KEO SCIENTIFIC

KeoRio

Multi-Channel Riometer

System Manual

Issue 3
March 18, 2026

REVISION HISTORY

Issue	Date	List of Changes
Issue 1	2023-12-06	This is the initial version of this document.
Issue 2	2025-02-05	1. Documented changes introduced in v1.2.0 and v1.3.0 of the software. • New config.ini file (see Section 5.1 for details) • Fixed median filtering on 10Hz data product and made median filter width (order) configurable. • Replaced apparent sky temperature plots with measured relative power plots. • Added diagnostics plots in a separate application. 2. Added details about output data format (see Section 5.7) 3. Added appendix with some LWA antenna mounting alternatives (see Appendix A:).
Issue 3	2026-03-18	1. Documented changes introduced in v1.4.0 and v1.5.0 of the software. • New config.toml file (see Section 5.1 for details) • Support for SDR calibration (see Section 5.2 for details) • Revised output data format for v1.5.0. 2. Renamed ‘Controller’ to ‘Receiver’ throughout the document.

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1 INTRODUCTION

Keo Scientific's *KeoRio* Multi-Channel Riometer couples a simple temperature-stabilized RF front-end with a multi-channel SDR-based sampler. This configuration reduces gain fluctuations and instability to negligible levels, even for fine-structure absorption studies. Our riometer is agile and robust, meeting all the requirements of radio-based ionospheric science in the noisy modern world.

Many years in the making, Keo Scientific's riometer may be considered a 'next-generation' riometer. Our unique approach means that new features can be implemented entirely as remotely installed software updates, a benefit not enjoyed by traditional analog riometers.

The *KeoRio* instrument is fundamentally a combination of two electronic technologies: a modified version of the Long Wavelength Array (LWA) antenna and software defined radio (SDR) receivers. Adding custom software to this combination produces a highly stable and sensitive riometer instrument. Keo Scientific provides the *KeoRio* as a turnkey solution to riometry and is currently the only such system commercially available.

Figure 1: Riometer receiver

Figure 2: Deployed riometer antenna

Information

We recommend that you hook up, test, and familiarize yourself with the instrument before transporting it to the field-site for installation. The front-end electronics at the antenna can be connected to the receiver in a laboratory environment without needing to assemble the antenna itself. Please refer to Section 3.3 for instructions on how to do this.

We stand by every one of our products throughout the entire lifetime of the instrument. Whether you require technical assistance or have an application-related question, please feel free to contact us at any time, at support@keoscientific.com.

1.1 GROUNDING AND SAFETY

Before powering on the riometer receiver, the ground prong of the power cord plug must be properly connected to the ground connector of the wall outlet. The wall outlet must have a third prong, or must be properly connected to an adapter that complies with these safety requirements.

Caution

If the equipment is damaged, the protective grounding might have become disconnected. Do **NOT** use damaged equipment until its safety has been verified by authorized personnel. Disconnecting the protective earth terminal, inside or outside the apparatus, or any tampering with its operation is also prohibited.

Inspect the supplied power cord. If it is not compatible with the power socket, replace the cord with one that has suitable connectors on both ends.

Caution

Replacement power cords or power plugs must have the same polarity and power rating as that of the original ones to avoid hazard due to electrical shock.

Ensure that the AC wall outlet adheres to all local building codes. Damage to the instrument or personal injury due to faulty wiring is not covered under our warranty.

Caution

Wall outlet wiring must adhere to local building codes to prevent damage to the instrument or personal injury.

The riometer receiver has a user-selectable AC voltage range – it is crucial that this be configured to the proper setting prior to powering on the device. Refer to Section 3.4.

Caution

Ensure the voltage selector on the back of the receiver is set properly for your particular locale before powering on the system. Failure to do so will damage the receiver and antenna electronics.

2 SYSTEM OVERVIEW

2.1 WHAT IS A RIOMETER?

A riometer (**R**elative **I**onospheric **O**pacity **Meter**) is an instrument that measures the opacity of the ionosphere to radio noise emanating from cosmic origins (galactic background radiation). Riometers use a ground-based antenna and RF receiver to measure the intensity of the galactic background radiation in the frequency range of approximately 20MHz to 50MHz, either in one or more low-bandwidth channels or in a sweep of frequencies inside the range. At frequencies below 20MHz the radio waves are often extinguished before they pass through the ionosphere, leading to a radio blackout. Higher than 50MHz, the attenuation is difficult to distinguish from the signal itself. Using frequencies between the two (20-50MHz), a riometer monitors the "steady" signal of the cosmic background and detects a reduction in the signal strength during particle precipitation events.

In the absence of any ionospheric absorption, the measured noise, averaged over a sufficiently long period of time, forms a *quiet-day curve (QDC)*. As the properties of the ionosphere change due to increased ionization, the measured noise will depart from the quiet-day curve. This difference between the quiet-day curve and the riometer signal is an indicator of the amount of ionospheric absorption and is measured in decibels (dB).

2.2 KEORIO OVERVIEW

The *KeoRio* multi-channel riometer system consists of a temperature stabilized active dipole antenna, a combined power and signal coaxial cable, and a 2U riometer receiver that can be rack or desktop mounted.

The antenna system is a modified version of the LWA antenna system developed by the University of New Mexico and its partners for deployment in a large baseline radio-telescope application. Our modifications optimize the filter cutoff frequencies for riometry, combine the two dipole channels at the antenna, and provide active temperature stabilization..

2.3 SYSTEM COMPONENTS

A standard *KeoRio* system consists of an antenna with front-end electronics (FEE) unit, a coaxial cable, and a receiver.

2.3.1 Antenna

The antenna consists of crossed dipole antenna elements combined into a single broadband channel by front-end electronics located in an enclosure on the top of the antenna. The front-end electronics contain integrated bandpass filters and high gain RF amplifiers on the antenna circuit boards. The enclosure contains heaters with user-selectable power levels, making this design suitable for Arctic and Equatorial deployments alike. Optional insulation can be added to the electronics enclosure for additional isolation in extremely cold environments.

Figure 3: Riometer antenna deployed in the field with wire-mesh ground plane

The antenna is cylindrically symmetrical in its operation so the azimuthal orientation of it is not all that important. Historically, these systems are installed with the antenna elements oriented in the North–South and East–West directions. It is our recommendation to do the same but ultimately it should not affect operation of the instrument no matter the final orientation.

In addition to the antenna provided with the *KeoRio* instrument, a user-provided ground plane will be required for successful deployment. Steel or aluminum fencing with a 2-in x 4-in mesh pattern (50x100mm) is a good choice for use as a ground plane for the *KeoRio*.

Additional Information

An ideal ground plane is a flat or nearly flat horizontal conducting surface that reflects the radio waves from the other antenna elements. This creates a virtual mirror image of the antenna which is added to the radiation pattern of the antenna, nullifying the radiation pattern along the horizon. This will create a radiation pattern for the *KeoRio* that will better reject terrestrial radiation sources in, or near, the desired frequency bands of the riometer channels.

2.3.2 Coaxial Cable

The coaxial cable is available in three standard lengths: 30 m, 60 m, and 90 m. They all have TNC connectors and are rated for 'direct bury' applications. This cable will connect between the TNC connector at the base of the antenna post and the TNC connector on the back of the receiver unit.

2.3.3 Receiver

The 2U Riometer Receiver is a self-contained unit that requires 115V or 230V AC power. The receiver contains a single board computer (SBC) running the Linux (Ubuntu) operating system, three SDR modules, a temperature-stabilized noise source, RF splitting/conditioning circuits, and power supplies. The SBC interfaces directly to the SDR modules, acquiring the raw data and processing it to software-selectable data products. A monitor, keyboard and mouse can be added, if desired, for local control of the system, or an Ethernet connection can be used to remotely control the Ubuntu system (via, e.g., VNC or SSH).

There are three SDR modules, two for the sky channels and one for the reference channel. The reference channel is connected to a noise source which is a reverse biased Zener diode in a temperature stabilized enclosure. This reference channel serves as a consistently stable RF noise source for comparison with measurements derived from the galactic background.

The *KeoRio* samples the SDR modules approximately 20 times per second (20 Hz). This is processed and averaged to produce the default 1 second (1Hz) and 1 minute data products. The software can be configured to also produce the 10Hz data if that is required as well as the raw spectral data (although this latter data product is only generally useful for system diagnostics during manufacture and servicing). These data products, along with many other parameters, can be configured by modifying the Core Service parameters described in Section 5.3.3.

Figure 4: Riometer receiver

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3 SYSTEM SETUP

The *KeoRio* riometer system consists of three main hardware components, all provided with your shipment: antenna with front-end electronics unit, coaxial cable, and receiver. In addition to these components, the following user-provided components and tools may be required for successful deployment:

- Ground plane – 10ft x 10ft of wire mesh (fencing), with holes no larger than 20cm.
- Cable wrap (e.g., a garden hose) for non-buried coaxial cable installations.
- Monitor, keyboard, and mouse for local control of the instrument.
- Various tools:
    - 8mm hex wrench
    - 7/16” socket/wrench
    - 5/16” socket/wrench
    - 5/32” hex key
    - Sledgehammer
    - Hammer

3.1 SYSTEM REQUIREMENTS

Successful deployment of the *KeoRio* riometer system will be dependent on the following requirements:

- The receiver must be installed in an indoor, environmentally controlled location that has a cable pass-through to the outdoors. The receiver itself can be either mounted in a standard 19” rack or placed on a desk/bench.
- The antenna must be installed within reach of the coaxial cable supplied with your system (30 m, 60 m, or 90 m depending on the variant ordered).
- The antenna must be mounted in a post holder either driven into the ground or otherwise secured in place. A ground stake is provided with the antenna, but other mounting techniques can be employed based on local conditions and availability of materials.
- A user-provided ground plane must be installed.

3.2 UNPACKING THE SYSTEM

The *KeoRio* riometer is shipped in 3 or 4 boxes, depending on the configuration purchased. All systems have a large box containing the antenna, and two smaller boxes with one containing the receiver and the other containing the front-end electronics, junction box, antenna element support plate, and antenna hardware kit. Systems purchased with the smaller 30 m coaxial cable will have that cable packed in the large antenna box, while systems with the longer 60 m and 90 m coaxial cables will have that cable packed in its own box.

Please keep all the original packing materials so you can safely ship the *KeoRio* to another location or return it for service, if necessary. If you have difficulty with any step of the instructions, contact the Keo Scientific support team for help and guidance. For support contact information, refer to Section 8.

1. Inspect the shipping boxes for any obvious signs of shipping-related damage. If any such damage is found, immediately notify the shipping agent/courier as well as Keo Scientific – shipping insurance should cover any damage incurred, so it is important that damage be reported immediately.

2. Carefully unpack the smaller packages which contain the receiver with AC power cord for the relevant locale, the front-end electronics, junction box, antenna element support plate, and antenna hardware kit.

3. The larger package contains the antenna elements, supports, and post. These components can be left in the package until they are needed for assembly.

3.3 INITIAL SYSTEM CHECKOUT

Prior to deploying the *KeoRio* to a field-site it is recommended that the components be connected in a laboratory environment to familiarize yourself with them and to confirm they are operating correctly. The antenna and coaxial cable are not needed for this – instead the antenna front-end electronics can be connected directly to the receiver in the laboratory.

