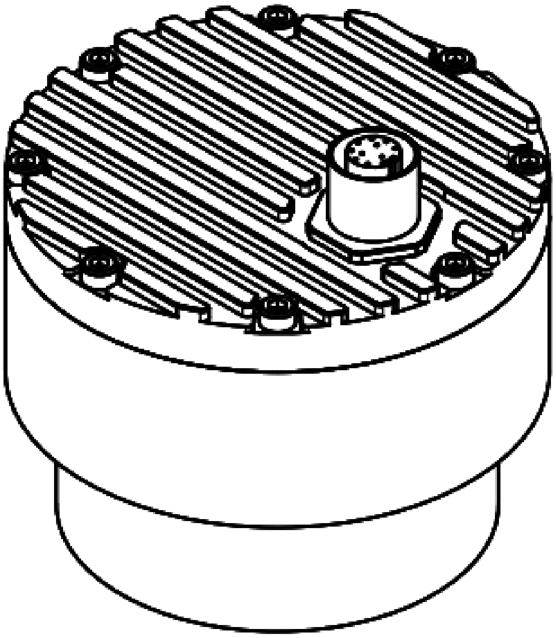
EXTREME ENVIRONMENTS. EXTREMELY RELIABLE.



NON-CONTACT LEVEL METER

Continuous Level Measurement

Operating Manual

1.800.548.4264 | www.ftsinc.com

700-SDI-RADAR-LX-80-Man   Rev 1   08 Oct 2021

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Contents

Chapter 1 SAFETY

1.1 APPROPRIATE USE

Operational reliability is ensured only if the instrument is properly used according to the specifications in this manual as well as possible supplementary instructions.

> ⚠ WARNING: Inappropriate or incorrect use of the instrument can give rise to application specific hazards, e.g., damage to system components through incorrect mounting or adjustment.

1.2 GENERAL SAFETY INSTRUCTIONS

This is a state-of-the-art instrument complying with all prevailing regulations and guidelines.

During the entire duration of use, the user is obliged to determine the compliance of the necessary occupational safety measures with the current valid rules and regulations for their area.

The safety instructions in this manual, the national installation standards as well as the valid safety regulations and accident prevention rules must be observed by the user.

For safety and warranty reasons, any invasive work on the device beyond that described in the operating instructions manual may be carried out only by personnel authorized by the manufacturer. Arbitrary conversions or modifications are explicitly forbidden.

The safety approval markings and safety tips on the device must also be observed.

Chapter 2 PRODUCT DESCRIPTION

The SDI-RADAR-LX-80 radar- based level sensor was developed specifically for continuous water level monitoring in rivers, lakes and sea unlike other radar level sensors that were initially developed for industrial applications and later adjusted to work in environmental monitoring applications. It comes in three versions: 8 meter, 15 meter and 30 meter each with a 10m cable[1]. Measurement frequency is 1 Hz.

FTS Part #	Model	Maximum Detection Range	Accuracy
21216	LX-80-8	0.1M– 8.0M (0.66 ft - 26.25 ft)	± 2mm (± 0.08 in)
21217	LX-80-15	0.1M – 15M (0.66 ft – 49.2 ft)	± 2mm (± 0.08 in)
21218	LX-80-30	0.1M – 30M (0.66 ft - 98.43 ft)	± 2mm (± 0.08 in)

The radar operates in the W-band (between 77 and 81 GHz), which provides high accuracy and allows multiple radars to operate close to each other without mutual interference. Unlike ultrasound level sensors, it is not affected by changes in air temperature and density.

The SDI-RADAR-LX80 is quickly and easily mounted to a pole above a water surface using the supplied mounting bracket (part number 21135) and requires minimum maintenance once installed. Mounting instructions are contained in Chapter 4.

For ease of reference, this manual shall refer to all models as the LX-80 throughout the document.

2.1 CHANGING UNITS

The following measurement units are supported:

- Millimeters
- Centimeters
- Meters
- Feet
- Inches

It is possible to change the measurement unit of the LX-80 using any of the supported communication protocols. When changing the unit of measurement, special care must be taken to ensure all related parameter values are also changed as the device will now use the selected measurement unit for every measurement and every measurement parameter.

> **IMPORTANT:** If measurement units are changed, other parameters which depend on the measurement unit (such as active zone parameters) should also be changed to the new unit

[1] 26.25 ft, 49.2 ft and 98.43 ft each with a 32.8 ft cable

2.2 RADAR CALIBRATION

The level meter is able to perform self-calibration which calibrates the radar transceiver electronics. Each instrument is calibrated in the factory, and the factory calibration parameters are stored in the device. Typically, there is no need to repeat self-calibration, even after using the level meter over several years. In extremely rare cases, if a level meter is not accurately measuring the water level, self-calibration may be required during troubleshooting. Self-calibration is conducted through the Instrument Configurator application (refer to Chapter 8) by clicking on *Calibrate radar* button which is visible in the Settings page of the application.

2.3 FUNCTIONAL PRINCIPLE

The LX-80 operates by transmitting a linear chirp in the frequency range between 77 GHz and 81 GHz and measuring the frequency shift of the electromagnetic wave reflected from the water's surface. The measured distance is proportional to the frequency difference between the transmitted and received signal due to the Doppler Effect, converted into an appropriate output signal and output as a measured distance. The modulation and detection process in the sensor enables precise measurements which are not affected by air temperature, humidity, or other environmental factors.

The distance measuring sensor in the instrument is designed to detect and eliminate obstacles from the distance measurement signal spectrum. However, vibrations in the radar's mounting position can negatively impact this ability.

The radar beam utilizes an averaging effect over the beam's surface footprint which assists in reducing measurement errors caused by oscillations and undulation of the water's surface. Slight to moderate waves on the water's surface will affect the measured signal level, usually seen as a reduced SNR (Signal to Noise Ratio), but in most cases will not affect measurement accuracy. However, if the measured surface is highly turbulent, the unpredictability of the water surface will reduce accuracy. In that case, the length of the radar filter can be adjusted to filter out most, if not all, the turbulence.

For best measurement results mount in accordance with directions given in Chapter 4.

2.3.1 MEASUREMENT THROUGH CONTAINERS

The LX-80 can be mounted outside of a container made of dielectric (non-conductive) materials to measure the level of the liquid inside of the container. The radar's microwave signals easily pass through most dielectric (non-conductive) materials. Common Dielectric materials used in industry and buildings such as ABS, PVC, Nylon, Teflon, Polycarbonate, Plexiglas, Polyamide, and Polypropylene are very suitable for microwave level measurement from outside of the containers. In such applications. The radar can be mounted above the container and pointed to the liquid inside the container below the sensor, following the same mounting principles outlines in Chapter 4.

2.3.2 RAIN AND WIND

The LX-80's integrated internal software filters out effects of rain, fog and wind. However, these filters have some limitations. The majority of measurement inaccuracies caused by environmental factors can be solved by proper sensor installation (see Chapter 4).

Rain and snow fall reduce the reflectivity of the water surface thus reducing the SNR[2]. However, the LX-80 is tested and calibrated to detect the surface even under heavy rainfall. For rain and snow suppression, the most effective solution is to mount the radar so that it points directly at the surface being measured.

Influence of the wind on the accuracy is negligible in most cases. The only exception is strong wind as it will create surface waves and turbulence which can be detected as a shift in level. As mentioned in Section 2.3, the length of the radar averaging filter can be increased so that it reports an average measurement over a longer period of time to filter out turbulence.

2.3.3 INTERFERENCE AND MULTIPLE RADARS

The radar operates in the W-band from 77 GHz to 81 GHz with continuous linear frequency modulation within the frequency range. Interference between two or more sensors will require precise coordination of the central frequencies with a timing synchronization in a range of 25 ns between each other. Such synchronization is very complex to achieve so the interference probability between several radars on the same location is very small.

Some wideband radiation sources can introduce small impulse interference for a short period of time, but this is very unlikely to affect measurements reported by the radar.

2.3.4 FOGGING AND EVAPORATION

Generally, LX-80s are not affected by fog or evaporation. However, heavy evaporation with high water density in the atmosphere can affect measurement accuracy.

The best solution in most cases is to increase the average period of the averaging filter to get a better average distance value. As evaporation is a naturally very turbulent event with a significant difference in atmospheric water density over the surface area over time, averaging of the distance measurement spectrum solves the accuracy problem.

2.3.5 REFLECTIONS

Water is very reflective medium for the radar waves and most of the power transmitted from the radar transmitter will be reflected from the water surface. Reflections of the transmitted radar beam follow the same physical laws as optics in that part of the power is reflected towards the radar, part of the power is reflected away from the radar, and a small part of power is absorbed by the water.

---

[2] Signal to noise ratio

Depending on the surface roughness, the incident angle ratio between power reflected away from the radar and towards the radar can significantly vary.

To maximize reflected power back to the radar, the radar should be mounted so that the angle of the transmitted radar beam to the water is 90°. In general, the ratio between power reflected to the sensor and power dispersed in all directions due to surface roughness is very small and it is unlikely that dispersed energy will cause additional multipath problems due to additional reflections from surrounding objects.

2.3.6 RELATIVE MEASUREMENT

Each sensor unit measures the distance between the sensor and the first detected object. For water level measurement, it is preferred to report the actual water level from the bottom of the riverbed to the surface of the water. That is why we offer relative measurement, which is calculated relative to the mounted sensor height. Sensor height is defined as the distance from the mounted sensor position to the bottom of the riverbed. This distance is a fixed value unique to every mounted unit. It can be set to the device in two ways.

1) First is by setting the sensor height parameter directly using any of communication protocols described in the following chapters. After setting the sensor height, relative measurement will be calculated by the following formula:

   $RM = SH - D$

   $where$:

   $RM = relative\ measurement$

   $SH = sensor\ height$

   $D = measured\ distance\ from\ sensor\ to\ water.$

   For example: if the sensor is mounted 6.35m above the riverbed, and the measured distance from sensor to the surface is 4.34m then the real water level is calculated as the difference of these two values:

   6.35m – 4.34m = 2.01m

   In this case the sensor will report 4.34m as the measured level and 2.01m as the measured relative level.

2) Alternatively, it is possible to set the sensor height indirectly, using the staff gauge measurement. In this case, the staff gauge measurement needs to be taken directly underneath the position of the mounted sensor. When setting the sensor height using the staff gauge height, the following formula will be used to calculate sensor height:

   $SH = D + SG$

   $where$:

   $SH = sensor\ height$

   $D = measured\ distance\ from\ sensor\ to\ water$

   $SG = staff\ gauge\ measurement.$

For example: the sensor is mounted at an unknown height above the riverbed and using staff gauge it is determined that the water level at that given time is 1.34m. The sensor detects water at the distance of 6.02m. By setting the value 1.34m as the staff gauge measurement at the same time when the device measures the distance as 6.02m, sensor height will be calculated as the sum of the two values:

6.02m + 1.34m = 7.36m

In this case the sensor will report 6.02m as the measured level and 1.34m as the measured relative level.

Chapter 3 ELECTRICAL CONNECTIONS

3.1 CONNECTOR PIN-OUT AND WIRING

The LX-80 sensor is supplied with a robust IP68 M12 connector and cable. The connector and cable details are shown on Figure 3-1. The user is responsible for connecting the sensor to the data collection platform using the flying leads. Users can attach their own connector, connect the cable via a terminal strip, or wire it directly to device electronics. Refer to Table 3-1 for wiring details.

