INSTRUCTION MANUAL

CS475, CS476, and CS477
Radar Water Level Sensors

Revision: 5/17

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- Prior to performing site or installation work, obtain required approvals and permits. Comply with all governing structure-height regulations, such as those of the FAA in the USA.
- 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, 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.

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.

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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CS475, CS476, and CS477 Radar Water Level Sensor

1. Introduction

The CS475, CS476, and CS477 are radar-ranging sensors that monitor the water level of rivers, lakes, tidal seas, and reservoirs. They output a digital SDI-12 signal to indicate distance and stage. Many of our dataloggers can read the SDI-12 signal.

NOTE

This manual provides information only for CRBasic dataloggers. It is also compatible with most of our retired Edlog dataloggers. For Edlog datalogger support, see an older manual at *www.campbellsci.com/old-manuals*.

2. Precautions

- READ AND UNDERSTAND the *Safety* section at the front 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.

- Depending on the model, the emitting frequencies of these radar sensors are either in the C or K band range. Their low transmitting power is well below the internationally permitted limits. When used correctly, the radar sensors present no danger to people.

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

- Care should be taken when opening the shipping package to not damage or cut the cable jacket. If damage to the cable is suspected, contact Campbell Scientific.

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

- 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.

- It is the responsibility of the user to ensure that the sensors are maintained and functioning properly.

- The sensor is designed for safe operations in accordance with the current technical, safety, and ANSI standards.

3.   Initial Inspection

When unpacking the equipment, do the following:

- Unpack the unit in a clean, dry area.

- Inspect the equipment for any damage that occurred during shipping or storage.

- If the equipment is damaged, file a claim against the carrier and report the damage in detail.

4.   QuickStart

Short Cut is an easy way to program your datalogger to measure the sensor and assign datalogger wiring terminals. *Short Cut* is available as a download on *www.campbellsci.com* and the *ResourceDVD*. It is included in installations of *LoggerNet*, *PC200W*, *PC400*, or *RTDAQ*. The following procedure shows using *Short Cut* to program the CS475 series.

1.   Open Short Cut and select **New Program.**
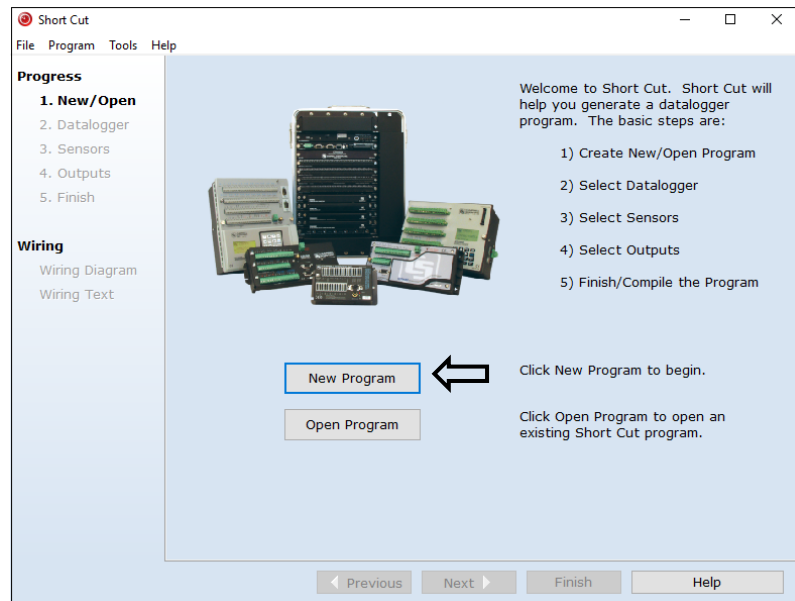
2. Select **Datalogger Model** and **Scan Interval** (default of **10** seconds is OK for most applications). Click **Next**.
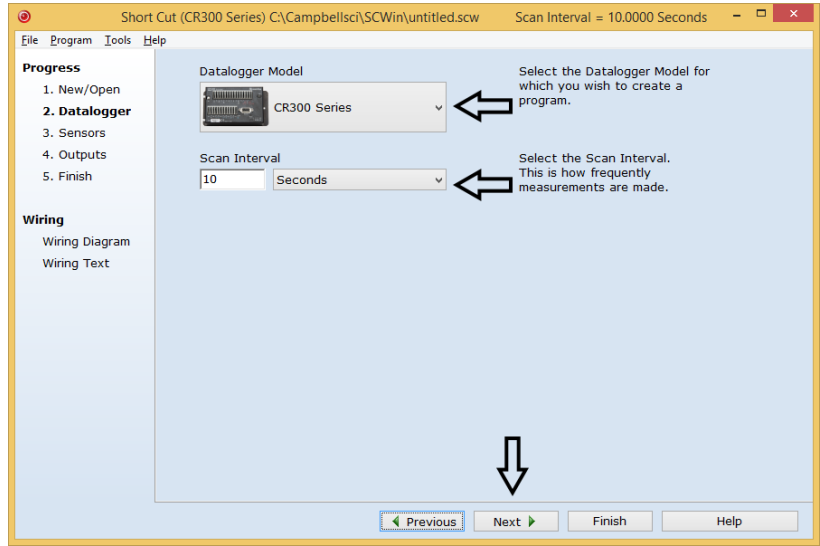
3. Under the **Available Sensors and Devices** list, select the **Sensors | Water | Level & Flow** folder. Select **CS475/CS476/CS477 Radar Water Level Sensor**, click to move the selection to the **Selected** device window. **SDI-12 Address** defaults to 0. Enter the correct **SDI-12 Address** for the radar sensor if it has been changed from the factory-set default value.
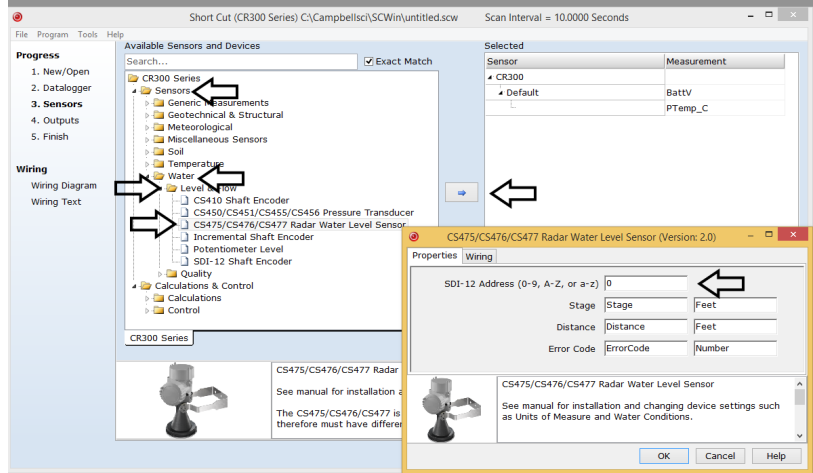
4. After selecting the sensor, click **Wiring Diagram** to see how the sensor is to be wired to the datalogger. The wiring diagram can be printed now or after more sensors are added.
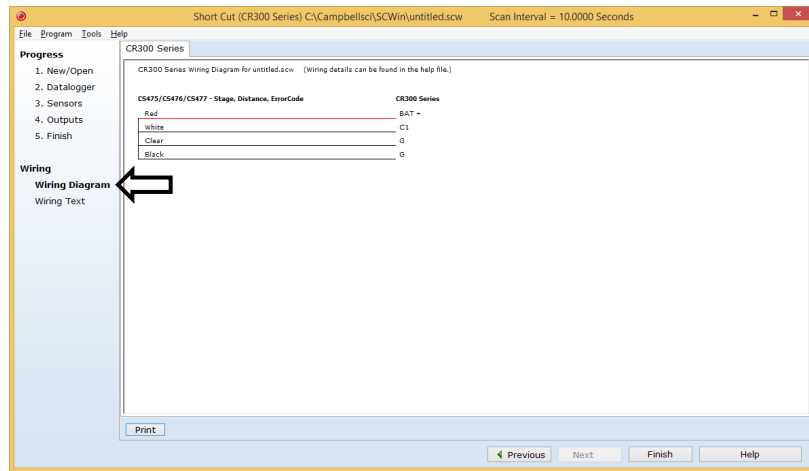
| CAUTION | Wire the sensor in this order: white, clear, red, black. |

5. Select any other sensors you have, then finish the remaining *Short Cut* steps to complete the program. The remaining steps are outlined in *Short Cut Help*, which is accessed by clicking on **Help** | **Contents** | **Programming Steps**.

