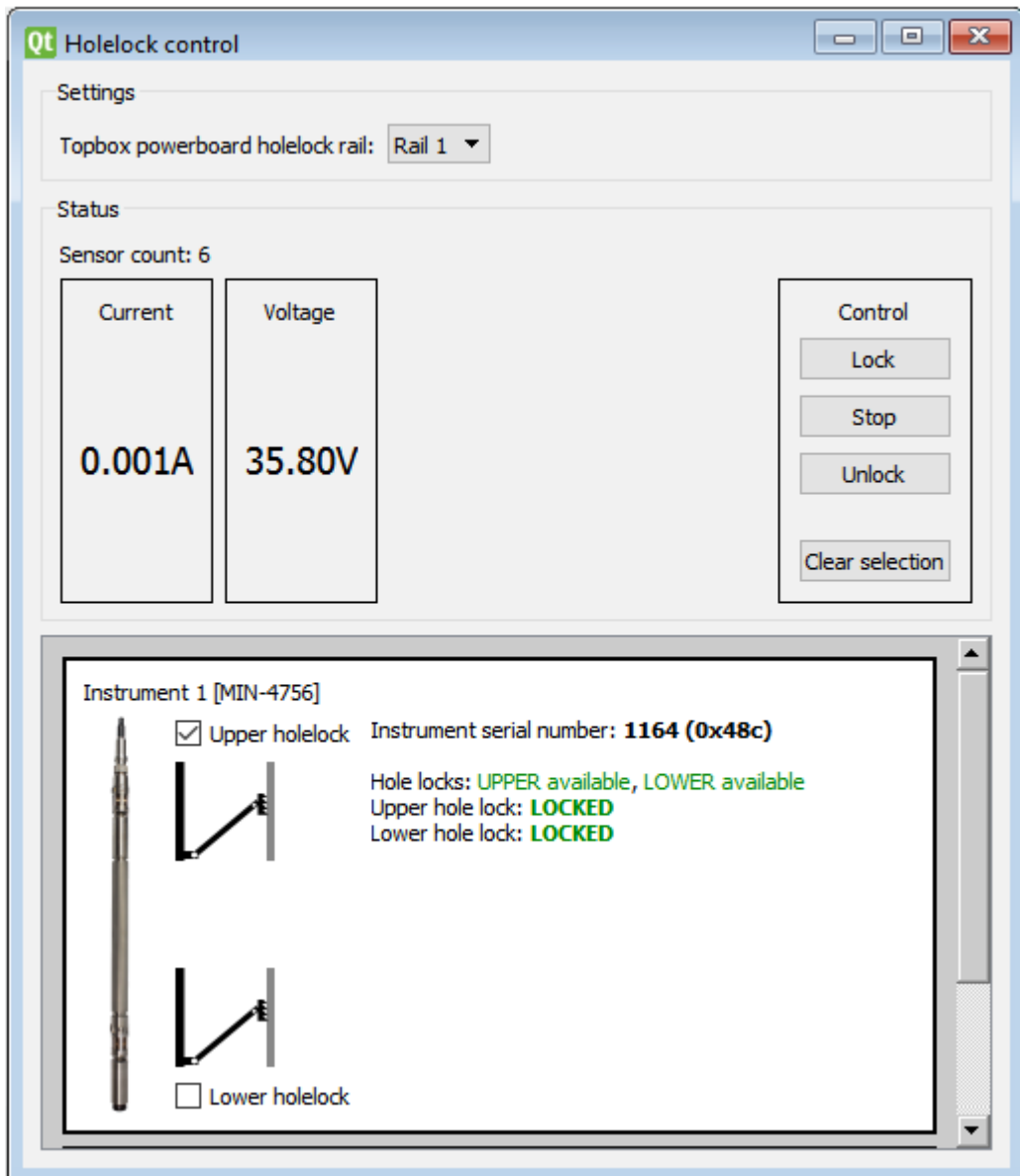
Hole-locks on connected Radian bore-hole instruments can be easily controlled using Güralp Discovery. To access the hole-lock control tools, launch the Control Centre by right-clicking on an active entry in Discovery's main window.

Click on the “Hole-lock control” button  to open the corresponding window: this shows the status of the upper and lower hole-locks of all the Radians connected to the selected SIU.

The Settings section allows selection of the output power-rail used to provide power to the hole-lock. This is always "Rail 1" in standard units so this setting must be left unchanged unless the SIU has a customised configuration.

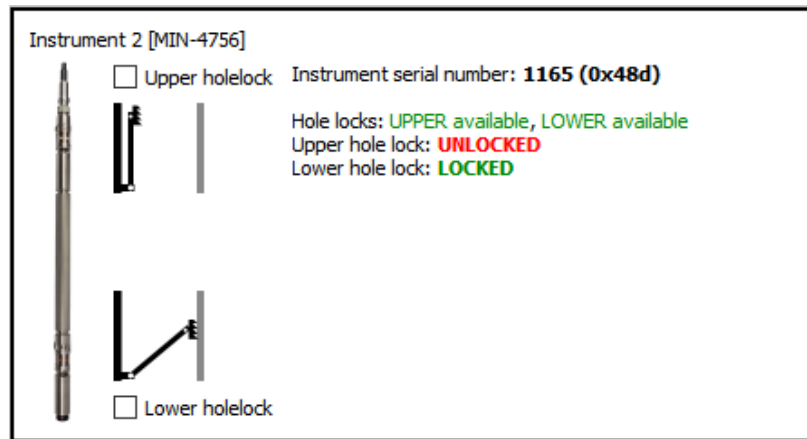
Under "Status", two boxes show the current being drawn and the voltage supplied to the hole-lock motors. These values are updated in real time.