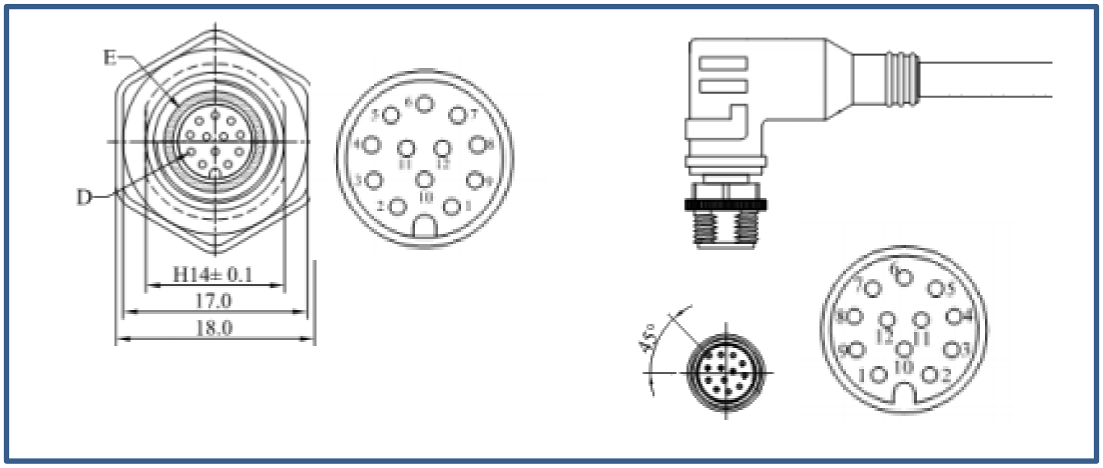


Figure 3-1: M12 connector details

Table 3-1: Wiring Details

PIN #	COLOUR	PIN NAME	PIN DESCRIPTION
1	**White**	GND	This pin should be connected to the ground (negative) pole of the power supply
2	**Brown**	+Vin	Power supply. Power supply voltage must be 9 to 27 VDC, and the power supply must be able to provide at least 0.65W.
3	**Green**	RS232 – TxD	RS-232 data transmit signal.
4	**Yellow**	RS232 – RxD	RS-232 data receive signal.
5	**Grey**	GND	Signal ground.
6	**Pink**	CAN – H	CAN2.0B high signal (optional)
7	**Blue**	CAN – L	CAN2.0B low signal (optional)
8	**Red**	V+	Output power supply (=Vin) for supply of external optional equipment and for use with analog 4-20mA output
9	**Orange**	RS485 – D-	RS-485 data transmitter/receiver low signal.
10	**Dark Red**	RS485 – D+	RS-485 data transmitter/receiver high signal.
11	**Black**	SDI-12	SDI-12 communication interface
12	**Purple**	4 – 20 mA Output	Analog 4 – 20 mA output

3.2 SDI-12 INTERFACE

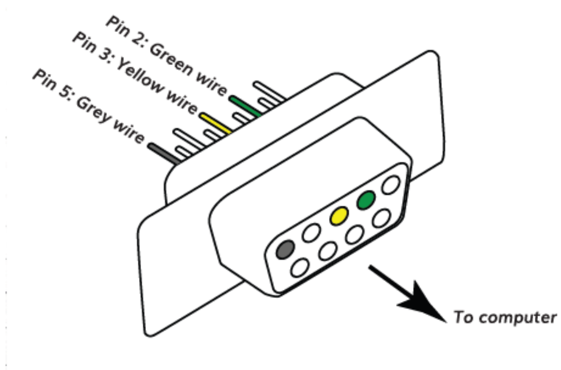
SDI-12 interface is widely used to connect hydrological equipment to dataloggers. SDI-12 uses a single communication line, and very slow speed communication to enable the use of very long communication cables.

For hydrological applications, SDI-12 communication interface is a valid option and the instrument is natively able to communicate directly with SDI-12 master devices (dataloggers etc.).

The device supports SDI-12 protocols version 1.3. The device is not an SDI-12 slave; however, it responds to SDI-12 commands as expected from an SDI-12 slave. When operating the SDI-12 interface, low power mode is not supported: the radar works continuously (does not have sleep/waking cycles).

3.3 SERIAL RS-232 INTERFACE

Serial RS-232 interface is implemented as standard PC full-duplex serial interface with voltage levels adequate for direct connection to PC computers or other embedded devices used for serial RS-232 communication.



3.4 SERIAL RS-484 INTERFACE

Serial RS-485 interface is implemented as standard industrial half-duplex communication interface. The most common communication protocol used with RS-485 interface is Modbus-RTU.

The communication interface is internally short-circuited, and overvoltage protected. Depending on the receiving device, the interface can be used with only two wires (D+ dark red wire & D- orange wire) while in some cases the ground connection (signal GND grey wire) is also required. For more details please consult the specifications of the receiving device.

3.5 ANALOG 4-20 MA OUTPUT

Analog current 4 – 20 mA output is provided for easier compatibility with older logging and control systems. Output is implemented as current sink architecture with common ground. Maximal voltage applied to the sink can go up to 30 VDC providing greater flexibility in connecting the LX-80 to PLCs, loggers, or data concentrators. The signal range and function for 4 – 20 mA analog output can be configured in the setup application so the sensor will be able to signal the best suitable value range with the available current range.

The sensor's current step has a limiting resolution of 0.3 µA. Ensure the minimal and maximal values representing 4 mA and 20 mA have sufficient resolution for system requirements.

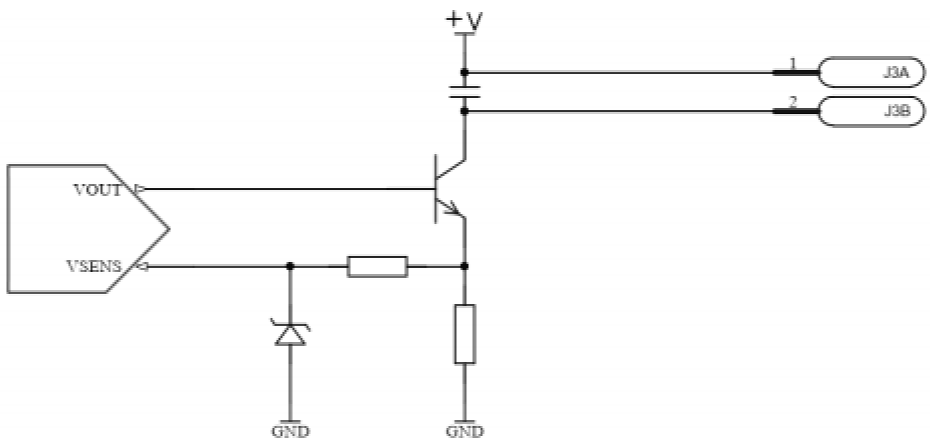


Figure 3-2: Analog 4-20 mA internal architecture

Measurement of the current by the client device (logger, PLC, modem etc.) must be implemented as the high side current measurement as shown in figure 3-3. If a sensing resistor is used, resistance should be selected from the range 10Ω to 500Ω, with a recommended value 100Ω for the sensing resistor.

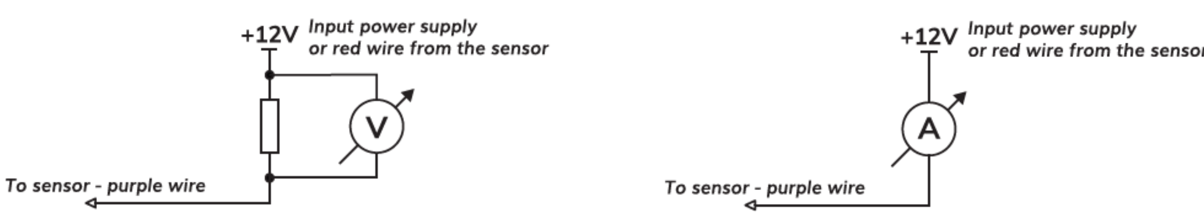


Figure 3-3: High side current measurement for the 4-20 mA analog output

Chapter 4 INSTALLATION

4.1 SITE SELECTION

For best results, the water's surface being measured should be calm, clean of vegetation, rocks, sand deposits or other obstacles. Additionally, the mounting location of the radar sensor should provide an unobstructed line to the measured surface. Any close object in the vicinity of the sensor can reduce accuracy and introduce offsets in measurements.

The radar beam is defined by a 3 dB width angle and covers a circular area on the water's surface. The size of the beam's pattern on the water's surface is dependent on the distance from the radar to the water. Refer to Table 4-1 to determine the radar beam's footprint and ensure it is free of obstacles and other interfering factors previously listed.

The mounting location should be sturdy as vibrations of the mounting structure can affect the radar's algorithm ability to discard detected obstacles.

Table 4-1: Radar Height and Radar Beam Diameter at Surface

METRIC	
Radar Height above water (m)	Radar Beam Diameter at Surface (m)
0.3	0.03
0.5	0.04
1	0.09
2	0.17
3	0.26
4	0.35
5	0.44
6	0.52
7	0.61
8	0.70
9	0.79
10	0.87
11	0.96
12	1.05
13	1.14
14	1.22
15	1.31
20	1.75
25	2.18
30	2.62

IMPERIAL	
Radar Height above water (ft and in)	Radar Beam Diameter (ft and in)
11.8 in	1.18in
19.7 in	1.57 in
39.4 in	3.54 in
6 ft 6.7in	6.7 in
9 ft 10 in	10.24 in
13 ft 1.5 in	1 ft 1.78 in
16 ft 4.85 in	1 ft 5.32 in
19 ft 8.2 in	1 ft 8.5 in
22 ft 11.6 in	2 ft
26 ft 3 in	2 ft 3.56 in
29 ft 6.3 in	2 ft 7.1 in
32 ft 9.7 in	2 ft 10.25 in
36 ft 1 in	3 ft 1.8 in
39 ft 4.4 in	3 ft 5.34 in
42 ft 7.8 in	3 ft 8.88 in
45 ft 11.2 in	4 ft
49 ft 2.5 in	4 ft 3.58 in
65 ft 7.4 in	5 ft 8.9 in
82 ft 0.25 in	7 ft 1.83 in
98 ft 5.1 in	8 ft 7.15 in

4.2 INSTALLATION POSITION

The level meter must be installed above the water surface at a 90° angle pointing directly towards the water surface and at a height within the range specified in Table 4-2. Ideally the tilt angle should be 0° along both the X and Y axes for a 90º angle between the radar beam and the water surface. However, the unit can tolerate up to ±2º along either axis if the site does not allow for a 0° tilt angle. During the installation a level should be used to confirm the unit's position. Additionally, the tilt angle can be determined by connecting the unit to a PC and checking the tilt angle in the Instrument Configurator. Refer to Table 4-2 for recommended installation heights.

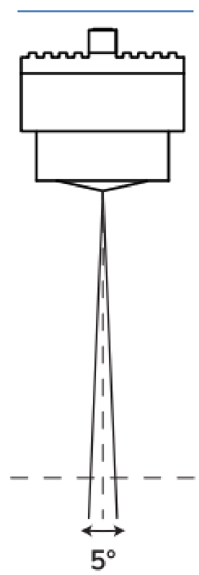


Figure 4-1: Installation Position

Table 4-2: Recommended installation heights

	Min	Recommended	Max
Installation distance to water surface	0.2m (7.9 in)	> 1m (39.4 in)	Maximum measurement range of the variant in use: 8, 10 or 30 m (26.25, 49.2 or 98.43 ft)

Chapter 5 RADAR PARAMETERS

The following radar parameters can be configured by connecting the radar to a PC and using the Instrument Configurator (refer to Chapter 8). Additionally, if using SDI-12 protocols, configuration can be done through a datalogger and using the SDI-12 commands outlined in Chapter 12.

1) Communication interfaces
2) Processing parameters
3) Measurement Parameters

5.1 COMMUNICATION INTERFACES

5.1.1 BAUD RATE

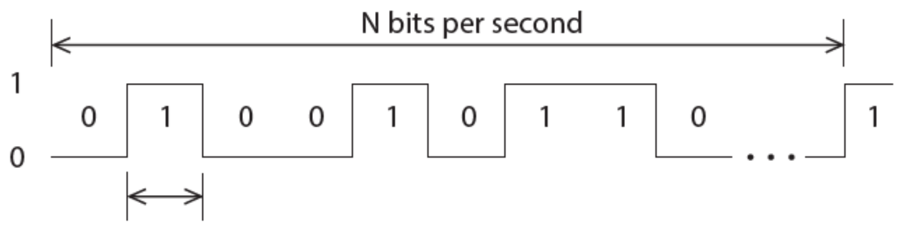


Figure 5-1: Baud Rate

RS-232 baud rate: Configures the baud rate (bits per second) for serial communication on the RS-232 data line. This setting controls how many bits are sent on the communication line in one second. The available values are standardised. Using higher baud rate over longer lines may introduce errors in transferred data. The default instrument RS-232 baud rate is 115200 bps.

RS-485 baud rate: Configures the baud rate (bits per second) for serial communication on the RS-485 data line. This setting controls how many bits are sent on the communication line in one second. The available values are standardised. Using higher baud rate over longer lines may introduce errors in transferred data. The default instrument RS-485 baud rate is 9600 bps.

