robosense LiDAR

Bpearl

User Guide

Version 1.0

Change Description

Version	Revision Date	Description
1.0	2023/8/19	Initial release
1.1	2023/11/6	1. Increase LiDAR weight tolerance range 2. Updated Time Synchronization Information on DIFOP

Reading Prompt

Symbolic Instructions

⚠ Warning: The usage process should be strictly followed, otherwise it may lead to potential dangerous situations such as minor injuries or property damage.

! Important: The usage process should be observed, otherwise it may cause potential harmful situations such as product damage.

ⓘ Tip: The usage process should be valued sufficiently to achieve maximum value of the product efficiently and smoothly.

Resource Download

Please click the following link to download the latest product manual, RSview and other resources: https://www.robosense.cn/resources

More Information

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Content

1 Safety Notices

1.1 Legal Statement

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1.2 User Guidelines

⚠ Please use this product in accordance with the following requirements:

1) Please strictly abide by relevant national laser safety laws and regulations.
2) Please read this product manual in detail before using the product.
3) Please use this product only in the relevant field of application.
4) Please avoid using this product in environments that are explosive, highly corrosive, or beyond the IP protection level of the equipment.

1.3 Illegal Operation

⚠ Please use this product in accordance with the regulations, otherwise it may cause product damage, property loss, and personal injury. Users are responsible for risk arising from unauthorized operations.

1) Do not disassemble or modify this product (including accompanying accessories).

2) Non-specified power supply and accompanying accessories are prohibited;
3) Please avoid abnormal operations such as dropping, colliding, burning, etc.;
4) If you notice any damage to the appearance of the device (arc protection cover), please immediately stop using it.
5) If you notice any abnormal operation of the product, please immediately stop using it and contact RoboSense in a timely manner.

1.4 Requirements for Operating Personnel

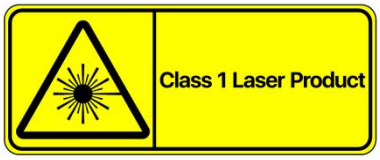
⚠ The use of this product requires certain basic professional knowledge and other related requirements for operating personnel. Unreasonable operations performed by personnel without basic knowledge or training do not constitute a fault of RoboSense and may cause damage to equipment and personal property.

1) Please read the product manual in detail before using the device.
2) Prohibit illegal operations.
3) Before working, personnel must undergo training and obtain relevant construction qualifications.
4) Have some basic knowledge of computer data connection, electrical, and so on.

1.5 Work Safety and Special Hazards

⚠ To avoid risks of accidents, damage to sensor or violating of your product warranty, please read and follow the instructions in this manual carefully before operating the product.

1) Laser Safety: This product meets the following standards for laser products: IEC 60825-1:2014.



2) High Temperature Warning: Please pay attention to the overheating sign on the LiDAR surface to avoid a hot LiDAR surface that may lead to sensor

failure or undesirable consequences.

3) Retain Instructions: The safety and operating instructions should be retained for future reference.
4) Heed Warnings: All warnings on the product and in the operating instructions should be adhered to.
5) Servicing: Except for what's described in this manual, the sensor has no field serviceable parts. For servicing, please contact RoboSense sales or the authorized distributors.

2 Product Description

2.1 Product Overview

Bpearl is a new type of short-range 3D LiDAR specifically designed by RoboSense to eliminate blind spots. It is primarily used in applications such as robot environment perception, autonomous vehicle environment perception, drone mapping, and smart cities.

Bpearl adopts RoboSense innovative signal processing technology, allowing for a minimum detection distance as close as 10 centimeters. With its hemispherical ultra-wide field of view design, it can effectively detect various extremely close-range obstacles over a large area.

2.2 Product Structure

The structure of Bpearl is illustrated in Figure 1 .

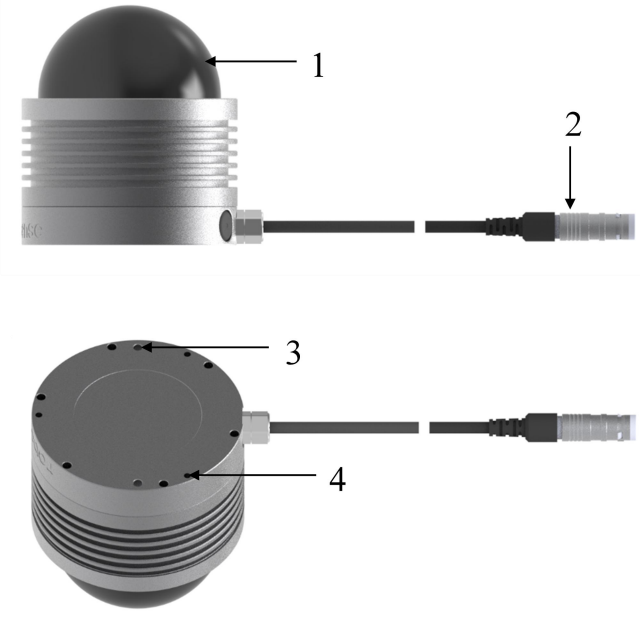


Figure 1 Product Structure Description

It mainly includes the following components:

1) Protective Cover

Both the emitted laser and returned laser need to pass through the specially designed arc-shaped protective cover. Therefore, any obstruction within the laser's field of view (FOV) is strictly prohibited.

2) Aviation Connector

The LiDAR body is connected to the interface box via an aviation connector, enabling power supply and data transmission functionalities.

3) Mounting Holes

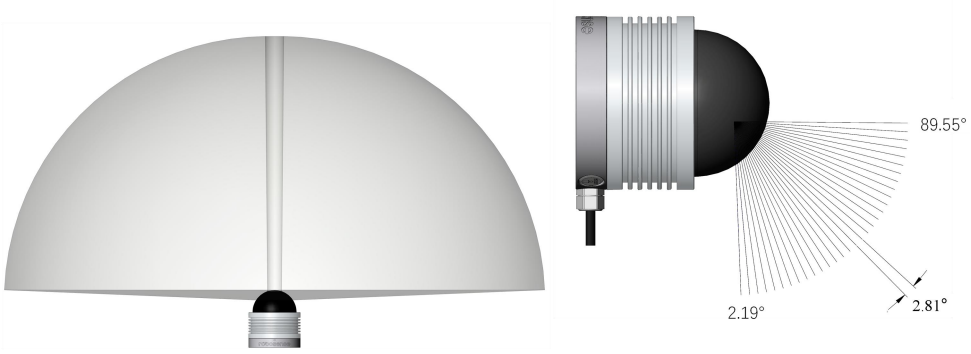
Used to support and fix the position and orientation between the LiDAR and the bracket, it enhances installation efficiency and accuracy.

4) M3 Screw Mounting Holes

Used to secure the LiDAR to the mounting bracket with M3 screws.

2.3 FOV Distribution

Bpearl's FOV has a horizontal angular range of 0 to 360 degrees and a vertical angular range of 0 to 90 degrees, with an angular interval of approximately 2.81 degrees. The 32 lasers are defined as 32 channels, and their corresponding relationship with the real vertical angles is shown in Figure 2 .



(a) FOV Area Distribution (b) Vertical Angular Distribution

Figure 2 FOV Illustration

2.4 Specifications

Table 1 Bpearl Specifications

Specifications			
Number of Channels	32	Horizontal Field of View (FOV)	360°
Laser Wavelength	905 nm	Vertical Field of View (FOV)	2.19° ~ 89.55°
Laser Emission Angle (Full Angle)	Horizontal 4 mrad, Vertical 6 mrad	Horizontal Angular Resolution	0.1° / 0.2° / 0.4°
Laser Safety Level	Class1Eye-Safe	Vertical Angular Resolution	2.81°
Measurement Range[1]	100 m(30 m @10% NIST)	Accuracy (Typical)[2]	1 cm (1 σ) / 3 cm (3 σ)
Blind Zone	0.1 m	Frame Rate	5 Hz / 10 Hz / 20 Hz
Rotation Speed	300 / 600 / 1200 rpm(5 / 10 / 20 Hz)		
Number of Output Points	576000 pts / s(Single Return Mode), 1152000 pts / s(Dual Return Mode)		
Ethernet Transmission Rate	100Base-TX		
Output Data Protocol	UDP Packets Over Ethernet		
Lidar Data Packet Content	Distance, Reflectivity, Timestamp, etc.		
Operating Voltage	9 V - 32 V	Dimensions	Diameter 100 mm × Height 111 mm
Product Power Consumption[3]	12 W(Typical)	Operating Temperature[4]	- 40℃ ~ + 60℃
Weight	890g ± 50g(LiDAR Body)	Storage Temperature	- 40℃ ~ + 85℃
Time Synchronization	GPS，PTP & gPTP	Protection Level	IP67 / IP6K9K
Product Model	BP32		

2.5 Product Principle

2.5.1 Coordinate Mapping

[1] Measurement Range is based on a 10% NIST diffuse reflection target, and the test results are subject to environmental factors such as ambient temperature and light intensity.;

[2] Measurement Accuracy is based on a 50% NIST diffuse reflection target, and the test results are affected by environmental factors, including ambient temperature and target distance. The accuracy value applies to most channels, but variations may exist between certain channels;

[3] Device Power Consumption test results are influenced by external environmental factors, including ambient temperature, target distance, and target reflectivity;

[4] Device Operating Temperature may be affected by external environmental factors, including lighting conditions and airflow variations;

As the LiDAR data packet contains only horizontal rotation angles and distance parameters, to present a three-dimensional point cloud, the polar coordinates (angle and distance) are transformed into Cartesian coordinates (x, y, z) according to the following equations:

$$\begin{cases} x = r\,cos\,(\omega)\,sin\,(\alpha) + \mathrm{R}\,cos\,(\alpha); \\ y = r\,cos\,(\omega)\,cos\,(\alpha) + \mathrm{R}\,sin\,(\alpha); \\ z = r\,sin\,(\omega) + \mathrm{Z}; \end{cases}$$

where r is the measured distance, ω is the laser's vertical angle, α is the laser's horizontal rotation angle, R is the plane radius from the optical center to the origin, Z is the height from the optical center to the origin, and x, y, z are the coordinates projected onto the Cartesian X, Y, Z axes.

2.5.2 Reflectivity Interpretation

Bpearl LiDAR provides reflectivity information to characterize the reflectance of measured objects. In Bpearl data, the calibrated reflectivity range is from 1 to 255.

2.5.3 Return Modes

2.5.3.1 Return Modes Principle

Bpearl supports multiple return modes, including Strongest Return, Last Return, First Return, and Dual Return modes. In the Dual Return mode, detailed information of the target object is displayed, and the data volume is twice that of the Single Return mode.

Bpearl analyzes multiple return values received and outputs the strongest, last, or first return value based on user selection, or outputs dual return values. In the Strongest Return mode, only the strongest reflected return value is output; in the Last Return mode, only the last detected return in the time domain is output.

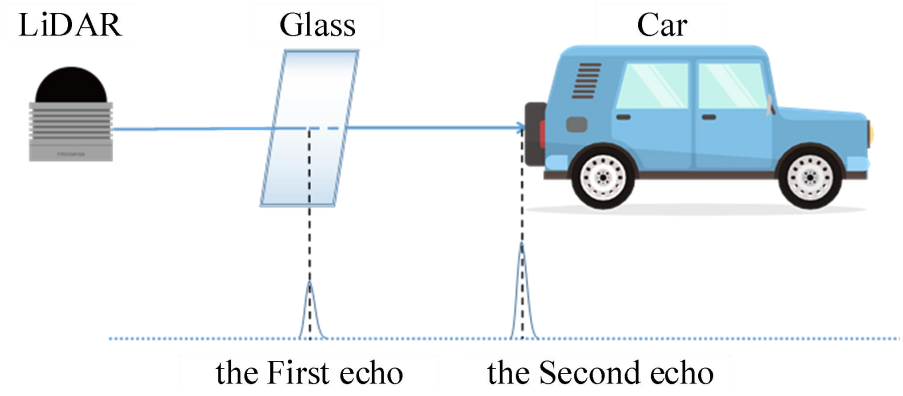


Figure 3 Dual Return Detection

Note:

In Dual Return mode, when the laser hits multiple targets, and the distance between the targets is greater than 1 meter, the LiDAR can detect two echoes, as shown in Figure 3 .

2.5.3.2 Return Mode Flags

By default, Bpearl is set to the Strongest Return mode. If the user needs to change the settings, please refer to Appendix A.2 in the product parameter setting for configuration. In DIFOP, the 300th byte represents the flag for the return mode, as shown in Table 2:

Table 2 Return Mode and Flags Mapping

DIFOP Offset	Flag	Return Mode
300	00	Dual Return
	04	Strongest Return
	05	Last Return
	06	First Return

2.5.4 Phase Locking

Bpearl's phase locking function allows the device to emit lasers at specific angles when the sensor reaches a whole second. Figure 4 illustrates Bpearl's setup with different phase angles. The red arrows indicate that at the whole second, the sensor rotates to 0°, 135°, and 270° to emit lasers. Refer to Figure 13 for the coordinate system details.

