CS475A

Radar Water Level Sensor

CAMPBELL SCIENTIFIC®

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1. Introduction

The CS475A radar sensor monitors the water level of rivers, lakes, tidal seas, and reservoirs, and is ideal for areas where submersed sensors can be damaged due to corrosion, contamination, flood-related debris, lightning, or vandalism. It outputs a digital SDI-12 signal to indicate distance and stage. All contemporary Campbell Scientific data loggers can read the SDI-12 signal.

> NOTE:
> This manual provides information only for CRBasic data loggers. The CS475A is also compatible with many of our retired Edlog data loggers. For Edlog data logger support, contact Campbell Scientific.

2. Precautions

- READ AND UNDERSTAND the Safety section at the back of this manual.

- Follow country-specific installation standards, prevailing safety regulations, accident prevention rules, and this manual's safety instructions. The sensor is designed for safe operation in accordance with the current technical, safety, and ANSI standards.

- The emitting frequencies of the CS475A is well below the internationally permitted limits. When used correctly, the radar sensor presents no danger to people.

- Do not attempt to install the sensor unless you are qualified to perform the installation.

- Handle the sensor carefully, since it is a precision instrument.

- If installing the sensor from tall structures over water, use appropriate safety equipment such as a safety harness or a life preserver when installing or performing maintenance on the sensor.

- The user is responsible for ensuring that the sensor is maintained and functioning properly.

3. Initial inspection

When unpacking the equipment, do the following:

- Unpack the unit in a clean, dry area.

- Carefully open the shipping package, ensuring that the cable jacket is not damaged or cut. Contact Campbell Scientific if the cable was damaged during unpacking.

- Inspect the equipment for any damage that occurred during shipping. If equipment was damaged during shipping, file a claim with the carrier and report the damage in detail.

4. QuickStart

A video that describes data logger programming using *Short Cut* is available at: www.campbellsci.com/videos/cr1000x-data logger-getting-started-program-part-3 ▶. *Short Cut* is an easy way to program your data logger to measure the sensor and assign data logger wiring terminals. *Short Cut* is available as a download on www.campbellsci.com ⬈. It is included in installations of *LoggerNet*, *RTDAQ*, and *PC400*.

1. Open *Short Cut* and click **Create New Program**.

2. Double-click the data logger model.

3. In the search box under the **Available Sensors and Devices** heading, start typing CS475A, or find the sensor in the **Sensors** > **Water** > **Level & Flow** > **CS475A Radar Water Level Sensor** folder. Double-click **CS475A Radar Water Level Sensor (average stage)** or **CS475A Radar Water Level Sensor (stage)** (FIGURE 4-1 (p. 3)). The **CS475A (stage)** measurement issues the M1! command and collects four values (stage, distance, battery voltage at the sensor, and error codes) (FIGURE 4-2 (p. 3)). The **CS475A (average stage)** issues the M1! command and completes a NOAA PORTS measurement; the user must configure the sensor for the number of measurements included in the average (FIGURE 4-3 (p. 3)).

    SDI-12 Address defaults to **0**. Enter the correct **SDI-12 Address** for the radar sensor if it has been changed from the factory default value. Default units for stage and distance measurements are in feet. Change the units to **Meter** if the **System Units** have been changed to meters.

> **NOTE:**
> Changing the units in *Short Cut* will NOT change the units in the device or provide any unit conversions by the data logger. It will only update the units label in the data table.
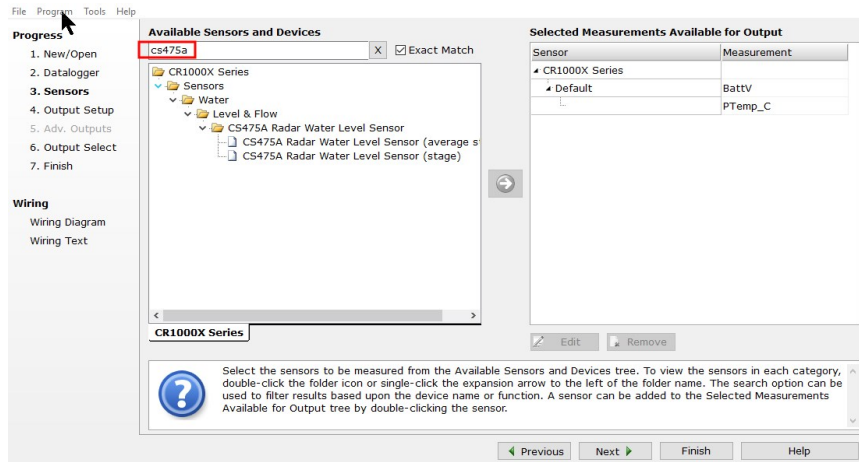
FIGURE 4-1. *Short Cut*, Sensor Selection
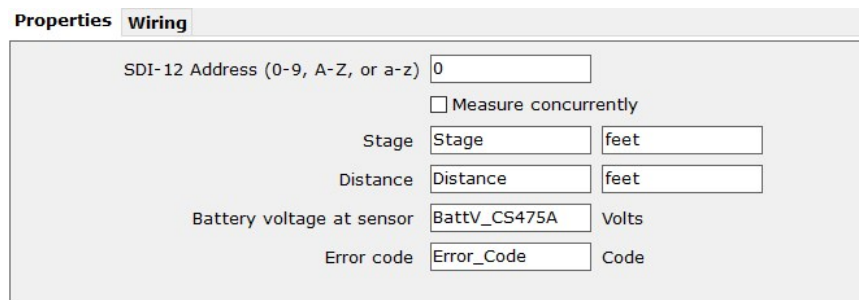
FIGURE 4-2. *Short Cut*, CS475A Stage Properties
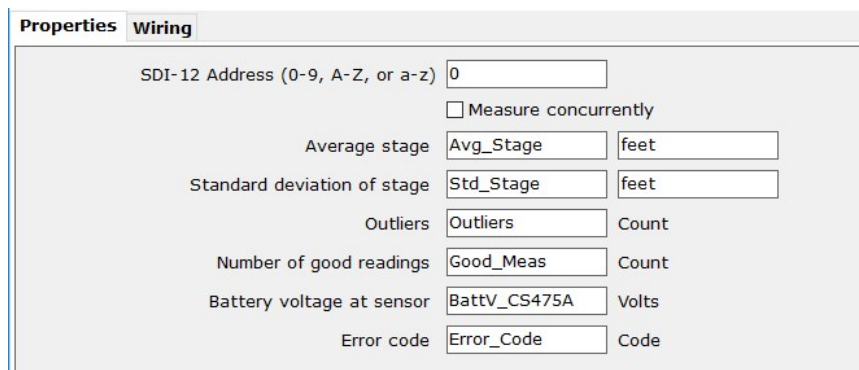
FIGURE 4-3. *Short Cut*, CS475A Average Stage Properties

4. Click the **Wiring** tab to see how the sensor is wired to the data logger. You can change a wire location by selecting the control terminal (C) (FIGURE 4-4 (p. 4)). Click **OK** after wiring the sensor.
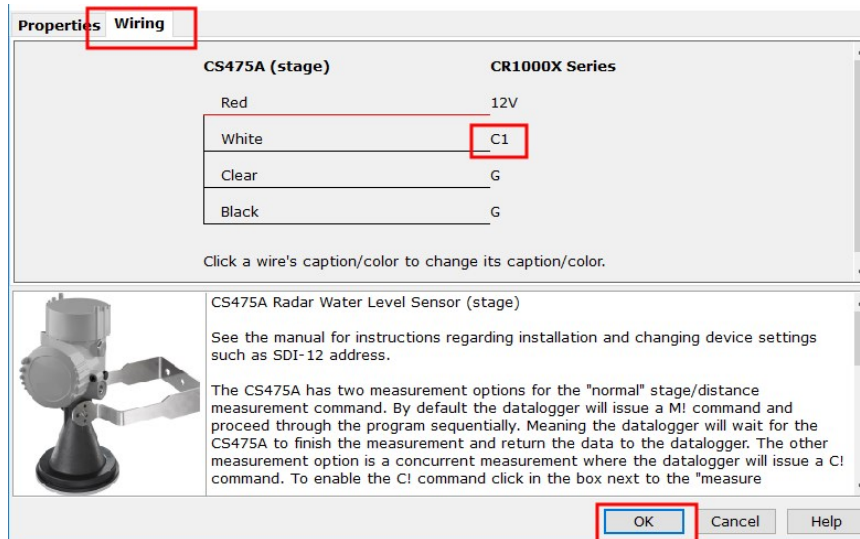
FIGURE 4-4. *Short Cut*, *Change Wire Location*

> **CAUTION:**
> Wire the sensor in this order: white, clear, red, black.

5. Repeat steps three and four for other sensors.

6. In **Output Setup**, type the scan rate, a **Table Name**, and **Data Output Storage Interval** (FIGURE 4-5 (p. 5)). Click **Next**.
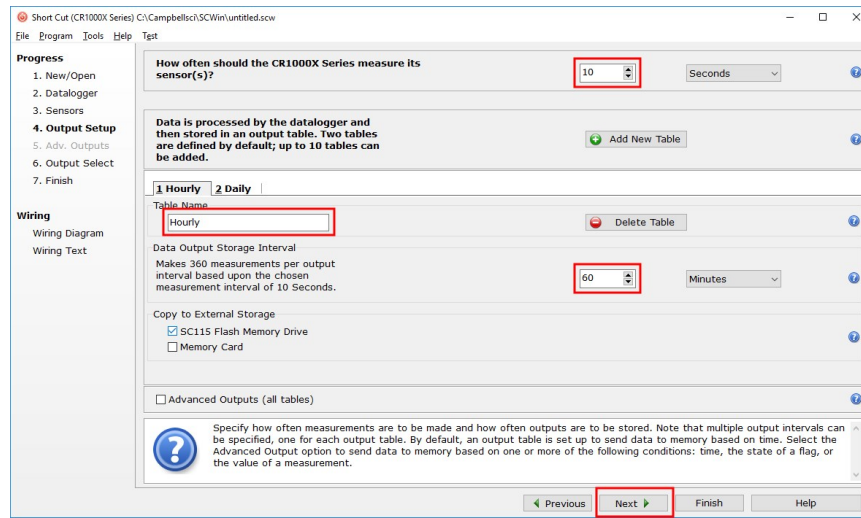
FIGURE 4-5. *Short Cut*, *Output Setup*

> **NOTE:**
> Because of the delays using SDI-12, Campbell Scientific recommends measurement scans of 10 seconds or more.