There is also a section labelled "Control", which is active when one of the check-boxes for the hole-locks in the graphical section at the bottom of the page is selected.



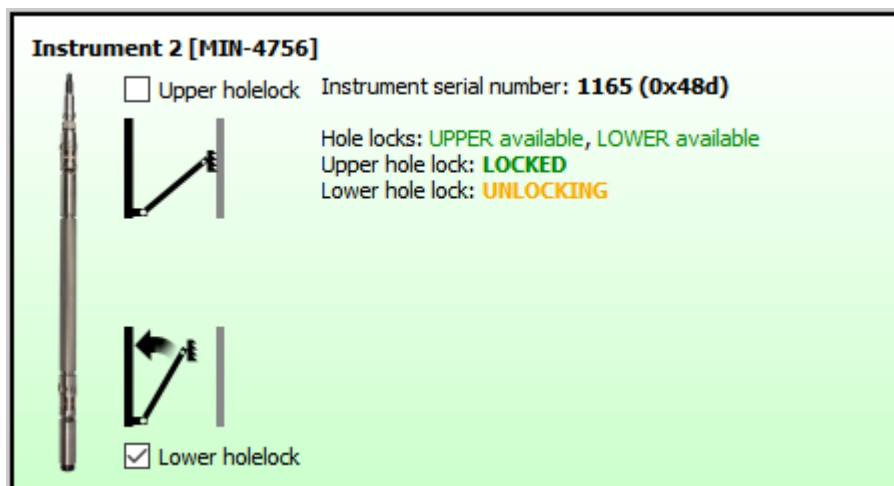
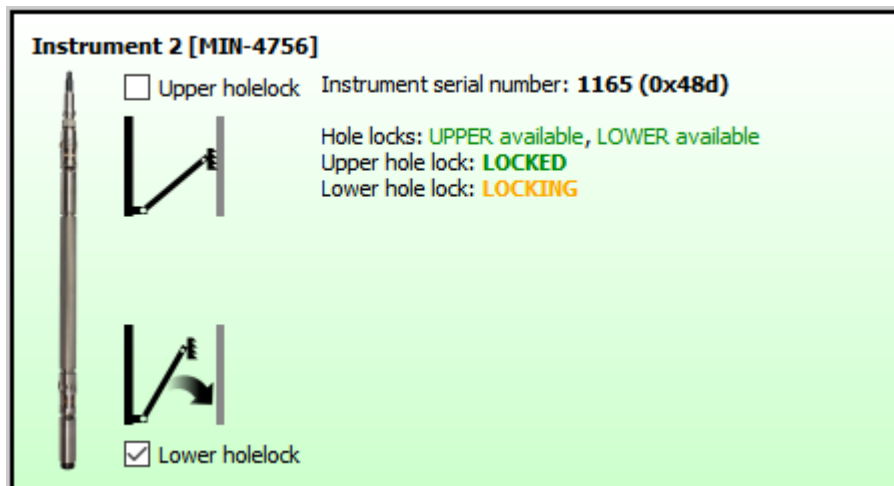
Within the graphical section:

- if the hole-lock is locked, the status will be displayed as **LOCKED**;
- if the hole-lock is unlocked, the status will be displayed as **UNLOCKED**.

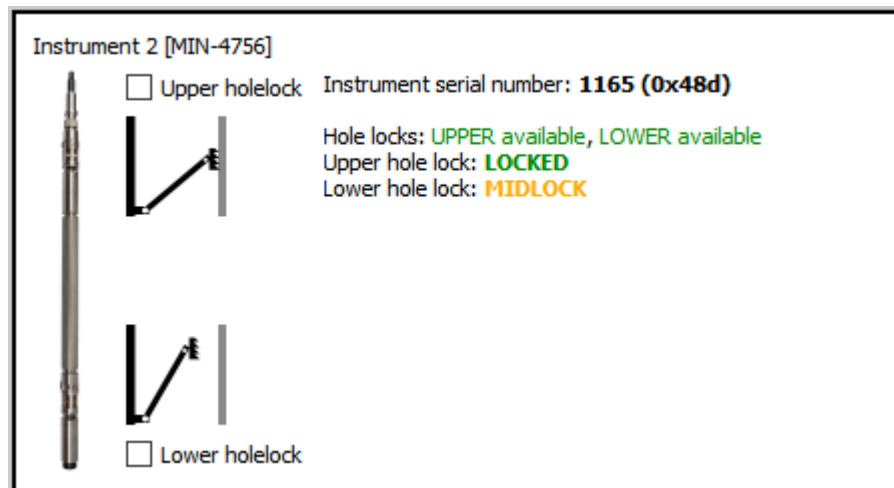


To retract a hole-lock, tick the relevant check-box for the hole-lock and then click the **Unlock** button; to deploy a hole-lock, click the **Lock** button.

During the locking/unlocking process, the status **LOCKING** and **UNLOCKING** will be shown, respectively. You can stop the locking or unlocking process by pressing the **Stop** button or by selecting a different hole-lock.



If the hole-lock is stopped while it is not completely locked or unlocked, the status **MIDLOCK** will be displayed.



