SYMEO LOCAL POSITIONING RADAR

SYMEO
ABSOLUTE POSITIONING

Product: LPR®-1DHP-350

Product Documentation

Content

Copyright © Symeo GmbH 2023

Copyright © Symeo GmbH 2023

The documentation for the LPR®-1DHP-350 Local Positioning Radar System is published by:

SYMEO GmbH
Prof.-Messerschmitt-Str. 3
D-85579 Neubiberg
www.symeo.com

If you have any questions or suggestions, please contact:

Email: info@symeo.com
phone: +49 89 660 7796 0

Copyright © Symeo GmbH

HISTORY

Version	Date	Description
0001	28-06-2022	Release for FCC/RED
0001b	09-08-2023	Values in technical data fixed

VERSION 0001b APPROVED:

Dirk Becker
Digitally signed by Dirk Becker
Date: 2023.08.09 15:45:08 +02'00'

SYMBOLS USED

The following symbols are used throughout the documentation:

Warning	This symbol appears before instructions that must be followed at all times. Failure to comply with these instructions will result in personnel injury.
Caution	This symbol appears before instructions that must be followed at all times. Failure to comply with these instructions will result in damage to equipment.
Note	This symbol appears before information of particular importance.

All rights reserved, particularly those relating to the translation, reprinting, and reproduction by photocopying or similar processes of all or part of the documentation and for purposes of the award of patents or submission of utility models.

Delivery options and technical changes reserved.

Wherever the term LPR®-1DHP-350 is used during this documentation, all products included in the LPR®-1DHP-350 are addressed.

1 Safety Notes

General

The LPR®-1DHP-350 is a radar distance measurement sensor that may be used to measure distances between a radar unit and a reflector or between two radar units.

Warning

LPR®-1DHP-350 radars are purely tracking and assistance systems. They do not feature a functional safety level, e.g., Safety Integrity Level (SIL) or Performance Level (PL), as specified in functional safety standards (e.g., IEC 61508, EN ISO 13849, EN 62061).

Do not expose the radar to flames or heat above the specified temperature range.

Caution

Read the documentation before operation of the radar and follow the included safety notes.

Take note of the safety and operating instructions of the system in which you want to install the device.

Follow national safety norms and regulations.

Installation

Caution

Installation must be carried out by qualified and trained technicians.

When the system is mounted on tubes, measures to prevent slippage of the system must be taken.

Only screwed connections with safety against loosening may be used for mounting the radar.

Adhere to the specified tightening torques for all screws and connectors.

Screwed connections must be examined at regular intervals, especially if the radar is mounted exposed.

Repairs and Modifications

Caution

Repairs or modifications may only be performed by the manufacturer.

Opening of the device is prohibited.

Any change or modification not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

The warranty shall be voided if defects are caused to the device by installing or exchanging system extensions.

Transport and Storage

Note

Do not drop the device and do not expose it to strong vibrations.

Copyright © Symeo GmbH 2023

Power Supply

Caution

While installing or using it in open-air, transient overvoltage cannot be excluded. Overvoltage protection is to be used for low voltage in accordance to DIN EN 61643-21 and IEC 61643-21.

Be careful that the device can be damaged by reverse polarity despite implementation of polarity reversal protection.

Setup and Operation

Caution

Protect the contacts of all of the device's sockets and plugs from static electricity.

Proper operation (in accordance with IEC60950/EN60950) of the device is only assured if the housing and integral covers for mounting slots are fully installed (electric shock, cooling, fire protection, noise suppression).

In case of intense, direct solar radiation or other radiant heat, it may be necessary to provide a sun or heat shield.

Be aware, that misuse, modification or damage of the sensor can lead to erroneous distance measurements.

After mounting and commissioning, compare the actual distance to the distance measured by the radar sensor with respect to your needed accuracy. This step must be repeated after major changes to your measurement setup.

System Extensions and Accessories

Note

For LAN cabling, the requirements in accordance with EN 50173 and EN 50174-1/2 apply. Use of either a Category 5 shielded cable for 10/100 Ethernet or Category 5e shielded cable for gigabit Ethernet is a minimum requirement. The specifications of standard ISO/IEC 11801 must be complied with.

General Requirements for Compliance of Radio Apparatus

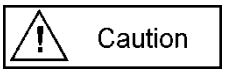
Note

The operation of this device requires compliance with regional radio regulations.
This device complies with Part 15 of the FCC Rules and with Industry Canada license-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Copyright © Symeo GmbH 2023

Exposure Requirements



To satisfy FCC exposure requirements a separation distance of 20 cm or more should be maintained between the antenna of this device and persons during operation.
To ensure compliance, operations at closer distances than this are not recommended.

To satisfy ISED exposure requirements a separation distance of 20 cm or more should be maintained between the antenna of this device and persons during operation.
To ensure compliance, operations at closer distances than this are not recommended.

Pour satisfaire aux exigences d'exposition ISED, une distance d-e sépa
ration de 20 cm ou plus doit être maintenue entre l'antenne de cet appareil et les personnes pendant le fonctionnement.
Pour assurer la conformité, les opérations à plus courte distance ne sont pas recommandées.

Copyright © Symeo GmbH 2023

2 The LPR®-1DHP-350

The LPR®-1DHP-350 radar system performs 1D distance measurements for short and medium ranges with high accuracy. By means of primary radar or secondary radar measurements, the LPR®-1DHP-350 can detect the position and speed - for example of cranes and rail-bound transport systems - in real-time and make the data available via the device interfaces.

Figure 2.1: LPR®-1DHP-350

Typical applications of the LPR®-1DHP-350 are:

- Positioning of cranes, crane trolleys, hoists and other railbound transport systems
- Process automation, monitoring and control
- Collision avoidance
- Radar barriers

3 Radar Basics

3.1 Radar Distance Measurement Principle

The LPR®-1DHP-350 radar distance sensors use electromagnetic waves to measure the distance and speed between two radars (secondary radar mode) or a single radar and a reflector (primary radar mode).