7. Select the output options.

8. Click **Finish** and save the program. Send the program to the data logger if the data logger is connected to the computer.

9. If the sensor is connected to the data logger, check the output of the sensor in the data display in *LoggerNet*, *RTDAQ*, or *PC400* to make sure it is making reasonable measurements.

5. Overview

The CS475A emits short microwave pulses and measures the elapsed time between the emission and return of the pulses. The elapsed time measurement is used to calculate the distance between the sensor face and the target (for example, water, grain, slurry). The distance value can be used to determine depth of the medium (FIGURE 5-1 (p. 6)).

This radar sensor outputs a digital SDI-12 signal to indicate distance and stage. The output is acceptable for recording devices with SDI-12 capability.

The CS475A can measure distances up to 35 m (114.8 ft) with an accuracy of ±2 mm (0.0065 ft). Once the water surface gets within 0.5 m of the sensor, the accuracy will decrease linearly the closer the water surface gets to the sensor.

$$y = m(X) + b$$

Where:
$y = Stage$
$m = -1$
$X = Distance$
$b = Offset$
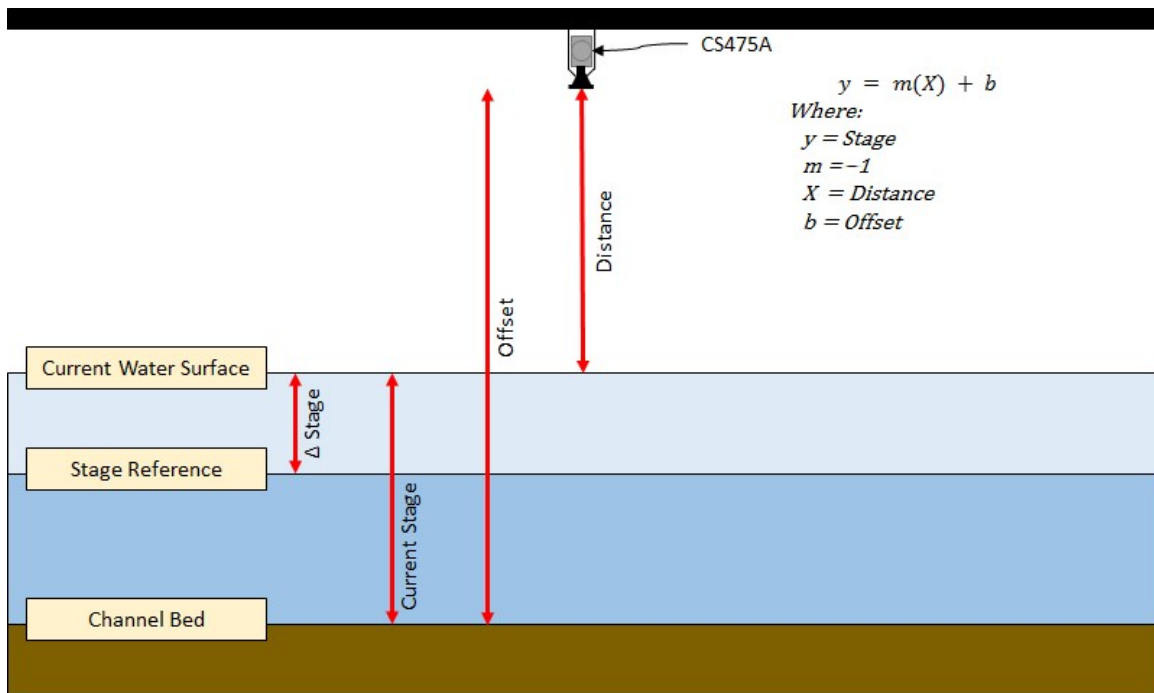
FIGURE 5-1. CS475A stage, distance, and offset

Features:

- Meets USGS Office of Surface Water (OSW) requirements for accuracy
- SDI-12 1.4 functionality including SHEF coded metadata
- 1 Hz measurements
- Monitors tides for NOAA physical oceanographic real-time system (PORTS®)
- Supports False Echo Suppression via extended SDI-12 command
- Easy to set up and configure over USB or SDI-12
- Low power mode available
- Optional display
- FCC compliant; individual FCC license not required
- Low maintenance—no moving parts significantly reduces maintenance cost and time
- Rugged enough for harsh environments—IP68 rating
- Compatible with Campbell Scientific data loggers CR6, CR3000, CR1000X, CR800 series, CR300 series, and CR1000

5.1 Components and hardware

The radar sensor consists of an integrated microwave transmitter and sensor together with a horn antenna (FIGURE 5-2 (p. 7)). The horn antenna serves to focus the transmitted signal and to receive the reflected echo. A built-in SDI-12 interface provides data processing and SDI-12 communications with the data logger.
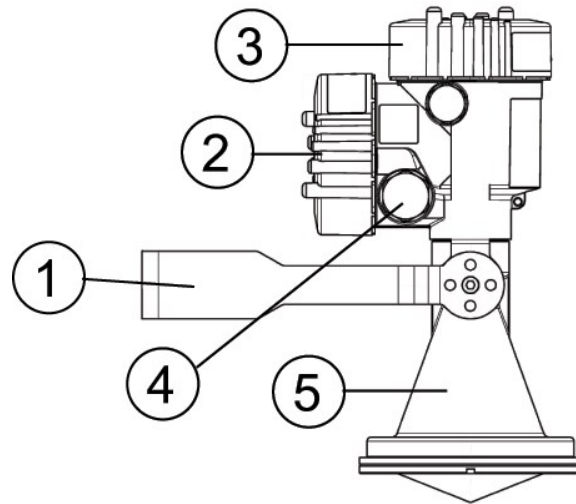
1	Mounting loop
2	Housing side cap
3	Housing cap
4	Unit secondary 0.5 inch NPT cable port, primary port on opposite side
5	Instrument horn

FIGURE 5-2. Components and hardware

6. Specifications

Measurement range: 0.5 to 35 m (1.64 to 114.8 ft); d in FIGURE 6-1 (p. 8)

Accuracy: ±2 mm (±0.0065 ft)

Resolution: 1 mm (0.0033 ft)

Output protocol:	SDI-12 1.4
Compliance information:	View the EU Declaration of Conformity at: www.campbellsci.com/cs475a-l⬈
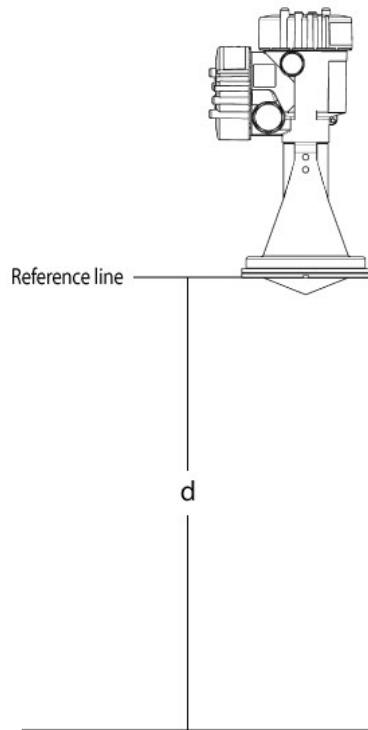
FIGURE 6-1. Reference line for measurement range

6.1 Radar unit

Frequency:	~26 GHz
Pulse energy:	1 mW maximum
Beam angle:	10° (3-inch diameter horn)
Power requirements	
Input voltage:	9.6 to 32 VDC
Surge protection:	1.5 kVA

Table 6-1: Power mode, current draw, and measurement response				
Power mode	Nominal Current Draw			Measurement response time
	Sleep state	Measurement state	Maximum	
Normal	5 mA	< 7 mA	8 mA	< 1 s
Low	< 550 µA	< 7 mA	8 mA	60 s + (5 × Integration Time) + (Measurement Time) For example: The measurement response time for the default integration time of 2 s and a measurement time of 1 s is: Measurement Response Time = 60 s + (5 × 2 s) + 1 s = 71 s

6.2 Environmental

Operating temperature range:　　−40 to 80 °C

Storage ranges

　Temperature:　　　　　　　　−40 to 80 °C

　Relative humidity:　　　　　　20 to 80% RH

Vibration resistance:　　　　　　　Mechanical vibrations with 4 g and 5 to 100 Hz

6.3 Physical

See FIGURE 6-2 (p. 10) for dimensions.

Mechanical rating:　　　　　　IP66/68

Housing material:　　　　　　　Aluminum

Horn material:　　　　　　　　PVDF plastic

Weight:　　　　　　　　　　　2 kg (4 lb)
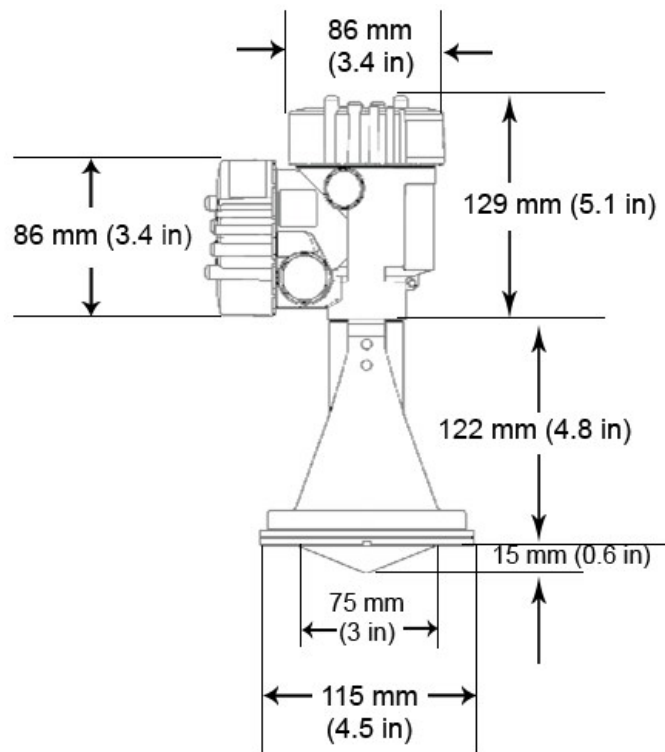
FIGURE 6-2. CS475A dimensions

7. Installation

If you are programming your data logger with **Short Cut**, skip Wiring to data logger (p. 10) and Data logger programming (p. 11). **Short Cut** does this work for you. See QuickStart (p. 2) for a **Short Cut** tutorial.

