Sensing Reality!

LiDAR Sensors
LR-16F
User Manual

Please read this user manual for best product performance before using the product.

Be sure to keep this manual properly for future reference.

OMEN-16F-202202

目录

1. Document description

This document summarizes supplementary information on mounting and electrical installation as well as measured value output format of the LR-16F. It is aimed at sufficiently qualified personnel for the purposes of installation, commissioning and further data processing. Notes on commissioning, configuration and maintenance can be found in the LR-16F operating instructions

2. Safety Instruction

- Read the notes on mounting and electrical installation before carrying out these tasks;
- Read additionally the LR-16F operating instructions to familiarize yourself with the device and its functions;
- The LR-16F complies with laser class 1.
- Only use the device in permissible ambient conditions (e.g. temperature, ground potential).Any applicable legal regulations or regulations of other authorities will have to be observed during operation.
- Opening the screws of the LiDAR housing will invalidate any warranty claims against OLEI.
- Repairs may only be performed on the LiDAR by trained and authorized OLEI service Personnel.

3. Measurement principle

With 16 laser emitting components rotating rapidly, LR-16F emits high-frequency laser beams to continuously scan the external environment; the ranging algorithm provides three-dimensional point cloud data and object reflectivity, allowing the machine to see the surrounding environment, and providing guarantee for positioning, navigation, obstacle avoidance, etc.

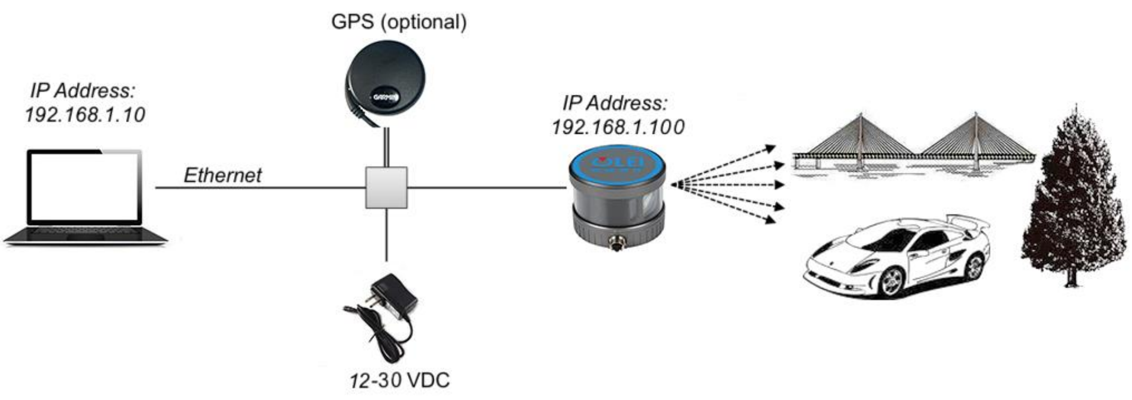


Figure 1 Diagram of LR-16F LiDAR work principle

The distance information between the object and the LiDAR is obtained based on the TOF (Time of Flight) principle, the flight speed and time of the laser beam. The calculation method is as follows:

$$D = \frac{CT}{2}$$

D—Detection range
T—Flight time
C—Speed of light

4. Installation and operation

4.1. Mechanical interface

LR-16F LiDAR can be installed at the bottom.
There is one M8 screw hole (hole depth is 5mm) at the bottom of the LiDAR.

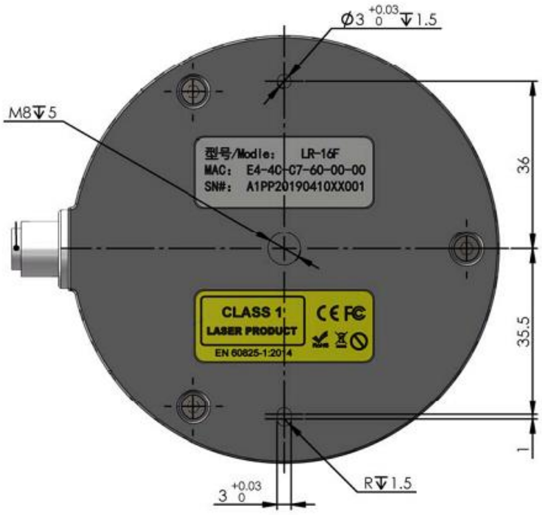


Figure 2 Installation interface of LR-16F

4.2. Electrical interface

LR-16F component includes one LiDAR main body, one junction box, one power adapter and one network cable.

Operating voltage scope of LR-16F is 12~30VDC. The input end of the power adapter is connected to 220VAC; the voltage at the power supply output end is converted to 12VDC by the power adapter, and is connected to the junction box.

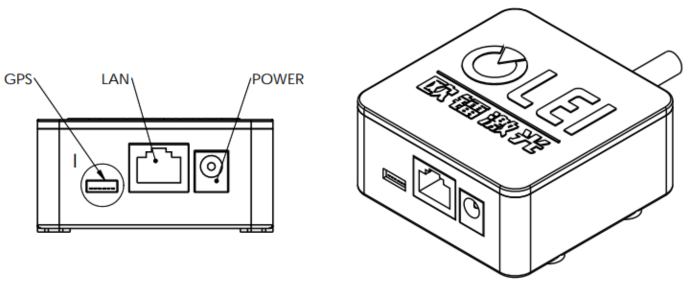


Figure 3 Electrical interface of LR-16F

4.2.1. Definition of aviation plugin

A cable containing an aviation plugin from the junction box, directly connects to the main body of LiDAR. The connection can only be successful when the red dots on the male and female plugs of the aviation plugin are aligned.

The aviation plug has a total of 12 PIN, among which PIN9 and PIN10 have two ground wires in parallel, and PIN11 and PIN12 have two power wires in parallel. Actually, 12 cables are connected to the junction box. The detailed definition of each PIN is shown in the table below.

Line order	color	function
1	orange	TXD- （send via network interface）
2	orange white	TXD+ （send via network interface）
3	green	RXD- （receiving via network interface）
4	green white	RXD+ （receiving via network interface）
5	grey	GPS-PPS （GPS sync pulse）
6	blue	GPS-RXD （GPS serial port receiving）
7	pink	reserved
8	yellow	reserved
9	brown	GND （grounding）
10	black	GND （grounding）
11	red	Vin （12~30V DC）
12	purple	Vin （12~30V DC）

Table 1 Definition of power supply and I/O interface

4.2.2. Definition of GPS

- GPS definition is shown in Table 2

No.	definition
1	PPS
2	5V
3	GND
4	RXD
5	GND
6	TXD

Table 2 Definition of GPS interface

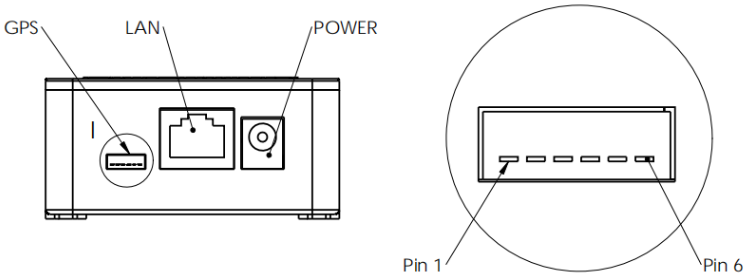


Figure 4 Definition of GPS

5V is the output voltage, used for GPS power supplying; PPS uses 3.3V TTL level; RXD, TXD uses 232 level.

- GPS analysis:

$GPRMC,061124,A,3148.5621,N,12342.2488,W,163.4,132.8,191018,120.2,W,A*70
<1> <2> <3> <4> <5> <6><7> <8> <9> <10> <11><12>

No.	Value	Definition
1	061124	<1> UTC time in hhmmss (hour, minute and second) format
2	A	<2> Positioning status, A=effective positioning, V=invalid positioning
3	3148.5621	<3> Latitude ddmm.mmmm (degree and minute) format (the front 0 will also be transmitted)
4	N	<4> Latitude Hemisphere N (Northern Hemisphere) or S (Southern Hemisphere)
5	12342.2488	<5> Longitude dddmm.mmmm (degree and minute) format (the front 0 will also be transmitted)
6	W	<6> Longitude hemisphere E (east longitude) or W (west longitude)
7	163.4	<7> Ground rate (000.0~999.9 knots, the front 0 will also be transmitted)
8	132.8	<8> Ground heading (000.0~359.9 degrees, with true north as the reference datum, the front 0 will also be transmitted)
9	191018	<9> UTC date in ddmmyy (day, month, year) format
10	120.2	<10> Magnetic declination (000.0~180.0 degrees, the front 0 will also be transmitted)
11	W	<11> Magnetic declination direction, E (east) or W (west)
12	A*70	<12> Mode indicator (only NMEA0183 version 3.00 display, A=autonomous positioning, D=differential, E=estimate, N=invalid data)

Table 3 Description of GPS analysis

For program analysis, please check "Appendix D: GPS code analysis" for reference.