The underlying measuring principle is based on the Round-Trip Time-Of-Flight (RTOF) measurement between a transmitted radar signal and a received signal. The radar estimates the time τ the radar signal needs to travel the unknown distance d from one radar to the other (or to a reflector) and back. The distance is then calculated with the formula

$$d = 0.5\,\tau\,c$$

where c is the speed of light.

Copyright © Symeo GmbH 2023

3.2 Radar Beam and Field of View (FoV)

The LPR®-1DHP-350 emits a high frequency electromagnetic radio signal with its integrated antenna. The EM-wave is focused by a dielectric lens and creates a radar beam with an FoV (half power beam width, HPBW) of +/-2,5°.

Distance d in m	3	10	30	50	70	100
Radar beam 3dB diameter in m	0.3	0.9	2.6	4.4	6.1	8.7

Table 3.1: Radar beam 3 dB diameter vs. distance

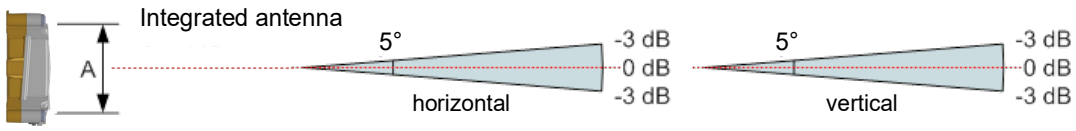


Figure 3.1: Radar beam and field of view

3.3 Fresnel Zone

The area for radio transmission between two antennas is called Fresnel zone. The main part of energy is concentrated in the first Fresnel zone.

Note	The Fresnel zone must be free of any obstacles to ensure that the signal is not attenuated or interrupted.

The maximum radius of the first Fresnel zone (in the middle between two antennas) can be calculated as follows:

$$r = 0.5 \cdot \sqrt{\lambda \cdot d}$$

λ is the wave length and d the distance between the two radar devices or a radar device and a reflective target. For a frequency of 122.5 GHz the wave length λ equals to 0.0025 m.

The maximum radius for different distances is given in Table 3.2.

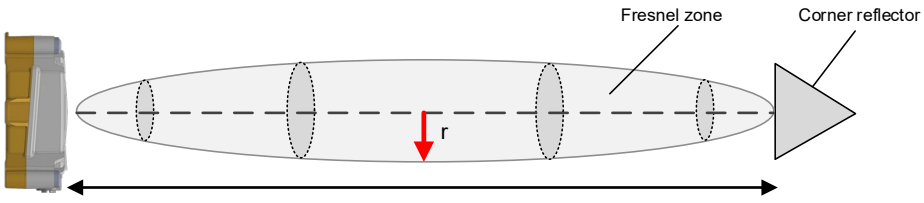


Figure 3.2: Fresnel zone

Copyright © Symeo GmbH 2023

Distance d in m	10	20	30	40	50	70	100
Fresnel zone Radius r in m	0.8	0.11	0.14	0.16	0.18	0.21	0.25

Table 3.2: Fresnel zone radius vs. distance

3.4 Radar Modes

3.4.1 Primary Radar Mode

In primary radar mode, a single radar measures the distance and speed to a reflective object/target, typically a metal corner reflector.

Figure 3.3 shows the typical setup of an LPR®-1DHP-350 radar and a corner reflector for a primary radar distance measurement.