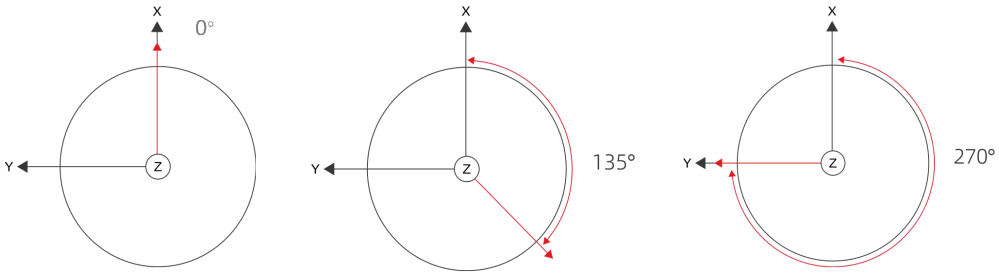


Figure 4 Bpearl Phase Lock Setting Illustration

The "Phase Lock" parameter setting is available in the Web interface under Setting > Phase Lock Setting. It allows users to set the locked phase angle, which should be an integer ranging from 0 to 359. For more details, refer to section 4.2 of the product manual.

2.5.5 Time Synchronization Method

Bpearl supports three time synchronization methods: GPS + PPS, PTP (IEEE 1588 V2 protocol), and gPTP (IEEE 802.1 AS protocol). Users can configure these settings through the Web interface. For more details, refer to section 4.2 of the product manual.

2.5.5.1 GPS Time Synchronization Principle

The GPS module continuously sends GPRMC data and PPS synchronization pulse signals to the product. The PPS synchronization pulse length should be between 20 to 200 ms, and the GPRMC data must be completed within 500 ms of the synchronization pulse. The timing diagram is shown in Figure 5 .

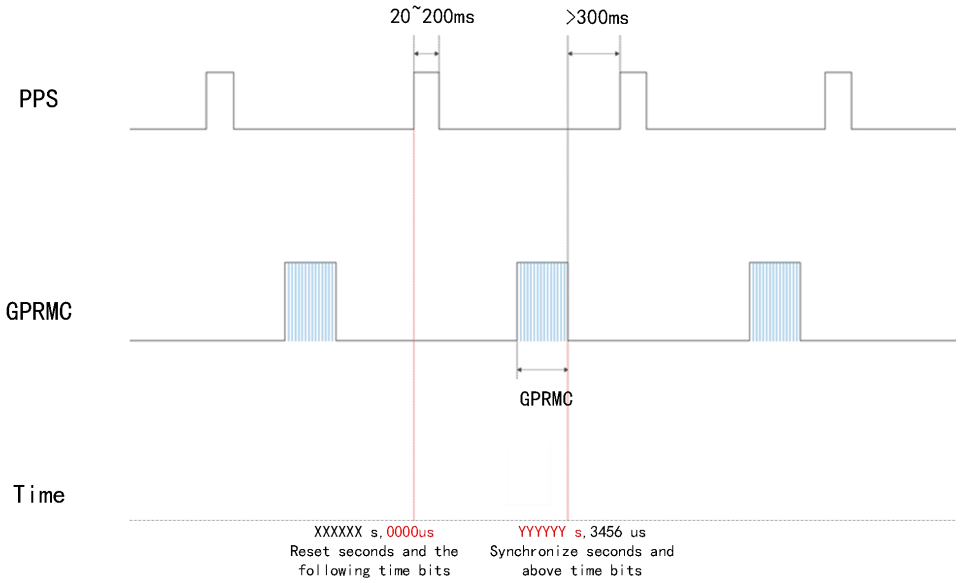


Figure 5 GPS Time Synchronization Timing Diagram

Note:

To ensure accurate time synchronization, it is recommended to set the PPS pulse width between 20 to 200 ms. The completion time of GPRMC is recommended to be within 500 ms after the rising edge of PPS.

2.5.5.2 GPS Time Synchronization Usage

The GPS_REC interface of Bpearl LiDAR adopts the RS232 electrical level protocol. Refer to Table 3 for the pin definition.

Table 3 Product Time Synchronization Pin Definitions

Communication	**Receiving Pin Definition**	
	GPS REC	**GPS PULSE**
RS232	RS232 Receives serial data with RS232 electrical level standard output from the GPS module	Receives positive synchronization pulse signal output from the GPS module, with a voltage requirement of 3.0 ~ 15.0 V

The external GPS module needs to set the output serial port baud rate to 9600 bps, 8 data bits, no parity bit, and 1 stop bit. Bpearl only reads GPRMC-formatted data sent by the GPS module. The standard format is as follows:

$ GPRMC,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>,<10>,<11>,<12> * hh

<1> UTC time

<2> Positioning status: A = valid positioning, V = invalid positioning

<3> Latitude

<4> Latitude hemisphere N (Northern Hemisphere) or S (Southern Hemisphere)

<5> Longitude

<6> Longitude hemisphere E (Eastern Hemisphere) or W (Western Hemisphere)

<7> Ground speed

<8> Ground course

<9> UTC date

<10> Magnetic declination

<11> Magnetic declination direction: E (East) or W (West)

<12> Mode indication (A = Autonomous positioning, D = Differential, E = Estimated, N = Data invalid)

*hh at the end represents the XOR sum of characters from $ to *

Note:

1) The GPS_REC interface specification on the Bpearl power box is SH1.0-6P female connector, with pin definitions shown in Table 7.
2) The interval for sending 1 PPS pulse should be controlled within 1s ± 200 us.
3) Time synchronization through GPS_REC is only allowed when the positioning status in the GPRMC message is valid (A).
4) Bpearl is compatible with most GPRMC message formats from GPS modules available in the market. If any compatibility issues are found during use, please contact RoboSense.

2.5.5.3 PTP Synchronization Principle

PTP (Precision Time Protocol, IEEE 1588V2 protocol) is a time synchronization protocol used for high-precision time synchronization between devices. It can also be used for frequency synchronization between devices. Compared to various existing time synchronization mechanisms, PTP offers the following advantages:

1) Compared to NTP (Network Time Protocol), PTP can meet higher precision time synchronization requirements. NTP generally achieves sub-millisecond level time synchronization accuracy, while PTP can reach sub-microsecond level accuracy.
2) Compared to GPS (Global Positioning System), PTP has lower construction and maintenance costs.

2.5.5.4 gPTP Synchronization Principle

gPTP (general Precise Time Protocol, IEEE 802.1AS protocol) is a derivative protocol

of PTP in Time-Sensitive Networking (TSN). The synchronization mechanism uses the same P2P peer delay mechanism as the PTP protocol and adopts Ethernet L2 layer communication. Unlike PTP, gPTP requires the use of hardware-based timestamps, i.e., hardware timestamps, so the requirements for switches and master clocks are more stringent, complying with the IEEE 802.1AS protocol.

2.5.5.5 PTP/gPTP Wiring Method

To use PTP/gPTP synchronization, the following preparations are required. Refer to section 3.4 of the product manual for connection details:

1) Select PTP/gPTP mode in the Web interface. See section 4.2 of the product manual for details.
2) PTP Master/gPTP Master time source (plug and play, no additional configuration required).
3) Ethernet switch.
4) Devices that support PTP/gPTP protocols and need time synchronization.

Note:

1) The PTP Master device is a third-party device and is not included in the RoboSense shipment. The user needs to purchase it separately.
2) RoboSense products, as Slave devices, only receive time from the Master and do not judge the accuracy of the Master's clock source. If there are sudden changes in the time when parsing LiDAR point cloud data, please check if the time provided by the Master is accurate.
3) After LiDAR synchronization, when the Master is disconnected, the time in the point cloud data packet will be accumulated based on the LiDAR's internal clock. The time will be reset when the LiDAR is powered off and restarted.

3 Product Installation

3.1 Accessory Description

The standard accessories included with Bpearl LiDAR are listed in Table 4 for reference.

Table 4 Standard Accessory List

No.	Accessory Name	Specification	Quantity
1	LiDAR	Bpearl	1
2	Interface Box	3m cable length	1
3	Power Adapter	DC12 V × 3.34 A /40 W	1
4	Power Cable	1.2 m	1
5	Ethernet Cable	1.5 m	1
6	Screw Pack	M4 × 15	3
		M4 × 20	3
7	Extended Cable (optional)	6 m	1
8	Product Packing List and Shipment Inspection Report	/	1

For specific requirements, refer to the commercial agreement.

3.2 Mechanical Installation

The structural installation diagram of the LiDAR is shown in Figure 6 .

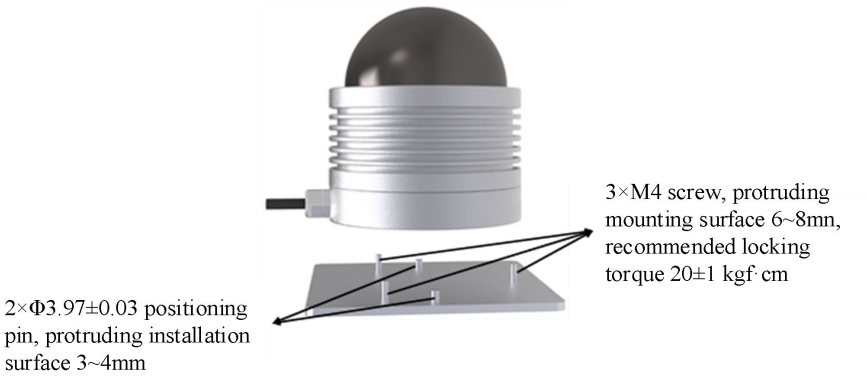


Figure 6 LiDAR Structural Installation Diagram

1) Screw Specifications:

   a) GB/T70.1, M4 × 15, internal hexagon socket head, strength grade 10.9, with an anti-drop feature;

b) GB/T70.1, M4 × 20, internal hexagon socket head, strength grade 10.9, with anti-drop feature.

2) Installation Requirements:

a) The installation surface flatness should be better than 0.2 mm.

b) Use three M4 screws to mount the bottom surface, extending 6 ~ 8 mm from the mounting surface. Recommended tightening torque is 20 ± 1 kgf.cm.

c) Use two Φ4 positioning pins for installation and positioning on the bottom surface, not higher than 4 mm.

d) During LiDAR installation, if both the top and bottom surfaces have contact-type mounting surfaces, ensure that the distance between the mounting surfaces is greater than the LiDAR's height to avoid squeezing the LiDAR.

e) When wiring the LiDAR during installation, do not make the wiring cables too tight (leave more than 2 cm installation allowance) to ensure that the cables have some slack.

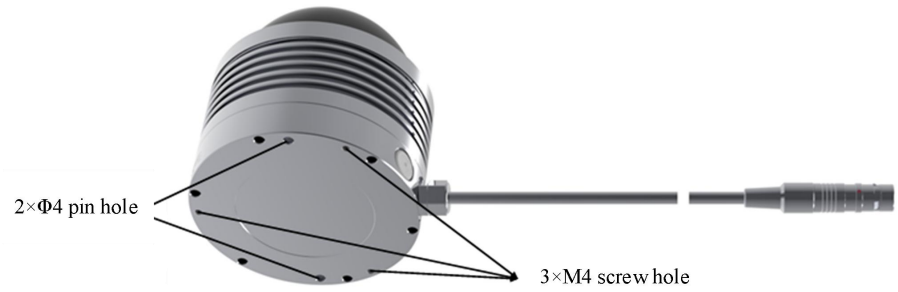


Figure 7 LiDAR Bottom Locator Pin and Screw Diagram

3) Bracket Stiffness and Strength Requirements:

a) The fixed bracket needs to have good rigidity for securely mounting the LiDAR and maintaining the LiDAR in a stable state under various conditions. Therefore, the first-order modal frequency of the LiDAR and its fixed bracket should be at least greater than 50 Hz.

b) The LiDAR will undergo various random vibrations and mechanical shocks during use. Under these conditions, the bracket needs to withstand significant loads, so it also requires sufficient strength. The bracket material is

recommended to be aluminum alloy (thickness above 4 mm) or galvanized steel plate (thickness above 2 mm). Strengthening ribs should be added in various directions to improve its rigidity and strength as much as possible. It is advisable to avoid designing structures with sharp angles, corners less than 0.3 mm, or notches, which may cause stress concentration. The bracket strength needs to be verified through simulation.

4) Heat Dissipation Requirements:
   a) The bracket material is recommended to be made of aluminum alloy or galvanized steel plate with a thermal conductivity greater than 50 W/m·K. Some heat dissipation fins should be added to the bracket, with reasonable spacing, height, and direction of the fins to increase the heat dissipation area. The direction should align with the air convection direction for more effective heat dissipation.
   b) Ensure that the LiDAR base or top cover is not covered with non-metallic materials to avoid affecting the overall heat dissipation, leading to excessive temperature rise of the LiDAR.

3.3 Interface Description

3.3.1 Aviation Plug Interface and Definitions

The cable aviation plug on the Bpearl LiDAR side is shown in Figure 8 .