4.3. Communication interface

The LR-16F is connected to the computer by a standard Ethernet RJ-45 interface. The computer IP address should be set up before communication. The LiDAR and computer IP must be set in the same subnet without any conflict. The output packet are mainly divided into data packet and information packet, the port number of the data packet is 2368, and the port number of the information packet is 9866.

The IP address settings on the computer is as follows:

- Computer IP:192.168.1.10
- Computer subnet mask: 255.255.255.0

The default factory settings of LiDAR are as follows:

- LiDAR IP:192.168.1.100
- LiDAR subnet mask:255.255.255.0

The specific setting process on the computer is as follows:

Figure 5 Step 1 of computer IP setting

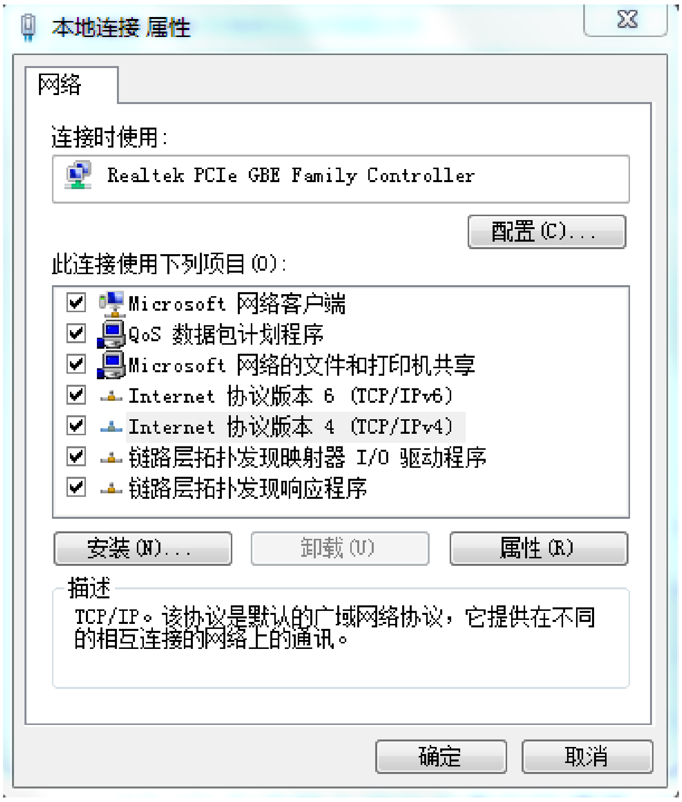


Figure 6 Step 2 of computer IP setting

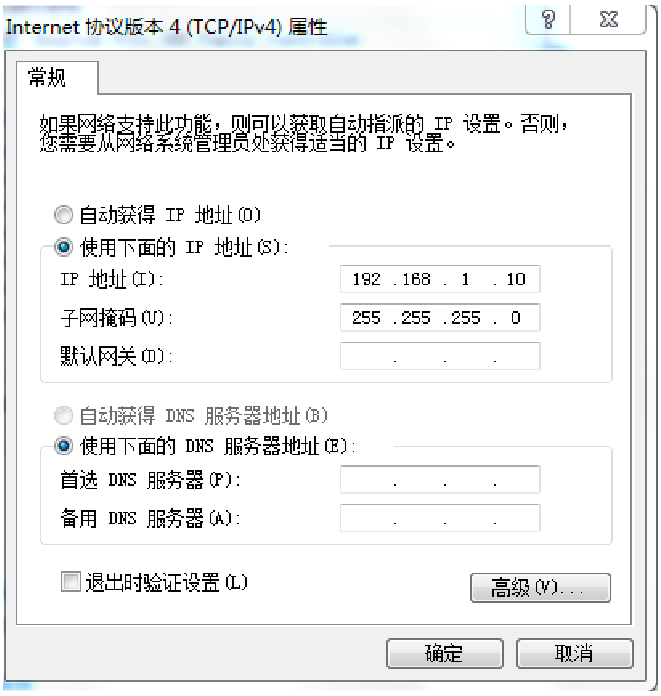


Figure 7 Step 3 of computer IP setting

5. Serial port and PPS

The serial port and PPS are mainly used when connecting to GNSS equipment. In order to synchronize the LiDAR clock with GNSS, standard time signal provided by the GNSS receiver should be input into LR-16F, including PPS signal and serial GPRMC data.

The PPS signal should be a TTL level signal, the signal pulse length is 20ms~200ms, and the GPRMC data must be completed within 500ms of the rising edge of the synchronous pulse.

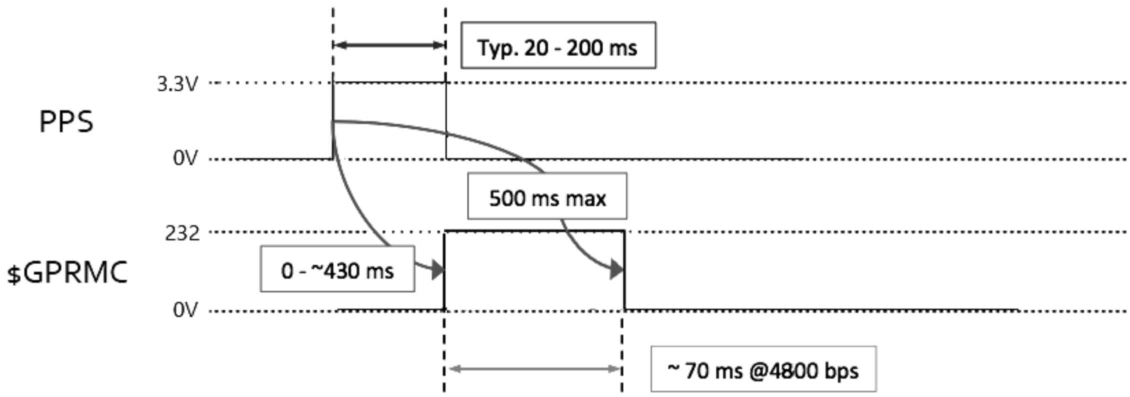


Figure 8 PPS synchronous sequence

The baud rate of the serial port has the following options: 4800, 9600, 115200bps, 8bit data bit, no parity bit, stop bit 1.

6. Definition of vertical angle

The vertical angle is defined as following:

Laser ID	Vertical Angle
0	-15°
1	1°
2	-13°
3	3°
4	-11°
5	5°
6	-9°
7	7°
8	-7°
9	9°
10	-5°
11	11°
12	-3°
13	13°
14	-1°
15	15°

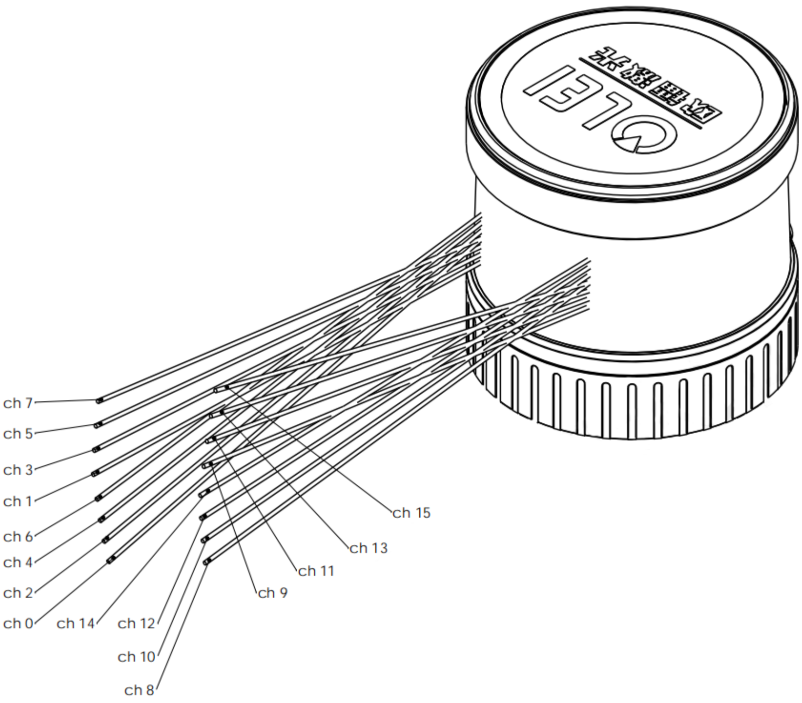


Figure 9 Schematic diagram of vertical angle definition

7. Format of data packet

LR-16F enables laser point cloud data transmission. Please refer to the following for the analysis of LiDAR point cloud data.

The information transmission between the LR-16F and the computer follows the UDP standard network protocol. The data packet adopts the Little-endian format, with the low byte in the front and the high byte in the back.

7.1. Communication protocol-data packet

7.1.1. Overview

The specific information stored in the data packet is the distance value, calibrated reflectivity, azimuth angle, time stamp and factory mark returned by the laser. The factory mark contains sensor model and return mode information.

The total length of the data packet is 1248 bytes, including 42 bytes for the header file, 1200 bytes for the laser returned data, 4 bytes for the time stamp, and 2 bytes for the factory mark. The basic structure is shown in the figure below.

