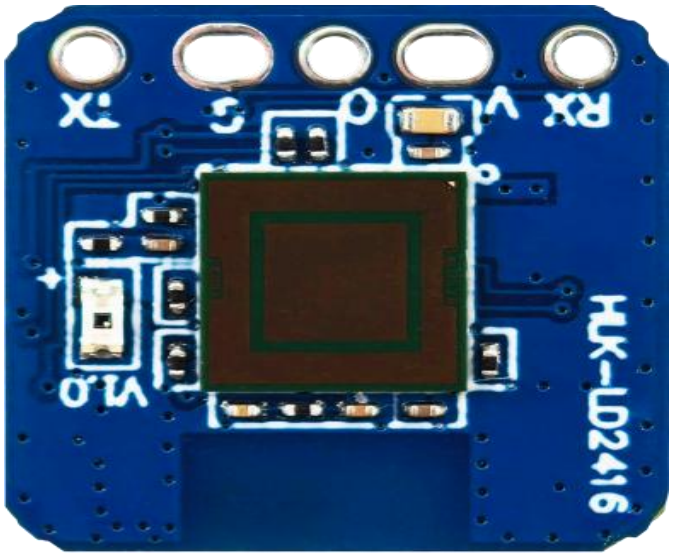
Shenzhen Hi-Link Electronic Co.,Ltd

HLK-LD2416

Datasheet



Introduction

This document primarily describes the basic functions, hardware specifications, software configuration, and installation requirements of the Hi-Link ultra-compact AIP Human Presence Sensor. Its aim is to assist developers in quickly getting started with this static human presence detection sensor, conveniently configuring parameters best suited to their specific application scenarios, and creating customized, high-precision sensing solutions.

Content

1. Product Description

The HLK-LD2416 is an ultra-compact, Antenna-in-Package (AiP) human presence and vital signs sensor belonging to Hi-Link's 24 GHz radar series. It integrates the highly miniaturized 2416 sensor hardware with intelligent firmware featuring human presence sensing algorithms, enabling the detection of individuals who are sitting or lying motionless.

The HLK-LD2416 hardware platform incorporates the ICL111A AiP millimeter-wave sensor, a high-performance 24GHz single-transmit/single-receive antenna, and requisite peripheral circuitry. With the antenna embedded directly within the AiP chip, the module eliminates the need for specialized high-frequency PCB substrates, thereby accelerating the manufacturing and processing workflow. The human presence sensing algorithm leverages millimeter-wave distance measurement technology—combined with advanced radar signal processing techniques proprietary to the S1 series chips—to achieve precise detection of gross motion, micro-movements, and stationary human presence (sitting or lying down). This intelligent firmware is primarily designed for indoor applications, where it monitors a designated zone to detect the presence of moving, slightly moving, or stationary individuals, providing real-time updates on detection status.

HLK-LD2416 offers a maximum sensing range of 7.5m for moving subjects. Its parameters can be easily configured to define the specific sensing range, set distinct trigger and hold thresholds for different distance zones, and specify the reporting delay for "no-one present" events. Supporting both GPIO and UART interfaces, the HLK-LD2416 offers plug-and-play functionality, allowing for flexible integration into a wide variety of smart scenarios and end-user products. Furthermore, the module supports the automatic generation of detection thresholds; this feature minimizes the need for manual calibration, enhances detection accuracy, simplifies the installation process, and facilitates large-scale deployment.

The key features of the HLK-LD2416 are as follows:

- Intelligent Design: Equipped with a single-chip intelligent AiP (Antenna-in-Package) millimeter -wave sensor SoC, featuring a built-in antenna and intelligent algorithms.
- Ultra-Compact Size: Sensor dimensions of 14 mm × 14 mm.
- Plug-and-Play: Pre-loaded with default human presence sensing configurations, enabling immediate plug-and-play functionality.
- Frequency Band Compliance: Operates within the 24 GHz ISM band and complies with FCC, CE, and domestic radio regulatory certifications.
- Voltage Support: Supports a 5 V power supply.
- Low Power Consumption: Features an average operating current of 80 mA.
- Multi-functional Detection: Effectively detects moving, micro-moving, and stationary human presence, reporting detection results in real-time.
- Ease of Integration: The SoC features an integrated built-in antenna, simplifying the design process and shortening manufacturing cycles.

- Visual Configuration: Provides visual tools for flexible configuration of detection distance ranges and target disappearance delay times, supporting the automatic generation of detection thresholds.
- Sensing Range Management: Supports the segmentation of sensing zones, effectively filtering out interference originating outside the designated range.
- Blind-Spot-Free Detection: Capable of sensing targets at close range, starting from just 0.2m.
- Wide-Angle Coverage: Offers a detection angle of ±60°, ensuring extensive coverage of the monitoring area.
- Versatile Mounting: Supports various installation methods, including ceiling-mount and wall-mount options.
- Independent Configuration: Trigger and hold states can be configured independently, ensuring robust resistance to interference.
- Enhanced Environmental Resilience: Resistant to moisture, corrosion, and static electricity, offering superior adaptability to diverse environmental conditions.

Capable of detecting and identifying human presence—whether in motion, standing, or stationary—this technology is widely applied across various AIoT scenarios, encompassing the following categories:

- Smart Home

Senses human presence and distance, reporting detection results to enable the main control module to intelligently manage the operation of home appliances.

- Smart Commercial

Identifies whether a person is approaching or moving away within a configured distance range; promptly activates the screen and keeps the device powered on while human presence is detected.

- Smart Security

Applications such as proximity-sensing access control systems, building intercoms, smart door viewers, and more.

- Smart Lighting

Identifies and senses human presence while performing precise location detection; suitable for use in lighting fixtures within public spaces (e.g., motion-sensing lights, smart light bulbs, etc.).

2. System Description

HLK-LD2416 is a static human presence sensor developed by Hi-link. Utilizing Frequency Modulated Continuous Wave (FMCW) technology, and incorporating radar signal processing alongside a built-in intelligent human sensing algorithm, the sensor detects human targets within a designated space and updates the detection results in real-time. By employing this module, users can rapidly develop their own high-precision human presence sensing products.

In terms of hardware, HLK-LD2416 primarily consists of Hi-link's fully integrated ICL111A (AiP 1T1R) millimeter-wave sensor, a 24 GHz transmit-and-receive antenna, and a main control MCU. On the software side, it is paired with Hi-link's proprietary intelligent human presence sensing firmware and a visual configuration tool, enabling flexible configuration of sensing distance, trigger and hold thresholds, and the "no-presence" reporting delay.

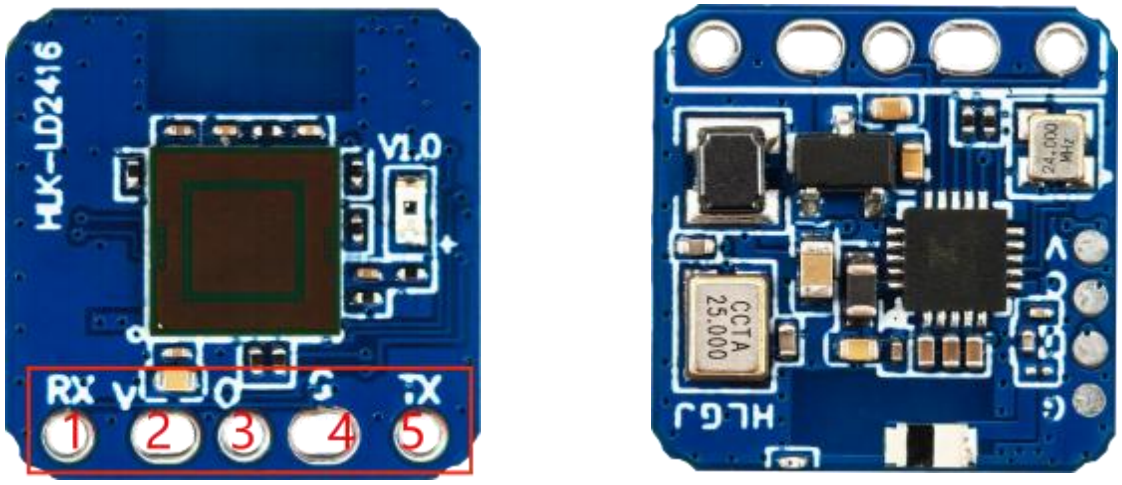
The specifications and parameters are as shown.

