UM10017
XenD101H User Manual

Rev.3.1 User Manual

Introduction

This document introduces the basic functions, hardware specifications, software configurations, and installation conditions of the ICLEGEND MICRO(ICL) stationary human presence sensor, XenD101H. It aims to assist developers in quickly getting started with the XenD101H stationary human presence sensor, facilitating the configuration of parameters best suited to their application scenarios, and creating personalized precision sensing sensors.

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1. XenD101H Overview

The XenD101H is a stationary human presence sensor of ICL EZ Sensor series, incorporating minimalist 24 GHz sensor hardware Xen101_L1 and intelligent firmware for human presence detection algorithms. It can detect humans in sitting or stationary lying status.

The hardware Xen101_L1 is equipped with the S1 series AIoT mmWave sensor, a high-performance 24 GHz transmit-receive antenna, and peripheral circuitry. The human presence detection algorithm utilizes mmWave sensor ranging technology and the proprietary advanced radar signal processing technology of the S1 series chip to achieve precise detection of motion, micro-motion, and stationary human presence. The intelligent firmware for human presence detection is primarily used in indoor scenarios to sense the presence of moving, micro-moving, or stationary humans within the area and refresh detection results in real-time.

XenD101H has a maximum sensing distance of 7 meters for moving humans and allows easy configuration of sensing distance ranges, trigger and hold thresholds for different range gates, and human absence reporting times. XenD101H supports GPIO and UART interfaces, enabling plug-and-play functionality and flexible application in various smart scenarios and end-products. It also supports automatic generation of detection thresholds, reducing manual debugging, enhancing detection accuracy, simplifying the installation process, and facilitating large-scale deployment.

The key features of XenD101H are as follows:

- Intelligent Design: Equipped with a single-chip intelligent mmWave sensor SoC and intelligent algorithm firmware.
- Compact Size: Sensor dimensions of 20 mm × 20 mm.
- Plug-and-Play: Loaded with default human sensing configurations for immediate use.
- Frequency Band Compliance: Operates in the 24 GHz ISM band, compliant with FCC, CE, and SRRC.
- Wide Voltage Range: Supports 3.3 V and 5V power supplies, compatible with a wide voltage range of 3.0~3.6 V and 4.5~5.5 V.
- Low Power Consumption: Average operating current of 50 mA.
- Multi-Function Detection: Effectively detects moving, micro-moving, and stationary humans, with real-time reporting of detection results.
- Visual Configuration: Provides visualization tools for flexible configuration of detection distance ranges and target disappearance delay times, supporting automatic generation of detection thresholds.
- Sensing Range Management: Supports sensing range division to effectively neglect interference from outside the designated area.
- No Blind Zone Detection: Capable of sensing from a close distance of 0.2 m.
- Wide Angle Coverage: Detection angle of ±60°, providing extensive coverage of the monitoring area.
- Versatile Installation: Supports various installation methods, including ceiling and wall mounting.
- Independent Configuration: Trigger and hold states can be independently configured, with strong anti-interference capabilities.

The XenD101H stationary human presence sensor can detect, recognize, and identify moving, standing, and stationary humans, making it widely applicable in various AIoT scenarios, including:

- **Smart Homes**

Senses the presence and distance of humans, reporting detection results for intelligent control of home appliances by the main control module.

- **Smart Commerce**

Recognizes human approach or departure within set distance intervals; promptly activates screens and keeps devices illuminated in the presence of humans.

- **Smart Security**

Used in access control, building intercoms, electronic peepholes, etc.

- **Smart Lighting**

Identifies and senses humans, with precise location detection, suitable for public lighting equipment (sensor lights, bulb lights, etc.).

2. System Characteristics

The XenD101H is a stationary human presence sensor developed based on ICL S1 series SoC. The sensor employs FMCW (Frequency Modulated Continuous Wave) technology, combined with radar signal processing and built-in intelligent human sensing algorithms, to detect human targets within a designated space and update detection results in real-time. With XenD101H, users can rapidly develop their own precise human presence sensing products.

The hardware Xen101_L1 mainly consists of a fully integrated ICL S1 series AIoT mmWave sensor, a 24 GHz transmit-receive antenna, and a main MCU. The software component is complemented by ICL intelligent human presence sensing firmware and a visualization tool, enabling flexible configuration of sensing distance, trigger and hold thresholds, and human absence reporting times for human sensing functionality.

The specifications and parameters of XenD101H are shown in Table 2-1.

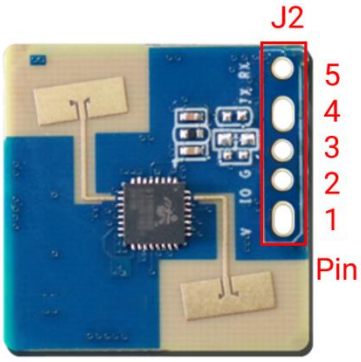
Table 2-1 XenD101H characteristics

Parameter	Min.	Typ.	Max.	Unit	Description
Hardware Xen101_L1 Characteristics					
Supporting frequency	24	-	24.25	GHz	FCC, CE, and SRRC compliant
Sweeping bandwidth	-	0.25	-	GHz	
Max. EIRP	-	11	-	dBm	-
Power supply	3.0	3.3	3.6	V	-
Power supply with LDO mounted	4.5	5	5.5	V	-
Size	-	20 × 20	-	mm^2	-
Environment temperature	-40	-	85	°C	-
XenD101H System Characteristics[1]					
Wall-mounted detection range	-	8.5	-	m	Moving/micro-moving human target
	-	7	-	m	Stationary lying human target
Top-mounted detection range	-	6.5	-	m	Moving/micro-moving human target
	-	4.8	-	m	Stationary lying human target
Range accuracy	-	±0.15	-	m	Moving human within 6 m
Average operating current	-	50	-	mA	-
Data report cycle	-	154	-	ms	-

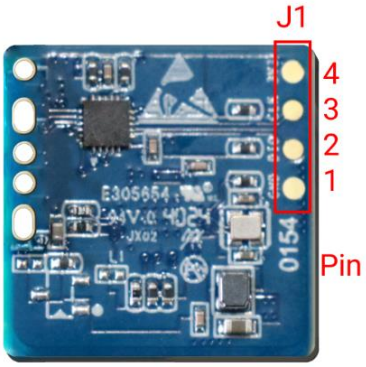
3. Hardware Overview

Figure 3-1 shows the top and bottom photos of the hardware Xen101_L1. The hardware reserves 5 pin holes (without pins provided at the factory) labeled as J2, which are used for power supply and communication. J1 is the SWD interface, used for MCU program burning and debugging. The PIN spacing is compatible with both 2.54 mm and 2.00 mm pin pitch.

[1] Note: The detection range is affected by the environment and the user's RCS, so the actual performance is subject to the test results in the application environment.



(a) Top



(b) Bottom

Figure 3-1 Xen101_L1 device map

Details of J1 and J2 pins are listed in Table 3-1 and Table 3-2.

Table 3-1 J1 pin description

J#PIN#	Name	Function	Operating Range
J2Pin1	GND	Ground	-
J2Pin2	DIO	SWD Data port	0 ~ 3.3 V
J2Pin3	CLK	SWD Clock signal	0 ~ 3.3 V
J2Pin4	3V3	Power input	3.0 V ~ 3.6 V, Typ. 3.3 V

Table 3-2 J2 pin description

J#PIN#	Name	Function	Operating Range
J2Pin1	V	Power input	3.0 V ~ 3.6 V, Typ. 3.3 V[2]
J2Pin2	IO	Detection status: high electric level means human target presence, low means no human target	0 ~ 3.3 V
J2Pin3	G	Ground	-
J2Pin4	T	UART_TX	0 ~ 3.3 V
J2Pin5	R	UART_RX	0 ~ 3.3 V

XenD101H supports programming hex files or source code projects using the Keil 5 IDE. Programs can be downloaded using programmers such as J-Link (version V9 or above) or CMSIS-DAP. Before programming, please ensure that the Puya.PY32F0xx_DFP.1.1.0.pack has been installed.

4. Visualization Tool

This chapter introduces the firmware debugging methods and the usage steps of the host computer tool for the XenD101H stationary human presence sensor.

The XenD101H sensor comes pre-programmed with system firmware at the factory. The specific firmware version can be found on the sensor's outer packaging. ICL provides a visualization tool for the hardware Xen101_L1, allowing developers to flexibly adjust the parameter settings of the XenD101H according to actual application scenarios, thereby optimizing its sensing effect.

4.1 Firmware Debugging

This section introduces how to use a third-party serial port tool to debug the firmware of the XenD101H mmWave sensor.

[2] After adding the LDO component, the power supply range is 4.5 ~5.5 V, Typ.5 V.

Step 1: Connect the host computer and the mmWave sensor through a USB-to-TTL serial port adapter board. The pin connections are shown in Table 4-1.

Table 4-1 Pin correspondence when connecting the sensor to the serial port adapter

Sensor Pin Name	Serial Port Pin Name
RX	TXD
TX	RXD
GND	GND
3V3	VCCIO

Step 2: Open the Device Manager on the host computer to check the serial port number of the mmWave sensor.

Step 3: Open the third-party serial port tool, select the serial port number of the mmWave sensor, set the serial port baud rate to 921600, and then click the "Open Serial Port" (or similar function) button to view the current detection results of the mmWave sensor in the output section of the tool interface.

4.2 Visualization Tool Instructions

This section introduces the use of the host computer tool that accompanies the XenD101H mmWave sensor to help users understand the meanings of relevant parameters and the methods for obtaining them.