1. Set up the receiver on a clean workbench by following the installation instructions in Section 3.4.

   > **Caution**
   >
   > Ensure the voltage selector on the back of the receiver is set properly before powering on the system. Failure to do so will damage the receiver and antenna front-end electronics.

2. Unpack the antenna front-end electronics and place it on the workbench beside the receiver.

3. Connect the front-end electronics cable to the connector on the rear of the receiver. There are two ways of doing this depending on whether an SMA to TNC adaptor is available or not.

   a. With a SMA to TNC adaptor:

      i. Remove the 50Ω terminator from the receiver's antenna connector. Place it in a safe place to be reinstalled after initial testing.

      ii. Confirm that the main receiver power switch is **OFF** in addition to the antenna power switch being **OFF**.

      iii. Connect the cable from the front-end electronics directly to the TNC connector on the rear panel of the receiver using the SMA to TNC adaptor.

   b. Without a SMA to TNC adaptor:

   i. Locate the junction box and coaxial cable – they will be used to convert the SMA connector to TNC.

   ii. Remove the 50Ω terminator from the receiver’s antenna connector. Place it in a safe place to be reinstalled after initial testing.

   iii. Connect the SMA cable from the front-end electronics into the SMA connector on the inside of the junction box.

   iv. Connect the TNC coaxial cable to the TNC connector on the junction box.

   v. Confirm that the main receiver power switch is **OFF** in addition to the antenna power switch being **OFF**.

   vi. Connect the coaxial cable to the TNC connector on the rear panel of the receiver.

4. Power up the riometer receiver and antenna using the instructions provided in Section 4.1.

5. Log into the computer using the instructions provided in Section 4.2.

6. Launch the Riometer UI application using the instructions provided in Section 5.4.2.

7. Confirm that the Raw Sky and Reference curves on the Frequency Spectrum plot are approximately -50dB to -70dB, similar to those shown in Figure 5 below. If the curves are much lower than this (towards the bottom, or -90dB), please confirm that the antenna is powered on. Once the antenna is powered on these curves should ‘float’ upwards to their expected ~-50dB values.

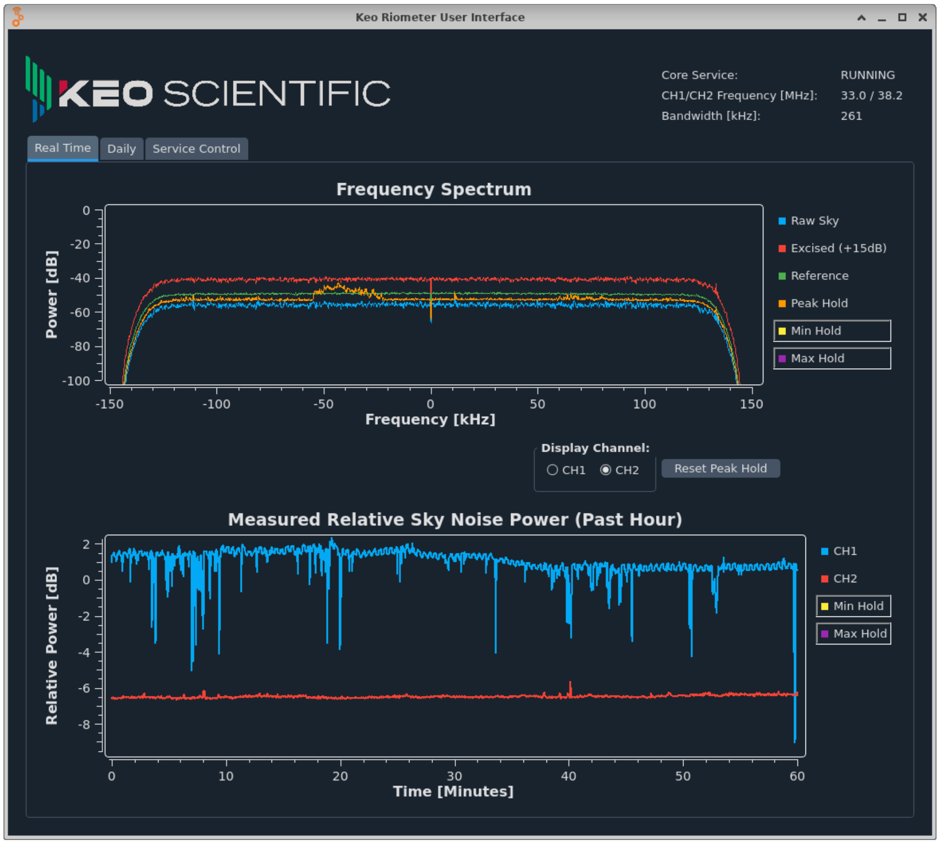


Figure 5: Riometer UI – expected readout (may contain noise during indoor/lab testing)

8. Familiarize yourself with the software system by modifying the riometer frequencies (see Section 6.2). This will require stopping the Core Service, modifying the configuration file, and then restarting the Core Service. After restarting, the new frequencies should be reflected in the upper-right corner of Riometer UI application.

9. Once testing is complete, shut down the system using the instructions in Section 4.3. All status LEDs on the front of the receiver should be OFF before proceeding to the next step.

10. Disconnect the front-end electronics cable from the rear of the receiver and reinstall the 50Ω terminator.

11. Repack the instrument for shipping to the final field-site.

12. Initial system testing is now complete.

3.4 RECEIVER INSTALLATION

The receiver is housed in a 2U rackmount enclosure that can be either rack mounted in a standard 19" electronics rack or used on a desktop with or without the included rubber feet.

1. Mount the receiver in the desired location. If used on a desktop, the provided rubber feet can be attached to the bottom of the receiver.

2. Confirm the main power switch on the front of the receiver is in the **OFF** position.

3. Confirm the antenna switch on the rear of the receiver is in the **OFF** position.

4. Set the voltage selector on the rear of the receiver to the correct value depending on your local AC power supply available.

> **Caution**
>
> Ensure the voltage selector on the back of the receiver is set properly before powering on the system. Failure to do so will damage the receiver and front-end electronics.

5. Connect the receiver to Ethernet if remote access is needed.

6. Connect a monitor/keyboard/mouse, if local control is desired. A USB hub will be required if using these with additional USB devices.

7. Connect the AC power cable between the receiver and the wall AC power source.

8. Do *not* turn on the receiver yet, this will be done once installation is complete.

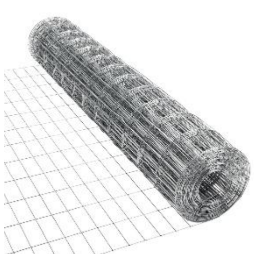
The receiver is now ready to be connected to the antenna.

3.5 ANTENNA INSTALLATION

The antenna component of the *KeoRio* riometer system contains the following items:

Post
The center post that supports the antenna. Note that it has a flattened area towards one end – this is the bottom of the post.

Post Ground Stake with Collar
The ground stake provided with the system is intended to be pounded into the ground at the desired antenna location. The post stake should be as far into the ground as possible. The collar will be used to secure the post to the ground stake.



Ground Plane (not included with riometer)
User-provided wire mesh to cover approximately 10ft x 10ft (3m x 3m). Wire mesh should have holes no larger than 20cm in any one dimension.

Junction Box
This grey weatherproofed junction box will be installed at the base of the post and provides a way to couple the cable from the antenna electronics to the coaxial cable.

Front-End Electronics
This white plastic box with attached SMA cable will be mounted at the top of the post and contains the front-end electronics.

Elements (x4)
These large triangular aluminum elements are the actual dipole antenna elements.

Element Supports (x4)
These triangular fiberglass components are used to support the antenna elements from the post.

Element Support Plate
This circular metal ring will connect the 4x antenna element supports to the post.

Bag of Hardware
Various screws and hardware for assembling the antenna.
- 4x short socket head screws
- 16x long hex head screws with lock washers
- 3x set screws
- 4x flanged hex nuts
- 1x screw clamp

The overall process for installing the antenna will be:

1. Install the antenna post in the desired location with surrounding ground plane.
2. Install the junction box and element support plate on the post.
3. Install the front-end electronics on top of the post and feed the SMA cable down through the post and out into the junction box.
4. Assemble the 4x element supports to the element support plate.
5. Assemble the 4x elements to the element supports and electronics box.

Figure 6: Finished antenna installation with ground plane

3.5.1 Antenna Post Installation

The antenna post needs to be securely mounted such that it is oriented as vertically as possible.

1. Remove the collar from the top of the ground stake prior to installing the ground stake into the ground.

2. Install the post ground stake in the desired location by hammering it into the ground using a sledgehammer or similar. Take care to ensure it is vertical since the final orientation of the antenna is dependent on the verticality of this stake. Alternatively, other user-provided post holders can be used to secure the post. For example, a concrete foundation could be poured with a post holder located in the center.

3. Install the user-provided ground plane flat on the ground around the post ground stake. It should extend approximately 5ft (1.5m) in all directions from the post and should be secured to the ground with staking. There must be no holes in the meshing larger than 20cm in any one direction. If multiple pieces of mesh are used, they should be overlapped slightly to ensure there are no gaps.

4. Re-install the collar removed in step 1 onto the top of the ground stake.

5. Install the post through the collar and into the post ground stake. The end of the post that has the slot (and flat area) on it should be near the bottom – this is where the junction box will be attached.

6. Secure the post in place by hammering the collar down onto the ground stake. This should compress the top of the ground stake onto the post and hold it securely in place.

3.5.2 Junction Box and Element Support Plate Installation

The junction box is installed at the base of the antenna post and allows the SMA cable from the antenna electronics at the top of the post to interface with the outdoor-rated coaxial cable from the receiver.

1. Remove the cover from the junction box. The cover will remain removed until after the electronics enclosure is installed.

2. Install the junction box to the base of the post using the 4x short socket-head screws provided in the bag of hardware and the 5/32” hex key. The connector on the junction box should be oriented towards the ground.

3. Depending on the expected environmental conditions, adding silicone or other sealant to the junction box or between the junction box and post may be advisable to keep moisture from reaching the inside of the post/junction box.

4. Slide the element support plate over the top of the post with the flat flange facing upwards and position it approximately 18 inches (45 cm) from the bottom of the post. Secure in place using the 3x set screws from the bag of hardware and a 5/32” hex key. Note that in the photo below the element supports are shown installed already but this will not be done until later in these instructions.

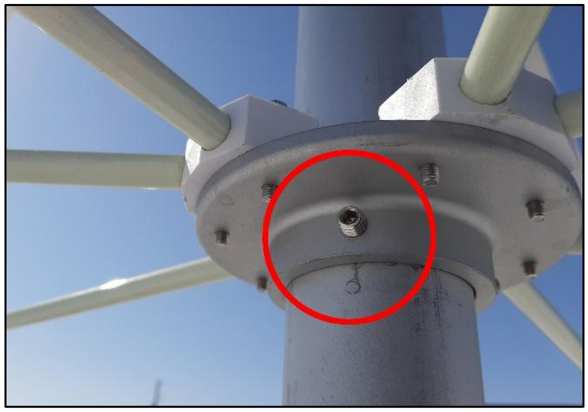


Figure 7: Location of one set screw on element support plate

3.5.3 Front-End Electronics Installation

The front-end electronics are inside the white plastic enclosure and are installed at the top of the post.

