Shenzhen Hi-Link Electronics Co., Ltd.

HLK- LD2402 User Manual

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Contents

1. HLK-LD2402 Overview

HLK-LD2402 is Hi-link 's static human life presence sensor , which includes a minimalist 24 GHz sensor hardware and human micro-motion sensing intelligent algorithm firmware.

The hardware is equipped with AIoT millimeter wave sensors, high-performance 24 GHz one-to-one antennas and peripheral circuits; the human presence sensing algorithm uses millimeter wave radar distance measurement technology and radar chip advanced proprietary radar signal processing technology to achieve accurate perception of motion, micro-movement and human presence . The human presence sensing intelligent algorithm firmware is mainly used in indoor scenes to sense whether there is motion , micro-movement or human presence in the area , and refresh the detection results in real time.

HLK-LD2402 for moving human bodies is 10 m. The sensing distance range, trigger and hold thresholds in different intervals, and unattended reporting time can be easily configured. HLK-LD2402 supports GPIO and UART interfaces, plug-and-play, and can be flexibly applied to different smart scenarios and terminal products. It also supports automatic generation of detection thresholds, reduces manual debugging, improves detection accuracy, simplifies the installation process, and facilitates large-scale deployment.

HLK-LD2402 are as follows:

- Equipped with single-chip intelligent millimeter wave sensor SoC and intelligent algorithm firmware
- Ultra-small sensor size: 20 mm x 20 mm
- Load the default human body sensing configuration, plug and play
- 24 GHz ISM band, can pass FCC, CE, and RF spectrum regulations certification
- 3.3 V, 5 V power supply, supports 3.0 V ~ 3.6 V, 4.5 ~ 5.5 V wide voltage range
- Average operating current 50 mA
- Detection targets include motion, micro-movement, and the presence of human bodies
- Report detection results in real time
- Provides visualization tools to support configuration of detection distance interval and target disappearance delay time
- Support automatic generation of detection thresholds
- Supports sensing range division, completely shielding any interference outside the range
- Motion sensor up to 10 m
- Large detection angle, coverage range up to ±60°
- Supports multiple installation methods such as ceiling hanging and wall hanging
- Trigger and hold states are configured independently, with strong anti-interference capability

The HLK-LD2402 static human life presence sensor can detect and identify moving, standing and static human bodies. It is widely used in various AIoT scenarios, covering the following types:

- **Smart Home**

  Sense the presence and distance of human body and report the detection results for the main control module to intelligently control the operation of home appliances.

- **Smart Business**

  Identify when a person is approaching or moving away within the set distance range; light up the screen in time and keep the device lit when a person is present.

- **Smart Security**

  Induction access control, building intercom, electronic cat's eye, etc.

- **Smart Lighting**

  Identify and sense the human body, accurately detect the position, and can be used for lighting equipment in public places (induction lamps, bulbs, etc.).

2. System Description

HLK-LD2402 is a stationary human life presence sensor developed based on the Hi-link millimeter wave sensor chip . The sensor uses FMCW frequency modulated continuous wave, combined with radar signal processing and built-in intelligent human body sensing algorithm to detect human targets in a set space and update the detection results in real time. Using HLK-LD2402 , users can quickly develop their own precise human presence sensing products.

The hardware is mainly composed of a fully integrated intelligent millimeter wave sensor SoC, a 24 GHz transmit-receive antenna and a main control MCU; the software part is equipped with intelligent human presence sensing firmware and a visual configuration tool to realize the human presence sensing function with flexible configuration of sensing distance, trigger and hold thresholds and unattended reporting time.

The specifications of HLK-LD2402 are shown in Table 2-1 .

Table 2- 1 HLK-LD2402 Specifications

Parameter	Minimum	Typical	Maximum	Unit	Remark
Hardware specifications					
Supported frequency bands	twenty four	-	24.25	GHz	Comply with FCC, CE, and NFPA certification standards
Supports maximum sweep bandwidth	-	0.25	-	GHz	
Maximum equivalent isotropic radiated power	-	11	-	dBm	-
Supply voltage	3.0	3.3	3.6	V	-
Add L DO supply voltage	4.5	5	5.5	V	Default not posted
size	-	20 x 20	-	mm	-
Ambient temperature	-40	-	85	°C	-
HLK-LD2402 System Performance					
Detection range (wall mounted)	-	10	-	m	Sports human target
	-	6	-	m	Micro-motion human target
		5		m	Sitting human body target
Detection range (ceiling mounted)	-	5	-	m	Sports human target
	-	4	-	m	Micro-motion human target

		4		m	Sitting human body target
		3		m	Lying human target
Detection accuracy	-	± 0.15	-	m	Moving target within 6 m of the sensor
Average operating current	-	50	-	mA	-
Data refresh cycle	-	1 65	-	ms	-

3. Hardware Description

Figure 3-1 shows the front and back photos of the hardware HLK-LD2402 .

Hardware HLK-LD2402 reserves 5 pin holes (factory equipped pins) called J2 for power supply and communication; J1 is the SWD interface for MCU program burning and debugging. The PIN spacing is compatible with 2.54mm and 2.00mm jack spacing.

(a) Front (b) Reverse side

Figure 3- 1 Hardware HLK-LD2402 front and back pictures

For the pin descriptions of J1 and J2, please refer to Table 3-1 and Table 3-2 respectively .

Table 3-1 J1 pin description

J#PIN#	name	Function	illustrate
J1Pin1	GND	Grounding	-
J1Pin2	DIO	SWD interface data cable	0 ~ 3.3 V
J1Pin3	CLK	SWD interface clock line	0 ~ 3.3 V
J1Pin4	3V3	Power Input	3.0 V ~ 3.6 V, Typ. 3.3 V

Table 3-2 J2 pin description

J#PIN#	name	Function	illustrate
J2Pin1	V	Power Input	3.0 V ~ 3.6 V, Typ. 3.3 V[1]
J2Pin2	I O	Used to report detection status: high level means someone is there, low level means no one is there	0 ~ 3.3 V
J2Pin3	G	Grounding	-
J2Pin4	T	UART_TX	0 ~ 3.3 V
J2Pin5	R	UART_RX	0 ~ 3.3 V

4. Software Description

This chapter introduces the firmware debugging of the HLK-LD2402 stationary human life presence sensor and the use of the host computer tools.

HLK-LD2402 has system firmware burned in the factory. Hi-link provides HLK-LD2402 visual host configuration tool software, which is convenient for developers to configure parameters of HLK-LD2402 according to the usage scenario and optimize the sensing effect.

4.1. Firmware Debugging

This section describes how to use third-party serial port tool software to debug the HLK-LD2402 mmWave sensor firmware.

Step 1: Connect the host computer and the millimeter wave sensor through the USB to TTL serial port adapter board. The pin connection method is shown in Table 4-1 .

Table 4-1 Correspondence between the pins when the sensor is connected to the USB serial port adapter board

sensor	Serial port adapter board
RX	TXD
TX	RxD
GND	GND
3V3	VCCIO

Step 2: Open the device manager of the host computer and check the serial port number of the millimeter wave sensor.

Step 3. Open the third-party serial port tool, select the serial port number of the millimeter wave sensor, set the serial port baud rate to 115200 , and then click the "Open Serial Port" (or

[1] After adding L DO , 4.5V~5.5V , Typ . 5V

equivalent function) button to view the current millimeter wave sensor detection results at the output end of the tool interface.

4.2. Host computer tool description

This section introduces the use of the host computer tool that comes with the HLK-LD2402 millimeter wave sensor to help users understand the meaning of related parameters and how to obtain them.

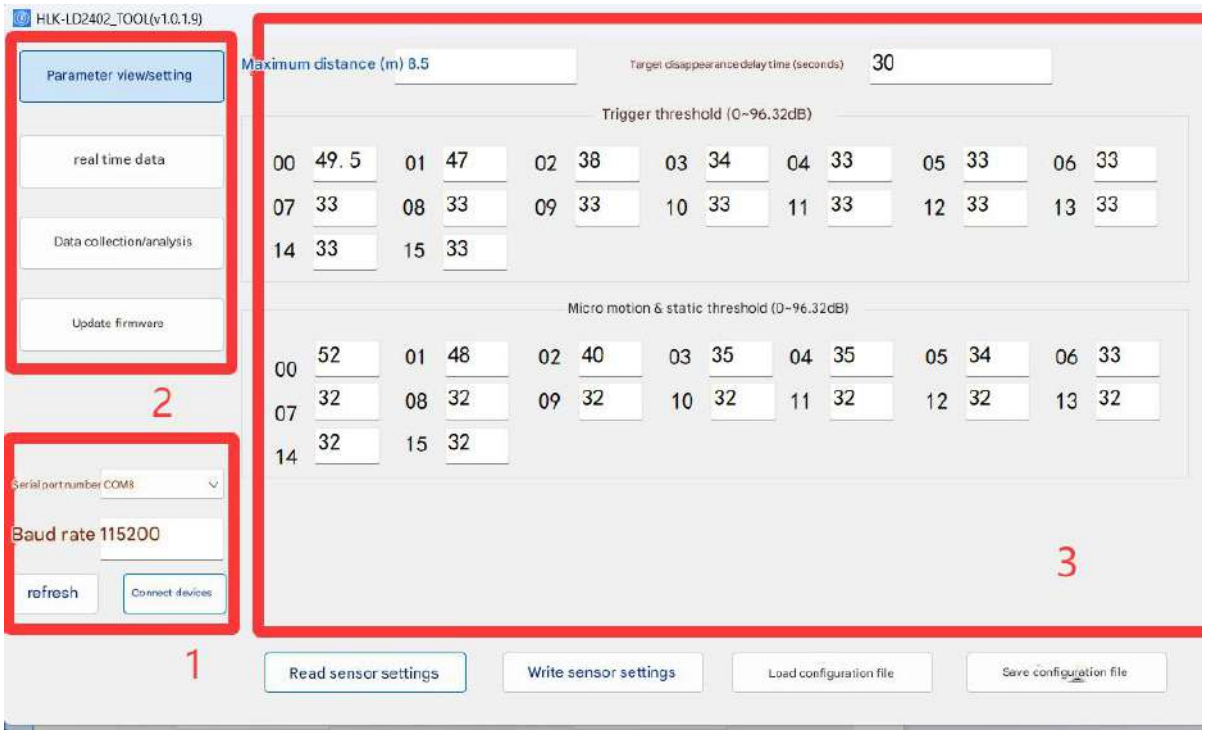
Note: The host computer tool and the third-party serial port tool cannot be used at the same time!