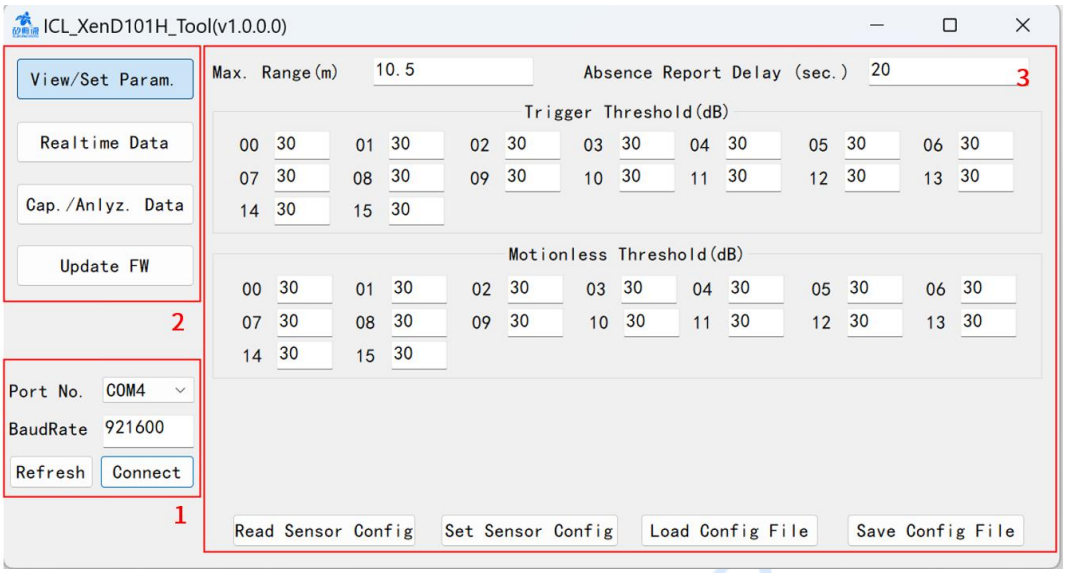
Note: The visualization tool and the third-party serial port tool cannot be used simultaneously!

Before using the various functions of the host computer tool, users should first connect the XenD101H to the host computer, following these steps:

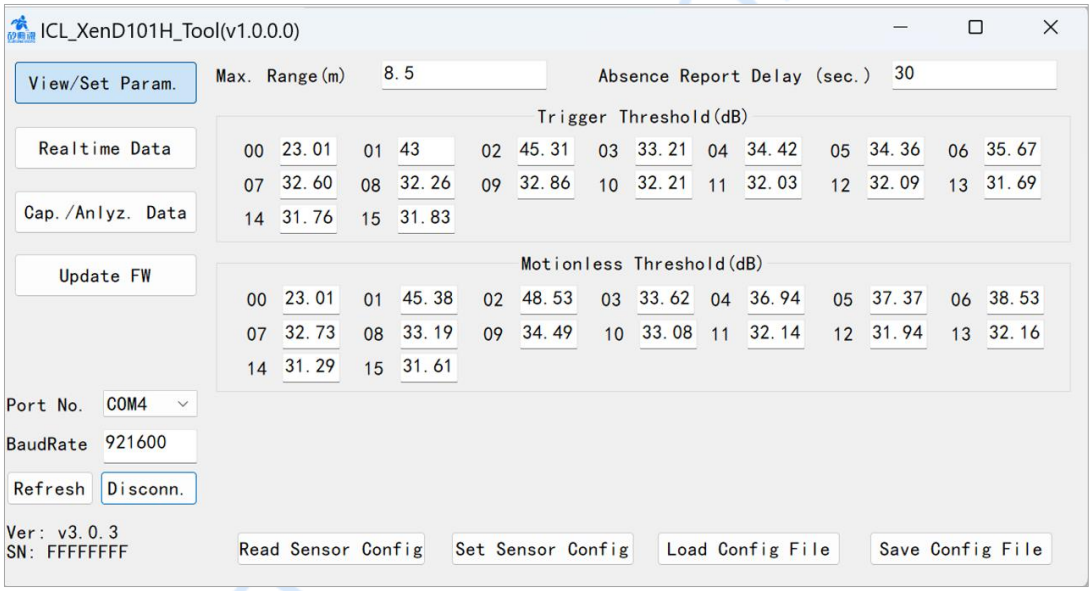
Step 1: Obtain the "ICL_XenD101H_Tool" from the ICL official website, which is released together with the XenD101H.

Step 2: Connect the mmWave sensor and the host computer using a serial port adapter board.

Step 3: Open the visualization tool, click the "Refresh" button, select the serial port number of the mmWave sensor in the "Port No." dropdown box, confirm that the "BaudRate" is 921600, and then click the "Connect" button to start connecting the host computer to the mmWave sensor.



(a) Before connecting to sensor



(b) After connecting to sensor

Figure 4-1 ICL_XenD101H_Tool

(c) As shown in After connecting to sensor Figure 4-1(a), the upper computer tool interface can be divided into three zones: Zone 1 for device operation, Zone 2 for functional buttons, and Zone 3 for functional pages.

(d) Upon successful connection between the upper computer tool and the sensor, the firmware version number (formatted as “Ver: …”) and serial number (formatted as “SN: …”; when the serial number is not burned, the software will display FFFFFFFF) of the sensor will be displayed in Zone 1. The functional page area for " View/Set Param." displays the current parameter values of the sensor, as shown in After connecting to sensor Figure 4-1 (b).

4.2.1 View/Set Parameters

The View/Set Param. page of the visualization tool is shown in Figure 4-2, it displays the parameter values of the mmWave sensor and allows users to modify each parameter for actual scenarios.

The step for reading mmWave sensor parameters is as follows:

- After connecting the XenD101H with the visualization tool, in the function buttons zone, click **Read Sensor Config** button, a window writing "Succeed reading parameters" will appear, and the function page will display the parameters of the mmWave sensor, click **OK** to close the prompt window.

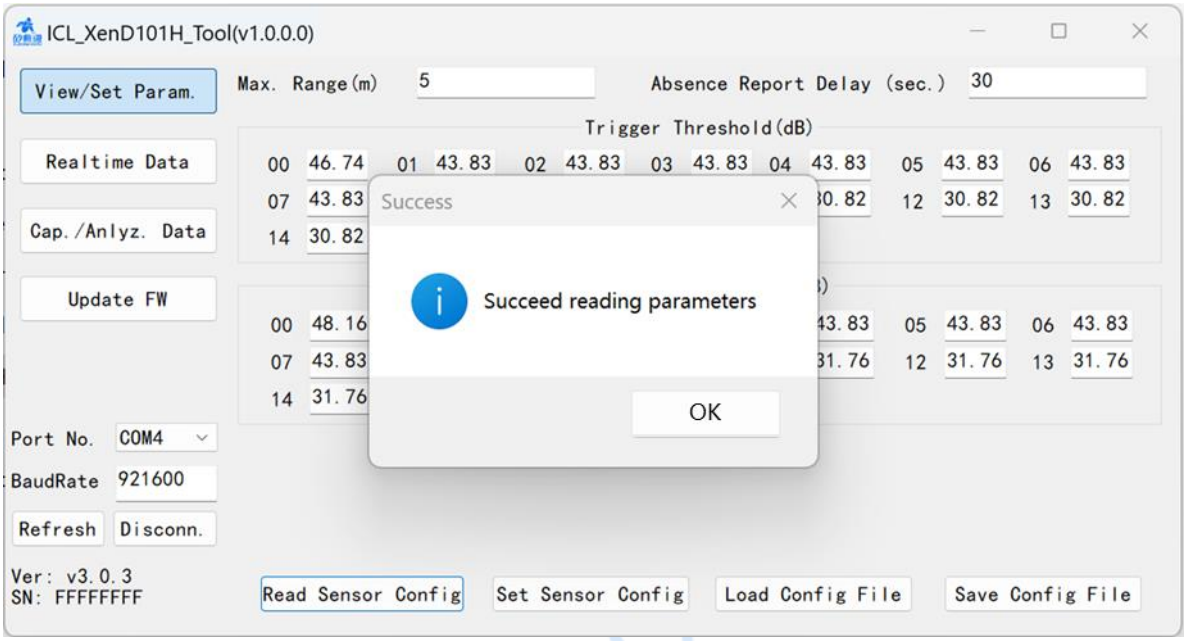


Figure 4-2 The View/Set Param page

The steps for setting mmWave sensor parameters are listed below:

Step 1: After connecting the XenD101H with the visualization tool, type in the new values for desired parameters;

Step 2: Click **Set Sensor Config** button, the visualization tool will send all the new values to the mmWave sensor, and a prompt window writing "Succeed setting parameters" will appear, click **OK** button to finish the process.

Descriptions of the parameters on the GUI are listed in Table 4-2.

Table 4-2 Descriptions of parameters on GUI

Parameter	Description	Range
Max. Range	For setting the maximum valid detection range of the mmWave sensor. The length of a range gate unit is 70 cm.	0~18, accurate to 0.1 m
Target Absence Report Delay (s)	For setting the delay time T before reporting target absence: during this time window, if mmWave sensor detects a target again, it will report target information and reset the delay T; if no target is detected during time T, mmWave sensor will report target absence.	0~65535
Trigger Threshold (dB)	For setting the motion energy threshold of the mmWave sensor to decide whether there is a target in the detection range, it can be automatically calculated through "Gen. Thres." function.	0~100, accurate to 0.01
Micro-motion Threshold (dB)	For setting the motion energy threshold of the mmWave sensor to decide whether the detected target is motionless and stays presence in the detection range, it can be automatically calculated through "Gen. Thres." function.	0~100, accurate to 0.01

The visualization tool supports saving and loading configuration files of the mmWave sensor:

- To save mmWave sensor configuration, click **Save Config File** button on the function page, choose a directory, the mmWave sensor will save the current configuration in a .xml file to the specified path; the

default saving path is the visualization tool directory.