7.1 Wiring to data logger

Connections to Campbell Scientific data loggers are given in Table 7-1 (p. 11).

> **CAUTION:**
> Connect the wires in the order shown in Table 7-1 (p. 11).

Table 7-1: Wire color, function, and data logger connection		
Wire color	Wire function	Data logger or RTU terminal
White	SDI-12 signal	**SDI-12 Data**, **C**, **SDI-12**, or **U** configured for SDI-12[1]
Clear	Shield	G
Red	Power	12V
Black	Power ground	G
[1]**U** and **C** terminals are automatically configured by the measurement instruction for Campbell Scientific CR6 data logger.		

Campbell Scientific recommends using separate terminals when possible. However, multiple SDI-12 sensors can be connected to a single data logger control or **U** terminal. Each SDI-12 device must have a unique SDI-12 address.

For the CR6 and CR1000X Campbell Scientific data loggers, triggering conflicts may occur when a companion terminal is used for a triggering instruction such as `TimerInput()`, `PulseCount()`, or `WaitDigTrig()`. For example, if the CS475A is connected to C3 on a CR1000X, C4 cannot be used in the `TimerInput()`, `PulseCount()`, or `WaitDigTrig()` instructions.

7.1.1 Built-in self-test (BIST)

After connecting the sensor to power, the sensor performs a BIST (built-in self-test) for approximately 50 seconds (factory default). During this self-check, an internal check of the electronics occurs.

7.2 Data logger programming

Short Cut is the best source for up-to-date programming code for Campbell Scientific data loggers. If your data acquisition requirements are simple, you can probably create and maintain a data logger program exclusively with *Short Cut*. If your data acquisition needs are more complex, the files that *Short Cut* creates are a great source for programming code to start a new program or add to an existing custom program.

> NOTE:
> *Short Cut* cannot edit programs after they are imported and edited in *CRBasic Editor*.

A *Short Cut* tutorial is available in QuickStart (p. 2). If you wish to import *Short Cut* code into *CRBasic Editor* to create or add to a customized program, follow the procedure in Importing Short Cut code into CRBasic Editor (p. 43). Programming basics for CRBasic data loggers are

provided in the following sections. Complete program examples can be found in Example programs (p. 44).

7.2.1 CRBasic programming

The `SDI12Recorder()` instruction is used to measure a CS475A. This instruction sends a request to the sensor to make a measurement and then retrieves the measurement from the sensor. See SDI-12 measurement commands (p. 37) for more information.

For most data loggers, the `SDI12Recorder()` instruction has the following syntax:

```
SDI12Recorder(Destination, SDIPort, SDIAddress, "SDICommand", Multiplier, Offset,
FillNAN, WaitonTimeout)
```

For the **SDIAddress**, alphabetical characters need to be enclosed in quotes (for example, **"A"**). Also enclose the **SDICommand** in quotes as shown. The **Destination** parameter must be an array. The required number of values in the array depends on the command (see Table 8-4 (p. 39)).

FillNAN and **WaitonTimeout** are optional parameters (refer to CRBasic Help for more information).

7.3 Field installation

Consider the following while selecting the site:

- **Sensor height:** Mount the sensor high enough to prevent submersion during flooding conditions.

  > WARNING:
  > Since the sensor is commonly installed over water from tall structures, use appropriate safety equipment such as a safety harness or a life preserver when installing or performing maintenance on the sensor.

- **Water surface:** Install the sensor above the smoothest part of the water surface.

  > NOTE:
  > The smoothest part of the water surface is typically found halfway between bridge piers. However, bridges with long spans between the piers experience more vibration. For these bridges, vibration can be minimized by mounting the sensor a quarter to a third of the distance to the next pier.

- **Horizontal structures:** Avoid mounting near horizontal structural surfaces such as beams, brackets, and sidewall joints because these surfaces reflect a strong signal. If these structures cannot be avoided, use the False Echo Supression command (`aXFES=xxx.xx!`) to map out the interfering structures in the beam profile.

- **Vessel walls:** When mounting in a vessel, mount the sensor at least 200 mm (8 in) from the vessel wall (see FIGURE 7-1 (p. 13)). In vessels with conical bottom, mount the sensor in the center of the vessel.
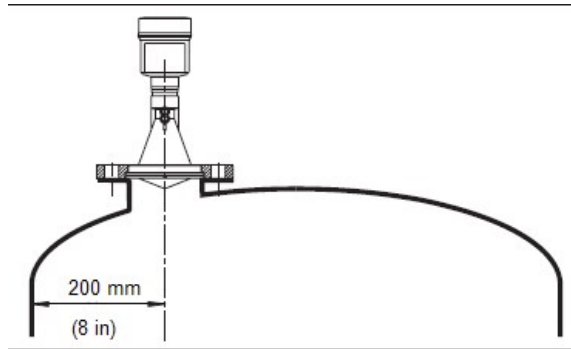
FIGURE 7-1. Mounted on vessel

- **Obstructions:** Mount the sensor away from obstructions (both above and under water) in the radiation beam path, which spreads as it leaves the sensor. Obstructions to be aware of include excessive waves, splashing, pipes, wires, rocks, bridge piers, and logs. Determine the required clearance for the beam angle using the following formula and FIGURE 7-2 (p. 14).

Clearance diameter formula:

$CONE_{diameter} = 0.176(CONE_{distance})$

Where,

$CONE_{distance}$ = the distance to the reference line (FIGURE 6-1 (p. 8))

$CONE_{diameter}$ = clearance diameter in the same measurement units as the $CONE_{distance}$
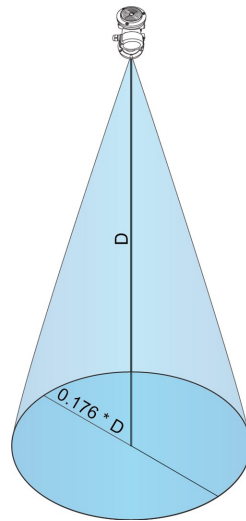
FIGURE 7-2. Beam path clearance

> **CAUTION:**
> Be aware that bridges contract and expand with temperature changes. Traffic loads or trucks can also cause changes to the bridge height.

After choosing an appropriate site, mount and align the sensor using the following procedure:

1. Orient the sensor such that one of its polarization markings is aligned or parallel with the wall or pier (FIGURE 7-3 (p. 14)). The polarization markings are designated by the mounting hex screws (M5-0.8 x 10 mm, ISO 4762/DIN 912 A2-70, stainless steel socket cap).
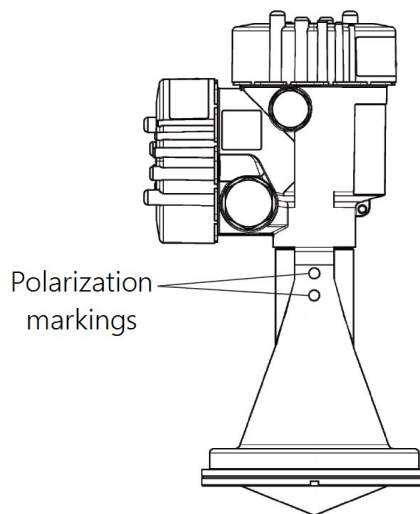
FIGURE 7-3. Polarization markings

2. Securely mount the sensor. Mounting hardware is included with the sensor.

3. After mounting, you can rotate the housing up to 350° to simplify access to the conduit entry and terminal compartment. To rotate the housing to the desired position:

   a. Loosen the set screw on the housing (FIGURE 7-4 (p. 15)).

   b. Rotate the housing as desired.

   c. Tighten the set screw.

Ground lug

Housing set screw

Mounting hex screws (polarization marks)
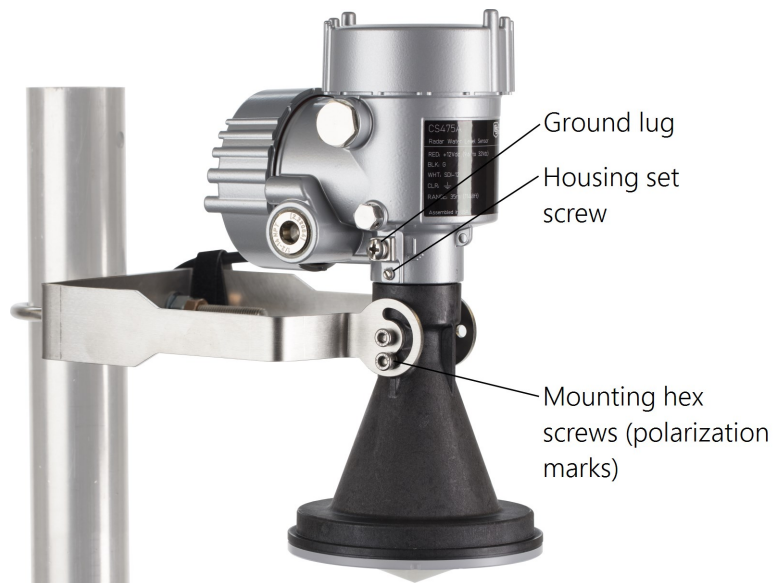
FIGURE 7-4. Housing set screw, mounting hex screws, and ground lug

4. Use a bubble level to make certain the antenna horn is aligned within 1° of vertical. A measurement error will be introduced if the antenna is not perpendicular to the water surface. The maximum range is reduced because of the off-axis return signal. To use the bubble level available from Campbell Scientific, do the following:

   a. Remove the top cap from the CS475A.

   b. Place the bubble level on the top of the CS475A (FIGURE 7-5 (p. 16)).

   c. Verify the sensor is level or make the needed changes to level the sensor.

   d. Remove the bubble level and replace the cap.
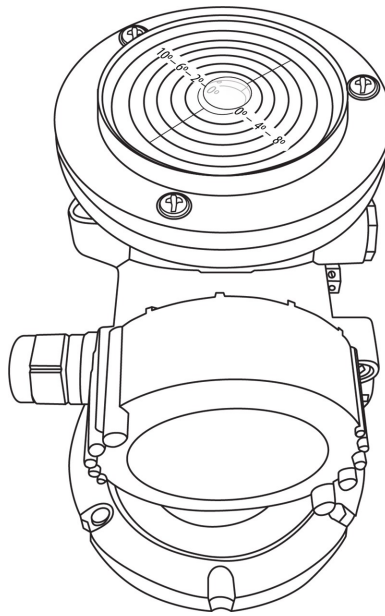
FIGURE 7-5. Campbell Scientific bubble level properly mounted on top of CS475A

5. Connect the sensor ground lug (FIGURE 7-4 (p. 15)) to a local earth ground using at least a 14 AWG wire. Connection to a local earth ground provides better surge or electrostatic discharge (ESD) protection than just grounding it via the sensor cable. While connected to local earth ground, the energy will pass to the local ground instead of traveling through the cable possibly damaging the electronics in the enclosure.