Before using the functions of the host computer, the user should first connect HLK-LD2402 to the host computer. The steps are as follows:

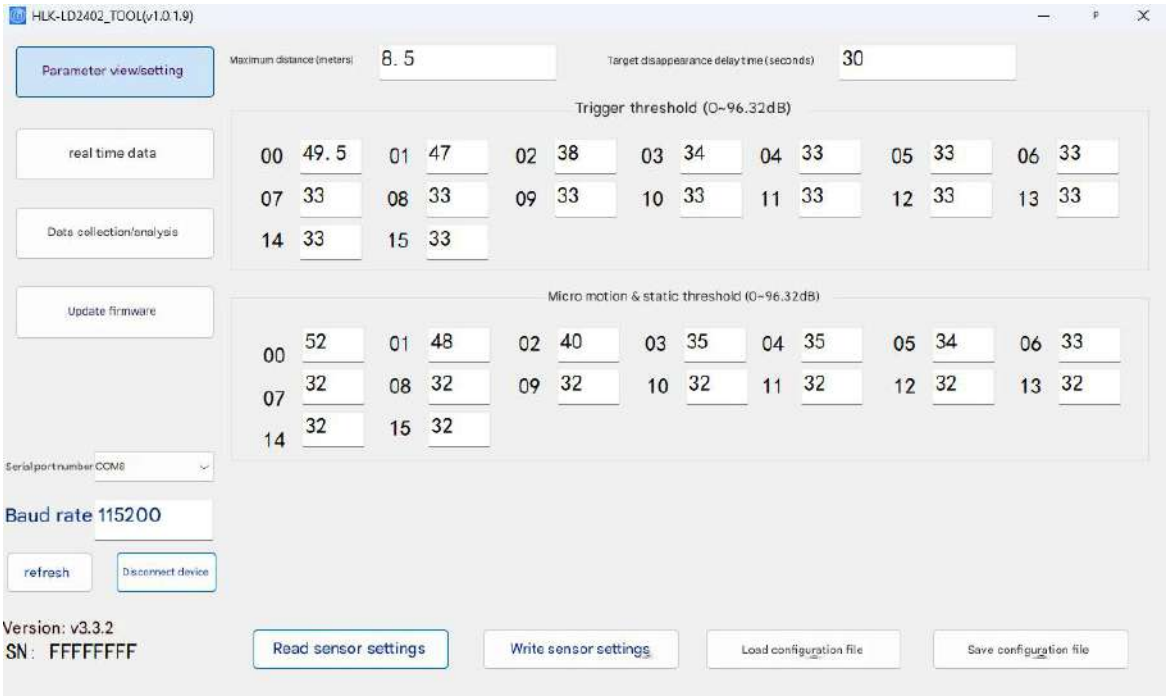
Step 1: Get the host computer tool " HLK-LD2402_Tool " for HLK-LD2402 from the official website of Hi-link .

Step 2: Use the serial port adapter board to connect the millimeter wave sensor and the host computer;

Step 3. Open the host computer tool, click the "Refresh" button, select the serial port number of the millimeter wave sensor in the "Serial Port Number" drop-down box, confirm that the "Baud Rate" is 115200 , and click the "Connect Device" button to start connecting the host computer and the millimeter wave sensor.



(a) Before connecting the device



(b) After the device is connected

Figure 4-1 HLK-LD2402 _Tool

Figure 4-1 (a), the host computer tool interface can be divided into three areas: device operation area (Zone 1), function button area (Zone 2), and function page area (Zone 3).

After the host computer tool is successfully connected to the millimeter wave sensor, the firmware version number (format: Version: ...) and serial number (format: SN: ..., if the serial number is not burned, the host computer software will display FFFFFFFF) of the millimeter wave sensor in the Zone 1 area of the interface. The current parameter values of the millimeter wave sensor are displayed in the "Parameter View/Set" function page area, as shown in Figure 4-1 (b).

4.2.1.Parameter view/setting

The "Parameter View/Set" page of the host computer tool is shown in Figure 4-2 , which allows users to view the current parameters of the millimeter wave sensor and modify the specified parameter configuration to meet the needs of specific application scenarios.

The steps to read the millimeter wave sensor parameters through the host computer tool are as follows:

After connecting HLK-LD2402 to the host computer tool, click the "Read Sensor Settings" button on the function page. A "Read Parameters Successfully" prompt window will pop up and display all the current parameter values of the millimeter wave sensor. Click "OK" to close the prompt window.

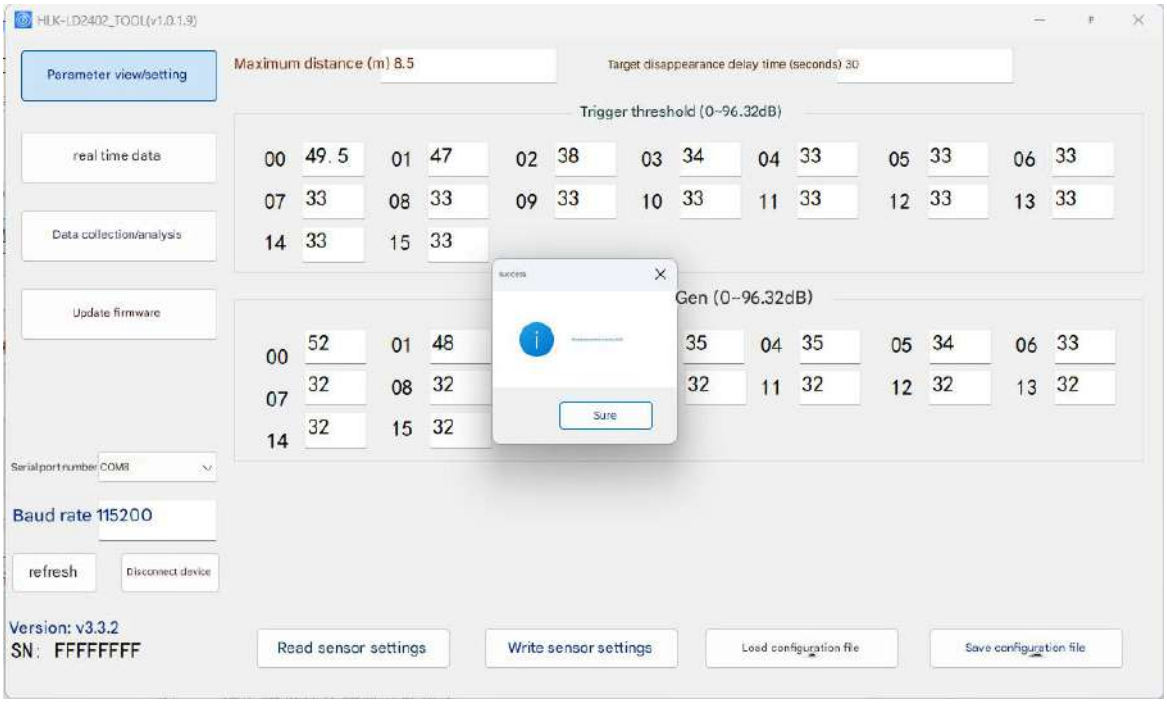


Figure 4-2 Reading millimeter wave sensor parameters interface

The steps to change one or more mmWave sensor parameters through the host computer tool are as follows:

Step 1: After connecting HLK-LD2402 to the host computer tool, enter new parameter values for all parameters that need to be changed on the function page;

Step 2. Click the "Write Sensor Settings" button on the function page. The host computer will write the parameter values in the current interface to the millimeter wave sensor. The page will pop up a "Write Parameters Successfully" prompt window. Click "OK" to complete the parameter setting.

For detailed explanation of the parameters on the “Parameter Setting” page of the host computer tool, see Table 4-2 .

Table 4-2 Parameter explanation of the host computer tool interface

Parameter name	explain	Parameter range
Maximum distance	Used to set the maximum effective detection distance of the millimeter wave sensor; The length of one distance door is 70 cm.	0.7 ~ 10 , accurate to 0.1m
Target disappears Delay time (seconds)	It takes a delay of T for the target state to switch from occupied to unoccupied. If a person is detected during this period, the timing of this period will be restarted. The millimeter wave sensor will only switch to the unoccupied state and report that no one is there after detecting that the unoccupied state has lasted for a full T period of time.	0~65535
Trigger threshold (dB)	Used to set the energy value threshold from unmanned to manned state, which can be calculated through the "Generate Threshold" function.	0~ 95 , accurate to 0.01
Micro-motion threshold (dB)	The energy value threshold used to detect the micro-motion state of the human body can be calculated through the "Generate Threshold" function.	0~ 95 , accurate to 0.01

The host computer tool supports saving and loading the parameter configuration of the millimeter wave sensor:

Click the "Save Configuration File" button and select the path you want to save. The host computer tool will save the current parameter configuration of the millimeter wave sensor in the form of an .xml file in the host computer. The default save address is the folder where the host computer tool is located.

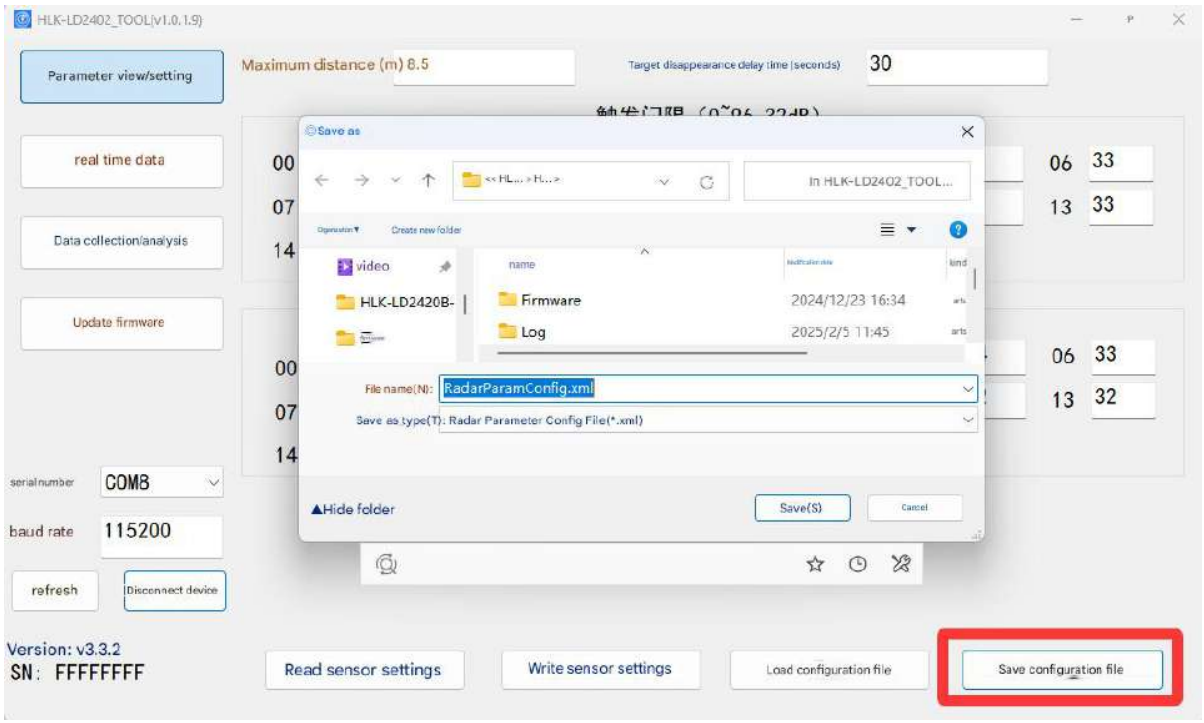


Figure 4- 3 Save configuration file interface

Click the "Load Configuration File" button, the host computer tool will open the millimeter wave sensor parameter configuration file in the path specified by the user and read the millimeter wave sensor parameters. Click the "Write Sensor Settings" button to write the parameters in the configuration file to the millimeter wave sensor.