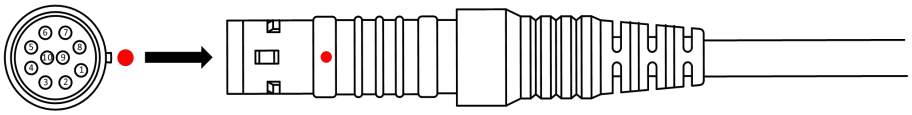


Figure 8 Aviation Plug Interface Pin Numbers

The cable length on the LiDAR side is 0.5m. The specific pin definitions of the aviation plug interface on the LiDAR side are shown in Table 5.

Table 5 Aviation Plug Interface Pin Definitions

Pin No.	Color	Signal
1	Red	+ 12 V
2	Yellow	+ 12 V
3	White	GROUND
4	Black	GROUND
5	Green	GPSPULSE
6	Blue	GPSREC
7	Brown	LiDAR Ethernet RX +
8	Brown White	LiDAR Ethernet RX -
9	Orange	LiDAR Ethernet TX +
10	Orange White	LiDAR Ethernet TX -

3.3.2 Interface Box

The Bpearl accessory Interface Box is equipped with power indicator lights and various interfaces, which can be connected to power input, RJ45 Ethernet port, and GPS input cable (the length of the interface box cable for aviation plug version is 3 meters, for other cable length requirements, please contact Robosense).

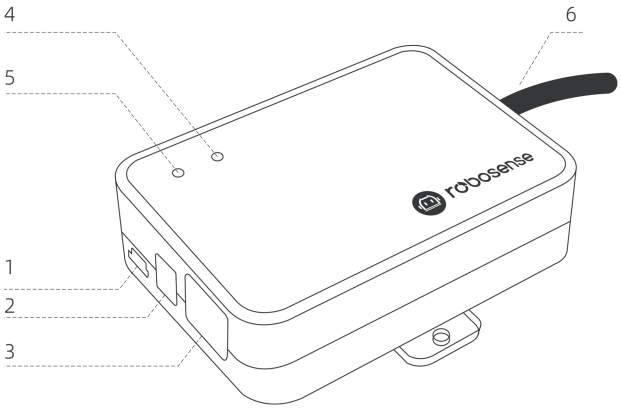


Figure 9 Interface Box Schematic

The detailed specifications of each Interface Box interface are listed in Table 6.

Table 6 Interface Box Interface Specifications

No.	Interface Name	Specification
1	Sync Interface	SH 1.0 - 6 P Female Connector
2	Power Interface	Standard DC 5.5 - 2.1 Interface
3	Ethernet Interface	Standard RJ45 Interface
4	Input Indicator Light	Red
5	Output Indicator Light	Green
6	Cable	/

3.3.3 Power Interface

The Bpearl power interface uses a standard DC 5.5 - 2.1 interface.

When the Interface Box is working normally, the red input and green output indicator lights will be lit. If the external power input is normal, but the indicator lights on the Interface Box are not lit, the Interface Box may be damaged. In this case, please contact Robosense.

3.3.4 RJ45 Ethernet Port

The Bpearl Ethernet interface follows the EIA/TIA568B standard.

3.3.4.1 GPS Sync Interface

The Bpearl sync interface is defined as follows: GPS REC is for GPS UART input, and GPS PULSE is for GPS PPS input.

The pin positions of the Interface Box sync interface are shown in Figure 10 .

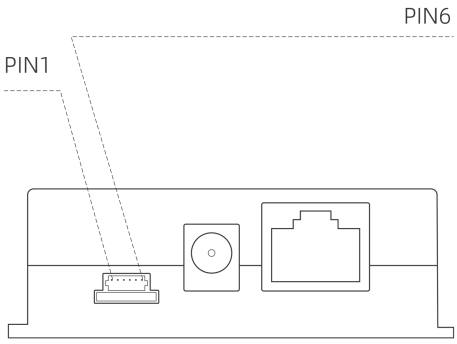


Figure 10 Sync Interface Pin Positions

For the detailed interface definitions, please refer to Table 7.

Table 7 Sync Interface Definitions

Pin Number	Signal
PIN 1	GPS_PPS
PIN 2	+5 V（Output）
PIN 3	GND
PIN 4	GPS_REC
PIN 5	GND
PIN 6	NC

! Important Note:

When connecting the "Ground" of Bpearl to an external system, the power supply

negative pole ("Ground") of the external system and the GPS system's "Ground" must be non-isolated and connected together.

3.4 Quick Connection

The Bpearl network parameters can be configured, and the default factory setting uses fixed IP and port number mode, as shown in Table 8.

Table 8 Default Factory Network Configuration Table

Device	IP Address	MSOP Package Port Number	DIFOP Package Port Number
Bpearl	192.168.1.200	6699	7788
Computer	192.168.1.102		

When using the product, the user needs to set the computer's IP address to be in the same subnet as the product, for example, 192.168.1.x (where x can be any value between 1 and 254), and the subnet mask is 255.255.255.0. For unknown product network configuration information, please connect the product and use Wireshark to capture the output package of the product for analysis. The IP configuration and connection methods are as follows:

1) Connecting the LiDAR

The connection method is shown in Figure 11 .

a) Connect the LiDAR and Interface Box using the aviation plug.

b) Connect the PC and Interface Box using the RJ45 Ethernet port.

c) After powering on, under normal working conditions, the red and green power indicator lights on the LiDAR's Interface Box will be constantly on. The positions of the indicator lights are shown in Figure 9 .

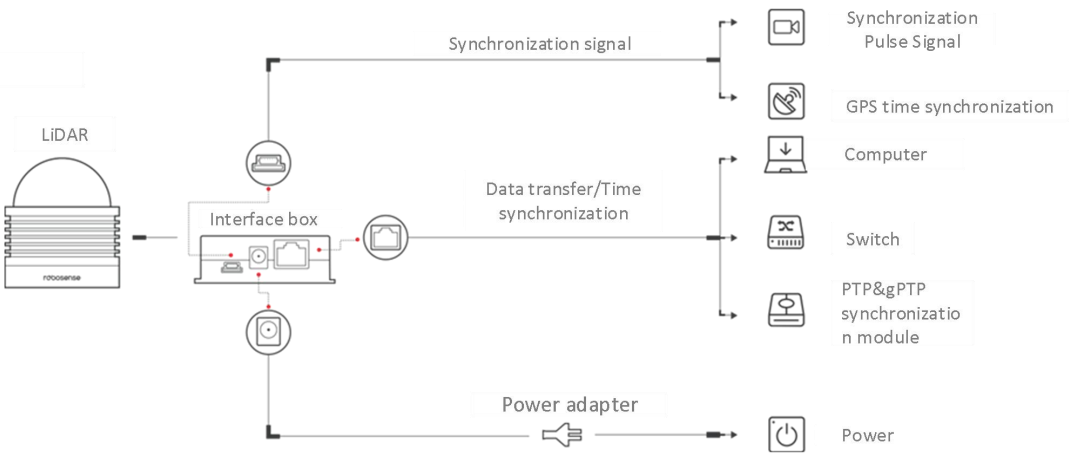


Figure 11 Interface Box Connection Diagram

1) Through the ".pcap" packets captured by Wireshark software, get the Local IP of Computer by analyzing " arp" packets

   a) Perform the following steps after the LiDAR and PC are connected:

   b) Start Wireshark (a third-party network analysis tool) and select the correct network interface to begin capturing packet.

   c) Use the search box in Wireshark and enter "arp" to search for the mutual addressing packets between the LiDAR and PC, as shown in Figure 12 .

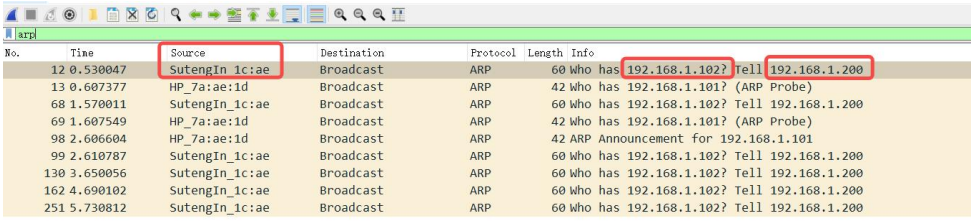


Figure 12 Analyzing ARP Packets

   d) In Figure 12 , the "SutengIn" in the Source column indicates the source information of the LiDAR, indicating that the Source IP is 192.168.1.200, which is the LiDAR's IP. The request is accessing 192.168.1.102, which is the PC's IP. If the local IP is not the requested access IP, then configure the PC's local IP as 192.168.1.102 as shown in step 3. If the access is successful, proceed to step 4.

2) Configuring the PC's Local IP

   a) In the Control Panel, go to "Network and Internet" and then "Network and Sharing Center." In the "View your active networks" section, click

on the corresponding Ethernet connection to enter the corresponding "Ethernet Status," and then click on "Properties."

b) Double-click "Internet Protocol Version 4 (TCP/IPv4)" to enter the IP information settings and use a static IP for configuration.

c) Set the local IP address to 192.168.1.102, subnet mask to 255.255.255.0, and click "OK" to complete the PC's static IP setting.

3) Connection Completed

Note:

1) The time synchronization module (PTP & gPTP, GPS time synchronization module) is not included as a standard product. If you need to use these features, please purchase them separately and follow the connection method shown in Figure 11 .

2) The configuration of the local static IP provided above is only an example for Windows operating systems. For other operating systems, please refer to the actual instructions.

4 Product Usage

4.1 Product Coordinate System

The coordinates and rotation direction of the product are shown in Figure 13 .

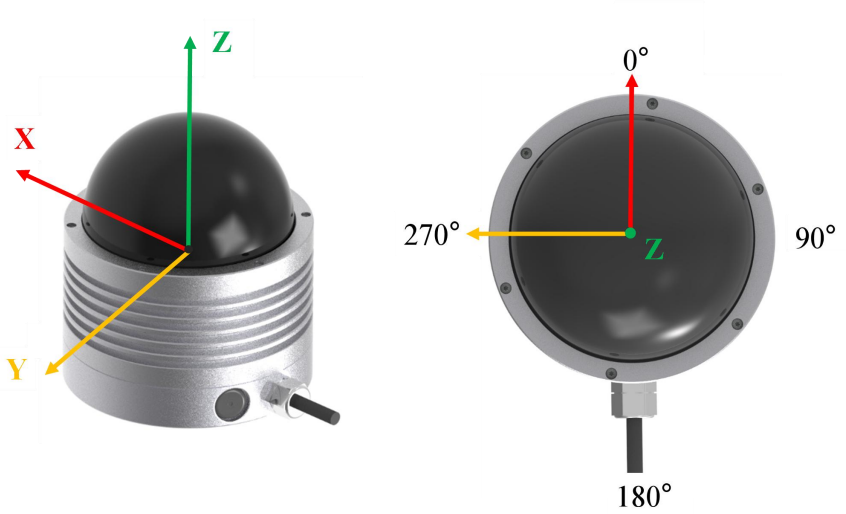


Figure 13 LiDAR Coordinate and Rotation Direction Illustration

4.2 Web UI Usage

4.2.1 Web UI Functions

Bpearl supports parameter settings, viewing of operational information/status, and firmware upgrades through the Web UI interface.

The Bpearl web address changes according to the Device IP. The default Device IP is 192.168.1.200. If you have changed the Device IP, the web address will be the newly set IP.

4.2.2 Accessing the Web UI Interface

Once the product is connected and correctly configured as required, use a computer browser to access the product's IP address (default Device IP: 192.168.1.200) to enter the Bpearl web homepage. The default page is the "Device" tab.

4.2.3 Using the Web UI Interface

For detailed instructions on using the Web UI interface, please refer to Appendix A of the product manual.

4.3 RSView Usage

For data visualization with Bpearl, you can use free tools such as Wireshark and tcp-dump to obtain raw data. RSView can provide a more convenient way to visualize the raw data.

4.3.1 Software Functions

RSView enables real-time visualization of Bpearl data. It can also replay data saved in ".pcap" file format, but does not support ".pcapng" files at the moment.

In RSView, the distance measurement values obtained by Bpearl are displayed as points. It supports various custom colors to display data, such as reflection intensity, time, distance, horizontal angle, and laser beam index. The displayed data can be exported and saved in ".csv" format, and RSView version 3.1.3 and later versions support exporting data in ".las" format.

RSView includes the following features:

1) Real-time display of data via Ethernet.
2) Save real-time data as PCAP files.
3) Replay data from recorded PCAP files.
4) Various visualization modes, such as distance, time, horizontal angle, etc.
5) Display point data in tabular format.
6) Export point cloud data as CSV files.
7) Distance measurement tool.
8) Display multiple frames of replayed data simultaneously.
9) Show or hide individual laser beams from Bpearl.
10) Clipping display.

4.3.2 Installing RSView

RSView can be run on Windows 64-bit and Ubuntu 18.04 or higher operating systems. You can download the latest version of RSView software compressed package from the Robosense official website (http://www.robosense.cn/resources). After downloading, make sure the extraction path does not contain Chinese characters. The software does not require installation; simply run the executable file after extraction to use it.