6. If *LoggerNet*, *PC400*, or *PC200W* is running on your PC, and the PC to datalogger connection is active, you can click **Finish** in *Short Cut* and you will be prompted to send the program just created to the datalogger.

7. If the sensor is connected to the datalogger, as shown in the wiring diagram in step 4, check the output of the sensor in the datalogger support software data display to make sure it is making reasonable measurements.

5.   Overview

The CS475, CS476, and CS477 emit short microwave pulses and measure 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.

These radar sensors output a digital SDI-12 signal to indicate distance and stage. This output is acceptable for recording devices with SDI-12 capability including Campbell Scientific dataloggers.

Three sensor models are available that differ in their measurement range and accuracy (FIGURE 5-1). The CS475 can measure distances up to 65 feet with an accuracy of ±0.2 inches; the CS476 can measure up to 98 feet with an accuracy of ±0.1 inches; and the CS477 can measure up to 230 feet with an accuracy of ±0.6 inches.

FIGURE 5-1. CS475, CS476, and CS477

5.1   Components and Hardware

The radar sensor consists of an integrated microwave transmitter and sensor together with a horn antenna (see FIGURE 5-2 and TABLE 5-1). 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 datalogger.
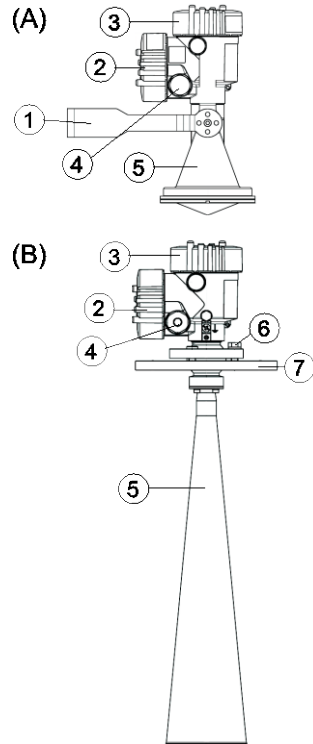
FIGURE 5-2. *Components and hardware (see TABLE 5-1 for description of labels)*

TABLE 5-1. Description of Components and Hardware Labels	
(A)	CS475
(B)	CS476 or CS477
1	Mounting Loop
2	PULS Housing Side Cap
3	PULS Housing Cap
4	PULS Unit Secondary 1/2" NPT Cable Port, Primary Port on Opposite Side
5	PULS Instrument Horn
6	5/8" Hex Head Cap Screw and Lock Washer
7	Swivel Mounting Flange

6.   Specifications

Features:
- FCC compliant
- Ideal for areas where submersed sensors can be damaged due to corrosion, contamination, flood-related debris, lightning, or vandalism
- Low maintenance—no moving parts significantly reduces maintenance cost and time
- Low power consumption
- Rugged enough for harsh environments—NEMA rated 4X
- Individual FCC license not required
- Compatible with Campbell Scientific dataloggers CR200(X) series, CR300 series, CR6 series, CR800 series, CR1000, CR3000, and CR5000

Measurement Range (see FIGURE 6-1)

CS475:	50 mm to 20 m (2 in to 65 ft)
CS476:	50 mm to 30 m (2 in to 98 ft)
CS477:	400 mm to 70 m (16 in to 230 ft)
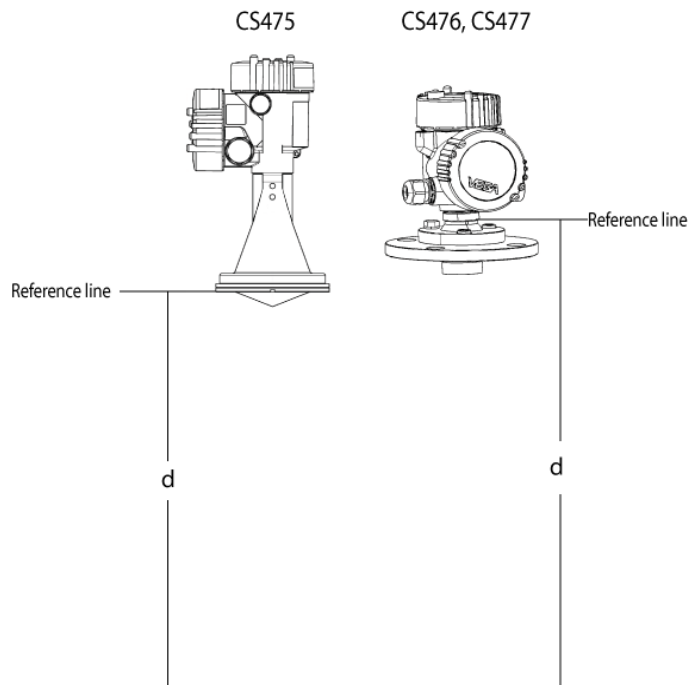
FIGURE 6-1.   Reference line for measurement range

Accuracy

CS475:	±5 mm (±0.2 in)
CS476:	±3 mm (±0.1 in)
CS477:	±15 mm (±0.6 in)

Resolution: 1 mm (0.0033 ft)

Output Protocol: SDI-12

6.1   Radar Unit

Frequency:	~26 GHz
Electromagnetic Compatibility:	Emission to EN 61326; Electrical Equipment Class B
Pulse Energy:	1 mW maximum

Beam Angle
CS475:	10° (3-in dia horn)
CS476, CS477:	8° (4-in dia horn)

Power Requirements
Input Voltage:	9.6 to 16 Vdc
Surge Protection:	1.5 kVA

Typical Current Drain with 12 V Power Supply
Sleeps:	4.7 mA
Measurement:	14 mA

6.2   Environmental

Operating Temperature Range:	–40 to 80 °C

Storage Ranges
Temperature:	–40 to 80 °C
Relative Humidity:	20% to 80% RH

Temperature Sensitivity:	average TK: 2 mm/10 K, max 5 mm over the entire temperature range of –40 to 80 °C
Vibration Resistance:	Mechanical vibrations with 4 g and 5 to 100 Hz

6.3   Physical

See FIGURE 6-2 and FIGURE 6-3 for dimensions.