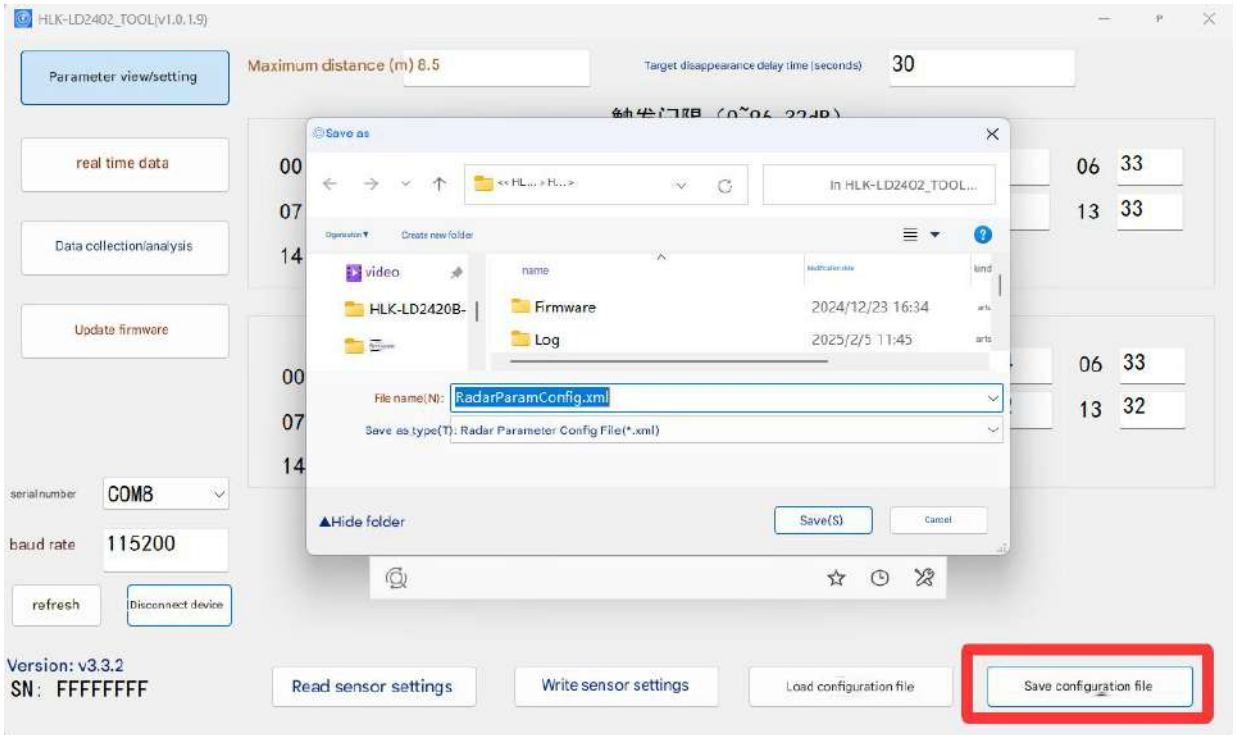


Figure 4-4 Loading configuration file interface

4.2.2.Real-time data

The "Real-time Data" page of the host computer is shown in Figure 4-5 . Its function page is mainly divided into target information area a, function button area b, and real-time data area c. The detailed introduction is shown in Table 4-3 .

Figure 4-5 Real -time data page

Table 4- 3 Function description of each area on the "Real-time Data" page

Page Area		Function	illustrate
a	Lantern Icon	the presence of human targets in the detection area.	Red means someone is there; green means no one is there
	Target information text box	Displays the detected target distance information	Displays the straight-line distance between the human target and the sensor.
b	Start/Pause toggle button	Start / stop sensor for human presence detection	-
	Generate Gate button	, " micro-motion threshold" and "hold threshold" of each distance gate according to the threshold generation coefficient	Table 4-2 for the definition of trigger threshold and micro- threshold .
c	"Motion	Real-time display of the motion	A black background indicates that the

	information/micro motion & stationary information " real-time detection data display	energy value (green line) and threshold value (red line) of each range gate	range gate is within the valid detection range, and a gray background indicates that the range gate is within the invalid detection range.
	“ Distance VS Time ” real-time detection data display	Real-time display of the distance change of the target human body detected by the millimeter wave sensor in the past 60 seconds	The gray background area indicates that the sensor detects the target person in this time period, and the black background area indicates that the sensor does not detect the target person in this time period.

The steps to view real-time data through the host computer are as follows:

Step 1. After connecting HLK-LD2402 and the host computer tool, click the "Real-time Data" button to switch to the function page. At this time, the host computer tool automatically turns on the detection function of the millimeter wave sensor, and the "Start/Pause" switch button displays "Pause". The two line graphs on the host computer function page begin to display the corresponding real-time data information;

Step 2 (optional) : Click the "Start/Pause" switch button to pause the detection function of the millimeter wave sensor. The colored light on the function page turns green, the target distance displays "0.00 meters", and the two line graphs below stop updating.

4.2.3.Automatic threshold generation

The steps to generate sensor detection thresholds through the host computer tool are as follows:

Step 1: On the "Real-time Data" page, click the "Generate Threshold" button, and the "Threshold Generation" window will appear;

The trigger and hold threshold generation coefficients are displayed above the "Threshold Generation" window. The threshold generation coefficient is proportional to the sensitivity of the millimeter wave sensor and the value range is 1.0~20.0 ; the threshold generation progress bar and the text of the specific generation progress are displayed below (the text is visible during the threshold generation process);

Step 2: After inputting the trigger and hold threshold generation coefficients in the "Threshold

Generation" window, click the "Start / Close" switch button, and the host computer tool will start to automatically generate the threshold. The progress bar and the text below will display the generation progress in real time, as shown in Figure 4-6 ;

Step 3. When the threshold generation is completed, the text in the lower left corner displays "Threshold generation successful.", and the "Start / Close" switch button displays "Close". Click the "Close" button to complete the threshold generation.

After the threshold is successfully generated, the generated threshold value is automatically saved, and the host computer tool automatically reads and applies the newly generated threshold.

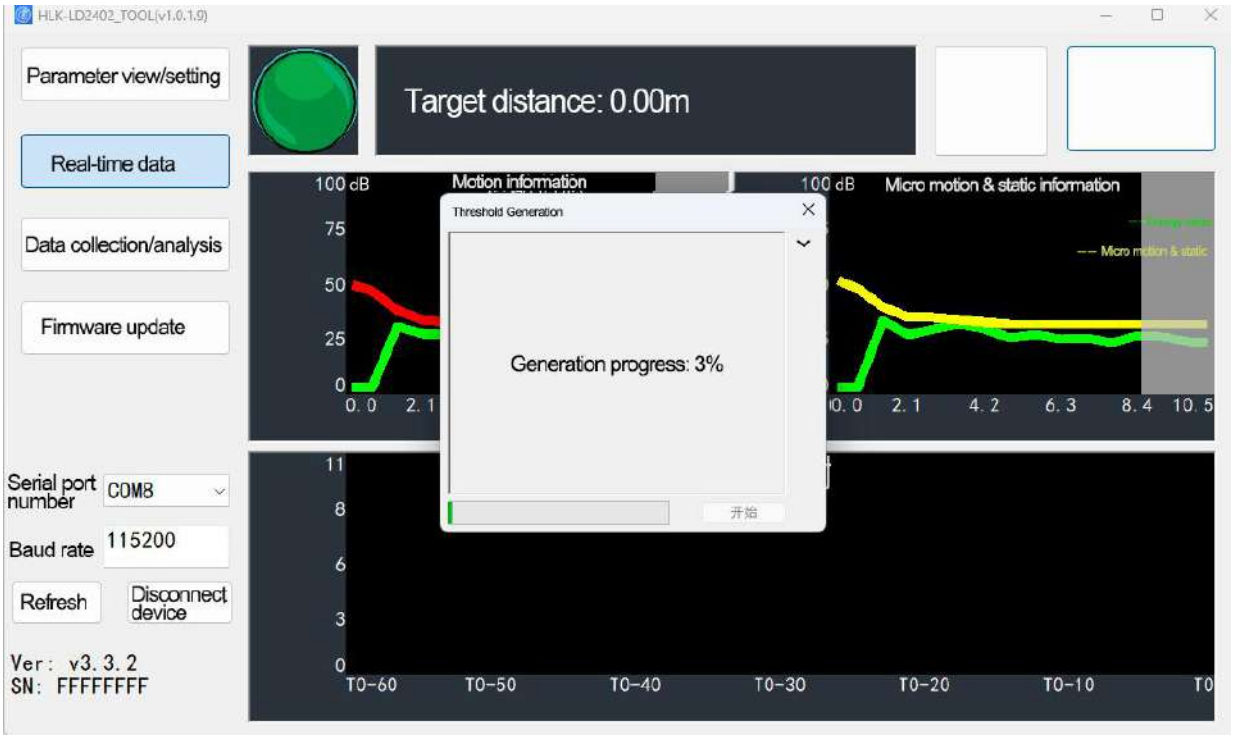


Figure 4-6 Threshold Generation Page

During the threshold generation process, the environment within the detection range must be kept clear. If there is obvious human movement during the generation period, the host will give a prompt after the generation is completed. If there is great interference in the environment so that the module cannot even work properly for basic motion detection, it will prompt to regenerate the threshold, as shown in Figure 4-7. If there is minor interference in the environment so that the module's detection performance is reduced, it will prompt the distance where the interference exists, and the user can choose whether to regenerate the threshold, as shown in Figure 4-8:

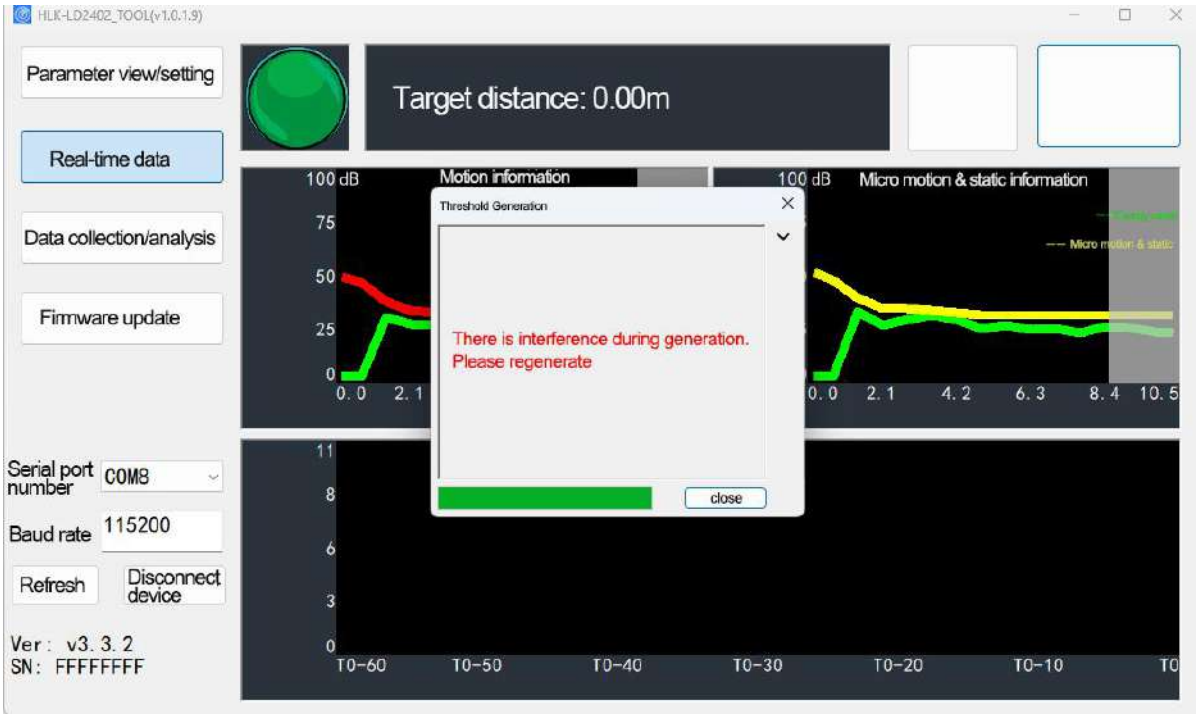


Figure 4-7 During the generation, there is a page that prompts obvious human interference