Table 2 — Specifications

Parameters	Min.	Typ.	Max.	Unit.	Note
HLK-LD2416 Hardware Specifications					
Supported Bands	24	-	24.25	GHz	Compliant with SRRC, FCC, CE, and Radio Management Committee certification standards.
Supports maximum sweep bandwidth	-	0.25	-	GHz	
Maximum equivalent isotropically radiated power	-	9	-	dBm	-
Supply voltage	4.7	5	5.3	V	-
Polarization mode	Dual polarization				-
Dimension	-	14 * 14	-	mm^2	-
Ambient temperature	-40	-	85	℃	-
System performance					
Detection range (Wall-mounted)	-	7.5	-	m	Moving human target
		6		m	Micro-motion human target
	-	4	-	m	Static human target
Detection range (Ceiling-mounted)	-	4.5	-	m	Micro-motion/Moving human target
	-	3.5	-	m	Static human target
Detection accuracy	-	±0.15	-	m	Moving corner reflector targets located within a straight-line distance of 6m from the sensor.
Average operating current	-	80	-	mA	-
Data refresh cycle	-	154	-	ms	-

3. Hardware Description

Shown here are photos of the front and back of the HLK-LD2416 hardware module. The module features five reserved pins for power supply and communication, spaced at 2.54 mm intervals.



(a) Front side **(b) Back side**

Figure 3 — Physical Views of the HLK-LD2416 Hardware (Front and Back)

Table 3-1 HLK-LD2416 Pin Description

PIN	Name	Function	Description
Pin1	RX	UART_RX	0 ~ 3.3 V
Pin2	VCC	Power input	5 V
Pin3	OUT	Used to report detection status: High level indicates presence; low level indicates absence.	0 ~ 3.3 V
Pin4	GND	GND	0V
Pin5	TX	UART_TX	0 ~ 3.3 V

4. Software Description

This chapter outlines the firmware debugging methods and the steps for using the host PC tool for the HLK-LD2416 narrow-bezel human presence millimeter-wave sensor.

The sensor comes pre-loaded with system firmware from the factory; please refer to the sensor's outer packaging for the specific firmware version. Hi-link provides an intuitive host PC configuration tool software to accompany the HLK-LD2416 hardware, enabling developers to flexibly adjust the sensor's parameter settings based on specific application scenarios, thereby optimizing its sensing performance.

4.1 Firmware Debugging

This section describes how to use third-party serial port tools to debug the firmware of the HLK-LD2416 millimeter-wave sensor.

Step 1: Connect the host PC to the millimeter-wave sensor using a USB to TTL serial adapter board. The pin connections are shown in Table 4-1.

Table 4 — Pin Mapping: Sensor Connected to USB-to-Serial Adapter Board

Sensor	Serial adapter board
RX	TXD
TX	RXD
GND	GND
5V	VCCIO

Step 2: Open the Device Manager on the host computer to identify the COM port number assigned to the millimeter-wave sensor.

Step 3: Launch a third-party serial port utility, select the COM port corresponding to the millimeter-wave sensor, set the baud rate to 921600, and then click the "Open Port" (or equivalent function) button to view the current detection results from the millimeter-wave sensor in the tool's output window.

4.2 Host PC Tool Description

This section describes how to use the companion PC-side tool for the HLK-LD2416 millimeter-wave sensor, aiming to help users understand the meaning of relevant parameters and the methods for retrieving them.

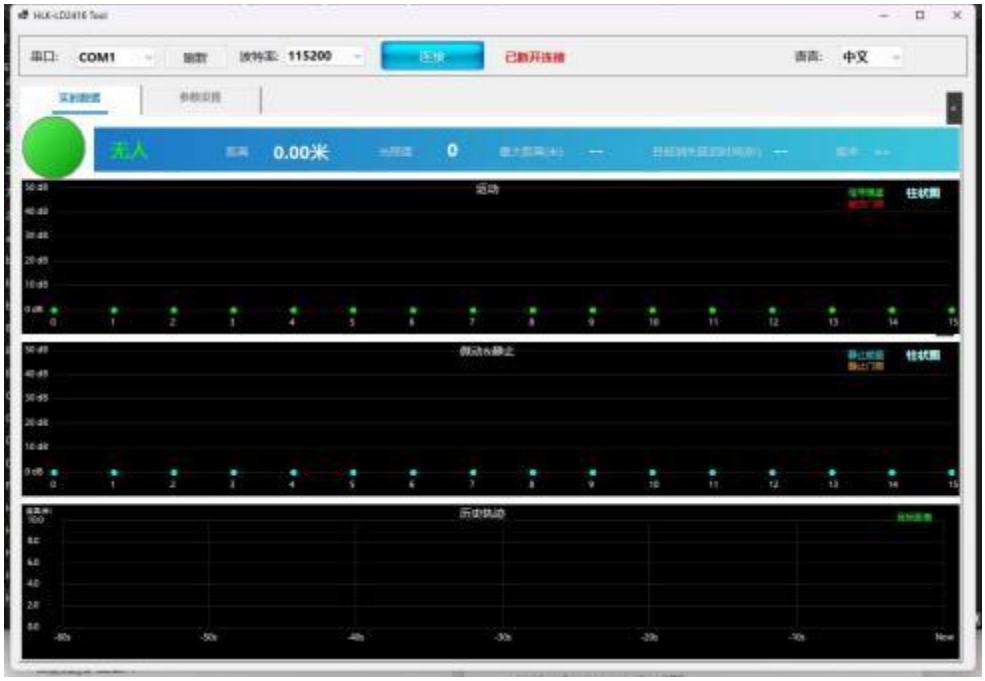
Note: The companion PC-side tool and third-party serial port tools cannot be used simultaneously!

Before utilizing the various functions of the PC-side tool, users must first establish a connection between the HLK-LD2416 and the host computer. The steps are as follows:

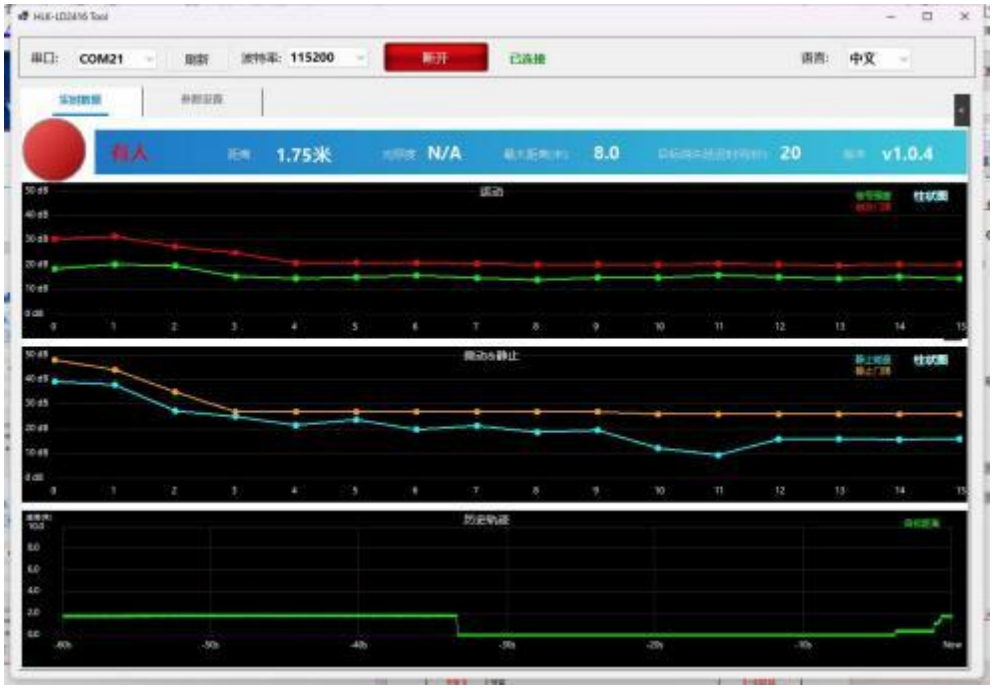
Step 1: Obtain the companion PC-side tool, "HLK-LD2416 Tool."