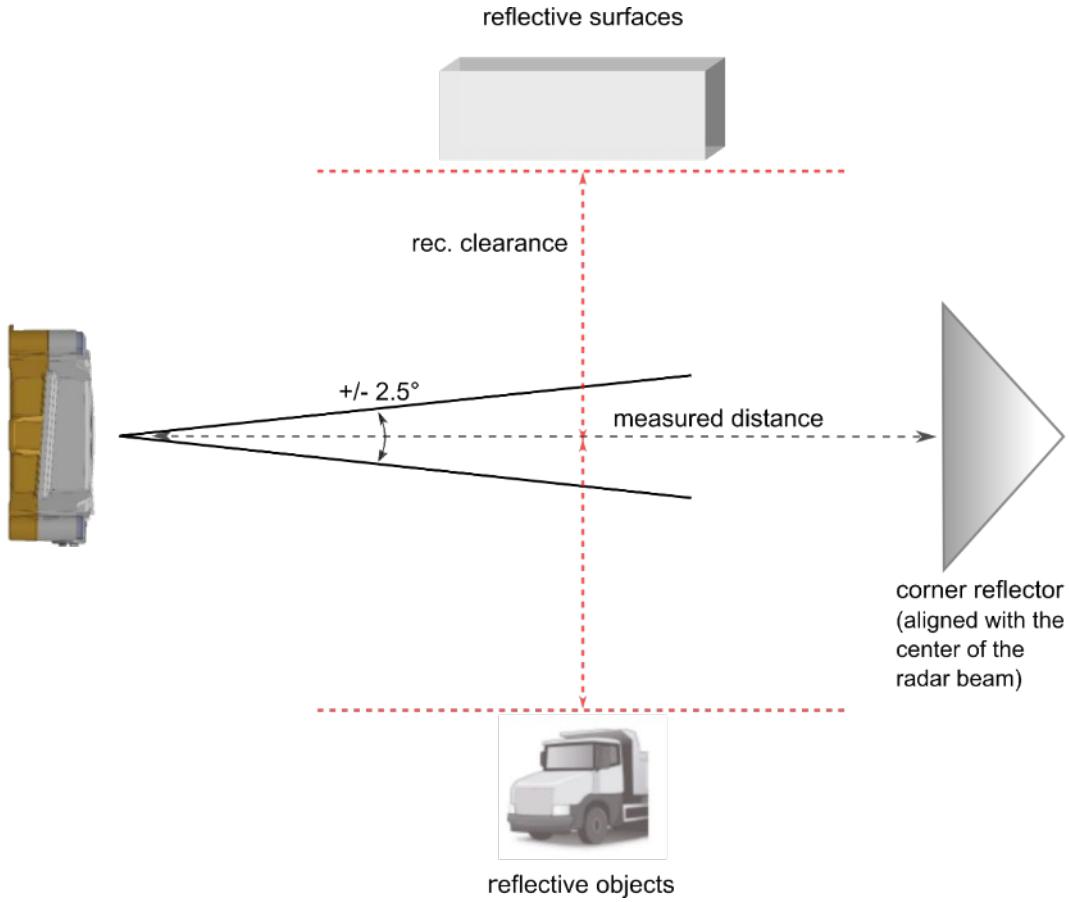


Figure 3.3: Primary radar mode measurement setup

Copyright © Symeo GmbH 2023

3.4.2 Secondary Radar Mode

In secondary radar mode, two radars measure the distance and speed between each other. Figure 3.4 shows the typical setup of two LPR®-1DHP-350 radars for a secondary radar range measurement.

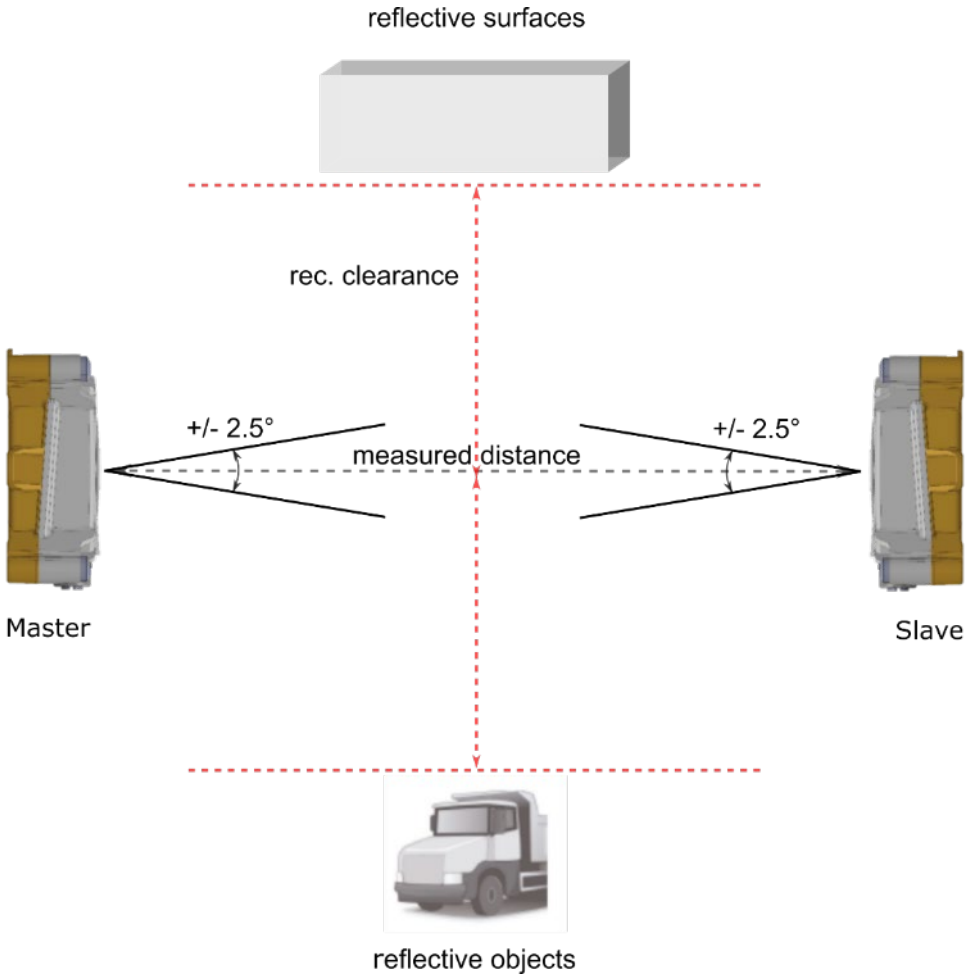


Figure 3.4: Secondary radar mode measurement setup

3.5 Bandwidth Modes

The LPR®-1DHP-350 is able to operate in the 121 - 123 GHz band. Depending on your used region and regulatory authority setting, a limited number of bandwidth modes are available for selection in the WebUI.

The selected bandwidth modes have impact on the accuracy, resolution and range of the radar. The dependency of performance and bandwidth mode with respect to regional restrictions is depicted in chapter 7.

Copyright © Symeo GmbH 2023

3.6 Accuracy

To maximize the accuracy of an LPR®-1DHP-350 measurement setup, different error sources which influence the accuracy need to be considered:

- Mounting position
  - Adhere to the mounting instructions (see chapter 5) to minimize systematic errors (e.g., horizontal or vertical offset and alignment)
- Reflective surfaces and objects
  - Unwanted reflections of the radar signal, e.g., from crane tracks or walls, can cause distance errors which vary with the measured distance. Ensure the recommended clearance to surfaces and objects described in chapter 5.1 or use diversity radar mode to minimize errors caused by reflections
- Measurement noise
  - Measurement noise caused by the radar itself is the lower limit to the overall accuracy. The noise will decrease with increasing bandwidth. For primary radar mode the influence of noise will increase with range and decrease with target radar cross section (dependent on target size, shape and material). In secondary radar mode noise is mostly constant within the specified range and will increase for longer ranges. A reduction of the transmit power can lead to a reduction of the measurement noise at the expense of maximum range
  - Temperature drift
  - Changes in device and air temperature can lead to measurement offsets.
  - Weather and environmental conditions
  - Under severe weather and environmental conditions such as very heavy rain or snow fall and layers of ice, snow, dust or other absorbing and reflecting material being attached to the lens the measurement may be prone to distance offsets.
  - The typical achievable 1σ distance errors are given in the technical specification in chapter 7.