When the locking or unlocking action terminates and the hole-lock has reached the desired status, locked or unlocked, a sound is generated.

5.5.1 Locking sequence

Locking should always proceed from the bottom upwards, so:

- For a single Radian, the **lower** hole-lock should be deployed **before** the **upper** hole-lock.



Note: If this order is not respected, a warning message is displayed. It is possible to proceed anyway, by-passing this warning, by clicking on the “Yes” button.

- If more than one Radian bore-hole is connected in a string, proceed as follows:
 1. Lock the lower hole-lock of the deepest instrument
 2. Lock the upper hole-lock of the deepest instrument
 3. Lock the lower hole-lock of the next-deepest instrument
 4. Lock the upper hole-lock of the next-deepest instrument
 5. Repeat steps 3 and 4 until the uppermost instrument is locked.



Note: If this order is not respected, a warning message is displayed. It is possible to proceed anyway, by-passing this warning, by clicking on the “Yes” button.

5.5.2 Unlocking sequence



Caution: Always provide secure support by tensioning the load-bearing cable before unlocking a deployed instrument. Failure to do so can result in the instrument dropping in an uncontrolled manner, risking damage to the instrument and/or cable.

When unlocking strings of instruments, take up the slack and re-tension the load-bearing cable after unlocking each individual instrument. The required tension will rise after each instrument is unlocked.

Unlocking should always proceed from the top downwards, so:

- For a single radian, the **upper** hole-lock should be retracted **before** the **upper** hole-lock.



Note: If this order is not respected, a warning message is displayed. It is possible to proceed anyway, by-passing this warning, by clicking on the “Yes” button.

- If more than one Radian bore-hole is connected in a string, proceed as follows:
 - Retract the **upper** hole-lock of the **shallowest** instrument
 - Retract the **lower** hole-lock of the **shallowest** instrument
 - Retract the **upper** hole-lock of the **next-shallowest** instrument
 - Retract the **lower** hole-lock of the **next-shallowest** instrument
 - Repeat steps 3 and 4 until the deepest instrument is unlocked.



Note: If this order is not respected, a warning message is displayed. It is possible to proceed anyway, by-passing this warning, by clicking on the “Yes” button.



Caution: If this order is not respected, a warning message is displayed. It is possible to proceed anyway, by-passing this warning, by clicking on the “Yes” button. **Do not do this** on a deployed system unless advised to do so by Güralp staff.

6 Recommended Field Procedures



Note: The Radian connector is fitted with two O-rings to guarantee the waterproofing. To connect the cable, maintain the Radian in vertical position and roughly align the grooves in the plug with the tongues in the socket before inserting the cable connector. Kindly push and rotate the connector until it lines up perfectly. Push it to down until it reaches the end stop. Screw the fixing ring down to the end of the thread.



Caution: The air compressed inside the connector can push in the opposite direction because of the O-rings. Do not use the fixing ring to help you pushing the connector inside the Radian to prevent any damage on the thread.

6.1 Post-hole installation

Compared to traditional vault-style installations, the post-hole method has the potential to save significant time and resources (material, labour), without loss of performance. The technique minimises thermal effects and improves noise performance, especially for horizontal sensor components at low frequencies.

To minimise surface noise effects, you should ensure that the hole is at least one metre deeper than the full length of the Radian Post-hole.

6.1.1 Procedure

1. Prior to arrive at the final installation site, you will need to calibrate the Radian's internal magnetometer.
2. Prior to arriving at the installation site, ensure that a microSD card (if appropriate, correctly formatted and with enough free space) is inserted into the SIU's card slot.
3. The magnetometer should be calibrated in a region where the local declination is known by pointing the axis towards maximum field components.
4. Create a hole for the installation using a portable motorised- or hand-auger. Ideally, the hole should be at least two metres deep and 65 cm wide.



Note: Note that, due to the Radian's unique sensors ($\pm 180^\circ$ tilt tolerance), the hole does not need to be exactly vertical.



Post-hole installation using a motorised hand auger

5. Clean the post-hole, ensuring that there is no loose material around the mouth of the hole or on its base.
6. Ensure that the bayonet connector joining the Radian to its power/signal cable is firmly tightened and free of dirt.
7. Add a 15 cm thick layer of packing material to the bottom of the hole. A mixture of 3 mm grade angular coarse grit with around 30% medium grit gives good results, allowing any water to permeate and soak away, whilst leaving the packing material moist. Slightly moisten the packing material in the hole and ram it firmly down, if possible.
8. Gently lower the vertically-hanging instrument to the bottom of the post-hole using the strain-relief power/signal cable. Keep the cable taut.



Note: Note that, due to the Radian's unique sensors ($\pm 180^\circ$ tilt tolerance), the instrument does not need to be exactly vertical within the hole and it does not need to be aligned with north.

9. Continue filling with the packing material and moistening, while keeping the power/signal cable taut until the instrument is fully buried.
10. Slacken the power/signal cable.
11. Install the SIU (and, if applicable, a power source such as a lead-acid battery) in a separate waterproof enclosure (e.g. a Peli™-case).
12. Attach the free end of the power/signal cable to the "DIGITAL" port on the SIU. Connect the rest of the cables and peripherals to the SIU (as shown/described in Section 5.2 on page 4).
13. Power up the SIU and connect to it using either Discovery, Scream! or GüVü.