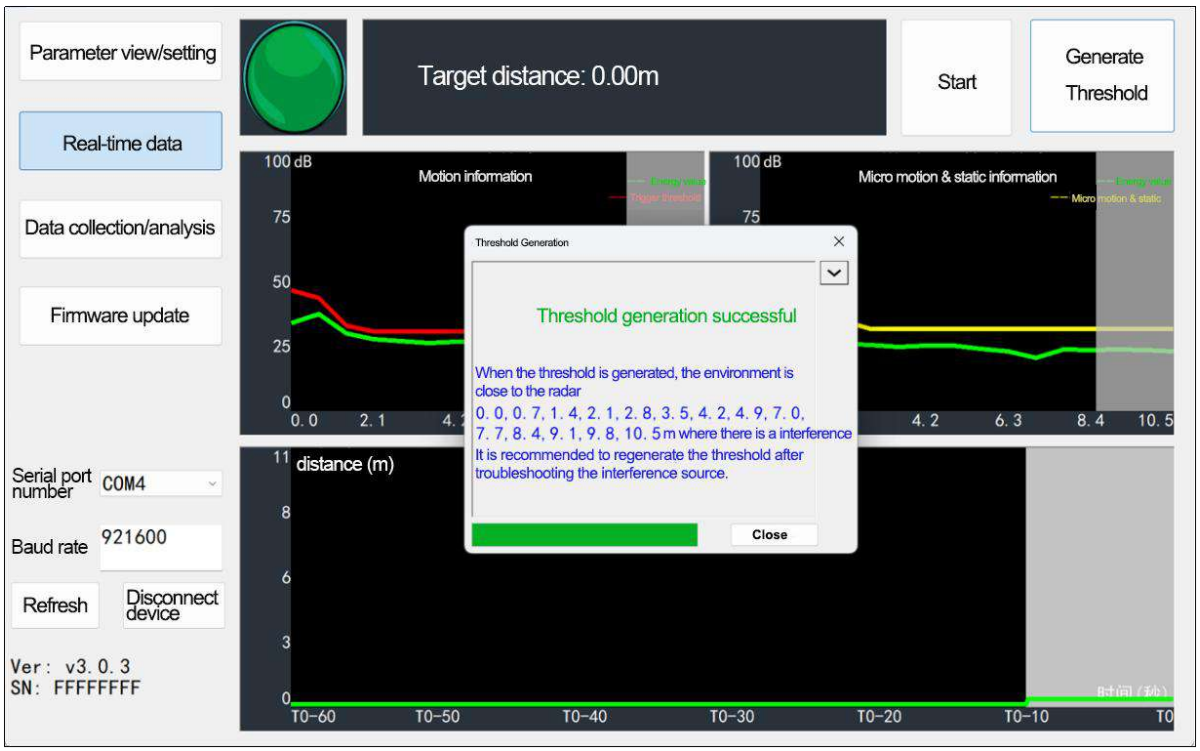


Figure 4-8 Page showing minor interference during generation

4.2.4. Power supply interference warning

After the radar module is powered on, it will perform a 10s self-test on the module power supply. If there is obvious interference in the power supply, the host computer will give a prompt

(the absence of a prompt from the host computer does not mean that there is no interference in the power supply), as shown in the following figure:

Figure 4- 9 Power supply interference prompt page

4.2.5. Update the firmware

The "Update Firmware" page of the host computer is shown in Figure 4-10 . The steps to update the millimeter wave sensor firmware through the host computer are as follows:

Step 1: After connecting HLK-LD2402 and the host computer tool, click the "Update Firmware" function button to switch to the function page;

Step 2 [2]: Click the "Get Firmware Information" button on the function page, and the ID information of the current device will be displayed in the prompt information box on the right;

Step 3. Click the "Select bin file path" button, select the required .bin file, and click the "Download" button to start upgrading the firmware. The prompt box on the right will display the download results in real time, and the bin file information and current download progress will be displayed below.

[2] This step is required and cannot be skipped when the user updates the firmware using the host computer interface.

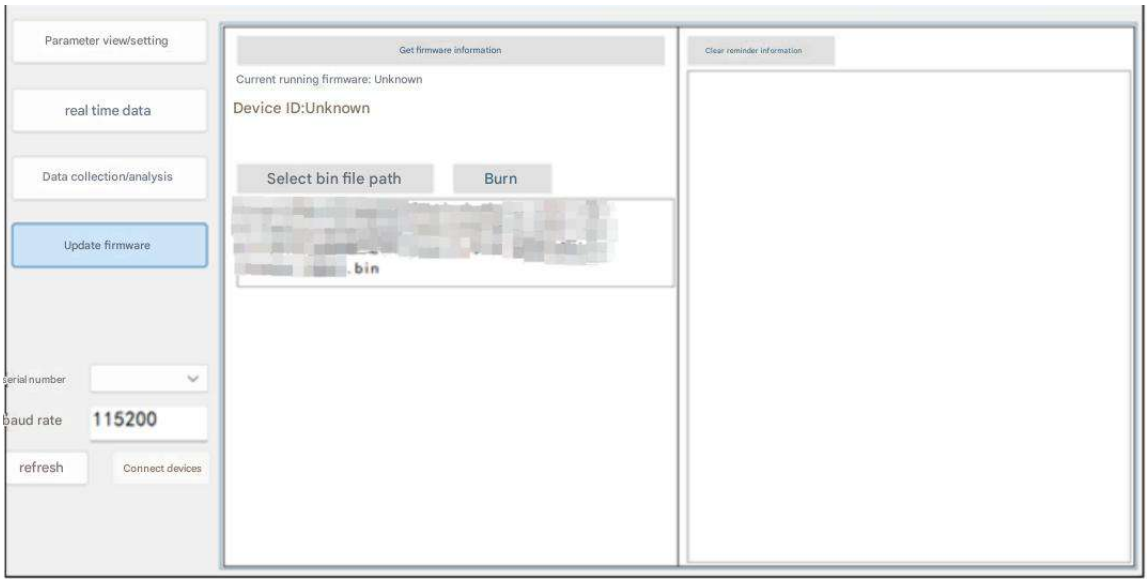


Figure 4-10 Firmware upgrade page

After the firmware upgrade is successful, the page prompt box will display "Download Successful!". If the firmware upgrade fails, the corresponding error message will be displayed in the prompt box.

5. Communication Protocol

This communication protocol is mainly used by users who need to perform secondary development without visualization tools. HLK-LD2402 communicates with the outside world through the serial port (TTL level). The data output and parameter configuration commands of the millimeter wave sensor are all carried out under this protocol. The default baud rate of the millimeter wave sensor serial port is 115200 , 1 stop bit, and no parity bit.

This chapter mainly introduces this communication protocol from three parts:

- Protocol format: including protocol data format and command frame format;
- Configuration command package format: including command package format and command return package format;
- Upload data frame format: including the upload data frame format of the debugging mode and the upload data frame format of the reporting mode.

The basic process of using commands to configure parameters is:

1. Enter command mode;
2. Configure parameter command/get parameter command;
3. Exit command mode.

5.1. Protocol Format

5.1.1.Protocol data format

HLK-LD2402 uses the little endian format. All the data in the following table are in hexadecimal.

5.1.2.Command protocol frame format

The mmWave sensor configuration command and ACK command formats defined by the protocol are shown in Table 5-1 and Table 5-3 .

Table 5-1 Send command protocol frame format

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

Table 5-2 Data format in the transmission frame

Command word (2 bytes)	Command value (N bytes)

Table 5-3 ACK command protocol frame format

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

Table 5- 4 ACK frame data format

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

5.2. Send command and ACK

5.2.1.Read firmware version command

This command reads the mmWave sensor firmware version information.

Command word: 0x0000

Command value: None

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

Sending data:

Frame Header	Data length in frame	Command word	Frame end
FD FC FB FA	02 00	00 00	04 03 02 01

ACK (success, data is an example):

Frame Header	Data length in frame	Command word	ACK	Version number length	Version Number	Frame end

FD FC FB FA	0C 00	00 01	00 00	06 00	76 33 2E 30 2E 33	04 03 02 01

ACK (success, 76 33 2E 30 2E 33 version number converted to string is V3.0.3):

5.2.2.Enable configuration command

Any other commands sent to the millimeter wave sensor must be executed after this command is sent, 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)

Sending data:

Frame Header	Data length in frame	Command word	Command Value	Frame end
FD FC FB FA	04 00	FF 00	01 00	04 03 02 01

ACK (success):

Frame Header	Data length in frame	Command word	ACK	Protocol Version	Buffer size	Frame end
FD FC FB FA	08 00	FF 01	00 00	02 00	20 00	04 03 02 01

5.2.3.End configuration command

After executing the end configuration command, the millimeter wave sensor resumes working mode. If you need to send other commands again, you need to send the enable configuration command first.

Command word: 0x00FE

Command value: None

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

Sending data:

Frame Header	Data length in frame	Command word	Frame end
FD FC FB FA	02 00	FE 00	04 03 02 01

ACK (success):

Frame Header	Data length in frame	Command word	ACK	Frame end
FD FC FB FA	04 00	FE 01	00 00	04 03 02 01

5.2.4.Read serial number command (hexadecimal format)

This command reads the serial number of the millimeter wave sensor. (Only versions 3.3.5 and above support this command)

Command word: 0x001 6

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

Sending data:

Frame Header	Data length in frame	Command word	Frame end
FD FC FB FA	02 00	1 6 00	04 03 02 01

ACK (successful , S N is an example):

Frame Header	Data length in frame	Command word	ACK	SN length	SN	Frame end
FD FC FB FA	0 9 00	1 6 01	00 00	0 3 00	25 03 18	04 03 02 01

5.2.5.Read serial number command (character form)

This command reads the serial number of the mmWave sensor.

Command word: 0x0011

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

Sending data:

Frame Header	Data length in frame	Command word	Frame end
FD FC FB FA	02 00	1 1 00	04 03 02 01

ACK (successful , S N is an example):

Frame Header	Data length in frame	Command word	ACK	SN length	SN	Frame end
FD FC FB FA	0 C 00	1 1 01	00 00	0 6 00	32 35 30 33 31 38	04 03 02 01

Note: For versions below 3.3.5, this command reads the SN code in hexadecimal format .

5.2.6.Read sensor parameter configuration command

This command can read the current configuration parameters of the sensor.