7.4 Determine and set reference stage

Change the reference stage setting at deployment. This setting allows the sensor to complete an offset calculation. Every future measurement will use the offset and the current distance measurement to calculate water stage or depth.

Using a staff plate or other physical datum, measure water level at the measurement site. Record the measurement. Ensure that the measurement is in the same units as the sensor unit setting. Default value is feet.

Enter reference stage using a terminal emulator (Configuring sensor via extended SDI-12 commands and terminal emulator (p. 21)).

8. Operation

This section discusses the following.

8.1 Default settings

Table 8-1 (p. 17) shows the default settings. The reference stage settings must be changed using a terminal emulator (Configuring sensor via extended SDI-12 commands and terminal emulator (p. 21)). The other default settings can be used in most circumstances.

Table 8-1: Default settings

Setting	Default	Read or write
SDI-12 address	0 (change only if two sensors are connected to the same port) valid addresses are 0 through 9, A through Z, and a through z.	Read/write
Power mode	1 = normal	Read/write
System units	0 = feet	Read/write
Stage reference	0	Read only in DevConfig (must be set using terminal emulation (Configuring sensor via extended SDI-12 commands and terminal emulator (p. 21))
Offset	0	Read/write though it can only be written in SDI-12

Table 8-1: Default settings

Setting	Default	Read or write
Number of NOAA measurements	360	Read/write
Number of **M2!** measurements	60	Read/write though it can only be written in SDI-12
Number of **M3!** measurements	15	Read/write though it can only be written in SDI-12
Integration time	10 s	Read/write

8.2 Configuring sensor using *Device Configuration Utility*

> **CAUTION:**
> Because the sensor board processor cannot speak HART when using the USB connection, the stage reference is set using the terminal emulator (Determine and set reference stage (p. 16)) during field installation.

1. Open side compartment of the sensor by unscrewing the side cap (FIGURE 8-1 (p. 19)).
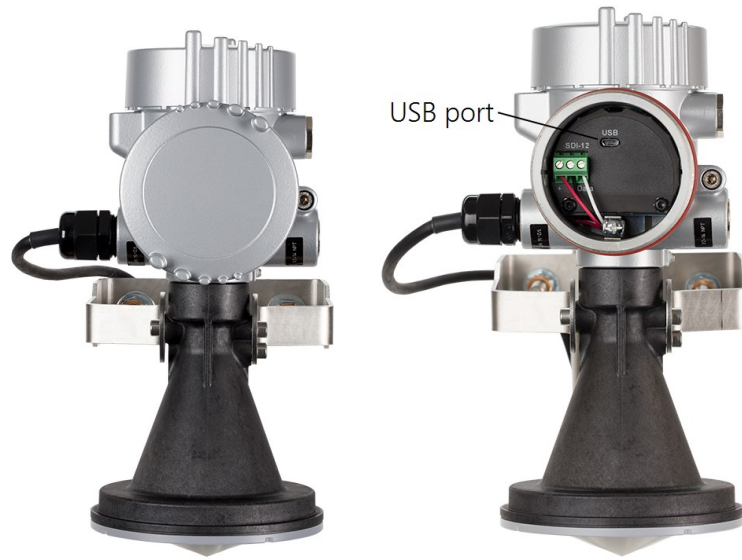
USB port

FIGURE 8-1. CS475A with end cap and side cap in place (left). Exposed connectors once the side cap is removed (right).

2. Connect the USB cable to the **USB** port on the CS475A.

3. Open Device Configuration Utility (version 2.15 or higher).

4. Type CS475A in the **Device Type** box and click CS475A.
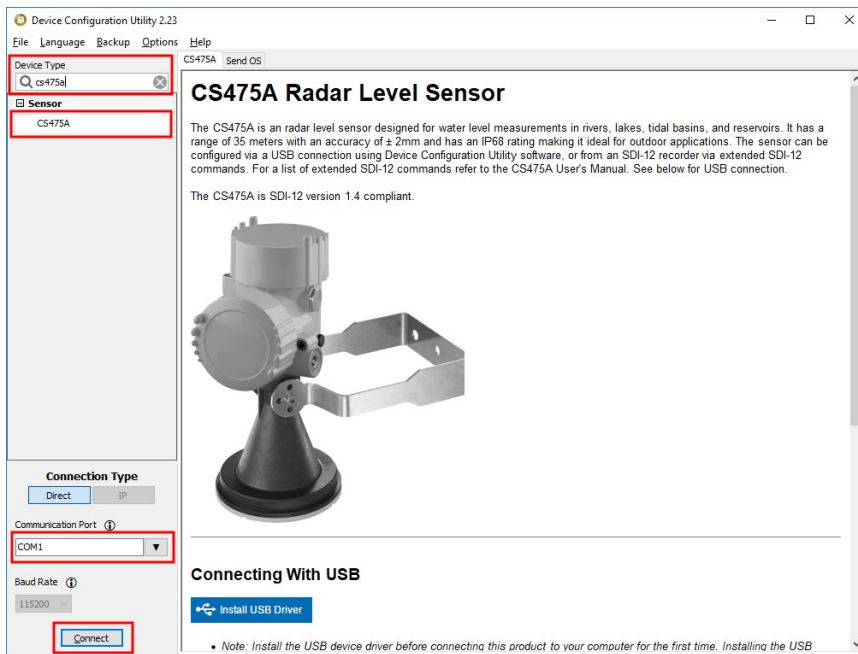
5. If this is the first time connecting the CS475A to the computer, click **Install USB Driver** before connecting the cable to the computer.

6. Choose the **Communication Port** in which the CS475A is connected. Then click **Connect**.

7. Refer to the Device Configuration Utility Help section for any questions regarding the individual settings.

8.3 Updating operating system

1. Go to www.campbellsci.com/downloads/cs475a-os ⬀, click **Download Now**, and click **Save File**. This will download an .exe file on your computer.

2. Double-click the .exe file. This will save the operating system file in C:\Campbellsci\Lib\OperatingSystems.

3. Open Device Configuration Utility (version 2.15 or higher).

4. Type CS475A in the **Device Type** box and click CS475A.

5. Click the **Send OS** tab and follow the **Operating System Download Instructions**.
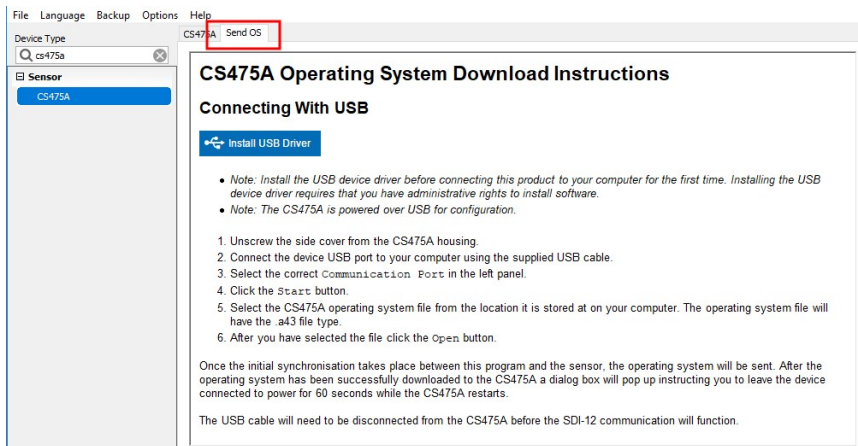
8.4 Configuring sensor via extended SDI-12 commands and terminal emulator

The CS475A is fully configurable via SDI-12 extended commands through a terminal emulator program. The following instructions step you through the initial setup process. Table 8-2 (p. 27) lists all the extended SDI-12 commands and the values that are returned. It is possible to completely reset the sensor to factory defaults settings as well. Most of the extended SDI-12 commands require 2 seconds to complete the change and respond to the **aD0!** command when the sensor is in normal power mode.

1. Connect the CS475A to your data logger (Wiring to data logger (p. 10)).

2. Connect to the data logger via *LoggerNet* or Device Configuration Utility and open the terminal emulator. In *LoggerNet*, the terminal emulator is located at: **LoggerNet > Main > Connect > data logger > Terminal Emulator**. For the Device Configuration Utility, follow steps 1 through 6 in Configuring sensor using Device Configuration Utility (p. 18), then click the Terminal Emulator tab.

3. Click **Open Terminal**.

4. Press **Enter** until a prompt appears.
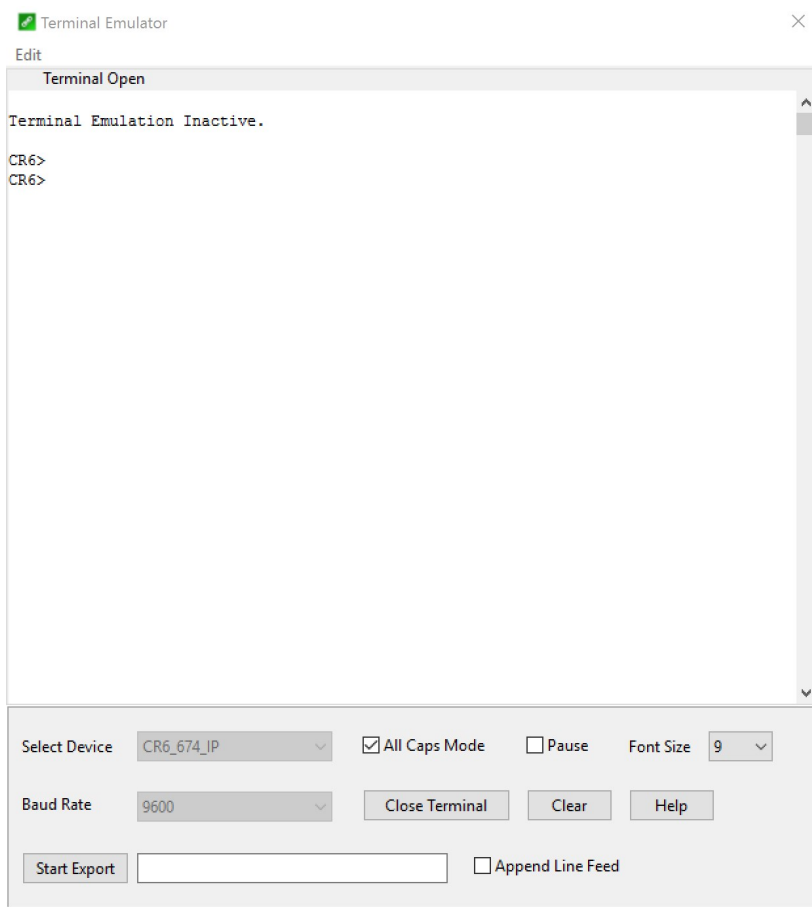
5. If using a Campbell Scientific data logger, type **SDI12** <Enter> once the prompt is present.