Rating:	NEMA 4x
Housing Material:	Aluminum, coated IP66/68
Horn Material:	316L stainless steel

Weight
CS475:	2 kg (4 lb)
CS476/CS477:	4.3 kg (9.4 lb)
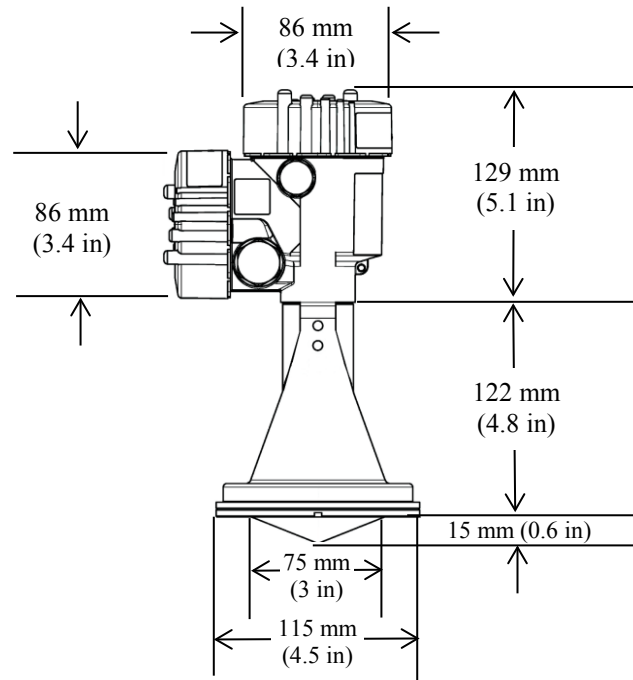
FIGURE 6-2. CS475 dimensions
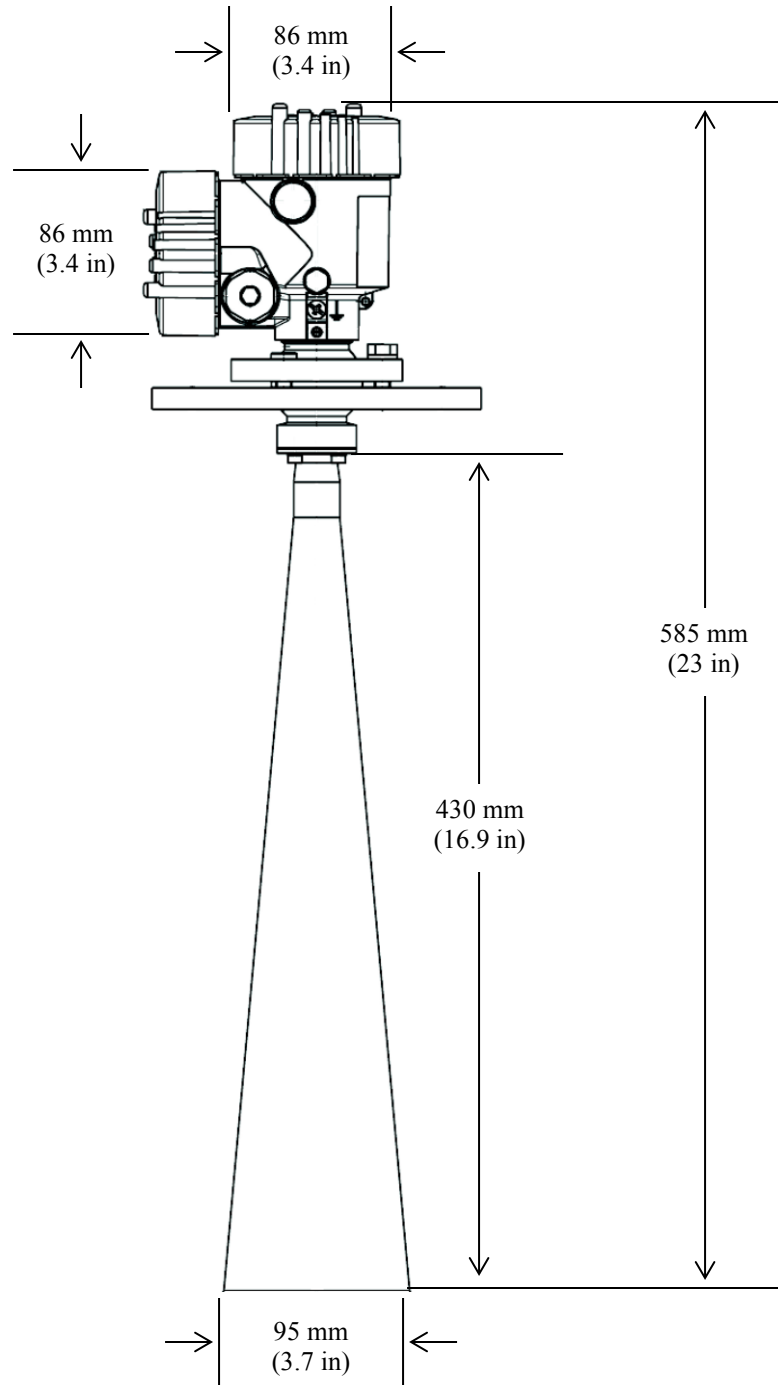
FIGURE 6-3. CS476/CS477 dimensions

7. Installation

If you are programming your datalogger with *Short Cut*, skip Section 7.3, *Wiring to Datalogger (p. 14)*, and Section 7.4, *Datalogger Programming (p. 14)*. *Short Cut* does this work for you. See Section 4, *QuickStart (p. 2)*, for a *Short Cut* tutorial.

7.1 Site Selection

1. 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.**

2. 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.

3. 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 Learn* command to map out the interfering structures in the beam profile (see Appendix C.1.3, *Start False Echo Learn (p. C-3)*).

4. Center the sensor beam a minimum of 2.5 m from any obstruction in the measurement range. Obstructions to be aware of include excessive waves, splashing, pipes, wires, and logs. The radiation beam spreads as it leaves the sensor (see TABLE 7-1 and TABLE 7-2).

NOTE	Usually the beam path is 10° for the CS475, and 8° for the CS476/CS477.

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

6. Do not install the sensor where submerged obstructions such as rocks or bridge piers can distort or disturb water level.

7.2 Mount and Align the Sensor

1. Choose an appropriate site away from obstructions and over the smoothest part of the water (see Section 7.1, *Site Selection (p. 11)*).

2. Center the sensor beam a minimum of 2.5 m from any obstruction in the measurement range. Obstructions can include excessive waves, splashing,

pipes, wires, and logs. The radiation beam spreads as it leaves the sensor (see TABLE 7-1 and TABLE 7-2).

| **NOTE** | Usually the beam path is 10° for the CS475, and 8° for the CS476/CS477. |

TABLE 7-1. Radiation Beam Spread for CS475 (10° Beam Angle)	
Distance in Meters	**Diameter of Footprint in Meters**
1	0.18
5	0.87
10	1.76
15	2.64
20	3.53

TABLE 7-2. Radiation Beam Spread for CS476/CS477 (8° Beam Angle)	
Distance in Meters	**Diameter of Footprint in Meters**
1	0.14
5	0.70
10	1.41
15	2.11
20	2.81
30	4.216
70 (CS477 only)	9.84

3. Securely mount the sensor.

4. Use a user-supplied bubble level or the 25619 bubble level to make certain the antenna horn is aligned within 1° of vertical. The cap needs to be removed when using the 25619. If the antenna is not vertical, a trigonometric measurement error can occur with respect to the water. The maximum range is reduced because of the off-axis return signal.