4.3.3 Using RSView

After opening RSView, you can access the user guide by pressing the F1 button or by clicking on the "RS-LiDAR User Guide" option in the Help menu.

4.4 Communication Protocols

Bpearl communicates with a computer via Ethernet using UDP (User Datagram Protocol). The communication protocols between Bpearl and the computer fall into two categories, as described in Table 9.

Table 9 Protocol Overview

Protocol Name	Abbreviation	Function	Type	Packet Size	Send Interval
Main data Stream Output Protocol	MSOP	Point cloud data	UDP	1248 bytes	Approx. 666.67 us
Device Information Output Protocol	DIFOP	LiDAR information output	UDP	1248 bytes	Approx. 1 s

Note:

1) Section 4.4 of the product manual describes and defines the payload (1248 bytes) of the protocols.
2) The Main Data Stream Output Protocol (MSOP) encapsulates the laser scanning data, including distance, angle, and reflection intensity, into packets for output.
3) The Device Information Output Protocol (DIFOP) outputs various configuration information about the current state of Bpearl.

4.4.1 MSOP and DIFOP Data Protocols

The UDP packets sent by Bpearl have a payload of 1248 bytes. The data structure for

the Main Data Stream Output Protocol (MSOP) and Device Information Output Protocol (DIFOP) is shown in Figure 14 .

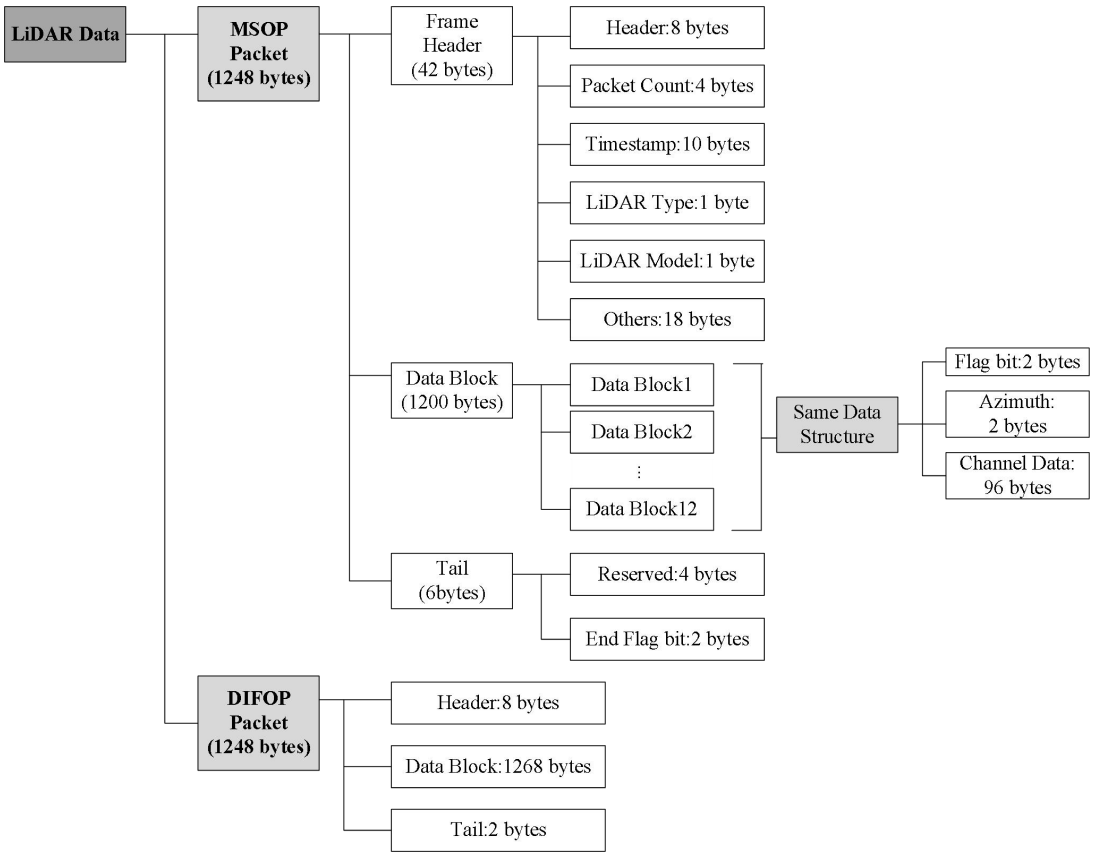


Figure 14 LiDAR Data Structure Illustration

4.4.2 Main Data Stream Output Protocol (MSOP)

Main Data Stream Output Protocol, abbreviated as MSOP, is used for product output and computer parsing. The default port number is 6699.

4.4.2.1 Header

The header consists of 42 bytes and is used to identify the start of the data. The data structure details are shown in Table 10.

Table 10 MSOP Header Data Table

Header(42 bytes)			
Field	**Offset**	**Length (byte)**	**Definition**
Header ID	0	8	8 bits for packet header detection, defined as: 0x55,0xAA,0x05,0x0A,0X5A,0XA5,0X50,0XA0
Reserved	8	4	/
Packet Count	12	4	Packet Count
Reserved	16	4	/
Timestamp	20	10	Stores the Unix timestamp
LiDAR Type	31	1	Used to indicate the LiDAR series 0x03 : Bpearl
LiDAR Model	32	1	0x00 : BP32 A00 0x04 : BP32 B00
Reserved	33	9	/

Note:

The defined timestamp is used to record the system time with a resolution of 1 us. For specific details, refer to Appendix C.13 in the product manual for time definition.

4.4.2.2 Data Block Interval

The data block is the measurement part of the MSOP packet and consists of 1200 bytes. It contains 12 Data blocks, each 100 bytes long, representing a complete set of ranging data.

Each Data block with 100 bytes includes 2 bytes of the flag, represented as 0xffee. It also contains 2 bytes of Azimuth, representing horizontal rotation angle information, with each angle corresponding to 32 channel data, constituting a complete set of 32-channel information.

Table 11 Data Block Packet Definition

Description	**Data Block (1200 bytes)**			
Data Block Number	Data Block 1	Data Block 2	…	Data Block 12
Flag	0xffee	0xffee	…	0xffee
Horizontal Rotation Angle	Azimuth 1	Azimuth 2	…	Azimuth 12
Channel 1	Channel data 1	Channel data 1	…	Channel data 1
Channel 2	Channel data 2	Channel data 2	…	Channel data 2
…	...	...	…	...
Channel 32	Channel data 32	Channel data 32	…	Channel data 32

Note:

In dual-return mode, the odd-numbered columns of Data Block store the first return,

while the even-numbered columns store the second return.

1) Channel Data Definition

The channel data, Channel data, is represented by 3 bytes. The high two bytes represent the distance information, and the low byte represents the reflectivity information, as shown in Table 12.

Table 12 Channel Data Representation

Channel data（3 bytes）		
2 bytes Distance		1 byte Reflectivity
Distance1 [15:8]	Distance2 [7:0]	Reflectivity(Reflectivity information)

Note:

Distance is represented by 2 bytes with a resolution of 0.25 cm.

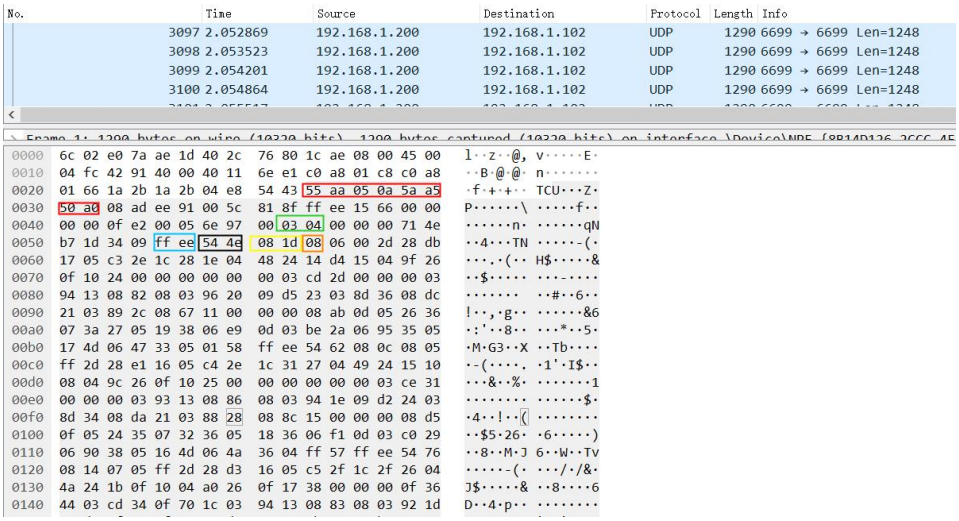


Figure 15 MSOP Packet Illustration

Red box: Header ID;

Green box: LiDAR Type and LiDAR Model;

Blue box: Data Block flag;

Black box: Azimuth value of Channel data 1;

Yellow box: Distance value of Channel data 1;

Orange box: Reflectivity value of Channel data 1.

The distance value calculation in the data packet can be calculated as follows:

a) Hexadecimal representation of the distance value in the data packet: 0x08, 0x1D;

b) Combine the data into 16 bits, representing 16-bit unsigned integer data. It

becomes: 0x081D;

c) Convert the distance value to a decimal number: 2077, and calculate according to different distance resolutions;

d) Result: 2077 × 0.25 cm = 519.25 cm = 5.1925 m.

The azimuth value calculation in the data packet can be calculated as follows:

a) Hexadecimal representation of the azimuth value in the data packet: 0x54, 0x4E;

b) Combine the data into 16 bits, representing 16-bit unsigned integer data. It becomes: 0x544E;

c) Convert to a decimal number: 21582, and divide the converted decimal data by 100;

d) Result: 21582° / 100 = 215.82°.

The reflectivity value calculation in the data packet can be calculated as follows:

a) Hexadecimal representation of the reflectivity value in the data packet: 0x08;

b) Convert to a decimal number: 08;

c) Result: Reflectivity value is 8.

2) Azimuth Value Definition

In each block, the azimuth value output by Bpearl represents the azimuth angle value of the first channel laser ranging in that block. The azimuth value comes from the azimuth encoder, and the resolution of the azimuth encoder is 0.01°.

4.4.2.3 Tail

The tail consists of 6 bytes, with 4 bytes reserved information and 2 bytes of 0x00, 0xFF.

4.4.3 Device Info Output Protocol (DIFOP)

Device Info Output Protocol, abbreviated as DIFOP, is used for product output and computer reading. The default port number is 7788.

DIFOP is an "output-only" protocol used to periodically send information such as

product serial number (S/N), firmware version, computer driver compatibility information, configuration information, angle information, running status, fault diagnosis, etc., to users. Users can read DIFOP to interpret specific information about the currently used product.

A complete DIFOP packet has a data format structure of synchronization header, data area, and tail. Each data packet consists of 8 bytes of synchronization header, 1238 bytes of data area (Data), and 2 bytes of tail. The basic structure of the data packet is shown in Table 13.

Table 13 Data Format Structure of DIFOP Packet

Paragraph Division	Index	Information	Offset	Length (byte)	Remarks
Header	0	DIFOP Header	0	8	a5_ff_00_5a_ 11_11_55_55
Data	1	Motor Speed Setting	8	2	Appendix C.1
	2	Ethernet	10	22	Appendix C.2
	3	FOV Setting	32	4	Appendix C.3
	4	TCP MSOP Port Number	36	2	Appendix C.4
	5	Motor Phase Locking Phase	38	2	Appendix C.5
	6	Mainboard Firmware Version	40	5	Appendix C.6
		Bottom Board Firmware Version	45	5	Appendix C.7
		APP Software Version	50	5	Appendix C.8
		Motor Firmware Version	55	5	Appendix C.9
	7	Reserved	60	228	/
	8	Baud Rate	288	1	Appendix C.10
	9	Reserved	289	3	/
	10	Product Serial Number	292	6	Appendix C.11
	11	Reserved	298	2	/
	12	Return Mode	300	1	Section 2.5.3
	13	Time Synchronization Information	301	2	Appendix C.12
		Time	303	10	Appendix C.13
	14	Operating Status	313	24	Appendix C.14
	15	Clockwise/Counterclockwise Flag	337	1	0x00: Clockwise 0x01: Counterclockwise

Table 13 (Continuation)

Paragraph Division	Index	Information	Offset	Length (byte)	Remarks
Data	16	Total Running Time of Product	338	4	Appendix C.15
	/	Reserved	342	9	/
	17	Fault Diagnosis	351	24	Appendix C.16
	/	Reserved	375	7	/
	22	GPRMC	382	86	Appendix C.17
	23	Vertical Angle Calibration	468	96	Appendix C.18
	24	Horizontal Angle Calibration	564	96	Appendix C.19
/	/	Reserved	660	586	/
Tail	25	Tail	1246	2	0f_f0

Note:

1) The Header (DIFOP Identification Header) consists of the bytes 0xA5, 0xFF, 0x00, 0x5A, 0x11, 0x11, 0x55, 0x55, and can be used as a check sequence for the packet.
2) The Tail contains the bytes 0x0F, 0xF0.
3) The definition and usage of each item's registers can be found in detail in Appendix C of the product manual. The corresponding relationship is specified in the Remarks column of Table 13.