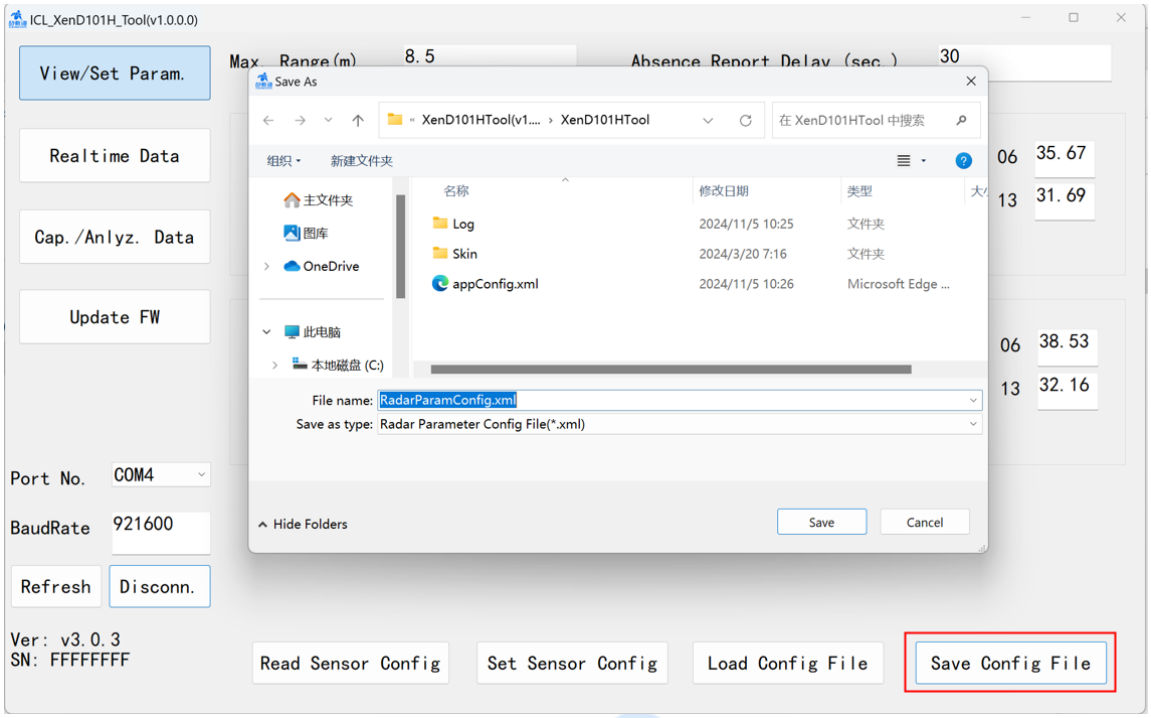


Figure 4-3 The Interface of Save Configuration File

- To load a mmWave sensor configuration file, click **Load Config File** button on the function page, choose the desired mmWave sensor configuration file, and the visualization will read and display the parameter values from the file; click **Set Sensor Config** button to send the loaded parameters to the mmWave sensor.

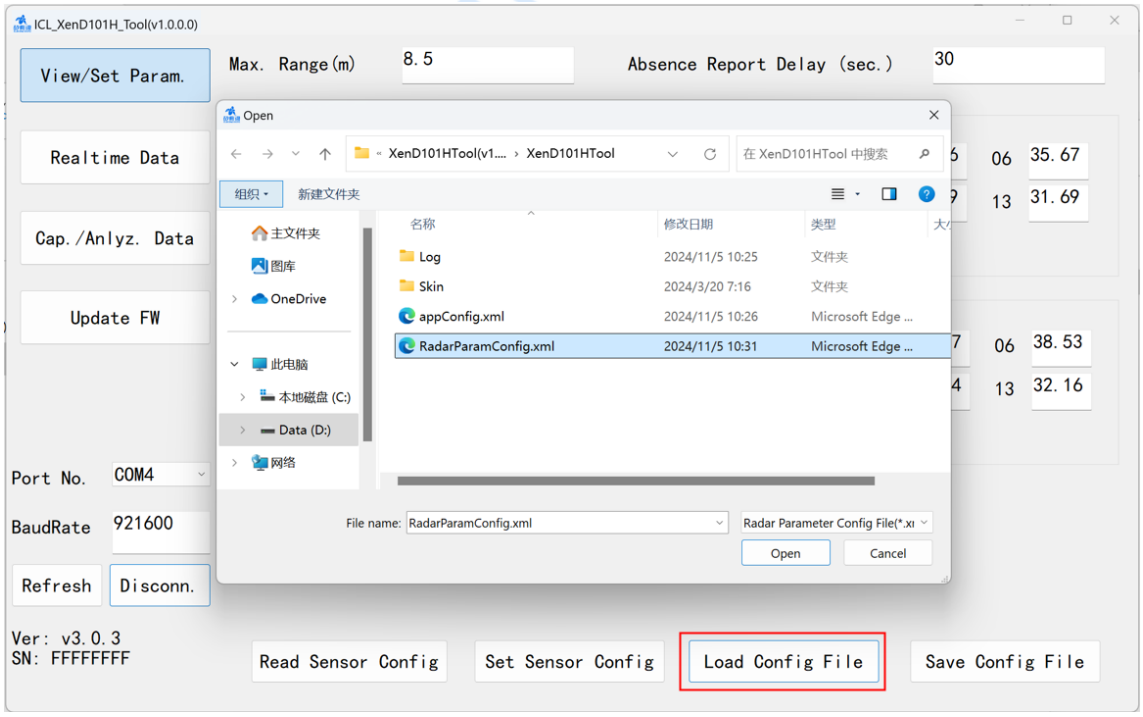


Figure 4-4 The Interface of load Configuration File

4.2.2 Realtime Data

The Realtime Data page is shown in Figure 4-5, and it can be separated into 3 zones: zone a displays target information, zone b is where the functional buttons lie, and zone c presents the real time data. Descriptions of this page are listed in Table 4-3.

Figure 4-5 The Realtime Data page

Table 4-3 Description of each zone on Realtime Data page

Zone		Function	Description
a	Light icon	The color of the light icon represents whether the mmWave sensor has detected a human target	Red means a human target is detected; Green means no human target is detected.
	Target information textbox	Displays the information of the detected target	Displays the radial range of the detected target.
b	Start/Pause button	To start or stop the detection	-
	Gen. Thres. button	To scan the environment noise and compute the trigger and hold threshold of each range gate according to the specified coefficients	Definitions of the trigger and hold threshold please refer to Table 4-2.
c	Motion Info. VS Micro-Motion Info. line-chart	To display the motion energy (green line) and threshold Value (red line) of each range gate in real time	The black background represents a valid detection range, and the grey background represents invalid detection range
	Range VS Time line-chart	To display the target range in the latest 60 s	The black background means there is no human target detected at that time, and the grey background means there is a target detected.

The steps for viewing the real time data are as follows:

Step 1: After connecting the XenD101H with the visualization tool, click **Realtime Data** button to open this function page, then the mmWave sensor will start detecting the human target and measuring the target range, and the visualization tool will display detection results in real time, **Start/Pause** button displays "Stop", and the two line-charts in zone c start presenting the detecting data in real time;

Step 2 (Optional): Click **Start/Pause** button to stop the detection, and the colored light turns green, Target Range turns to 0.00 m, and the two line-charts stop updating.

4.2.3 Automatic Threshold Generation

The steps for automatically generating trigger and hold thresholds are as follows:

Step 1: On the Realtime Data page, click **Gen. Thres.** button, the Threshold Generation window appears;

The upper part of the Threshold Generation window presents two parameters: the Trigger and Hold Threshold Coefficients, which are positively proportional to the mmWave sensor's sensibility, and range from 1.0 to 20.0; The lower part of the window displays the generating progress with a progress bar and text (the text displays during the threshold generation process);

Step 2: On the Threshold Generation window, type in the Trigger and Hold Threshold Coefficients, and click **Start/Close** button, the visualization tool starts computing trigger and hold thresholds, and the progress bar and the text below starts displaying the progress in real time, as shown in Figure 4-6;

Step 3: When the generating process finishes, the text on the bottom shows "Successfully generated", and **Start/Close** button displays Close; Click **Start/Close** button to end the threshold generation;

After the thresholds being successfully generated, the sensor automatically saves the newly generated thresholds, and the visualization tool reads and applies the newly generated thresholds.