3.7 Range

To maximize the range of an LPR®-1DHP-350 measurement setup the following aspects must be taken into account:

- Mounting position
  - Adhere to the mounting instructions (see chapter 5). Ensure minimum alignment error and vertical / horizontal offset and equal orientation (for secondary and diversity radar mode)
- Fresnel zone
  - Ensure the Fresnel zone is free of absorbing or reflecting objects
- Reflective surfaces and objects
  - Reflections of the radar signal, e.g., from walls, can lead to a reduction of the received signal strength and hence maximum range. Ensure the recommended

Copyright © Symeo GmbH 2023

clearance to surfaces and objects described in chapter 5.1 or use diversity radar mode to counter the effects caused by reflections

- Target RCS (only primary radar mode)
  - In primary radar mode the maximum range depends on the target RCS (radar cross section) which is a function of target size, material and shape.)
- Weather and environmental conditions
  - Under severe weather and environmental conditions as stated in chapter 3.6 the maximum operating range may be decreased.

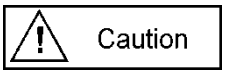
The measurement range given in the technical specification in chapter 7 and the datasheets is the typical range in which operation is possible under most conditions. The sensor may be operated at higher or lower ranges if circumstances permit.

4 Components

4.1 Device Overview

The LPR®-1DHP-350 consists of the following parts (see Figure 4.1 and Figure 4.2):

- Integrated 3D Fresnel antenna (A1)
- M12 gland (metal) (A2)
- Housing (A3)
  - provides LEDs (B1) and a pressure equalization membrane (B2)
  - provides the x-coded M12 jack (C1)
  - provides 3 x M4 screwing holes (B3) for mounting in the mounting bracket
  - ensures IP65 protection class and heat dissipation



The housing must not be opened.