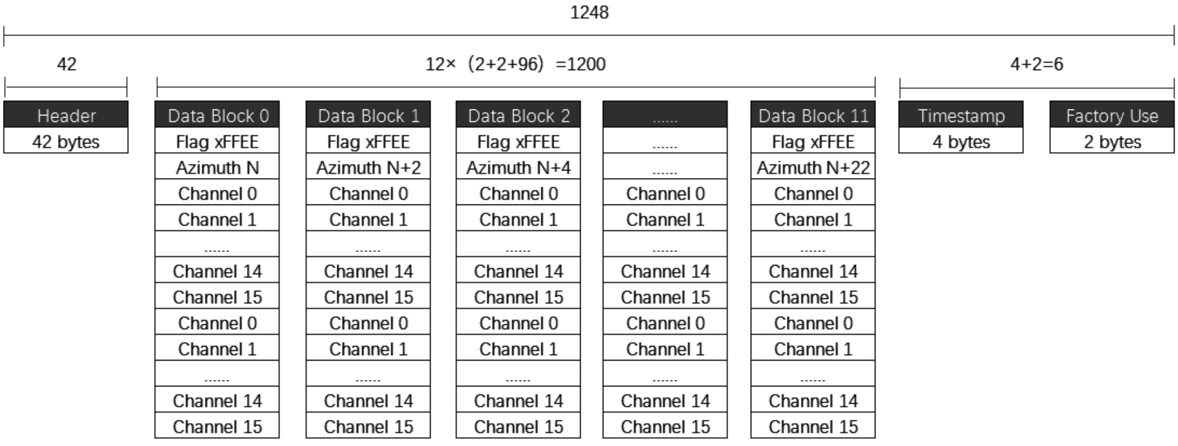


Figure 10 Format of point cloud information packet

The total length of the data frame is 1248 bytes, among which

- Frame header: 42 bytes
- Data block: 12×(2+2+96)=1200 bytes
- Time stamp: 4 bytes.
- Factory mark: 2 bytes

7.1.2. Header File

Offset	Length	Description
0	14	Ethernet II include Destination MAC: (6 Byte) Sourse MAC: (6 Byte) Type: (2 Byte)
14	20	Internet Protocol include Version & Header Length :(1 Byte) Differentiated Services Field: (1 Byte) Total Length:(2 Byte) Identification: (2 Byte)

		Flags: (1 Byte) Fragment Offse: (1 Byte) Time to Live: (1 Byte) Protocol: (1 Byte) Header Checksum: (2 Byte) Destination IP: (4 Byte) Sourse IP: (4 Byte)
34	8	User Datagram Protocol include Sourse Port: (2 Byte) Destination Port: (2 Byte) Data Length:(2 Byte) Checksum: (2 Byte)

Table 4 Header files

The laser returned data consists of 12 data blocks. Each data block starts with a 2-byte identifier 0xFFEE, followed by a 2-byte azimuth angle and a total of 32 data points. The laser returned value of each channel contains a 2-byte distance value and a 1-byte calibration reflectivity value.

Offset	Length	Description
0	2	Identifier, fixed value as 0xFFEE
2	2	Angle data
4	2	Ch0 distance data
6	1	Ch0 reflectance data
7	2	Ch1 distance data
9	1	Ch1 reflectance data
10	2	Ch2 distance data
12	1	Ch2 reflectance data
...	...	...
49	2	Ch15 distance data
51	1	Ch15 reflectance data
52	2	Ch0 distance data
54	1	Ch0 reflectance data
55	2	Ch1 distance data
57	1	Ch1 reflectance data
58	2	Ch2 distance data
60	1	Ch2 reflectance data
...	...	...
97	2	Ch15 distance data
99	1	Ch15 reflectance data

Table 5 Data block structure

7.1.3. Time stamp

Offset	Length	Description
0	4	time stamp[31:0] [31:20] count of seconds [19:0] count of milliseconds

7.1.4. Factory mark

Offset	Length	Description
0	2	Factory:(2 Byte)0x00,0x10

7.2. Communication protocol-information packet

7.2.1. Overview

Header	LiDAR Info	GPS Info
42 Bytes	768 Bytes	74 Bytes

Length of data packet: 884 Bytes

Note: The port number of the information packet cannot be changed, the local and target ports are both 9866

7.2.2. Definition of header

Offset	Length	Description
0	14	Ethernet II include Destination MAC: (6 Byte) Sourse MAC: (6 Byte) Type: (2 Byte)
14	20	Internet Protocol include Version & Header Length :(1 Byte) Differentiated Services Field: (1 Byte) Total Length:(2 Byte) Identification: (2 Byte) Flags: (1 Byte) Fragment Offse: (1 Byte) Time to Live: (1 Byte) Protocol: (1 Byte) Header Checksum: (2 Byte) Destination IP: (4 Byte) Sourse IP: (4 Byte)
34	8	User Datagram Protocol include Sourse Port: (2 Byte) Destination Port: (2 Byte) Data Length:(2 Byte) Checksum: (2 Byte)

Table 6 Definition of header

7.2.3. Definition of LiDAR Info

offset	Length	Description
0	6	Factory code
6	12	Machine model
18	12	Serial number
30	4	Sourse IP
34	2	Sourse data Port
36	4	Destination IP
40	2	Destination data Port
42	6	Sourse MAC
48	2	Motor speed
50	1	[7] GPS connection flag, 0: connected, 1: not connected [6] Upper circuit error flag 0: normal, 1: error [5:0]Reserved
51	1	GPS enable & baud rate, 0x00: GPS power off 0x01: GPS power on, baud rate 4800 0x02: GPS power on, baud rate 9600 0x03: GPS power on, baud rate 115200
52	1	Reserved
53	1	Reserved
54	2	The temperature of the upper circuit board, the data should multiply by 0.0625℃
56	2	The temperature of the lower circuit board, the data should multiply by 0.0625℃
58	2	Reserved
60	32	CH0-CH15 channel static offset
92	4	Reserved
96	672	Reserved
768	74	GPS information

Table 7 Definition of LiDAR Info

7.3. Setup the protocol

Follow the UDP protocol, user setup protocol, upper computer sends 8 bytes

Name	address	data
number of bytes	2 bytes	6 bytes

address	Name	Byte meaning [31:0]
F000	IP Local IP	[47:16]=local_ip, [15:0] =local_port
F001	Remote IP	[31:0]=remote_ip, [15:0]= remote_port
F002	Speed, GPS	[47:32] =rom_speed_ctrl

	enable, baud rate	[31:24]=GPS_en [23:0]Reserved	0x00 = off 0x01 = enabled and the baud rate is 4800 0x02= enabled and the baud rate is 9600 0x03 = enabled and 115200 baud rate

Example:

Local ip and port	F0 00 C0 A8 01 64 09 40	192.168.1.100 2368
Target ip and port	F0 01 C0 A8 01 0A 09 40	192.168.1.10 2368
Rotating speed	F0 02 02 58 00 00 00 00	speed 600

Restart the 3D radar each time the modification is completed.
Optional rotating speed: 300 or 600. optional baud rate:4800/9600/115200 .

8. Numerical calculation

8.1. Coordinate conversion

The information in the LR-16F data packet is the azimuth value and distance value established in the polar coordinate system. It's more convenient to construct three-dimensional scene through the point cloud data by converting polar coordinate value to Cartesian coordinate system.

The above values corresponding to each channel is shown in the following table:

Channel number	Vertical angle ω	Horizontal angle α	Horizontal offset A	Vertical offset B
CH0	-15°	α	21mm	5.06mm
CH1	1°	α+1*0.00108*H	21mm	-9.15mm
CH2	-13°	α+2*0.00108*H	21mm	5.06mm
CH3	3°	α+3*0.00108*H	21mm	-9.15mm
CH4	-11°	α+4*0.00108*H	21mm	5.06mm
CH5	5°	α+5*0.00108*H	21mm	-9.15mm
CH6	-9°	α+6*0.00108*H	21mm	5.06mm
CH7	7°	α+7*0.00108*H	21mm	-9.15mm
CH8	-7°	α+8*0.00108*H	-21mm	9.15mm
CH9	9°	α+9*0.00108*H	-21mm	-5.06mm
CH10	-5°	α+10*0.00108*H	-21mm	9.15mm
CH11	11°	α+11*0.00108*H	-21mm	-5.06mm
CH12	-3°	α+12*0.00108*H	-21mm	9.15mm
CH13	13°	α+13*0.00108*H	-21mm	-5.06mm
CH14	-1°	α+14*0.00108*H	-21mm	9.15mm
CH15	15°	α+15*0.00108*H	-21mm	-5.06mm

Table 8 Coordinate conversion

Note: Under normal accuracy, the horizontal angle α only needs to increase the parameters in the table above.