5.1.2 DEVICE ID

Figure 5-2: Device ID

Modbus ID: Configures the device (slave) ID to be used for Modbus RTU protocol. Modbus RTU uses request/response format and allows multiple instruments to be connected on the same bus. When a remote master transmits the request message, it will use the device ID as a device address. All instruments will receive the request, but only the instrument with the matching device ID will answer to the received request.

SDI-12 ID: The SDI-12 device ID to be used on SDI-12 interface. In SDI-12 request/response protocol, this ID will be used to define the instrument address, and the instrument will respond only to requests with the matching ID.

5.1.3 MODBUS PARITY

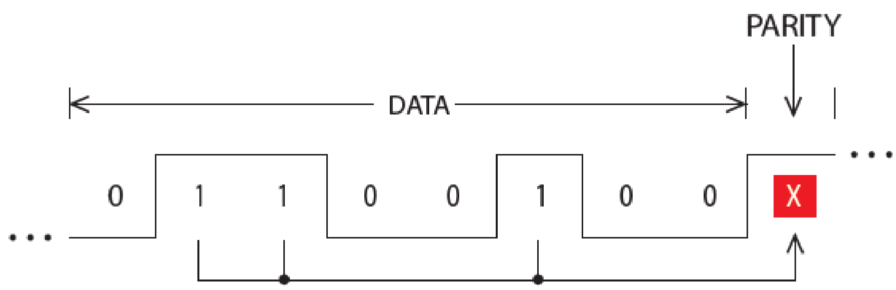


Figure 5-3: Modbus Parity

Parity is used in serial communication for basic error detection. In general, all bytes on the receiver side where the parity bit does not match the message will be discarded.

There are three parity options which can be selected:

None: No parity is used, and no error detection is possible on bit level.

Odd Parity: An additional bit is added to the communication that will be set to 1 when there is odd number of bits with value 1 in the 8-bit payload byte.

Even Parity: An additional bit is added to the communication that will be set to 1 when there is even number of bits with value 1 in the 8-bit payload byte.

The default setting on most devices that use Modbus is even parity.

5.1.4 MODBUS STOP BITS

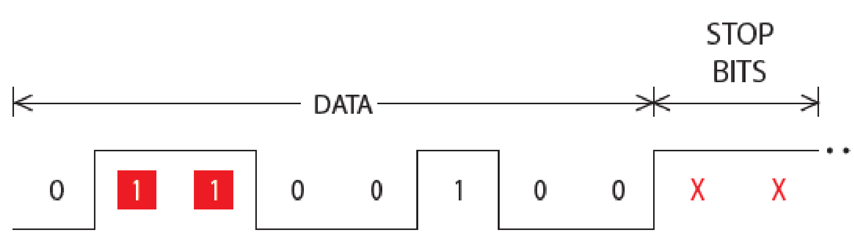


Figure 5-4: Modbus Stop Bits

Stop bits are added to the end of each data byte transferred over serial communication to allow a pause between two bytes. One or two bits may be used. The default setting on most Modbus RTU devices is one stop bit, but some dataloggers may require that the instrument is configured to use two stop bits.

5.1.5 4-20 mA PARAMETERS

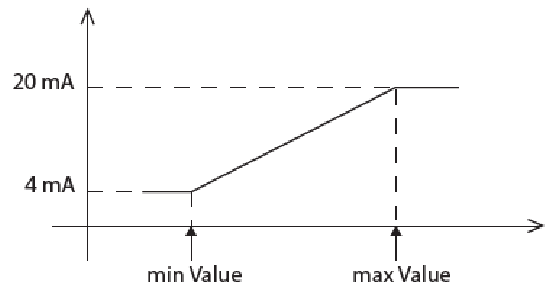


Figure 5-5: 4-20 mA Parameters

4-20 mA min: To configure the 4-20 mA output range, the minimum measured value which will correspond to 4 mA analog output needs to be set. The value is set in the currently configured measurement unit.

Example: If measured values are expected to fall within the range of 700 mm to 5000 mm, it is recommended to configure the minimum value to slightly below 700 mm (for example 500 mm). Alternatively, if the resolution is not critical, then the minimum value for 4-20 mA output can be left to the instrument minimum of 0 mm.

4-20 mA max: To configure the 4-20 mA output range, the maximum measured value which will correspond to 20 mA analog output needs to be set. The value is set in the currently configured measurement unit.

Example: If measured values are expected to fall within the range of 700 mm to 5000 mm, it is recommended to configure the maximum value to slightly above 5000 mm (for example 6000 mm). Alternatively, if the resolution is not critical, then maximum value for 4-20 mA output can be left to the instrument maximum.

5.2 PROCESSING PARAMETERS

5.2.1 FILTER TYPE

Changes the type of filter which is used to smooth the measured data.

Note that not all firmware versions support all the Filter Types. Firmware versions and what they support are listed at then end of this section.

No Filter: - No filtering is used and the raw measurements are reported.

IIR (Infinite Impulse Response): This filter is used to smooth the data. When compared to a moving average filter, the IIR filter reacts more quickly to initial changes in the data, but it takes longer for the smoothed value to reach the new measurement. The use of the IIR filter is discouraged for general applications. The IIR constant can be configured separately.

Moving Average: The moving average filter calculates the average value of a number of raw measurements. The length for the moving average filter is configured separately through the Filter Length parameter.

Median: The median filter finds the median value from a number of raw measurements. The length for the median filter is configured separately through the Filter Length parameter.

Standard deviation: This type of filter is similar to the moving average filter. It takes a number of raw measurements (as defined by the Filter Length parameter), removes 20% of outliers, and calculates the average of the remaining 80% of values.

Devices with firmware versions up to 2.2.8. support only No filter, IIR and Moving average. In this case, it is recommended to use the moving average filter.

Devices with firmware versions up to 2.3.2. support No filter, IIR, Moving average and Median. For those devices it is recommended to use moving average or median filter.

Devices with firmware versions greater than 2.3.3. support all the filters listed above. The standard deviation filter gives the best results.

5.2.2 FILTER LENGTH

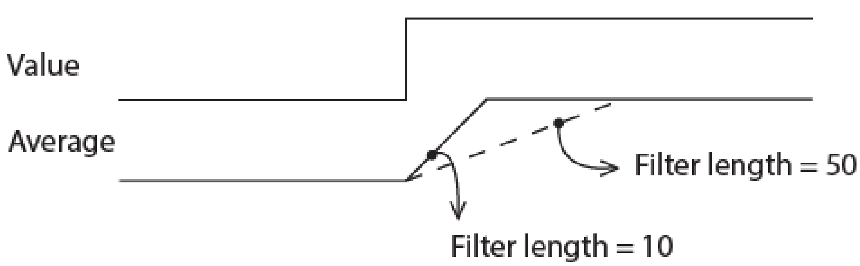


Figure 5-6: Filter Length

The length of the averaging filter, in number of readings, used to smooth the measured values. The LX-80 performs 1 reading per second, so a filter length value of 10 will result in 10 seconds integration time. When using longer filter lengths, more measured values are used for filtering and the resulting data will be smoother. However, when the water level changes, it will take more time for the new measurement to be reported. Typically, this parameter should be set to a value between 10 and 50. For highly turbulent water, a longer filter length is recommended.

5.2.3 IIR (INFINITE IMPULSE RESPONSE) CONSTANT

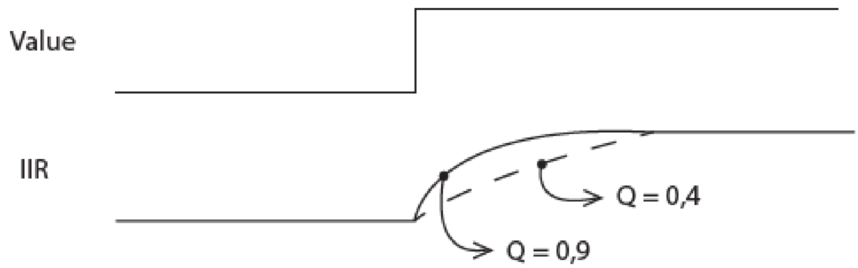


Figure 5-7: IIR Constant

The constant used by the infinite impulse response (IIR) filter. Accepted values are decimal numbers between 0 and 1. When the IIR constant value is closer to 0.0, the filter response will be slower. When the IIR constant value is closer to 1.0, the filter response will be faster.

5.2.4 AMPLITUDE THRESHOLD

Sets the minimum amplitude of the spectral peak in the signal analysis algorithm required to detect peak and report distance. If no peak above this value is detected, the sensor will report distance equal to 0. The threshold is used to filter noise and false readings and it is recommended to keep this value in the range 0 to 1000.

5.2.5 PEAK DETECTOR TYPE

Configures the type of algorithm which is used to detect the peaks in the radar echo curve. The default setting should be Maximum peak. In specific cases, such as when a water level needs to be measured, but there is a lot of vegetation protruding from the water surface, use Last Peak Detector type.

5.3 MEASUREMENT PARAMETERS

5.3.1 LEVEL UNIT

The measurement unit used to report the measured level value. The default measurement unit is millimetres.

> **IMPORTANT:** When changing the measurement unit, other parameters which depend on the measurement unit (such as active zone parameters) should also be changed to the new unit.

5.3.2 LEVEL OFFSET

Changes the measurement level offset. This value should not be changed.

5.3.3 *ACTIVE ZONE PARAMETERS*

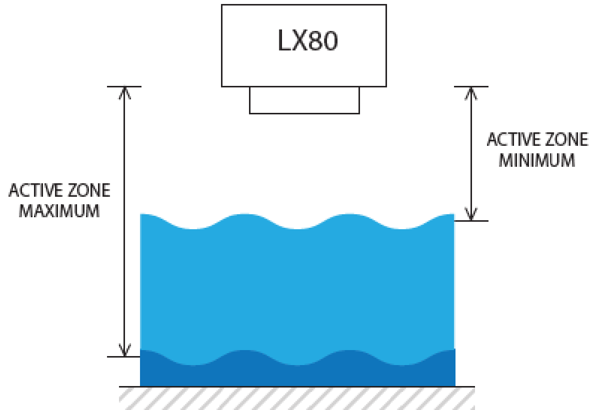


Figure 5-8: Active Zone Parameters

This parameter limits the operational range of the instrument. The instrument will detect water level only within the range set by the Active Zone Minimum and Active Zone Maximum parameters. This parameter is the best way to filter unwanted radar reflections from other structures and objects that could cause false instrument readings.

Active zone min: It is strongly recommended to set the Active zone min. value to the minimum possible distance between the water and the instrument at the specific monitoring site.

Active zone max: It is strongly recommended to set the Active zone max. value to the maximum possible distance between the water and the instrument at the specific monitoring site. Typically, this is the distance between the instrument and the lowest point in the channel.

5.3.4 *SENSOR HEIGHT*

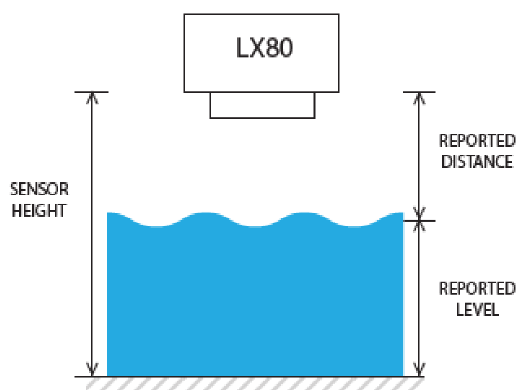


Figure 5-9: Sensor Height

The height of the instrument needs to be set above the water's zero-level "gauge zero". The instrument will output relative measurement of the actual water level based on its height above the zero-level.

Example: If the instrument is mounted exactly 5 metres above the gauge zero level, then this parameter should be set to 5 m. Then, if the instrument measures the distance between the instrument and the water as 4 m, it will report that the water level is 1 m, because the water is 1 m above the gauge-zero level. For user convenience, this parameter can also be indirectly set by inputting the current staff gauge reading, by clicking on the "Enter Staff Gauge Reading" button in the Instrument Configurator.