6. Enter the number corresponding to the terminal your sensor is wired into.
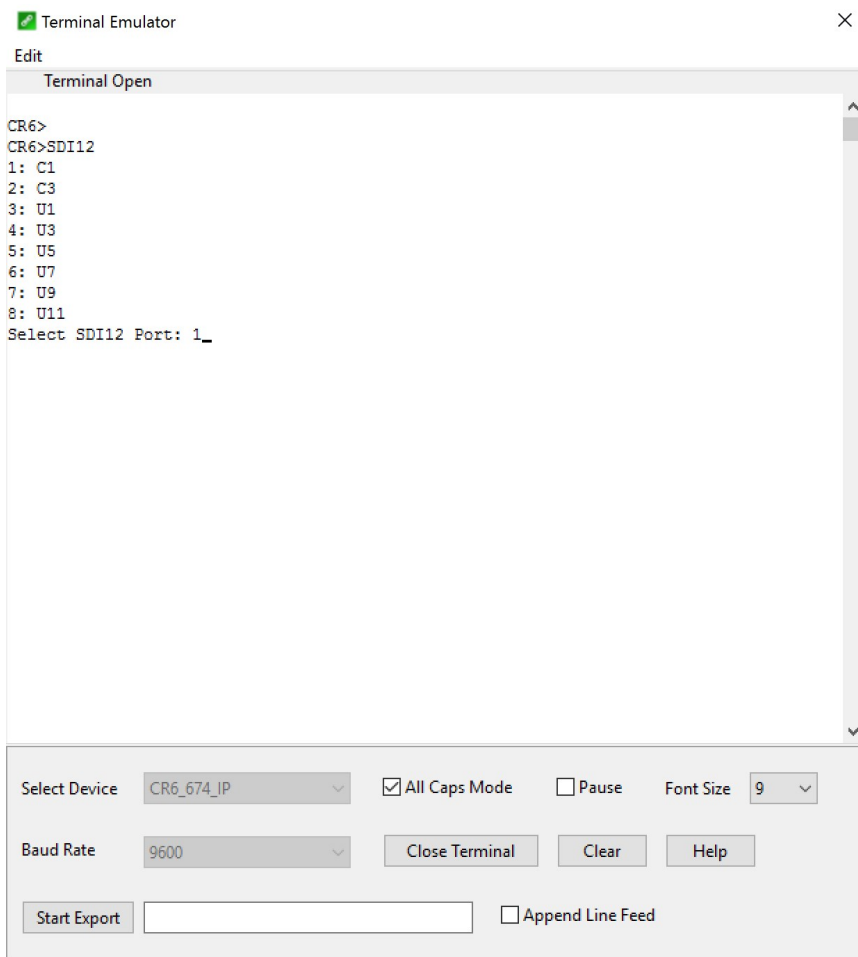
7. Set the **Current or Reference Stage**. This should be set at deployment. Using a staff plate or other physical datum at the study site, measure and enter the current stage. This allows the sensor to complete an offset calculation based on the entered stage and the measured distance to water surface. Every future measurement will use the offset and measured distance to water surface to calculate water stage or depth.

   Command: 0XWSR=50! (where 50 is the reference stage)

   Response: 00022

   Command: 0D0!

   Response: 0+50.000+0

   The sensor response to the **0D0!** command includes the sensor address (0) + reference stage (50.000) + error code (0). The CS475A error codes are explained in .

8. The default SDI-12 address for the sensor is **0**. Change the sensor address if you will have more than one SDI-12 sensor on the same terminal with the **aAb!** command, where a is the current sensor address and b is the desired address. The sensor will respond with the new address if it was successfully changed.

    Command: 0A1!

    Response: 1

9. The default measurement units for the CS475A are English with stage and distance both being returned in feet. If you want the sensor to measure in metric units, you will need to change the units. Change the measurement units with **aXWSU=1!** (where feet = 0, meters = 1, and user defined = 2). See step 10 for more information on user-defined units.

    Command: 0XWSU=1!

    Response: 00022

    Command: 0D0!

    Response: 0+1+0

    The sensor response to the **0D0!** includes the sensor address (0) + system units (1) + error code (0).

10. If the user wants units other than feet or meters, and has set the units = option 2. The next step is to issue the **aXWSS=xx.xx!** command to accommodate other units. The value entered using this command scales the radar units from Feet to the desired unit of measure. For example, **aXWSS=12.00!** will scale the radar readings to inches.

11. Set the **Power Mode** of the sensor. The default power mode is normal and has a numeric code of 1. Low power mode turns off the processor of the sensor in between measurements consuming significantly less power. However, it will take longer to respond to each measurement command since it will power down after a measurement is complete. Measurement time will be a function of boot time and the integration time. To run in low power mode, use the following command.

    Command: 0XWPM=0!

    Response: 00022

    Command: 0D0!

    Response: 0+0+0

The sensor response to the **0D0!** includes the sensor address (0) + power mode (0) + error code (0).

12. Set the number of measurements to be averaged if the data logger program will be using the **M1!** command. The default is 360 measurements to meet the NOAA ports and tides protocol. The number of measurements can range from 1 to 360.

> Command: 0XWNM=60! (where 18.5 is the distance to water surface minus 1.5)
>
> Response: 00022
>
> Command: 0D0!
>
> Response: 0+60+0

The sensor will respond with the sensor address (0) + the number of measurements to be included (60) + error code (0).

13. Change the sensor integration time based on the water surface conditions. Integration time can range from 0 to 60 s. The lower the number, the smoother the water surface. Lower integration times make the sensor more responsive to changes in the water level, but can result in less accurate measurements in rough conditions. Longer integration times result in slower responses (especially if operating in low power mode) to changes in water level, but eliminate inaccuracies due to rough water conditions. Integration time of 2 s is recommended for smooth conditions, 10 s for medium conditions, and 30 s for rough conditions. The default integration time is 10 s.

> Command: 0XWIT=2!
>
> Response: 00022
>
> Command: 0D0!
>
> Response: 0+2+0

The sensor response to the **0D0!** command includes the sensor address (0) + new integration time (2) + error code (0).

14. If obstacles are between the sensor and the water surface that may create an echo that would interfere with the echo/signal from the water surface, issue the False Echo Suppression command. This will "train" the sensor to know where the water surface is located. Once completed, the sensor will track the water surface and ignore the other signals. With the False Echo Suppression command, enter a distance that is 0.5 m (1.5 ft) short of the distance to the water surface, as measured in meters or feet, depending on the unit setting.

> **CAUTION:**
> Do not enter the distance to the water surface or you will suppress the signal of the water surface.

Also, this process will be more helpful if the water surface is low therefore exposing more obstacles between the sensor and the bottom of the water body.

Command: 0XFES=18.5! (where 18.5 is the distance to water surface minus 1.5)

Response: 00412

Command: 0D0!

Response: 0+18.5+0

The sensor response to the **0D0!** command includes the sensor address (0) + distance to suppress (18.5) + error code (0).

To remove the False Echo Map from the radar, reissue the command with the distance set to 0.00 (ft/m) (**0XFES=000.00!**).

15. For some situations, you may want to narrow the radar measurement range. Narrowing the measurement range can eliminate the possibility of return echoes that are outside the valid distance range at a given location, which can cause the radar to return false readings. Also limiting the measuring range improves the accuracy by limiting the distance range that the radar is focusing on. The result will be improved data stability and accuracy. For instance, if the maximum distance the radar will ever measure is 50 feet, changing the Measuring Range to 52 feet will eliminate false reading beyond this.

Command: 0XXWMR=52.00!

Response: 00022

Command: 0D0!

Response: 0+52.00+0

The sensor response to the **0D0!** command includes the sensor address (0) + new measuring range+ error code (0).

Command name	Command format	Sensor response	Configuration by sensor
Write SDI-12 Address	`aAb!`	`b`	Change the sensor address
Read Sensor SDI-12 Address	`?!`	`a`	Returns the address of the sensor connected to the bus. This command is helpful when only one sensor connected to the bus at a time.

Write System Units
 	
Returns: New units, error code
	`aXWSU=u!`
	`aD0!`
		`atttn`
		`a+u+ee`
			Change current measurement units
			
			u: new units setting, where:
			  0 = feet
			  1 = meters
			  2 = custom
			ee: error code
			When the new unit setting is 2 (custom), a Write Slope command (`aXWSS=xxx.xx`) is required to enter a new slope value.