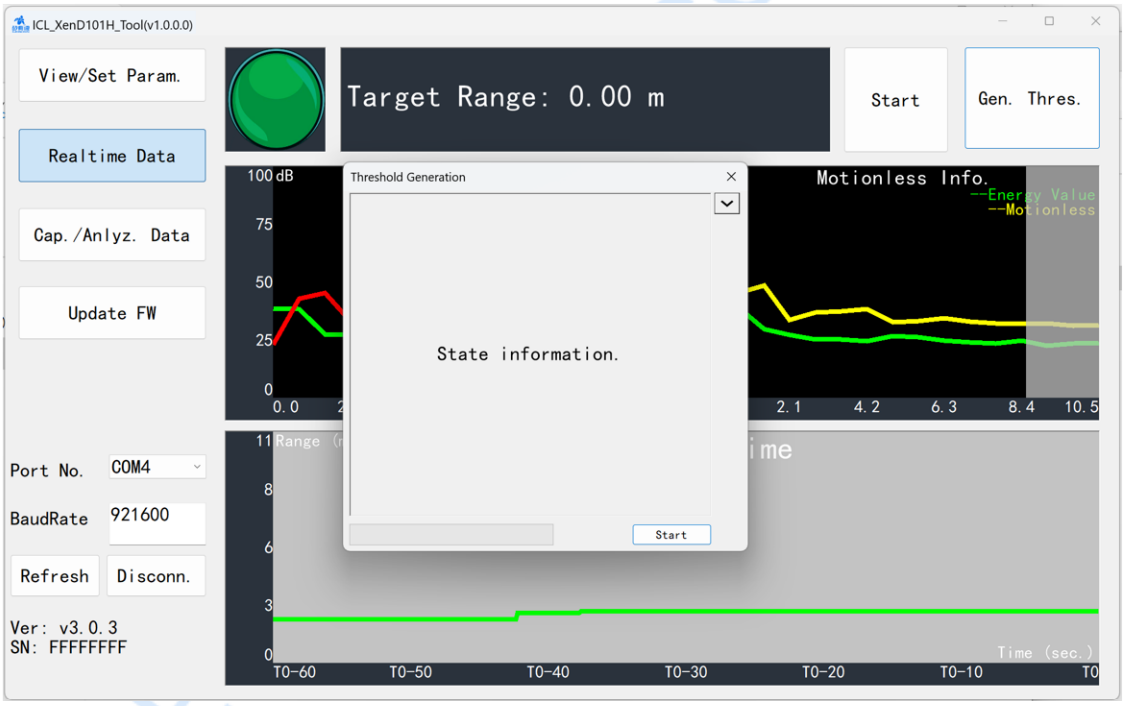


Figure 4-6 Threshold Generation page

During the threshold generation process, the environment within the detection range must be kept clear. If there is significant movement of human targets during the generation period, the host computer will provide a prompt upon completion of the generation. If there is extreme interference in the environment that prevents the module from functioning properly even for basic motion detection, a prompt will indicate to regenerate the threshold. As shown in Figure 4-7, if there is minor interference in the environment resulting in decreased detection performance of the module, a prompt will indicate the distance of the interference, and the user can choose whether to regenerate the threshold, as shown in Figure 4-8.

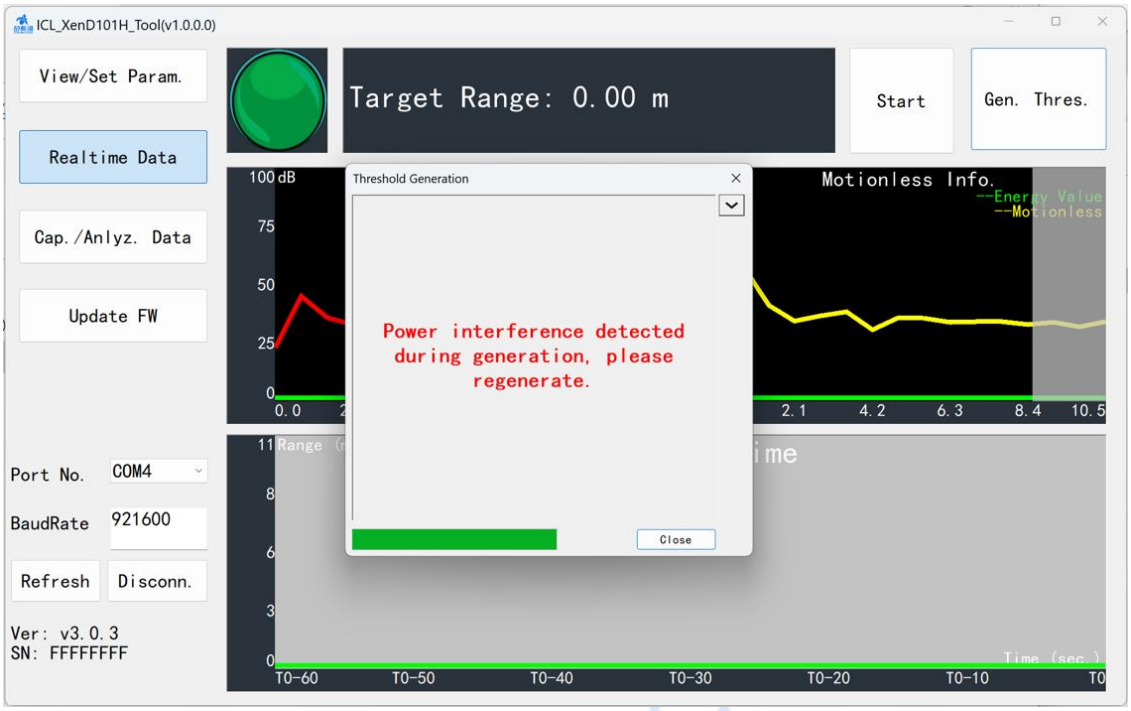


Figure 4-7 Prompt page for significant moving human body interference during generation

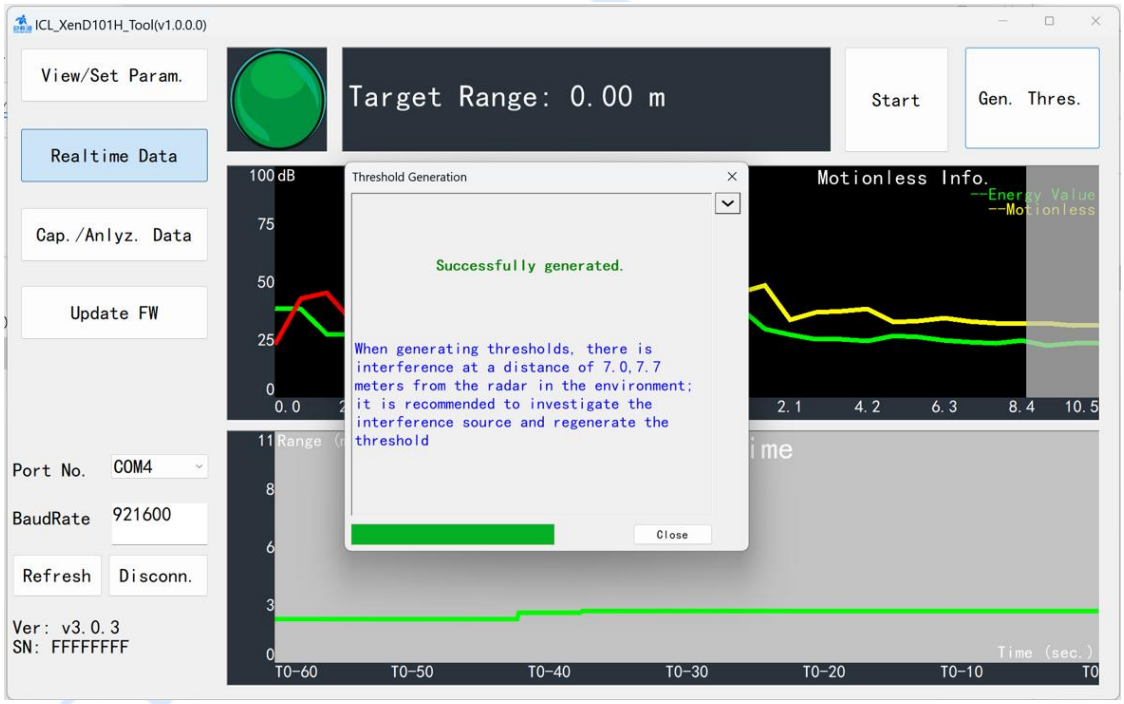


Figure 4-8 Prompt page for minor interference during generation

4.2.4 Power Interference Prompt

After the sensor is powered on, it will perform a self-check on the power supply. If there is significant interference in the power supply, the host computer will provide 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 Figure 4-9.

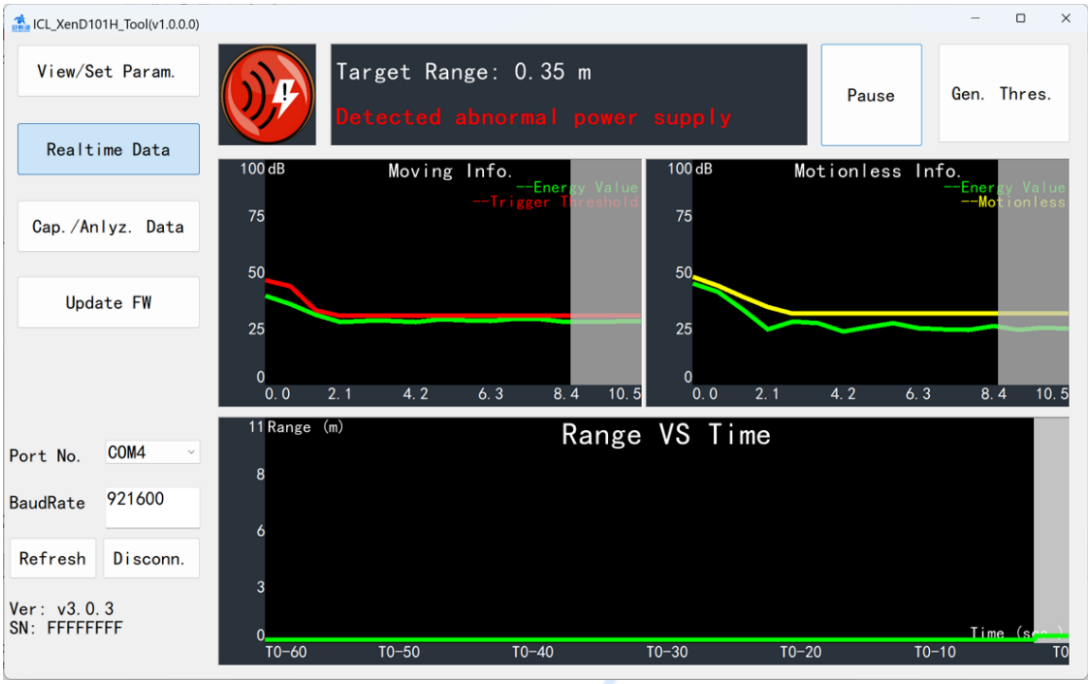


Figure 4-9 Power Interference Prompt Page

4.2.5 Update Firmware

The Update FW page is shown in Figure 4-10. The steps for updating mmWave sensor firmware are as follows:

Step 1: After connecting the XenD101H with the visualization tool, click **Update FW** button to open this function page;

Step 2[3]: Click **Obtain Firmware Info.** button, and the text box on the rightmost will display device information;

Step 3: Click **Choose bin file path** button to choose the firmware file, click **Flash** button to start updating firmware, and the text box on the right will print the downloading status, the bin file information, and the downloading progress.