Step 2: Use a serial port adapter board to connect the millimeter-wave sensor to the host computer.

Step 3: Launch the PC-side tool, click the "Refresh" button, and select the serial port corresponding to the millimeter-wave sensor from the "Serial Port" drop-down menu. After confirming that the "Baud Rate" is set to 115200, click the "Connect" button to establish the connection between the host computer and the millimeter-wave sensor.



(a) Before connecting the device



(b) After the device is connected

Figure 4 — ICL_HLK-LD2416_Tool

Once the host PC tool successfully connects to the millimeter-wave sensor, the sensor's firmware version number (formatted as "Ver: ...") will be displayed in the "Zone1" area of the interface, while the current parameter values of the sensor will be shown in the "Parameter Settings" section.

4.2.1 View/Set Parameters

The "Parameter Viewing/Setting" page of the host PC tool is shown in Figure 4-2; it allows users to view the current parameters of the millimeter-wave sensor and modify specific parameter configurations to meet the requirements of specific application scenarios.

The steps for reading millimeter-wave sensor parameters using the host PC tool are as follows:

After connecting the HLK-LD2416 to the host PC tool, click the "Read Sensor Settings" button on the Function page. A "Parameters Read Successfully" notification window will pop up, displaying all current parameter values of the millimeter-wave sensor; click "OK" to close the window.

Figure 4 — Millimeter-Wave Sensor Parameter Reading Interface

The steps for modifying one or more millimeter-wave sensor parameters using the host PC tool are as follows:

Step 1: After connecting to the host PC tool, enter the new values for all parameters requiring modification within the "Functions" page.

Step 2: On the "Functions" page, click the "Write Sensor Settings" button. The host PC will then write the parameter values currently displayed on the interface to the millimeter-wave sensor. A "Parameters Written Successfully" notification window will pop up; click "OK" to complete the parameter configuration.

For detailed explanations of the parameters on the "Parameter Settings" page of the host PC tool, please refer to the following.

Table 4 — Explanation of Parameters in the Host PC Tool Interface

Parameters	Description	Parameter range
Max distance	Used to set the maximum effective detection range of the millimeter-wave sensor;	0–10.5, accurate to 0.1m

Target disappearance delay (s)	Switching the target state from "occupied" to "unoccupied" requires a time delay of duration T; if a person is detected during this interval, the timer restarts. The millimeter-wave sensor will only switch to the "unoccupied" state—and report it as such—after the "unoccupied" condition has persisted continuously for the full duration of T.	0~65535
Baud rate	Module serial output baud rate	-
Installation method	Installation method for the actual application of the module	-
Motion detection coefficient	Determine the presence or absence of a person based on the degree of fluctuation in the motion threshold value.	10~500
Micro-motion & stationary threshold (dB)	The energy thresholds used to detect human micro-motion and stationary states can be calculated using the "Generate Threshold" function.	0–96.32, accurate to 0.1m

The host PC tool supports saving and loading parameter configurations for the millimeter-wave sensor:

- Click the "Save Configuration" button and select the desired save path; the host software tool will save the millimeter-wave sensor's current parameter configuration as a .json file on the host computer. The default save location is the folder containing the host software tool.

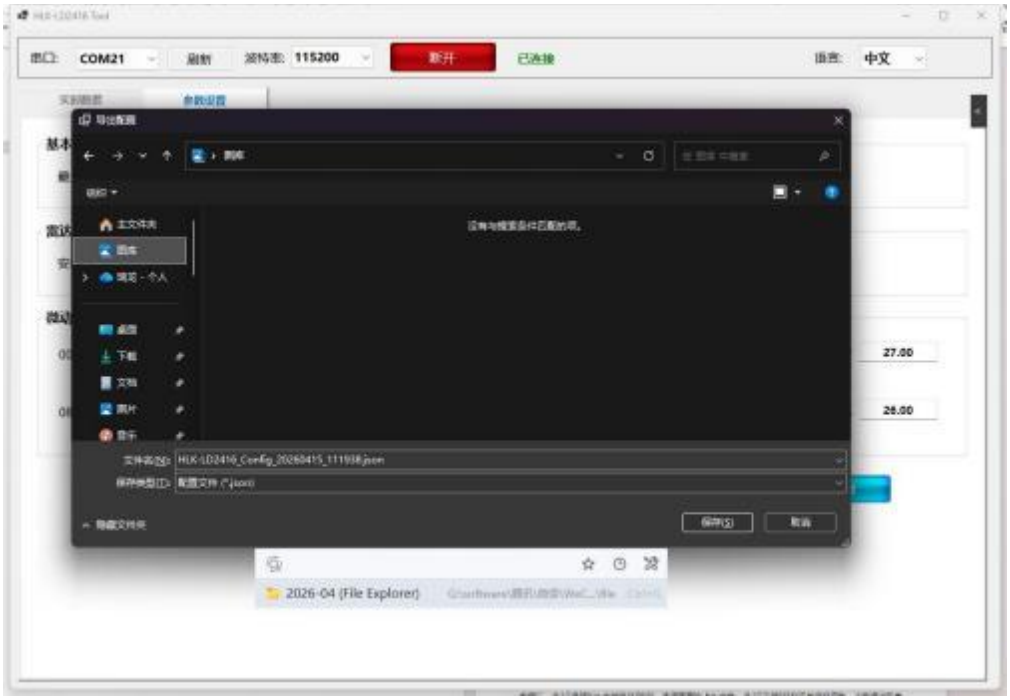


Figure 4-3 Save Configuration File Interface

- Click the "Load Configuration File" button; the host software tool will open the millimeter-wave sensor parameter configuration file from the user-specified path and load the parameters. Clicking the "Write Sensor Settings" button allows the parameters from the configuration file to be written to the millimeter-wave sensor.

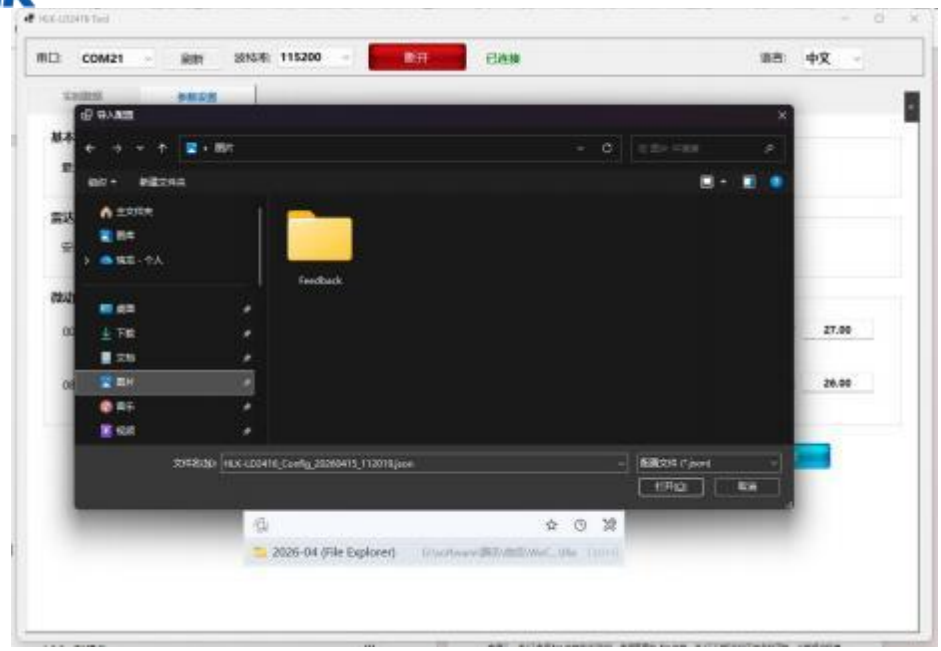


Figure 4-4 Configuration file loading interface

4.2.2 Real-time Data

The "Real-time Data" page of the host computer is shown in Figure 4-5.