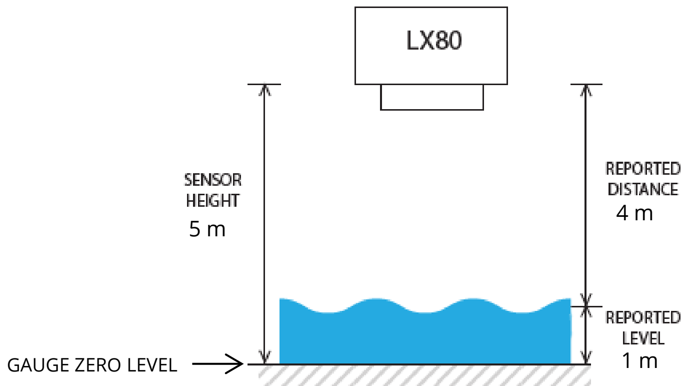


Figure 5-10: Sensor Height Example

5.3.5 STAFF GAUGE

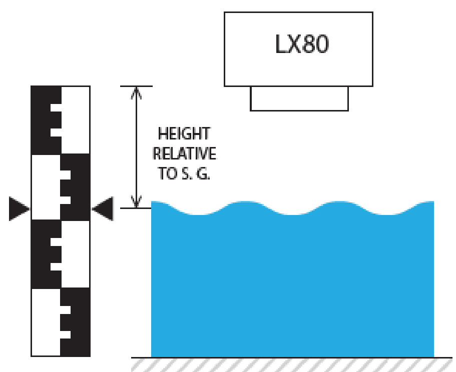


Figure 5-11: Staff Gauge

Setting the sensor height relative to the measurement is done using a staff gauge reading. The sensor will output relative measurement of the actual water level based on its height above the riverbed. Using the Instrument Configurator, select the "Enter Staff Gauge Reading" button and enter the current staff gauge reading.

5.3.6 OPERATION MODE

There are two operating modes.

Standby: The device will communicate through communication interfaces, but no measurements will be made. In standby mode, the power consumption is reduced by 50%.

Operating: In operating mode, the device continuously performs measurements.

5.3.7 POWER MANAGEMENT

There are two power modes: Continuous scanning and SDI-12. Power consumption can be reduced by operating in SDI-12 mode

Continuous Mode: In continuous mode the device constantly performs measurements, which are transmitted over the RS-232 interface and made available over Modbus and SDI-12 interfaces. The device is always available over RS-232 and Modbus interfaces.

SDI-12 mode: The device remains in sleep mode until the SDI-12 Measure (aM!) command is received. While in sleep mode, the device will not be able to connect to Modbus or RS-232 interfaces. While the device is in sleep mode, it consumes only 0.03 W.

For the reconfiguration of the device which is set to operate in SDI-12 mode, it's necessary to power-cycle the device, and then use the Instrument Configurator to connect to the device within 1 minute after power-up. If there is no attempt to connect to the device over RS-232 within one minute, the device will automatically go back to sleep mode.

Chapter 6 DATA INTERFACES

The LX-80 level meter offers multiple data interfaces, for ease of integration with existing SCADA/telemetry systems.

6.1 SERIAL RS-232 INTERFACE

The Serial RS-232 interface is used for direct connection of a single level meter unit with the computer. The serial interface is used both for retrieving live level measurements and for configuration of the level meter device. Use the PC application, Instrument Configurator for instrument configuration and level monitoring.

Default communication parameters are:

Bitrate: 115200 bps

Data bits: 8

Stop bits: 1

Parity: None

An NMEA-like communication protocol is used to deliver level measurements over the RS-232 interface. Detailed description of the protocol is given in Chapter 7 of this user manual.

6.2 SERIAL RS-485 INTERFACE

Serial RS-485 interface is used for connecting multiple level meters to a single data logger using a single RS-485 bus. The main difference from the protocol used over RS-232 interface is that the level measurements are not reported automatically but are instead reported only after being requested by the master device (data logger unit). The LX-80 supports Modbus protocol over the RS-485 bus. Detailed description of the protocol is given in Chapter 7 of this user manual.

Default communication parameters are:

Bitrate: 9600 bps

Data bits: 8

Stop bits: 1

Parity: Even

Device ID: 1

Chapter 7 DATA PROTOCOLS

The LX-80 level meter supports the following data protocols:

1) SDI-12 protocol over SDI-12 interface
2) NMEA-like protocol on RS-232 interface that constantly outputs the detected current level and averaged level, depending on the active settings for data filtering
3) Servicing protocol on RS-232 interface for configuring the unit
4) Request-response protocol (Modbus) on RS-485 interface that allows multiple units to be used on a single RS-485 bus

7.1 SDI-12 PROTOCOL

The LX-80 is capable of reading and writing with the standard set of SDI-12[3] commands. The following basic SDI-12 commands are implemented in the radar sensor. Note the "a" in each command should be replaced with the sensor address number and every command must terminate with an exclamation mark (!).

Name	Command	Response and Details
Address Query	?!	a Device responds with its SDI-12 address. Default address is 0 (zero)
Acknowledge Active	a!	a Sensor at input address "a" is active
Address Change	aAb!	b Device at address "a" has changed address to "b"
Send Identification	aI!	a13ccccccccmmmmmmvvvxxx . . . xxx 13 - the SDI-12 version number cccccccc - 8 character vendor identification mmmmmm - 6 characters specifying the sensor model number vvv - 3 characters specifying the sensor firmware version
Start Verification	aV!	One value is ready imminently. 0 indicates not ready 1 indicates ready Verification values can be retrieved by the Send Data Command
Send Data	aD0!	a<values>

7.1.1 MEASUREMENT COMMANDS

These commands tell the sensor to take a measurement. The sensor returns the time until one or more measurements will be ready and the number of measurements that it will make. It does not return the measurement to the data recorder after this command. The send data (D0!) command must be issued to get the measurement values.

[3] *For a detailed explanation of SDI-12 protocols and commands refer to SDI-12 Specification, Version 1.3 at* http://www.sdi-12.org

COMMAND(S)	RESULTS
aM! aMC! aC! aCC!	ammm8 mmm = number of seconds before measurements will be ready 8 = number of values that will be returned
aDO!	a+f+f+d+d+d+d+f+f +f – measured relative level depending on sensor height +f – measured distance from sensor to water +d – measured temperature inside device +d – measured water temperature (on request only) +d – measured tilt angle of device in x direction (on request only) +d – measured tilt angle of device in y direction (on request only) +f – SNR of latest measurement +f - standard deviation of the data in mm

7.1.2 X COMMANDS

In addition to the standard set of commands the LX-80 has an extension of custom SDI-12 commands called X commands that access specific features of the sensor.

The format of X commands follows the requirement for standard SDI commands in that the first character of every command must be a sensor address which is then followed by the X command and terminated by an exclamation mark. Likewise, the first character of a response is also the address character.

Set commands should normally be followed by a get command to verify the parameter set was successful

In order for X commands to be valid, the following format conditions must be met:

1) The X and other mandatory characters must be capitalized as shown in the table
2) Do not place spaces within the command
3) Replace the "a" with the sensor address

X COMMAND	DEFINITION	RESPONSE AND DETAILS
aXGLUN!	Get measurement unit for level	Response: a+d In which "d' is the measurement unit code 0 – m 1 – cm 2 – mm 3 – in 4 – ft
aXGLUN+d!	Set measurement unit for level	Replace "d" with desired measurement unit code (see codes above in Get Measurement Unit Level details)

X COMMAND	DEFINITION	RESPONSE AND DETAILS
aXGDZ0!	Get minimum active zone value	Response: a+f In which "f" =the active zone minimum value. Sensor will not report a measurement lower than this value.
aXGDZ0+f!	Set minimum active zone value	Replace "f" with desired minimum active zone value. Sensor will not report a measurement lower than this value.
aXGDZ1!	Get maximum active zone value	Response: a+f In which "f" = the active zone maximum value. Sensor will not report a measurement higher than this value.
aXGDZ1+f!	Set maximum active zone value	Replace "f" with desired active zone maximum value. Sensor will not report a measurement higher than this value.
aXGSHR!	Get sensor height value	Response: a+f In which f = sensor height above riverbed
aXGSHR+f!	Set sensor height value	Replace "f" with sensor height above riverbed. Response: a+f
aXGSGR+f!	Set current staff gauge reading	Response: a+f In which "f" is the current staff gauge reading, Device will calculate sensor height above riverbed as: staff gauge reading + distance from sensor to water
aXGLAV!	Get average time in second for level	Response: a+f In which "f" = averaging time in seconds
aXGLAV+f!	Set average time in second for level	Replace "f" with desired averaging time in seconds. Response: a+f
xGLFT!	Get filter type for data filtering	Response: a+t In which "t"= filter type: 0 – no filter 1 – IIR filter 2 – Moving average 3 – Median 4 – Standard deviation
xGLFT+t!	Set filter type for data filtering	Replace "t" with desired filter type code (see codes above in "Get filter type for data filtering" Response: a+t
xGLIR!	Get IIR filter constant	Response: a+c In which "c" = IIR filter constant used in the IIR filter
xGLIR+c!	Set IIR filter constant	Replace "c" with desired IIR filter constant used n the IIR filter. Response: a+c Recommended range is from +0.0 to +1.0

X COMMAND	DEFINITION	RESPONSE AND DETAILS
xGPDT!	Get peak detector type	Response: a+t In which "t" = the peak detector type: 0 – report the distance to the maximum peak which corresponds to the maximum radar signal reflection 1 - report the last peak which corresponds to the furthest reflection from the radar; this may include multipath reflections in typical cases and should be avoided
xGPDT+t!	Set peak detector type	Replace "t" with desired peak detector type code (see codes above in "Get peak detector type". Response: a+t
xGBKG+d!	Save background signal level	Response: a+d n which "d" = distance in currently used units Stores the radar echo curve signature from zero distance up to defined distance "d". The stored echo curve is used as a reference signal background level, and only reflections stronger than the saved level will be used when searching for the water level. To clear this setting, send this command with a parameter d set to 0 (zero).
xGLWU!	Wake up from sleep mode	Response: a+0 When the instrument is configured to operate in SDI-12 mode, it goes to sleep until SDI-12 measure command (aM!) is issued. Connection to the instrument through RS-232 and RS-485 interfaces is not possible while the instrument is in the sleep mode. To facilitate connecting to the instrument from the PC application, after issuing this command, the instrument will wake up and remain in active state for 60 seconds. During that time, a connection over serial cable can be established using the Instrument Configurator PC application. If the connection is established within this 60-second period, the instrument will remain in the active state as long as the PC application is connected to the instrument.
xGCLR!	Clear the stored radar calibration, perform self-calibration, and store new calibration parameters.	Response: a+1 Forces the instrument to clear the stored radar calibration, and to perform the self-calibration again. In majority of cases the factory calibration will be valid through the whole lifetime of the instrument, and there will be no need to redo the self-calibration.

7.2 NMEA PROTOCOL (RS-232)

NMEA protocol is based on the standard protocol family widely used by navigation equipment. NMEA protocol is sentence oriented and can send multiple sentences with different information. The sentence content is designated by the starting keyword which is different for each sentence type. NMEA sentences are terminated with the checksum which makes this protocol extremely reliable. NMEA protocol is unidirectional: data is only transmitted from the level meter.

At RS-232 interface the device periodically outputs following data sentences:

7.2.1 LEVEL MEASUREMENT REPORT

$LVX,L1,L2,T1,L3,L4,S1 <CR><LF> firmware versions up to 2.3.2

$LVX,L1,L2,T1,L3,L4,S1,S2<CR><LF> firmware versions greater than 2.3.2

$LVX: The keyword sent in the beginning of each detection report. This sentence is sent whenever here is detected level.

L1: The actual distance between the instrument and the water surface, as measured by the instrument.

L2: The average distance between the instrument and the water surface, as measured by the instrument. This value is calculated by applying the averaging filter to the data measurements. Filter parameters can be adjusted using the Instrument Configurator application under device Settings.

T1: The internal temperature of the instrument.

L3: The actual water level measured by the instrument. The measured water level depends on the measured distance between the instrument and the water surface, and on the predefined instrument offset which can be adjusted using the Instrument Configurator application under device Settings.

L4: The average water level measured by the instrument. The measured water level depends on the measured distance between the instrument and the water surface, and on predefined instrument offset which can be adjusted under device Settings. The measured water level is filtered using averaging filer, to smooth the measured data. Filter parameters can be adjusted using the Instrument Configurator application under device Settings.