1. Remove the front-end electronics from its anti-static packaging.
2. Position the screw clamp over the cylindrical part of the enclosure and just tighten enough to hold it in place – this will be fully tightened once the enclosure is on the post and oriented correctly.

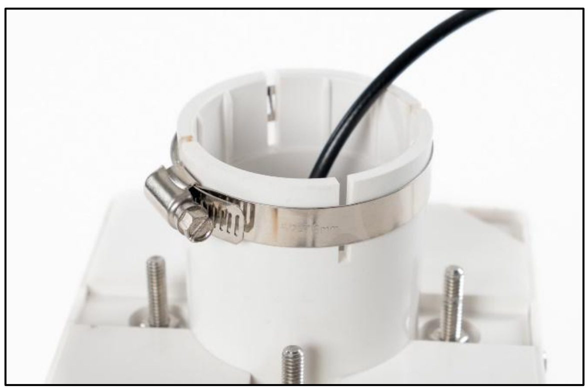


Figure 8: Electronics unit with screw clamp

3. Feed the SMA cable on the unit down from the top of the post and feed it out into the junction box.
4. Slide the front-end electronics down onto the post until it stops and rotate the enclosure so that the 4x threaded rods on the bottom of the unit are approximately oriented in the **North-South**, **East-West** direction.

> **Additional Information**
>
> Traditionally these systems are oriented in the North-South, East-West directions but this is not necessary with the *KeoRio*. Still, out of habit and for consistency, we recommend doing the same for new installations.

5. Tighten the screw clamp to secure the enclosure in place. Note that in the photo below the antenna elements are shown installed but this will not be done until later in these instructions.

Figure 9: Electronics unit screw clamp

6. In the junction box, remove the 50Ω terminator from the SMA cable and attach the SMA cable to the passthrough connector on the bottom of the box. Use a 8mm wrench to tighten this connection. **Do not overtighten.**

Figure 10: Junction box with SMA cable connected

7. Re-install the junction box cover that was removed previously.

3.5.4 Assemble the Element Supports

There are 4x fiberglass element supports that will provide support from the post to the elements.

1. Fasten the element support mounting blocks (see Figure 11) to the element support plate using 8x long hex screws with 8x lock washers using a 5/16” wrench/socket.

   The orientation of the element supports is important – the sloped face with threaded insert should be facing upwards as shown in Figure 12 – this is where the elements themselves will attach to the supports. They must not be installed upside down as shown in Figure 13.

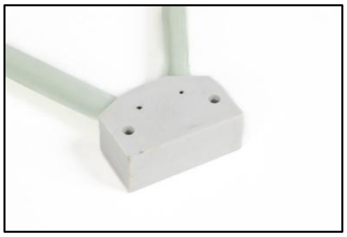


Figure 11: Element support mounting block

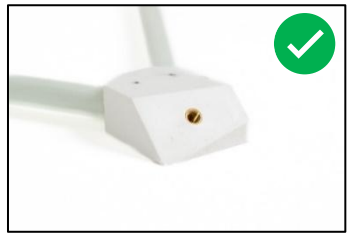


Figure 12: Correct orientation of element support

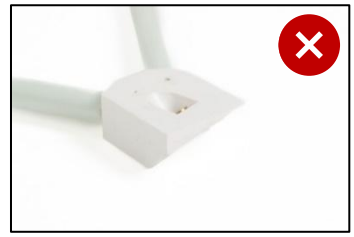


Figure 13: Incorrect orientation of element support

   After installation, the element support plate and element supports will look as shown in Figure 14 and Figure 15.

Figure 14: Element support plate with element supports

Figure 15: Antenna post with element supports

2. Rotate the antenna elements and element support (first loosen the 3x set screws) so that the gap between the triangular element supports is roughly aligned with the 4x threaded rods on the bottom of the electronics unit. The elements themselves will span between two adjacent element supports and connect to the threaded rods on the electronics unit. Do not fully tighten the set screws because this positioning will need to be adjusted further in the following instructions.

3.5.5 Assemble the Elements

Each element is secured in three places – to a threaded stud on the bottom of the front-end electronics and to two adjacent element supports.

1. Secure an antenna element to one of the four threaded rods on the bottom of the front-end electronics using a flanged hex nut from the bag of hardware. Do not fully tighten at this time. Note the correct orientation of the elements as shown below in Figure 16.

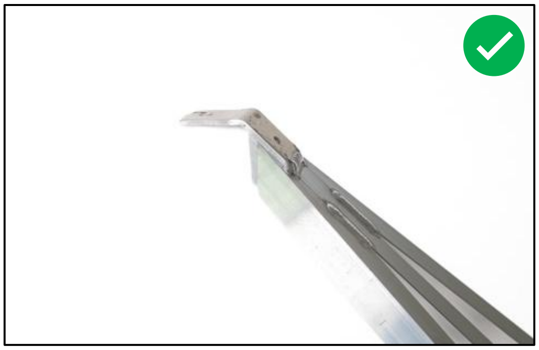


Figure 16: Correct antenna element orientation

Figure 17: Incorrect antenna element orientation

Figure 18: Antenna element connection to electronics unit

2. Adjust the vertical and rotational position of the element support plate so that the element supports align with the corresponding holes in the antenna elements.

3. Secure the antenna element to two element supports using 2x long hex screws and 2x lock washers from the bag of hardware.

Figure 19: Element to element support connection

4. Repeat steps 1 through 3 for the remaining 3 antenna elements.

5. Perform one final vertical adjustment of the element support plate to ensure that the element supports are approximately horizontal with minimal deflection.

6. Fully tighten all screws and nuts.

3.6 INSTALL AND CONNECT THE COAXIAL CABLE

After the installation of the receiver and antenna, the next step is to establish the connection between these two components using the coaxial cable.

Caution

The receiver must be powered **OFF** before installing or removing the coaxial cable, otherwise damage to the front-end electronics may occur.

1. Route the coaxial cable between the receiver and the antenna. If desired, this cable can be buried in the ground directly without any additional protection. If run over the ground, it is advised to wrap the cable to protect it from rodents and other small vermin.

Information

Slitting a UV rated garden hose lengthwise and wrapping it around the cable can be a cost-effective way of protecting the coaxial cable. Aluminum foil wrap is also acceptable.

2. Remove the 50Ω terminator from the receiver's antenna connector. Place it in a safe place, so that it can be reinstalled if relocating the *KeoRio* to a new field-site in the future.

3. Confirm that the main receiver power switch is **OFF** in addition to the antenna power switch being **OFF**.

4. Discharge any built-up static in the coaxial cable by gently shorting the center and outer conductors with a conductive object (e.g., a screwdriver). This is best practice to ensure the cable does not carry any residual charge that may damage the front-end electronics when connected.

5. Connect the coaxial cable to the rear panel of the receiver.

6. Connect the coaxial cable to the antenna junction box.

The *KeoRio* riometer system is now fully installed and is ready for initial testing.

4 OPERATION

4.1 POWERING UP

Caution

Ensure the voltage selector on the back of the receiver is set properly before powering on the system. Failure to do so will damage the receiver and front-end electronics.

1. Ensure the Antenna switch on the back of the receiver is set to the **OFF** position. While not strictly required, it is best practice to only power the antenna once the rest of the system is powered and to power it off before powering down the complete system.

2. Turn on the receiver by flipping the switch on the front of the receiver to the **ON** position. This will power up the integrated computer system in addition to the antenna electronics power supply. The Receiver[1] and DC Power status LEDs on the front of the receiver should both turn green to indicate they are powered on.

3. Turn on the antenna by flipping the Antenna switch on the back of the receiver to the **ON** position. This will power up the front-end electronics located on the top of the antenna. The Antenna status LED on the front of the receiver should now turn green.

Current power status is indicated on the front panel of the receiver as shown below.

Status LED	Meaning
Receiver[1]	Off: Integrated computer is powered OFF Green: Integrated computer is powered ON Yellow: Integrated computer is SLEEPING
DC Power	Off: Linear power supply is OFF Green: Linear power supply is ON
Antenna	Off: Antenna is powered OFF Green: Antenna is powered ON

Once the integrated computer boots (this will take approximately 30 seconds), the riometer software will automatically start running and data collection will begin. It is not required to log in or manually start data

[1] KeoRio systems shipped prior to March 2026 use the label ‘Controller’ for this LED instead of ‘Receiver’.

collection. If the computer is powered on and data collection has not been manually halted, it will continue to collect and save data.

4.2 LOGGING INTO THE COMPUTER

The integrated computer is running Ubuntu and upon boot will prompt you to log in. We strongly recommend changing the password after logging in for the first time. The default login is configured as:

Username: riometer
Password: riometer

The computer can also be accessed via SSH or VNC using the same credentials.

4.3 SHUTTING DOWN

When powering down the system for disassembly or maintenance the following procedure should be used.

> **Caution**
>
> To avoid potential data loss and system corruption, it is important to allow the computer to fully power off before turning off the main power switch on the receiver.

1. Turn the Antenna power switch on the back of the receiver to the **OFF** position.

2. Shut down the computer. This can be done by logging into it via local login or VNC and then using the normal system shutdown menu options. Alternatively, the computer can be shut down via SSH (or a terminal from the desktop environment) using the following command.

```
shutdown -h now
```

> **Important Information**
>
> When the computer is powered off in this manner (commanded to turn off), the only way to turn it back on is to turn the receiver power off completely, wait a few seconds, then turn the power back on. The computer is configured to automatically power on but it will only do so after power is fully removed and then restored.

3. Once the Receiver LED on the front of the Riometer receiver has turned OFF then the main power switch on the front of the receiver can be turned **OFF**.

5 SOFTWARE OVERVIEW

The riometer control software runs on an Ubuntu Linux system. This manual assumes a basic understanding of using a Linux-based system for navigating and performing basic tasks (such as, opening terminal, entering commands, and editing text files).

The riometer control software consists of three components:

Core Service (keo_riometer_core): This is a service that always runs (unless manually stopped) and handles all routine riometer data collection and processing.

Riometer UI (keo_riometer_ui): This is a graphical user interface front-end to the core service. This can be started and stopped when needed and does not affect the operation of the core service.

Diagnostics UI (keo_riometer_diag): This is a graphical user interface front-end that provides several plots used for diagnostic purposes only. Under normal operation this component will not be used.

5.1 CONFIGURATION FILE

The riometer control software components share a common configuration file, `config.toml`, located in the `~/riometer_scripts/` directory. If this file does not exist, the `config-sample.toml` file in the same location can be used as a template. Note that during software updates the `config.toml` file is not overwritten so any customization of the configuration of the software should be preserved. Further details about the parameters in this file are documented with each software component in the following sections.

> **Important Information**
>
> The configuration file is a new feature as of software version 1.2.0. When upgrading from a previous version, the configuration file must be manually created and customized. See Section 5.6 for details.