Command word: 0x0008

Command value: (2-byte parameter ID) * N

Return value: (4-byte parameter value) * N

Send data (example):

Frame Header	Data length in frame	Command word	Parameter ID	Frame end
FD FC FB FA	04 00	08 00	01 00	04 03 02 01

Frame Header	Data length in frame	Command word	ACK	Parameter Value	Frame end
FD FC FB FA	08 00	08 01	00 00	64 00 00 00	04 03 02 01

ACK (success, 0x64 converted to decimal is 100 , reduced by ten times and the maximum distance is 10):

5.2.7.Configure sensor parameter commands

This command sets the parameters of the millimeter wave sensor. For specific parameter IDs , please refer to Table 5-5 , which adds micro-motion threshold parameters and power supply interference alarm parameters.

Table 5- 5 Sensor parameter table

Parameter name	Parameter ID	Parameter range
Maximum distance	0x0001	7 ~ 1 0 0 (maximum setting range is 10m, effective distance is 10m)
Target disappearance delay	0x0004	0~65535 Unit: seconds
Motion trigger threshold	0x0010 ~ 0x001F	0-95 , is the square of the modulus value
Micro-threshold	0x0030 ~ 0x003F	0-95 , is the square of the modulus value
Power supply interference alarm	0x 0005	0: not performed; 1: no interference; 2: There is interference. This parameter is read-only.

Command word: 0x0007

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

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

Send data (Example: 0x78 converted to decimal is 120, reduced by ten times and the maximum distance is 12) :

Frame Header	Data length in frame	Command word	Parameter ID	Parameter Value	Frame end
FD FC FB FA	08 00	07 00	01 00	78 00 00 00	04 03 02 01

ACK (Success):

Frame Header	Data length in frame	Command word	ACK	Frame end
FD FC FB FA	04 00	07 01	00 00	04 03 02 01

Threshold parameter description: Assume that N is the parameter configured by the host computer, and M is the parameter configured by the serial port. The parameter conversion relationship between the host computer and the serial port is N= $(10 * \log_{10} M)$ M = $10^{\frac{N}{10}}$. For example , if the serial port configures the distance gate 0 threshold value as 65536, the corresponding host computer is $（10 * \log_{10} 65536）\approx 48.16$. For example , if the parameter set by the host computer is 70, the corresponding serial port configuration parameter is $10^{\frac{70}{10}} \approx$ 10000000, and the instruction is converted to hexadecimal, with the little end first, it is: *0x80969800*

5.2.8.Configure data output mode command

This command can configure the mmWave sensor system parameters and is used to configure the sensor's data output mode.

Command word: 0x0012

Command value: 0x0000

Parameter value : 0x00000004 (engineering mode), 0x00000064 (normal working mode)

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

Send data (example) :

Frame Header	Data length in frame	Command word	Command Value	Parameter Value	Frame end
FD FC FB FA	08 00	12 00	00 00	04 00 00 00	04 03 02 01

ACK (Success):

Frame Header	Data length in frame	Command word	ACK	Frame end
FD FC FB FA	04 00	12 01	00 00	04 03 02 01

5.2.9.Start automatic threshold generation command

This command sets the parameters for automatic threshold generation and enables the MCU to start automatically generating threshold calculations. For specific parameter words, please refer to Table 5-6 .

Table 5- 6 Automatic threshold generation parameter table

Parameter name	Parameter range	illustrate
Trigger threshold generation coefficient	0x000A~0x00C8	10 times magnification factor, for example, when the factor is 3 , the parameter value is 0x001 E
Keep threshold generation coefficient	0x000A~0x00C8	10 times magnification factor, for example, when the factor is 2 , the parameter value is 0x0014
Micro-threshold generation coefficient	0x000A~0x00C8	10 times magnification factor, for example, when the factor is 3 , the parameter value is 0x001 E

Command word: 0x0009

Command value: 6-byte parameter value

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

Send data (for example: the trigger threshold generation factor is 3 , the hold threshold generation factor is 3):

Frame Header	Data length in frame	Command word	Parameter Value	Frame end

FD FC FB FA	08 00	09 00	Two-byte trigger threshold + two-byte hold threshold + two-byte micro-threshold (default coefficient is 3)	04 03 02 01
FD FC FB FA	08 00	09 00	1 E 00 14 00 1 E 00	04 03 02 01

ACK (Success):

Frame Header	Data length in frame	Command word	ACK	Frame end
FD FC FB FA	04 00	09 01	0000: Success; Others: Failure	04 03 02 01

5.2.10.Automatic threshold progress query command

This command can be used to query the progress of automatic threshold generation. The return value contains the progress percentage. When the percentage is 100 , it means that the threshold generation is complete.

Command word: 0x000A

Return value: 2 bytes ACK status (0 success, 1 failure) + 2 bytes percentage

Sending data:

Frame Header	Data length in frame	Command word	Frame end
FD FC FB FA	02 00	0A 00	04 03 02 01

ACK (successful, example: the percentage is 60%):

Frame Header	Data length in frame	Command word	ACK	percentage	Frame end
FD FC FB FA	06 00	0A 01	00 00	3C 00	04 03 02 01

5.2.11.Report automatic threshold interference

This command reports the millimeter wave sensor automatic threshold motion human interference alarm.

Frame Header	Data length in frame	Command word	Frame end
FD FC FB FA	02 00	14 00	04 03 02 01

ACK :

Frame Header	Data length in frame	Command word	Command word	Frame end
FD FC FB FA	06 00	14 01	2-byte status byte + 2-byte range gate status . Status byte: 0000: Success, no interference; 0001: Failure, interference Range gate status: Example: 0x84, converted to binary, is 1000_0100_0000_0010, corresponding to the existence of 1, 10, and 15 distance gates.	04 03 02 01

5.3. Parameter save command

This command is used to save the configuration parameters after power failure . (Only versions 3.3.2 and above support this command)

Frame Header	Data length in frame	Command word	Frame end
FD FC FB FA	02 00	FD 00	04 03 02 01

ACK :

Frame Header	Data length in frame	Command word	ACK	Frame end
FD FC FB FA	0 4 00	FD 01	00 00	04 03 02 01

This command is sent after writing the parameters, and the enable configuration can be exited after receiving the radar reply .

5.4. Power-on automatic gain adjustment command

This command is used to automatically adjust the internal gain of the module. (Only versions 3.3.5 and above support this function)

Function introduction: The firmware contains the initial values of the transmit power and receive gain . When the radar is not well matched with the shell, it may be saturated and cannot work normally . If 2402 detects saturation, it will automatically reduce the gain to make the radar unsaturated. This is the automatic gain adjustment function.

Frame Header	Data length in frame	Command word	Frame end
FD FC FB FA	02 00	EE 00	04 03 02 01

ACK :

Frame Header	Data length in frame	Command word	ACK	Frame end
FD FC FB FA	0 4 00	EE 01	00 00	04 03 02 01

Adjustment completed reply:

Frame Header	Data length in frame	Command word	ACK	Frame end
FD FC FB FA	0 4 00	F0 0 0	0 1 00	04 03 02 01

5.5. Parameter power-off saving function setting process

Since the firmware will only save the parameter after recognizing the parameter name as 0x003F, the power-off saving function is divided into two steps, namely 5.2.6 reading parameters and 5.2.7 setting parameters.

（1）When the parameter value corresponding to 0x003F does not need to be modified, first read the parameter value and then set the parameter command to reset the read parameter value.

（2）When you need to modify the parameter value corresponding to 0x003F, you do not need to read it again, just set the parameter directly.

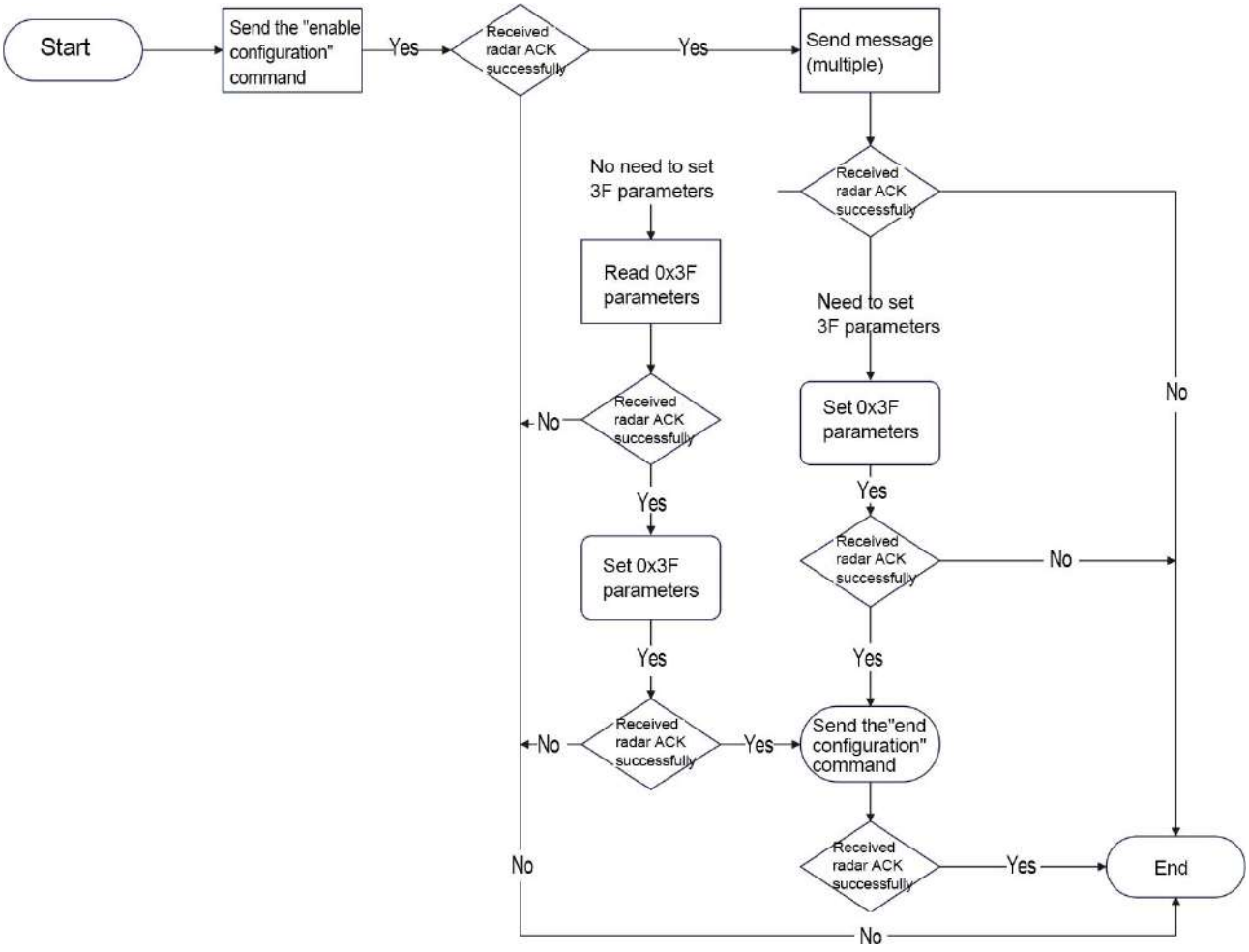


Figure 5-1 Parameter power-off saving configuration flow chart

5.5.1.Read 0X3F parameter

Send data (example):

Frame Header	Data length in frame	Command word	Parameter ID	Frame end
FD FC FB FA	04 00	08 00	3F 00	04 03 02 01