S1: Signal to Noise Ratio of the detected signal. SNR is the difference between signal level corresponding to measured distance and the noise floor level. Low SNR levels indicate that the measured value may be inaccurate.

S2: The standard deviation of water level measurements. The number of samples used to calculate the standard deviation is equal to the configured filter length. This parameter is available on units with firmware versions greater than 2.3.2.

7.2.2 TILT ANGLE REPORT

$ANG,A1,A2 <CR><LF> firmware versions greater than 2.3.5

$ANG: The keyword sent in the beginning of each angle report.

A1: The tilt angle of the instrument along X axis. For proper operation of the instrument, ensure that this angle is zero, or as close to zero as possible (between -1 and +1 degrees).

A2: The tilt angle of the instrument along Y axis. For proper operation of the instrument ensure that this angle is zero, or as close to zero as possible (between -1 and +1 degrees).

7.3 SERVICING PROTOCOL (RS-232)

The servicing protocol is used to retrieve and modify the instrument's operating parameters. Various instrument settings, such as unit system and filtering parameters are configured using this protocol. Since NMEA protocol is one way (it only outputs the data), the servicing protocol is always active.

Easy radar configuration can also be done using the Instrument Configurator as described in Chapter 8.

The servicing protocol listens on RS-232 serial port for incoming requests, and on each received request, it will answer back.

The following requests are recognized by the servicing protocol and every command should be followed by <CR>, <LF> or <CR><LF> (enter):

7.3.1 CHANGE INTERFACE PARAMETERS:

RS-232 baud rate: Configures the baud rate (bits per second) for serial communication on RS-232 data line. This setting controls how many bits are sent on the communication line in one second. The available values are standardised. Using higher baud rate over longer lines may introduce errors in transferred data. The default instrument RS-232 baud rate is 115200 bps.

```
#set_baud_rate = 9600
#set_baud_rate = 38400
#set_baud_rate = 57600
#set_baud_rate = 115200
#set_baud_rate = 19200
```

RS-485 baud rate: Configures the baud rate (bits per second) for serial communication on RS-485 data line. This setting controls how many bits are sent on the communication line in one second. The available values are standardised. Using higher baud rate over longer lines may introduce errors in transferred data. The default instrument RS-485 baud rate is 9600 bps.

#set_modbus_baud_rate=9600
#set_modbus_baud_rate=38400
#set_modbus_baud_rate=57600
#set_modbus_baud_rate=115200
#set_modbus_baud_rate=1200
#set_modbus_baud_rate=19200

Modbus ID: Configures the device (slave) ID to be used for Modbus RTU protocol. Modbus RTU uses request/response format and allows multiple instruments to be connected on the same bus. When a remote master transmits the request message, it will use the device ID as a device address. All instruments will receive the request, but only the instrument with matching device ID will answer to the received request.

Modbus parity: Parity is used in serial communication for basic error detection. When parity is set to none, no parity is used, and no error detection is possible on bit level. When parity is set to odd parity, an additional bit is added to the communication that will be set to 1 when there is odd number of bits with value 1 in the 8-bit payload byte. Similarly, when parity is set to even parity, an additional bit is added to the communication that will be set to 1 when there is even number of bits with value 1 in the 8-bit payload byte. In general, all bytes on the receiver side where the parity bit is not matching the message will be discarded. Default setting on most devices that use Modbus is even parity.

#set_modbus_parity=0 (none)
#set_modbus_parity=1 (odd parity)
#set_modbus_parity=2 (even parity)

Modbus stop bits: Stop bits are added to the end of each data byte transferred over serial communication, to allow pause between two bytes. One or two bits may be used. The default setting on most Modbus RTU devices is one stop bit, but some dataloggers may require that the instrument is configured to use two stop bits.

#set_modbus_stopbits=1
#set_modbus_stopbits=2

SDI-12 ID: The SDI-12 device ID to be used on SDI-12 interface. In SDI-12 request/response protocol, this ID will be used to define the instrument address, and the instrument will respond only to requests with matching ID

#set_sdi_id=<0-61>

4-20 mA min: To configure the 4-20 mA output range, the minimum measured value which will correspond to 4 mA analog output needs to be set. The value is set in the currently configured measurement unit.

Example: if values measured by the instrument are expected to be within the range of

700 mm to 5000 mm, it is recommended to configure the minimum value to slightly below 700 mm (for example 500 mm). Alternatively, if the resolution is not critical, then minimum value for 4-20 mA output can be left to the instrument minimum of 0 mm.

#set_analog_min=<value>

4-20 mA max: To configure the 4-20 mA output range, the maximum measured value which will correspond to 20 mA analog output needs to be set. The value is set in the currently configured measurement unit.

Example: if values measured by the instrument are expected to be within the range of 700 mm to 5000 mm, it is recommended to configure the maximum value to slightly above 5000 mm (for example 6000 mm). Alternatively, if the resolution is not critical, then maximum value for 4-20 mA output can be left to the instrument maximum.

#set_analog_max=<value>

7.3.2 CHANGE PROCESSING PARAMETERS:

Filter type - Changes the type of filter used for smoothing measured data.

No filter - No filtering is used and the raw measurements are reported.

IIR - Infinite-impulse response filter is used to smooth the data. When compared to the moving average filter, the IIR filter reacts more quickly to initial changes in the data, but it takes longer for the smoothed value to reach the new measurement. The use of IIR filter is discouraged for general applications. The IIR constant can be configured separately.

Moving average - The moving average filter calculates the average value of a number of raw measurements. The length for the moving average filter is configured separately through the Filter length parameter.

Median - The median filter finds the median value from a number of raw measurements. The length for the median filter is configured separately through the Filter length parameter.

Standard deviation - This type of filter is similar to the moving average filter. It takes a number of raw measurements (as defined by Filter length parameter), removes 20% of outliers, and calculates the average of the remaining 80% of values.

#set_filter_type=0 (No filter)
#set_filter_type=1 (IRR)
#set_filter_type=2 (Moving average)
#set_filter_type=3 (Median) Supported on units with firmware versions greater than 2.2.8.

#set_filter_type=4 (Standard deviation) Supported on units with firmware versions greater than 2.3.2.

Filter length - The length of the averaging filter, in number of readings, to smooth the measured values. The instrument performs 1 reading per second, so a filter length value of 10 will result in 10 seconds integration time. When using longer filter lengths, more measured values are used for filtering, and the resulting data will be smoother. However, when the water level changes, it will take more time for the new measurement to be reported. Typically, this parameter should be set to a value between 10 and 50. For highly turbulent water, a larger filter length is recommended.

#set_frame_number=<1-1000>

IIR constant - The constant used by infinite impulse response (IIR) filter - if IIR filter is selected to be used instead of average filter. Accepted values are decimal numbers between 0 and 1. When the IIR constant value is closer to 0.0, the filter response will be slower. When the IIR constant value is closer to 1.0, then the filter response will be faster.

#set_IR_constant=<0-1>

Peak detector type - Configuring the type of algorithm which is used to detect the peaks in the radar echo curve. The default setting should be Maximum peak. In specific cases, such as when water level needs to be measured, but there is a lot of vegetation protruding from the water surface, Last peak detector type should be used. This setting is available on units with firmware versions greater than 2.3.2.

#set_peak_detector=0 (Maximum peak)
#set_peak_detector=1 (Last peak)

7.3.3 CHANGE PROCESSING PARAMETERS:

Level unit: The measurement unit used to report the measured level value. The default measurement unit is millimetres. When changing the measurement unit, it's important to make sure that other parameters which depend on the measurement unit (such as active zone parameters) are also changed to the new unit. The measurement unit used to report the measured level

#set_unit=0 (mm)
#set_unit=1 (cm)
#set_unit=2 (m)
#set_unit=3 (in)
#set_unit=4 (ft)

Level offset - Changes the measurement level offset. This value should not be changed.

#set_level_offset=<value>

Amplitude threshold - Sets the minimum amplitude of the spectral peak in signal analysis algorithm required to detect peak and report distance. If no peak above this value is detected, the sensor will report distance equal to 0. The threshold is used to filter noise and false readings and it is recommended to keep this value in the range 0 to 1000.

#set_amplitude_threshold=<value>

Active zone min. - This parameter limits the operational range of the instrument. The instrument will detect water level only within the range set by the Active zone min. and Active zone max. parameters. This parameter is the best way to filter unwanted radar reflections from other structures and objects that are present on the monitoring site that could cause false instrument readings. It is strongly recommended to set the Active zone min. value to the minimum possible distance between the water and the instrument at the specific monitoring site.

#set_deadzone_min=<value>

Active zone max. - This parameter limits the operational range of the instrument. The instrument will detect water level only within the range set by the Active zone min. and Active zone max. parameters. This parameter is the best way to filter unwanted radar reflections from other structures and objects that are present on the monitoring site, that could cause false instrument readings. It is strongly recommended to set the Active zone max. value to the maximum possible distance between the water and the instrument at the specific monitoring site. Typically, this is the distance between the instrument and the lowest point in the channel.

#set_deadzone_max=<value>

Sensor height - The height of the instrument needs to be set above the water zero-level "gauge zero". The instrument will output relative measurement of the actual water level based on its height above the water zero-level. Example: if the instrument is mounted exactly 5 metres above the gauge zero level, then this parameter should be set to 5 metres. Then, if the instrument measures that the distance between the instrument and the water is 4 metres, it will report that the water level is 1 metre, because the water is 1 metre above the gauge-zero level. For user convenience, this parameter can also be indirectly set by inputting the current staff gauge reading, by clicking on Enter staff gauge reading button.

#set_sensor_height=<value>

Staff gauge - Setting the sensor height relative to the measurement is done using staff gauge. The sensor will output relative measurement of the actual water level based on its height above the riverbed.

#set_staff_gauge=<value>

Operation mode - Switches the device between operating mode and standby mode. While the device is in standby mode, it will communicate through communication interfaces, but no measurements will be made. In operating mode, the device continuously performs the measurements. In standby mode, the power consumption is reduced by 50%.

#set_power_save=0 (Operating mode)
#set_power_save=1 (Standby mode)

Power management - Switches the device between continuous scanning mode and SDI- 12 mode. In continuous mode the device constantly makes the measurements which are transmitted over the RS-232 interface and made available over Modbus and SDI-12 interfaces. The device is always available over RS-232 and Modbus interfaces. In SDI-12 mode, the device remains in the sleep mode until the SDI-12 Measure (aM!) command is received. While in sleep mode, the device will not be able to connect to Modbus or RS-232 interface. For reconfiguring the device which is set to operate in SDI-12 mode, it's necessary to power-cycle the device, and then use this application to connect to the device within 1 minute after power-up. If there is no attempt to connect to the device over RS-232 within one minute, the device will automatically go back to sleep mode. In sleep mode, it consumes only 0.03 W.

#set_sdi_sleep=0 (SDI-12 automatic sleep)
#set_sdi_sleep=1 (Continuous scanning)

Retrieve current device status: Requests the current device status.

#get_info

Example status output:

```
# device_type:999
# firmware:16
# serial_number:000000
# modbus_id:2
# baud_rate:115200
# rs485_baud_rate:9600
# rs485_parity:2
# rs485_stopbits:1
# level_range:15360.000000
# level_resolution:7.500000
# level_offset:0.100000
# deadzone_min:0.200000
# deadzone_max:15.360000
# averaging_frame_number:24
# spectrum_amplitude_threshold:15
# IR_constant:0.250000
# FFT_size:4096
# chirp_slope_rate:40
# ramp_duration:100
# sampling_rate:8191
# number_of_samples:777
# RX_gain:34
# active_TX_antenna:1
```

7.4 MODBUS PROTOCOL (RS-485)

The unit responds to Modbus requests over RS-485 data line. The baud rate is configured through the PC application, and 1 stop bit, even parity, 8 data bits configuration is used.

Modbus registers that are accessed by Modbus protocol are 16-bit (2-byte) registers. Any number of registers can be read or written over Modbus.

Modbus is a request-response protocol where a master (such as datalogger) sends out requests, and slave devices (such as the LX-80 sensor) respond. The request and response format, with examples is given in Sections 7.4.1 and 7.4.2.

In each request, the master can either ask the slave to retrieve the value of one or more registers, or the master can set the value of one or more registers. Each register holds one 16-bit value.