Copyright © Symeo GmbH 2023

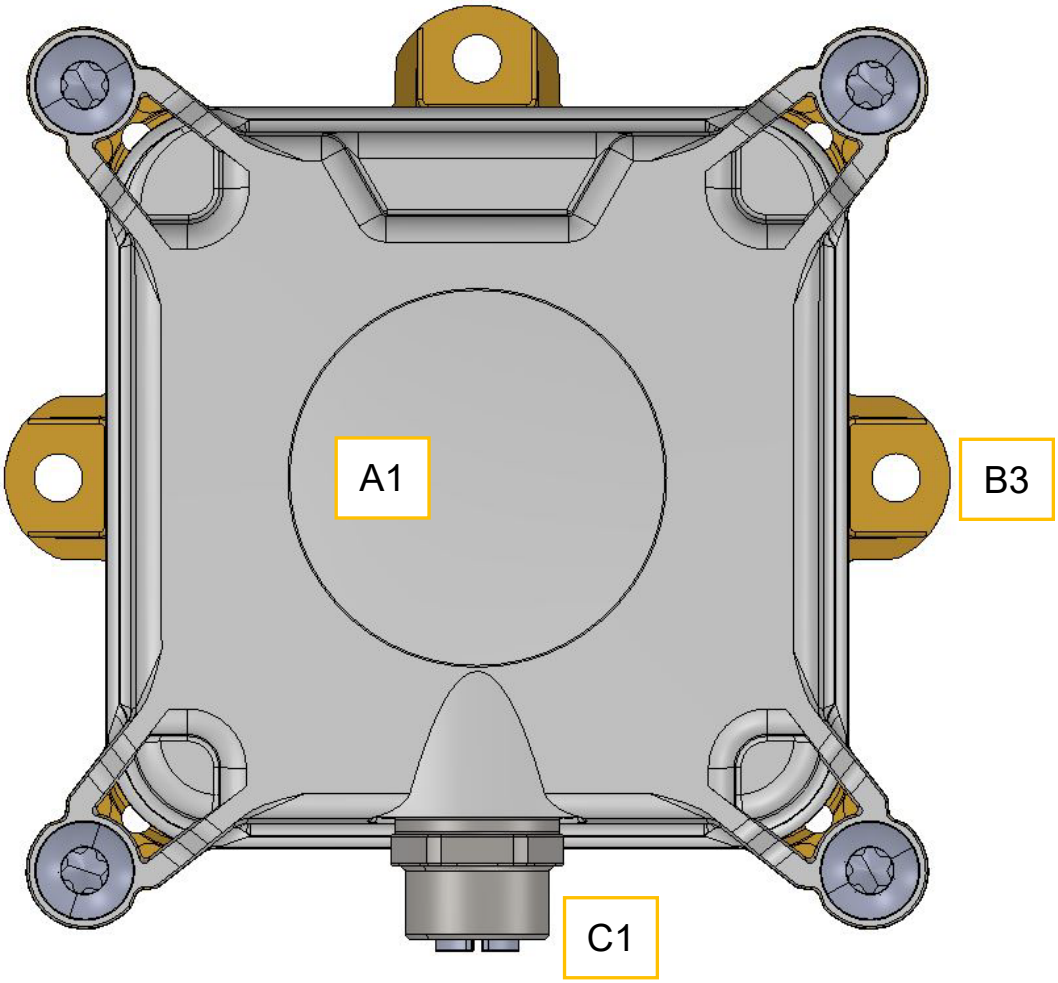


Figure 4.1: Front view of the LPR®-1DHP-350

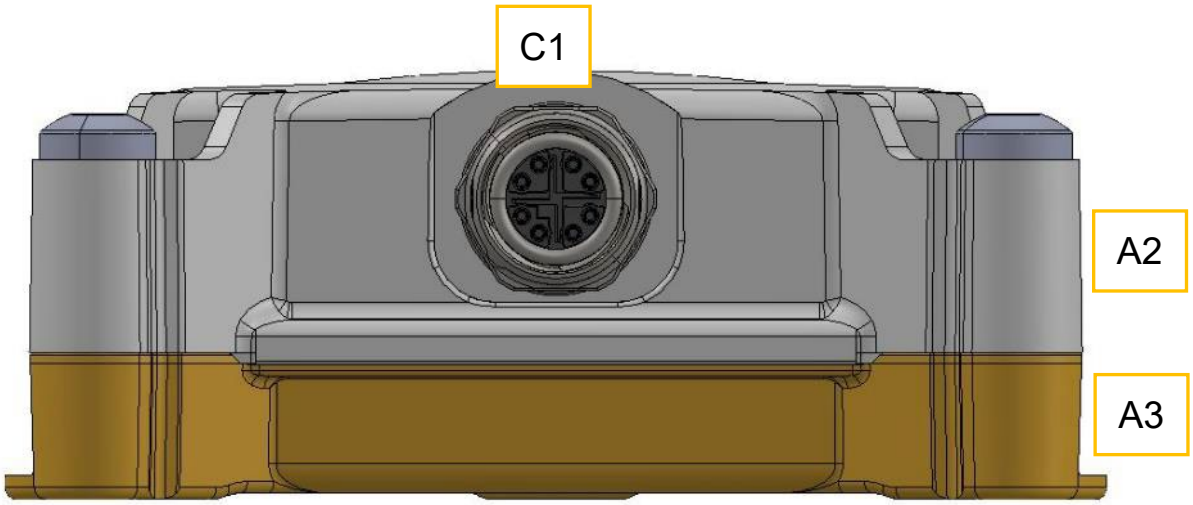


Figure 4.2: Side view of the LPR®-1DHP-350

Copyright © Symeo GmbH 2023

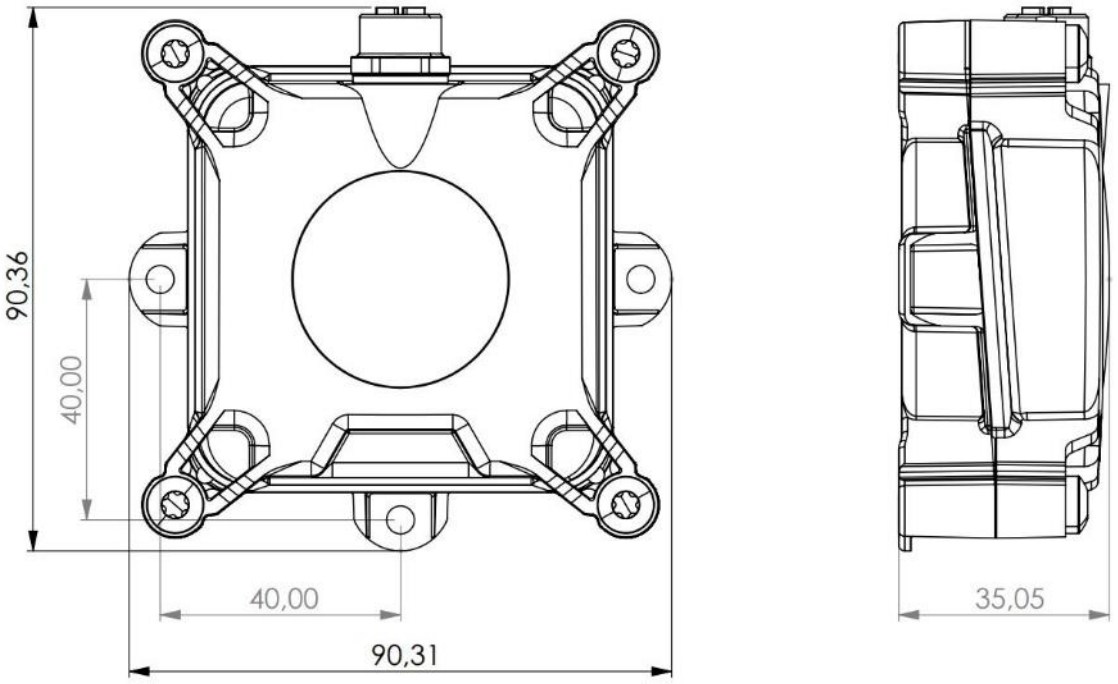


Figure 4.3: LPR®-1DHP-350 housing dimensions

4.2 LED Display

The LEDs () indicate the different states of the device (see Table 4.1).

LED Indication	Status of the Device
Status LED lights up BLUE	Device is booting up
Status LED lights up RED	Invalid measurement
Status LED lights up GREEN	Valid measurement
Status LED flashes BLUE	Firmware update in progress
Ethernet LED lights up WHITE	Ethernet interface established
Ethernet LED flashes WHITE	Ethernet interface transmits data

Table 4.1: LED Display

4.3 Connectors

The housing of the LPR®-1DHP-350 provides the following connector (see Figure 4.1 and Figure 4.2):

Copyright © Symeo GmbH 2023

- Ethernet jack 8-pin x-coded M12 (C1)

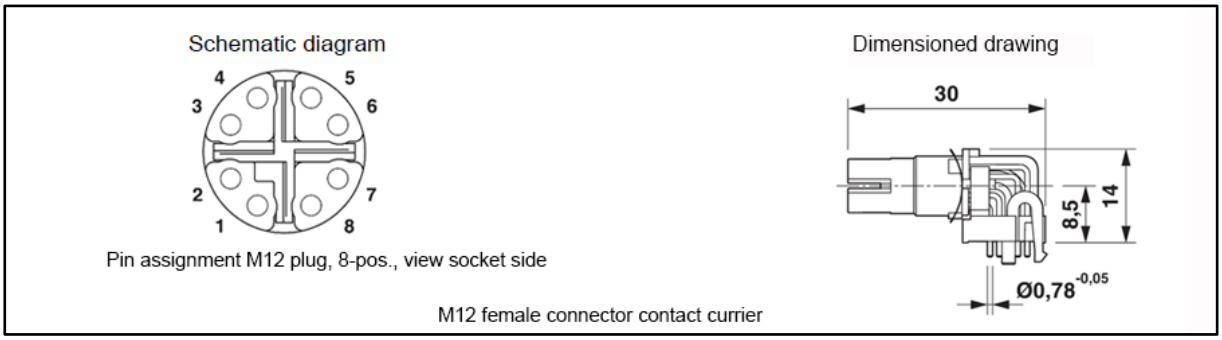


Figure 4.4: X-coded M12 jack

Pin Assignment

Function	Wire Colours T568A	Wire Colours T568B	Contact Assignment RJ-45	Contact Assignment M12-4 pair
TD/RD 1	White/Orange	White/Green	3	3
	Orange	Green	6	4
TD/RD 2	White/Green	White/Orange	1	1
	Green	Orange	2	2
TD/RD 3	White/Blue	White/Blue	5	7
	Blue	Blue	4	8
TD/RD 4	White/Brown	White/Brown	7	5
	Brown	Brown	8	6