5. Orient the sensor such that one of its polarization markings is aligned with the wall or pier (see FIGURE 7-1 and TABLE 7-3).
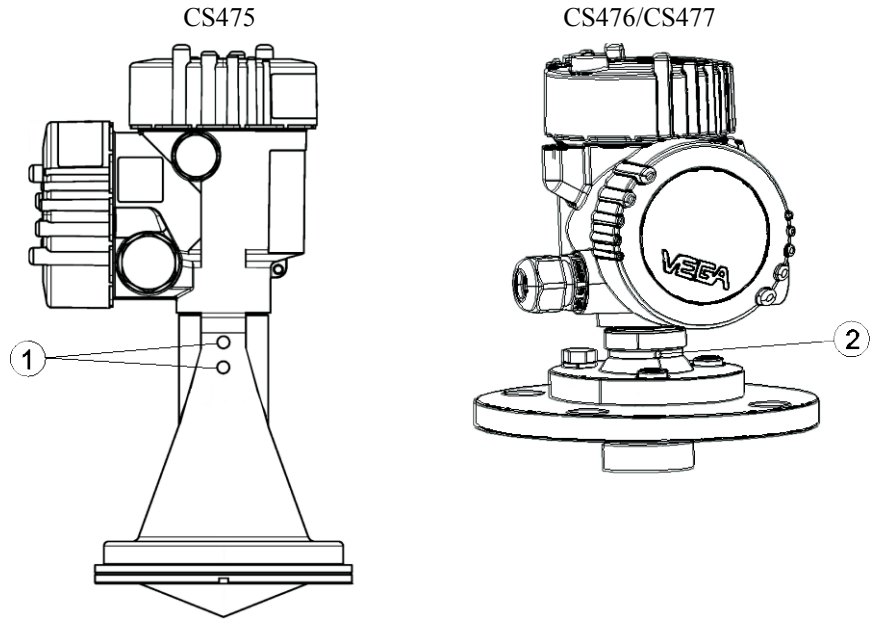
FIGURE 7-1. Polarization markings (see TABLE 7-3 for label descriptions)

TABLE 7-3. Description of Polarization Markings Labels		
	Sensor	**Description**
1	CS475	Polarization marks are designated by the mounting loop screws.
2	CS476/CS477	Polarization mark is machine-tooled.

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

1. Loosen the set screw on the housing.

2. Rotate the housing as desired.

3. Tighten the set screw.

7.3   Wiring to Datalogger

Connections to Campbell Scientific dataloggers are given in TABLE 7-4.

CAUTION	Connect the wires in the order shown in TABLE 7-4.

TABLE 7-4. Wire Color, Function, and Datalogger Connection

Wire Color	Wire Function	Datalogger Connection
White	SDI-12 Signal	**Control Port**[1] or **U** configured for SDI-12[2]
Clear	Shield	**G**
Red	Power	**12V**
Black	Power Ground	**G**

[1] Dedicated SDI-12 port on CR5000.
[2] U channels are automatically configured by the measurement instruction.

To use more than one probe per datalogger, you can either connect the different probes to different SDI-12 compatible ports on the datalogger or change the SDI-12 addresses of the probes and let them share the same connection. Using the SDI-12 address minimizes the use of ports on the datalogger and also allows probes to be connected in a daisy-chain fashion which can minimize cable runs in some applications.

7.3.1 Built-in Self Test (BIST)

After connecting the sensor to the datalogger's power terminals, the sensor performs a BIST (built-in self test) for approximately 80 seconds (factory default). During this self-check, an internal check of the electronics occurs.

7.4   Datalogger Programming

Short Cut is the best source for up-to-date datalogger programming code. Programming code is needed when:

- Creating a program for a new datalogger installation
- Adding sensors to an existing datalogger program

If your data acquisition requirements are simple, you can probably create and maintain a datalogger 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 Section 4, *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 Appendix A, *Importing Short Cut Code Into*

CRBasic Editor (p. A-1). Programming basics for CRBasic dataloggers are provided in the following sections. A complete program example can be found in Appendix B, *Example Program (p. B-1)*.

7.4.1 SDI12Recorder() Instruction

Use the **SDI12Recorder()** measurement instruction to program the datalogger to measure the sensor. This instruction sends a request to the sensor to make a measurement and then retrieves the measurement from the sensor. See Section 8.2, *Sensor Measurement (p. 16)*, for more information.

When using a CR200(X), the **SDI12Recorder()** instruction has the following form:

```
SDI12Recorder(Destination, OutString, Multiplier, Offset)
```

For the other CRBasic dataloggers, the **SDI12Recorder()** instruction has the following form:

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

The Destination parameter must be an array of length three, with the first index for stage measurement (m or ft), the second for distance (m or ft), and the third for an error code (see Section 9, *Diagnostics, Repair, and Maintenance (p. 16)*). The stage measurement calculation is based on an initial water stage value; see Appendix C.1.2, *Set Water Stage (p. C-3)*, for instructions on changing the SDI-12 address through the datalogger.

Variations:

- Set **SDICommand** to *"M!"* or *"C!"*– see Section 8, *Operation (p. 15)*, to determine which is best for your application.

8. Operation

8.1 Default Settings

The default settings (TABLE 8-1) are used in most circumstances.

<table>
<tr><td colspan="2" align="center">**TABLE 8-1. Default Settings**</td></tr>
<tr><td align="center">**Setting**</td><td align="center">**Default**</td></tr>
<tr><td>SDI-12 Address</td><td>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; see Appendix C.1.1, *Query/Set the Address (p. C-2)*)</td></tr>
<tr><td>Units of Measure</td><td>1 = feet (see Appendix C.1.4, *Set Units (p. C-4)*)</td></tr>
<tr><td>Water Conditions</td><td>1 = smooth (typical peak to trough of wave ≤4 inches; see Appendix C.1.5, *Set Water Conditions (p. C-5)*)</td></tr>
<tr><td>Power Operation Mode</td><td>1 = on (sensor is always on until new power operation mode command received; see Appendix C.1.6, *Set Power Operation Mode (p. C-6)*)</td></tr>
</table>

The 25616, *Adjustment/Display Module*, or the terminal emulator in *LoggerNet* or *PC400* can be used to enter SDI-12 commands. Appendix C.2, *Using Terminal Emulator and a Datalogger to Send Commands (p. C-9)*, describes entering commands using the terminal emulator.

8.2 Sensor Measurement

CRBasic instruction **SDI12Recorder()** measures the radar sensors using the Start Measurement (**aM!**) or Concurrent Measurement (**aC!**) command. In all cases "a" is the address of the sensor and "!" is the command terminator. The factory-set SDI-12 address is 0. See Appendix C.1.1, *Query/Set the Address (p. C-2)*, for instructions on changing the SDI-12 address through the datalogger.

The sensor returns three values: stage measurement (m or ft), distance (m or ft), and error code (see Section 9, *Diagnostics, Repair, and Maintenance (p. 16)*). The stage measurement calculation is based on an initial water stage value, which is entered using the Set Water Stage Command (**aXSS+nnn.nnn!**). See Appendix C.1.2, *Set Water Stage (p. C-3)*, for instructions on changing the SDI-12 address through the datalogger.

A measurement is initiated with the **aM!** or **aC!** command. To these commands, the sensor responds with the time until the measurement data are available and the number of values to be returned when one or more subsequent **aD!** commands are issued.

When using the **aM!** command, the datalogger waits for the time specified by the sensor, sends the **aD!** command, pauses its operation, and waits until either it receives the data from the sensor or the sensor timeout expires. If the datalogger receives no response, it will send the command a total of three times, with three retries for each attempt, or until a response is received. Because of the delays this command requires, it is only recommended in measurement scans of 10 seconds or more.

The **aC!** command follows the same pattern as the **aM!** command with the exception that it does not require the datalogger to pause its operation until the values are ready. Rather, the datalogger picks up the data with the **aD!** command on the next pass through the program. Another measurement request is then sent so that data are ready on the next scan. The radar sensor's output is measured using a standard SDI-12 instruction to read the data from an SDI-12 sensor.

If using the sensor with other SDI-12 recorders, please refer to your system's documentation. Further details of the SDI-12 commands can be found in Appendix C, *SDI-12 Commands/ Changing Settings (p. C-1),* and at: *www.sdi-12.org*.