[3] This step is necessary, users MUST NOT skip it when updating firmware through the visualization tool.

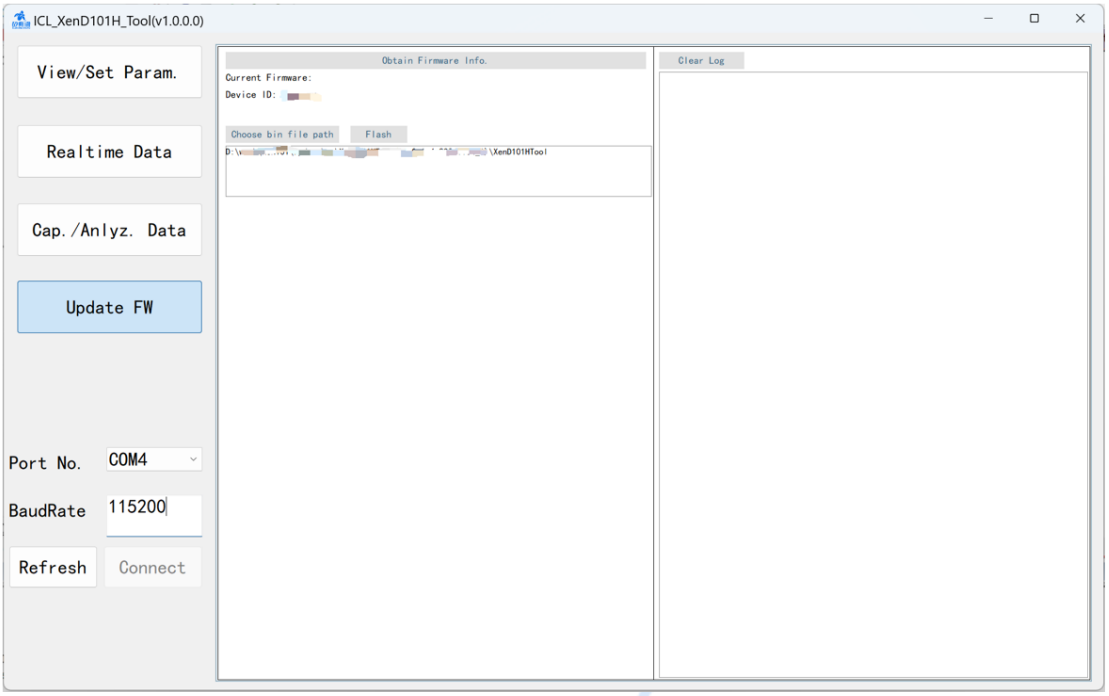


Figure 4-10 The Update Firmware page

After successfully updating the firmware, the text box on the right will print "Download successful!". Otherwise, the text box will print the error message.

5. Communication Protocol

This communication protocol is mainly for users who need to conduct further development without the visualization tool. The wide coverage human micro-motion detection mmWave sensor XenD101H communicates with the outside via the serial port (TTL). Both the data output and parameter configuration follow this protocol. The default serial port baud rate is 115200, with 1 stop bit and no parity bit.

This chapter consists of the following three parts:

- Protocol format: includes the formats of the protocol data and command frame;
- Configuration command format: includes the formats of the command and the acknowledgement (ACK);
- Report data format: includes the report data format applied in both the debugging mode and the normal working mode.

Steps for using commands to configure the mmWave sensor are as follows:

1. Enter command mode;
2. Send the command for configuring/reading the parameter;
3. Exit command mode.

5.1 Protocol Format

5.1.1 Protocol Data Format

The XenD101H adopts MSB for data communication, and all the data in the tables of the following sections are hexadecimal.

5.1.2 Protocol Command Format

The formats of mmWave sensor configuration command and ACK are shown in Table 5-1 and Table 5-3.

Table 5-1 Command frame format

Header	Length of Data Inside the Frame	Intra-frame Data	Trailer
FD FC FB FA	2 bytes	Refer to Table 5-2	04 03 02 01

Table 5-2 Intra-frame data format

Command ID (2 bytes)	Command Parameter (N bytes)

Table 5-3 Sensor ACK frame format

Header	Length of Data Inside the Frame	Data Inside the Frame	Trailer
FD FC FB FA	2 bytes	Refer to Table 5-4	04 03 02 01

Table 5-4 Data format of the ACK frame

ACK ID (2 bytes)	Command Status (2 bytes)	Return value (N bytes)

5.2 Command and ACK

5.2.1 Read Firmware Version Command

This command reads the mmWave sensor firmware version number.

Command word: 0x0000

Command value: NA

Return value: Length of the version number (2 bytes) + Version number

Sending data:

Header	Intra-frame Data Length	Command Word	Trailer
FD FC FB FA	02 00	00 00	04 03 02 01

ACK (Succeed, the firmware version is an example):

Header	Intra-frame Data Length	Command Word	ACK	Ver. Length	Firmware Ver.	Trailer
FD FC FB FA	0C 00	00 01	00 00	06 00	76 31 2E 35 2E 35	04 03 02 01

5.2.2 Enable Configuration Command

This command enables the mmWave sensor to enter configuration mode. All the other commands should be sent after this command, otherwise the command will be invalid.

Command word: 0x00FF

Command value: 0x0001

Return value: 2 bytes ACK status (0 for success, 1 for failure) + 2 bytes protocol version number (0x0002) + 2 bytes buffer size (0x0020)

Sending data:

Header	Intra-frame Data Length	Command Word	Command Value	Trailer
FD FC FB FA	04 00	FF 00	01 00	04 03 02 01

ACK(Succeed):

Header	Intra-frame Data Length	Command Word	ACK	Protocol Ver.	Buffer Size	Trailer
FD FC FB FA	08 00	FF 01	00 00	02 00	20 00	04 03 02 01

5.2.3 End Configuration Command

This command enables the mmWave sensor to exit configuration mode. After successfully conducting this command, the mmWave sensor will return to normal working mode. If another mmWave sensor command needs to be conducted, an Enable Configuration Command needs to be sent beforehand.

Command word: 0x00FE

Command value: NA

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

Sending data:

Header	Intra-frame Data Length	Command Word	Trailer
FD FC FB FA	02 00	FE 00	04 03 02 01

ACK(Succeed):

Header	Intra-frame Data Length	Command Word	ACK	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 mmWave sensor.

Command word: 0x0011

Command value: NA

Return value: 2 bytes ACK status (0 for success, 1 for failure) + Length of SN (2 bytes) + SN (2 bytes)

Sending data:

Header	Intra-frame Data Length	Command Word	Trailer
FD FC FB FA	02 00	11 00	04 03 02 01

ACK(Succeed, the SN here is an example):

Header	Intra-frame Data Length	Command Word	ACK	Length of SN	SN	Trailer
FD FC FB FA	08 00	11 01	00 00	02 00	CD AB	04 03 02 01

5.2.5 Write Serial Number Command

This command writes the serial number into the mmWave sensor.

Command word: 0x0010

Command value: Length of SN (2 bytes) + SN (2 bytes)

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

Sending data (Example):

Header	Intra-frame Data Length	Command Word	Length of SN	SN	Trailer
FD FC FB FA	06 00	10 00	02 00	CD AB	04 03 02 01

ACK(Succeed):

Header	Intra-frame Data Length	Command Word	ACK	Trailer
FD FC FB FA	04 00	10 01	00 00	04 03 02 01

5.2.6 Read Register Command

This command reads the register value of the mmWave sensor.

Command word: 0x0002

Command value: 2 bytes SoC address + (2 bytes register address) * N

Return value: (2 bytes register data) * N

Sending data (Example):

Header	Intra-frame Data Length	Command Word	SoC Address	Register Address	Trailer
FD FC FB FA	06 00	02 00	40 00	40 00	04 03 02 01

ACK(Succeed, the register data is an example):

Header	Intra-frame Data Length	Command Word	ACK	Register Data	Trailer
FD FC FB FA	06 00	02 01	00 00	07 02	04 03 02 01

5.2.7 Configure Register Command

This command writes the register value of the mmWave sensor.

Command word: 0x0001

Command value: 2 bytes SoC address + (2 bytes register address + 2 bytes register data) * N

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

Sending data (Example):

Header	Intra-frame Data Length	Command Word	SoC Address	Register Address	Register Data	Trailer
FD FC FB FA	08 00	01 00	40 00	40 00	07 42	04 03 02 01

ACK(Succeed):

Header	Intra-frame Data Length	Command Word	ACK	Trailer
FD FC FB FA	04 00	01 01	00 00	04 03 02 01

5.2.8 Read Parameter Command

This command reads the mmWave sensor parameters.

Command word: 0x0008

Command value: (2 bytes parameter ID) * N

Return value: (4 bytes parameter value) * N

Sending data (Example):

Header	Intra-frame Data Length	Command Word	Parameter ID	Trailer
FD FC FB FA	04 00	08 00	01 00	04 03 02 01

ACK (Succeed, the maximum range gate is 12):

Header	Intra-frame Data Length	Command Word	ACK	Parameter Value	Trailer
FD FC FB FA	08 00	08 01	00 00	0C 00 00 00	04 03 02 01

5.2.9 Configure Parameter Command

This command sets the parameter values of the mmWave sensor. The parameter word for each mmWave sensor parameter is presented in Table 5-5. Increase micro-motion threshold parameters and power interference alarm parameters.