Table 4.2: Pin assignment for Ethernet

i Note

Connector Cable M12 – RJ45

A connector cable M12 – RJ45 (5 m) with an Ethernet connector for connecting the radar to a PC for initial commissioning and configuration is available from Symeo:

- **Symeo order number**: MTE102866

4.4 Mounting Brackets

4.4.1 Mounting Bracket – MTM103102

For mounting the LPR®-1DHP-350 to a pipe, a mounting bracket is available from Symeo. The pipe diameter should measure between 40 and 75 mm.

Copyright © Symeo GmbH 2023

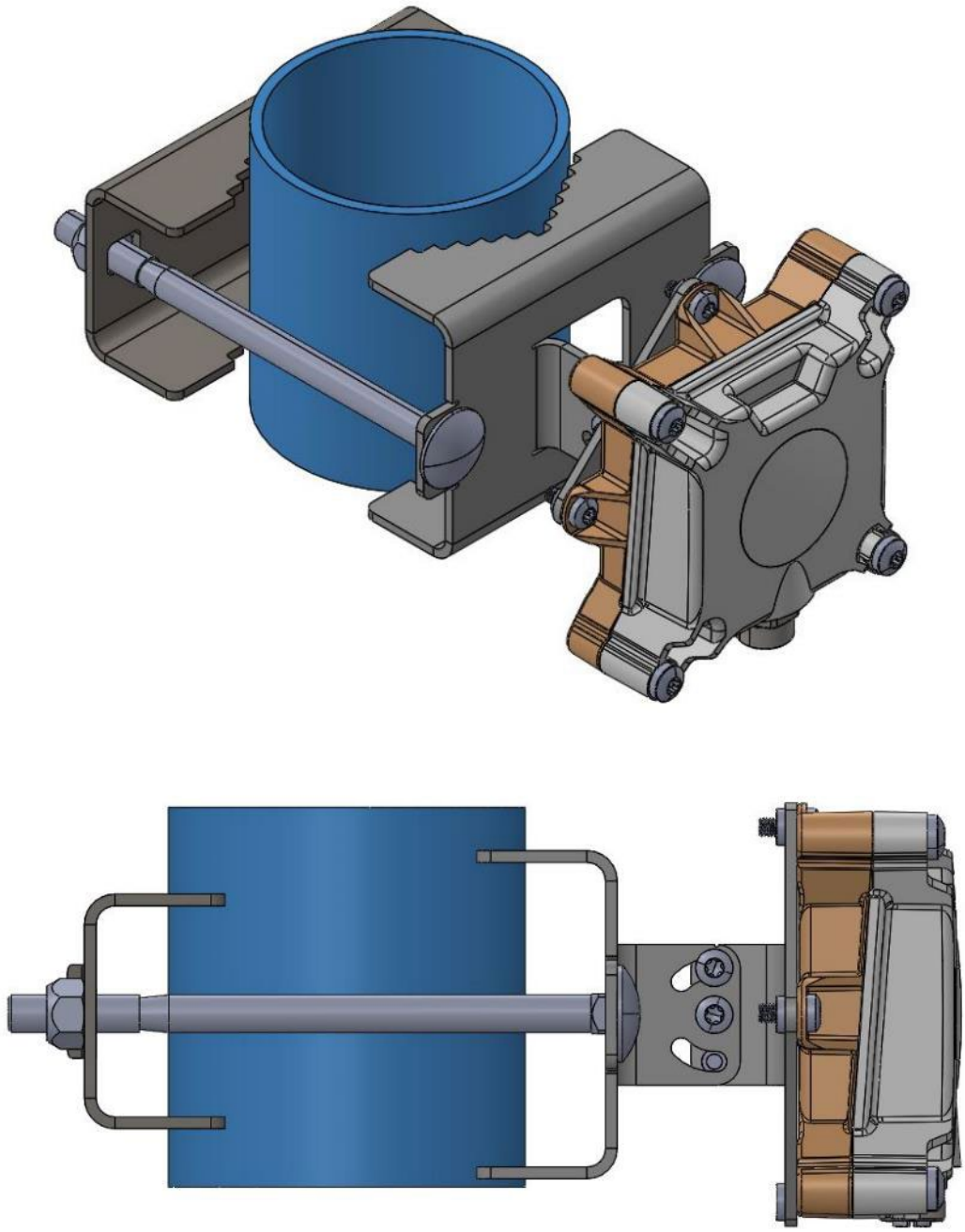


Figure 4.5: LPR®-1DHP-350 mounted to a pipe with the mounting bracket

Copyright © Symeo GmbH 2023

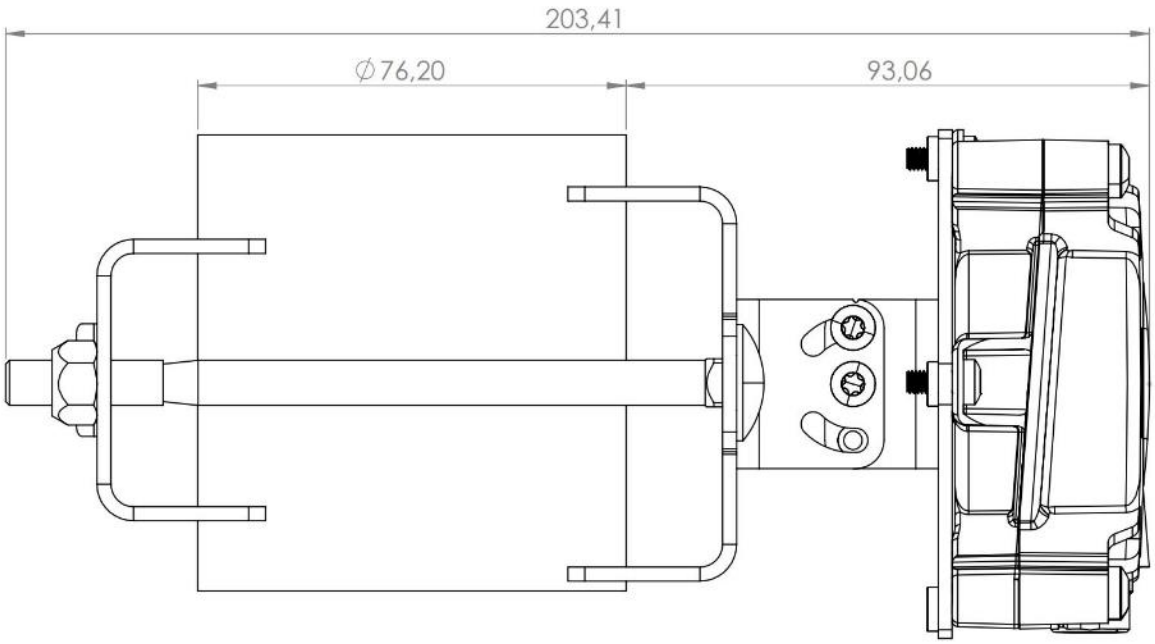


Figure 4.6: MTM103102 dimensions

Adhere to the following tightening torques for mounting:

- LPR®-1DHP-350 to mounting bracket (6x M4 screws x 8 mm): 3.5 Nm
- Tube clamp (2x M8 screws x 130 mm): 8 Nm

4.5 Corner Reflectors

For operation in the primary radar mode, different types of corner reflectors used as targets for the distance measurement are available from Symeo.

4.5.1 Corner Reflector 250 mm – MTE001011

Corner reflector with edge length 250 mm. Range is reduced to approx. 70% compared to MTE000958.

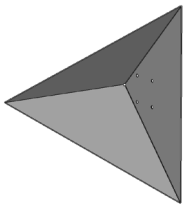


Figure 4.7: Corner reflector 250 mm

4.5.2 Adjustable mounting device tube/wall – MTM000169

For mounting the corner reflector, a pipe mounting bracket is available from Symeo. The pipe diameter should be between 40 and 75 mm.

Copyright © Symeo GmbH 2023

5 Mounting

5.1 General Mounting Instructions

- Site-specific mounting instructions must be followed if available.
- The more accurately the radar units and reflectors are aligned to each other, the better the performance of the measurement setup will be in terms of accuracy and range.
- Ensure that the Fresnel Zone is free of obstacles.
- Ensure that your measured distances lie in the specified measuring range (see chapter 7).

Ensure that reflective surfaces (e.g. walls, the roof, the floor, crane tracks) and other reflective objects (e.g. poles, tubes, bridges, vehicles) have the recommended clearance to the center of the radar beam that is in accordance with Table 5.1 (see also Figure 3.3 and Figure 3.4).

Measuring distance d in m	10	20	30	50	70	100
Recommended clearance in m	0.2	0.5	0.7	1.1	1.6	2.2

Table 5.1: Recommended clearance to reflective surfaces and objects

5.2 Mounting for Primary Radar Mode