The calculation formula for space coordinates is

$$X = R*\cos(\omega)*\sin(\alpha) + A*\cos(\alpha)$$
$$Y = R*\cos(\omega)*\cos(\alpha) - A*\sin(\alpha)$$
$$Z = R*\sin(\omega) + B$$

Definitions

- The measured distance output by each channel of the LiDAR is set as R. Note that the unit of the LiDAR input is 2mm, please convert to 1mm first
- Rotating speed of LiDAR is set as H (usually 10Hz)
- The vertical angle of each channel of the LiDAR is set as ω
- The horizontal angle output by the LiDAR is set as α
- The horizontal offset of each channel of the LiDAR is set as A
- The vertical offset of each channel of the LiDAR is set as B
- The spatial coordinate system of each channel of the LiDAR is set as X, Y, Z

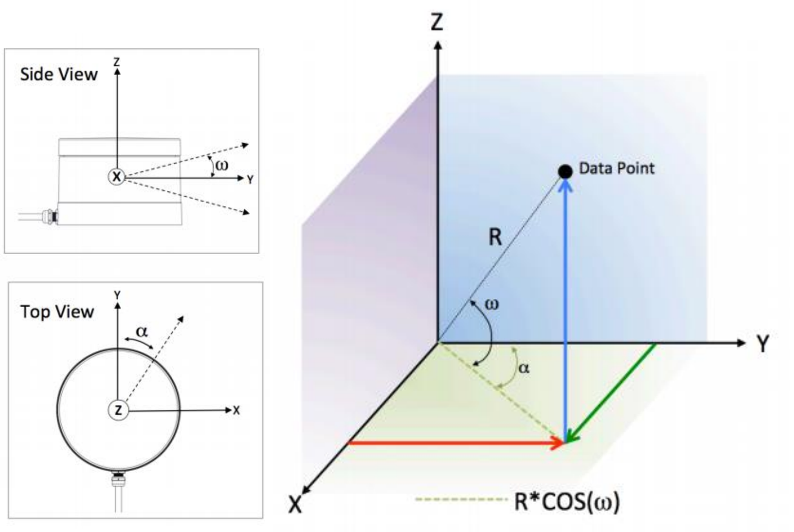


Figure 11 Coordinate transformation definition

For program analysis, see “Appendix E: 3D LiDAR Coordinate Code Analysis” for reference.

8.2. Azimuth

Each data packet records 12 azimuth values, which are located after the 0xFFEE flag of each data block. The azimuth angles of the last 16 laser beams of each data block are obtained through interpolation calculation. See the next section for specific methods.

The specific calculation method and steps of the azimuth angle are shown in the following example:

1) Obtain the azimuth value: 0x21 & 0x63
2) Interchange of high byte and low byte: 0x63 & 0x21
3) Combine into an unsigned hexadecimal number: 0x6321
4) Converted to decimal number: 25377
5) Multiply by the minimum resolution: 0.01°
6) Result: 253.77°

The 0° of the azimuth is coaxial with the base of LiDAR main body,and in the opposite direction.

8.3. Azimuth interpolation

LR-16F can directly obtain the azimuth angle of the first 16-line laser pulse sequence in each data block through the data packet, and then obtain the azimuth angle value of the second 16-line laser pulse sequence through interpolation calculation.

Assuming that among the 24 laser sequences of 12 data blocks, the adjacent 3 sequence numbers are N, N+1, and N+2, and the values of N and N+2 are known. The simplest and most direct method is to calculate the azimuth value of N+1 through N and N+2 interpolation (By default, the rotation speed is constant during the whole process). For the interpolation procedure, see “Appendix F: Interpolation Code Analysis” for reference.

8.4. Distance

Distance calculation method of LR-16F is similar to that of azimuth angle, as is shown in the following example:

1） Obtain the distance value:0x11 & 0x21
2） Interchange of high byte and low byte:0x21 & 0x11
3） Combine into an unsigned hexadecimal number:0x2111
4） Convert to decimal number:8465
5） Multiply by the minimum resolution:2mm
6） result:16930mm

8.5. Time stamp

The calculation method of time stamp of LR-16F is shown in the following example:

1） Obtain time stamp data:0x43 & 0x32&0x21&0x10
2） Interchange of high byte and low byte:0x10&0x21&0x32&0x43
3） Combination

0X10								0X21								0X32								0X43							
0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	1	0	0	1	0	0	1	0	0	0	0	1	1
Second(uint16)												Microsecond(uint32)																			

Calculation of second

0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0
				Second(uint16)											

Convert from binary to decimal: 258 unit:s

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	1	0	0	1	0	0	0	0	1	1

Convert from binary to decimal: 78403 unit: us

4） Calculate seconds:258+78403/1000000=258.078403

8.6. Emission time

The laser emission time of each channel of LR-16F is 3us, and there is a waiting time of 3us after all 16-line lasers are emitted. The total time for each 16 channels of laser to complete a round is 51us. Therefore, the laser beam after the first channel has a corresponding time offset.

To calculate emission time of the laser beam of any channel in any data block in the data packet, the 24 laser sequences should be numbered as M(M is 0~23) according to the sequence of data blocks, the 16 laser channels for each laser sequence are numbered as N, and the laser emission time T_{shift} of each channel is: (refer to Appendix C)

$$T_{\text{shift}} = (51 * M) + (3 * N)$$

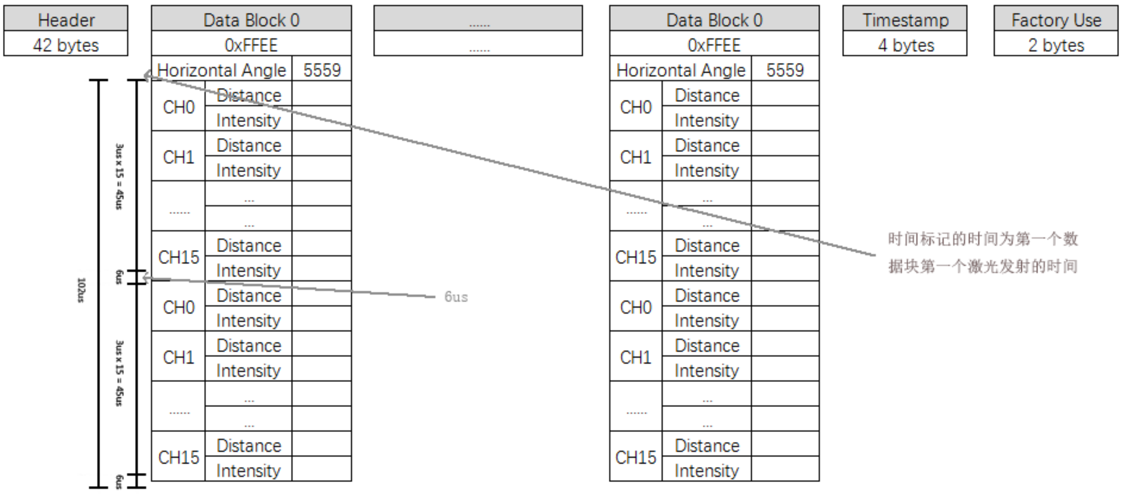


Figure 12　Laser emission time

In fact, the final emission time should add a time stamp. The time stamp records the emission time of the first channel of the first data block in each data package. The true value T_{real} is:

$$T_{\text{real}} = \text{Timestamp} + T_{\text{shift}}$$

9. Parameter configuration of upper computer software

Upper computer software is divided into display software configuration software and ROS driver packet.

9.1. Display software

The upper computer display software interface is shown in the figure below. Please refer to the Olamview 2.0 software manual for detailed usage.