9. Diagnostics, Repair, and Maintenance

9.1 Testing Procedure

NOTE The testing procedure uses several SDI-12 commands. Detailed information about these commands are provided in Appendix C, *SDI-12 Commands/ Changing Settings (p. C-1)*.

The test procedures for the sensor require the following steps:

1. Double check all wiring connections.

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

3. Compare the Output Stage versus the Actual Stage using the Start Measurement command (**aM!**) followed by the Send Data command (**aD!**).

4. 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.

5. Send the Identification command (**aI!**).

6. Send the Start Verification command (**aV!**) followed by the Get Data command (**aD0!**).

7. Use the Get Unit command (**aXGU!**) to ensure the units are what you want.

8. Use the Get Water Condition command (**aXGWC!**) to ensure that the water condition fit the body of water you are monitoring.

9. Use the Get Power Operation Mode command (**aXGPOM!**) to ensure that the power mode is what you want.

10. Use the False Echo Learn command (**aXSFEL+nnn.nnn!**) if you encounter a problem that could be caused by noise.

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 datalogger. 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 very good at identifying errors caused by noise in transmission channels. The **aV!** command followed by the **aD0!** command will perform a CRC and return either a 0 (OK) or 1 (failed); see Appendix C.1.10, *Start Verification Command (p. C-8)*, for more information.

9.3 Diagnostics and Repair

NOTE	All factory repairs and recalibrations require a returned material authorization (RMA) and completion of the "Declaration of Hazardous Material and Decontamination" form. Refer to the *Assistance* page at the beginning of this manual for more information.

The radar sensor is extremely reliable, but problems can occur during operation. Most of these problems are caused by the following:

- Sensor
- Environmental conditions
- Power supply
- Signal processing

When you encounter a problem with the radar sensor, check the error messages from the **aM!**, followed by the **aD0!** command to help evaluate the issue.

NOTES	1. 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.
	2. A typical response to the **aD0!** command results in a response of **108003,** where approximately 80 seconds is the required time to complete the BIST (Built In Self Test) of the instrument. After power up is complete, normal SDI-12 communication starts.

9.3.1 No Measured Value Available — Error E013

If you are unable to find a measured value, check the following:

- Sensor in boot phase

- Update the *Start False Echo Learn* (**aXSFEL**). See Appendix C.1.3, *Start False Echo Learn (p. C-3)*.

9.3.2 No Measured Value Available — Error E041, E042, E043

If you have a hardware error or have defective electronics, try cycling the power to the sensor. If the sensor recovers, no further steps are required. If the sensor does not recover, do one of the following:

- Exchange the electronics module (see Section 9.3.2.1, *Exchange Electronics Module (p. 18)*)

- Return the equipment for repair

9.3.2.1 Exchange Electronics Module

If you do not have an electronics module onsite, order one from Campbell Scientific.

The electronics module is replaced by doing the following steps (see FIGURE 9-1 and TABLE 9-1):

1. Unscrew the housing cap (cap is not shown in FIGURE 9-1).

2. Remove all wires that are attached or plugged into the electronics and note their location for reassembly.

3. Loosen the two screws securing the electronics to the housing (3 in FIGURE 9-1). These screws are captive screws and will remain nested with the electronics.

4. Gently remove the electronics from the housing (4 in FIGURE 9-1).

NOTE	Some friction is normal when removing the electronics because a seal is between the electronics and the lower portion of the housing.

5. Replace the electronics with a new module.

NOTE	Make sure the two (2) screws holding the electronics module in are tight, but do not over tighten. Over tightening these screws can strip the threads.

6. Tighten the two screws to secure the electronics to the housing (3 in FIGURE 9-1).

7. Reassemble all wires that were originally attached or plugged into the electronics.

8. Tighten the housing cap.
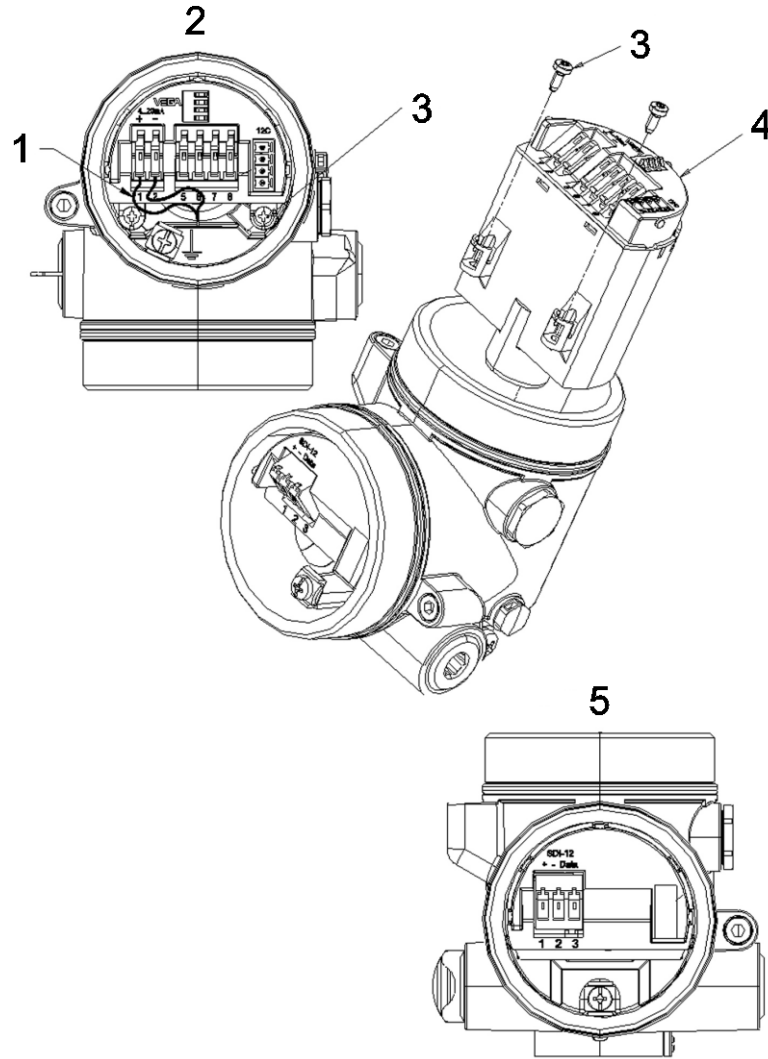
FIGURE 9-1. Changing the electronics (see TABLE 9-1 for label
descriptions)

TABLE 9-1. Description of Changing the Electronics Labels

	Description
1	Red Wire
2	Housing Top View
3	Screws to Secure Electronics to Housing
4	Electronics
5	Housing Side View

9.4   Maintenance

The sensors are maintenance free under normal operation.

Appendix A. Importing Short Cut Code Into CRBasic Editor

This tutorial shows:

- How to import a *Short Cut* program into a program editor for additional refinement

- How to import a wiring diagram from *Short Cut* into the comments of a custom program

Short Cut creates files, which can be imported into *CRBasic Editor*. Assuming defaults were used when *Short Cut* was installed, these files reside in the C:\campbellsci\SCWin folder:

- .DEF (wiring and memory usage information)
- .CR2 (CR200(X)-series datalogger code)
- .CR300 (CR300-series datalogger code)
- .CR6 (CR6-series datalogger code)
- .CR8 (CR800-series datalogger code)
- .CR1 (CR1000 datalogger code)
- .CR3 (CR3000 datalogger code)
- .CR5 (CR5000 datalogger code)

Use the following procedure to import *Short Cut* code and wiring diagram into *CRBasic Editor*.