Table 5-5 Sensor parameters

Parameter	Parameter ID	Range of Parameter Value
Minimum Range Gate	0x0000	0~15
Maximum Range Gate	0x0001	0~15
Absence Report Delay	0x0004	0~65535, unit s (second)
Motion Trigger Threshold	0x0010 ~ 0x001F	0~65535, squared magnitude.
Motion Hold Threshold	0x0020 ~ 0x002F	0~65535, squared magnitude.
Micro-Motion Threshold	0x0030 ~ 0x003F	0~65535, squared magnitude.
Power Interference Alarm	0x0005	Low 16 bit: 0: Not performed; 1: No interference; 2: Interference present. High 16 bit: Interference frequency, range 0 to 256, unit kHz; Only valid when the Low 16-bit value is 2. This parameter is read-only.

Command word: 0x0007

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

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

Sending data (Example: set the maximum range gate to 12):

Header	Intra-frame Data Length	Command Word	Parameter ID	Parameter Value	Trailer
FD FC FB FA	08 00	07 00	01 00	12 00 00 00	04 03 02 01

ACK(Succeed):

Header	Intra-frame Data Length	Command Word	ACK	Trailer
FD FC FB FA	04 00	07 01	00 00	04 03 02 01

5.2.10 Save Sensor Parameter Command

This command saves the mmWave sensor's current parameter setting.

Command word: 0x00FD

Command value: None

Return value: 2 bytes ACK status (0 for success, 1 for failure) + SN Length(2 bytes) + SN Value(2 bytes)

Sending data:

Header	Intra-frame Data Length	Command Word	Trailer
FD FC FB FA	02 00	FD 00	04 03 02 01

ACK(Succeed):

Header	Intra-frame Data Length	Command Word	ACK	Trailer
FD FC FB FA	04 00	FD 01	00 00	04 03 02 01

5.2.11 Configure System Parameter Command

This command configures the system parameter of the mmWave sensor.

Command word: 0x0012

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

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

Sending data (Example):

Header	Intra-frame Data Length	Command Word	Parameter ID	Parameter Value	Trailer
FD FC FB FA	08 00	12 00	00 00	04 00 00 00	04 03 02 01

ACK(Succeed):

Header	Intra-frame Data Length	Command Word	ACK	Trailer
FD FC FB FA	04 00	12 01	00 00	04 03 02 01

5.2.12 Start Automatic Threshold Generation Command

This command configures the automatic threshold generation, and informs the MCU to start computing the thresholds automatically. The parameter definition for automatic threshold generation is shown in Table 5-6.

Table 5-6 Automatic Threshold Generation Parameters

Parameter	Value	Description
Trigger Threshold Coefficient	0x000A~0x00C8	The parameter value is the product of 10 and the actual coefficient, for example, if the actual coefficient is 2, the parameter value is 0x0014
Hold Threshold Coefficient	0x000A~0x00C8	
Micro-Motion Threshold Coefficient	0x000A~0x00C8	

Command word: 0x0009

Command value: 4 bytes parameter value

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

Sending data (Example: Trigger Threshold Coefficient = 4, Hold Threshold Coefficient = 1.5):

Header	Intra-frame Data Length	Command Word	Parameter Value	Trailer
FD FC FB FA	08 00	09 00	2 bytes trigger threshold + 2 byte hold threshold + 2 bytes micro-motion threshold	04 03 02 01

ACK(Succeed):

Header	Intra-frame Data Length	Command Word	ACK	Trailer
FD FC FB FA	04 00	09 01	0000: Success, Others: Failure.	04 03 02 01

5.2.13 Query Threshold Generation Progress Command

This command queries the progress of the Threshold Generation. The return value contains the percentage of the progress, and 100 means the Threshold Generation finishes.

Command word: 0x000A

Command value: NA

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

Sending data:

Header	Intra-frame Data Length	Command Word	Trailer
FD FC FB FA	02 00	0A 00	04 03 02 01

ACK(Succeed, example: the percentage value is 60%):

Header	Intra-frame Data Length	Command Word	ACK	Percentage	Trailer
FD FC FB FA	06 00	0A 01	00 00	3C 00	04 03 02 01

5.2.14 Report Automatic Threshold Interference

This command reports the mmWave sensor's automatic threshold motion human interference alarm.

Header	Intra-frame Data Length	Command Word	Trailer
FD FC FB FA	02 00	14 00	04 03 02 01

ACK:

Header	Intra-frame Data Length	Command Word	Parameter Value	Trailer
FD FC FB FA	06 00	14 01	2 bytes of status byte + 2 bytes of range gate status. Status byte: 0000: Success, no interference; 0001: Failure, interference present. Range gate status: Example: 0x84, converted to binary as 1000_0100_0000_0010, corresponding to disturbances at 1, 10, and 15-meter range gates.	04 03 02 01

5.3 Report Data

In normal operating mode, the XenD101H released firmware outputs the detection results via the serial port. It outputs OFF when no target is detected and outputs the target distance when a target is present. In special modes, the host computer will access data during the processing of the millimeter-wave sensor. Therefore, in command-line mode, the firmware provides two additional transmission formats: debug mode and report mode.

In command mode, users can control the report data type by adjusting the working mode parameter in the command frame. Figure 5-1 presents an example of the structure of a command frame.

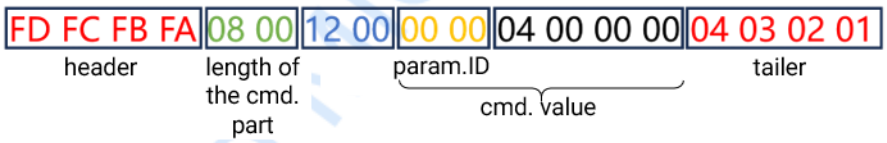


Figure 5-1 Example of a command (cmd.) frame

Table 5-7 displays an example of a data frame transmitted via serial port during reporting mode.

Table 5-7 Report data format of reporting mode

Header	Length of Data Inside the Frame	Detection Result	Distance of the Target	Energy of Each Range Gate	Trailer
F4 F3 F2 F1	2 bytes (The sum of data bytes of Detection Result, Target Distance, and Energy of Each Range Gate)	1 byte (0x00 for no target; 0x01 for target exists)	2 bytes	32 bytes 16(the total number of range gates) * 2 bytes	F8 F7 F6 F5

6. Installation and Detection Range

The wide coverage human micro-motion detection mmWave sensor XenD101H supports both top mounted and wall mounted installation. The recommended method is top mounted installation.

Directions relative to the mmWave sensor are shown in Figure 6-1. The direction of X axis is defined as 0°, Z axis is defined as 90°, and Y axis is perpendicular to X-Z plane (also known as normal direction).

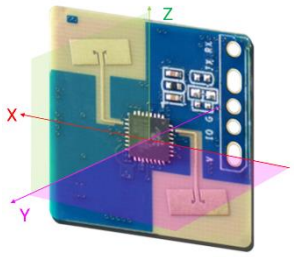


Figure 6-1 Illustration of the relative directions of XenD101H

6.1 Top Mounted

The maximum motion sensing range of the XenD101H installed at a height of 3 meters, is a conical space with a base radius of 5 meters, as shown in Figure 6-2.

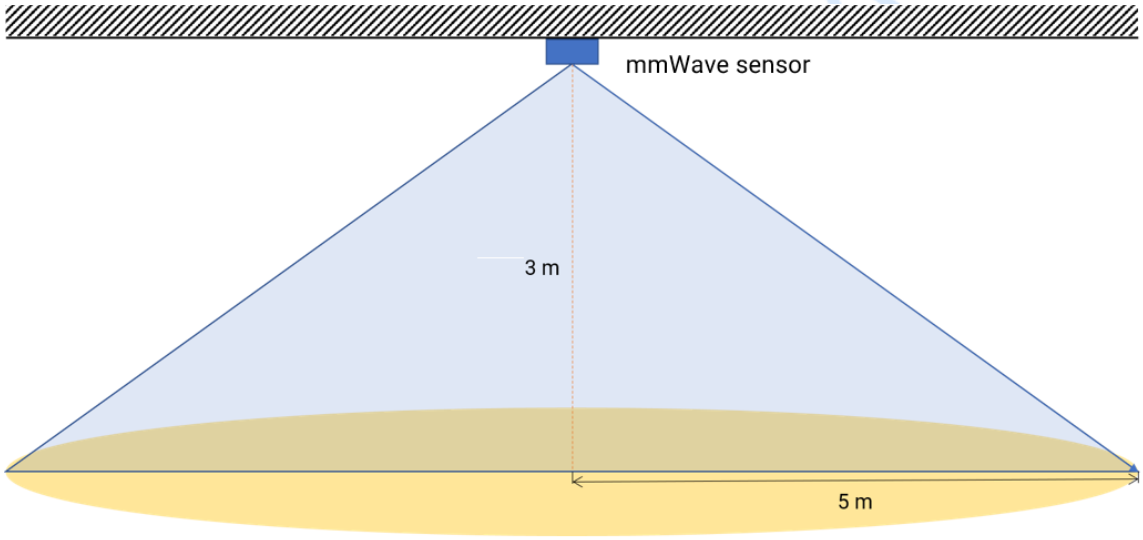


Figure 6-2 Illustration of top mounted XenD101H detection range

It is important to note that as the installation height decreases, the maximum sensing range gradually shrinks, as shown in Figure 6-3.