7.4.1 MASTER REQUEST FORMAT

Name	Address	Fun	Data Start Address		Register Count		CRC16	
Length	1 byte	1 byte	2 bytes (H,L)		2 bytes (H,L)		2 bytes (L,H)	
Example	0X01	0X03	0X00	0X00	0X00	0X01	0X84	0X0A

Master Request Example

Name	Content	Detail
Address	0X01	Slave address (Sensor id)
Function	0X03	Read holding register
Data start address	0X00	The address of the first register to read minus one (HIGH)
	0X00	The address of the first register to read minus one (LOW)
Number of regs	0X00	High
	0X01	Low (read only 1 register)
CRC16	0X84	CRC Low
	0X0A	CRC High

7.4.2 SLAVE (SENSOR) RESPONSE FORMAT

Name	Address	Fun	Byte Count		Data		CRC16	
Length	1 byte	1 byte	1 byte		2 bytes(H,L)		2 bytes(L,H)	
Example	0X01	0X03	0X02	0X00	0X01	0X79	0X84	0X0A

Please note that Modbus register addresses start with 1. The lowest possible address for the Modbus register is 1. However, in the Modbus request packet the data start address is written as the address of the first register to read minus one. For example, to retrieve the Modbus register number 5, in the Modbus data packet the address of that register should be written as 4.

Slave Response Example

Name	Content	Detail
Name	Content	Detail
Address	0X01	Slave address (Sensor id)
Function	0X03	Read holding register
Data length	0X02	Data length is 2 bytes
Data	0X00	Data high byte
	0X01	Data low byte, means ID is 1
CRC16	0X79	CRC Low
	0X84	CRC High

7.4.3 RETRIEVING DATA FROM THE SENSOR

The following table defines the data returned by the instrument when the master requests that the register is read. Rows highlighted in blue denote the important values measured by the sensor. Rows highlighted in green denote operating parameters that could be changed in the field. "Fun" corresponds to Modbus function codes, i.e. 0X03 – Read holding register and 0X05 – Write holding register.

Fun	Register Address	Data Length	Data Range	Details
0X03	0x0001	2 bytes	0 – device range[mm]	Current level measurement
	0x0002	2 bytes	0 – device range[mm]	Average level measurement
	0x0003	2 bytes	0 → 9600 1 → 38400 2 → 57600 3 → 115200 4 → 1200 5 → 19200 0xFF → other/error	RS-232 baud rate
	0x0004	2 bytes	1 - 255	Modbus ID
	0x0005	2 bytes	0 → 9600 1 → 38400 2 → 57600 3 → 115200 4 → 1200 5 → 19200 0xFF → other/error	RS-485 baud rate (Modbus)
	0x0006	2 bytes	0 → no parity, 1 stop bit 1 → no parity, 2 stop bits 2 → odd parity, 1 stop bit 3 → odd parity, 2 stop bits 4 → even parity, 1 stop bit 5 → even parity, 2 stop bits default → even parity, 1 stop bit	RS-485 parity and stop bits

Fun	Register Address	Data Length	Data Range	Details
0X03	0x0007	2 bytes	1-65535	SDI-12 ID
	0x000A	2 bytes	900 - 65535	Device type; LX-80 → 999, 998, 997
	0x000B	2 bytes	1 – 200 default: 24	Filter length
	0x000C	2 bytes	1 – 65535 default: 0	Minimum spectrum amplitude threshold, used for detecting peaks
	0x000D	2 bytes	0 – device range default → 0	Active zone minimum in selected unit
	0x000E	2 bytes	0 – device range default → device range [unit]	Active zone maximum in selected unit
	0x000F	2 bytes	0 – device range default → 0	4-20mA minimum value in selected unit
	0x0010	2 bytes	0 – device range default → device range [unit]	4-20mA maximum value in selected unit
	0x0011	2 bytes	0 – device range [unit]	Level measurement offset
	0x0012	2 bytes	0 – 1000	IR filter constant $IR_{const} = \frac{value_{int}}{1000}$
	0x0013	2 bytes	0 – 34	RX gain
	0x0014	2 bytes	1 – 3	Active TX antenna
	0x0015	2 bytes	2 printable characters	Serial number[0-1]
	0x0016	2 bytes	2 printable characters	Serial number[2-3]
	0x0017	2 bytes	2 printable characters	Serial number[4-5]
	0x0018	2 bytes	Firmware version	Current firmware version
	0x0019	2 bytes	4096, 8192	Number of FFT samples
	0x001A	2 bytes	0 – 255	Temperature of electronics inside the case
	0x001B	2 bytes	0+	SNR
	0x001C	2 bytes	0 – 4	0 – no filter 1 – IIR filter 2 – Moving average 3 – Median 4 – Standard deviation

Fun	Register Address	Data Length	Data Range	Details
0X03	0x001D	2 bytes	0 → mm 1 → cm 2 → m 3 → ft 4 → in	Level unit
	0x0020	2 bytes	Current relative level	Current level measured depending on the sensor height; Calculated as sensor height – current level
	0x0021	2 bytes	Average relative level	Average level measured depending on the sensor height; Calculated as sensor height – average level
	0x0022	2 bytes	Sensor height	Sensor height above the riverbed
	0x0024	2 bytes	0 → Operating mode 1 → Standby mode	Power management
	0x0025	2 bytes	0 → SDI-12 mode 1 → Continuous scanning	Number of FFT samples
	0x0028	2 bytes	0 → Maximum peak 1 → Last peak	Peak detector type
	0x0029	2 bytes	Standard deviation	Standard deviation of measurement
	0x002A	2 bytes	0 – 360	x-axis tilt angle
	0x002B	2 bytes	0 – 360	y-axis tilt angle

7.4.4 WRITING TO THE DEVICE'S CONFIGURATION

The following table defines how to write the device configuration. Rows highlighted in blue denote the important values measured by the sensor. Rows highlighted in green denote operating parameters that could be changed in the field. "Fun" corresponds to Modbus function codes, i.e. 0X05 – Write holding register.

Fun	Register Address	Data Length	Data Range	Details
0X06	0x0003	2 bytes	0 → 9600 1 → 38400 2 → 57600 3 → 115200 4 → 1200 5 → 19200	RS-232 baud rate
	0x0004	2 bytes	1 - 255	Modbus ID

Fun	Register Address	Data Length	Data Range	Details
0X06	0x0004	2 bytes	1 - 255	Modbus ID
	0x0005	2 bytes	0 → 9600 1 → 38400 2 → 57600 3 → 115200 4 → 1200 5 → 19200	RS-485 baud rate (Modbus)
	0x0006	2 bytes	0 → no parity, 1 stop bit 1 → no parity, 2 stop bits 2 → odd parity, 1 stop bit 3 → odd parity, 2 stop bits 4 → even parity,1 stop bit 5 → even parity, 2 stop bits	RS-485 parity and stop bits
	0x0007	2 bytes	1 – 65535	SDI-12 ID
	0x000B	2 bytes	1 – 1000 default: 100	Filter length
	0x000C	2 bytes	1 – 65535 default: 0	Minimum spectrum amplitude threshold, used for detecting peaks
	0x000D	2 bytes	0 – device range default → 0	Active zone minimum
	0x000E	2 bytes	0 – device rang default → device range	Active zone maximum
	0x000F	2 bytes	0 – device range default → device range	4-20mA minimum value
	0x0010	2 bytes	0 – device range default → device range	4-20mA maximum value
	0x0011	2 bytes	0 – device range	Level measurement offset
	0x0012	2 bytes	0 – 1	IR filter constant $IR_{const} = \frac{value_{Int}}{1000}$
	0x0015	2 bytes	2 printable characters	Serial number[0-1]
	0x0016	2 bytes	2 printable characters	Serial number[2-3]
	0x0017	2 bytes	2 printable characters	Serial number[4-5]
	0x001C	2 bytes	0-4	0 – no filter 1 – IIR filter 2 – Moving average 3 – Median 4 – Standard deviation

Fun	Register Address	Data Length	Data Range	Details
0X06	0x001D	2 bytes	0 → mm 1 → cm 2 → m 3 → ft 4 → in	Level unit
	0x0022	2 bytes	Sensor height	Sensor height above the riverbed
	0x0023	2 bytes	Staff gauge	Staff gauge measurement used to indirectly determine sensor height; Sensor height = staff gauge + current measured distance from sensor to water
	0x0024	2 bytes	0 → Operating mode 1 → Standby mode	Power management
	0x0025	2 bytes	0 → SDI-12 mode 1 → Continuous scanning	Operation mode
	0x0026		Clear calibration	Recalibrate the instrument
	0x0027		Save background	Save background
	0x0028	2 bytes	0 → Maximum peak 1 → Last peak	Peak detector type

Chapter 8 INSTRUMENT CONFIGURATOR

The Instrument Configurator is a user-friendly PC application which can be used for setting up the level meter operating parameters. Additionally, the Instrument Configurator displays current level measurements. The Instrument Configurator can be downloaded here under SOFTWARE: https://www.geolux-radars.com/lx-80.html

8.1 CONNECTING THE RADAR TO THE CONFIGURATOR

Open the Instrument Configurator on your PC. Note that the main window will be blank. No level data is displayed as the connection to the instrument is not established.

To connect the Instrument Configurator with the instrument:

1) Connect your PC to the radar using a serial cable connection.
2) Then, click the *Connect* button in the upper left corner and select *Level meter* from the window which appears.
3) In the next window, select the appropriate COM port and interface. If RS-485 interface is selected, additionally select the baud rate and the Modbus ID. In case of multiple devices connected on a single RS-485 bus, make sure that each device has a unique Modbus ID.
4) Select the *Connect* button. If the connection is successful, the device will appear under *Connected devices* and level measurements will be displayed in the *Data* tab as shown in Figure 10-1.

Figure 8-1: Data Tab Example

8.2 *CONFIGURATOR FUNCTIONS*

A detailed description of the displayed parameters is available when hovering the mouse over the icon of a specific parameter. Initially, only the most important parameters are displayed while the rest are hidden. By clicking on the button with arrows next to the displayed parameters, the user can view all the data received from the device.

8.2.1 *SETTINGS*

Clicking the Settings button enables the user to configure the instrument or upgrade the device to a newer firmware version.

Instrument settings are sorted into 3 groups: Interfaces, Processing and Measurement, as shown below. By clicking the name of a specific group, all the settings which belong to that group can be viewed and changed. The following settings are displayed:

Interfaces	**Processing**	**Measurement**
RS-232 baud rate	Filter type	Level unit
RS-485 baud rate	Filter length	Level offset
Modbus ID	IIR constant	Active zone min.
Modbus parity	Amplitude threshold	Active zone max.
Modbus stop bits	Peak detector type	Sensor height
SDI-12 ID		Operation mode
4-20 mA min.		Power management
4-20 mA max.		