5 Product Maintenance

5.1 Transportation and Logistics

! Important

Improper transportation can cause product damage!

1) The product should be packaged with shockproof and moisture-proof materials to avoid damage during transportation. It is recommended to use the original packaging;
2) Handle with care during transportation to avoid impact or dropping;
3) When receiving the goods, carefully check the delivery list for any damages (including the product and packaging);
4) If there is any transportation damage, refuse to accept the delivery and contact RoboSense promptly.

5.2 Storage

! Important

Improper storage may cause product damage!

1) Store the product in an indoor environment with normal temperature and dry conditions;
2) Handle the product gently to avoid impact or dropping;
3) The product should be stored in a safe environment to avoid corrosion, mechanical impact, or exposure to environments exceeding the protection level;
4) Regularly inspect the condition of all components and packaging, and it is recommended to check every three months.

5.3 Product Cleaning

To ensure accurate perception of the surrounding environment, keep the RS-LiDAR's circular protective cover clean.

5.3.1 Precautions

! Before cleaning the RS-LiDAR, carefully read and understand the content of this section. Improper cleaning may damage the product.

! When using the LiDAR in harsh environmental conditions, clean the surface regularly to keep the LiDAR clean. Otherwise, it may affect the normal operation of the LiDAR.

5.3.2 Required Materials

1) Clean and dust-free cloth;
2) Neutral solution at moderate temperature (such as soapy water, distilled water, 99% concentration of ethanol, etc.).

5.3.3 Cleaning Method

1) If the LiDAR surface is only covered with some dust:
   a) Use a clean and dust-free cloth, dip it in a small amount of neutral solution;
   b) Gently wipe the LiDAR surface;
   c) Dry it with a clean and dry dust-free cloth.
2) If the LiDAR surface is covered with mud or other solid foreign objects:
   a) First, spray clean water on the dirty part of the LiDAR surface to remove the mud or foreign objects (Note: Do not directly wipe off the mud with a dust-free cloth, as it may scratch the surface, especially the protective cover);
   b) Then spray warm soapy water on the dirty part. The lubricating effect of the soapy water helps to remove the foreign objects. Gently wipe the LiDAR surface with a fiber cloth, but be careful not to scratch the surface;
   c) Finally, rinse off the residual soap on the LiDAR surface with clean water (if there is still residue, clean it again with 99% ethanol) and dry it with a clean and dry dust-free cloth.

6 Fault Diagnosis

This chapter lists some common problems encountered during the use of the product and their corresponding troubleshooting methods. For details, refer to Table 14.

Table 14 Common Fault Troubleshooting Methods

Fault Phenomenon	Solution
Red/Green Indicator Light on the Interface Box is Not On/Flashing	Check if the connection line between the interface box and the power supply terminal is loose; Check if the cable harness is damaged.
The Product Motor Does Not Rotate	Check if the indicator light on the interface box is normal; Check if the connection line between the interface box and the power supply/product terminal is loose and if the cable harness is damaged.
The Product Keeps Restarting During Startup	Check the input power connection and polarity; Check if the voltage and current of the input power meet the requirements (when 12V voltage is applied, the input current should be ≥ 2A); Check if the installation plane of the product is level or if the screws on the bottom of the LiDAR are tightened too tightly.
The Product Internally Rotates, But There is No Data	Check if the LiDAR emits light normally; Check if the network connection is normal; Confirm if the computer-side network configuration is correct; Use other software (such as Wireshark) to check if the data is received; Disable the firewall and other security software that may block the network; Check if the power supply is normal; Try restarting the product.
Wireshark Can Receive Data, But RSView Does Not Display Point Cloud	Close the computer's firewall and run RSView through the firewall; Confirm that the computer's IP configuration matches the destination address set in the product; Confirm that the Sensor Network Configuration in RSView is set correctly; Confirm that the installation directory or configuration file storage directory of RSView does not contain any Chinese characters; Confirm that the data packets received by Wireshark are of

	the MSOP type.

Table 14 (Continuation)

Fault Phenomenon	Solution
The Product Has Frequent Data Loss	Confirm if there is a large number of other network packets or network conflicts in the network; Confirm if there are other network products sending a large amount of data in broadcast mode, causing sensor data blocking; Confirm if the computer's performance and interface performance meet the requirements; Remove all other network products and directly connect to the computer to confirm if data loss occurs.
Unable to Synchronize GPS/PTP/gPTP Time	Confirm if the synchronization mode has been switched to the correct mode on the web page; Under the GPS+PPS time synchronization mode: Confirm if the GPS module's baud rate is 9600 bps, 8 data bits, no parity bit, and 1 stop bit; Confirm if the GPS module outputs 3.3V TTL or RS232 level; Confirm if the 1PPS pulse is continuous and the wiring is correct; Confirm if the NMEA message format of GPRMC is correct; Confirm if the GPS module and interface box share the same ground; Confirm if the GPS module receives a valid fix; Confirm if the GPS module is validly positioned (outdoors); Under the PTP / gPTP time synchronization mode: Confirm if the PTP / gPTP Master synchronization protocol complies with the current PTP / gPTP protocol; Confirm if the PTP / gPTP Master is working properly.
No Data Output After Passing Through the Router	Close the DHCP function of the router or set the IP address of the sensor to the correct IP address internally in the router.
ROS Driver Displays a Fixed Blank Area Rotating When Showing Point Cloud	This phenomenon is normal. It occurs because the ROS driver splits the data into fixed packages for frame display. The blank part of the data will be displayed in the next frame.
RSView software outputs point clouds as a single ray	For Windows 10 systems, set RSView to run in Windows 7 compatibility mode to resolve the issue.

Note:

If the above troubleshooting steps fail to resolve the issue, please contact RoboSense for further assistance.

7 After-sales Service

If the solutions provided in Chapter 6 of the troubleshooting guide do not solve the problem, please promptly contact RoboSense.

Official Website: https://www.robosense.cn/contact

Email: support@robosense.cn

Phone: 0755-86325830 / 15338772453

Additional Information:

1) Please wait for a confirmation response from RoboSense after-sales service before sending the product back.
2) When sending the product back, please use the original packaging or an equivalent cushioned and moisture-resistant packaging.

Appendix A Web UI Operation

A.1 Product Information

The web interface of the LiDAR provides the default product information page, as shown in Figure 16 :

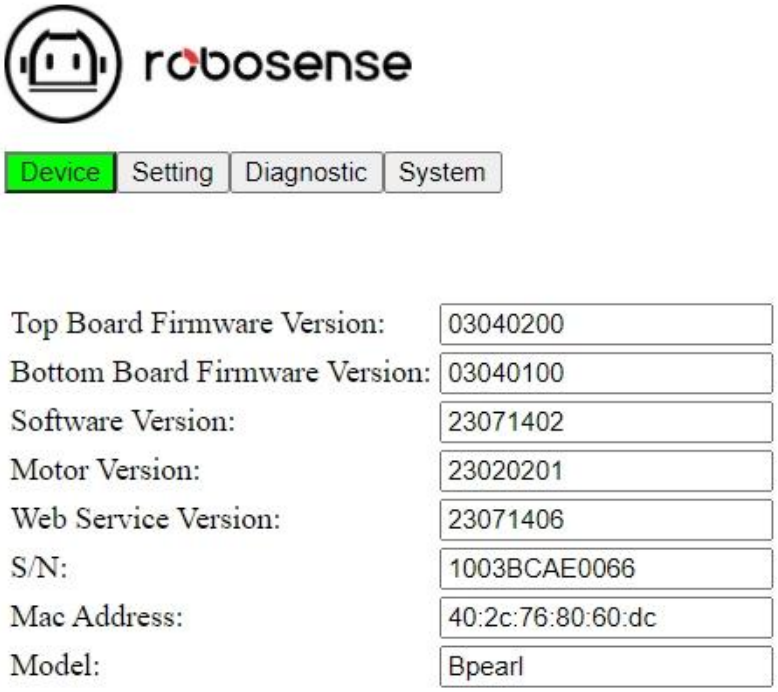


Figure 16 Web Interface Home Page

1) Top Board: Mainboard firmware version.
2) Bottom Board: Baseboard firmware version.
3) Software Version: Software version.
4) Motor Firmware Version: Motor version.
5) S/N: Product serial number.
6) Mac Address: MAC address.
7) Model: Product name.

A.2 Product Parameter Settings

The "Setting" section on the web page allows users to config parameters such as

Device IP, port number, return mode, speed, angle trigger, and more. The illustration and functionality description are shown in Figure 17 :

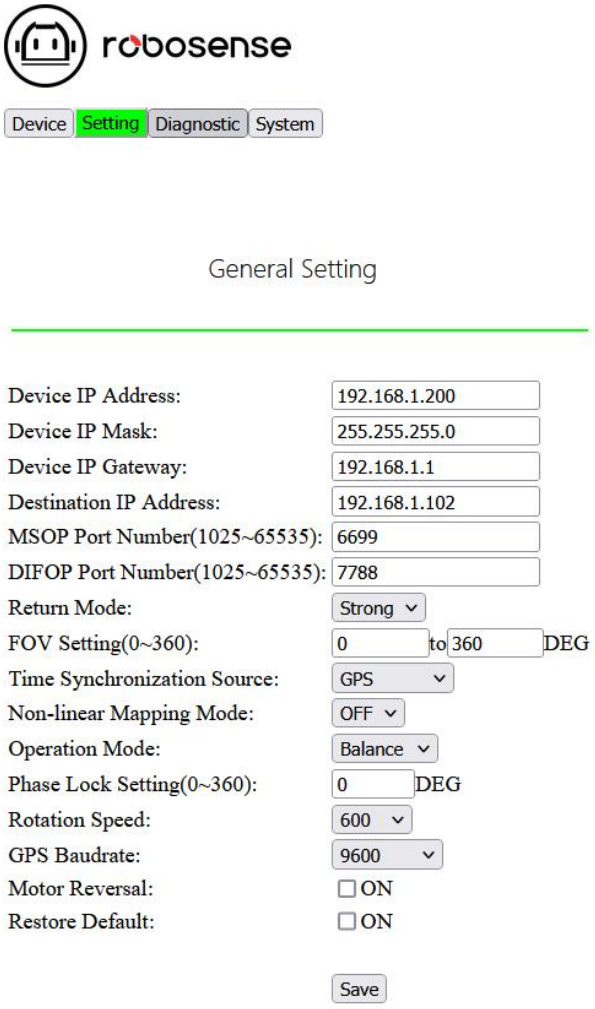


Figure 17 Web Interface LiDAR Settings

1) Destination IP can be set to either unicast (default) or broadcast mode. Setting Destination IP to 255.255.255.255 enables broadcast mode. The default value is 192.168.1.102.
2) MSOP and DIFOP data ports can be modified, with values ranging from 1025 to 65535.
3) Return Mode dropdown allows selecting the strongest (default)/last/first/dual return mode.
4) FOV (Field of View) can be set within the range of 0 to 360 degrees. Once set, only point cloud data within the specified FOV will be output.
5) Users can set the rotation speed, with options for 300 rpm, 600 rpm (default), and

1200 rpm.

6) Users can select "Time Synchronization Source" from GPS, PTP - P2P, PTP - E2E, and PTP - gPTP for time synchronization.
7) Users can choose different reflectivity mapping modes based on their requirements through the dropdown of "Nonlinear Mapping Mode." "OFF" represents the original reflectivity mode without any mapping, while "ON" is the enhanced reflectivity mode that improves lane discrimination.
8) Users can select the "Operation Mode" from Standby / High Performance (default). When selecting Standby mode, the LiDAR motor and transmitter will stop operating.
9) Phase Lock supports phase locking settings within the range of 0 to 360 degrees.
10) Motor Reversal determines the motor rotation direction. Checking "on" will result in counterclockwise rotation.
11) Restore Default enables resetting the configuration. Checking this function and saving it will restore the current configuration to its default settings.

Note:

1) Device IP and Destination IP should be in the same network segment; otherwise, the connection may fail.
2) The values for MSOP and DIFOP range from 1025 to 65535, and MSOP port and DIFOP port cannot be set to the same port.
3) After making changes, click "Save" to apply the settings. A successful prompt indicates that the settings have taken effect.