Read System Units
 	
Returns: Current units, error code
	`aXRSU!`
	`aD0!`
		`atttn`
		`a+u+ee`
			Pull configured units out of memory
			
			u: units value from memory, where:
			  0 = feet
			  1 = meters
			  2 = custom
			ee: error code

Table 8-2: Extended SDI-12 commands for the CS475A

Command name	Command format	Sensor response	Configuration by sensor
Table 8-2: Extended SDI-12 commands for the CS475A			
Write Slope Returns: New slope, error code	`aXWSS=xxx.xxxx` `aD0!`	`atttn` `a+xxx.xxxx+ee`	Change the slope. xxx.xxxx: new slope setting ee: error code To use this command, the System Units command needs to be set to 2 (`aXWSU=2!`)
Read Slope Returns: Slope, error code	`aXRSS!` `aD0!`	`atttn` `a+xxx.xxxx+ee`	Pull the slope out of memory. xxx.xxxx: current slope ee: error code
Write Stage Reference Returns: New stage, error code	`aXWSR=sss.ss!` `aD0!`	`atttn` `a+sss.ss+ee`	Change stage reference to 'sss.ss' in configured units. ee: error code
Read Stage Reference Returns: Current stage reference, error code	`aXRSR!` `aD0!`	`atttn` `a+sss.ss+ee`	Pull stage reference out of memory. sss.ss: stage reference from memory in configured units ee: error code
Write Calculated Offset Returns: New offset, error code	`aXWCO=ooo.oo!` `aD0!`	`atttn` `a+ooo.oo+ee`	Change calculated offset value ooo.oo: new offset in the configured units ee: error code
Read Calculated Offset Returns: Offset, error code	`aXRCO!` `aD0!`	`atttn` `a+ooo.oo+ee`	Pull current calculated offset value out of memory ooo.oo: current calculated offset value out of memory ee: error code

Command name	Command format	Sensor response	Configuration by sensor

Write Power Mode
 	
Returns: New power mode, error code
	aXWPM=p!
	
	aD0!
		atttn
		
		a+p+ee
			Change the power mode of the sensor
			
			p: new current power mode setting, where:
			
			  0 = low power mode;
			
			  1 = normal power mode
			
			ee: error code

Read Power Mode
 	
Returns: Current power mode, error code
	aXRPM!
	
	aD0!
		atttn
		
		a+p+ee
			Pull power mode value out of memory
			
			p: current power mode setting, where:
			
			  0 = low power mode;
			
			  1 = normal power mode
			
			e: error code

Write Number of Measurements Returns: New number of measurements for the NOAA command	aXWNM=nnn! aD0!	atttn a+nnn+ee	Change the number of measurements completed for the M1! Response nnn: number of measurements (2 to 360) ee: error code
Read: Number of Measurements Returns: New number of measurements, error code	aXRNM! aD0!	atttn a+nnn+ee	Pull the number of measurements for the M1! command from memory nnn: number of measurements ee: error code

Table 8-2: Extended SDI-12 commands for the CS475A

Table 8-2: Extended SDI-12 commands for the CS475A			
Command name	Command format	Sensor response	Configuration by sensor
Write Number of Measurements for the M2! Command Returns: New number of measurements for the M2! command	aXWNM2=nn! aD0!	atttn a+nn+ee	Change the number of measurements completed for the M2! Response nnn: number of measurements (max is 60) ee: error code
Read Number of Measurements for the M2! Command Returns: Number of measurements for the M2! command	aXRNM2! aD0!	atttn a+nn+ee	Pull the number of measurements completed for the M2! Response from memory nn: number of measurements (max is 60) ee: error code
Write Number of Measurements for the M3! Command Returns: New number of measurements for the M3! command	aXWNM3=nn! aD0!	atttn a+nn+ee	Change the number of measurements completed for the M3! Response nn: number of measurements (max is 15) ee: error code

Command name	Command format	Sensor response	Configuration by sensor
Read Number of Measurements for the M3! Command Returns: Number of measurements for the M3! command	aXRNM3! aD0!	atttn a+nn+ee	Pull the number of measurements completed for the M3! Response from memory nn: number of measurements (max is 15) ee: error code
Write Integration Time Returns: New integration time, error code	aXWIT=ii! aD0!	atttn a+ii+ee	Change the integration time to the value of 'tt' ii: 0 to 60 (integer number of seconds) ee: error code
Read Integration Time Returns: Integration time, error code	aXRIT! aD0!	atttn a+ii+ee	Pull integration time out of memory ii: current integration time (0 to 60 s) ee: error code
False Echo Suppression Returns: Suppression Distance, error code	aXFES=xxx.xx! aD0!	atttn a+xxx.xx+ee	Create a false echo suppression curve xxx: Distance just short of the water surface. ee: error code
Write Measuring Range Returns: New measuring range, error code	aXWMR=mmm.mm! aD0!	atttn a+mmm.mm+ee	Change the measuring range. mmm.mm: new measuring range ee: error code

Table 8-2: Extended SDI-12 commands for the CS475A

Table 8-2: Extended SDI-12 commands for the CS475A			
Command name	**Command format**	**Sensor response**	**Configuration by sensor**
Read Measuring Range Returns: Measuring range, error code	`aXRMR!` `aD0!`	`atttn` `a+mmm.mm+ee`	Pull the measuring range out of memory. mmm.mm: current measuring range ee: error code
Write Rising Amplitude Averaging Factor Returns: New rising amplitude averaging factor, error code	`aXWAF=y!` `aD0!`	`atttn` `a+y+ee`	Change the rising amplitude averaging factor (0-5).[2] y: new rising amplitude averaging factor ee: error code
Read Rising Amplitude Averaging Factor Returns: Rising amplitude averaging factor, error code	`aXRAF!` `aD0!`	`atttn` `a+y+ee`	Pull the rising amplitude averaging factor (0-5) out of memory y: current rising amplitude averaging factor ee: error code
Write Falling Amplitude Averaging Factor Returns: New falling amplitude averaging factor, error code	`aXWAS=z!` `aD0!`	`atttn` `a+z+ee`	Change the falling amplitude averaging factor (0-5).[2] z: new falling amplitude averaging factor ee: error code

Table 8-2: Extended SDI-12 commands for the CS475A			
Command name	**Command format**	**Sensor response**	**Configuration by sensor**

Read Falling Amplitude Averaging Factor
 	
Returns: Falling amplitude averaging factor, error code
	`aXRAS!`
	
	`aD0!`
		`atttn`
		
		`a+z+ee`
			Pull the falling amplitude averaging factor (0-5) out of memory
			
			z: current falling amplitude averaging factor
			
			ee: error code

Write Width Focusing Range
 	
Returns: New width focusing range, error code
	`aXWFR=xxx.xx!`
	
	`aD0!`
		`atttn`
		
		`a+xxx.xx+ee`
			Change the width focusing range (0 - 229.6 ft)
			
			xxx.xx: new width focusing range
			
			ee: error code

Read Width Focusing Range
 	
Returns: Width focusing range, error code
	`aXRFR!`
	
	`aD0!`
		`atttn`
		
		`a+xxx.xx+ee`
			Pull the width focusing range (0 - 229.6 ft) out of memory
			
			xxx.xx: current width focusing range
			
			ee: error code

Command name	Command format	Sensor response	Configuration by sensor
Read Configuration Summary Returns: Units, stage reference, offset, power mode, integration time, error code	aXRCS! aD0!	atttn a+u+ooo.oo+p+ nnn+ii+mmm.mm+ y+xxx.xx	Pull settings out of memory u: current units value out of memory (0 = ft; 1 = m, 2 = custom) ooo.oo: calculated offset out of memory p: current power mode setting out of memory (0 = low; 1 = normal) nnn: number of measurements for average calculation out of memory[1] ii: integration time out of memory mmm.mm: measuring range y: rising amplitude factor (0-5) z: falling amplitude factor (0-5) xxx.xx: width focusing range
Reset Configuration to Default Returns: Error code	aXATZ! aD0!	atttn a+ee	Resets all configuration parameters back to defaults. Includes: SDI-12 Address, Units, Stage Reference, Calculated Offset, Power Mode, Number of Measurements for M1!, M2!, and M3!, and Integration Time ee = error code

Table 8-2: Extended SDI-12 commands for the CS475A			
Command name	Command format	Sensor response	Configuration by sensor

Continuous Output mode
 	
Returns: 1 Hz data of stage, distance, voltage, and error code
	`aXTEST!`
	
	`aD0!`
		`a++sss.ss+`
		`ddd.dd+`
		`vv.vv+ee`
		
		`a++sss.ss+`
		`ddd.dd+`
		`vv.vv+ee`
		
		`a++sss.ss+`
		`ddd.dd+`
		`vv.vv+ee`
			This command will put the sensor into a continuous output mode with data coming into the terminal every second. Any other command will interrupt the continuous output mode and resume normal operation.
			
			sss.ss: current calculated stage
			
			ddd.dd: current measured distance
			
			vv.vv: current measured battery voltage at the sensor
			
			ee: error code

Table 8-2: Extended SDI-12 commands for the CS475A			
Command name	Command format	Sensor response	Configuration by sensor
Read Command List Returns: All the recognized SDI-12 commands of the CS475A	aXHELP!	A CS475A SDI-12 Command List: a! – Acknowledge Active aI! – Send Identification aAb! – Change Address aM! – Start Measurement aM1! – Start NOAA Measurement aM2! – Start Measurement aM3! – Start Measurement aC! – Start Concurrent Measurement aC1! – Start Concurrent NOAA Measurement aD0!…aD9! – Send Data aV! – Start Verification aXWSU=x! – Write System Units aXRSU! – Read System Units aXWSS=xxx.xx! – Write Slope aXRSS! – Read Slope aXWSR=sss.ss! – Write Stage Reference aXRSR! – Read Stage Reference aXWCO=xxx.xx! – Write Calculated Offset aXRCO! – Read Calculated Offset aXWPM=p! – Write Power Mode aXRPM! – Read Power Mode aXWNM=nnn! – Write Number of M1 Measurements aXRNM! – Read Number of M1 Measurements aXWN2=nnn! – Write Number of M2 Measurements	

Table 8-2: Extended SDI-12 commands for the CS475A			
Command name	Command format	Sensor response	Configuration by sensor
		`aXRN2!` – Read Number of M2 Measurements	
		`aXWN3=nnn!` – Write Number of M3 Measurements	
		`aXRN3!` – Read Number of M3 Measurements	
		`aXWIT=ii!` – Write Integration Time	
		`aXRIT!` – Read Integration Time	
		`aXFES=xxx.xx!` – False Echo Suppression	
		`aXWMR=xxx.xx!` – Write Measuring Range	
		`aXRMR!` – Read Measuring Range	
		`aXWAF=x!` – Write rising amplitude averaging factor	
		`aXRAF!` – Read rising amplitude averaging factor	
		`aXWAS=x!` – Write falling amplitude averaging factor	
		`aXRAS!` – Read falling amplitude averaging factor	
		`aXWFR=xxx.xx!` – Write width focusing range	
		`aXRFR!` – Read width focusing range	
		`aXRCS!` – Read Configuration Summary	
		`aXATZ!` – Reset To Factory Defaults	
		`aXTEST!` – Continuous Output at 1 Hz	
		`aXHELP!` – Display Command List	

[1] Number of measurements for `M2!` and `M3!` commands are NOT returned in this summary.

[2] The rising and falling amplitude averaging factor should not be changed for most applications. With a setting of 0, there will be no signal processing and the data set will be very noisy. A setting of 5 increases the signal processing and is used to find the actual echo from the water.

8.5 SDI-12 measurement commands

The data logger can send three categories of measurement commands to the CS475A using the `SDI12Recorder()` instruction. The two main categories of measurement commands are the Start Measurement (`aMb!`) and Start Concurrent Measurement (`aCb!`) commands. The measurement sequences for both types of commands are explained below.