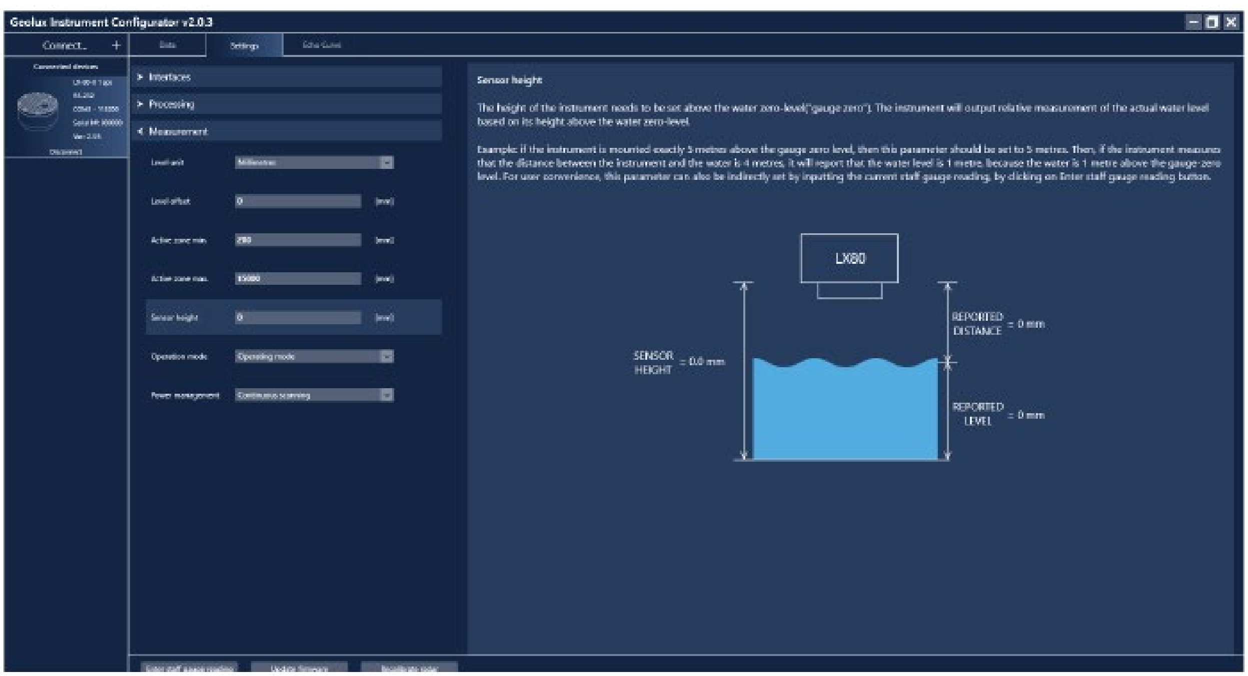


Figure 8-2: Settings View

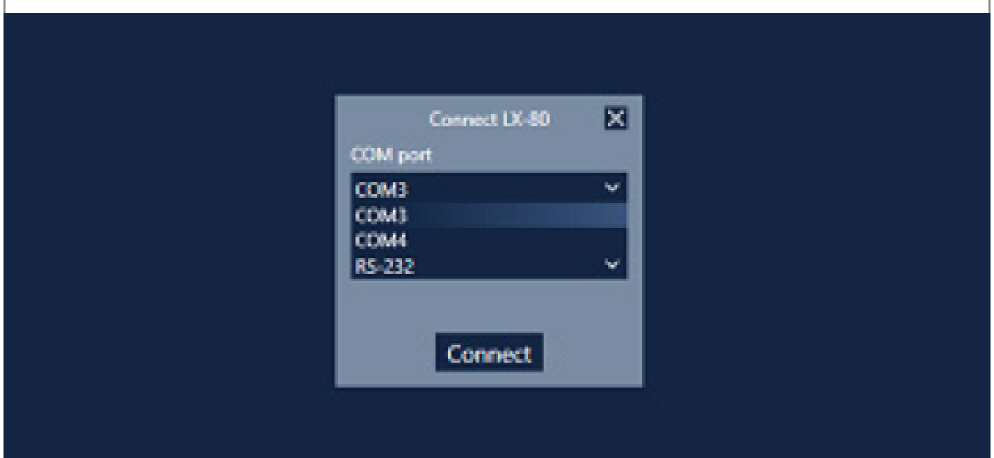
A detailed description of the selected setting appears on the right side of the window when the user clicks on, or begins to change, a specific setting. When a setting is changed, the Set button will appear next to the setting. By clicking the Set button, the user confirms the change and the new setting is saved.

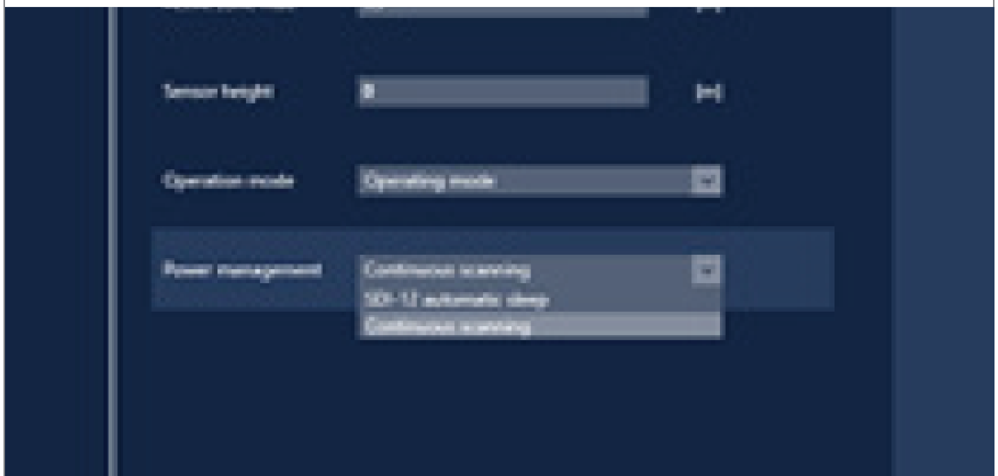
8.2.2 ECHO CURVE

The Instrument Configurator also enables echo curve acquisition. Navigating to the Echo Curve tab and clicking the “Load Echo Curve” button loads the current echo curve, as shown in Figure 10-3. The echo curve plot shows the current echo curve in yellow, as well as the background echo curve in blue. The user can choose to clear the background by clicking the Clear background button or set the background echo curve to a desired distance by clicking the Set background button. After setting or clearing the background, echo curves should be reloaded by clicking the Reload echo curve button. Echo curves can be saved to a .csv file by clicking on “Save toCSV…” button.

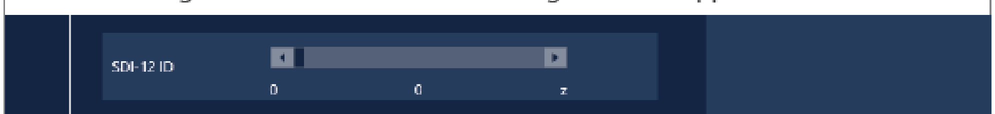
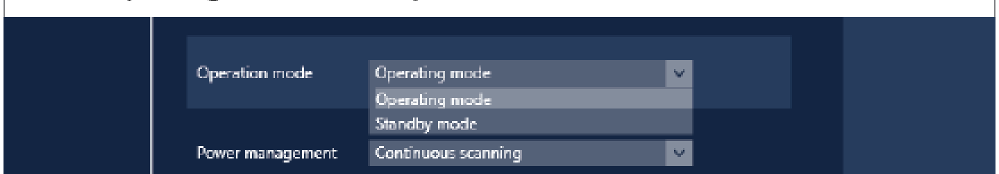
Figure 8-3: Echo Curve Page

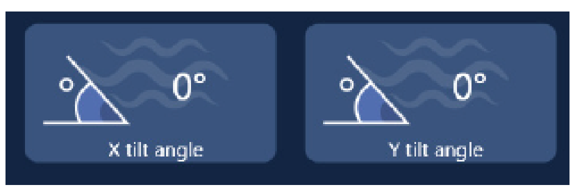
Chapter 9 TROUBLESHOOTING

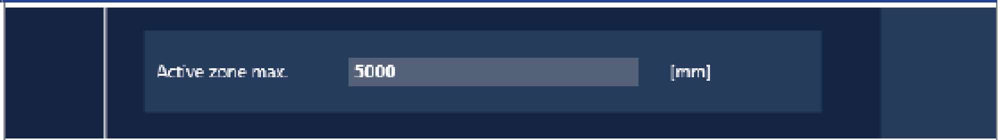
Problem	Possible solutions
The instrument does not connect to the PC application over RS-232 connection.	**1. Make sure that the cable is properly connected to the instrument** Check that the cable M12 circular connector is firmly connected and screwed to the instrument. It is not sufficient to simply attach the cable connector to the instrument connector, the cable connector must be screwed into the instrument connector. **2. Check power supply** Make sure that the power is being supplied to the instrument. A direct-current voltage, between 9 and 27 Volts must be connected to brown (+) and white (-) wires of the instrument cable. The power supply must be able to deliver at least 500 mA of current. **3. Check RS-232 connector** The yellow, green and grey wires from the instrument cable must be properly connected to the serial port on the computer. Make sure that the grey wire (signal ground) is connected – the RS-232 connection will not work if the signal ground is not connected. Also, make sure that the yellow (device Rx) and green (device Tx) are properly connected. If you are using a standard DB9 type connector on the PC computer, the wires should be connected like in the following diagram: **4. Make sure that you are using the correct COM port** If there are multiple COM ports available on your computer, make sure that you are selecting the correct COM port in the PC application. If you are not certain which COM port number is assigned to the COM port that is being used to establish a connection with the instrument, try setting up the connection with each COM port available in the system, until the connection is established.  **5. Check that the device is not operating in SDI-12 mode** The instrument can be configured to operate in SDI-12 mode. In this mode the instrument enters low power mode unless it receives an SDI-12 command over the SDI-12 interface. While the device is in SDI-12 mode, it will not respond to commands over RS-232 connection. To establish a RS-232 connection with the device which operates in SDI-12 mode, power off the device and then power it back on. After power-up there is a one minute period in which the device will not enter the SDI-12 low power mode and it will be possible to establish a connection over the RS-232 line. If the connection is established within 60 seconds after power-up, and as long as the Geolux Instrument Configurator application is connected to the sensor,

Problem	Possible solutions
The instrument does not connect to the PC application over RS-232 connection. (continued)	it will remain in operating mode. To change between regular operating mode (*Continuous scanning*) and SDI-12 mode (*SDI-12 automatic sleep*), change the *Power management* parameter in the *Settings* tab.  **6. Make sure that the COM port is not already open** Only one application may use a single COM port in the system. Make sure that no other open application uses the same COM port that you are trying to open. **7. Try restarting the application and/or the computer** Close and reopen the configurator application and try to establish the connection again. Restart your computer and try to establish the connection to the instrument again.
The instrument does not respond over Modbus (RS-485) interface.	**1. Make sure that the cable is properly connected to the instrument** Check that the cable M12 circular connector is firmly connected and screwed to the instrument. It is not sufficient to simply attach the cable connector to the instrument connector, the cable connector must be screwed into the instrument connector. **2. Check power supply** Make sure that the power is being supplied to the instrument. A direct-current voltage, between 9 and 27 Volts must be connected to brown (+) and white (-) wires of the instrument cable. The power supply must be able to deliver at least 500 mA of current. **3. Check RS-485 connector** Make sure that the RS-485 lines on the instrument cable are properly connected to the RS-485 connector. The dark red wire should be connected to D+ line, and the orange line should be connected to D- line. Make sure that the D+ and D- lines are not swapped. Make sure that you have correctly identified and connected the dark red (magenta) wire, as there is also another bright red wire that is used to provide output power for 4-20mA output. It is possible to misidentify the wire and to connect the bright red wire to D+ instead of dark red wire. **4. Check that you are using the correct slave device ID** The default Modbus device ID is 1. The Modbus device ID can be changed by connecting the instrument to the PC application (over RS-232 connection).

Problem	Possible solutions
The instrument does not connect to the PC application over RS-232 connection. (continued)	Connect the instrument to the PC using RS-232 connection. Open the Geolux Instrument Configurator application and establish a connection between the instrument and the PC. Then check the *Modbus ID* parameter and make sure that it is the same as the slave device ID used in issued Modbus requests.  **5. Make sure that there are no two devices on the bus with the same Device ID.** Modbus allows to have multiple devices connected on the same bus simultaneously. Each device must have a unique slave device ID assigned, so that the bus master can distinguish between the devices. If two or more devices are assigned the same slave device ID, a bus conflict will happen and prohibit the master to correctly communicate with the slave devices. To resolve this problem, change the instrument's slave device ID to a unique number through the Geolux Instrument Configurator PC application. **6. Check that you are using the correct Modbus connection parameters (baud rate, parity, stop bits)** The default Modbus connection parameters are 9600 bps, even parity, 1 stop bit. These parameters can be changed by connecting the instrument to the PC application (over RS-232 connection). Connect the instrument to the PC using RS-232 connection. Open the Geolux Instrument Configurator application and establish a connection between the instrument and the PC. Then check and verify that all Modbus connection parameters are correct.  **7. Check that the device is not operating in SDI-12 mode** The instrument can be configured to operate in SDI-12 mode. In this mode the instrument enters low power mode unless it receives an SDI-12 command over SDI-12 interface. While the device is in SDI-12 mode, it will not respond to commands over RS-232 and RS-485 (Modbus) connections. To change the instrument's operating mode from SDI-12 mode to normal mode, first you need to connect the Geolux Instrument Configurator to the device. To establish a RS-232 connection with the device which operates in SDI-12 mode, power off the device and then power it back on. After power-up, there is a one minute period in which the device will not enter SDI-12 low power mode and it will be possible to establish a connection over the RS-232 line. If the connection is established within 60 seconds and as long as the Geolux Instrument Configurator application is connected to the sensor, it will remain in operating mode. To change between regular operating mode (*Continuous scanning*) and SDI-12 mode (*SDI-12 automatic sleep*), change the *Power management* parameter in the *Setting* tab. 