1. Create the *Short Cut* program following the procedure in Section 4, *QuickStart (p. 2)*. Finish the program and exit *Short Cut*. Make note of the file name used when saving the *Short Cut* program.

2. Open *CRBasic Editor*.

3. Click **File | Open**. Assuming the default paths were used when *Short Cut* was installed, navigate to C:\CampbellSci\SCWin folder. The file of interest has the .CR2, .CR300, .CR6, .CR8, .CR1, .CR3, or .CR5 extension. Select the file and click **Open**.

4. Immediately save the file in a folder different from C:\Campbellsci\SCWin, or save the file with a different file name.

NOTE	Once the file is edited with *CRBasic Editor*, *Short Cut* can no longer be used to edit the datalogger program. Change the name of the program file or move it, or *Short Cut* may overwrite it next time it is used.

5. The program can now be edited, saved, and sent to the datalogger.

6. Import wiring information to the program by opening the associated .DEF file. Copy and paste the section beginning with heading "-Wiring for CRXXX–" into the CRBasic program, usually at the head of the file. After pasting, edit the information such that an apostrophe (') begins each line. This character instructs the datalogger compiler to ignore the line when compiling.

Appendix B. Example Program

CRBasic Example B-1. CR1000 Program Measuring the CS475

```
'CR1000 Series Datalogger

'Declare the variable for the water level measurement

Public CS475(3)

'Rename the variable names
Alias CS475(1)=Stage
Alias CS475(2)=Distance
Alias CS475(3)=Error_Code

'Define a data table for 60 minute maximum and minimums
DataTable (Hourly,True,-1)
  DataInterval(0,60,Min,10)
  Maximum(1,Distance,FP2,0,0)
  Minimum(1,Distance,FP2,0,0)
  Average(1,Distance,FP2,False)
  StdDev(1,Distance,FP2,False)
  Maximum(1,Stage,FP2,0,0)
  Minimum(1,Stage,FP2,0,0)
  Average(1,Stage,FP2,False)
  StdDev(1,Stage,FPs,False)
  Sample(1,Error_Code,UINT2)
EndTable

'Read sensor every 60 seconds
BeginProg
  Scan(60,sec,1,0)

    'Code for SDI-12 measurements:
    SDI12Recorder(CS475,1,0,"M!",1,0)

    'Call the data table:
    CallTable(Hourly)

NextScan

EndProg
```

Appendix C. SDI-12 Commands/ Changing Settings

The SDI-12 commands are entered using the 25616, *Adjustment/Display Module*, or the terminal emulator in *LoggerNet* or *PC400* (see Appendix C.2, *Using Terminal Emulator and a Datalogger to Send Commands (p. C-9)*). These commands are also used in CRBasic or Edlog programming (see Section 7.4, *Datalogger Programming (p. 14)*).

SDI-12 commands have three components:

- *Sensor address (a)* – a single ASCII character, and is the first character of the command. The sensor address allows multiple sensors to be connected to a single control port. The default address is zero, and typically is only changed when multiple sensors are connected to the same port. Valid addresses are 1 to 9, A to Z, or a to z.

- *Command body (e.g., M1)* – an upper case letter (the "command") followed by alphanumeric qualifiers.

- *Command termination (!)* – an exclamation mark.

An active sensor responds to each command. Responses have several standard forms and terminate with <CR><LF> (carriage return – line feed). SDI-12 commands supported by the radar sensors are listed in TABLE C-1.

TABLE C-1. SDI-12 Commands	
Function	**SDI-12 Command**
Address Query	**?!**
Send Identification	**aI!**
Acknowledge Active	**a!**
Change Address	**aAb!** Where a is the current address and b is the new address.
Start Verification	**aV!**
Start Measurement	**aM!**
Start Measurement and Request CRC	**aMC!**
Send Data	**aD0!...aD9!**
Additional Measurements	**aM1!...aM9!**
Additional Measurement and Request CRC	**aMC1!...aMC9!**
Start Concurrent Measurement	**aC!**

Start Concurrent Measurement and Request CRC	**aCC!**
Additional Concurrent Measurements	**aC1!...aC9!**
Additional Concurrent Measurements and Request CRC	**aCC1!...aCC9!**
Start False Echo Learn	**aXSFEL+n.nnn!** *n* = distance necessary to clear the obstruction
Set Power n Operation Mode	**aXSPOM+n!** *n* = 2 (auto), 1 (on), or 0 (off)
Get Power Operation Mode[1]	**aXGPOM!** 2 = auto; 1=on; 0=off
Set Water Conditions[1]	**aXSWC+n!** n = 0 (custom), 1 (smooth) 2 (medium), or 3 (rough) Where n is the new water condition.
Get Water Conditions[1]	**aXGWC!** n = 0 (custom), 1 (smooth) 2 (medium), or 3 (rough)
Set Water Stage[1]	**aXSS+n.nnn!** n = floating point number that is the initial stage or level of the water surface above the reference. Where n is the new water stage.
Get Unit[1]	**aXGU!** 0 = meters; 1=feet
Set Unit	**aXSU+n!** n = 0 (meters) or 1 (feet) Where n is the new unit of measurement.

[1]Must follow each **Get** or **Set** command with the **aD0!** command to retrieve the results**.**

C.1 SDI-12 Command Descriptions

C.1.1 Query/Set the Address

Valid addresses are 0 to 9; A through Z; and a through z. The factory default address is set to 0. The address can be verified by sending the sensor the *Address Query* command (see TABLE C-2).

TABLE C-2. SDI-12 Command for Querying the Address	
Initial Command	**Response**
?!	**a\<cr\>\<lf\>** Where a is the current address of the sensor.

Change the sensor's address by sending the sensor the **aAb!** command, where "a" is the original address and "b" is the new address. TABLE C-3 shows an example of the command and response for setting the address.

TABLE C-3. Example of Setting Address	
Initial Command	**Response**
0A1! Where 0 is the original address and 1 is the new address.	**1\<cr>\<If>** The new address (1) is set in response.

C.1.2 Set Water Stage

With the *Set Water Stage* command, you enter the initial depth of the water, and the sensor will automatically measure the distance between the sensor and the water surface. The water stage setting and the initial distance measurement are used to calculate subsequent water stage measurements. Correct stage measurements require that the water stage setting be in the same units as the Units of Measure setting. You can find out if the sensor is set to meters or feet by using the **aXGU!** (*Get Unit*) command.

To set the water stage, do an **aXSS+nnn.nnn!** command (where nnn.nnn = the initial water depth) followed by the **aD0!** (*Send Data*) command. TABLE C-4 shows an example of the command and response for entering this setting.

TABLE C-4. Example for Setting Water Stage	
Initial Command	**Response**
0XSS+7.010! Where (from left to right), 0—sensor's address; 7.010—the initial water depth value used to calculate subsequent stage measurements.	**00011\<cr>\<If>** Where (from left to right), 0—sensor's address; 001—the amount of time (in seconds) that you must wait before sending the send data command; 1—the number of values that will be placed in the buffer.
Subsequent Command	**Command Response**
0D0! Where the first zero is the sensor address. This is the send data command.	**0+7.010\<cr>\<If>** Where (from left to right), 0—sensor's address; 7.010—the initial water depth value used to calculate subsequent stage measurements.

C.1.3 Start False Echo Learn

The *Start False Echo Learn* command is an essential function during the startup of the sensor. It is also used during testing if a problem is encountered. The command allows the unit to learn about false echoes (noise) in the area. With the *False Echo Learn* command, you enter the actual distance to the water surface, as measured in meters or feet, depending on the unit setting. The

radar sensor then emits the short microwave pulses. Any echo occurring 0.5 m (1.6 ft) short of the distance you entered will be considered noise.