A.3 Product Diagnostics / Operating Status

This page allows real-time monitoring of the LiDAR's operating status, including voltage, current, real-time speed, runtime, temperature, and other information, as shown in Figure 18 :

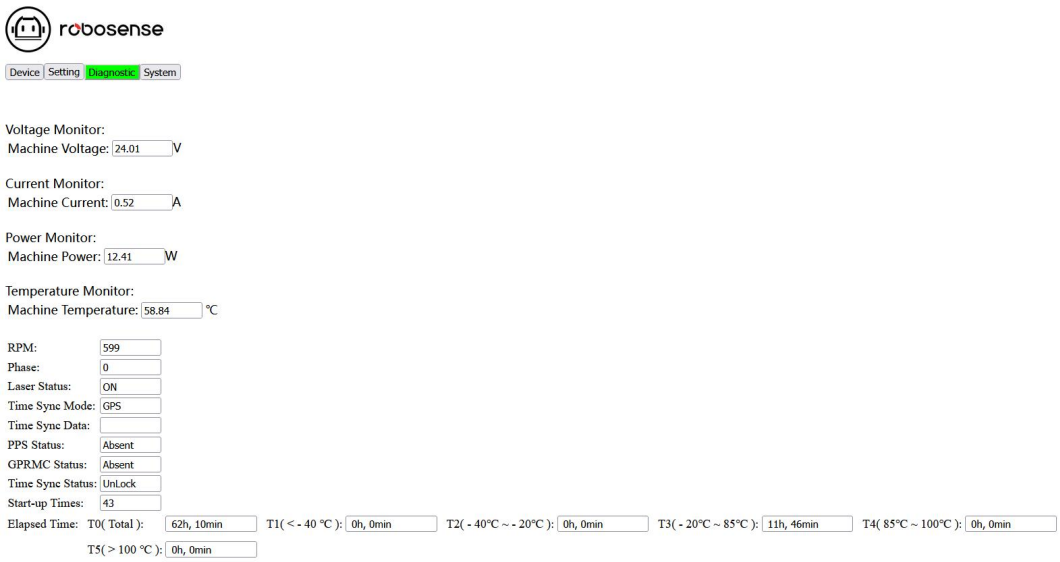


Figure 18 Web Interface Operating Status / Diagnostics

1) Voltage Monitor: Monitors the product's voltage. In Standby mode, this section will be highlighted in red.
2) Current Monitor: Monitors the product's current. In Standby mode, the current will reduce to approximately 0.2 A.
3) Power Monitor: Displays the product's power consumption. In Standby mode, the power consumption will decrease to around 5 W.
4) Temperature Monitor: Displays the current operating temperature of the product.
5) RPM: Displays the real-time rotation speed of the product.
6) Phase: Displays the real-time phase angle of the product.
7) Laser Status: Indicates "On" (default) or "Off." In Standby mode, the laser status will be "Off."
8) Star-up Times: Shows the total number of times the product has been started up. It increments once after each power cycle.
9) Elapsed time Total T0: Displays the total running time of the product and the accumulated working time at various temperatures.

Note:

1) The page refresh rate is 1 second.
2) If the voltage/current section turns red, please check if the product is in Standby mode. If not, check if the product is operating normally.

A.4 Product Firmware Upgrade

Click on the "System" on the web page. This page allows the firmware upgrade for the mainboard, baseboard, software, web interface, and motor. Follow the steps below:

1) Contact RoboSense to obtain the upgrade firmware. Once the firmware is ready, click "Choose File," as shown in Figure 19 .

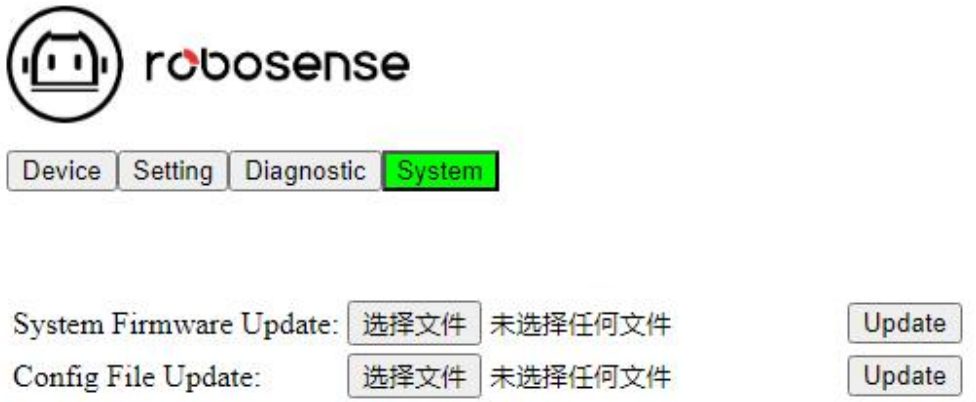


Figure 19 Step 1 - Click "Choose File"

2) Select the folder containing the corresponding firmware for the upgrade, then click "Open" (avoid using Chinese characters in the file path), as shown in Figure 20 .

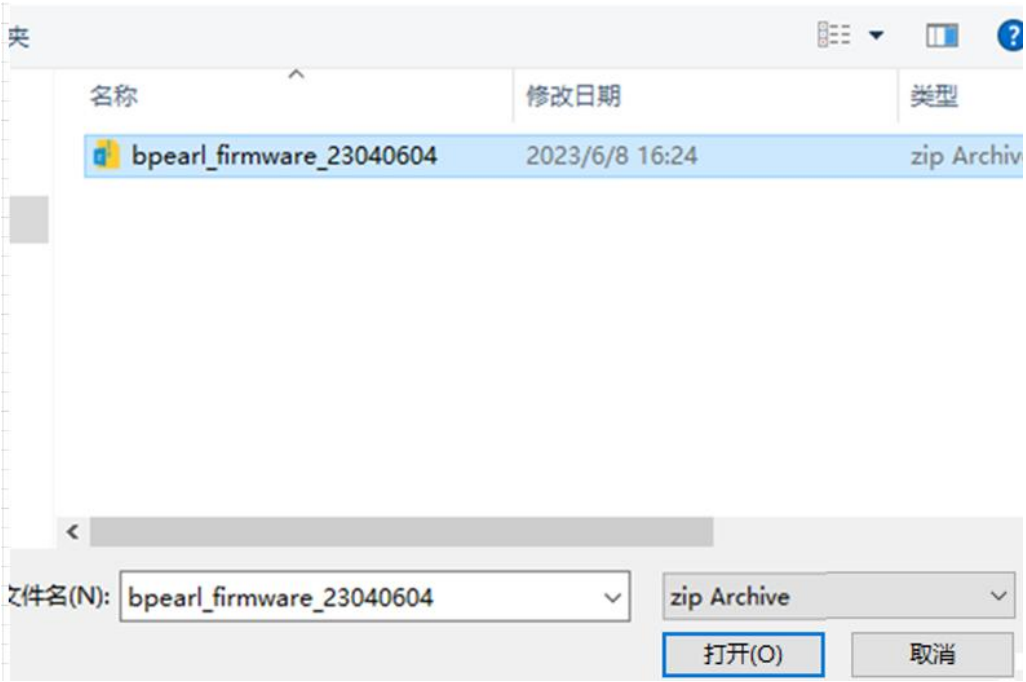


Figure 20 Step 2 - Select Firmware for Upgrade

3) After selecting the firmware for upgrade, the filename will change to the selected firmware name, indicating that it is successfully loaded, as shown in Figure 21 . Click "Update" to proceed with the upgrade.

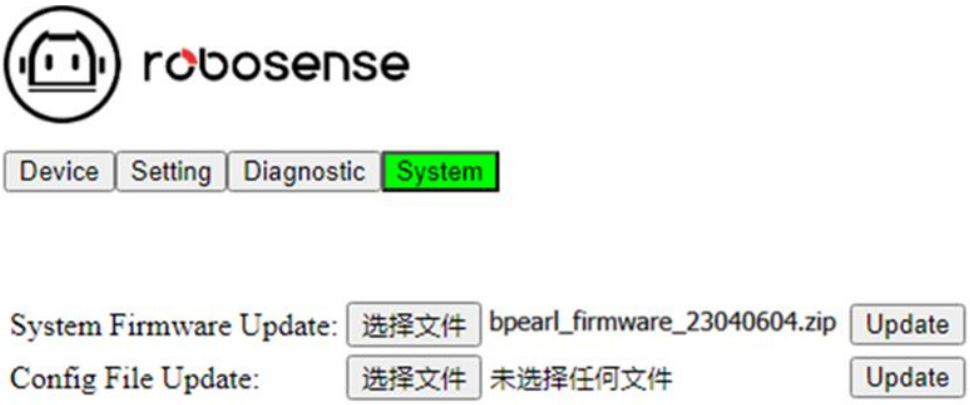


Figure 21 Step 3 - Click "Update"

4) The web interface will prompt the upgrade success (or indicate if there is a duplicate version). The product will automatically restart. After the restart, log in again to the web interface homepage and check the Device section to confirm if the upgrade was successful, as shown in Figure 22 .

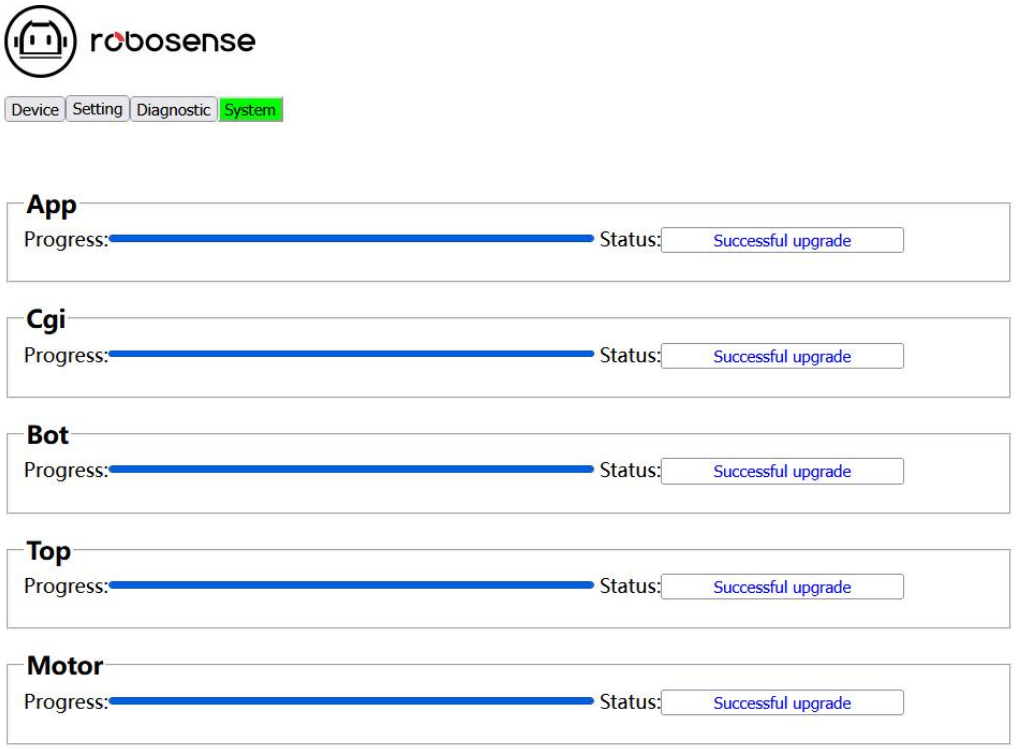


Figure 22 Step 4 - Upgrade Successful

Appendix B ROS & ROS2 Package

rslidar_sdk is the ROS-based driver SDK. You can download it from the RoboSense GitHub repository or contact RoboSense for access.

1) rslidar_sdk depends on rs_driver, which is the basic RoboSense driver. Download rs_driver from the GitHub platform.
2) If you are using ROS2, rslidar_sdk also depends on rslidar_msg, which defines the message format. Download the msg file from the GitHub platform.
3) The SDK package contains comprehensive usage guidelines. Before using the driver SDK, please read the README file and documentation under the doc folder.

Note:

SDK Download Link: https://github.com/RoboSense-LiDAR/rsLiDAR_sdk

rs_driver Download Link: https://github.com/RoboSense-LiDAR/rs_driver

msg Download Link: https://github.com/RoboSense-LiDAR/rslidar_msg

Appendix C Register Definitions

This appendix provides additional information to Section 4.4, defining the various registers in the protocol. All calculations are in big-endian format. The "Value" represents the decimal value obtained after converting the offset bytes.

C.1 Motor Speed (MOT_SPD) Register

Table 15 Motor Speed Register

Motor Speed Register (2 bytes)		
Index	byte 1	byte 2
Function	MOT_SPD	

Register Description:

1) This register is used to read the motor speed setting value.
2) For example, if the set value is 600 RPM, and the byte 1 = 0x02 and byte 2 = 0x58, then the Value = 600 RPM.

C.2 Ethernet (ETH) Register

Table 16 Ethernet Register

Ethernet Register (22 bytes)								
Index	byte 1	byte 2	byte 3	byte 4	byte 5	byte 6	byte 7	byte 8
Function	LIDAR_IP				DEST_PC_IP			
Index	byte 9	byte 10	byte 11	byte 12	byte 13	byte 14	byte 15	byte 16
Function	MAC_ADDR						MSOP	
Index	byte 17	byte 18	byte 19	byte 20	byte 21	byte 22	/	/
Function	Reserved		DIFOP		Reserved		/	

Register Description:

1) LIDAR_IP: The source IP address of the LiDAR, occupying 4 bytes.
2) DEST_PC_IP: The IP address of the destination PC, occupying 4 bytes.
3) MAC_ADDR: The MAC address of the LiDAR.
4) MSOP and DIFOP each occupy 2 bytes.