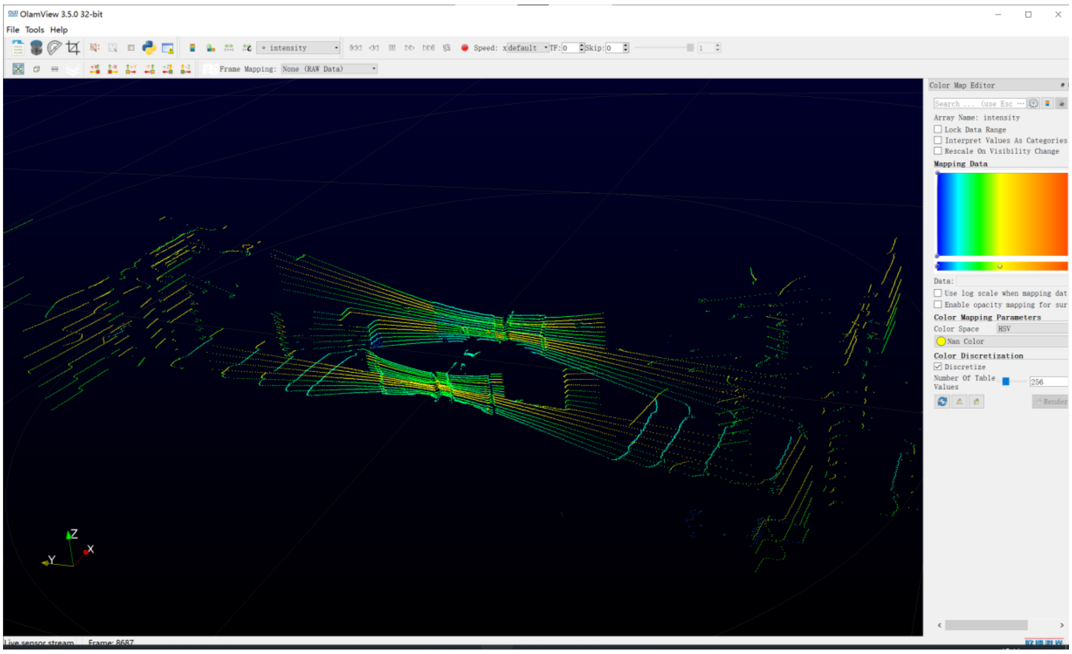
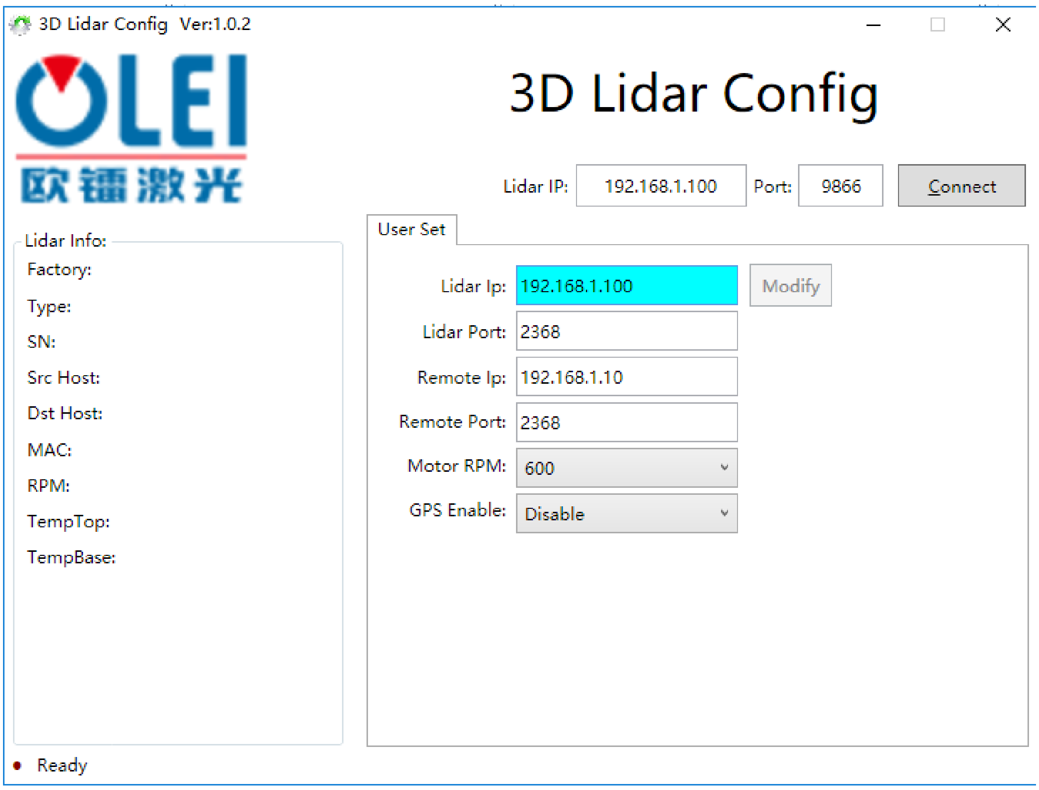


Figure 13 Example of upper computer software interface

The web page setting interface and the upper computer software interface may change due to continuous updated products, and the actual content shall prevail.

9.2. Configuration software

The configuration software 3D LiDAR config Ver1.0.2 is mainly used to modify and configure the basic parameters of 16-line LiDAR. The software interface is as shown below



- Lidar Ip: LiDAR IP;
- Lidar Port: LiDAR Port;

- Remote Ip: host IP;
- Remote Port: host port;
- Motor RPM: LiDAR rotating speed, optional 300/600;
- GPS Enable: GPS port, select Disable if there's no GPS.

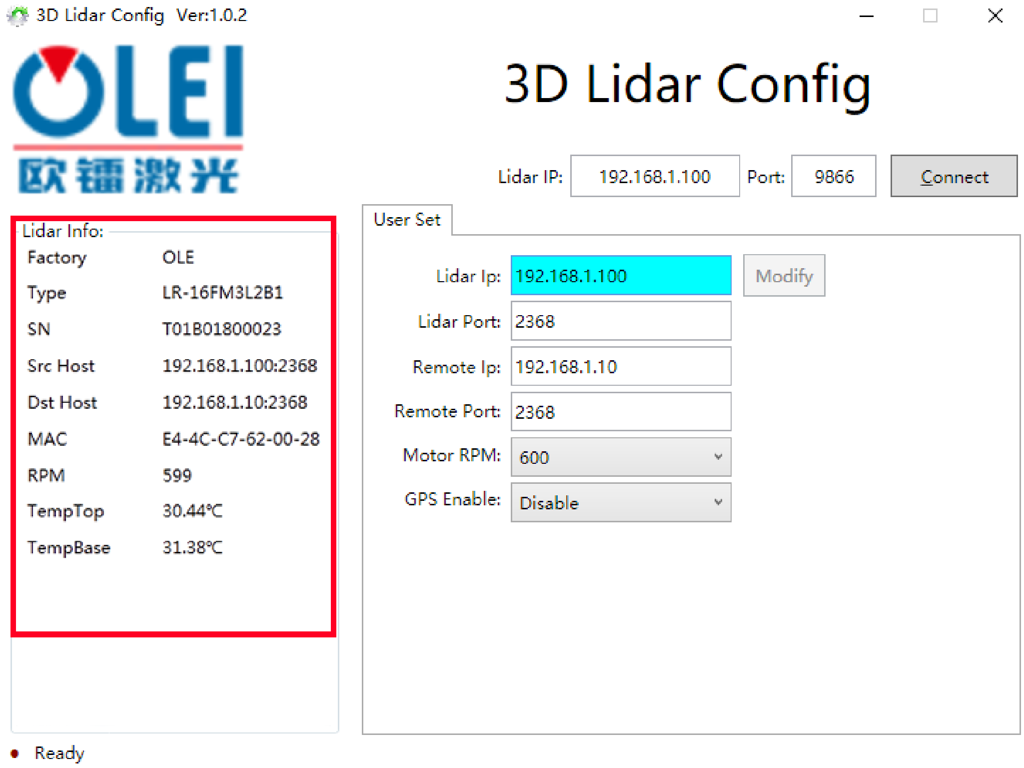
Instructions:

1.Connect the LiDAR according to the correct method to make the communication normal;

2.Click Connect. After the data on the left side of the figure below is normal, click Modify to modify the corresponding parameters as needed;

3.Restart LiDAR to make parameters effective.

4.When in the Connect state, in the right-click menu of the LiDAR Info area, you can choose to reset the LiDAR IP configuration to factory defaults.



9.3. ROS driver packet

In order to make it easier for customers to use ROS platform in the Linux environment, we developed the ROS driver packet Olam3D_C.zip. Refer to Appendix G for specific building and compiling steps Please contact technical staff from OLEI if necessary.

Note: If a red error message appears during the process of driver installation, it maybe caused by limited authority under Ubuntu. Please run the instruction "chmod -R 777 src" to obtain executable permissions.

10.Troubleshooting

Problem	Method
LiDAR fails to scan	Verify whether the power supply is properly connected

	Verify whether the power voltage meets 12~30VDC Verify whether the motor rotates normally
No data on LiDAR scan	Verify whether the network connection is normal Try to use third-party data scraping software to obtain data Verify the settings of the data receiving computer, such as IP, etc. Verify whether there is security software blocking data transmission