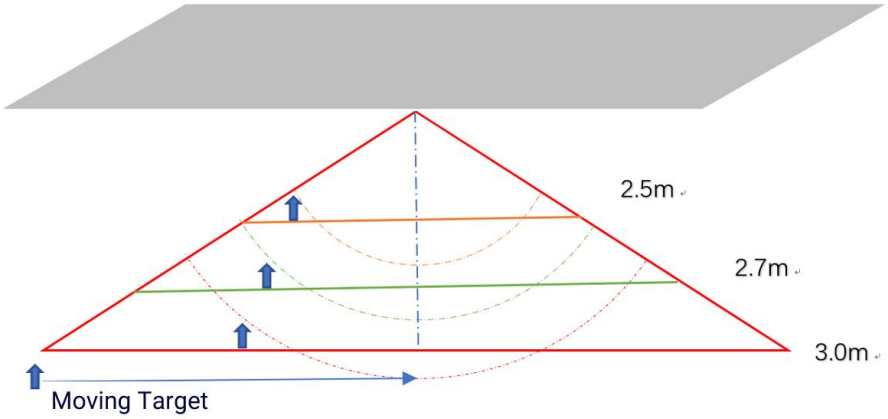


Figure 6-3 Schematic of the relationship between the installation height and the detection range of XenD101H

The detailed detection ranges of both moving target and motionless target are shown in Figure 6- when applying top mounted with the height of 2.7 m.

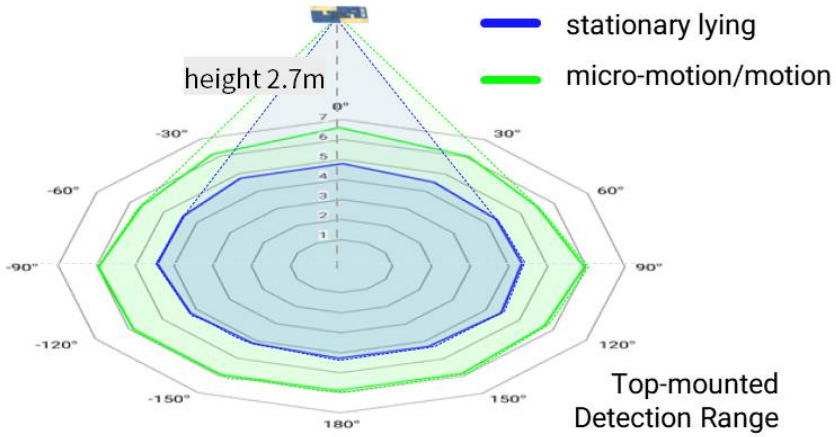


Figure 6-4 Detection range of top mounted XenD101H

6.2 Wall Mounted

The recommended installation height for wall mounting method is 1.5 ~ 2 m. When wall mounted, the X axis of mmWave sensor (refer to Figure 6-1) should be horizontal, Z axis should point upwards, Y axis should point to the detecting area. the motion detection range of sensor XenD101H under default setting is a conic area formed within the sensor's radial distance of 8 m, azimuth and elevation angle of ±60°, as shown in Figure 6-.

The detailed detection ranges of both moving target and motionless target are shown in Figure 6-, when applying wall mounted with the height of 1.5 m.

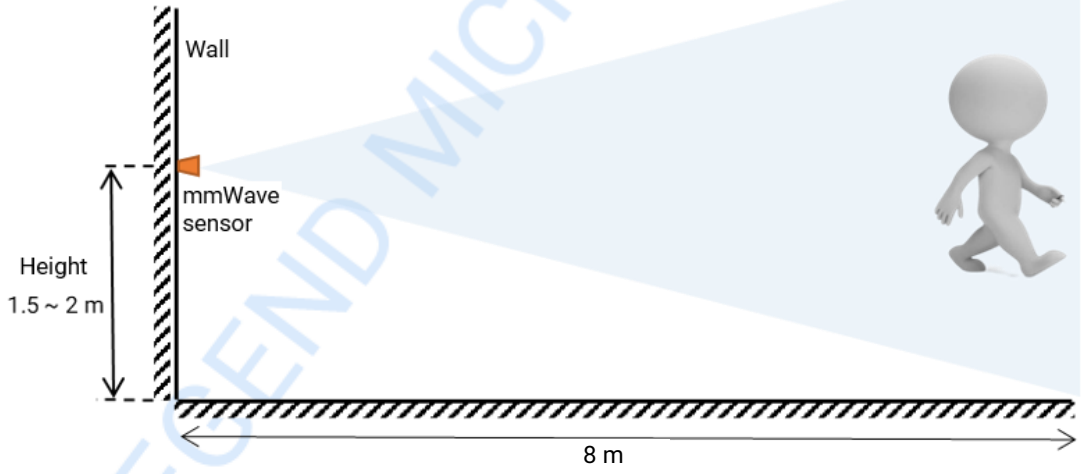


Figure 6-5 Illustration of wall mounted XenD101H detection range

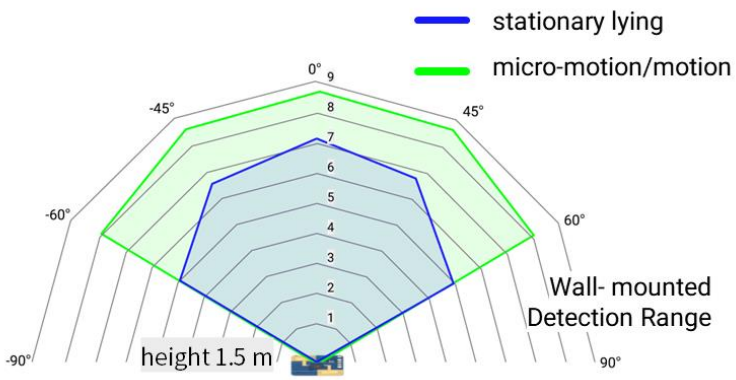


Figure 6-6 Detection range of wall mounted XenD101H

6.3 Detection Range Test

This section introduces how to test the trigger and hold detection range of sensor XenD101H.

- **Trigger detection range:**

  The tester stands somewhere inside the mmWave sensor FOV but further than the mmWave sensor detection range and the mmWave sensor reports *No Target*, then the tester gradually walks towards the mmWave sensor and stops immediately when the mmWave sensor reports target detected, the radical distance between the tester and the mmWave sensor is called trigger border in this direction; the trigger boarder in various direction forms the trigger detection range of the mmWave sensor.

- **Hold detection range:**

  The tester stands somewhere inside the mmWave sensor FOV and detection range, with the mmWave sensor reports a target is detected, then the tester keeps making minor movements such as shrug and moving hands for 60 s, if the mmWave sensor reports a target is detected during the whole process, then the location of the tester is within the hold detection range, otherwise, the location is outside the hold detection range.

7. Mechanical Size

Figure 7-1 presents the mechanical size of hardware Xen101_L1, all the unit is mm. The board thickness is 1.2 mm with a tolerance of ±10%.

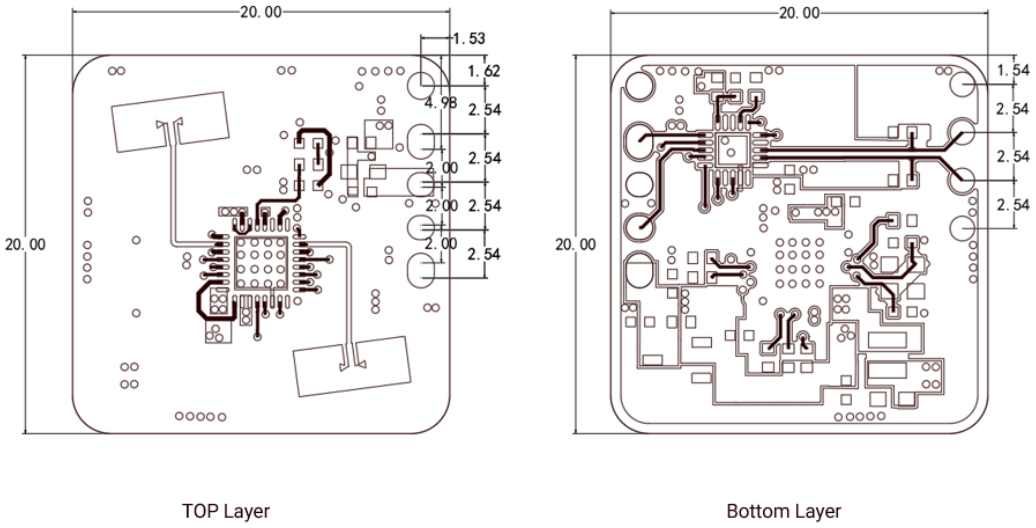


Figure 7-1 Mechanical size of hardware Xen101_L1

8. Installation Requirement

8.1 Radome Requirements

If there is a need to install a radome, the material selected must have good transparency for 24 GHz wave, and do not contain any material that may block electromagnetic wave such as metal. More details please refer to mmWave Radar Sensor Antenna Radome Design Guide .

Before installing the mmWave sensor, it is required to try out the minimum mounting clearance between the antennas and the cover. It is recommended to maintain the gap within 4 ~ 6 mm, because the mmWave sensor will reach saturation if the cover is too close to the antenna. The minimum mounting clearance varies with respect to the material, thickness and shape of the cover.

8.2 Installation Environment

When installing the product, certain requirements should be taken into consideration in case the detection performance is interfered. Features of unsuitable environment are listed below.

- Continuous moving non-human objects in detection area, such as moving animals, swinging curtains, big shaking plants in front of an active vent etc.
- Large strong reflectors will interfere with detection performance when put in front of the antennas.
- Interferences of on-ceiling home appliances such as air-conditioners, fans, etc. should be taken into consideration while top mounted.