The third type of measurement command includes a cyclic redundancy check or checksum at the end of the returned data and works with both the M and C type commands. The checksum generated by the sensor will be evaluated by the data logger to determine if data was lost during transmission. This is a valuable measurement tool when using long cable lengths or trying to diagnose a problem. Table 8-3 (p. 38) provides examples of using the SDI-12 commands. In these examples, a is the SDI-12 sensor address (default of 0). See Table 8-4 (p. 39) for the measurement commands recognized by the CS475A, the values returned with each command, and the response time of the sensor to each command.

Table 8-3: Measurement examples

Command	Description
aMb!	Start measurement data logger transmits: 0M! Sensor returns: 00014 (returns four values in 1 s)[1] Sensor returns service request if it is done measuring early: 0 data logger transmits get data command: 0D0![2] Sensor transmits: 0+sss.ss+ddd.dd+vv.vvv+ee[3]
aCb!	data logger transmits: 0C! Sensor returns: 00014 (returns four values in 1 s)[4] data logger transmits get data command after 1 s has passed or on the next scan through the program: 0D0![2] Sensor transmits: 0+sss.ss+ddd.dd+vv.vvv+ee[5]

[1] Regardless of the time to respond, the data logger will wait for the data to be returned before moving on in the data logger program.

[2] Depending on the number of characters that needs to be returned, the data logger will increment from **0D0!** to **0D1!** up to **0D9!**.

[3] **aMCb!** – Start measurement with checksum will follow the same pattern as the **aMb!** command however it will add a checksum to the end of the returned data. Sensor returns: 0+sss.ss+ddd.dd+vv.vvv+ee.ee<CRC>

[4] When using the concurrent command, the data logger will continue doing other measurements and then return to collect the data once the measurement time has lapsed.

[5] **aCC!** – Start measurement with checksum will follow the same pattern as the **aC!** command. Sensor returns: 0+sss.ss+ddd.dd+vv.vvv+ee.ee

Table 8-4: Measurement commands			
SDI-12 command	Response format	Values	Time to respond (s)[1]
Basic Measurement (ft/m)[2] aM! aMC! aC! aCC!	0+sss.ss+ddd.dd +vv.vvv+ee	Stage, distance, voltage, and error code	1
NOAA Tide Monitoring (ft/m)[2] aM1! aMC1! aC1! aCC1!	0+sss.ss+$\sigma\sigma.\sigma\sigma$ +oo+gg+vv.vv+ee	When the sensor first powers up and finds all of the the parameters it will set the measurement buffer size for the command based on the number of measurements each is configured. Then once the buffers are full the sensor can return a 360 s average[3] within 1 s. Returns: mean stage, standard deviation, # of outliers, # of good readings, voltage, and error code	1

Table 8-4: Measurement commands			
SDI-12 command	Response format	Values	Time to respond (s)[1]
NOAA Ports and Tide Monitoring (ft/m)[2,4] aM2 ! aC2 !	a+sss.ss+vv.vv+ee	When the sensor first powers up and finds all of the the parameters it will set the measurement buffer size for the command based on the number of measurements each is configured. Then once the buffers are full the sensor can return a 60 s average[3] within 1 s. Returns: mean stage, voltage, and error code	1
NOAA Ports and Tide Monitoring (ft/m)[2,4] aM3 ! aC3 !	a+sss.ss+vv.vv+ee	When the sensor first powers up and finds all of the the parameters it will set the measurement buffer size for the command based on the number of measurements each is configured. Then once the buffers are full the sensor can return a 15 s average[3] within 1 s. Returns: mean stage, voltage, and error code	1 s [3]

[1] The time to respond, documented in the previous table, is only valid when the sensor is in normal power mode. If the power mode is changed to low, it will take longer to respond.

[2] The units of the measurement returned to the user depend on the configuration of the sensor. The default units are feet. See the previous table for extended SDI-12 command to change the measurement units.

[3] The number of measurements averaged in these commands depends with how the sensor is configured to record. See extended SDI-12 commands to change the number of measurements averaged in the M1, M2, and M3 commands.

[4] The M2, C2, M3, C3 commands are commonly used in NOAA ports and tides applications for simple average stage values of the 1 second data.

9. Diagnostics, repair, and maintenance

> **NOTE:**
> All factory repairs and recalibrations require a returned material authorization (RMA) and completion of the "Statement of Product Cleanliness and Decontamination" form. Refer to the Assistance page at the end of this manual for more information.

9.1 Testing procedure

1. Double-check all wiring connections.

   > **CAUTION:**
   > The data logger cannot issue SDI-12 commands when a USB cable is connected to the sensor.

2. Connect the sensor to your data logger and apply +12 V power.

3. Send the Acknowledge Active command (`a!`). This command is used to check the presence of the sensor on the bus. Only the address is sent back in response.

4. Send the Identification command (`aI!`).

5. Compare the output stage versus the actual stage using the Start Measurement command (`aM!`) followed by the Send Data command (`aD!`).

6. Send the Read Configuration Summary command (`aXRCS!`) to retrieve the stored settings for measurement units, reference stage, calculated offset, power mode, number of measurements for the average calculation, integration time, and error code. If the sensor is set up correctly and you are still getting erroneous readings, try completing a False Echo Suppression to map the sensor to the water surface (`aXFES=xxx.xx!`).

7. Reset the sensor to the defaults (send `aXATZ!`).

9.2 Cyclic redundancy check

The cyclic redundancy check (CRC) is used to produce and send a small, fixed-size checksum of a larger block of data to the data logger. This checksum detects errors after transmission or storage. The CRC is computed and added before any transmission or storage. The CRC is also

authenticated by the recipient, after the transmission, to confirm that no alterations occurred. CRCs are good at identifying errors caused by noise in transmission channels. See Table 8-4 (p. 39) for measurement commands with CRC.

9.3 Diagnostics

The radar sensor is extremely reliable, but problems can occur during operation. When you encounter a problem with the radar sensor, check the error messages to help evaluate the issue Table 9-1 (p. 42)). The error code is part of the data stream when using a measurement command (aM!, aMC!, aC!, aCC!, aM1!, aMC1!, aC1!, aCC1!).

> **NOTE:**
> During the initial power up or resumption of supply voltage to the sensor, some SDI-12 commands, such as the I command, will not yield the expected responses.

Table 9-1: CS475A error codes

Error code	Description	User action
0	No Error	None
1	Timeout during data communication	Sometimes this resolves itself without any action by the user. If it doesn't resolve itself, try restarting the system. If problem persists, contact technical support.
2	Internal Communication Error	Often this error flag is triggered due to one packet that wasn't transmitted correctly, so the issue normally resolves itself. If it doesn't resolve itself, try restarting the system. If problem persists, contact technical support.
4	Invalid Units	The command that was sent didn't have a valid unit indicator. Send the command again with a valid unit indicator.
8	Invalid Range	The value sent with the command was outside of the valid range for that value. Send the command again with a valid value.
16	Communication Error	There was an error on the communication line. Check all of the connections to make sure they are correct. Restart the system. If the problem persists, contact technical support.

9.4 Maintenance

The CS475A is maintenance free under normal operation.

Appendix A. Importing *Short Cut* code into *CRBasic Editor*

Short Cut creates a .DEF file that contains wiring information and a program file that can be imported into the *CRBasic Editor*. By default, these files reside in the C:\campbellsci\SCWin folder.

Import *Short Cut* program file and wiring information into *CRBasic Editor*:

1. Create the *Short Cut* program. After saving the *Short Cut* program, click the **Advanced** tab then the **CRBasic Editor** button. A program file with a generic name will open in CRBasic. Provide a meaningful name and save the CRBasic program. This program can now be edited for additional refinement.

   > **NOTE:**
   > Once the file is edited with *CRBasic Editor*, *Short Cut* can no longer be used to edit the program it created.

2. To add the *Short Cut* wiring information into the new CRBasic program, open the .DEF file located in the C:\campbellsci\SCWin folder, and copy the wiring information, which is at the beginning of the .DEF file.

3. Go into the CRBasic program and paste the wiring information into it.

4. In the CRBasic program, highlight the wiring information, right-click, and select **Comment Block**. This adds an apostrophe (') to the beginning of each of the highlighted lines, which instructs the data logger compiler to ignore those lines when compiling. The **Comment Block** feature is demonstrated at about 5:10 in the CRBasic | Features video ▶.

Appendix B. Example programs

```
'CR300 program that uses the M! command.

Public CS475A(4)

Alias CS475A(1) = Stage 'Measured/current stage based on reference conditions
                       'in sensor
Alias CS475A(2) = Distance 'Measured distance from the sensor to the water
                           'surface
Alias CS475A(3) = Batt_volt_sensor 'This is the voltage seen at the sensor
Alias CS475A(4) = Error_Code 'error code returned by the sensor.

Units Stage = ft 'Could be meters based on settings in sensor
Units Distance = ft 'Could be meters based on settings in sensor
Units Batt_volt_sensor = V
Units Error_Code = NA 'unitless

DataTable(CS475A,1,-1)
  Sample(4,CS475A(),FP2)
EndTable

BeginProg
  Scan (5,Sec,0,0)
  'The sensor takes up to 1 s to respond to the M! command in normal power
  'mode.

    SDI12Recorder (CS475A,C1,0,"M!",1.0,0,-1)
    CallTable CS475A
  NextScan
EndProg
```

CRBasic Example 2: CR300 program using the M1! command

```
'This program runs the M1! command that completes the NOAA ports and tides
'calculation. The length of time to respond to this command will depend on
'the number of measurements the user configures the sensor to collect. The
'default is 360 measurements based on the NOAA specification. The sensor can
'be set to collect up to 360 measurements. The command then returns the
'average stage, standard deviation of the stage measurements, number of
'outliers, number of good readings, battery voltage at the sensor, and error
'code.

Public CS475A(6)

Alias CS475A(1) = Avg_Stage 'Average stage based on number of measurements
                            'configured in sensor
Alias CS475A(2) = st_dev_stage 'Standard deviation of the stage measurements
Alias CS475A(3) = outliers 'This is the voltage seen at the sensor
Alias CS475A(4) = good_meas 'The number of good measurements collected during
                            'the configured time period
Alias CS475A(5) = Batt_volt_sensor 'The voltage seen at the sensor
Alias CS475A(6) = Error_Code 'Error code returned by the sensor

Units Avg_Stage = ft 'Could be meters based on settings in sensor
Units st_dev_stage = ft 'Could be meters based on settings in sensor
Units outliers = count
Units good_meas = count
Units Batt_volt_sensor = V
Units Error_Code = NA 'unitless

DataTable(CS475A,1,-1)
  Sample(6,CS475A(),FP2)
EndTable

BeginProg
  Scan (5,Sec,0,0)
    SDI12Recorder (CS475A,C1,0,"M1!",1.0,0,-1)
    CallTable CS475A
  NextScan
EndProg
```

Appendix C. SDI-12 version 1.4 identify measurement commands and responses

Version 1.4 compliant sensors must respond to identify commands for each type of measurement command and each parameter with a command. The broad identify commands return how many variables will be returned with a given measurement command and the time it will take the sensor to respond. The specific identify parameter commands will return a SHEF code, the measurement units, and the type of measurement (sample, count, or average). For more information see the SDI-12 version 1.4 specification.