For a primary radar distance measurement, typically a single radar unit and a recommended corner reflector are mounted facing each other (see Figure 5.1 and Figure 3.3).

Figure 5.1: Mounting alignment of radar and reflector

For operation in the primary radar mode the following issues must be considered:

- The radar and the corner reflector must be installed in a way that the center of the corner reflector is aligned with the center of the radar beam (see Figure 5.1).
- The radar units and/or corner reflectors must move parallel to the radar beam in the installation.
- The reflector has to be either the nearest (first) target or the strongest target to be detected properly.

Copyright © Symeo GmbH 2023

- Radar and radar reflector must be aligned to each other with maximum accuracy (at least +/- 2.5°).
- Minimum horizontal and vertical offset between radar and reflector must be ensured.

Follow the subsequent steps for proper installation of radar unit and reflector:

⇨ Mount a standard mounting bracket on one side of your measurement setup.

⇨ Mount the radar into the mounting bracket.

⇨ Mount a corner reflector to the other side of your measurement setup in a way, that the opening faces the radar. The 3 corners of the corner reflector opening should have about equal distance to the radar.

⇨ Carefully align the radar to the corner cube reflector. To do so, it is recommended to use a laser level fitted into the alignment aid, which should point at the middle of the reflector.

⇨ Fix the system by tightening the screws of the mounting bracket and the pipe clamp with the correct tightening torques.

⇨ Connect the Ethernet cable with M12 jack as specified in chapter 4.3.

5.3 Mounting for Secondary Radar Mode

For a secondary radar distance measurement, two radar units, one configured as a “master” and one as a “slave” are mounted facing each other. The master unit initiates the measurement while the slave unit replies.

For operation in the secondary radar mode the following issues must be considered:

- The two radar units must be installed in a way, that the center of the emitted radar beam of each unit hits the other unit.
- The radar units must move parallel to the radar beam in the installation.
- The two radar units must be oriented exactly equally or turned by 180° along the radar beam axis (e.g., connectors of both devices facing downwards).
- Minimum horizontal and vertical offset between both radar units must be ensured.
- Both radar units must be aligned to each other with maximum accuracy (at least +/- 2.5°).