5.2 CALIBRATION

KeoRio systems shipped in 2025 or later include an automatic calibration feature that is enabled by default. This calibration feature is used to compensate for minor variations in the internal reference of the SDR modules that occurs between power cycles of the instrument.

> **Important Information**
>
> The calibration feature requires specialized hardware in the Riometer receiver. Please contact Keo Scientific if you are interested in upgrading your older Riometer to have this feature.

The calibration system switches the sky channels from measuring the antenna signal to measuring the temperature-stabilized noise source. By sampling the noise source on each SDR channel and comparing with the provided calibration coefficients, an offset is calculated and applied to each channel.

Riometers that have this feature will have an additional file named `calibration.toml` that is provided with the instrument. This file contains calibration coefficients that characterize how the noise source in that receiver compares to our in-lab 'standard' noise source. If this file is missing, then the calibration feature will be automatically disabled.

Calibration is done in two phases based on how it is configured in the `[calibration]` section of the `config.toml` file:

- An initial startup calibration is performed after the core service is started once `startup_delay_s` (default: 15 seconds) has passed.
- A recalibration is performed once the instrument has warmed up and thermally stabilized after `warm_up_time_min` (default: 180 minutes) has passed.

Calibration can also be configured to run hourly or daily by setting the `scheduled_min` and `scheduled_hr` values. These options default to a value that disables them because they should not be required for most installations.

5.3 CORE SERVICE

The core service is responsible for collecting the raw data from the software defined radio (SDR) modules, filtering and processing that data, and then saving it to various data files. It does not have a user interface of its own and runs unattended unless manually stopped.

The core service is managed using Supervisor, a Linux process control system which allows for easy monitoring and control of processes.

5.3.1 Starting the Core Service

Starting the core service can also be done in one of two ways:

- From the Riometer UI, navigate to the **Service Control** tab and click the **Start Riometer Service** button. The "Riometer Service State" will change to RUNNING to indicate it is now running.

Figure 20: Start Riometer Service button

- Or, from a terminal window, run the command:

```
sudo supervisorctl start riometer_core
```

5.3.2 Stopping the Core Service

There are some situations where the core service will need to be stopped such as to change a configuration parameter (see Section 5.3.3) or to perform a software update. This can be done in one of two ways:

1. From the Riometer UI, navigate to the **Service Control** tab and click the **Stop Riometer Service** button. The "Riometer Service State" will change to STOPPED to indicate it is now stopped.

Figure 21: Stop Riometer Service button

2. From a terminal window, run the command:

```
sudo supervisorctl stop riometer_core
```

5.3.3 Core Service Configuration Parameters

The behavior of the core service is controlled by the parameters in the `config.toml` configuration file found in the `~/riometer_scripts/` directory. These are documented below for your reference. To change a parameter, first stop the core service, then modify and save the `config.toml` file as desired, then start the core service again.

Caution

The `longitude` parameter in the `[site]` section of the configuration file is used to calculate the Local Mean Sidereal Time (LMST). Failure to set this parameter will result in incorrect LMST values in the data products.

Section	Parameter	Description
[logging]	directory	The directory to store logfiles in. *Default:* `"/home/riometer/logs"`
	retention	Number of days to keep logfiles before deleting them. `0`: Keep all logfiles (disable logfile pruning) `1+`: Delete logfiles after this many days *Default:* `0`

	level	Logging severity, one of: `DEBUG, INFO, WARN, ERROR, FATAL` *Default:* `"INFO"`
[site]	name	Site name to use for naming data files. *Default:* `"keo"`
	longitude	Site longitude (east is positive, west is negative) *Default:* `-114.07`
[data]	directory	The directory to store data in. *Default:* `"/home/riometer/data"`
	retention	Number of days to keep data before deleting it. `0`: Keep all data (disable data pruning) `1+`: Delete data after this many days *Default:* `0`
	use_site_prefix	Whether data files are named with the site name as a prefix or not, `true` or `false`. *Default:* `true`
	save_1hz	1Hz data to save (averaged from 10Hz data), `true` or `false`. *Default:* `true`
	save_minute	Minute data to save (averaged from 1Hz data), `true` or `false`. *Default:* `true`
	save_10hz	10Hz data to save (no averaging), `true` or `false`. *Default:* `false`
	save_spectral	Spectral data to save, `true` or `false`. *Default:* `false`
	headers	Whether data files have column headers on the first row or not, `true` or `false`. *Default*: `true`
	median_filter_width	The width (order) of median filter to apply to data. `0` or `1`: Disable median filtering `2+`: The number of samples to median filter *Default:* `13`
[ref_channels.REF]	frequency	The reference channel frequency in Hz, usually set to the average of sky channel frequencies. *Default:* `34.2e6`
[sky_channels.SKY1]	frequency	The sky1 channel frequency in Hz. *Default:* `30.0e6`
	ref_channel	The name of the reference channel to use as reference. *Default:* `"REF"`
[sky_channels.SKY2]	frequency	The sky2 channel frequency in Hz. *Default:* `38.2e6`
	ref_channel	The name of the reference channel to use as reference.

		Default: "REF"
[hardware]	sample_rate	SDR sample rate in Hz. *Default:* `902e3`
	buffer_length	SDR buffer length. *Default:* `8192`
	gain	SDR gain *Default:* `40`
	bandwidth	SDR bandwidth in Hz. *Default:* `250e3`
	update_rate	Internal update rate in Hz. *Default:* `30`
[calibration]	enable	Enable calibration routine, `true` or `false`. *Default:* `true`
	coeffs_file	Path to calibration coefficients file. *Default:* "/home/riometer/riometer_scripts/calibration.toml"
	startup_delay_s	Number of seconds to wait after starting before performing initial calibration. *Default:* `15`
	warm_up_time_min	Number of minutes to let the system warm up before performing recalibration. *Default:* `180`
	scheduled_min	Minute in each hour to perform hourly recalibration. This takes priority over scheduled_hr setting. Set to `-1` to disable hourly recalibration. *Default:* `-1`
	scheduled_hr	UT Hour to perform daily recalibration. Set to `-1` to disable daily recalibration. *Default:* `-1`

5.3.4 Core Service Logfile

Logging of the core service is done to a file named `riometer-core.log` located in the directory specified by the `directory` parameter in the `[logging]` section of the `config.toml` configuration file. This logfile is rotated daily to archive the previous day's logs to a separate file with the date appended to the filename (e.g., `riometer-core-20260318.log`).

A sample logfile is shown below. In it you can see the application starting, loading the configuration file, configuring the channels, and performing calibrations. This is typical behavior and represents what you would normally see in this file. If you are experiencing issues with the core service, such as it not starting properly or continually restarting, please have a look at the contents of the logfile to help determine the source of the problem.

```
2026-03-13T20:58:30.363Z [INFO ] __main__: starting application
```

```
2026-03-13T20:58:30.363Z [INFO ] __main__: configuration loaded from
/home/riometer/riometer_scripts/config.toml
2026-03-13T20:58:30.376Z [INFO ] riometer: added reference channel REF with
frequency 34200000.0
2026-03-13T20:58:30.377Z [INFO ] riometer: added sky channel SKY1 with frequency
30000000.0 and reference channel REF
2026-03-13T20:58:30.377Z [INFO ] riometer: added sky channel SKY2 with frequency
38200000.0 and reference channel REF
2026-03-13T20:58:30.379Z [INFO ] calibration: calibration loaded from
/home/riometer/riometer_scripts/calibration.toml
2026-03-13T20:58:30.380Z [INFO ] calibration: startup calibration is scheduled
for 2026-03-13T20:58:45.379Z
2026-03-13T20:58:45.387Z [INFO ] calibration: starting calibration procedure
2026-03-13T20:59:10.408Z [INFO ] riometer: calibrating channel REF
2026-03-13T20:59:10.921Z [INFO ] channel: channel REF offset set to -5.42dB
2026-03-13T20:59:35.958Z [INFO ] riometer: calibrating channel SKY1
2026-03-13T20:59:36.243Z [INFO ] channel: channel SKY1 offset set to -5.42dB
2026-03-13T20:59:36.271Z [INFO ] riometer: calibrating channel SKY2
2026-03-13T20:59:36.525Z [INFO ] channel: channel SKY2 offset set to -4.91dB
2026-03-13T20:59:51.535Z [INFO ] calibration: finished calibration
2026-03-13T20:59:51.541Z [INFO ] calibration: warm up calibration is scheduled
for 2026-03-13T23:58:30.379Z
2026-03-13T23:58:30.387Z [INFO ] calibration: starting calibration procedure
2026-03-13T23:58:55.403Z [INFO ] riometer: calibrating channel REF
2026-03-13T23:58:55.723Z [INFO ] channel: channel REF offset set to -5.37dB
2026-03-13T23:59:20.751Z [INFO ] riometer: calibrating channel SKY1
2026-03-13T23:59:21.026Z [INFO ] channel: channel SKY1 offset set to -5.27dB
2026-03-13T23:59:21.028Z [INFO ] riometer: calibrating channel SKY2
2026-03-13T23:59:21.281Z [INFO ] channel: channel SKY2 offset set to -4.69dB
2026-03-13T23:59:36.299Z [INFO ] calibration: finished calibration
```

5.4 RIOMETER UI

The Riometer UI application provides a graphical user interface front-end to the core service. This application allows for real-time visualization of the data being collected and a means to quickly start and stop the core service.

5.4.1 Riometer UI Overview

The Riometer UI application presents a range of information to the user. At the top right there is some core service status information and the majority of the application window is filled with a series of tabs – Real Time, Daily, and Service Control.

5.4.1.1 Status Information

In the top right corner, the current status of the core service is displayed along with the frequency and bandwidth that is configured for the SDRs. It will always show the current settings being used for acquisition.

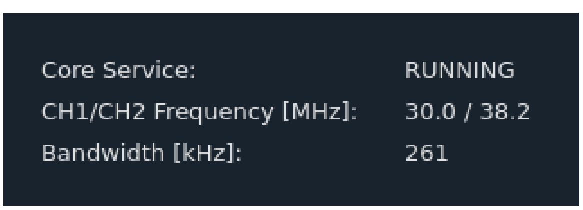


Figure 22: Riometer UI – Status information

5.4.1.2 Real Time Tab

This tab shows the current real-time Frequency Spectrum plot at the top and the last 60 minutes of reduced data at the bottom.