Frame Header	Data length in frame	Command word	ACK	Parameter Value	Frame end
FD FC FB FA	08 00	08 01	00 00	A0 86 01 0 0	04 03 02 01

ACK (success, micro-move 15 distance gate threshold 50):

5.5.2.Configure 0x3F parameters

Sending data:

Frame Header	Data length in frame	Command word	Command Value	Parameter Value	Frame end
FD FC FB FA	08 00	07 00	3F 00	A0 86 01 00	04 03 02 01

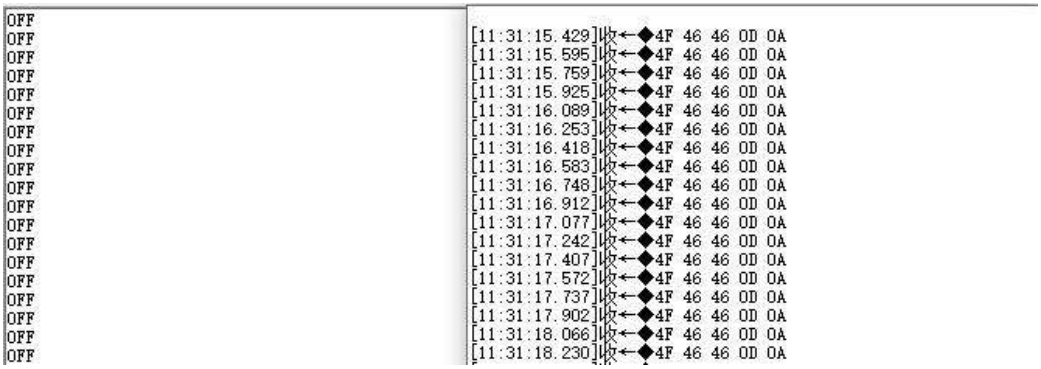
ACK (Success):

Frame Header	Data length in frame	Command word	ACK	Frame end
FD FC FB FA	04 00	07 01	00 00	04 03 02 01

5.6. Reporting data

5.6.1.Normal working mode

The HLK-LD2402 factory firmware outputs the detection results through the serial port in normal working mode. When there is no target, it outputs OFF, and when there is a target, it outputs the target distance : XX . The left side is the character data, and the right side is the hexadecimal data corresponding to the character data.



```
distance:436
distance:388
distance:339
distance:292
distance:295
distance:295
distance:295
distance:295
distance:295
distance:295
distance:295
distance:295
distance:295
distance:295
distance:295
distance:295
distance:295
distance:295
distance:294
distance:294
distance:294
```

```
[10:52:27.122]收←◆64 69 73 74 61 6E 63 65 3A 34 33 36 0D 0A
[10:52:27.288]收←◆64 69 73 74 61 6E 63 65 3A 33 38 38 0D 0A
[10:52:27.452]收←◆64 69 73 74 61 6E 63 65 3A 33 33 39 0D 0A
[10:52:27.616]收←◆64 69 73 74 61 6E 63 65 3A 32 39 32 0D 0A
[10:52:27.781]收←◆64 69 73 74 61 6E 63 65 3A 32 39 35 0D 0A
[10:52:27.946]收←◆64 69 73 74 61 6E 63 65 3A 32 39 35 0D 0A
[10:52:28.114]收←◆64 69 73 74 61 6E 63 65 3A 32 39 35 0D 0A
[10:52:28.275]收←◆64 69 73 74 61 6E 63 65 3A 32 39 35 0D 0A
[10:52:28.439]收←◆64 69 73 74 61 6E 63 65 3A 32 39 35 0D 0A
[10:52:28.605]收←◆64 69 73 74 61 6E 63 65 3A 32 39 35 0D 0A
[10:52:28.769]收←◆64 69 73 74 61 6E 63 65 3A 32 39 35 0D 0A
[10:52:28.934]收←◆64 69 73 74 61 6E 63 65 3A 32 39 35 0D 0A
[10:52:29.099]收←◆64 69 73 74 61 6E 63 65 3A 32 39 35 0D 0A
[10:52:29.264]收←◆64 69 73 74 61 6E 63 65 3A 32 39 35 0D 0A
[10:52:29.428]收←◆64 69 73 74 61 6E 63 65 3A 32 39 35 0D 0A
[10:52:29.594]收←◆64 69 73 74 61 6E 63 65 3A 32 39 35 0D 0A
[10:52:29.759]收←◆64 69 73 74 61 6E 63 65 3A 32 39 35 0D 0A
[10:52:29.923]收←◆64 69 73 74 61 6E 63 65 3A 32 39 35 0D 0A
[10:52:30.088]收←◆64 69 73 74 61 6E 63 65 3A 32 39 35 0D 0A
[10:52:30.253]收←◆64 69 73 74 61 6E 63 65 3A 32 39 34 0D 0A
[10:52:30.417]收←◆64 69 73 74 61 6E 63 65 3A 32 39 34 0D 0A
```

5.6.2.Engineering Mode

In a special mode, the host computer will obtain the data during the millimeter wave sensor processing process. Therefore, the firmware provides two additional transmission formats in the command line mode, which are the normal character reporting mode and the energy value reporting mode.

In command line mode, the data format reported by the serial port can be controlled by adjusting the working mode parameters in the command packet. Figure 5-2 shows an example of a command packet.

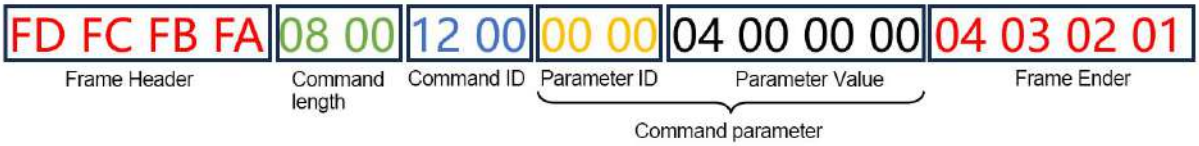


Figure 5-2 Command packet format example

Table 5-7 shows the data frame format in reporting mode.

Table 5-7 Data frame format of reporting mode

Frame Header	length	Test results	Target distance	Energy value of each range gate	Frame end
F4, F3, F2, F1	2 bytes, the total number of bytes of detection results, target distance and energy values of each	1 byte, 00No one 01Someone 02Someone is still	2 bytes	128 bytes 32 (total number of range gates) * 4 bytes	F8, F7, F6, F5

	range gate				

Sample data frame: F4 F3 F2 F1 83 00 01 66 00 F6 11 00 00 6C 0A 00 00 3D 02 00 00 A3 02 00 00 20 03 00 00 50 06 00 00 57 03 00 00 48 01 00 00 F3 01 00 00 3B 01 00 00 07 01 00 00 00 01 00 00 D2 00 00 00 23 01 00 00 F3 00 00 00 F4 00 00 00 B1 27 03 00 F3 0B 01 00 70 3E 00 00 8E 12 00 00 C5 08 00 00 3F 10 00 00 25 03 00 00 7A 06 00 00 7F 08 00 00 7E 07 00 00 FB 05 00 00 64 04 00 00 F3 04 00 00 2D 04 00 00 F9 03 00 00 43 04 00 00 F8 F7 F6 F5

Frame header: F4 F3 F2 F1

Length: 83 00 (little endian format, converted to decimal: 131)

Detection result: 01 (someone is present)

Target distance: 66 00 (little endian format, converted to decimal: 102cm)

Sports energy value: F6 11 00 00 6C 0A 00 00 3D 02 00 00 A3 02 00 00 20 03 00 00 50 06 00 00 57 03 00 00 48 01 00 00 F3 01 00 00 3B 01 00 00 07 01 00 00 00 01 00 00 D2 00 00 00 23 01 00 00 F3 00 00 00 F4 00 00 00

2D 04 00 00 F9 03 00 00 43 04 00 00 3F 10 00 00 25 03 00 00 7A 06 00 00 7F 08 00 00 7E 07 00 00 FB 05 00 00 64 04 00 00 F3 04 00 00 2D 04 00 00 F9 03 00 00 43 04 00 00

Example analysis: F6 11 00 00 (little endian format, converted to 000011F6, converted to decimal 4598, energy value: $（10 * \log_{10} 4598）\approx 36.62$**)**

Frame end: F8 F7 F6 F5

6. Installation and detection range

HLK-LD2402 supports two installation methods: ceiling-mounted and wall-mounted. The recommended method is ceiling-mounted installation.

The direction definition of the HLK-LD2402 millimeter wave sensor is shown in Figure 6-1, where the X-axis direction is 0° , the Z-axis direction is 90° , and the Y-axis is perpendicular to the XZ plane (also called the normal direction).

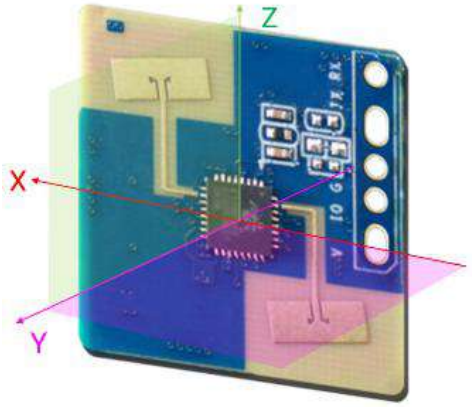


Figure 6- 1 HLK-LD2402 Direction Definition Diagram

6.1. Ceiling installation

the HLK-LD2402 mounted on the ceiling at a height of 3m is a conical space with a bottom radius of 5m, as shown in Figure 6-2.

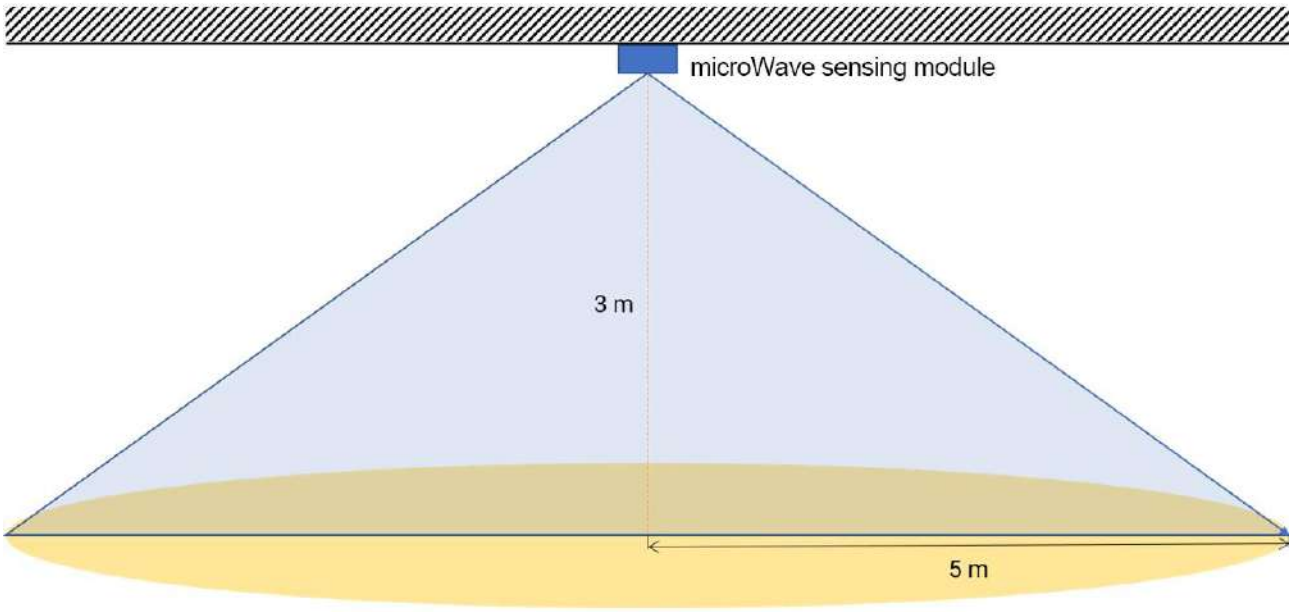


Figure 6- 2 HLK-LD2402 ceiling installation detection range diagram

It should be noted that as the installation height decreases, the maximum sensing range

gradually decreases, as shown in Figure 6-3 .