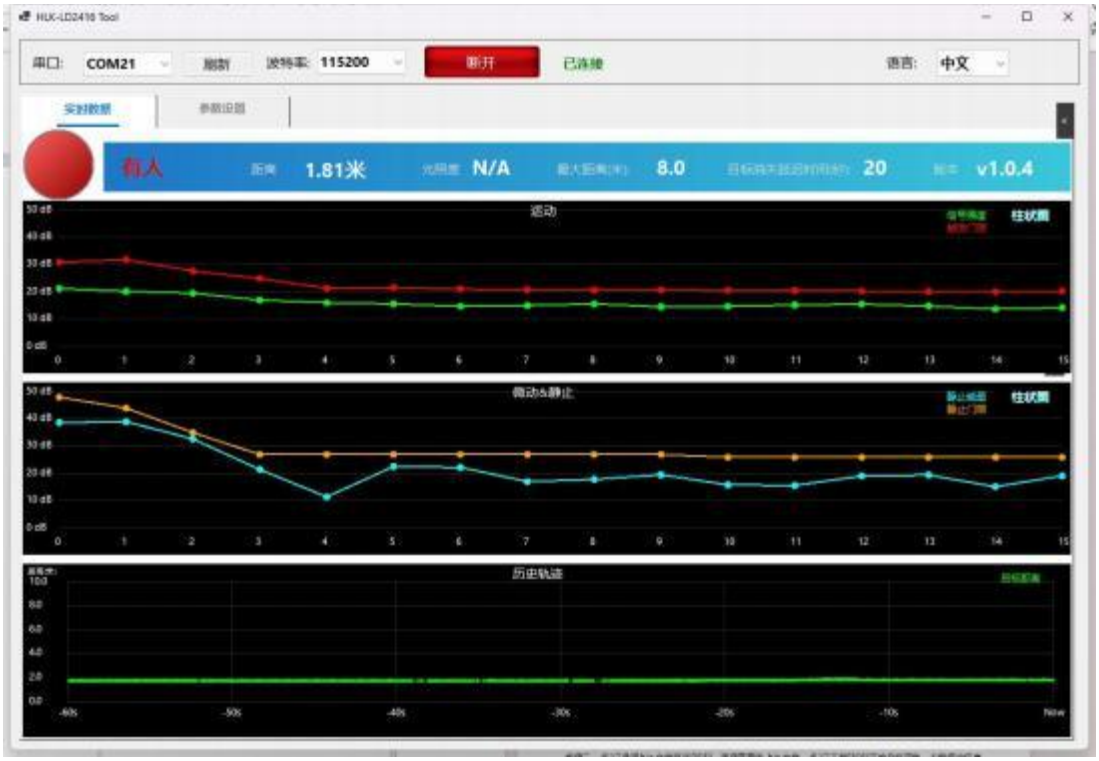


Figure 4-5 Real-time data page

5. Communication Protocol

This communication protocol is primarily intended for users performing secondary development without relying on the visualization tool. The HLK-LD2416 narrow-bezel mmWave human presence sensor communicates with external devices via a serial port (TTL level). Both data output and parameter configuration commands for the sensor are handled under this protocol. The default serial port settings are 115200 baud, 1 stop bit, and no parity.

This chapter introduces the communication protocol in three parts:

- Protocol format: Includes protocol data format and command frame format;
- Configuration command packet format: Includes command packet format and command response packet format;
- Uploaded data frame format: Includes formats for debug mode and reporting mode.

The basic workflow for configuring parameters using commands is as follows:

1. Enter command mode;
2. Send parameter configuration or parameter retrieval commands;
3. Exit command mode.

5.1 Protocol Format

5.1.1 Protocol Data Format

The HLK-LD2416 uses little-endian format for data communication; all data in the following table is in hexadecimal.

5.1.2 Command Protocol Frame Format

The formats of the millimeter-wave sensor configuration commands and ACK commands defined by the protocol are shown in Table 5-1 and Table 5-3.

Table 5-1 Send Command Protocol Frame Format

Header	Intra-frame data length	Intra-frame data	Frame trailer
FD FC FB FA	2 bytes	See Table 5-2	04 03 02 01

Table 5-2 Transmitted Frame Data Format

Command code (2 bytes)	Command value (N bytes)

Table 5-3 ACK Command Protocol Frame Format

Header	Intra-frame data length	Intra-frame data	Frame trailer
FD FC FB FA	2 bytes	See Table 5-4	04 03 02 01

Table 5-4 Data Format within the ACK Frame

Send command word (2 bytes)	Command execution status (2 bytes)	Return value (N bytes)

5.2 Sending Commands and ACK

5.2.1 Command to Read Firmware Version

This command reads the mmWave sensor firmware version information.

Command code: 0x0000

Command value: None

Return value: Version number length (2 bytes) + Version number byte string

Send data:

Header	Intra-frame data length	Command words	Frame trailer
FD FC FB FA	02 00	00 00	04 03 02 01

ACK (Success, data is an example):

Header	Intra-frame data length	Command words	ACK	Version number length	Version	Frame trailer
FD FC FB FA	0C 00	00 01	00 00	06 00	31 2E 35 2E 35	04 03 02 01

5.2.2 Enable Configuration Command

Any other commands sent to the millimeter-wave sensor must be issued after this command; otherwise, they will be invalid.

Command word: 0x00FF

Command value: 0x0001

Return value: 2-byte ACK status (0: Success, 1: Failure) + 2-byte protocol version (0x0002) + 2-byte buffer size (0x0020)

Send data:

Header	Intra-frame data length	Command words	Command value	Frame trailer
FD FC FB FA	04 00	FF 00	01 00	04 03 02 01

ACK (Success):

Header	Intra-frame data length	Command words	ACK	Protocol version	Buffer size	Frame trailer
FD FC FB FA	08 00	FF 01	00 00	02 00	20 00	04 03 02 01

5.2.3 Configuration Termination Command

The millimeter-wave sensor resumes its operating mode after the configuration completion command is executed. To issue other commands subsequently, the configuration enable command must be sent first. Command Code: 0x00FE

Command value: None

Return value: 2-byte ACK status (0: Success, 1: Failure)

Send data:

Header	Intra-frame data length	Command words	Frame trailer
FD FC FB FA	02 00	FE 00	04 03 02 01

ACK (Success):

Header	Intra-frame data length	Command words	ACK	Frame trailer
FD FC FB FA	04 00	FE 01	00 00	04 03 02 01

5.2.4 Read Serial Number Command

This command reads the serial number of the millimeter-wave sensor.

Command code: 0x0011

Command value: None

Return value: 2-byte ACK status (0: success, 1: failure) + SN length (2 bytes) + SN (2 bytes)

Send data:

Header	Intra-frame data length	Command words	Frame trailer
FD FC FB FA	02 00	11 00	04 03 02 01

ACK (Success, SN as example):

Header	Intra-frame data length	Command words	ACK	SN length	SN	Frame trailer
FD FC FB FA	08 00	11 01	00 00	02 00	CD AB	04 03 02 01

5.2.5 Command to Read Sensor Parameter Configuration (It's recommended to use the command in 5.2.11 to read them all at once)

This command reads the sensor's current configuration parameters.