C.3 FOV Setting (FOV_SET) Register

Table 17 FOV Setting Register

FOV Setting Register (4 bytes)				
Index	byte 1	byte 2	byte 3	byte 4
Function	FOV_START		FOV_END	

Register Description:

1) This register is used to read the FOV (Field of View) setting value.
2) FOV_START and FOV_END have a range of 0 to 36000, corresponding to angles from 0 to 360°. Details are as follows:
   a) FOV_START: byte 1 = 0x5d, byte 2 = 0xc0, Value = 24000.
   b) FOV_END: byte 3 = 0x1f, byte 4 = 0x40, Value = 8000.
   c) With two decimal places, the FOV range is set to 240° to 80°.

C.4 TCP MSOP Port Number

Table 18 TCP MSOP Port Number Register

TCP MSOP Port Number Register (2 bytes)		
Index	byte 1	byte 2
Function	Port	

Register Description:

TCP communication mode MSOP port number setting.

C.5 Motor Phase Lock (MOT_PHASE) Register

Table 19 Motor Phase Lock Register

Motor Phase Lock Register (2 bytes)		
Index	byte 1	byte 2
Function	MOT_PHASE	

Register Description:

1) This register is used to read the motor phase lock setting value.
2) MOT_PHASE ranges from 0 to 360, corresponding to angles from 0 to 360°. Details are as follows:
   a) MOT_PHASE: byte 1 = 0x00, byte 2 = 0x64, Value = 100.

b) This indicates that the motor phase lock angle is set to 100°.

C.6 Mainboard Firmware Version (TOP_FRM) Register

Table 20 Mainboard Firmware Version Register

Mainboard Firmware Version Register (5 bytes)					
Index	byte 1	byte 2	byte 3	byte 4	byte 5
Function	TOP_FRM				

Register Description:

If byte 1 = 0x00, byte 2 = 0x03, byte 3 = 0x04, byte 4 = 0x01, byte 5 = 0x50, then the firmware version number is: 00 03 04 01 50.

C.7 Baseboard Firmware Version (BOT_FRM) Register

Table 21 Baseboard Firmware Version Register

Baseboard Firmware Version Register (5 bytes)					
Index	byte 1	byte 2	byte 3	byte 4	byte 5
Function	BOT_FRM				

Register Description:

If byte 1 = 0x00, byte 2 = 0x03, byte 3 = 0x04, byte 4 = 0x00, byte 5 = 0x06, then the firmware version number is: 00 03 04 00 06.

C.8 APP Software Version (SOF_FRM) Register

Table 22 APP Software Version Register

APP Software Version Register (5 bytes)					
Index	byte 1	byte 2	byte 3	byte 4	byte 5
Function	SOF_FRM				

Register Description:

If byte 1 = 0x00, byte 2 = 0x23, byte 3 = 0x03, byte 4 = 0x08, byte 5 = 0x02, then the firmware version number is: 00 23 03 08 02.

C.9 Motor Firmware Version (MOT_FRM) Register

Table 23 Motor Firmware Version Register

Motor Firmware Version (5 bytes)					
Index	byte 1	byte 2	byte 3	byte 4	byte 5
Function	MOT_FRM				

Register Description:

If byte 1 = 0x00, byte 2 = 0x23, byte 3 = 0x02, byte 4 = 0x02, byte 5 = 0x01, then the firmware version number is: 00 23 02 02 01.

C.10 Baud Rate Settings

Table 24 Baud Rate Settings Register

Baud Rate Settings Register (1 byte)						
Index	byte 1					
Function	Baud_Set（Baud Rate Settings Register）					
Explanation	0x00:1200	0x01:2400	0x02:4800	0x03:9600	0x04:14400	0x05:19200
	0x06:38400	0x07:43000	0x08:57600	0x09:76800	0x0A:115200	0x0B:128000
	0x0C:230400	0x0D:256000	0x0E:460800	0x0F:921600	0x10:1382400	/

Baud Rate Settings Register (1 byte)

C.11 Serial Number (SN) Register

Table 25 Serial Number Register

Serial Number Register (6 bytes)						
Index	byte 1	byte 2	byte 3	byte 4	byte 5	byte 6
Function	SN					

Register Description

Similar to MAC address, the product serial number is indicated by a 6-byte value in hexadecimal format.

C.12 Time Synchronization Information (TIME_SYNC_INF)

Table 26 Time Synchronization Information Register

Time Synchronization Information Register (2 bytes)		
Index	byte 1	byte 2
Function	Time_Sync_Mode	Time_Sync_State

Register Description:

1) Byte 1 represents the time synchronization mode status and is defined as follows:

   0x00: GPS synchronization; 0x01: E2E synchronization;

   0x02: P2P synchronization; 0x03: gptp synchronization

2) Byte 2 represents the time synchronization success status and is defined as follows:

   0x00: Not synchronized;

   0x01: Synchronization successful.

C.13 Time (UTC_TIME)

Table 27 Time Register

Time Register (10 bytes)										
Index	byte 1	byte 2	byte 3	byte 4	byte 5	byte 6	byte 7	byte 8	byte 9	byte10
Function	sec						us			

Register Description:

The value of "us" ranges from 0 to 999999.

C.14 Operating Status (STATUS)

Table 28 Operating Status Register

Operating Status Register (8 bytes)								
Index	byte 1	byte 2	byte 3	byte 4	byte 5	byte 6	byte 7	byte 8
Function	Reserved	Machine Current		Reserved			Machine Voltage	

Register Description:

1) Machine Current: Current of the entire machine, measured in Amperes (A). The current value is represented by 2 bytes and calculated as follows:

   Machine Current = Value / 100

2) Machine Voltage: Voltage of the entire machine, measured in Volts (V). The voltage value is represented by 2 bytes and calculated as follows:

Machine Voltage = Value / 100

C.15 Product Operating Time (Elapsed Time)

Table 29 Product Operating Time Register

Product Operating Time Register (2 bytes)				
Index	byte 1	byte 2	byte 3	byte 4
Function	Elapsed Time			

Register Description:

Elapsed Time: Total operating time of the product, measured in minutes. After 4 bytes overflow, the counting restarts.

For example, if Byte 1=0x00, Byte 2=0x00, Byte 3=0x09, and Byte 4=0xe4, the hexadecimal value converted to decimal is 2532 minutes.

C.16 Fault Diagnostics (FALT_DIGS)

Table 30 Fault Diagnostics Register

Fault Diagnostics Register (24 bytes)								
Index	byte 1	byte 2	byte 3	byte 4	byte 5	byte 6	byte 7	byte 8
Function	Start-Up Times		Reserved				GPS Status	Machine
Index	byte 9	byte 10	...	byte 20	byte 21	byte 22	byte 23	byte 24
Function	Temperature	Reserved			Phase		Rotation Speed	

Table 31 GPS Signal Input Status Register

GPS Signal Input Status Register (GPS_ST)			
Index	Function	Status Value	Description
bit 0	PPS Flag: PPS_LOCK	0	PPS signal invalid
		1	PPS signal valid
bit 1	GPRMC Flag: GPRMC_LOCK	0	GPRMC signal invalid
		1	GPRMC signal valid
bit 2	UTC Lock Flag: UTC_LOCK	0	UTC time not synchronized
		1	UTC time synchronized
bit 3	GPRMC Input Status	0	No input
		1	Input present
bit 4	PPS Input Status	0	No input
		1	Input present

bit 5 ~ bit7	Reserved	x	N/A

Register Description:

1) Start-Up Times: Number of times the machine has been started up, measured in occurrences. The value is represented by 2 bytes and starts refreshing after 1 minute of boot-up. The calculation formula is:

   Start-Up Times = Value; when two bytes overflow and the start-up count exceeds 65535, the counting restarts from 0.

2) Machine Temperature: Temperature of the product, measured in degrees Celsius (°C). The value is represented by 2 bytes.

   Machine Temperature = Value

3) Phase: Real-time phase value, measured in degrees (°). The value is represented by 2 bytes.

   Phase = Value

4) Rotation Speed: Real-time rotation speed of the machine, measured in revolutions per minute (RPM). The value is represented by 2 bytes.

   Rotation Speed = Value

C.17 GPRMC Data Packet - ASCII Code Data Type

The GPRMC data packet reserves 86 bytes and adapts to the complete storage of received GPRMC messages based on the length of the GPRMC message output by the external GPS module. It can be parsed and viewed in ASCII code.

C.18 Vertical Angle Calibration (COR_VERT_ANG)

Table 32 Vertical Angle Calibration Register

Vertical Angle Calibration Register (96 bytes)									
Index	byte 1	byte 2	byte 3	byte 4	byte 5	byte 6	byte 7	byte 8	byte 9
Function	Channel 1 Vertical Angle			Channel 2 Vertical Angle			Channel 3 Vertical Angle		
Index	byte 10	byte 11	byte 12	byte 13	byte 14	byte 15	byte 16	byte 17	byte 18
Function	Channel 4 Vertical Angle			Channel 5 Vertical Angle			Channel 6 Vertical Angle		
Index	byte 19	byte 20	byte 21	byte 22	byte 23	byte 24	byte 25	byte 26	byte 27
Function	Channel 7 Vertical Angle			Channel 8 Vertical Angle			Channel 9 Vertical Angle		
Index	byte 28	byte 29	byte 30	byte 31	byte 32	byte 33	byte 34	byte 35	byte 36
Function	Channel 10 Vertical Angle			Channel 11 Vertical Angle			Channel 12 Vertical Angle		
Index	byte 37	byte 38	byte 39	byte 40	byte 41	byte 42	byte 43	byte 44	byte 45
Function	Channel 13 Vertical Angle			Channel 14 Vertical Angle			Channel 15 Vertical Angle		
Index	byte 46	byte 47	byte 48	byte 49	byte 50	byte 51	byte 52	byte 53	byte 54
Function	Channel 16 Vertical Angle			Channel 17 Vertical Angle			Channel 18 Vertical Angle		
Index	byte 55	byte 56	byte 57	byte 58	byte 59	byte 60	byte 61	byte 62	byte 63
Function	Channel 19 Vertical Angle			Channel 20 Vertical Angle			Channel 21 Vertical Angle		
Index	byte 64	byte 65	byte 66	byte 67	byte 68	byte 69	byte 70	byte 71	byte 72
Function	Channel 22 Vertical Angle			Channel 23 Vertical Angle			Channel 24 Vertical Angle		
Index	byte 73	byte 74	byte 75	byte 76	byte 77	byte 78	byte 79	byte 80	byte 81
Function	Channel 25 Vertical Angle			Channel 26 Vertical Angle			Channel 27 Vertical Angle		
Index	byte 82	byte 83	byte 84	byte 85	byte 86	byte 87	byte 88	byte 89	byte 90
Function	Channel 28 Vertical Angle			Channel 29 Vertical Angle			Channel 30 Vertical Angle		
Index	byte 91	byte 92	byte 93	byte 94	byte 95	byte 96	/	/	/
Function	Channel 31 Vertical Angle			Channel 32 Vertical Angle			/		

Register Description:

1) The angle value is represented as positive or negative. Each channel's vertical angle is composed of 3 bytes, where the first byte indicates whether it is positive or negative, and the second and third bytes together form the angle's value.

2) To determine the sign (positive or negative) of the angle, check the attribute of the first byte. If the attribute of the first byte is 0x00, the channel's vertical angle is positive. If the attribute is 0x01, the channel's vertical angle is negative.

3) The angle resolution is 0.01°.

4) For example, if the value of the Channel 1 register is byte 1=0x00 (positive value), byte 2=0x00, and byte 3=0xE7 (converted to decimal 231). Then, the vertical angle value of Channel 1 is 2.31°.