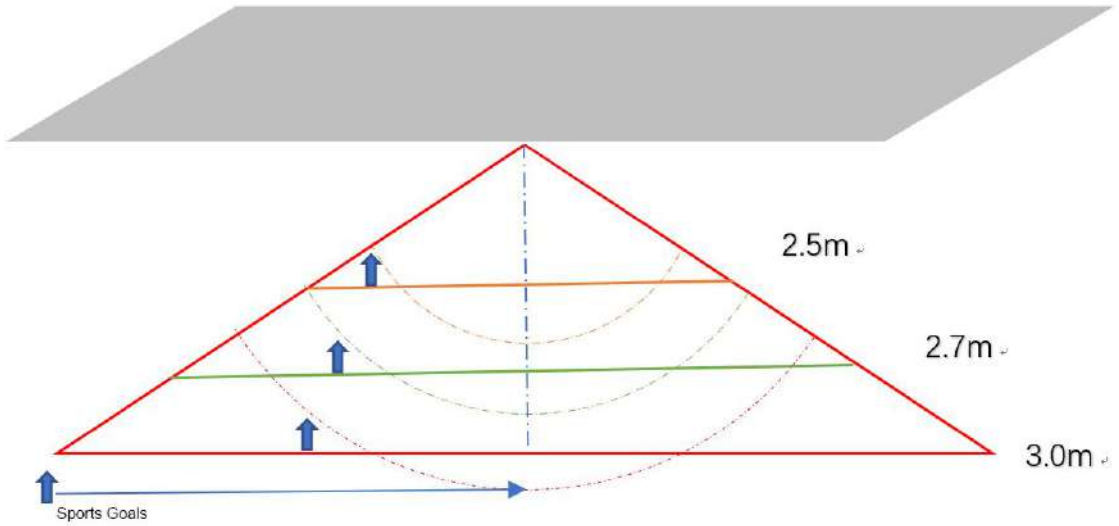


Figure 6- 3 Schematic diagram of the relationship between HLK-LD2402 ceiling installation height and detection range

The schematic diagram of the motion and micro-motion detection range of this reference scheme when the ceiling installation height is 2.7 m is shown in Figure 6-4 .

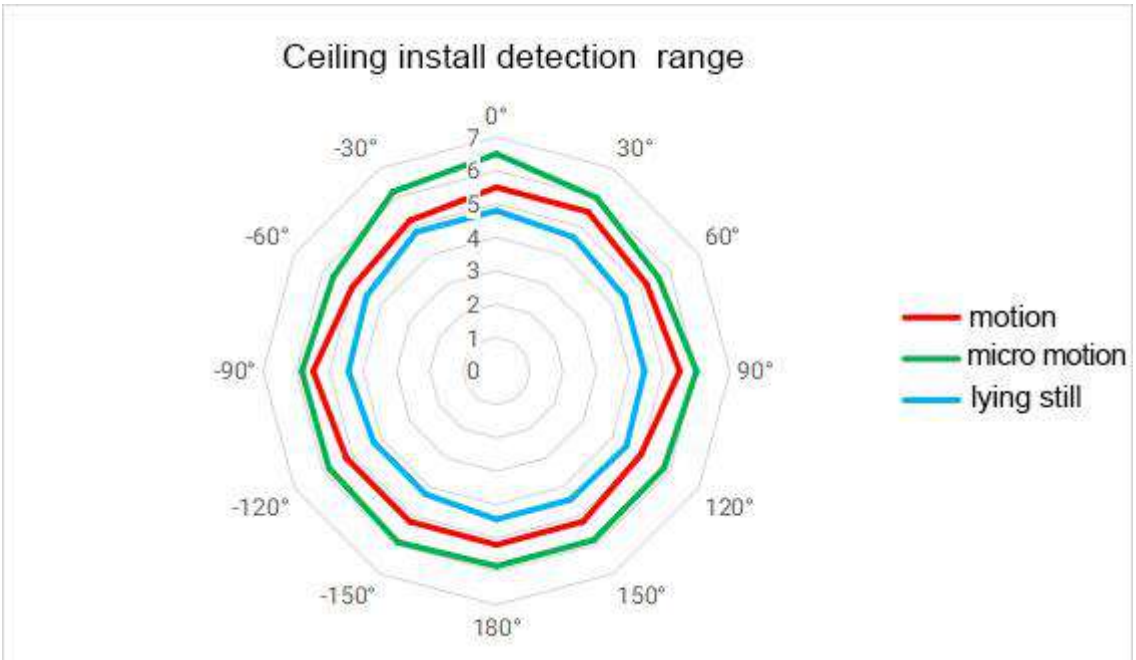


Figure 6- 4 HLK-LD2402 ceiling mounted sensing range

6.2. Wall Mounting

The recommended wall mounting height is 1.5~2 m. When mounted on a wall, the X-axis (reference) of the millimeter wave sensor points horizontally, the Z-axis points upward, and the Y-axis points to the detection area. The maximum motion sensing range of the wall-mounted HLK-LD2402 in the default configuration is a conical space within 10 m in the normal direction of the sensor and within ±60° in the horizontal and pitch directions, as shown in Figure 6-5.

The detection range diagram of this reference solution when the wall-mounted installation height is 1.5 m is shown in Figure 6-6 .

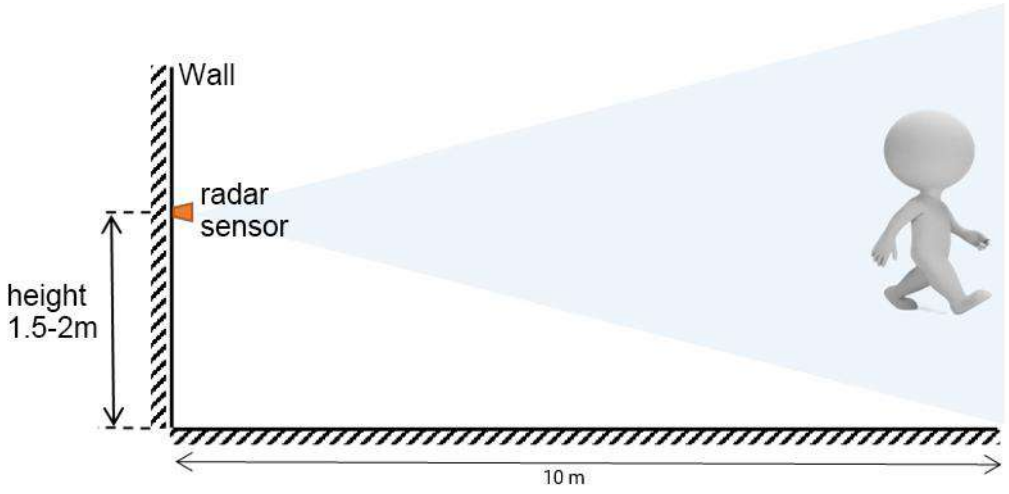


Figure 6- 5 HLK-LD2402 wall-mounted detection range diagram

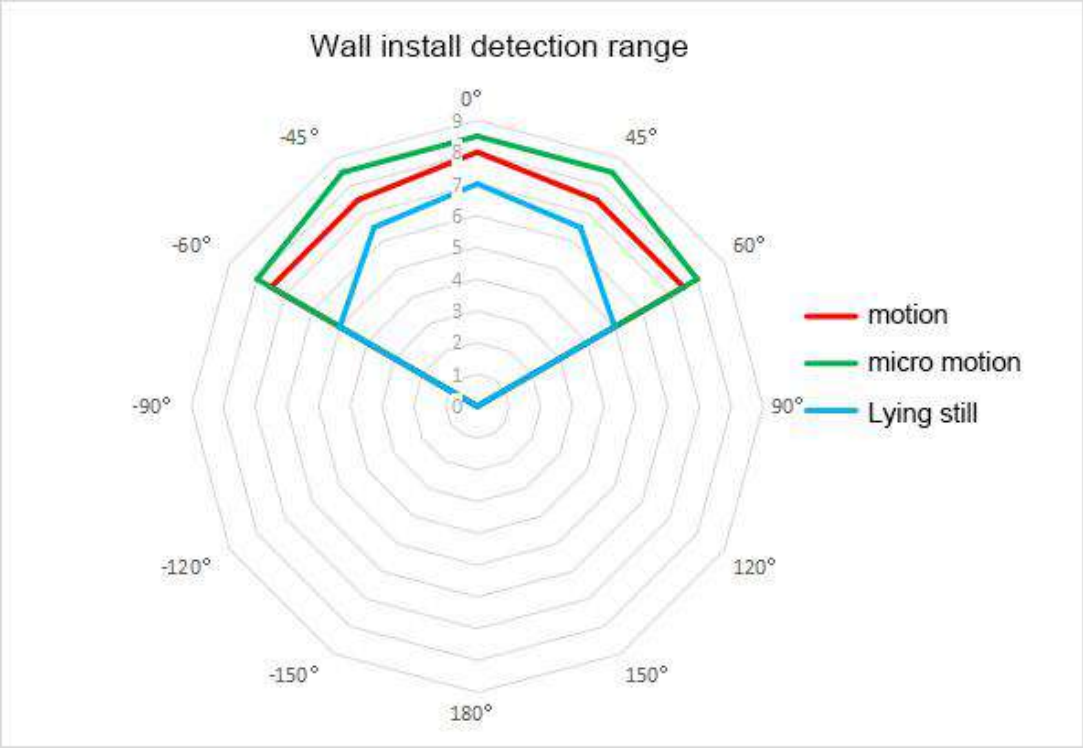


Figure 6- 6 HLK-LD2402 wall mounted sensing range

6.3. Detection range test

The test methods for triggering and maintaining the detection range of the millimeter wave sensor are described as follows:

Trigger range: When the target person approaches the sensor from a distance while the millimeter wave sensor reports that there is no one, and stops moving when the sensor starts to report that there is someone, the current position is the boundary of the millimeter wave sensor's trigger detection range; the area surrounded by the detection boundaries in all directions is the millimeter wave sensor's trigger detection range;

Holding range: When the millimeter wave sensor reports that there is a person, the target person keeps a small movement at the position to be detected, such as shrugging or raising the hand. If the millimeter wave sensor continues to report that there is a person within 60 seconds, the current position is within the holding detection range of the millimeter wave sensor; otherwise, the detection position is outside the holding detection range.