To start *False Echo Learn*, do the **aXSFEL+nnn.nnn!** command (where nnn.nnn = the actual distance to the water) followed by the **aD0!** (*Send Data*) command. TABLE C-5 shows an example of the command and response.

<table>
<tr><td colspan="2" align="center">TABLE C-5. Example of a Start False Echo Learn Command</td></tr>
<tr><td align="center">Initial Command</td><td align="center">Response</td></tr>
<tr><td>0XSFEL+2.500!
Where (from left to right),
0—sensor's address;
2.500—the water surface distance.</td><td>02001<cr><lf>
Where (from left to right),
0—sensor's address;
200—the amount of time (in seconds) that you must wait before sending the send data command;
1—the number of values that will be placed in the buffer.</td></tr>
<tr><td align="center">Subsequent Command</td><td align="center">Response</td></tr>
<tr><td>0D0!
Where the first zero is the sensor address.
This is the send data command.</td><td>0+2.500<cr><lf>
Where (from left to right),
0—sensor's address;
2.500—the water surface distance.</td></tr>
</table>

C.1.4 Set Units

The distance measurement can be reported in feet (default) or meters. Change the units by first using the **aXSU+n!** command (where n = 1 (feet) or 0 (meters)) followed by the **aXGU!** (*Get Units*) command. TABLE C-6 shows an example of the command and response for changing this setting.

<table>
<tr><td colspan="2" align="center">TABLE C-6. Example of Setting and Getting Units</td></tr>
<tr><td align="center">Initial Command</td><td align="center">Response</td></tr>
<tr><td>0XSU+0!
Where the first zero is the sensor address and the second zero sets the units to meters.</td><td>00011<cr><lf>
Where (from left to right),
0—sensor's address;
001—the amount of time (in seconds) that you must wait before sending another command;
1—the number of values that will be placed in the buffer.</td></tr>
<tr><td align="center">Subsequent Command</td><td align="center">Response</td></tr>
<tr><td>0D0! 0+0<cr><lf>
Where the first and third zero is the sensor's address and the fourth zero indicates the units to meters</td><td>0+0<cr><lf>
Where the first zero is the sensor address and the second zero indicates that the units are now meters.</td></tr>
</table>

Initial Command	Response
0XGU! Where zero is the sensor address. This is the get units command	**00011\<cr>\<lf>** Where (from left to right), 0—sensor's address; 001—the amount of time (in seconds) that you must wait before sending another command; 1—the number of values that will be placed in the buffer.
Subsequent Command	**Response**
0D0! Where the first zero is the sensor's address.	**0+0\<cr>\<lf>** Where the first zero is the sensor address and the second zero indicates that the units are meters.

C.1.5 Set Water Conditions

The *Set Water Conditions* command adapts the sensor to different water conditions.

There are four different settings:

- 1 (smooth—typical peak to trough of wave < 4")

- 2 (medium—typical peak to trough of wave < 8")

- 3 (rough—typical peak to trough of wave > 8")

The factory default water conditions are set to 1, which is smooth. The water condition settings should closely mimic the actual water conditions during normal river flow.

Change this setting by first using the **aXSWC+n!** command (where n = 1 (smooth), 2 (medium), or 3 (rough)) followed by the **aXGWC!** (*Get Water Conditions*) command. TABLE C-7 shows an example of the command and response for changing this setting.

TABLE C-7. Example for Setting and Getting Water Conditions	
Initial Command	**Response**
0XSWC+2! Where, 0—sensor's address; 2—the new water condition setting (2 = medium).	**00011\<cr>\<lf>** Where (from left to right), 0—sensor's address; 001—the amount of time (in seconds) that you must wait before sending another command; 1—the number of values that will be placed in the buffer.

Subsequent Command	Response
0D0! Where the first zero is the sensor's address.	**0+2\<cr>\<lf>** Where, 0—sensor's address; 2—the new water condition setting (2 = medium).
Initial Command	**Response**
0XGWC! Where zero is the sensor address. This is the send water conditions command.	**00011\<cr>\<lf>** Where (from left to right), 0—sensor's address; 001—the amount of time (in seconds) that you must wait before sending another command; 1—the number of values that will be placed in the buffer.
Subsequent Command	**Response**
0D0! Where the first zero is the sensor's address.	**0+2\<cr>\<lf>** Where, 0—sensor's address; 2—the water condition setting (2 = medium).

C.1.6 Set Power Operation Mode

The following three power operation modes are available:

- 1 (ON—sensor is always on until a new set power command is received.)

- 2 (AUTO—sensor is powered by an incoming request from the SDI-12 bus and sends back a response including the information on power up time.)

- 0 (OFF—this mode is typically not recommended; sensor is completely off until a new set power command is received)

CAUTION

The OFF power mode should only be used by advanced users who want to turn the sensor off for extended time periods. In this mode, the sensor is completely off and only responds to a new set power command.

The factory default Power Operation Mode is 1 (ON). In this mode of operation, the instrument is continuously making measurements and draws approximately 13.5 mA. The AUTO Power Operation Mode puts the instrument in quiescent mode between measurement request queries.

Change this setting by first using the **aXSPOM+n!** command (where n=1 (on), 2 (auto), or 0 (off)) followed by the **aXGPOM!** (*Get Power Mode*) command. TABLE C-8 shows an example of the command and response for changing this setting.

TABLE C-8. Example for Setting and Getting Power Operation Mode

Initial Command	Response
0XSPOM+2! Where, 0—sensor's address; 2—the new power mode setting (2 = auto).	**00011\<cr>\<lf>** Where (from left to right), 0—sensor's address; 001—the amount of time (in seconds) that you must wait before sending another data command; 1—the number of values that will be placed in the buffer.
Subsequent Command	**Response**
0D0! Where the first zero is the sensor's address.	**0+2\<cr>\<lf>** Where, 0—sensor's address; 2—the new power mode setting (2 = auto).
Initial Command	**Response**
aXGPOM! Where zero is the sensor address. This is the get power mode command.	**00011\<cr>\<lf>** Where (from left to right), 0—sensor's address; 001—the amount of time (in seconds) that you must wait before sending another data command; 1—the number of values that will be placed in the buffer.
Subsequent Command	**Response**
0D0! Where the first zero is the sensor's address.	**0+2\<cr>\<lf>** Where, 0—sensor's address; 2—the power mode setting (2 = auto).

C.1.7 Acknowledge Active Command

The Acknowledge Active command is used to check the presence of the sensor on the bus (see TABLE C-9).

TABLE C-9. Acknowledge Active Command

Initial Command	Response
a!	**a\<cr>\<lf!>** Only the address is sent back in response.

C.1.9 Send Identification Command

The **aI!** command gets the following identification information in response to sending **aI!** (see TABLE C-10).

- Compatibility level: Version of SDI-12 protocol version; for example, 1.3.

- Manufacturer's Name: VEGA

- Manufacturer's Model Number: PS61 (CS475), PS62 (CS476), or PS63 (CS477)

- Three Digit Firmware Version Number.

- Eight Digit Serial Number of Sensor.

TABLE C-10. Send Identification Command	
Initial Command	**Response**
aI!	**a13VEGAbbbbPS6233212345678\<cr>\<If>** Where (from left to right), a—sensor address; 13—SDI-12 compatibility number; VEGA = Manufacturer's Name; PS62 = Manufacturer's Model Number; 3.32 = Sensor Version Number; Serial Number = 12345678.

C.1.10 Start Verification Command

The **aV!** command requests three verification values from the sensor. This command is always followed by the **aD0!** (*Send Data*) command.