Table 9 Troubleshooting

Appendix A: Data Packet

```
312… 38.064195   192.168.1.100   192.168.1.10   UDP   1248 2368 → 2368 Len=1206
312… 38.065420   192.168.1.100   192.168.1.10   UDP   1248 2368 → 2368 Len=1206
312… 38.066742   192.168.1.100   192.168.1.10   UDP   1248 2368 → 2368 Len=1206
312… 38.067897   192.168.1.100   192.168.1.10   UDP   1248 2368 → 2368 Len=1206
312… 38.069116   192.168.1.100   192.168.1.10   UDP   1248 2368 → 2368 Len=1206
313… 38.070409   192.168.1.100   192.168.1.10   UDP   1248 2368 → 2368 Len=1206
313… 38.071630   192.168.1.100   192.168.1.10   UDP   1248 2368 → 2368 Len=1206
313… 38.072863   192.168.1.100   192.168.1.10   UDP   1248 2368 → 2368 Len=1206

▷ Frame 31302: 1248 bytes on wire (9984 bits), 1248 bytes captured (9984 bits) on interface 0
◢ Ethernet II, Src: Xilinx_01:fe:c0 (00:0a:35:01:fe:c0), Dst: Broadcast (ff:ff:ff:ff:ff:ff)
  ◢ Destination: Broadcast (ff:ff:ff:ff:ff:ff)
      Address: Broadcast (ff:ff:ff:ff:ff:ff)

0000  ff ff ff ff ff ff 00 0a  35 01 fe c0 08 00 45 00   ........ 5.....E.
0010  04 d2 82 22 40 00 80 11  f0 39 c0 a8 01 64 c0 a8   ..."@... .9...d..
0020  01 0a 09 40 09 40 04 be  00 00 ff ee c4 57 19 01   ...@.@.. .....W..
0030  30 e2 01 46 47 01 43 7b  02 43 34 01 38 66 02 44   0..FG.C{ .C4.8f.D
0040  95 01 0a 00 00 00 0b 01  39 ed 02 31 fd 00 23 e9   ........ 9..1..#.
0050  02 3b 00 00 00 fa 02 33  28 02 0a b0 03 32 16 01   .;.....3 (....2..
0060  31 0f 02 44 46 01 42 7a  02 43 3e 01 33 62 02 44   1..DF.Bz .C>.3b.D
0070  73 01 0a 00 00 00 0d 01  39 f8 02 34 0d 01 22 f5   s....... 9..4..".
0080  02 3c 00 00 00 04 03 34  06 02 0a b1 03 2e ff ee   .<.....4 ........
0090  ea 57 15 01 30 2e 02 43  45 01 42 79 02 44 44 01   .W..0..C E.By.DD.
00a0  32 61 02 44 78 01 0a 00  00 00 0e 01 35 fd 02 34   2a.Dx... ....5..4
00b0  17 01 16 fd 02 3b 00 00  00 0f 03 32 fd 01 0e 92   .....;.. ...2....
00c0  03 28 14 01 31 48 02 43  46 01 42 76 02 44 42 01   .(..1H.C F.Bv.DB.
00d0  2f 60 02 44 3b 01 0a 00  00 00 0f 01 33 05 03 34   /`.D;... ....3..4
00e0  22 01 0b 05 03 38 00 00  00 13 03 2d f1 01 1d 81   "....8.. ...-....
00f0  03 26 ff ee 0f 58 11 01  2f 5c 02 43 48 01 41 71   .&...X.. /\.CH.Aq
0100  02 42 44 01 2e 59 02 42  72 01 0b 00 00 00 19 01   .BD..Y.B r.......
0110  30 0b 03 35 02 01 0a 09  03 37 d8 01 0a 1d 03 27   0..5.... .7.....'
0120  cb 01 25 71 03 26 15 01  30 69 02 43 45 01 41 6f   ..%q.&.. 0i.CE.Ao
0130  02 3f 45 01 31 55 02 3e  99 01 0a 65 02 0a 23 01   .?E.1U.> ...e..#.
0140  30 0d 03 36 09 01 0a 0e  03 34 35 02 0a 1a 03 18   0..6.... .45.....
0150  b4 01 2d 7c 03 29 ff ee  33 58 19 01 30 73 02 43   ..-|.).. 3X..0s.C
0160  46 01 41 71 02 35 40 01  34 4a 02 2c 81 01 0a 24   F.Aq.5@. 4J.,...$
0170  02 1b 1e 01 25 0f 03 31  3e 01 0a 0f 03 31 01 02   ....%..1 >....1..
0180  0a 28 03 0a 9f 01 32 c2  03 37 1a 01 30 79 02 41   .(....2. .7..0y.A
0190  46 01 41 6b 02 2a 3c 01  35 51 02 33 98 01 11 3e   F.Ak.*<. 5Q.3...>
01a0  02 23 23 01 2c 0e 03 30  1f 01 0a 0f 03 29 32 02   .##.,..0 .....)2.
01b0  0a 00 00 00 8c 01 34 b4  04 45 ff ee 59 58 1c 01   ......4. .E..YX..
01c0  2f 7e 02 3d 48 01 40 6d  02 38 36 01 39 53 02 3b   /~.=H.@m .86.9S.;
01d0  78 01 0a 79 02 2d 1c 01  1d 0a 03 30 1d 01 0a 0c   x..y.-.. ...0....
01e0  03 20 e6 01 0a 00 00 00  81 01 35 e5 06 36 1b 01   . ...... ..5..6..
01f0  2f 6f 02 30 48 01 40 6f  02 3d 2e 01 39 50 02 40   /o.0H.@o .=..9P.@
0200  87 01 12 90 02 34 17 01  2d 0b 03 2f 21 01 10 03   .....4.. -../!...
0210  03 14 dc 01 0a 00 00 00  7d 01 36 f2 06 34 ff ee   ........ }.6..4..
0220  7d 58 1d 01 2e 67 02 25  4b 01 3f 6d 02 40 2a 01   }X...g.% K.?m.@*.
0230  3a 52 02 3f 8b 01 1c 9c  02 32 1f 01 1d 0f 03 2a   :R.?.... .2.....*
0240  1d 01 0a 1b 03 0b c1 01  0a 00 00 00 82 01 37 fa   ........ ......7.
```

```
0250  06 33 1e 01 2e 57 02 25  4e 01 3f 6d 02 3d 34 01   .3...W.% N.?m.=4.
0260  38 53 02 3c 7c 01 24 a4  02 30 1f 01 2b 0c 03 1f   8S.<|.$. .0..+...
0270  2f 01 0b 00 00 00 b0 01  0a 00 00 00 8b 01 36 fe   /....... ......6.
0280  06 32 ff ee a2 58 20 01  2d 72 02 31 52 01 3e 6e   .2...X . -r.1R.>n
0290  02 3c 37 01 38 52 02 3c  80 01 27 ad 02 32 21 01   .<7.8R.< ..'..2!.
02a0  2f 0a 03 0a 22 01 0a 00  00 00 b2 01 0a 00 00 00   /..."... ........
02b0  98 01 37 fe 06 33 21 01  2d 79 02 36 4e 01 3e 71   ..7..3!. -y.6N.>q
02c0  02 3b 3b 01 3a 51 02 3d  7e 01 2d 9f 02 36 1d 01   .;;.:Q.= ~.-..6..
02d0  33 00 00 00 4d 01 0a 00  00 00 a4 01 0a 00 00 00   3...M... ........
02e0  ac 01 37 fc 06 33 ff ee  c8 58 1f 01 2c 85 02 3a   ..7..3.. .X..,..:
02f0  4d 01 3d 6b 02 3d 3e 01  3b 50 02 40 77 01 2f 99   M.=k.=>. ;P.@w./.
0300  02 3a 18 01 35 00 00 00  11 01 0a 00 00 00 90 01   .:..5... ........
0310  0a 00 00 00 c1 01 36 fc  06 32 23 01 2d 84 02 3b   ......6. .2#.-..;
0320  4b 01 3c 63 02 40 3c 01  3a 4d 02 42 75 01 32 96   K.<c.@<. :M.Bu.2.
0330  02 3d 16 01 37 00 00 00  27 01 0a 00 00 00 aa 01   .=..7... '.......
0340  0a df 06 1d cc 01 36 f9  06 33 ff ee ed 58 24 01   ......6. .3...X$.
0350  2c 87 02 3d 4b 01 3b 61  02 42 3c 01 3c 49 02 44   ,..=K.;a .B<.<I.D
0360  72 01 35 95 02 3f 14 01  38 00 00 00 0d 01 0a 00   r.5..?.. 8.......
0370  00 00 84 01 15 cc 06 31  e6 01 34 fc 06 34 25 01   .......1 ..4..4%.
0380  2c 81 02 3f 42 01 39 5f  02 43 3d 01 3d 48 02 44   ,..?B.9_ .C=.=H.D
0390  6d 01 37 92 02 40 13 01  38 00 00 00 d7 00 0a 00   m.7..@.. 8.......
03a0  00 00 7f 01 1e c9 06 37  05 02 33 f7 06 33 ff ee   .......7 ..3..3..
03b0  11 59 22 01 2c 7d 02 41  40 01 37 5c 02 44 3a 01   .Y".,}.A @.7\.D:.
03c0  3e 47 02 45 68 01 39 92  02 40 14 01 37 00 00 00   >G.Eh.9. .@..7...
03d0  c8 00 0a 00 00 00 7b 01  23 c3 06 39 1a 02 33 f9   ......{. #..9..3.
03e0  06 33 24 01 2b 78 02 42  3f 01 34 5a 02 44 39 01   .3$.+x.B ?.4Z.D9.
03f0  3d 46 02 45 64 01 39 8e  02 41 17 01 37 00 00 00   =F.Ed.9. .A..7...
0400  08 01 0a 00 00 00 66 01  29 bf 06 39 28 02 33 f5   ......f. )..9(.3.
0410  06 32 ff ee 37 59 25 01  2d 76 02 43 45 01 34 58   .2..7Y%. -v.CE.4X
0420  02 44 38 01 3e 45 02 45  61 01 39 8b 02 41 1a 01   .D8.>E.E a.9..A..
0430  36 00 00 00 11 01 0a 00  00 00 60 01 2e bd 06 38   6....... ..`....8
0440  32 02 33 f8 06 32 24 01  2c 72 02 44 4d 01 33 52   2.3..2$. ,r.DM.3R
0450  02 44 3b 01 3d 42 02 45  5f 01 3a 8a 02 41 1d 01   .D;.=B.E _.:..A..
0460  34 00 00 00 f0 00 0a 00  00 00 59 01 30 bd 06 37   4....... ..Y.0..7
0470  3a 02 34 f8 06 32 ff ee  5c 59 2b 01 2d 71 02 44   :.4..2.. \Y+.-q.D
0480  53 01 33 53 02 44 3c 01  3e 41 02 45 5f 01 3a 87   S.3S.D<. >A.E_.:.

0490  02 42 24 01 33 00 00 00  12 01 0a 00 00 00 59 01   .B$.3... ......Y.
04a0  32 bd 06 37 3e 02 34 f0  06 31 2d 01 2b 6f 02 44   2..7>.4. .1-.+o.D
04b0  56 01 35 50 02 44 3f 01  3d 40 02 45 5e 01 3a 86   V.5P.D?. =@.E^.:.
04c0  02 42 2c 01 30 00 00 00  3a 01 0a 00 00 00 5b 01   .B,.0... :.....[.
04d0  33 bc 06 37 45 02 34 f0  06 31 9a 8a 36 7e 00 10   3..7E.4. .1..6~..
```