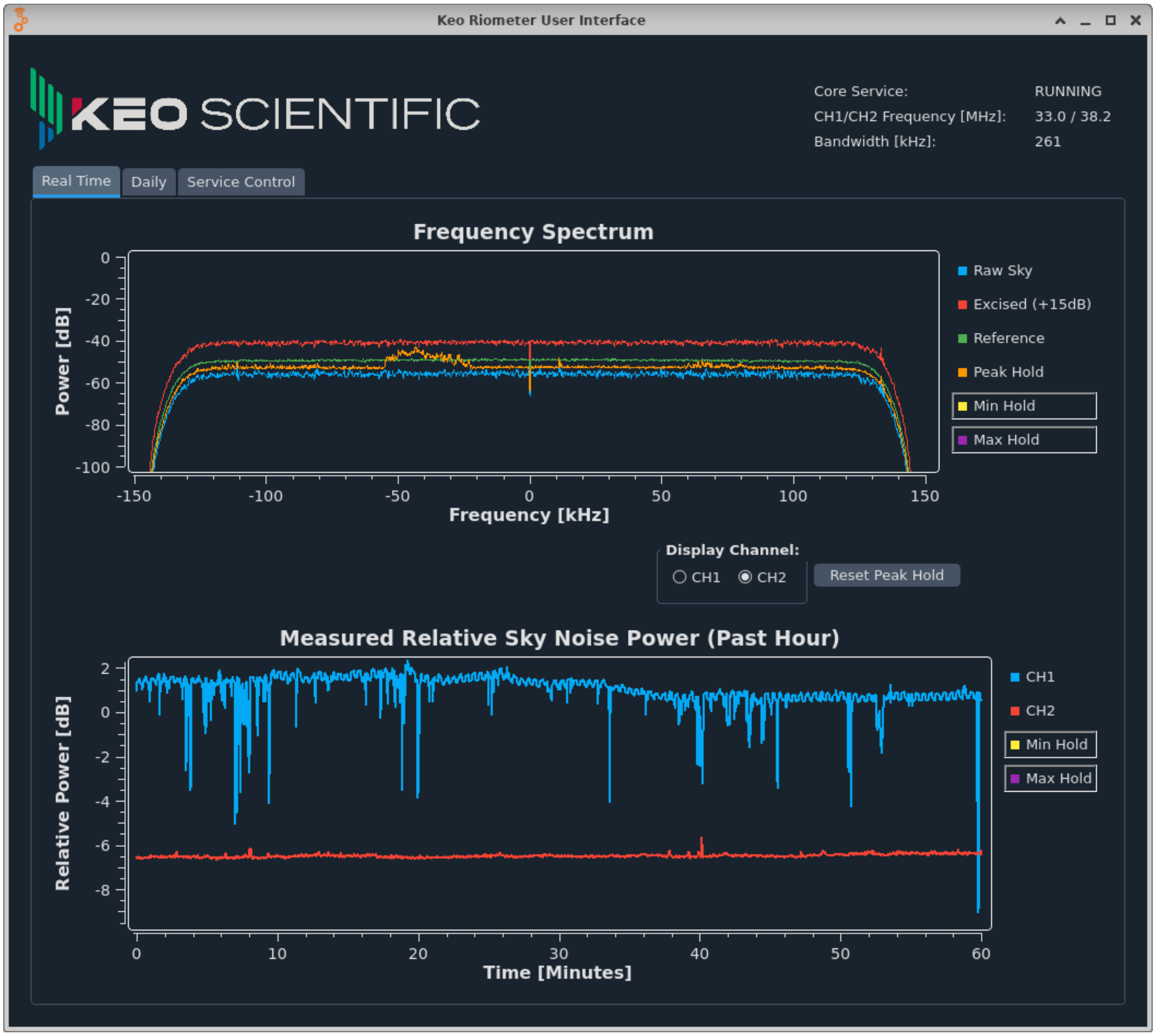


Figure 23: Riometer UI – Real Time tab

The **Frequency Spectrum** plot has several different values displayed and the display of channels 1 and 2 can be toggled using the **Display Channel** selector below the Frequency Spectrum plot.

Raw Sky [Blue]: This is the raw spectral data being captured by the SDRs.

Excised (+15dB) [Red]: This is the filtered and processed data displayed +15dB to make it visually easy to see.

Reference [Green]: This is the signal from the reference noise source internal to the instrument.

Peak Hold [Orange]: This displays the maximum value for any given frequency since the last time the peak hold was reset. The **Reset Peak Hold** button located below the Frequency Plot can be used to reset the peak hold.

The **Integrated Noise Power (Last Hour)** plot at the bottom displays the measured sky noise power over the last 60 minutes. Both channels 1 and 2 are displayed simultaneously.

5.4.1.3 Daily Tab
This tab displays the last 24 hours' worth of measured relative sky noise power. This should represent your typical 'Quiet Day Curve' (QDC).

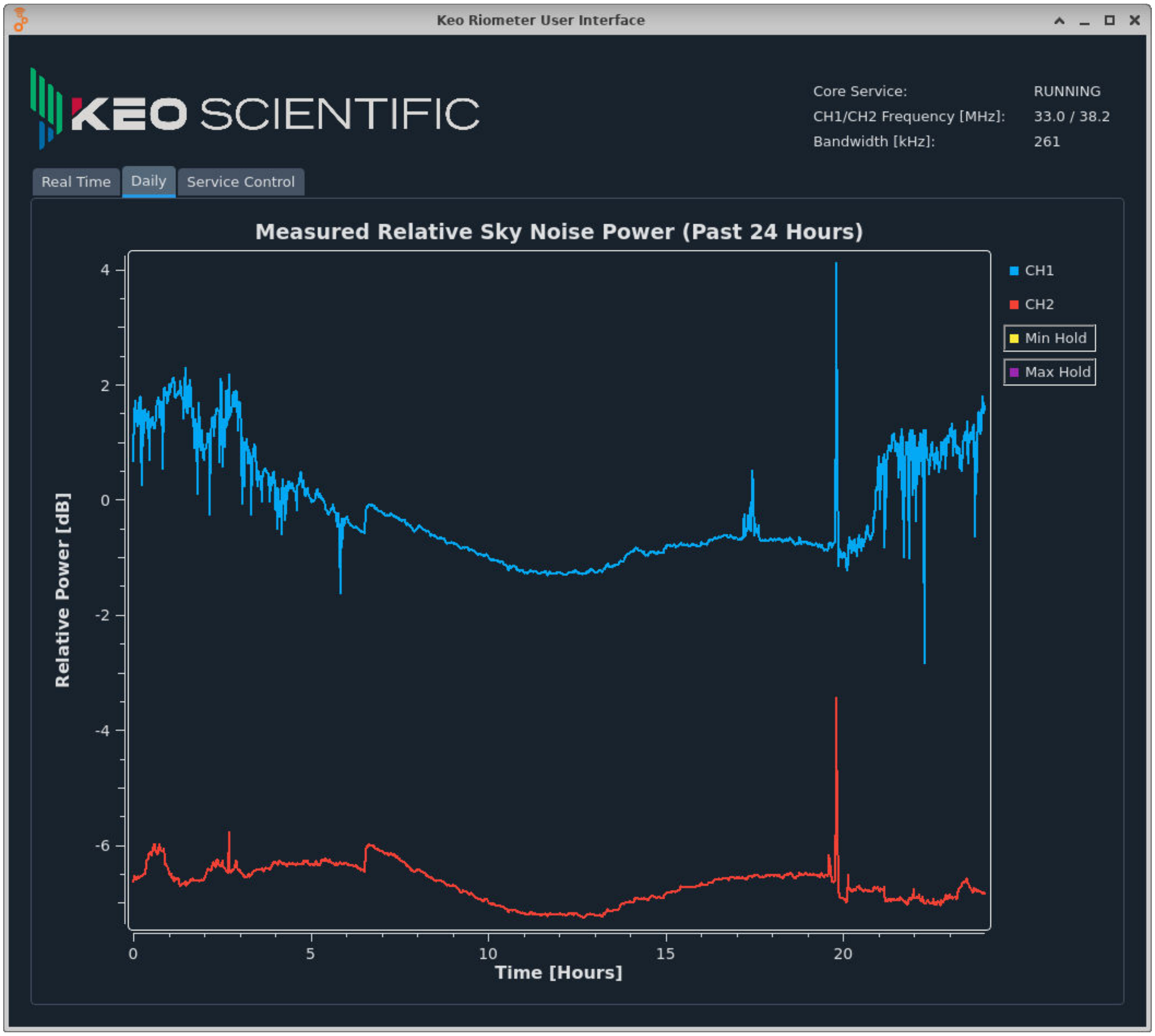


Figure 24: Riometer UI – Daily tab

Similar to the **Integrated Noise Power (Last Hour)** plot on the **Real Time** tab, this plot displays the measured sky noise power but over the last 24 hours.

5.4.1.4 Service Control Tab
This tab allows for manually starting and stopping the core service. See Section 5.3 for details on how to use the controls found on this tab.

5.4.2 Opening Riometer UI
The Riometer UI application is started from a terminal window as follows.

1. Navigate to the `riometer_scripts` directory.

```
cd ~/riometer_scripts
```

2. Start the Riometer UI application.

```
./start_riometer_ui
```

5.4.3 Closing Riometer UI

To cleanly exit Riometer UI, simply click the X in the top right corner of the application window.

5.4.4 Riometer UI Parameters

The Riometer UI application shares its configuration with the Riometer Core application found in the `config.toml` file found in the `~/riometer_scripts/` directory. These parameters are documented below for your reference. To change a parameter, first exit the Riometer UI application, then modify and save the `config.toml` file as desired, then start the Riometer UI application again.

Section	Parameter	Description
[logging]	directory	The directory to store logfiles in. *Default:* `"/home/riometer/logs"`
	retention	Number of days to keep logfiles before deleting them. `0`: Keep all logfiles (disable logfile pruning) `1+`: Delete logfiles after this many days *Default:* `0`

5.4.5 Riometer UI Logfile

When the Riometer UI application is started it creates a new logfile located in directory specified by the `directory` parameter in the `[logging]` section of the `config.toml` configuration file. The name of this logfile will be similar to the one shown below where the number represents the timestamp of when the application was started.

```
riometer-ui-202311292300.log
```

The contents of the logfile will be minimal and will look something like shown below. Everything shown here is considered normal and is not cause for concern.

```
buffer_double_mapped :warning: allocate_buffer: tried to […]
buffer_double_mapped :warning: allocate_buffer: tried to […]
buffer_double_mapped :warning: allocate_buffer: tried to […]
buffer_double_mapped :warning: allocate_buffer: tried to […]
QCoreApplication::sendPostedEvents: Cannot send posted events for
objects in another thread
setting operating mode to CALIBRATING
setting operating mode to RUNNING
setting operating mode to STOPPED
```

5.5 RIOMETER DIAGNOSTICS

The Riometer Diagnostics application provides a graphical user interface front-end to view diagnostics information from the core service. This application is only used when trying to diagnose an issue with the instrument and should not be used under normal circumstances. Should you need to run it, you can start it from a terminal as follows.

1. Navigate to the `riometer_scripts` directory.

```
cd ~/riometer_scripts
```

2. Start the Riometer Diagnostics application.

```
./start_riometer_diag
```

5.6 UPDATING THE SOFTWARE

The *KeoRio* software package is open source and freely available on bitbucket at the link below.

https://bitbucket.org/keosci/keo_riometer/

The software is managed through a `git` repository which provides a relatively straightforward method of updating requiring only a few commands from a terminal window.