Command code: 0x0008

Command value: (2-byte Parameter ID) × N

Return value: (4-byte Parameter Value) × N

Send data:

Header	Intra-frame data length	Command words	Parameter ID	Frame trailer
FD FC FB FA	04 00	08 00	01 00	04 03 02 01

ACK (Success, Max Distance Gate 12):

Header	Intra-frame data length	Command words	ACK	Parameter value	Frame trailer
FD FC FB FA	08 00	08 01	00 00	0C 00 00 00	04 03 02 01

5.2.6 Command for configuring sensor parameters (It's recommended to use the command in section 5.2.12 to configure them all at once).

This command configures the parameters for the millimeter-wave sensor. Please refer to Table 5-5 for specific parameter details; parameters for micro-motion and stationary thresholds, as well as power supply interference alarms, have been added.

Table 5-5 Sensor Parameter Table

Parameter name	Words	Parameter range
Maximum distance gate	0x0001	0~15
Target disappearance delay	0x0004	0~65535, Unit: s
Micro-motion & stationary thresholds	0x0030 ~ 0x003F	0~2^32, is the square of the magnitude
Motion detection coefficient	0x0900	0~65535
Installation method	0x0E00	0 Ceiling-mounted 1 Wall-mounted
Power supply interference alarm	0x0005	Lower 16 bits: 0: Not performed; 1: No interference; 2: Interference present. Upper 16 bits: Interference frequency; range 0–256, unit kHz; valid only when the lower 16 bits are 2. This parameter is read-only.

Command code: 0x0007

Command value: (2-byte Parameter ID + 4-byte Parameter Value) * N

Return value: 2-byte ACK status (0: Success, 1: Failure)

Send data (Example: Max Distance Gate 12):

Header	Intra-frame data length	Command words	Parameter ID	Parameter value	Frame trailer
FD FC FB FA	08 00	07 00	01 00	0C 00 00 00	04 03 02 01

ACK (Success):

Header	Intra-frame data length	Command words	ACK	Frame trailer
FD FC FB FA	04 00	07 01	00 00	04 03 02 01

5.2.7 Serial Port Baud Rate Modification Command

This command is used to set the baud rate of the module's serial port; the configuration value is retained after power-off.

Command code: 0x00A1

Command value: 2-byte baud rate selection index

Return value: 2-byte ACK status (0: success, 1: failure)

Table 2-2 Serial Port Baud Rate Selection

Baud rate selection index value	Baud rate
0x0001	9600
0x0002	19200
0x0003	38400
0x0004	57600
0x0005	115200
0x0006	230400
0x0007	256000
0x0008	460800
0x0009	921600

The factory default value is 0x0005, i.e., 115200.

Send data:

Header	Intra-frame data length	Command words	Baud rate	Frame trailer
FD FC FB FA	04 00	A1 00	07 00	04 03 02 01

Radar ACK (Success):

Header	Intra-frame data length	Command words	ACK	Frame trailer
FD FC FB FA	04 00	A1 01	00 00	04 03 02 01

5.2.8 Restore Factory Settings

This command is used to restore all configuration values to factory defaults.

Command code: 0x00A2

Command value: None

Return value: 2-byte ACK status (0: success, 1: failure)

Send data:

Header	Intra-frame data length	Command words	Frame trailer
FD FC FB FA	02 00	A2 00	04 03 02 01

Radar ACK (Success):

Header	Intra-frame data length	Command words	ACK	Command value	Frame trailer
FD FC FB FA	04 00	A2 01	00 00	00 00	04 03 02 01

5.2.9 Restart Module

Upon receiving this command, the module will automatically restart after the response has been sent.

Command code: 0x00A3

Command value: None

Return value: 2-byte ACK status (0: Success, 1: Failure)

Send data:

Header	Intra-frame data length	Command words	Frame trailer
FD FC FB FA	02 00	A3 00	04 03 02 01

Radar ACK (Success):

Header	Intra-frame data length	Command words	ACK	Command value	Frame trailer
FD FC FB FA	04 00	A3 01	00 00	00 00	04 03 02 01

5.2.10 Serial Port Baud Rate Query Command

This command is used to query the current baud rate of the module's serial port; the result is the baud rate index value.

Command Code: 0x00D3

Command Value: None

Return Value: 2-byte ACK status (0 for success, 1 for failure) + 2-byte baud rate index value.

Table 2-3 Serial Port Baud Rate Index

Baud rate selection index value	Baud rate
0x0001	9600
0x0002	19200
0x0003	38400
0x0004	57600
0x0005	115200
0x0006	230400
0x0007	256000
0x0008	460800
0x0009	921600

The factory default value is 0x0005, i.e., 115200.

Send data:

Header	Intra-frame data length	Command words	Frame trailer
FD FC FB FA	02 00	D3 00	04 03 02 01

Radar ACK (Success):

Header	Intra-frame data length	Command words	ACK	Command value	Frame trailer
FD FC FB FA	04 00	D3 01	00 00	05 00	04 03 02 01

5.2.11 Radar Parameter Configuration Query Command

Upon receiving this command, the module will respond with the radar's parameter configuration values. The unit for the stationary threshold is 0.1 dB. Command code: 0x00A4

Command value: None

Return value: 2-byte ACK status (0 for success, 1 for failure)

Send data:

Header	Intra-frame data length	Command words	Frame trailer
FD FC FB FA	02 00	A4 00	04 03 02 01

Radar ACK (Success):

Header	Intra-frame data length	Command words	ACK	Max distance (0.1 m)	Delay time (s)	Motion detection coefficient	Installation Method: 01 Wall-mounted / 00 Ceiling-mounted	Stationary threshold 00
FD FC FB FA	2C 00	A4 01	00 00	09 00	05 00	3C 00	01 00	E0 01
Stationary threshold 01	**Stationary threshold 02**	**Stationary threshold 03**	**Stationary threshold 04**	**Stationary threshold 05**	**Stationary threshold 06**	**Stationary threshold 07**	**Stationary threshold 08**	**Stationary threshold 09**
B8 01	5E 01	0E 01	0E 01	0E 01	0E 01	0E 01	0E 01	0E 01
Stationary threshold 10	**Stationary threshold 11**	**Stationary threshold 12**	**Stationary threshold 13**	**Stationary threshold 14**	**Stationary threshold 15**	**Frame trailer**		
0E 01	0E 01	0E 01	0E 01	0E 01	0E 01	04 03 02 01		

5.2.12 Radar Parameter Configuration Command

Upon receiving this command, the module configures the radar parameters. The unit for the stationary threshold is 0.1 dB.

Command code: 0x00A5

Command value: None

Return value: 2-byte ACK status (0: Success, 1: Failure)

Send data:

Header	Intra-frame data length	Command words	Max distance (0.1 m)	Delay time (s)	Motion detection coefficient	Installation Method: 01 Wall-mounted / 00 Ceiling-mounted	Stationary threshold 00
FD FC FB FA	2A 00	A5 00	09 00	05 00	3C 00	01 00	E0 01
Stationary threshold 01	**Stationary threshold 02**	**Stationary threshold 03**	**Stationary threshold 04**	**Stationary threshold 05**	**Stationary threshold 06**	**Stationary threshold 07**	**Stationary threshold 08**

B8 01	5E 01	0E 01	0E 01	0E 01	0E 01	0E 01	0E 01
Stationary threshold 09	**Stationary threshold 10**	**Stationary threshold 11**	**Stationary threshold 12**	**Stationary threshold 13**	**Stationary threshold 14**	**Stationary threshold 15**	**Frame trailer**
0E 01	0E 01	0E 01	0E 01	0E 01	0E 01	0E 01	04 03 02 01

Radar ACK (Success):

Header	Intra-frame data length	Command words	ACK	Command value	Frame trailer
FD FC FB FA	04 00	A5 01	00 00	00 00	04 03 02 01

5.3 Reporting Data

In the standard operating mode of the HLK-LD2416 factory firmware, detection results are output via the serial port; the data format is shown in Table 5-6.