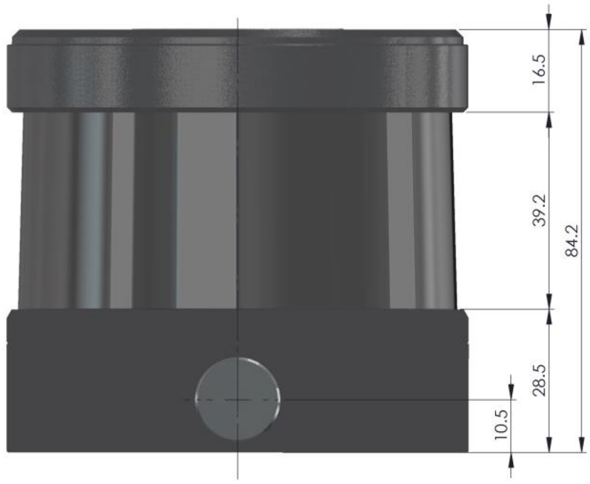
```
263… 32.036315   192.168.1.100   192.168.1.10   UDP   884 9866 → 9866 Len=842
271… 33.036360   192.168.1.100   192.168.1.10   UDP   884 9866 → 9866 Len=842
280… 34.092633   192.168.1.100   192.168.1.10   UDP   884 9866 → 9866 Len=842
288… 35.092650   192.168.1.100   192.168.1.10   UDP   884 9866 → 9866 Len=842
296… 36.081610   192.168.1.100   192.168.1.10   UDP   884 9866 → 9866 Len=842
304… 37.074067   192.168.1.100   192.168.1.10   UDP   884 9866 → 9866 Len=842
313… 38.073042   192.168.1.100   192.168.1.10   UDP   884 9866 → 9866 Len=842
321… 39.085051   192.168.1.100   192.168.1.10   UDP   884 9866 → 9866 Len=842
```

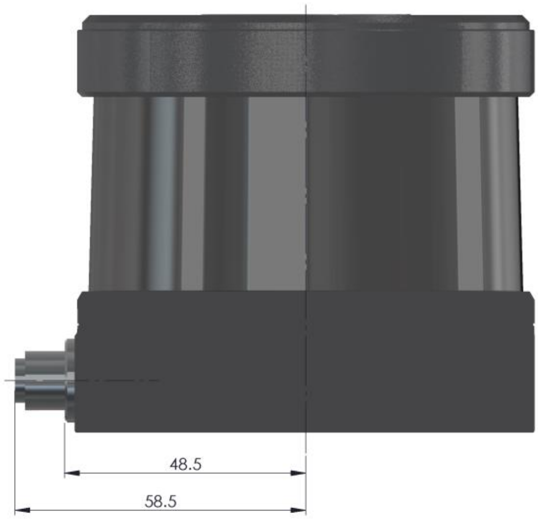
```
◢ Destination: Broadcast (ff:ff:ff:ff:ff:ff)
    Address: Broadcast (ff:ff:ff:ff:ff:ff)
    .... ..1. .... .... .... .... = LG bit: Locally administered address (this is NOT the factory default)
    .... ...1 .... .... .... .... = IG bit: Group address (multicast/broadcast)
```

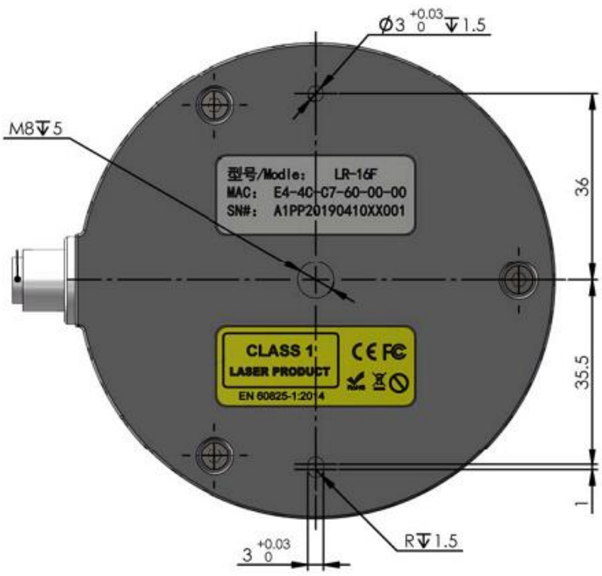

```
0000  ff ff ff ff ff ff 00 0a  35 01 fe c0 08 00 45 00   ........ 5.....E.
0010  03 66 82 22 40 00 80 11  f1 a5 c0 a8 01 64 c0 a8   .f."@... .....d..
0020  01 0a 26 8a 26 8a 03 52  00 00 4f 4c 45 00 00 00   ..&.&..R ..OLE...
0030  4c 52 2d 31 36 46 4d 33  4c 32 42 31 50 50 32 30   LR-16FM3 L2B1PP20
0040  31 39 30 37 32 39 30 31  c0 a8 01 64 09 40 c0 a8   19072901 ...d.@..
0050  01 0a 09 40 00 0a 35 01  fe c0 02 56 08 00 00 00   ...@..5. ...V....
0060  01 77 01 68 ff ff 02 96  02 ad 02 a9 02 c6 02 c4   .w.h.... ........
0070  02 ca 02 af 02 b1 02 cd  02 c3 02 cc 02 c5 02 c9   ........ ........
0080  02 c5 02 cc 02 a9 00 00  00 00 00 00 00 00 00 00   ........ ........
0090  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00a0  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00b0  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00c0  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00d0  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00e0  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00f0  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
0100  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
0110  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
0120  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
0130  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
0140  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
0150  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
0160  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
0170  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
0180  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
0190  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
01a0  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
01b0  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
01c0  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
01d0  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
01e0  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
01f0  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
0200  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
0210  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
0220  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
0230  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
0240  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........

0250  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
0260  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
0270  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
0280  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
0290  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
02a0  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
02b0  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
02c0  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
02d0  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
02e0  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
02f0  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
0300  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
0310  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
0320  00 00 00 00 00 00 00 00  00 00 24 47 50 52 4d 43   ........ ..$GPRMC
0330  2c 30 30 33 33 34 30 2c  41 2c 33 31 34 38 2e 35   ,003340, A,3148.5
0340  37 39 35 2c 4e 2c 31 31  39 35 32 2e 35 36 32 34   795,N,11 952.5624
0350  2c 45 2c 30 30 30 2e 30  2c 30 30 30 2e 30 2c 33   ,E,000.0 ,000.0,3
0360  30 31 30 31 39 2c 30 30  35 2e 35 2c 57 2a 36 31   01019,00 5.5,W*61
0370  0d 0a 0d 0a                                        ....
```

Appendix B: Mechanical Dimensions







Appendix C: Timetable

	ID	Data Block											
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
First Firing	**0**	0	102	204	306	408	510	612	714	816	918	1020	1122
	1	3	105	207	309	411	513	615	717	819	921	1023	1125
	2	6	108	210	312	414	516	618	720	822	924	1026	1128
	3	9	111	213	315	417	519	621	723	825	927	1029	1131
	4	12	114	216	318	420	522	624	726	828	930	1032	1134
	5	15	117	219	321	423	525	627	729	831	933	1035	1137
	6	18	120	222	324	426	528	630	732	834	936	1038	1140
	7	21	123	225	327	429	531	633	735	837	939	1041	1143
	8	24	126	228	330	432	534	636	738	840	942	1044	1146
	9	27	129	231	333	435	537	639	741	843	945	1047	1149
	10	30	132	234	336	438	540	642	744	846	948	1050	1152
	11	33	135	237	339	441	543	645	747	849	951	1053	1155
	12	36	138	240	342	444	546	648	750	852	954	1056	1158
	13	39	141	243	345	447	549	651	753	855	957	1059	1161
	14	42	144	246	348	450	552	654	756	858	960	1062	1164
	15	45	147	249	351	453	555	657	759	861	963	1065	1167
Second Firing	**0**	51	153	255	357	459	561	663	765	867	969	1071	1173
	1	54	156	258	360	462	564	666	768	870	972	1074	1176
	2	57	159	261	363	465	567	669	771	873	975	1077	1179
	3	60	162	264	366	468	570	672	774	876	978	1080	1182
	4	63	165	267	369	471	573	675	777	879	981	1083	1185
	5	66	168	270	372	474	576	678	780	882	984	1086	1188
	6	69	171	273	375	477	579	681	783	885	987	1089	1191
	7	72	174	276	378	480	582	684	786	888	990	1092	1194
	8	75	177	279	381	483	585	687	789	891	993	1095	1197
	9	78	180	282	384	486	588	690	792	894	996	1098	1200
	10	81	183	285	387	489	591	693	795	897	999	1101	1203
	11	84	186	288	390	492	594	696	798	900	1002	1104	1206
	12	87	189	291	393	495	597	699	801	903	1005	1107	1209
	13	90	192	294	396	498	600	702	804	906	1008	1110	1212
	14	93	195	297	399	501	603	705	807	909	1011	1113	1215
	15	96	198	300	402	504	606	708	810	912	1014	1116	1218