5.6.1 View Current Version

The current version of software installed can be determined by inspecting the `CHANGELOG.md` file in the code.

```
cd ~/dev/keo_riometer
nano CHANGELOG.md
```

This should produce an output similar to that shown below where the current version of the software is the newest release documented. In the example below, this would correspond to version 1.1.0 of the software released on 2023-08-03.

```
# Changelog
All notable changes to this project will be documented in this
file.

The format is based on [Keep a Changelog]
(http://keepachangelog.com/en/1.0.0/) and this project adheres to
[Semantic Versioning](http://semver.org/spec/v2.0.0.html).

## [1.1.0] - 2023-08-03

### Added
- This changelog :)
- Project `README`
- GPLv3 license (see `COPYING` file)

…
```

5.6.2 Upgrading from 1.5.0 or newer

Since version 1.5.0, a helper script is provided to aid in the updating procedure. This script will automatically pull the latest version of the software from the git repository and perform all steps necessary to upgrade the system to the latest version. When complete, it will prompt you to inspect your configuration files to ensure your settings were migrated properly and the update procedure can be completed by running the script a second time with the `-c` argument to cleanup backup files and restart the core service.

1. Navigate to the keo_riometer source code folder.

   ```
   cd ~/dev/keo_riometer/install
   ```

2. Run the update script.

   ```
   ./update
   ```

3. Inspect your configuration files to ensure all settings are correct and then run the update script again with the -c argument.

   ```
   ./update -c
   ```

4. The upgrade is now complete.

5.6.3 Upgrading from 1.4.1 or older

Prior to version 1.5.0, the software was not aware of its version so it cannot automatically know what upgrades to apply.

1. Navigate to the keo_riometer source code folder.

   ```
   cd ~/dev/keo_riometer
   ```

2. Inspect the changelog file to determine the current version you are upgrading from and make note of it.

   ```
   nano CHANGELOG.md
   ```

3. Pull the latest version of the code from our bitbucket repository.

   ```
   git pull
   ```

4. Navigate into the install folder and execute the update script with the version you are upgrading from (replace `x.y.z` with your current version).

   ```
   cd install
   ./update -f x.y.z
   ```

5. Inspect configuration files and confirm all settings are correct and then finish the update using the -c argument.

```
./update -c
```

6. The update is complete.

5.7 OUTPUT DATA FORMAT

Riometer data is output to the folder specified by the `directory` parameter in the `[data]` section of the `config.toml` configuration file found in the `~/riometer_scripts/` directory.

The *KeoRio* samples two SDR modules approximately 20 times per second (20Hz). This is processed and averaged to produce the default 1 second (1Hz) and 1 minute data products. 10Hz data is also available if enabled in the configuration file. One CSV-format data file is output for each channel. Example file names:

keo-data-1Hz-0-20250205.csv (1Hz CH1 data for site 'keo' from 2025-02-05 UT)
keo-data-1Hz-1-20250205.csv (1Hz CH2 data for site 'keo' from 2025-02-05 UT)

The following shows the first five lines of a data file:

```
hr_ut,min_ut,sec_ut,hr_lmst,min_lmst,sec_lmst,freq,bw,timestamp,sky_pwr,ref_pwr,sky_pwr_raw,ref_p
wr_raw
00,00,00,03,57,51,30000000,261580,2026-03-15T23:59:59.986Z,3.41e-04,1.00e-02,1.14e-03,3.46e-02
00,00,01,03,57,52,30000000,261580,2026-03-16T00:00:01.117Z,3.38e-04,1.00e-02,1.14e-03,3.46e-02
00,00,02,03,57,53,30000000,261580,2026-03-16T00:00:02.049Z,3.34e-04,1.01e-02,1.12e-03,3.47e-02
00,00,03,03,57,54,30000000,261580,2026-03-16T00:00:03.091Z,3.35e-04,1.01e-02,1.13e-03,3.47e-02
00,00,04,03,57,55,30000000,261580,2026-03-16T00:00:04.125Z,3.38e-04,1.00e-02,1.14e-03,3.46e-02
```

The columns are as described in the following table.

Column #	Header	Description
1	hr_ut	UT hour of the current data entry
2	min_ut	UT minute of the current data entry
3	sec_ut	UT second of the current data entry
4	hr_lmst	Local Mean Sidereal Time[2], hour, of current data entry
5	min_lmst	Local Mean Sidereal Time[2], minute, of current data entry
6	sec_lmst	Local Mean Sidereal Time[2], second, of current data entry
7	freq	Center frequency of the riometer channel (Hz)
8	bw	Bandwidth of the riometer channel (Hz)

[2] IMPORTANT: Correct Local Mean Sidereal Time requires that the site longitude is set in the `config.toml` configuration file. See Section 5.3.3 for details.

9	timestamp	UT timestamp from the riometer computer, ISO8601[3] formatted
10	sky_pwr	Sky power (calibrated), total RF power in the channel (∝W)
11	ref_pwr	Reference power (calibrated), total RF power in the reference channel (∝W)
12	sky_pwr_raw	Sky power (uncalibrated), total RF power in the channel (∝W) with no calibration applied.
13	ref_pwr_raw	Reference power (uncalibrated), total RF power in the reference channel (∝W) with no calibration applied.

[3] See https://en.wikipedia.org/wiki/ISO_8601 for details.

6 SYSTEM CONFIGURATION

6.1 ANTENNA ELECTRONICS HEATING SETPOINT

The antenna front-end electronics (FEE) are equipped with heaters to maintain them at a desired temperature which helps keep the amplifier gain stable throughout varying weather and across seasons. We recommend choosing a setpoint value that is 10-20°C above your typical daytime high temperature in your local warm season, if possible, or at minimum setting a value of 10°C to keep the circuit boards above the dew point.

The heaters are split into 2x 5W and 2x 15W circuits for a range of available heating powers between 5W and 40W in 5W increments. This heat is applied to the boards using a simple on/off thermostat with a 2°C hysteresis. Additionally, the FEE produce its own heat equivalent to approximately 5W which is present anytime the antenna is powered on.

Select a heater wattage to achieve the temperature setting based on the following guidelines:

1. Determine your coldest expected annual ambient temperature and subtract that from your desired setpoint to determine the required heating temperature delta.
2. The heaters provide approximately 3°C/W of temperature. Calculate the required total heating power (wattage) by dividing the temperature delta by 3°C/W.
3. If additional cooling due to wind is expected, add 5-10W extra to account for it.
4. Always round your necessary wattage up to the next 5W increment.
5. Finally, subtract the antenna electronics base heating power of 5W to get the amount of heat required from the heaters.

For example, if your site is expected to reach -30°C during the coldest part of the winter and +20°C during the hottest part of the summer, your desired setpoint would be +30°C. This gives a required temperature delta of 60°C which when divided by 3°C/W yields 20W of required total heating power. Subtract 5W base heat from this to yield a heater power of 15W.

6.1.1 Adjusting the Antenna Temperature Setpoint

This procedure requires access to the electronics box at the top of the antenna and the antenna must be powered off before adjusting the setpoint.

Caution

Ensure that the antenna is powered **OFF** before starting these instructions. Damage to the antenna electronics may occur otherwise.

1. **Remove the lid of the electronics box.**
   This can be done by removing the 4x screws found around its perimeter using a Phillips head screwdriver.

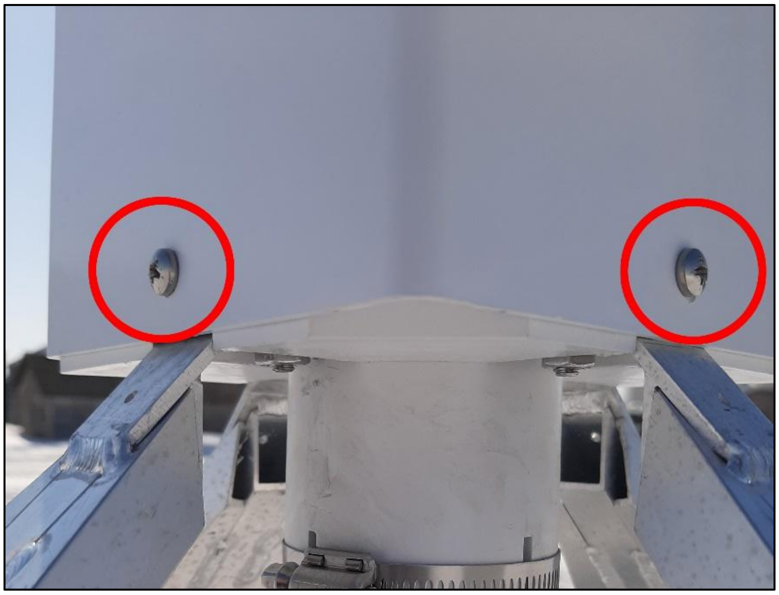


Figure 25: Screws to remove on lid of electronics enclosure (two more not shown)

2. **Set the desired temperature setpoint.**
   Locate the 8-position rotary switch on the top circuit board. Setpoint values in °C are printed in white text on the circuit board around the switch and the small red arrow on the rotary switch indicates the current setting. Rotate this switch to the desired setpoint value.

Figure 26: Setpoint rotary switch

3. **Set the required heater power.**
   Locate the heater power selection header on the lower circuit board as shown in Figure 27.

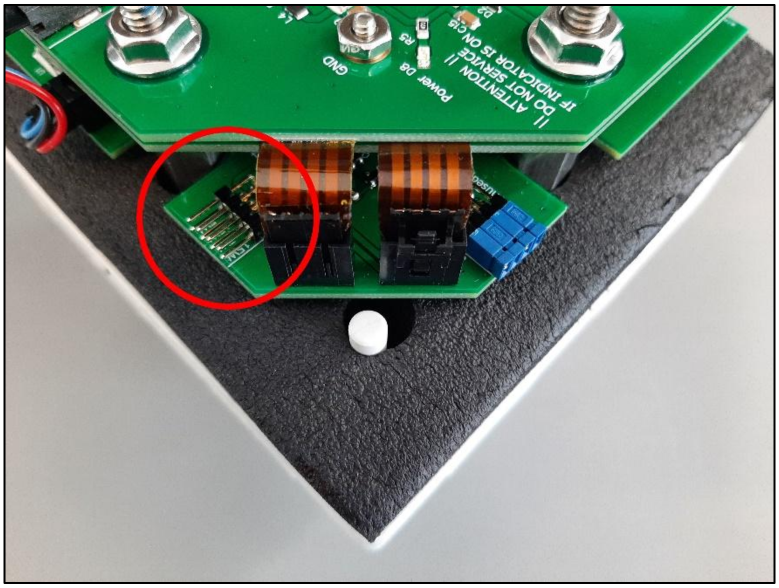
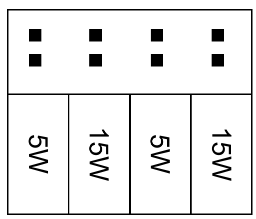


Figure 27: Heater power selection header

There are markings on the board indicating the heater power provided by each jumper – see below for a graphical representation of this. Apply jumpers to this header to yield the desired total heater power.



The header on the right side of the board shown in Figure 27 is used to store unused jumpers. It does not matter which positions are used for unused jumpers.

4. **Replace the lid of the electronics box.**
If your electronics box lid is equipped with insulation on the inside, note the cutout in it which should be aligned with the connector sticking off the side of the circuit boards. Replace the lid and fasten in place using the 4x screws originally removed using a Phillips head screwdriver.

6.2 CONFIGURING RIOMETER FREQUENCIES

All *KeoRio* systems are shipped with their frequencies configured at 30.0MHz and 38.2MHz, commonly used in riometry, but these defaults may need to be adjusted if there are interfering signals in the local area. It is quite common to have interfering signals, so some trial and error is usually required to find quiet frequencies. We recommend limiting the frequencies to values within the 25-40 MHz range.