Table 5 - Data frame format for debug mode

Header	Length	Test results	Target distance	Photo-sensitivity value	Kinetic energy (0.1 dB)
F4 F3 F2 F1	2 bytes; total number of bytes for detection results, target distance, and energy values for each range gate.	1 byte, 00 Unoccupied 01 Occupied	2 bytes	2 bytes	16 distances gates * 2 bytes
Motion trigger threshold (0.1 dB)	**Rest energy (0.1 dB)**	**Frame trailer**			
16 distances gates * 2 bytes	16 distances gates * 2 bytes	F8 F7 F6 F5			

6. Installation and Detection Range

The HLK-LD2416 supports both ceiling and wall mounting, with wall mounting being the recommended method.

6.1 Ceiling-mounted Installation

When ceiling-mounted at a height of 3 m, the HLK-LD2416 has a maximum motion detection range defined by a conical space with a base radius of 4.5 m, as shown.

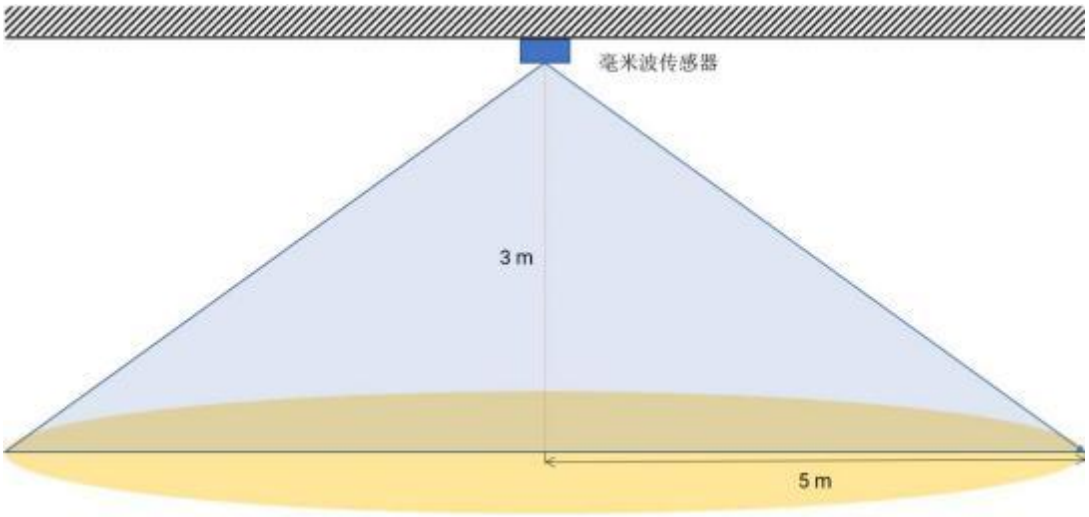


Figure 6-1 Schematic diagram of the detection range for ceiling-mounted installation

It should be noted that as the installation height decreases, the maximum detection range gradually shrinks, as shown in Figure 6-2.

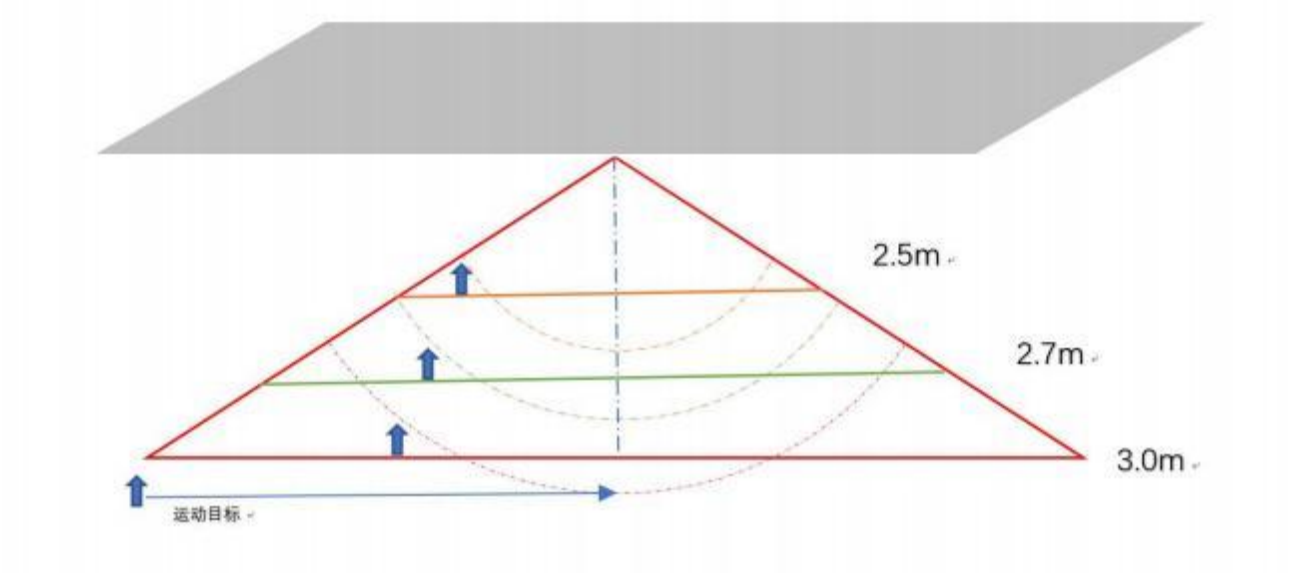


Figure 6-2 Schematic diagram showing the relationship between ceiling-mounted installation height and detection range.

Figure 6-2 illustrates the relationship between ceiling-mounted installation height and detection range. The diagram shows the motion and micro-motion detection ranges of the HLK-LD2416 when mounted on the ceiling at a height of 2.7 m.

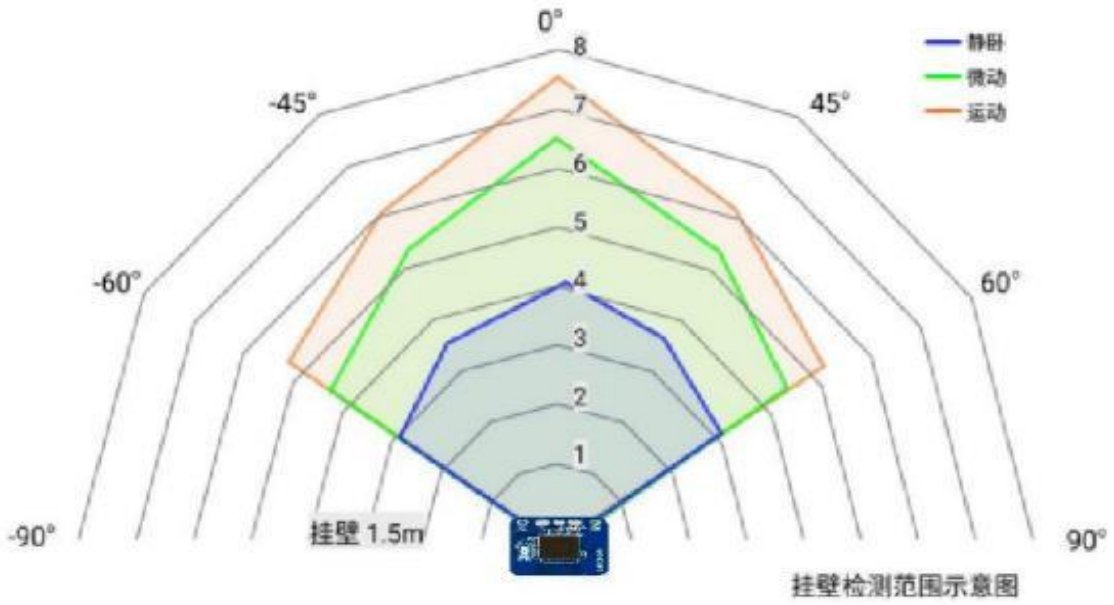


Figure 6-3 Ceiling-mounted detection range

6.2 Wall-mounted Installation

Under default configuration, the maximum motion detection range is a conical space extending 8 m along the sensor's normal axis, within an angle of ±60° in both the horizontal and pitch directions, as illustrated. Figure 6-5 shows a diagram of the detection range for this reference design when wall-mounted at a height of 1.5 m.