14. Carry out a stomp test to ensure that the waveforms look acceptable.
15. If necessary, configure the Sensor, Networking and Recording settings (see Section 7 on page 29).
16. Back-fill the remainder of the hole with the originally excavated soil/material.

6.2 Single-instrument bore-hole installation

6.2.1 Installation using hole-locks

For a bore-hole installation, you should have been provided with a winch and tripod from Güralp.

The key benefit of the Radian instrument is that it can operate at any angle so excellent seismic data can be obtained even if the the bore-hole is not completely vertical.

Before installing any instrument in a bore-hole, you should prepare the installation site.

- Clean the area around the bore-hole head, so there is clear access all around it.
- Keep the bore-hole capped at all times except when inserting or removing the instrument, so that debris and tools do not accidentally fall in.
- Lay out the cables beside the bore-hole, or set up a cable drum nearby, so that they do not become tangled.
- Ensure the tripod is tall enough to hang the entire sonde from it, with the sensor clear of the ground.
- Use a winch with a depth gauge, if possible, or measure out the cable beforehand.
- Test the hole-lock mechanism before installing the sensor (see Section 5.5 on page 19).

6.2.1.1 Procedure

1. Connect the power/signal cable to the connector on top of the sensor. Fully tighten the knurled nut to its end stop using firm hand pressure.
2. Using the winch, hoist up the sensor package until it is hanging by the power/signal cable.
3. Position the instrument over the top of the bore-hole. Do not allow it to drag across the ground.

4. Lower the instrument so that its base is just level with the bore-hole mouth. If there is a depth gauge on the winch, set it to zero now.
5. Continue to lower the instrument to a depth of about one metre, so that the instrument is still visible.
6. Power up the Surface Interface Unit and Instrument, and extend the hole-lock arm (see Section 5.5 on page 19) to check that it fits your bore-hole. Monitor the hole-lock current: it should dip slightly as the arm touches the casing, then drop to zero when it is fully extended. Check that the instrument is firmly anchored to the bore-hole casing by attempting to slacken the load bearing cable. If it remains taut, the instrument is still loose within the bore-hole. Do not proceed with installation in this case. Instead, you should either move the instrument to a narrower section of the bore-hole and try again, or contact Güralp Systems to fit a wider hole-lock, quoting accurate measurements of your bore-hole.
7. Check that the sensor is functioning correctly by looking at the waveforms being shown on, e.g., Discovery software. If the sensor fails to register ground movements, contact Güralp Systems.
8. Re-tension the load-bearing cable and retract the hole-lock jaws using Discovery software.
9. Gently lower the sensor to the required depth. Fix the sensor system into the bore-hole using the hole-lock arm.
10. Lower the cable by around 30 cm to provide some slack in the cable.
11. Clamp the cable to the top of the bore-hole.
12. The winch can now be dismantled and removed from site.

6.2.2 Installation using sand back-fill

Dry sand back-fill is a convenient and effective way of installing a single Radian bore-hole instrument in a time-stable environment. The presence of sand not only fixes the sensor in place at the bottom of the hole, but also reduces noise due to air convection.

The ideal type of sand to use is the fine, kiln-dried sand supplied for use in children's play sandpits. This is readily available in airtight bags, is thoroughly washed and clean, and will contain little sediment (when dried out after wetting, sand containing foreign matter may solidify and form a concrete-like substance, permanently trapping the sensor in position.) This sand is suitable for use in both dry and damp bore-holes.

In the procedure outlined below, the sensor will rest on a pad of sand around 300 mm thick. This pad will absorb any residual moisture at the bottom of the bore-hole, and ensure that the surroundings of the instrument are kept dry.

After positioning the sensor, more sand is added to fill the space between it and the bore-hole casing, holding it firmly in place. The sand should reach within 30 mm of the top of the instrument, but should not cover it. This way, the instrument can be more easily recovered when it requires maintenance or replacement. This is particularly important if the bore-hole is not completely dry, since moist sand does not flow well.

6.2.2.1 Procedure

1. Measure or calculate the physical volume of the unit which is to be installed in the bore-hole (the volume of a cylinder is given by $v = \pi r^2 h$ where r is the radius and h is the height). Also measure the internal diameter of the bore-hole.
2. Measure and pour in a sufficient quantity of sand to fill the bore-hole to a depth of around 300 mm.
3. Connect the power/signal cable to the connector on top of the sensor. Fully tighten the bayonet connector nut to its end stop.
4. Using a winch, hoist up the sensor package until it is hanging by the power/signal cable.
5. Position the instrument over the top of the bore-hole. Do not allow it to drag across the ground.
6. Lower the instrument so that its base is just level with the bore-hole mouth. If there is a depth gauge on the winch, set it to zero now.
7. Begin lowering the sensor down the bore-hole, keeping track of the depth reached.
8. Whilst monitoring the depth of the sensor, carefully approach the sand layer at the bottom of the bore-hole. The tension of the power/signal cable will reduce when the sensor makes contact with the sand.



Note: If the tension of the power/signal cable reduces before the sensor has reached the sand layer, the sonde may have become caught on a bad joint or lip in the bore-hole; carefully raise and lower the instrument to free it.

9. When the sonde reaches the bottom, use the winch to lift the package slightly, re-tensioning the cable. This ensures that the sensor is hanging vertically within the bore-hole and is no longer in contact with the sand bed.
10. Calculate the volume of dry sand required to fill the gap between the sensor and the bore-hole liner to the level of the top of the sensor ($v = \pi r^2 h$ using the internal radius of the bore-hole, from which you should subtract the volume of the instrument, as determined in step 1).