Follow the subsequent steps for proper installation of the radar units:

⇨ Mount a standard mounting bracket to one side of the measurement setup.

⇨ Mount the radar unit into the mounting bracket.

⇨ Repeat the first two steps on the other side of the measurement setup.

⇨ Carefully align both radar units to each other. To do so, it is recommended to use a laser level fitted into the alignment aids. The laser dot should point to the other sensor for both directions (Master -> Slave, Slave -> Master).

⇨ Fix the systems by tightening the screws of the mounting brackets and the pipe clamps with the correct tightening torques.

Copyright © Symeo GmbH 2023

Connect the Ethernet cable with the x-coded **M12** jack as specified in chapter 4.3 to both stations.

6 Quick Setup

This chapter gives a short introduction for the setup of the radar sensors with the help of the WebUI. For detailed information on all possible settings, please refer to chapter **Error! Reference source not found.**.

6.1 Initial Setup

The following steps must be followed for the initial setup of all radar units:

⇨ Mount and align the radar units as outlined in chapter 5.

⇨ Connect the radar units to a power source and wait until booting is finished (blue LED switches to red or green).

⇨ Connect the radar units to a PC via Ethernet and open the Webinterface (WebUI) in a Webbrowser (http://192.168.1.99). See chapter **Error! Reference source not found.** for a detailed description.

⇨ Sign in to the WebUI (see chapter **Error! Reference source not found.**). Enter the user name "**symeo**" and the password "**xxxxx**" and press "*Login*". Now your status is displayed as "*Logged in*".

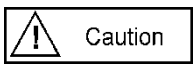
⇨ Choose country and regulatory authority.

⇨ Change the IP addresses of all radars in your measurement setup to unique values in the same TCP/IP subnet (see chapter **Error! Reference source not found.**).

6.2 Quick Setup for Primary Radar Mode

The following settings must be set in the WebUI for operation in primary radar mode:

- *Device -> Settings -> Measurement*
  - Station mode = Primary
  - Bandwidth mode = Choose a bandwidth that fits your required range and accuracy
  - Channel block = Use recommended selection
  - Sync channel = different than any other LPR®-1DHP-350 sensor in range; for neighboring measurement paths use only every fourth sync channel.
- *Device -> Settings -> Measurement details*
  - Target search mode = “First” if the reflector is the first target in range, “Strongest” if the reflector is the strongest target in range.



The setting “*Target search mode*” highly impacts the behavior of the radar, especially in multi target environments (see **Error! Reference source not found.**). “First target” may lead to distance measurements to unintended targets in the vicinity of the radar (e.g., a person passing the radar beam). “Strongest target” may lead to distance measurements to unintended targets present in the background of your intended target (e.g., a wall

Copyright © Symeo GmbH 2023

behind a corner reflector). Perform therefore always a test to verify this setting.

6.3 Quick Setup for Secondary Radar Mode

The following settings must be set in the WebUI of the master and slave sensor for operation in secondary radar mode.

Note	Only the Master unit outputs range data.

Master

- *Device -> Settings -> Measurement*
  - Station mode = Master
  - Bandwidth mode = Choose a bandwidth that fits your required range and accuracy
  - Channel block = Use recommended selection
  - Sync channel = different than any other LPR®-1DHP-350 sensor in range (except the related Slave); for neighboring measurement paths use only every fourth sync channel.

Slave

- *Device -> Settings -> Measurement*
  - Station mode = Slave
  - Bandwidth mode = same as Master
  - Channel block = same as Master
  - Sync channel = same as Master

Copyright © Symeo GmbH 2023

Copyright © Symeo GmbH 2023

7 Technical Data

7.1 General Technical Data

Feature	Value
Radar measuring modes	Primary Radar, secondary Radar
Frequency range	122.25 - 123 GHz (ETSI) 121-123 GHz (FCC)
Antenna	Integrated 3D Fresnel antenna
Field of view	Azimuth: ±2.5° (3 dB) Elevation: ±2.5° (3 dB)
Transmit power (EIRP)	20 dBm peak (ETSI) 15.5 dBm mean (FCC)
Bandwidth	FCC: up to 2 GHz; ETSI: up to 750 MHz [1]
Supply voltage	Power over Ethernet IEEE802.3af Class 0
Power consumption	< 5 W
Ambient temperature	-40 °C to +60 °C
Output data	Profinet (tba) Symeo Binary Data Protocol Other industrial busses on request
Data interface	100 Mbit/s Fast-Ethernet IEEE802.3 100BASE-TX
Response time	< 100 ms
Wireless	Synchronized FMCW sweeps
Dimensions / weight	90 x 90 x 35 mm
External connectors	1x M12 x-coded
International Protection (IP)	IP67
Compliance	ETSI FCC KCC

Table 7.1: General technical data

1) Depending on settings

Copyright © Symeo GmbH 2023

7.2 Mode Dependent Technical Data

The following tables depict the technical data, which are dependent on the used radar mode, the used bandwidth mode and your regional settings.

7.2.1 Primary Radar Mode

Feature	Value
Measuring rate[1]	Up to 350 Hz
Range[2]	Up to 40 m
Measurement accuracy[3]	Up to ±9 mm
Repeatability[3]	Up to ±5 mm

Table 7.2: Technical data primary radar mode

1) *Depending on measurement mode and target*
2) *Depending on the environment and on RCS of target reflector*
3) *Error under consistent ambient conditions. Depending on the measurement distance*

7.2.2 Secondary Radar Mode

Feature	Value
Measuring rate	Up to 110 Hz
Range	Up to 100 m
Measurement accuracy	Up to ±9 mm
Repeatability	Up to ±5 mm

Table 7.3: Technical data secondary radar mode

1) *Depending on measurement mode and target*
2) *Depending on the environment and on RCS of target reflector*
3) *Error under consistent ambient conditions. Depending on the measurement distance*

Copyright © Symeo GmbH 2023

Copyright © Symeo GmbH 2023