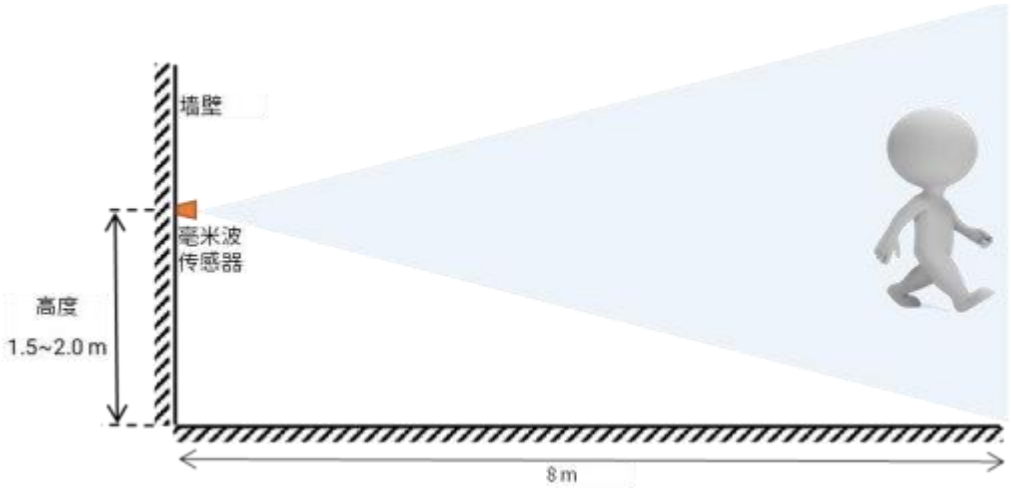


Figure 6-4 Schematic diagram of the detection range for wall-mounted installation

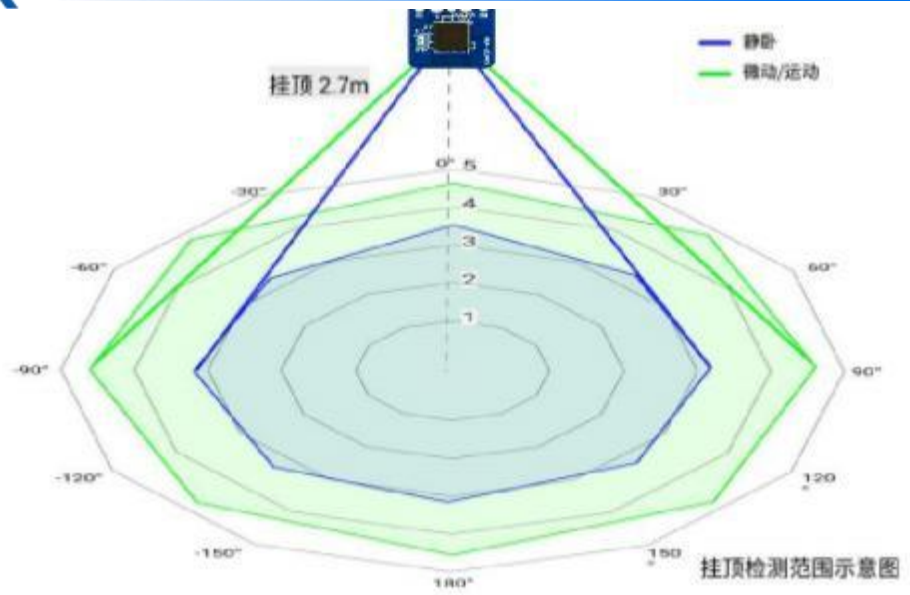


Figure 6-5 Wall-mounted installation detection range

6.3 Detection Range Test

The test methods for the trigger and hold detection ranges of millimeter-wave sensors are described below:

- **Trigger Range:** A target human approaches the sensor from a distance while the sensor is reporting a "no-presence" status; the point where the target stops moving—as the sensor switches to reporting "presence"—marks the boundary of the trigger detection range. The area enclosed by these detection boundaries across all directions constitutes the sensor's trigger detection range.
- **Hold Range:** A target human performs slight movements (such as shrugging shoulders or raising an arm) at a specific location while the sensor is reporting "presence." If the sensor continues to report "presence" throughout a 60-second period, that location falls within the sensor's hold detection range; otherwise, the location lies outside the hold detection range.

7. Dimension

The mechanical dimensions of the HLK-LD2416 hardware are shown. All units are in mm. The board thickness of the HLK-LD2416 is 1 mm, with a tolerance of ±10%.

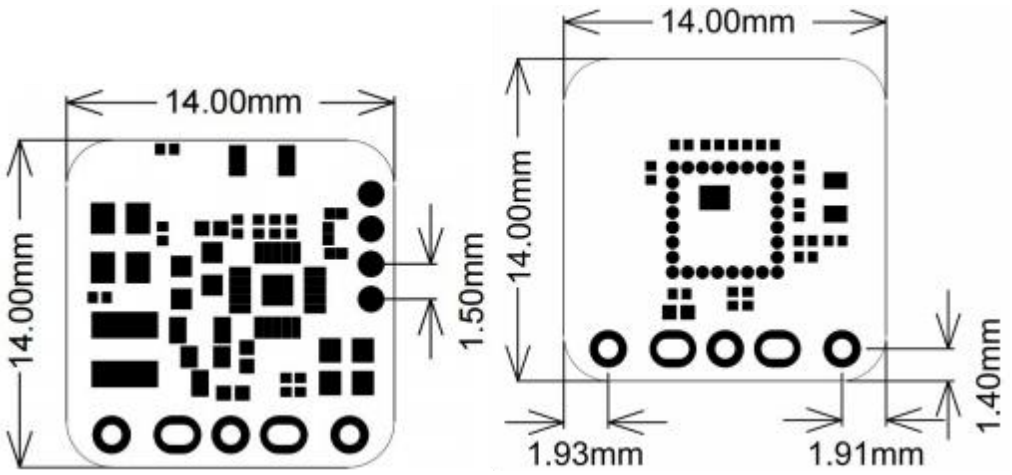


Figure 7-1 HLK-LD2416 hardware mechanical dimension

8. Installation Instructions

8.1 Millimeter-wave Sensor Housing Requirements

If the millimeter-wave sensor requires an enclosure, the enclosure must exhibit good wave-transmitting properties in the 24 GHz frequency band and must not contain metal or materials that shield electromagnetic waves. Please refer to the relevant documentation for further precautions.

8.2 Installation Environment Requirements

This product must be installed in a suitable environment; detection performance will be compromised if used in the following conditions:

- Presence of continuously moving non-human objects within the detection zone, such as animals, curtains swaying continuously, or large potted plants positioned directly in front of air vents.
- Presence of large, highly reflective surfaces within the detection zone; such objects can interfere with the sensor.
- For wall-mounted installations, external sources of interference—such as ceiling-mounted air conditioners or electric fans—must be taken into account.

8.3 Precautions for Installation

- Ensure the antenna faces the detection area directly and that the surrounding space is open and unobstructed.
- Ensure the millimeter-wave sensor is mounted securely and stably; any oscillation of the sensor itself will affect detection performance.