11. Pour this sand into the bore-hole. If you can, check how much of the sensor is covered with sand. Güralp can provide bore-hole cameras with built-in illumination for this purpose. Do not over-fill the hole.
12. Carefully slacken the power/signal cable to secure the installation within the bore-hole.
13. Without pulling or lifting the sensor, lightly shake the cables to remove any sand that may have fallen onto them.

6.3 Multi-instrument bore-hole installation (i.e. VSP tool)

The maximum number of instruments that can be strung together is six; this is due to limitations in the voltage that can be carried through to the vertical array and the safe loading strength of the power/signal cables.

6.3.1 Procedure



Caution: To prevent ingress of moisture, make sure that an end cap is securely fitted to the bottom of the lowermost instrument

1. Connect a 15 metre, 5 mm diameter slave cable to the power/signal cable above the lowermost sensor
2. Winch this assembly into the bore-hole until the top of the cable is almost level with the top of the bore-hole
3. Slide the cable trap plate over the cable and rest it on the top of the bore-hole
4. Continue to winch the assembly down until the weight is taken entirely by the cable trap plate.
5. Remove the lifting eye cable termination from the cable and attach the bottom of the next sensor to the exposed cable
6. Connect a the 15 metre, 5 mm diameter slave cable to the power/signal cable above this sensor
7. Lift the deployed assembly slightly to allow the cable trap plate to be removed
8. Repeat from step 3.

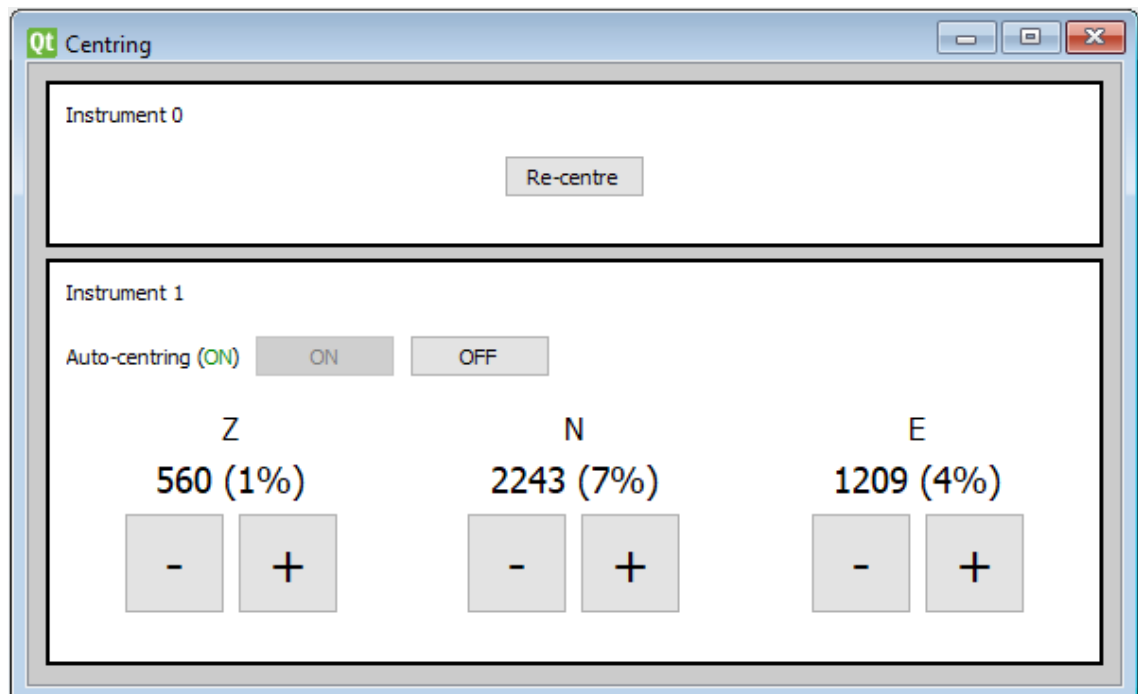
7 Configuration and control of Radian instruments

7.1 Mass centring

By default, the Radian automatically keeps its masses centred. The Radian's unique motorised mass centring system allows the masses to centre when the instrument is installed at any angle.

To perform a manual centring of the masses, launch the Minimus or Minimus+ Control Centre by right-clicking on the device in the Discovery main window.

- The Radian is identified with the title "Instrument 1" when connected to a Minimus.
- The Radian is defined with the title "Instrument 2" when connected to a Minimus+.