C.19 Horizontal Angle Calibration (COR_HOR_ANG)

Table 33 Horizontal Angle Calibration Register

Horizontal Angle Calibration Register (96 bytes)									
Index	byte 1	byte 2	byte 3	byte 4	byte 5	byte 6	byte 7	byte 8	byte 9
Function	Channel 1 Horizontal Angle			Channel 2 Horizontal Angle			Channel 3 Horizontal Angle		
Index	byte 10	byte 11	byte 12	byte 13	byte 14	byte 15	byte 16	byte 17	byte 18
Function	Channel 4 Horizontal Angle			Channel 5 Horizontal Angle			Channel 6 Horizontal Angle		
Index	byte 19	byte 20	byte 21	byte 22	byte 23	byte 24	byte 25	byte 26	byte 27
Function	Channel 7 Horizontal Angle			Channel 8 Horizontal Angle			Channel 9 Horizontal Angle		
Index	byte 28	byte 29	byte 30	byte 31	byte 32	byte 33	byte 34	byte 35	byte 36
Function	Channel 10 Horizontal Angle			Channel 11 Horizontal Angle			Channel 12 Horizontal Angle		
Index	byte 37	byte 38	byte 39	byte 40	byte 41	byte 42	byte 43	byte 44	byte 45
Function	Channel 13 Horizontal Angle			Channel 14 Horizontal Angle			Channel 15 Horizontal Angle		
Index	byte 46	byte 47	byte 48	byte 49	byte 50	byte 51	byte 52	byte 53	byte 54
Function	Channel 16 Horizontal Angle			Channel 17 Horizontal Angle			Channel 18 Horizontal Angle		
Index	byte 55	byte 56	byte 57	byte 58	byte 59	byte 60	byte 61	byte 62	byte 63
Function	Channel 19 Horizontal Angle			Channel 20 Horizontal Angle			Channel 21 Horizontal Angle		
Index	byte 64	byte 65	byte 66	byte 67	byte 68	byte 69	byte 70	byte 71	byte 72
Function	Channel 22 Horizontal Angle			Channel 23 Horizontal Angle			Channel 24 Horizontal Angle		
Index	byte 73	byte 74	byte 75	byte 76	byte 77	byte 78	byte 79	byte 80	byte 81
Function	Channel 25 Horizontal Angle			Channel 26 Horizontal Angle			Channel 27 Horizontal Angle		
Index	byte 82	byte 83	byte 84	byte 85	byte 86	byte 87	byte 88	byte 89	byte 90
Function	Channel 28 Horizontal Angle			Channel 29 Horizontal Angle			Channel 30 Horizontal Angle		
Index	byte 91	byte 92	byte 93	byte 94	byte 95	byte 96	/	/	/
Function	Channel 31 Horizontal Angle			Channel 32 Horizontal Angle			/		

Register Description:

1) The angle value is represented as positive or negative. Each channel's horizontal angle is composed of 3 bytes, where the first byte indicates whether it is positive or negative, and the second and third bytes together form the angle's value.

2) To determine the sign (positive or negative) of the angle, check the attribute of the first byte. If the attribute of the first byte is 0x00, the channel's horizontal

offset angle is positive. If the attribute is 0x01, the channel's horizontal offset angle is negative.

3) The angle resolution is 0.01°.
4) For example, if the value of the Channel 1 register is byte 1=0x01 (negative value), byte 2=0x00, and byte 3=0x04 (converted to decimal 4). Then, the horizontal offset angle of Channel 1 is -0.04°.

Appendix D Accurate Point Time Calculation

It takes 55.56 us for 32 channels to complete one round of transmission sequentially. In each MSOP (Multi-segment Offset Protocol) Packet, there are 12 blocks, and each block contains a complete set of data for 32 channels. Therefore, one packet contains 12 complete sets of laser data. The time calculation for a single return point can be found in Table 34.

In the dual return mode, each MSOP Packet contains 12 blocks. Every two blocks represent the dual return ranging results obtained from the 32-channel laser after one round of transmission. For example, Block 1 and Block 2 represent the dual return data obtained after 32 channels transmit laser once, where Block 1 contains the data of the strongest return, and Block 2 contains the data of the second strongest return. The time calculation for a dual return point can be found in Table 35.

Table 34 Time Offset for Each Laser Point in Single Return within MSOP Packet

Time Offset (us)													
Channel Number	Vertical Angle	Data Block											
		1	2	3	4	5	6	7	8	9	10	11	12
1	2.19	0.00	55.55	111.10	166.65	222.20	277.75	333.30	388.85	444.40	499.95	555.50	611.05
2	47.29	1.67	57.22	112.77	168.32	223.87	279.42	334.97	390.52	446.07	501.62	557.17	612.72
3	5.01	3.34	58.89	114.44	169.99	225.54	281.09	336.64	392.19	447.74	503.29	558.84	614.39
4	50.12	5.00	60.55	116.10	171.65	227.20	282.75	338.30	393.85	449.40	504.95	560.50	616.05
5	7.84	6.67	62.22	117.77	173.32	228.87	284.42	339.97	395.52	451.07	506.62	562.17	617.72
6	52.94	8.34	63.89	119.44	174.99	230.54	286.09	341.64	397.19	452.74	508.29	563.84	619.39
7	10.66	10.01	65.56	121.11	176.66	232.21	287.76	343.31	398.86	454.41	509.96	565.51	621.06
8	55.75	11.68	67.23	122.78	178.33	233.88	289.43	344.98	400.53	456.08	511.63	567.18	622.73
9	13.47	13.34	68.89	124.44	179.99	235.54	291.09	346.64	402.19	457.74	513.29	568.84	624.39
10	58.57	15.01	70.56	126.11	181.66	237.21	292.76	348.31	403.86	459.41	514.96	570.51	626.06
11	16.29	16.68	72.23	127.78	183.33	238.88	294.43	349.98	405.53	461.08	516.63	572.18	627.73
12	61.39	18.35	73.90	129.45	185.00	240.55	296.10	351.65	407.20	462.75	518.30	573.85	629.40
13	19.11	20.02	75.57	131.12	186.67	242.22	297.77	353.32	408.87	464.42	519.97	575.52	631.07
14	64.20	21.68	77.23	132.78	188.33	243.88	299.43	354.98	410.53	466.08	521.63	577.18	632.73
15	21.92	23.35	78.90	134.45	190.00	245.55	301.10	356.65	412.20	467.75	523.30	578.85	634.40
16	67.01	25.02	80.57	136.12	191.67	247.22	302.77	358.32	413.87	469.42	524.97	580.52	636.07
17	24.74	26.69	82.24	137.79	193.34	248.89	304.44	359.99	415.54	471.09	526.64	582.19	637.74
18	69.82	28.36	83.91	139.46	195.01	250.56	306.11	361.66	417.21	472.76	528.31	583.86	639.41
19	27.56	30.02	85.57	141.12	196.67	252.22	307.77	363.32	418.87	474.42	529.97	585.52	641.07
20	72.63	31.69	87.24	142.79	198.34	253.89	309.44	364.99	420.54	476.09	531.64	587.19	642.74
21	30.37	33.36	88.91	144.46	200.01	255.56	311.11	366.66	422.21	477.76	533.31	588.86	644.41
22	75.44	35.03	90.58	146.13	201.68	257.23	312.78	368.33	423.88	479.43	534.98	590.53	646.08
23	33.20	36.70	92.25	147.80	203.35	258.90	314.45	370.00	425.55	481.10	536.65	592.20	647.75
24	78.26	38.36	93.91	149.46	205.01	260.56	316.11	371.66	427.21	482.76	538.31	593.86	649.41
25	36.02	40.03	95.58	151.13	206.68	262.23	317.78	373.33	428.88	484.43	539.98	595.53	651.08
26	81.07	41.70	97.25	152.80	208.35	263.90	319.45	375.00	430.55	486.10	541.65	597.20	652.75
27	38.84	43.37	98.92	154.47	210.02	265.57	321.12	376.67	432.22	487.77	543.32	598.87	654.42
28	83.89	45.04	100.59	156.14	211.69	267.24	322.79	378.34	433.89	489.44	544.99	600.54	656.09
29	41.66	46.70	102.25	157.80	213.35	268.90	324.45	380.00	435.55	491.10	546.65	602.20	657.75
30	86.71	48.37	103.92	159.47	215.02	270.57	326.12	381.67	437.22	492.77	548.32	603.87	659.42
31	44.47	50.04	105.59	161.14	216.69	272.24	327.79	383.34	438.89	494.44	549.99	605.54	661.09
32	89.55	51.71	107.26	162.81	218.36	273.91	329.46	385.01	440.56	496.11	551.66	607.21	662.76

Table 35 Time Offset for Each Laser Point in Dual Return within MSOP Packet

Time Offset (us)													
Channel Number	Vertical Angle	Data Block											
		1	2	3	4	5	6	7	8	9	10	11	12
1	2.19	0.00	0.00	55.55	55.55	111.10	111.10	166.65	166.65	222.20	222.20	277.75	277.75
2	47.29	1.67	1.67	57.22	57.22	112.77	112.77	168.32	168.32	223.87	223.87	279.42	279.42
3	5.01	3.34	3.34	58.89	58.89	114.44	114.44	169.99	169.99	225.54	225.54	281.09	281.09
4	50.12	5.00	5.00	60.55	60.55	116.10	116.10	171.65	171.65	227.20	227.20	282.75	282.75
5	7.84	6.67	6.67	62.22	62.22	117.77	117.77	173.32	173.32	228.87	228.87	284.42	284.42
6	52.94	8.34	8.34	63.89	63.89	119.44	119.44	174.99	174.99	230.54	230.54	286.09	286.09
7	10.66	10.01	10.01	65.56	65.56	121.11	121.11	176.66	176.66	232.21	232.21	287.76	287.76
8	55.75	11.68	11.68	67.23	67.23	122.78	122.78	178.33	178.33	233.88	233.88	289.43	289.43
9	13.47	13.34	13.34	68.89	68.89	124.44	124.44	179.99	179.99	235.54	235.54	291.09	291.09
10	58.57	15.01	15.01	70.56	70.56	126.11	126.11	181.66	181.66	237.21	237.21	292.76	292.76
11	16.29	16.68	16.68	72.23	72.23	127.78	127.78	183.33	183.33	238.88	238.88	294.43	294.43
12	61.39	18.35	18.35	73.90	73.90	129.45	129.45	185.00	185.00	240.55	240.55	296.10	296.10
13	19.11	20.02	20.02	75.57	75.57	131.12	131.12	186.67	186.67	242.22	242.22	297.77	297.77
14	64.20	21.68	21.68	77.23	77.23	132.78	132.78	188.33	188.33	243.88	243.88	299.43	299.43
15	21.92	23.35	23.35	78.90	78.90	134.45	134.45	190.00	190.00	245.55	245.55	301.10	301.10
16	67.01	25.02	25.02	80.57	80.57	136.12	136.12	191.67	191.67	247.22	247.22	302.77	302.77
17	24.74	26.69	26.69	82.24	82.24	137.79	137.79	193.34	193.34	248.89	248.89	304.44	304.44
18	69.82	28.36	28.36	83.91	83.91	139.46	139.46	195.01	195.01	250.56	250.56	306.11	306.11
19	27.56	30.02	30.02	85.57	85.57	141.12	141.12	196.67	196.67	252.22	252.22	307.77	307.77
20	72.63	31.69	31.69	87.24	87.24	142.79	142.79	198.34	198.34	253.89	253.89	309.44	309.44
21	30.37	33.36	33.36	88.91	88.91	144.46	144.46	200.01	200.01	255.56	255.56	311.11	311.11
22	75.44	35.03	35.03	90.58	90.58	146.13	146.13	201.68	201.68	257.23	257.23	312.78	312.78
23	33.20	36.70	36.70	92.25	92.25	147.80	147.80	203.35	203.35	258.90	258.90	314.45	314.45
24	78.26	38.36	38.36	93.91	93.91	149.46	149.46	205.01	205.01	260.56	260.56	316.11	316.11
25	36.02	40.03	40.03	95.58	95.58	151.13	151.13	206.68	206.68	262.23	262.23	317.78	317.78
26	81.07	41.70	41.70	97.25	97.25	152.80	152.80	208.35	208.35	263.90	263.90	319.45	319.45
27	38.84	43.37	43.37	98.92	98.92	154.47	154.47	210.02	210.02	265.57	265.57	321.12	321.12
28	83.89	45.04	45.04	100.59	100.59	156.14	156.14	211.69	211.69	267.24	267.24	322.79	322.79
29	41.66	46.70	46.70	102.25	102.25	157.80	157.80	213.35	213.35	268.90	268.90	324.45	324.45
30	86.71	48.37	48.37	103.92	103.92	159.47	159.47	215.02	215.02	270.57	270.57	326.12	326.12
31	44.47	50.04	50.04	105.59	105.59	161.14	161.14	216.69	216.69	272.24	272.24	327.79	327.79
32	89.55	51.71	51.71	107.26	107.26	162.81	162.81	218.36	218.36	273.91	273.91	329.46	329.46

Appendix E Channel Ranging Capability Corresponding Table

Table 36 Channel Ranging Capability Corresponding Table

Channel Number	Vertical Angle (°)	Distance @ 10% Target Reflectivity (m)	Maximum Range (m)
1	2.19	20	50
3	47.29	20	50
5	5.01	20	50
7	50.12	20	50
9	7.84	20	50
11	52.94	30	100
13	10.66	30	100
15	55.75	30	100
17	13.47	30	100
19	58.57	30	100
21	16.29	30	100
23	61.39	30	100
25	19.11	30	100
27	64.20	30	100
29	21.92	30	100
31	67.01	30	100
2	24.74	30	100
4	69.82	30	100
6	27.56	30	100
8	72.63	30	100
10	30.37	30	100
12	75.44	30	100
14	33.20	30	100
16	78.26	30	100
18	36.02	30	100
20	81.07	30	100
22	38.84	30	100
24	83.89	20	50
26	41.66	20	50
28	86.71	20	50
30	44.47	20	50
32	89.55	20	50

Appendix F Mechanical Drawings