Appendix D: GPS code analysis

```
//GPS Timestam Parse and lidar Timestam Parse
                var temp = new byte[4];
                Buffer.BlockCopy(DataBytes, 1200, temp, 0, temp.Length);
                // 1.Reverse
                var t = temp.Reverse().ToArray();
                var str1 = Convert.ToString(t[0], 2).PadLeft(8, '0');
                var str2 = Convert.ToString(t[1], 2).PadLeft(8, '0');
                var str3 = Convert.ToString(t[2], 2).PadLeft(8, '0');
                var str4 = Convert.ToString(t[3], 2).PadLeft(8, '0');
                //2.reassemble
                var tt1 = $"{str1}{str2.Substring(0, 4)}".PadLeft(16,'0');
                var tt2 = $"{str2.Substring(4, 4)}{str3}{str4}".PadLeft(24, '0');
                var a = IrAdvanced.ConvertBase(tt1, 2, 16).PadLeft(4,'0').ToHexBytes().Reverse().ToArray();
                var b = IrAdvanced.ConvertBase(tt2, 2, 16).PadLeft(8,'0').ToHexBytes().Reverse().ToArray();
               //Second(uint16)
                TimeS = BitConverter.ToUInt16(a, 0);
                //Microsecond(uint32)
                TimeM = (int)BitConverter.ToUInt32(b, 0);
              //  $"Second:{TimeS}  Microsecond:{TimeM}".ToDebug();
                return true;
```

Appendix E: analysis of 3D LiDAR coordinate code

```
    public class Lpoint3DTemp:Lpoint3D
    {
        /// <summary> Temperature correction factor </summary>
        public int Temperature { get; set; } = 0;
        public override void Init()
        {
            R = R - SubConst - Temperature;
            var ang = (Angle + Ch * 0.00108 * 10) * Math.PI / 180;      // Horizontal angle linear error compensation
            var wTemp = W * Math.PI / 180;   //Angle radian conversion
            /*
             Definitions：
                The measured distance output by each channel of the radar is set as R. （Note that the unit of the radar input is 2mm, please convert to 1mm first)
                Rotating speed of radar is set as H (usually 10Hz)
                The vertical angle of each channel of the radar is set as ω
                The horizontal angle output by the radar is set as α
```

```
                The horizontal offset of each channel of the radar is set as A
                The vertical offset of each channel of the radar is set as B
                The spatial coordinate system of each channel of the radar is set as X, Y, Z
                Level Difference compensate table                offsetH
                vertical Difference compensate table                offsetV
                The calculation formula for space coordinates is:
                X = R * cos(ω) * sin(α) + A * cos(α)
                Y = R * cos(ω) * cos(α) - A * sin(α)
                Z = R * sin(ω) + B
            */
            X = (int)(R * Math.Cos(wTemp) * Math.Sin(ang) + offsetH * Math.Sin(ang));
            Y = (int)(R * Math.Cos(wTemp) * Math.Cos(ang) - offsetH * Math.Cos(ang));
            Z = (float)(R * Math.Sin(wTemp) + offsetV);
            Color = Color.FromArgb(100, (int)Reflection, 0);
        }
    }
```

Appendix F: analysis of interpolation code

```
//Differential complement
                for (int i = 0; i < 16; i++)
                {
                    var w = ChList[i];
                    ushort t2 = BitConverter.ToUInt16(block, 52 + i * 3);
                    byte f2 = block[54 + i * 3];
                    if (f2 > 0)
                    {
                        //3D point oper,Convert polar coordinates to spatial coordinates and make coefficient compensation
                        var pB = new Lpoint3DTemp()
                        {
                            R = t2,           //In this type of 3D radar, the return unit system is 2mm
                            Ang = ang + (uint)18,
                            W = w,
                            Reflection = f2,
                            Ch = 16 + i,
                            SubConst = SubConstList[i],
                        };
                        if (Vlist?.Length > 16) pB.Temperature = Vlist[i + 1];
                        pB.Init();
                        Plist.Add(pB);
                    }
                }
```

Appendix G:ROS

This appendix will explain how to use Ubuntu+ROS1 to obtain and visualize OLE-LiDAR data.

G.1 Install software

1.Download and install Ubunutu 16.04 operating system. ROS1.0 driver can run on trusty, xenial, bionic version of Ubuntu operating system
2.Install and test the basic functions of ROS1 Indigo according to the link (http://wiki.ros.org/indigo/Installation/Ubuntu).
3.Download and install libpcap-dev.

Note:

The operating environment of the driver is ROS1.0 version. If you need ROS2.0 version, please contact the technical staff of OLEI.

The appendix demonstrates the driver construction and operation under ROS1.0 version.

G.2 Construction

1. Create a workspace in the ubuntu system where the ROS environment is installed
> mkdir -p ole3d_ws/src
2. Unzip the driver folder 'src' ROS to ole2d_ws
>cp src ole2d_ws
3. Install "depend"
>rosdep install --from-paths src --ignore-src --rosdistro=${ROS_DISTRO} -y
4. Compile
>chmod -R 777 src
>catkin_make

Note: Before compiling, ask chmod to grant executable permissions under the src folder.

G.3 Operation

1. Configure source
>source devel/setup.bash
2. Open a new terminal and run roscore
>roscore
3. Check and connect lidar
The default factory IP of lidar: 192.168.1.100. It will send UDP package to 192.168.1.10:2368 Therefore, the local static IP : 192.168.1.10 needs to be configured, Subnet mask: 255.255.255.0
4. Run the launch script in the terminal where the source is currently configured
>roslaunch ole_pointcloud LR16F_points.launch

G.4 Real-time display

1. Open a new terminal and run rviz

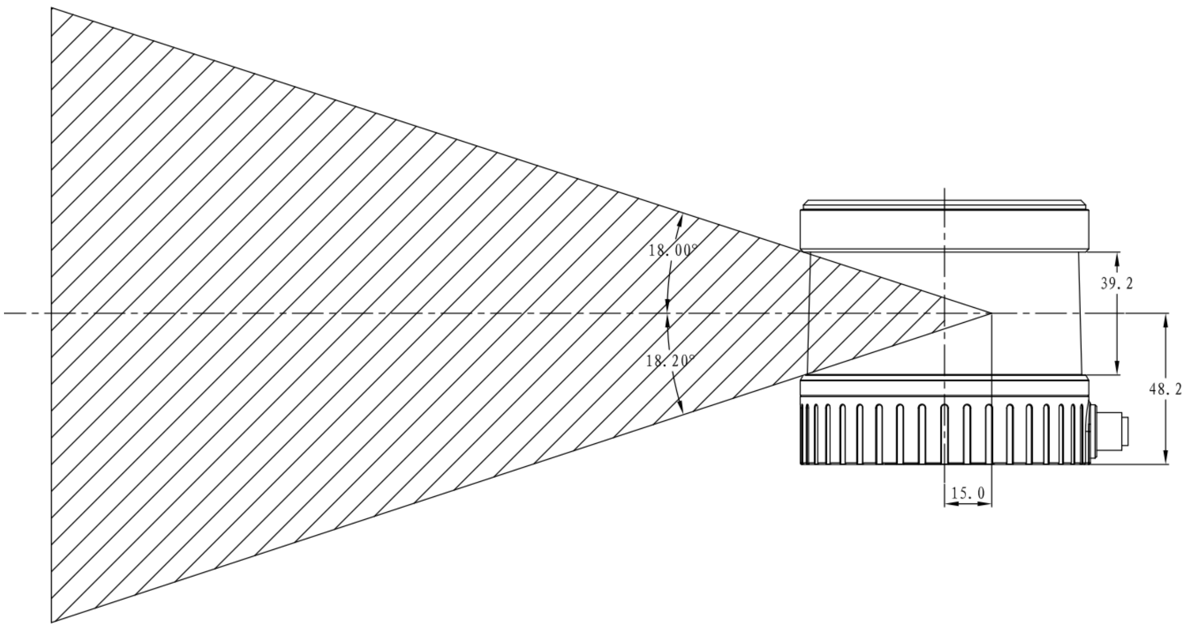
>rosrun rviz rviz -f olei_lidar

2. Add a topic PointCloud2 in rviz

3. If there is an error prompt “no fixed frame”, use the instruction:

>rosrun tf static_transform_publisher 0 0 0 0 0 0 1 map olei_lidar 10

Appendix H: Optical Avoidance Zone



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