(http://sdi-12.org/current_specification/SDI-12_version-1_4-Jan-10-2019.pdf ⬀)

Table C-1: Identify commands for the CS475A			
Type of command	Command	Sensor response	Comment
Identify Measurement for 'M' Commands	aIM!, aIMC! aIM1!, aIMC1! aIM2!, aIMC2! aIM3!, aIMC3!	atttn	ttt: response time n: # of values returned
Identify Measurement for 'C' Commands	aIC!, aICC! aIC1!, aICC1! aIC2!, aICC2! aIC3!, aICC3!	atttnn	ttt: response time nn: # of values returned
Identify Measurement for the 'V' Command	aIV!	atttn	ttt: response time n: # of values returned

Table C-2: Identify measurement parameters for M! and C! commands

Parameter	Commands		Sensor response	Comment
	M!	C!		
Stage	`aIM_001!`	`aIC_001!`	`a,hg,xx,sample;`	xx: configured units FT=feet, M=meters
Distance	`aIM_002!`	`aIC_002!`	`a,ha,xx,sample;`	xx: configured units FT=feet, M=meters
Battery Voltage	`aIM_003!`	`aIC_003!`	`a,vb,vdc,sample;`	
Error Code	`aIM_004!`	`aIC_004!`	`a,error,code,sample;`	

Table C-3: Identify measurement parameters for M1! and C1! commands

Parameter	Commands		Sensor response	Comment
	M1!	C1!		
Stage Average	`aIM1_001!`	`aIC1_001!`	`a,hg,xx,average;`	xx: configured units FT=feet, M=meters
Stage Stand Dev	`aIM1_002!`	`aIC1_002!`	`a,sd,xx,sample;`	xx: configured units FT=feet, M=meters
# of Outliers	`aIM1_003!`	`aIC1_003!`	`a,bad,count,sample;`	
# of Good Values	`aIM1_004!`	`aIC1_004!`	`a,good,count,sample;`	
Battery Voltage	`aIM1_005!`	`aIC1_005!`	`a,vb,vdc,sample;`	
Error Code	`aIM1_006!`	`aIC1_006!`	`a,error,code,sample;`	

Table C-4: Identify measurement parameters for M2! and C2! commands

Parameter	Commands		Sensor response	Comment
	M2!	C2!		
Stage Average	`aIM2_001!`	`aIC2_001!`	`a,hg,xx,average;`	xx: configured units FT=feet, M=meters
Battery Voltage	`aIM2_002!`	`aIC2_002!`	`a,vb,vdc,sample;`	
Error Code	`aIM2_003!`	`aIC2_003!`	`a,error,code,sample;`	

Table C-5: Identify measurement parameters for M3! and C3! commands

Parameter	Commands		Sensor response	Comment
	M2!	C2!		
Stage Average	`aIM3_001!`	`aIC3_001!`	`a,hg,xx,average;`	xx: configured units FT=feet, M=meters
Battery Voltage	`aIM3_002!`	`aIC3_002!`	`a,vb,vdc,sample;`	
Error Code	`aIM3_003!`	`aIC3_003!`	`a,error,code,sample;`	

Appendix D. FCC/IC equipment authorization (USA/Canada only)

The CS475A is FCC compliant (FCC IC # M01PULS616263). Modifications to the sensor must have express agreement from Campbell Scientific. Any modifications not approved by Campbell Scientific will cause the expiration of the operating license issued by the FCC/IC. The radar sensor is in conformity with Part 15 of the FCC directives and fulfills the RSS-210 regulations.

Regulations for operation include:

- These devices must not cause any interfering emissions.
- These devices must accept any interfering emissions received, including interference that may cause unwanted operating conditions.

Limited warranty

Products manufactured by Campbell Scientific are warranted by Campbell Scientific to be free from defects in materials and workmanship under normal use and service for twelve months from the date of shipment unless otherwise specified on the corresponding product webpage. See Product Details on the Ordering Information pages at www.campbellsci.com. Other manufacturer's products, that are resold by Campbell Scientific, are warranted only to the limits extended by the original manufacturer.

Refer to www.campbellsci.com/terms#warranty for more information.

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Assistance

Products may not be returned without prior authorization.

Products shipped to Campbell Scientific require a Returned Materials Authorization (RMA) or Repair Reference number and must be clean and uncontaminated by harmful substances, such as hazardous materials, chemicals, insects, and pests. Please complete the required forms prior to shipping equipment.

Campbell Scientific regional offices handle repairs for customers within their territories. Please see the back page for the Global Sales and Support Network or visit www.campbellsci.com/contact to determine which Campbell Scientific office serves your country.

To obtain a Returned Materials Authorization or Repair Reference number, contact your CAMPBELL SCIENTIFIC regional office. Please write the issued number clearly on the outside of the shipping container and ship as directed.

For all returns, the customer must provide a "Statement of Product Cleanliness and Decontamination" or "Declaration of Hazardous Material and Decontamination" form and comply with the requirements specified in it. The form is available from your CAMPBELL SCIENTIFIC regional office. Campbell Scientific is unable to process any returns until we receive this statement. If the statement is not received within three days of product receipt or is incomplete, the product will be returned to the customer at the customer's expense. Campbell Scientific reserves the right to refuse service on products that were exposed to contaminants that may cause health or safety concerns for our employees.

Safety

DANGER — MANY HAZARDS ARE ASSOCIATED WITH INSTALLING, USING, MAINTAINING, AND WORKING ON OR AROUND **TRIPODS, TOWERS, AND ANY ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS, ETC.** FAILURE TO PROPERLY AND COMPLETELY ASSEMBLE, INSTALL, OPERATE, USE, AND MAINTAIN TRIPODS, TOWERS, AND ATTACHMENTS, AND FAILURE TO HEED WARNINGS, INCREASES THE RISK OF DEATH, ACCIDENT, SERIOUS INJURY, PROPERTY DAMAGE, AND PRODUCT FAILURE. TAKE ALL REASONABLE PRECAUTIONS TO AVOID THESE HAZARDS. CHECK WITH YOUR ORGANIZATION'S SAFETY COORDINATOR (OR POLICY) FOR PROCEDURES AND REQUIRED PROTECTIVE EQUIPMENT PRIOR TO PERFORMING ANY WORK.

Use tripods, towers, and attachments to tripods and towers only for purposes for which they are designed. Do not exceed design limits. Be familiar and comply with all instructions provided in product manuals. Manuals are available at www.campbellsci.com. You are responsible for conformance with governing codes and regulations, including safety regulations, and the integrity and location of structures or land to which towers, tripods, and any attachments are attached. Installation sites should be evaluated and approved by a qualified engineer. If questions or concerns arise regarding installation, use, or maintenance of tripods, towers, attachments, or electrical connections, consult with a licensed and qualified engineer or electrician.

General
- Protect from over-voltage.
- Protect electrical equipment from water.
- Protect from electrostatic discharge (ESD).
- Protect from lightning.
- Prior to performing site or installation work, obtain required approvals and permits. Comply with all governing structure-height regulations.
- Use only qualified personnel for installation, use, and maintenance of tripods and towers, and any attachments to tripods and towers. The use of licensed and qualified contractors is highly recommended.
- Read all applicable instructions carefully and understand procedures thoroughly before beginning work.
- Wear a **hardhat** and **eye protection**, and take **other appropriate safety precautions** while working on or around tripods and towers.
- **Do not climb** tripods or towers at any time, and prohibit climbing by other persons. Take reasonable precautions to secure tripod and tower sites from trespassers.
- Use only manufacturer recommended parts, materials, and tools.

Utility and Electrical
- **You can be killed** or sustain serious bodily injury if the tripod, tower, or attachments you are installing, constructing, using, or maintaining, or a tool, stake, or anchor, come in **contact with overhead or underground utility lines**.
- Maintain a distance of at least one-and-one-half times structure height, 6 meters (20 feet), or the distance required by applicable law, **whichever is greater**, between overhead utility lines and the structure (tripod, tower, attachments, or tools).
- Prior to performing site or installation work, inform all utility companies and have all underground utilities marked.
- Comply with all electrical codes. Electrical equipment and related grounding devices should be installed by a licensed and qualified electrician.
- Only use power sources approved for use in the country of installation to power Campbell Scientific devices.

Elevated Work and Weather
- Exercise extreme caution when performing elevated work.
- Use appropriate equipment and safety practices.
- During installation and maintenance, keep tower and tripod sites clear of un-trained or non-essential personnel. Take precautions to prevent elevated tools and objects from dropping.
- Do not perform any work in inclement weather, including wind, rain, snow, lightning, etc.

Maintenance
- Periodically (at least yearly) check for wear and damage, including corrosion, stress cracks, frayed cables, loose cable clamps, cable tightness, etc. and take necessary corrective actions.
- Periodically (at least yearly) check electrical ground connections.

Internal Battery
- Be aware of fire, explosion, and severe-burn hazards.
- Misuse or improper installation of the internal lithium battery can cause severe injury.
- Do not recharge, disassemble, heat above 100 °C (212 °F), solder directly to the cell, incinerate, or expose contents to water. Dispose of spent batteries properly.

WHILE EVERY ATTEMPT IS MADE TO EMBODY THE HIGHEST DEGREE OF SAFETY IN ALL CAMPBELL SCIENTIFIC PRODUCTS, THE CUSTOMER ASSUMES ALL RISK FROM ANY INJURY RESULTING FROM IMPROPER INSTALLATION, USE, OR MAINTENANCE OF TRIPODS, TOWERS, OR ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS, ETC.

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