8.3 Important Requirements

- Ensure the antennas are facing squarely to desired detection area with a clear field of view.
- Ensure the installation position of the mmWave sensor is solid and stable. Motion of the mmWave sensor itself can hugely impact signal processing.
- Ensure there is no object moving or vibrating behind the mmWave sensor. Motion behind the antennas can also be detected due to the penetrability of mmWave, thus interferes detection accuracy. It is recommended to use a radome or a backplane to reduce the interference.
- When there are multiple 24 GHz mmWave sensors installed in close areas, ensure their beamforms do not face to each other, try to separate them as far as possible to avoid interference.

8.4 Power Supply

The XenD101H supports power supply from 3.3 V to 3.6 V, and the power ripple should show no obvious spectral peaks within 100 kHz. Additionally, developers should take EMC design such as ESD and lightning surge into consideration.

9. Important Tips

9.1 Maximum Detection Range

The maximum detection range of sensor XenD101H is 10 m in radical direction. Within this range, the mmWave sensor reports the direct distance of the detected moving target. Currently, the mmWave sensor only reports the direct distance of moving human body, and does not support range measurement of motionless human target in close range.

9.2 Modifying Firmware Baud Rate

The default baud rate of sensor XenD101H is 921600. It can be modified through the macro USART0_BAUDRATE defined under engineering directory \platform\py32\inc\py32_uart.h.

9.3 Maximum Detection Range and Range Accuracy

Theoretically, the range accuracy of sensor XenD101H is ±0.15 cm. However, the value together with the maximum range may vary according to human target size, pose, and RCS.

9.4 Absence Report Dela

When human absence is detected in detection area, the mmWave sensor will delay the absence report. The delay mechanism works as such: once no human target is detected in detection area, the mmWave sensor will start a timer whose duration is the parameter absence report delay, and if there is no target showing up during this timing the mmWave sensor will end the timer and send the non-human report; however, if a human target is detected in detection area during the timing, the mmWave sensor will end and refresh the timer before sending the target information.

9.5 Micro-Motion Detection Range

The sensor's detection range for human micro-motion is inversely proportional to the angle between the normal direction of the human body[4] and that of the sensor. Therefore, in micro-motion detection scenarios, it is recommended to adjust the position and angle of the mmWave sensor during installation, 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.

9.6 Optimized automatic threshold generation function

The optimization of the automatic threshold generation function in this update has enhanced the overall performance of XenD101H, delivering a better user experience. The specific optimizations are detailed below:

- **Reduce on-site debugging workload**

  Through the automatic threshold generation function, the system can automatically calculate and set appropriate threshold values, significantly reducing the workload of on-site debugging. This avoids the drawbacks of manual adjustment of the threshold values for each millimeter wave radar in traditional product deployment processes, making large-scale deployment more efficient and convenient. This has improved deployment efficiency and reduced the risk of human errors.

- **Improve detection accuracy**

  The automatic threshold generation function can automatically calculate the most suitable threshold value for the current environment through precise environmental perception and data analysis. This approach reduces the interference of manual adjustment, ensuring that the radar maintains optimal detection accuracy in various complex environments. Whether for stable detection of stationary targets or rapid response to dynamic targets, XenD101H can provide accurate and reliable results, offering users a more outstanding experience.

- **Simplify installation process**

  The automatic threshold generation function simplifies the radar installation process. Users only need to complete the basic installation steps, and the radar will automatically optimize the threshold settings without the need for complex manual tuning.

- **Reduce maintenance costs**

  The radar can automatically adjust threshold values in real-time based on environmental changes, reducing the need for regular manual adjustments due to environmental variations. This decreases the workload for maintenance personnel, enhances system operational efficiency and stability, ultimately saving maintenance costs for users.

- **Flexible triggering methods**

  To meet the needs of various users and application scenarios, we offer two flexible methods for

[4] When a person stands relaxed with the eyes facing straight ahead, the direction of the gaze is the normal direction of the body.

automatic trigger threshold generation: external triggering and radar automatic determination of start conditions.

External triggering: Users can initiate the automatic generation of thresholds through external signals. This approach allows users to manually control the timing of threshold generation according to their application scenario requirements.

Radar automatic determination of start conditions: For users who require a higher level of automation, we offer the functionality of radar automatically determining the start conditions. This feature, based on the radar's built-in intelligent algorithms, automatically decides when to initiate threshold generation. Note that custom firmware may be required to enable this feature.

Users can flexibly choose according to their actual needs and application scenarios.

9.7 Description of Stationary Lying Testing

The radar can detect stationary lying states, with sensitivity in the tangential direction being superior to that in the radial direction. Examples of tangential and radial stationary states are shown in the figure below:

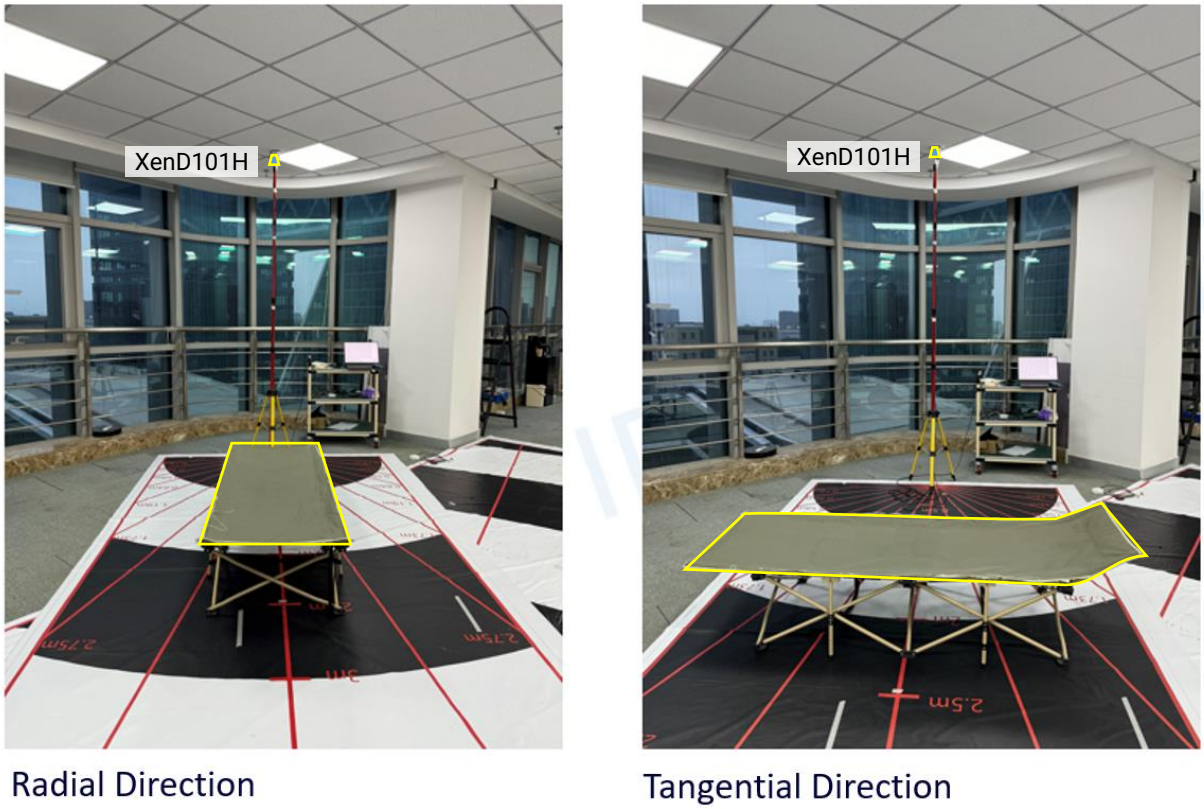


Figure 9-2 The example of Radial and Tangential Direction

10. Revision History

Revision	Date	Modification
1.1	2023/5/22	Initial release.
1.2	2023/6/1	Align the description of the reference design with the website content, update the description as human micro-motion detection mmWave sensor.
1.3	2023/7/27	Added Chapter 5 Communication Protocol; The visualization tool added displaying mmWave sensor serial number, and its version is updated from v1.2.0.0 to v1.2.1.1; The firmware added serial number related functions, and its version is updated to v1.5.5.
1.4	2023/8/8	Optimized the communication protocol of the visualization tool, and the tool version is updated from v1.2.1.1 to v1.2.1.2; Updated the definitions of mmWave sensor relative direction.
1.5	2023/10/7	Corrected typos in Table 4-1and adjusted the table layout; Updated the layout of Table 2-1; Unified the reference of the product as “mmWave sensor” or “sensor”; Unified the reference of the sensor hardware as “hardware Xen101”; Updated the reference of “serial port tool” as “third party serial port tool”; Updated the presentation style of 4.2.2 and 4.2.3; Updated the command and ACK format tables of the communication protocol in section 5.2.
2.0	2023/12/26	Added introduction to automatic threshold generation in Chapter 1; The visualization tool has upgraded to v1.2.1.5, and the sensor firmware to v2.0.0, updated Realtime Data; Added Start Automatic Threshold Generation Command and Query Threshold Generation Progress Command; Added 9.5 Micro-Motion Detection Range.
2.01	2024/5/27	Added the advantages of automatic threshold generation in overview; Added Section 9.6. Optimized automatic threshold generation function.
3.0	2024/10/16	Increased the capability to detect stationary lying and sitting; Changed the sensor type from XenD101MM to XenD101H; Replaced the wide-coverage human micro-motion millimeter-wave sensor with a stationary human presence millimeter-wave sensor; Added Section 4.2.4 power interference prompts; Updated Section 5.1 Communication Protocol; Update Figure 6-4; Figure 6-6; Removed chip model number and changed to S1 series.
3.1	2024/12/4	Updated hardware to Xen101_L1; Updated firmware: improved the sensor’s detection performance, can detect stationary sitting and lying human.

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