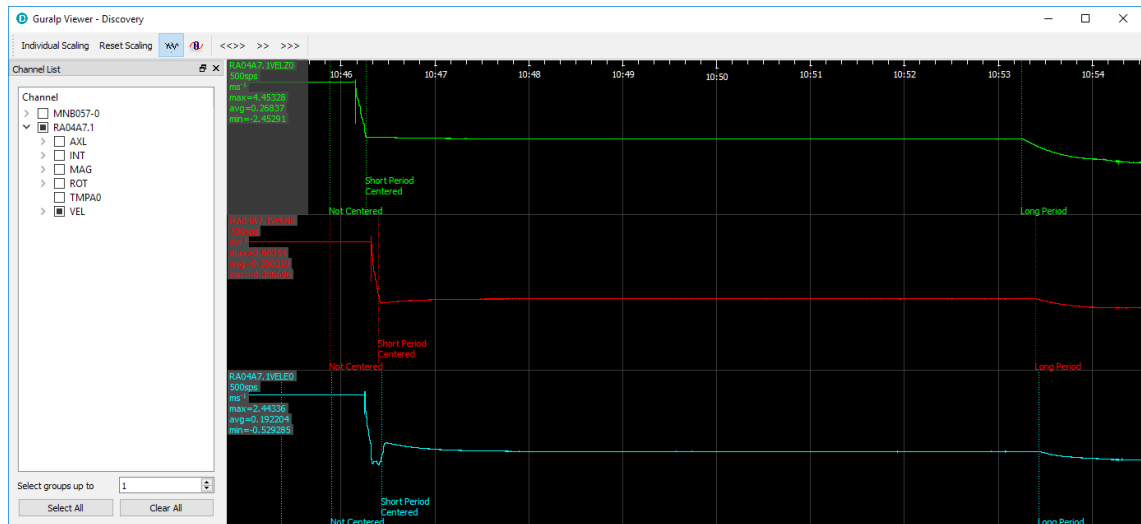
The mass position values in counts of the three components are showed in real-time under the corresponding component indicators (Z, N, E).

The mass positions can be adjusted manually:

- click the button to decrease the mass position value (i.e. make it less positive or more negative).

- click the button to increase the mass position value (i.e. make it more positive or less negative).

In action starts the auto-centring procedure. The first stage consists in a rough mechanical centring which it is followed by a more accurate electrical centring sequence that lasts 7 minutes.



When the auto-centring is enabled, the centring procedure is activated as soon as the percentage reaches $\pm 100\%$. To turn off Automatic Mass Centring, select the button in the Auto Centring option (not recommended). To restore the default setting, click on the button.

7.2 Calibration

7.2.1 Seismic channels calibration

Calibration is a procedure used to verify or measure the frequency response and sensitivity of a sensor. It relates the output voltage to the actual corresponding ground motion.

The Radian is a digital sensor and it calibrated once in the factory. The calibration parameters are saved in the instrument and automatically transmitted to the Minimus digitiser during each boot-up phase.

To access the Radian's calibration page, go to Discovery's main screen, right-click on the instrument and select "Calibration" → "Calibration Page Editor".

Please refer to Section 5.11.4 of **MAN-MIN-0001** for full details on using the Calibration Page Editor.

7.2.2 Accelerometer calibration

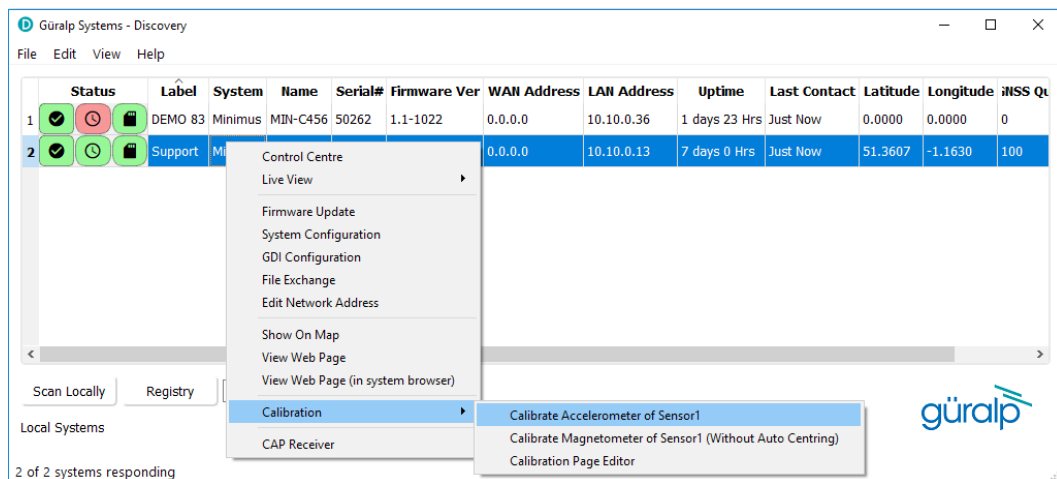


Caution: The calibration of the Radian MEMS accelerometer is carried-out in the factory. Please, follow the procedure below only in case suggested by Güralp. It is recommended to use the standing jigs provided on request.

The Radian is supplied with an internal three-axis MEMS accelerometer with a measuring range of ± 2 g. The accelerometer helps to determine the Radian's position in space (pitch and roll).