7. Mechanical Dimensions

Figure 7-1 shows the mechanical dimensions of the hardware HLK-LD2402 , all units are mm. The board thickness of the hardware HLK-LD2402 is 1.2 mm, with a tolerance of ±10%.

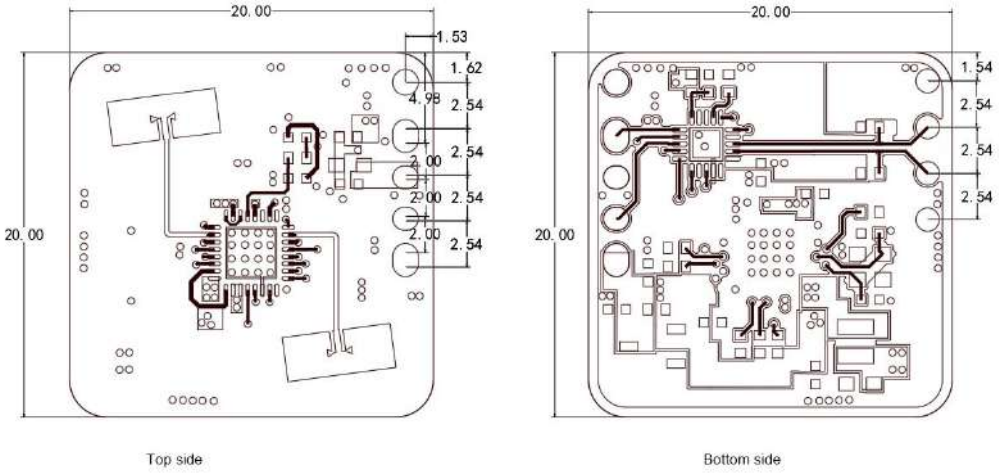


Figure 7-1 Hardware HLK -LD2402 Mechanical Dimensions

8. Installation Instructions

8.1. mmWave sensor housing requirements

If the millimeter wave sensor needs to be installed in a housing, the housing must have good wave transmission characteristics in the 24 GHz frequency band and cannot contain metal or materials that have a shielding effect on electromagnetic waves. For more considerations, please refer to the "Millimeter Wave Sensor Antenna Cover Design Guide" .

8.2. Installation environment requirements

This product needs to be installed in a suitable environment. If used in the following environment, the detection effect will be affected:

There are non-human objects that are constantly moving in the sensing area, such as animals, continuously swinging curtains, and large green plants facing the air vents.

There is a large area of strong reflective plane in the sensing area, and the strong reflective object facing the antenna will cause interference.

When wall-mounted, external interference factors such as air conditioners and electric fans on the ceiling of the room need to be considered.

8.3. Notes on installation

Try to ensure that the antenna is facing the area to be detected and that there is an open area around the antenna without any obstructions.

It is necessary to ensure that the installation position of the millimeter wave sensor is firm and

stable; the shaking of the sensor itself will affect the detection effect.

Make sure that there is no movement or vibration on the back of the millimeter wave sensor. Since millimeter waves are penetrating, the antenna back lobe may detect moving objects on the back of the sensor. A metal shield or metal back plate can be used to shield the antenna back lobe to reduce the impact of objects on the back of the sensor.

When there are multiple 24 GHz band millimeter wave sensors, do not face each other with their beams and install them as far away as possible to avoid possible mutual interference.

8.4. Power Supply Considerations

The power input voltage range is 3.0 V ~ 3.6 V, and the power ripple has no obvious spectrum peak within 100 kHz. This solution is a reference design, and users need to consider the corresponding electromagnetic compatibility design such as ESD and lightning surge.

9. Precautions

9.1. Maximum detection distance

The maximum range of the millimeter wave sensor to detect a target is 10 meters in radial distance. Within the detection range, the millimeter wave sensor will report the straight-line distance of the target from the millimeter wave sensor.

9.2. Maximum distance and accuracy

Theoretically, the ranging accuracy of the millimeter wave sensor in this reference scheme is ± 0.15 m . Due to the differences in the body shape, state, and RCS of human targets, the ranging accuracy will fluctuate, and the maximum detection distance will also fluctuate to a certain extent.

9.3. Target disappearance delay

When the millimeter wave sensor detects that there is no human in the target area, it will not immediately report the "no one" status in the area, but will be delayed. The mechanism of delayed reporting is: once no human target is detected in the test range, the millimeter wave sensor will start timing, the duration is the duration of no one, if no one is detected during the timing, then the "no one" status will be reported after the timing ends; if a person is detected during this time period, the timing will be immediately ended and updated, and the target information will be reported.

9.4. Micro motion detection range

The detection range of the millimeter wave sensor for micro-motion of the human body [3]is inversely proportional to the angle between the normal direction of the human body and the normal

[3] When a person stands relaxed and looks straight ahead, the direction of the line of sight is the normal direction of the person.

direction of the sensor. Therefore, in the micro-motion detection scenario, it is recommended to adjust the position and angle of the millimeter wave sensor when installing it so that the angle between its normal direction and the normal direction of the detected human body is as small as possible, thereby improving the detection accuracy and range.

9.5. Optimization of automatic threshold generation function

The optimization of the automatic threshold generation function improves the overall performance of HLK-LD2402 and brings a better experience to users. The specific optimization contents are as follows:

- **Reduce on-site commissioning workload**

Through the automatic threshold generation function, the system can automatically calculate and set the appropriate threshold value, which significantly reduces the workload of on-site debugging and avoids the shortcomings of engineers needing to manually adjust the threshold value of each millimeter-wave radar during traditional product deployment, making large-scale deployment more efficient and convenient. Improves deployment efficiency and reduces the risk of human error.

- **Improve detection accuracy**

The automatic threshold generation function can automatically calculate the threshold value that best suits the current environment through precise environmental perception and data analysis. This method reduces the interference of manual adjustment and ensures that the radar can maintain optimal detection accuracy in various complex environments. Whether it is stable detection of static targets or fast response to dynamic targets, HLK-LD2402 can provide accurate and reliable results, bringing users a more excellent experience.

- **Simplify the installation process**

The automatic threshold generation function simplifies the radar installation process. Users only need to complete basic installation steps, and the radar can automatically complete the threshold optimization setting without complicated manual debugging.

- **Reduce maintenance costs**

The radar can automatically adjust the threshold value according to environmental changes in real time, reducing the need for regular manual adjustments due to environmental changes. It reduces the workload of maintenance personnel, improves the operating efficiency and stability of the system, and saves maintenance costs for users.

- **Flexible triggering methods**

In order to meet the needs of different users and application scenarios, we provide two flexible trigger threshold automatic generation methods: external trigger and radar automatic judgment of

start conditions.

External trigger: Users can trigger the automatic generation of thresholds through external signals. This method allows users to manually control the time of threshold generation according to the needs of actual application scenarios.

Radar automatically determines the start condition: For users who need a higher degree of automation, we provide the function of radar automatically determining the start condition. This function is based on the radar's built-in intelligent algorithm and can automatically determine when to start generating threshold values. Note that custom firmware may be required to implement this function.

Users can make flexible choices based on their actual needs and application scenarios.

9.6. Ceiling-mounted static lying test instructions

The radar can detect the static state, and the detection sensitivity in the tangential direction is better than that in the radial direction. The following figure shows the examples of the tangential and radial static states:

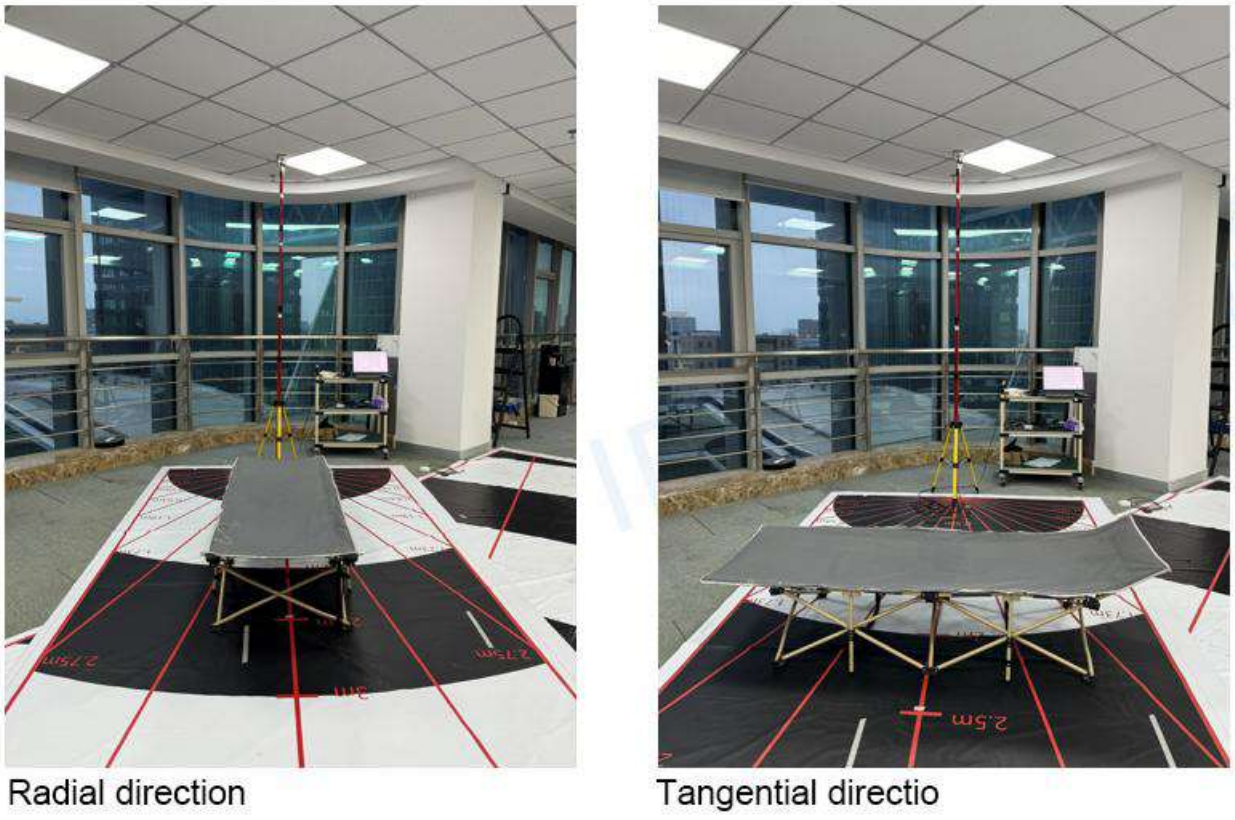


Figure 9-1 Tangential and radial static state examples

Appendix A Document Revision History

Version Number	Scope of Revision	date
V1.00	Initial release.	November 1, 2024
V1.01	Modify dimension units	November 4, 2024
V1.02	（1）Added parameter power-off saving process ; （2）Modify the range gate parameter value settings ; （3）Modify the sensing range and some pictures;	November 7, 2024
V1.03	（1）Modify the energy value output data description and add energy value output data analysis （2）Modify the maximum detection distance	November 19, 2024
V1.04	Modify the default baud rate and add the default LDO not attached note	November 23, 2024
V1.05	Modify the back photo of HLK-LD2402	December 2, 2024
V1.07	Add parameter saving command	February 18, 2025
V1.08	（1）Add automatic gain adjustment command （2）Added the command to read the hexadecimal serial number	March 18, 2025