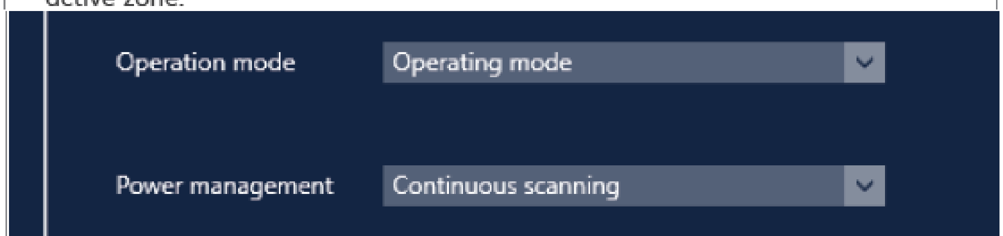
Problem	Possible solutions
The instrument does not respond over SDI-12 interface.	**1. Make sure that the cable is connected properly to the instrument** Check that the cable M12 circular connector is firmly connected and screwed to the instrument. It is not sufficient to simply attach the cable connector to the instrument connector, the cable connector must be screwed into the instrument connector. **2. Check power supply** Make sure that the power is being supplied to the instrument. A direct-current voltage, between 9 and 27 Volts must be connected to brown (+) and white (-) wires of the instrument cable. The power supply must be able to deliver at least 500 mA of current. **3. Check SDI-12 connection** Check and verify that the black wire from the instrument cable is connected to the SDI-12 data line, and that the grey wire from the instrument cable is connected to the Ground (GND) line on the SDI-12 data logger. It is important that both the data line and the signal ground lines are connected. **4. Check that you are using the correct SDI-12 device ID** The default SDI-12 device ID is A. The device ID can be changed by connecting the instrument to the PC application (over RS-232 connection). Connect the instrument to the PC using RS-232 connection. Open the Geolux Instrument Configurator application and establish a connection between the instrument and the PC. Then check the *SDI-12 ID* parameter and make sure that it is the same as the device ID used in issued SDI-12 requests.  **5. Make sure that there are no devices with the same device ID connected on the bus.** SDI-12 allows to have multiple devices connected on the same bus simultaneously. Each device must have a unique device ID assigned, so that the SDI-12 master device (datalogger) can distinguish between the devices. If two or more devices are assigned the same device ID, a bus conflict will happen and prohibit the master to correctly communicate with the slave devices. To resolve this problem, change the instrument's SDI-12 device ID to a unique value through the Geolux Instrument Configurator PC application. 
The instrument consumes too much power while operating in SDI-12 mode (it does not reduce power between two SDI-12 Measure! Commands)	**1. Switch the instrument from operating mode to standby mode.** Establish the connection to the device over RS-232 connection from the Geolux Instrument Configurator PC application. Change the *Operation mode* parameter from *Operating mode* to *Standby mode*. 

Problem	Possible solutions
The 4-20 mA output is not correct.	**1. Make sure that the cable is properly connected to the instrument** Check that the cable M12 circular connector is firmly connected and screwed to the instrument. It is not sufficient to simply attach the cable connector to the instrument connector, the cable connector must be screwed into the instrument connector. **2. Check power supply** Make sure that the power is being supplied to the instrument. A direct-current voltage, between 9 and 27 Volts must be connected to brown (+) and white (-) wires of the instrument cable. The power supply must be able to deliver at least 500 mA of current. **3. Make sure that the wires from the cable are properly connected** For 4-20 mA redout, the bright red wire from the instrument cable must be connected to the positive (+) input, and the purple wire (4-20 mA sink output) must be connected to the negative (–) input of the 4-20 mA interface. Make sure that the correct bright red wire is used for connection, and not the dark red (magenta) wire. **4. Check the instrument configuration parameters related to 4-20 mA output** Connect the instrument over RS-232 connection to the Geolux Instrument Configurator application. Check the parameters related to 4-20 mA: *4-20 mA min.* and *4-20 mA max.* Properly configure these parameters. 
The instrument is operating, but: -it does not report distance/level measurement, -it reports 0 (zero) distance, -it reports incorrect measurement	**1. Check that the instrument is positioned properly** Make sure that the instrument is level and pointing towards the water surface at the right angle (the radar beam should be perpendicular to the water surface). Both tilt angles should be zero degrees, or not bigger than 2° in any direction.  **2. Check that there are no obstructions between the instrument and the water surface** There should be no obstructions between the instrument and the water surface, so that the radar waves can freely travel from the instrument's antenna to the water surface and back. Objects such as rocks, construction elements (metal, concrete, etc.), vegetation (tree branches, water vegetation, etc.) can all affect the instrument's reading. If there are some minimal obstructions far away from the water surface, and the radar is reporting the distance to these objects instead of the distance to the water surface, you can adjust the active zone of the instrument. The active zone limits the minimum and maximum range within which the instrument searches for the water surface. For example, if there is an obstruction 1 meter away from the instrument, and the instrument reports a distance of 1 meter, but the water surface is expected to be between 3 and 5 meters, you can adjust the active zone to be within 3 and 5 meters, and then the instrument will discard all measurements outside of that range.

<table>
<tr><th>Problem</th><th>Possible solutions</th></tr>
<tr><td></td><td>


3. Check that the distance between the instrument and the water surface is within the instrument's operating range.
Use a tape measure or a similar tool to measure the distance between the instrument's antenna and the water surface. If the distance to the water surface is greater than the instrument's operational range, the instrument will not be able to measure the distance and the water level.

4. Check that the distance between the instrument and the water surface is within configured active zone.
Connect the instrument to the Geolux Instrument Configurator PC application over RS-232 connection. Check the active zone parameters – if the distance to the actual water surface is outside of the predefined active zone, the instrument will not be able to report the correct distance. Modify the active zone parameters so that the actual distance to the water surface is within the active zone.



5. Update device firmware
Connect the instrument to the Geolux Instrument Configurator PC application over RS-232 connection. Check the active zone parameters – if the distance to the actual water surface is outside of the predefined active zone, the instrument will not be able to report the correct distance. Modify the active zone parameters so that the actual distance to the water surface is within the active zone.

6. Re-calibrate the device
If none of the above mentioned suggestions have helped resolve the problem, perform device re-calibration. The instrument has the capability to perform self-calibration. Normally there is no need to re-calibrate the instrument after its initial calibration in the factory, but in rare cases, re-calibration can resolve the operating problems of the device. To re-calibrate the instrument, connect it over RS-232 to the Geolux Instrument Configurator PC application, and then, under *Settings*, click on the *Recalibrate radar* button.

</td></tr>
<tr><td>Firmware upgrade has failed, or firmware upgrade gets stuck on "Erasing flash", or there is no reading after performing the firmware upgrade.</td><td>

1. Repeat the firmware upgrade procedure
If the firmware upgrade fails, gets stuck on Erasing flash, or if after the firmware upgrade it is not possible to get any readings from the instrument, power off the device and close the Geolux Instrument Configurator application. After that, power the instrument back on, re-establish the RS-232 connection to the Geolux instrument Configurator PC application, and perform the firmware upgrade procedure again.
</td></tr>
</table>

Chapter 10 TECHNICAL DATA

10.1 SPECIFICATIONS

Characteristics and Performance Data	
Measuring Frequency	77-81GHz (W band)
Measuring Cycle Time **- Standard electronics** **- Increased sensitivity (optional)**	 1 sample per second 10 samples per second
Beam Angle (3dB)	5º both axes (±2.5 ºeach side)
Measurement Range • **LX-80-8** • **LX-80-15** • **LX-80-30**	 0.1m – 8m (0.32ft – 26.2ft) 0.1m – 15m (0.32ft – 49.2ft) 0.1m-30m (0.32ft – 98.4ft)
Accuracy	±3mm
Resolution	0.5mm

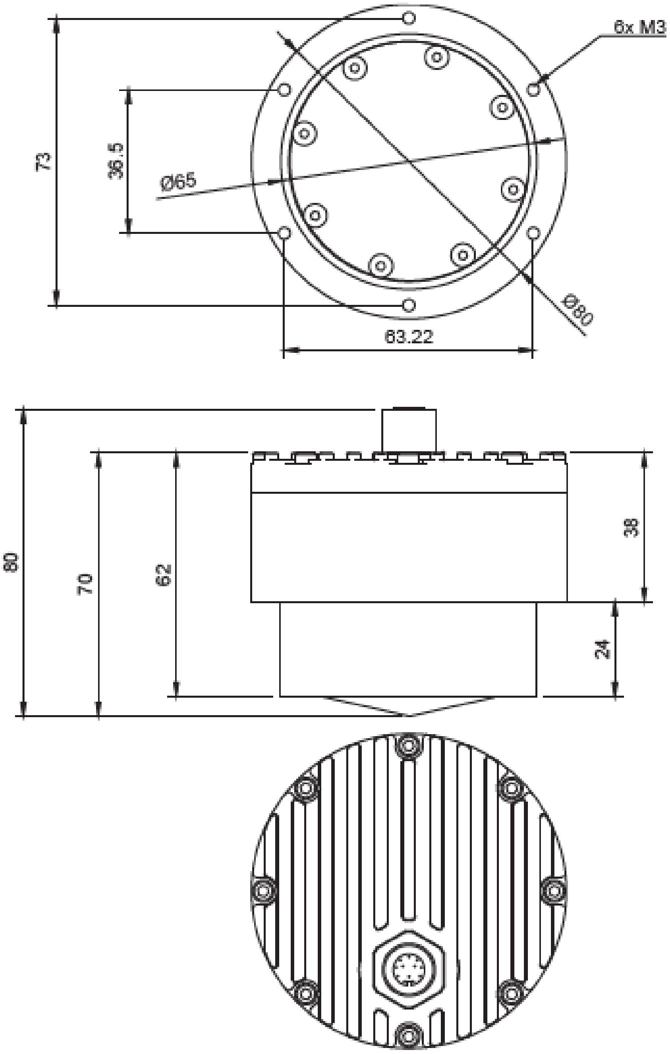
Power	
Supply Voltage	9 – 27 V (12V typical)
Average Power	0.05W
Average Current	30mA
Maximal Current	150mA (SDI-12 low power)

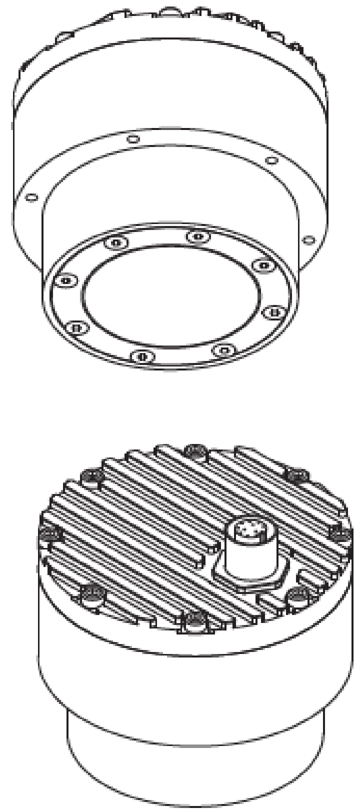
Communication Interface	
Serial Interface	RS-232 (two wire interface): RS-485 half duplex
Baud Rate	9600 bps – 115,20035 bps
Serial Protocols	Modbus/RS-485, GLX-NMEA
Other Interfaces	SDI-12 Analog 4-20 mA

Physical	
Operating Temperature Range	-40º - +85ºC (-40º - +185ºF)
Ingress Protection Rating	IP68
Connector	M12 circular 12-pin
Enclosure Dimensions	Φ 65 mm x H 55 mm (Φ 2.56 in x H 2.16 in)
Weight	500g (1.1 lb)

10.2 MECHANICAL ASSEMBLY

All measurements in mm.





DOCUMENT REVISION HISTORY

Revision	Date	Description
1	09 Oct 2021	Original. PM-287.