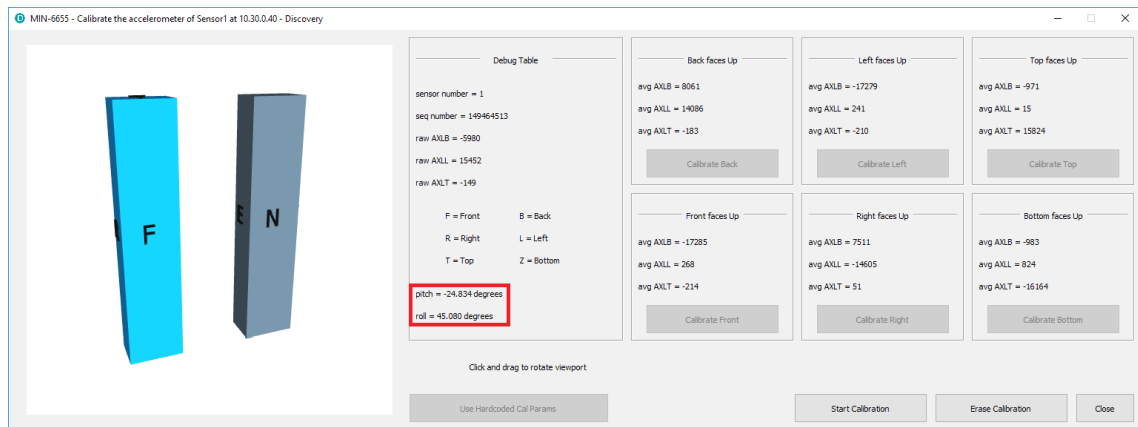
The MEMS accelerometer should be calibrated once in the factory and it is not required to repeat the calibration on the deployment site because the Earth's gravitational pull can be considered constant in each part of the world.

To calibrate the Radian's accelerometer, go to Discovery's main screen, right-click on the instrument and select "Calibration" → "Calibrate Accelerometer of Sensor1".



In the calibration window (see below), the left-hand panel gives a three-dimensional visualisation of the Radian's orientation (left) with respect to a fixed reference frame (right). The view can be rotated by sliding the "Viewport" bar. The labels, "F", "B", "L" and "R" refer to the Front (North), Back (South), Left (West) and Right (East) directions of the Radian respectively.

The right-hand side of the panel gives real-time values of accelerometer measurements, with calculated angles of pitch and roll.



The calibration of the accelerometer is performed in six stages, one for each combination of polarity and axis of the instrument.

The North face of the Radian can be determined from where the label is attached or from the connector (the larger orientation groove points North/Front).

The Top face of the Radian is the one where the cable is connected and the Bottom face is the one with the pilot cone.



Note: It is recommended to use an external digital level or inclinometer to make sure that the Radian is perfectly aligned to the direction of interested. The jigs are required to obtain an accurate result and they are available on request.

To perform the calibration follow the steps below:

1. Using the jigs and the inclinometer, accurately position the Radian on a horizontal surface with the Back facing up, click on "Start Calibration" button and wait for 15-20 seconds without moving the Radian;
2. Click on the "Calibrate Back" button;
3. Rotate the Radian and, using the jigs and inclinometer, accurately position the it with the Left facing up, wait for 15-20 seconds without moving the Radian;
4. Click on the "Calibrate Left" button;
5. Rotate the Radian and, using the jigs and inclinometer, accurately position the it with the Front facing up, wait for 15-20 seconds without moving the Radian;
6. Click on the "Calibrate Front" button;
7. Rotate the Radian and, using the jigs and inclinometer, accurately position the it with the Right facing up, wait for 15-20 seconds without moving the Radian;
8. Click on the "Calibrate Right" button;

9. Using the jigs and inclinometer, accurately position the Radian against a vertical surface with the Top facing up, wait for 15-20 seconds without moving the Radian;
 10. Click on the “Calibrate Top” button;
 11. Rotate the Radian upside-down and, using the jigs and inclinometer, accurately position the it against a vertical surface with the Bottom facing up, wait for 15-20 seconds without moving the Radian;
 12. Click on the “Calibrate Bottom” button;
 13. Click on “Close” button.
-

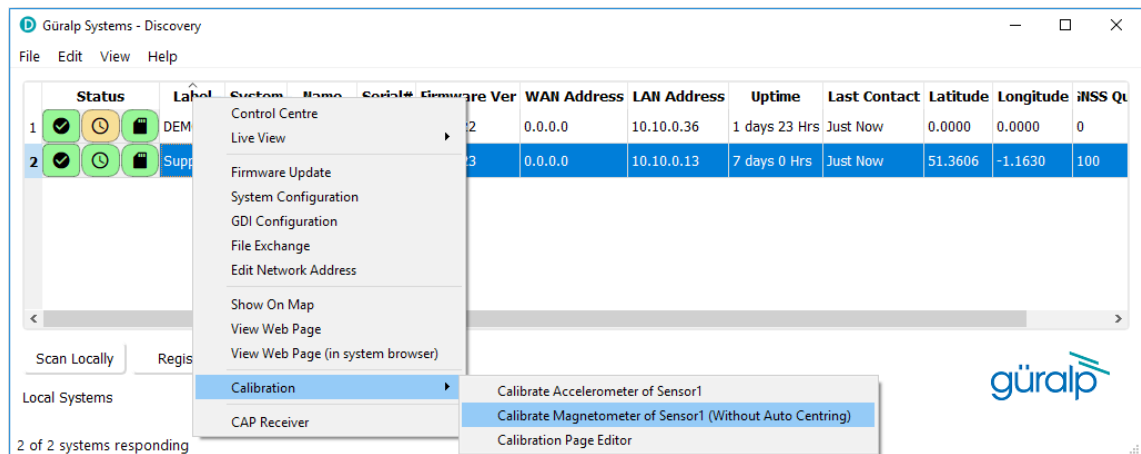
7.2.3 Magnetometer calibration

The Radian contains an internal three-axis magnetometer that can measure the Earth’s magnetic field (in nanoTeslas) allowing the instrument to be used as a digital compass. The magnetometer can be affected by magnetic and environmental interference (including other electronic equipment), so it must be carried out at least several metres away from any electronic devices, any magnetic objects or any large metallic objects.