- Ensure there is no moving object or vibration behind the millimeter-wave sensor. Due to the penetrating nature of millimeter waves, the antenna's back lobe may detect moving objects behind the sensor. A metal shield or metal backplate can be used to block the back lobe and mitigate interference from objects behind the sensor.
- When using multiple 24 GHz millimeter-wave sensors, avoid pointing their beams directly at each other and install them as far apart as possible to prevent potential mutual interference.

8.4 Power Supply Considerations

- The power supply input voltage range is 4.8 V to 5.3 V, and the power supply ripple exhibits no significant spectral peaks within the 100 kHz range. This solution serves as a reference design; users must incorporate appropriate electromagnetic compatibility (EMC) measures, such as protection against ESD and lightning surges.

9. Precautions

9.1 Maximum Detection Range

The maximum radial detection range of the millimeter-wave sensor is 8 meters. Within this detection range, the sensor reports the straight-line distance from the target to the sensor itself.

9.2 Maximum Range and Accuracy

In theory, the ranging accuracy of the millimeter-wave sensor in this reference design is ± 0.15 m. However, ranging accuracy and maximum detection range may fluctuate due to variations in the human target's physique, state, and radar cross-section (RCS).

9.3 Target Disappearance Delay Time

When a millimeter-wave sensor detects the absence of human presence in the target area, it does not immediately report an "unoccupied" status; instead, there is a delay. The mechanism for this delayed reporting is as follows: once no human target is detected within the monitoring range, the sensor initiates a timer to track the duration of the unoccupied state. If the absence of humans persists throughout this timing period, the sensor reports the "unoccupied" status upon the timer's completion; conversely, if a human presence is detected during this interval, the timing process is immediately terminated and reset, and the target information is reported.

9.4 Micro-motion Detection Range

The detection range of a millimeter-wave sensor for subtle human movements is inversely proportional to the angle between the sensor's normal vector and the human body's normal vector. Therefore, in scenarios involving the detection of subtle movements, it is recommended to adjust the sensor's position and orientation so that the angle between these two normal vectors is minimized, thereby enhancing detection accuracy and range.

9.5 Optimization of the Automatic Threshold Generation Function

The optimization of the automatic threshold generation function has enhanced the overall performance of the HLK-LD2416 and improved the user experience. The specific optimizations are as follows:

- Reduces On-Site Commissioning Workload

With the automatic threshold generation feature, the system automatically calculates and sets appropriate threshold values. This significantly reduces the workload associated with on-site commissioning and eliminates the need for engineers to manually adjust thresholds for each millimeter-wave sensor—a common drawback in traditional deployment processes—thereby making large-scale deployment more efficient and convenient. It enhances deployment efficiency and minimizes the risk of human error.

- Improves Detection Accuracy

The automatic threshold generation feature utilizes precise environmental sensing and data analysis to automatically calculate the optimal threshold for the current environment. This approach minimizes interference from human factors associated with manual adjustments and ensures the sensor maintains peak detection accuracy across various complex environments. Whether detecting static targets stably or responding rapidly to dynamic targets, the HLK-LD2416 delivers accurate, reliable results, providing a superior user experience.

- Simplifies Installation

The automatic threshold generation feature streamlines the sensor installation process. Users need only complete basic installation steps; the sensor then automatically optimizes its threshold settings, eliminating the need for complex manual commissioning.

- Lowers Maintenance Costs

The sensor automatically adjusts threshold values in real-time based on environmental changes, reducing the need for periodic manual adjustments caused by environmental shifts. This alleviates the workload for maintenance personnel and enhances system operational efficiency and stability, ultimately saving maintenance costs for the user.

- Flexible Triggering Methods

To meet the diverse needs of users and application scenarios, we offer two flexible methods for triggering automatic threshold generation: external triggering and sensor-initiated automatic triggering.

External Triggering: Users can trigger automatic threshold generation via an external signal. This method allows users to manually control the timing of threshold generation based on specific application requirements.

Sensor-Initiated Automatic Triggering: For users requiring a higher level of automation, we provide a feature where the sensor automatically determines when to initiate threshold generation. This function relies on the sensor's built-in intelligent algorithms to automatically decide when to start generating threshold values. Note that implementing this feature may require custom firmware. Users can choose the method that best suits their specific needs and application scenarios.

When the human body is standing in a relaxed posture and gazing straight ahead, the direction of the line of sight corresponds to the body's normal vector.

9.6 Overhead Static Test Instructions

The sensor can detect the state of lying still, with detection sensitivity being superior in the tangential direction compared to the radial direction. Examples of tangential and radial lying -still states are shown in Figure 9-1.

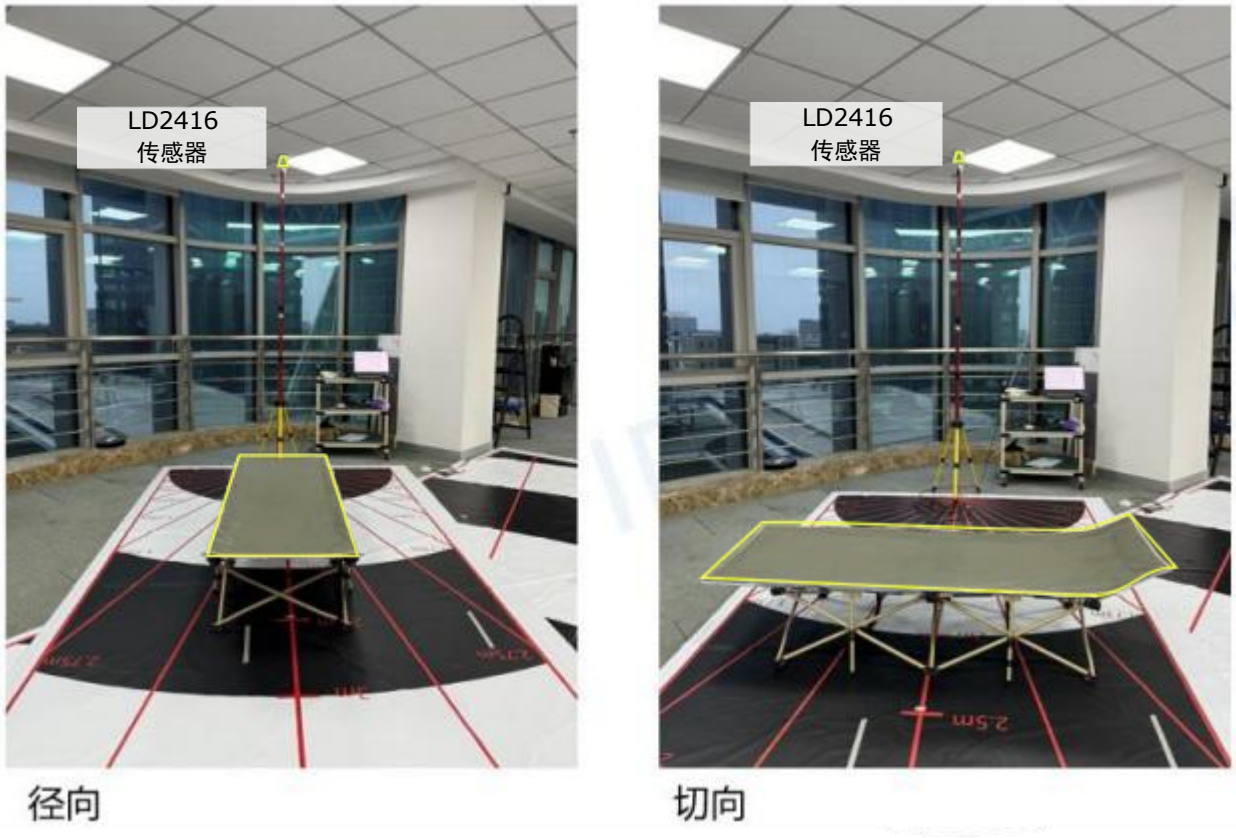


Figure 9-1 Examples of tangential and radial orientations in the resting state

10. Technical support and contact

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