Additional Information

The inexpensive tinySA [https://www.tinysa.org] spectrum analyzer, or similar tool, can be used to survey the site to identify viable frequency candidates. Interfering signals can be intermittent so some trial and error may still be required to find the ideal frequencies for your site. The tinySA has a Peak Hold Mode, useful for surveying purposes.

To set a new frequency for the sky1 and sky2 channels, modify the `frequency` parameters found in the `[sky_channels.SKY1]` and `[sky_channels.SKY2]` sections respectively in the core service parameters file (see Section 5.3.3 for details).

A typical quiet frequency will look like the one shown below in Figure 28. Notice that the blue Raw Sky curve is relatively flat, corresponding to typical galactic background emissions.

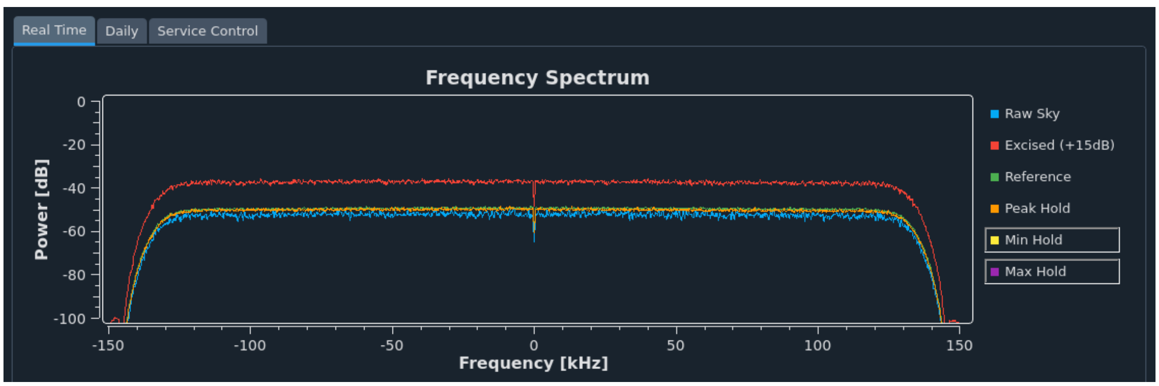


Figure 28: Quiet riometer frequency spectrum

Interfering signals will present themselves in the real-time Frequency Spectrum plot as large spurious peaks in blue Raw Sky data as shown below. If these are observed and they occur frequently at the same frequencies, adjust the frequency for that channel and try again.

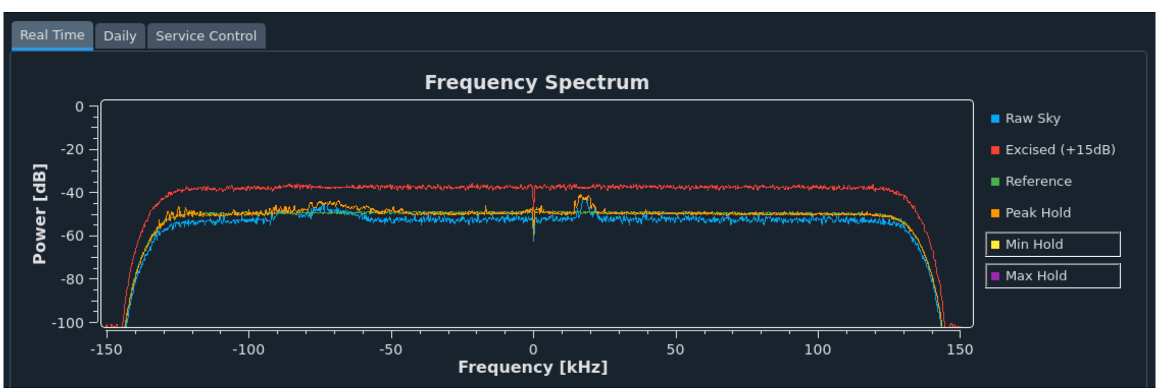


Figure 29: Noisy riometer frequency spectrum

Note that despite these interfering signals in the plot above, they are not present in the red Excised (+15dB) curve due to the software filtering that is taking place. This will work for most minor interfering signals but it is still best practice to try to find a frequency that has minimal interfering signals.

Additional Information

Finding the ideal frequency to use tends to be an iterative process and may require more than one session of frequency selection since interfering signals may be intermittent. Conveniently, operating frequencies can be modfied remotely.

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7 WARRANTY & SERVICE

THREE YEAR LIMITED WARRANTY

Keo Scientific Ltd. (Keo) warrants this product (see Exclusions below) to meet published functional specifications and to be free of defects in materials and workmanship as defined in the specifications with a 3 years Keo Scientific Warranty starting from the date of original shipment from Keo. During this time, Keo will arrange to have the product repaired or replaced without charge to you. You must return the instrument to Keo for inspection and assessment. *You are only responsible for shipping costs to return the product.*

EXCLUSIONS

The warranty does not cover:

1. Damage resulting from accident, misuse, abuse, lack of reasonable care, subjecting the product to any but the specified electrical service, other than normal and ordinary use of the product, subjecting the product to abnormal working conditions or any other failure not resulting from defects in materials or workmanship. Keo Scientific Riometer Receivers are intended for *indoor* use only, in a climate-controlled (HVAC) environment.

2. Damage resulting from modification, tampering with or attempted repair by anyone other than Keo Scientific Ltd.

3. Damage to the Riometer Receiver due to water/humidity as a result of a cracked or insufficiently weather-proofed/sealed premises.

4. The warranty of the computer manufacturer applies.

SHIPPING DAMAGE

You must report any damage occurring to the instrument while in transit from Keo to the shipping company or courier company immediately upon receipt of goods. Keo insures shipments separately, and such insurance covers such damage. *Please thoroughly inspect the instrument immediately upon arrival.*

HOW TO MAKE A WARRANTY CLAIM

1. Contact Keo Scientific by email to obtain support under Warranty.

2. Deliver, mail, or ship the product to the Keo Scientific Ltd. main office, *following instructions provided by Keo Scientific as to insurance and customs' related valuation.*

You must pay any postage, shipping charges, insurance costs, and other expenses to return the product to Keo Scientific, Calgary, Canada. However, if the Warranty covers the necessary repairs, Keo will pay the return shipping charges to the original destination.

You must ship the product back to Keo in the original shipping container.

CONTACT INFORMATION

Keo Scientific's main office is located at the following address:

Keo Scientific Ltd.
430 – 11979 40 ST SE
Calgary AB T2Z 4M3
Canada

Tel: +1 (403) 452-7222
Email: support@keoscientific.com

An up-to-date list of addresses and telephone numbers is available on our website [https://keoscientific.com/contact/].

8 TECHNICAL SUPPORT

In the event that you need technical support to troubleshoot a problem with your riometer, please do not hesitate to contact our support team at support@keoscientific.com.

Customers are encouraged to provide feedback on any aspect of the product or user experience. All suggestions are reviewed and considered for future enhancements.

Your purchase includes lifetime technical support and software updates at no additional cost.

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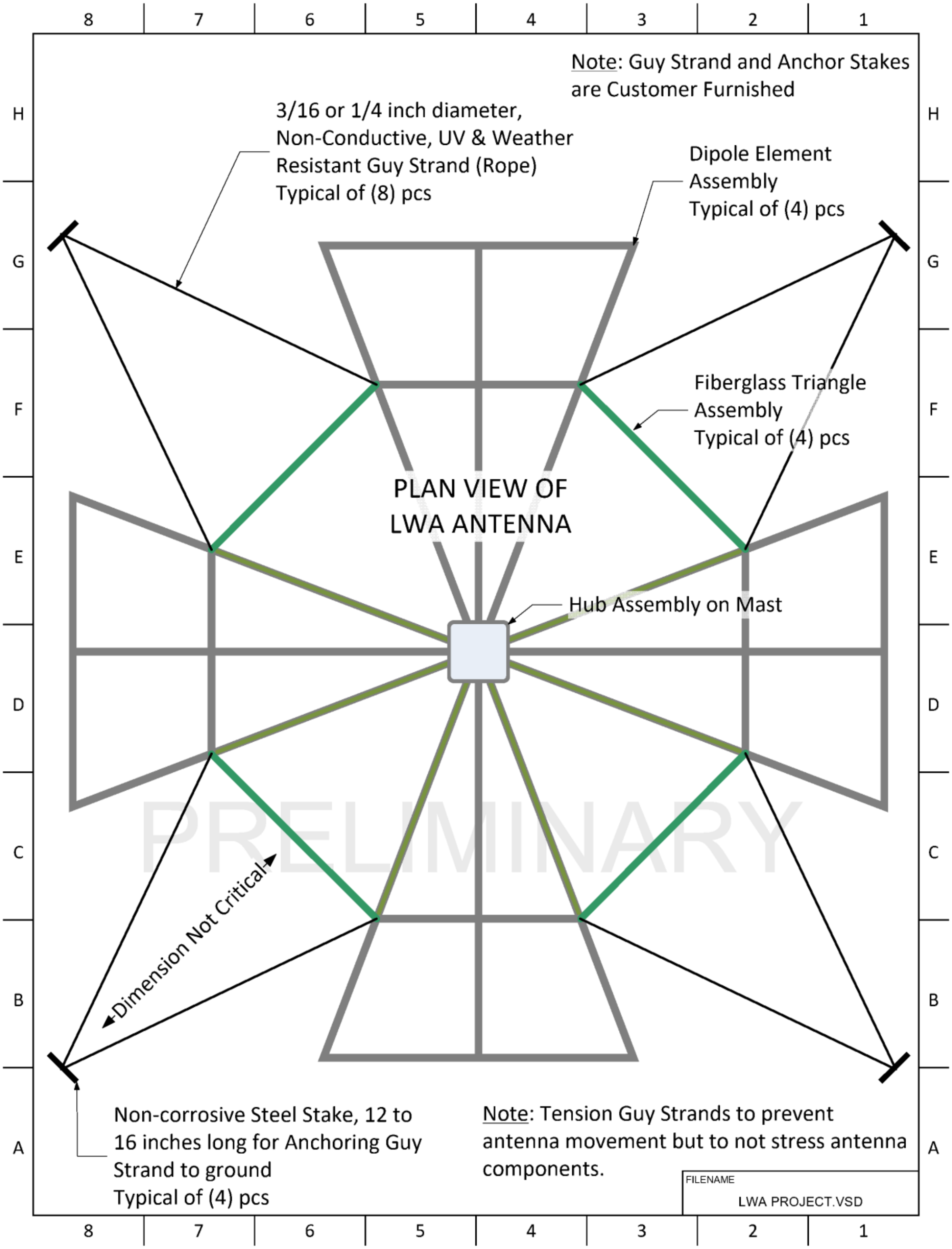
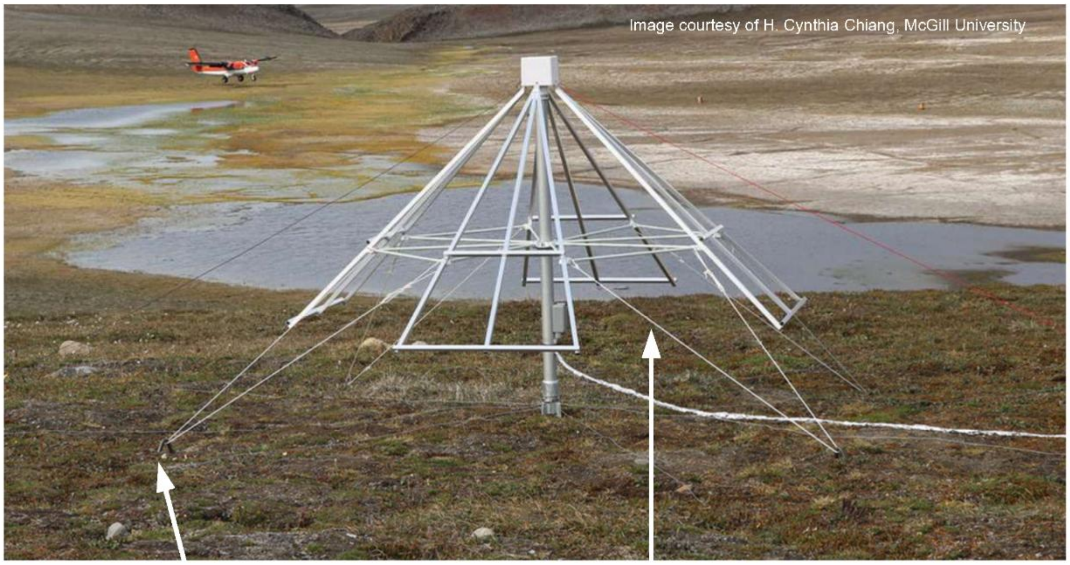
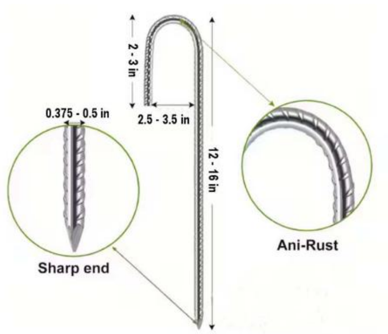
APPENDIX A: LWA ANTENNA MOUNTING ALTERNATIVES