The verification values that will be returned are:

- CRC check (error check)—values are 0 (OK) or 1 (failed)

- SDI-12 Radar firmware version number

- HART Sensor firmware version

TABLE C-11 shows an example of checking the CRC.

TABLE C-11. Checking CRC Example	
Initial Command	**Response**
0V! Where 0 is the sensor's address.	**00013\<cr>\<lf>** Where (from left to right), 0—sensor's address; 001—the amount of time (in seconds) that you must wait before sending the send data command; 3—the number of values that will be placed in the buffer.
Subsequent Command	**Response**
0D0! Where the first zero is the sensor's address.	**0+0+1610000+3320000\<cr>\<lf>** Where (from left to right), 0—sensor's address; 0—CRC check (0 = OK); 1610000—adapter version (1.61.00.00); 3320000—sensor version (3.32.00.00).

C.2 Using Terminal Emulator and a Datalogger to Send Commands

Commands can be sent to the sensor by connecting the sensor to an SDI-12 compatible central port on a datalogger and use the SDI-12 transparent mode.

C.2.1 SDI-12 Transparent Mode

System operators can manually interrogate and enter settings in probes using transparent mode. Transparent mode is useful in troubleshooting SDI-12 systems because it allows direct communication with probes. Datalogger security may need to be unlocked before transparent mode can be activated.

Transparent mode is entered while the PC is in telecommunications with the datalogger through a terminal emulator program. It is easily accessed through Campbell Scientific datalogger support software, but is also accessible with terminal emulator programs such as Windows HyperTerminal. Datalogger keyboards and displays cannot be used.

The terminal emulator is accessed by navigating to the Datalogger menu in *PC200W*, the Tools menu in *PC400*, or the Datalogger menu in the Connect screen of *LoggerNet*.

The following examples show how to use *LoggerNet* software to enter transparent mode and change the SDI-12 address of a sensor. The same steps are used to enter transparent mode with *PC200W* and *PC400* software after accessing the terminal emulator as previously described.

C.2.2   CR200(X) Series Datalogger Example

1. Connect a single sensor to the datalogger as follows:

    - White to Control Port C1/SDI12

    - Black, Clear to G

    - Red to Battery +

2. In the *LoggerNet Connect* screen navigate to the Datalogger menu and select Terminal Emulator. The "Terminal Emulator" window will open. In the Select Device menu, located in the lower left-hand side of the window, select the CR200Series station.

3. Click on the Open Terminal button.

4. Press the <enter> key until the datalogger responds with the "**CR2XX>**" prompt. At the "**CR2XX>**" prompt, make sure the All Caps Mode box is checked and enter the command **SDI12** <enter>. The response "SDI12>" indicates that the sensor is ready to accept SDI-12 commands.

5. To query the sensor for its current SDI-12 address, key in ?! <enter> and the sensor will respond with its SDI-12 address. If no characters are typed within 60 seconds, then the mode is exited. In that case, simply enter the command SDI12 again and press <enter>.
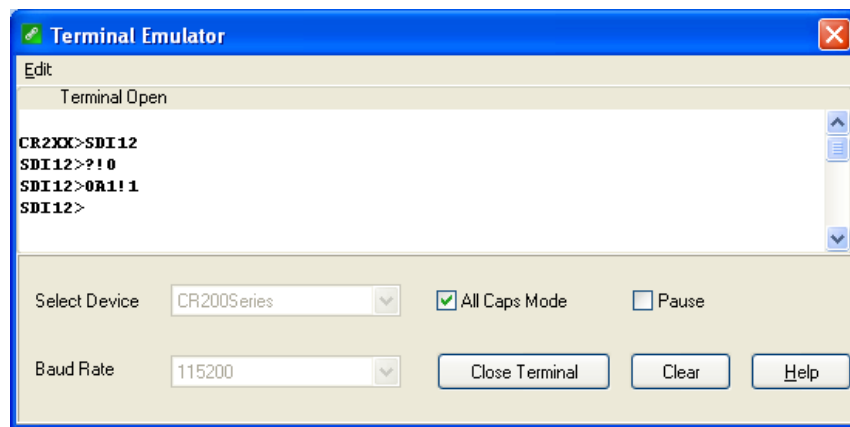

FIGURE C-1. SDI-12 transparent mode on CR200(X)-series datalogger using control port C1/SDI12 and changing SDI-12 address from 0 to 1

6. To change the SDI-12 address, key in **aAb!<enter>** where *a* is the current address from the above step and *b* is the new address. The sensor will change its address and the datalogger will respond with the new address. To exit SDI-12 transparent mode select the Close Terminal button.

C.2.3 CR1000 Datalogger Example

1. Connect a single sensor to the datalogger as follows:

    -   White to Control Port C1

    -   Black, Clear to G

    -   Red to 12V

2. In the *LoggerNet Connect* screen navigate to the Datalogger menu and select Terminal Emulator. The "Terminal Emulator" window will open. In the Select Device menu, located in the lower left-hand side of the window, select the CR1000 station.

3. Click on the Open Terminal button.

4. Press the <enter> key until the datalogger responds with the "**CR1000>**" prompt. At the "**CR1000>**" prompt, make sure the All Caps Mode box is checked and enter the command **SDI12** <enter>. At the "Enter Cx Port 1, 3, 5, or 7" prompt, key in the control port number where the sensor's white lead is connected and <enter>. The response "Entering SDI12 Terminal" indicates that the sensor is ready to accept SDI-12 commands.

5. To query the sensor for its current SDI-12 address, key in ?! <enter> and the sensor will respond with its SDI-12 address. If no characters are typed within 60 seconds, then the mode is exited. In that case, simply enter the command SDI12 again, press <enter>, and key in the correct control port number when prompted.
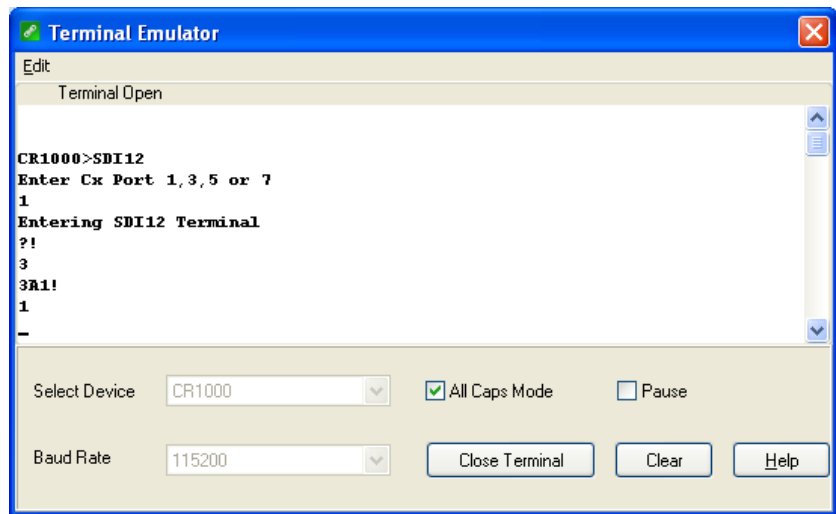

FIGURE C-2. SDI-12 transparent mode on CR1000 datalogger using control port 1 and changing SD1-12 address from 3 to 1

6. To change the SDI-12 address, key in **aAb!<enter>** where *a* is the current address from the above step and *b* is the new address. The sensor will change its address and the datalogger will respond with the new address. To exit SDI-12 transparent mode, press the Esc key or wait for the 60 second timeout, then select the Close Terminal button.

Appendix D. FCC/IC Equipment Authorization (USA/Canada only)

The CS475, CS476, and CS477 are FCC compliant (FCC IC # M01PULS616263). Modifications to the sensors 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.

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