The magnetometer uses information from the internal MEMS accelerometer (pitch and roll) to determine the Radian’s position in space. The magnetometer helps to determine the Radian’s horizontal orientation (yaw). In addition, the magnetometer may be used to determine relative changes in the near-field magnetic field that may be caused by noise sources.

The magnetometer should be calibrated to find the direction of maximum magnetic field strength, which may be interpreted as Magnetic North. If the magnetometer is being used for this purpose, magnetic declination (<http://www.ngdc.noaa.gov/geomag-web/#declination>) must be accounted for to estimated the orientation of True North.

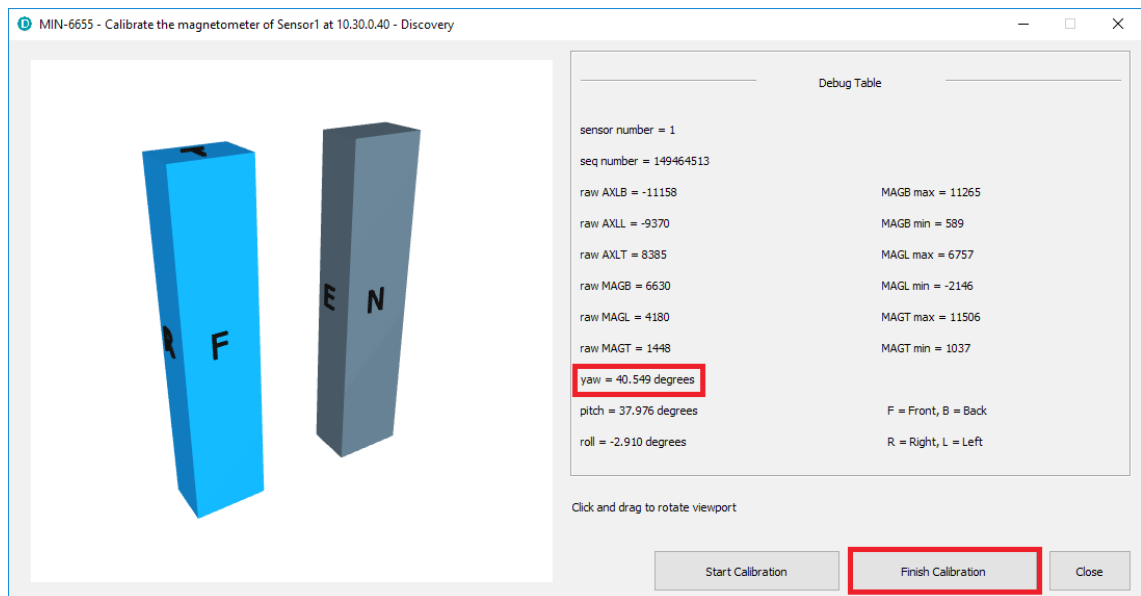
The magnetometer should be re-calibrated upon delivery of the Radian and, ideally, every time the instrument is moved to a different location, in order to account for local magnetic field variations.



To proceed, right-click on the instrument in Discovery and select “Calibration” → “Calibrate Magnetometer of Sensor1 (Without Auto Centring)”.

In the calibration window, the left-hand panel gives a three-dimensional visualisation of the Radian’s orientation (as described previously when discussing the accelerometer calibration window).

When the calibration process is started, the right-hand side of the panel gives real-time values of accelerometer and magnetometer measurements, with calculated angles of yaw, pitch and roll.



To perform the calibration, follow the steps below:

1. Click on “Start Calibration” button;
2. Rotate the Radian in all the possible angles. This is so that all of the faces are exposed to the maximum magnetic field present on the site.
3. Keep moving the Radian around until the *max* and *min* values shown on the right-side column stop being updated.

4. Click on "Finish Calibration" button when the *max* and *min* values are stable.
5. Click on "Close" button.

8 Appendix 3 – Connector pin-outs

8.1 Digital connector

This is a standard 10-pin military-specification bayonet plug, conforming to MIL-DTL-26482 (formerly MIL-C-26482).



Pin	Function
A	Ground
B	Power
C	RS422 serial transmit – positive
D	RS422 serial transmit – negative
E	RS422 serial receive – negative
F	Hole-lock out
G	Signal Ground
H	<i>not connected</i>
J	RS422 serial receive – positive
K	Hole-lock return



Note: The Radian connector is fitted with two O-rings to guarantee the waterproofing. To connect the cable, maintain the Radian in vertical position and roughly align the grooves in the plug with the tongues in the socket before inserting the cable connector. Kindly push and rotate the connector until it lines up perfectly. Push it to down until it reaches the end stop. Screw the fixing ring down to the end of the thread.



Caution: The air compressed inside the connector can push in the opposite direction because of the O-rings. Do not use the fixing ring to help you pushing the connector inside the Radian to prevent any damage on the thread.

9 Revision History

E	15/03/2018	Updated Discovery screen-shots. Updated Hole-lock control. Updated centring. Added connector instructions note.
D	16/08/2017	Added accelerometer calibration. Updated magnetometer calibration.
C	19/05/2017	Updated Web-page screen-shot. Added connector pin-out.
B	20/09/2016	Removed information that overlaps with newly-created Minimus manual (MAN-MIN-0001).
A	08/08/2016	Version 1.0