A variety of environmental situations can require thinking outside the box for how to secure the LWA antenna. For example, in extremely windy environments it might be desired to provide additional tie-downs on the antenna elements to keep them in place. Or you may wish to use an alternative to the provided post anchor for securing the post. This section contains some ideas to help with these issues.

A.1. GUY ROPES FOR STABILITY IN WINDY ENVIRONMENTS







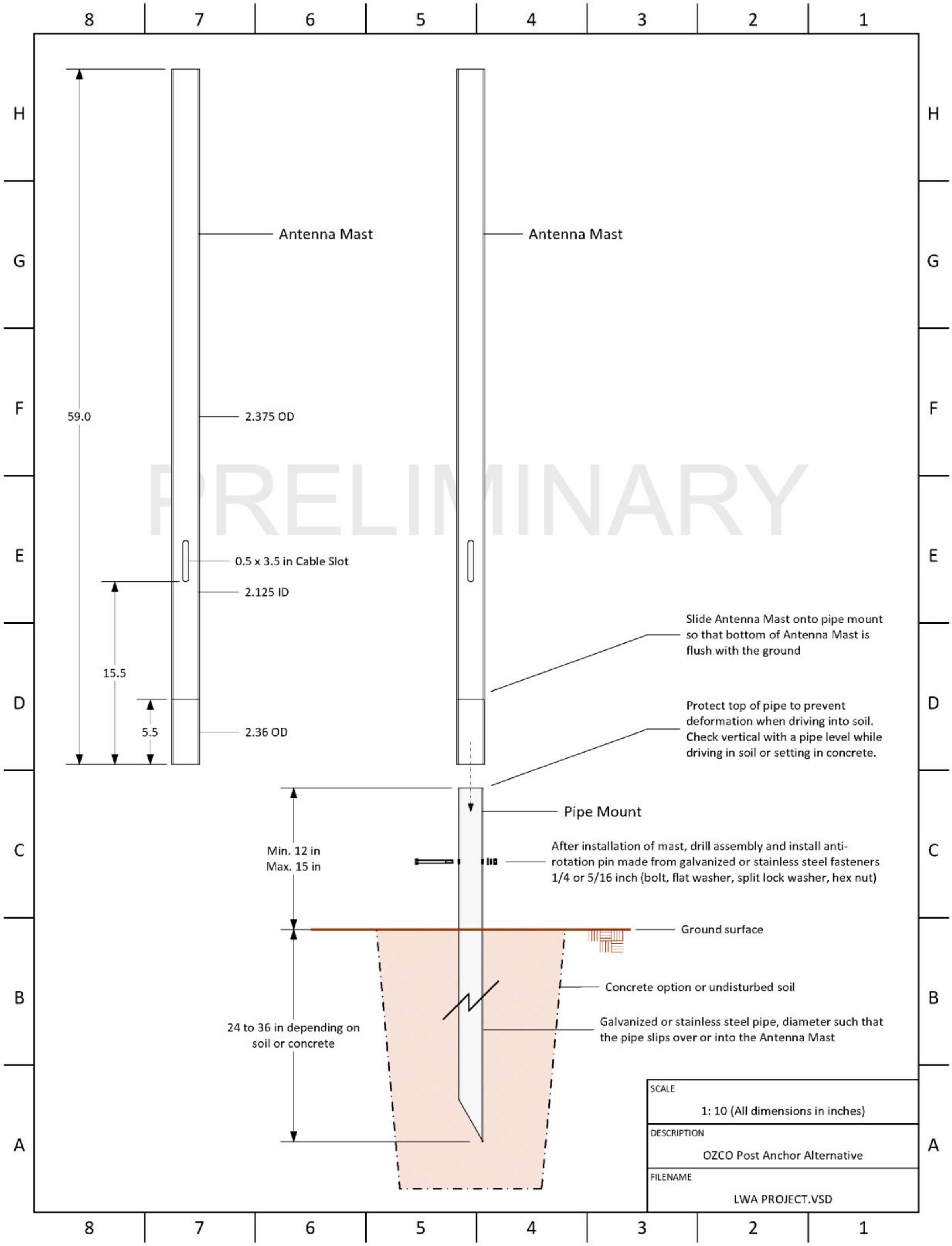
Steel Stake made from Reinforcing Steel (Rebar) with anti-rust coating

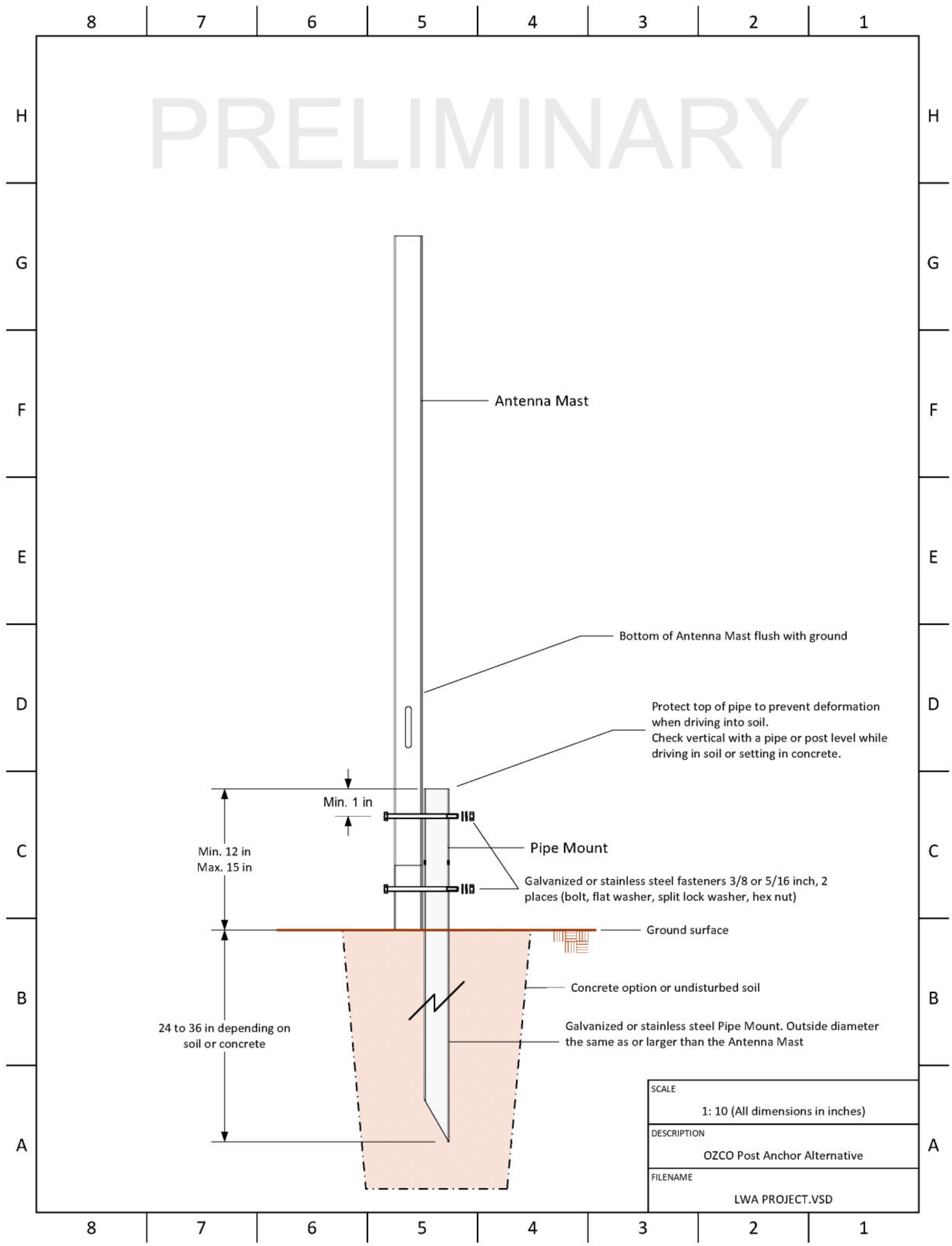
Similar commercial products available at hardware stores

Non-conductive, UV and Weather resistant guy strand (rope)

Example: https://www.mastrant.com/

A.2. ALTERNATIVE POST MOUNTING METHODS




PRELIMINARY
Antenna Mast
Bottom of Antenna Mast flush with ground
Protect top of pipe to prevent deformation when driving into soil.
Check vertical with a pipe or post level while driving in soil or setting in concrete.
Min. 1 in
Min. 12 in
Max. 15 in
Pipe Mount
Galvanized or stainless steel fasteners 3/8 or 5/16 inch, 2 places (bolt, flat washer, split lock washer, hex nut)
Ground surface
Concrete option or undisturbed soil
24 to 36 in depending on soil or concrete
Galvanized or stainless steel Pipe Mount. Outside diameter the same as or larger than the Antenna Mast
SCALE
1: 10 (All dimensions in inches)
DESCRIPTION
OZCO Post Anchor Alternative
FILENAME
LWA PROJECT.VSD