UM10066
XenD101HS User Manual

Rev.1.0 User Manual

Introduction

This document describes the basic functions, hardware specifications, software configuration, and installation conditions of the XenD101HS, an ultra-small-size AIP (Antenna-in-Package) human life presence sensor from ICLEGEND MICRO(ICL). It aims to assist developers in quickly getting started with the XenD101HS stationary human life presence sensor, conveniently configuring parameters that best suit their application scenarios, and creating personalized precision induction sensors

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1. XenD101HS Overview

The XenD101HS is an ultra-small-size AIP human life presence sensor in ICL's EZ Sensor series. It includes a highly simplified 24 GHz sensor hardware (Xen101S) and a human presence sensing intelligent algorithm firmware, capable of detecting stationary, sitting, and lying-down humans.

The hardware Xen101S is equipped with an ICM ICL111A AiP mmWave sensor, a high-performance 24 GHz one-transmit-one-receive antenna, and peripheral circuits. The AIP chip antenna is embedded, eliminating the need for high-frequency material and enabling faster processing. The human presence sensing algorithm utilizes mmWave sensor distance measurement technology and advanced radar signal processing techniques specific to the S1 series chip, achieving precise perception of moving, micro-moving, and stationary humans.

The XenD101HS can detect moving humans up to 7.5 meters away and allows for easy configuration of sensing distance ranges, different interval trigger and hold thresholds, and unoccupied reporting times. It supports GPIO and UART interfaces, is plug-and-play, and can be flexibly applied to various smart scenarios and end products.

The main features of XenD101HS include:

- **Intelligent Design**: Equipped with a single-chip intelligent AiP mmWave sensor SoC, featuring an embedded antenna and intelligent algorithms.
- **Ultra-Small Size**: Sensor dimensions of 12 mm × 12 mm.
- **Plug-and-Play**: Loaded with default human sensing configurations for immediate use.
- **Frequency Compliance**: Operates in the 24 GHz ISM band and complies with FCC, CE, and domestic radio frequency spectrum regulations.
- **Voltage Support**: 3.3 V power supply, supporting 3.0~3.6 V.
- **Low Power Consumption**: Average operating current of 42 mA.
- **Multi-Function Detection**: Effectively detects moving, micro-moving, and stationary humans, providing real-time detection results.
- **Easy Processing**: Integrated antenna in the SoC, simplifying design and reducing processing cycles.
- **Visual Configuration**: Provides a visualization tool for flexible configuration of detection distance intervals and target disappearance delay times, supporting automatic generation of detection thresholds.
- **Sensing Range Management**: Supports sensing range division to effectively shield interference from outside the range.
- **Blind Spot-Free Detection**: Detects as close as 0.2 meters.
- **Wide Angle Coverage**: Detection angle of ±60°, widely covering the monitoring area.
- **Diverse Installation**: Supports ceiling and wall mounting.
- **Independent Configuration**: Trigger and hold states can be independently configured, with strong anti-interference capabilities.
- **Environmental Resilience**: Resistant to moisture, corrosion, and electrostatic discharge, with better environmental adaptability.

The XenD101HS can detect and identify moving, standing, and stationary humans, making it widely applicable in various AIoT scenarios, including:

- **Smart Home:**

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

- **Smart Commercial:**

Identifies human approach or departure within set distance intervals; timely illuminates screens and keeps devices on when humans are present.

- **Smart Security:**

Induction for door access, building intercoms, electronic doorbells, etc.

- **Smart Lighting:**

Identifies and perceives human presence for precise position detection, applicable to public lighting equipment (induction lights, bulb lights, etc.).

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2. System Characteristics

The XenD101HS is a stationary human life presence sensor based on ICL111A chip. The sensor employs FMCW radar combined with radar signal processing and built-in intelligent human presence algorithms to detect human targets in designated spaces and update detection results in real-time. Users can quickly develop their precise human presence sensing products using the XenD101HS.

The hardware, Xen101S, is primarily composed of a fully integrated ICL111A (AiP 1T1R) mmWave sensor, a 24 GHz single-transmit-single-receive antenna, and a main control MCU. The software is paired with ICL's intelligent human presence sensing firmware and visualization configuration tools to achieve flexible configuration of induction distances, trigger and hold thresholds, and unoccupied reporting times for human presence sensing functions.

The specifications of the XenD101HS are shown in Table 2-1.

Table 2-1 XenD101HS characteristics

Parameter	Condition	Min.	Typ.	Max.	Unit
Xen101S Hardware Characteristics					
Supporting frequency	-	24	-	24.25	GHz
Max. bandwidth	-	-	0.25	-	GHz
Maximum Equivalent Isotropically Radiated Power	EIRP	-	11	-	dBm
Supply voltage	-	3.0	3.3	3.6	V
Polarization Mode			Dual-linear		-
Size	-	-	12 × 12	-	mm × mm
Environment temperature	-	-40	-	85	°C
XenD101HS System Characteristics					
Detection range (wall-mounted)	Moving human target	-	7.5	-	m
	Micro-moving human targets	-	6	-	m
	Stationary lying-down human targets	-	4	-	m
Detection range (ceiling-mounted)	Moving human target	-	4	-	m
	Micro-moving human targets	-	4.5	-	m
	Stationary lying-down human targets	-	3.5	-	m
Detection accuracy	Distance to a moving corner reflector target within 6 m of the sensor	-	±0.15	-	m
Average operating current	-	-	42	-	mA
Data Refresh Cycle	-	-	154	-	ms

3. Hardware Overview

Figure 3-1 shows the top and bottom photos of the hardware Xen101S. The hardware reserves five pinholes (pins not included in factory delivery), referred to as J2, for power supply and communication; J1 is an SWD interface for MCU program burning and debugging. The pin spacing is 2.54 mm.

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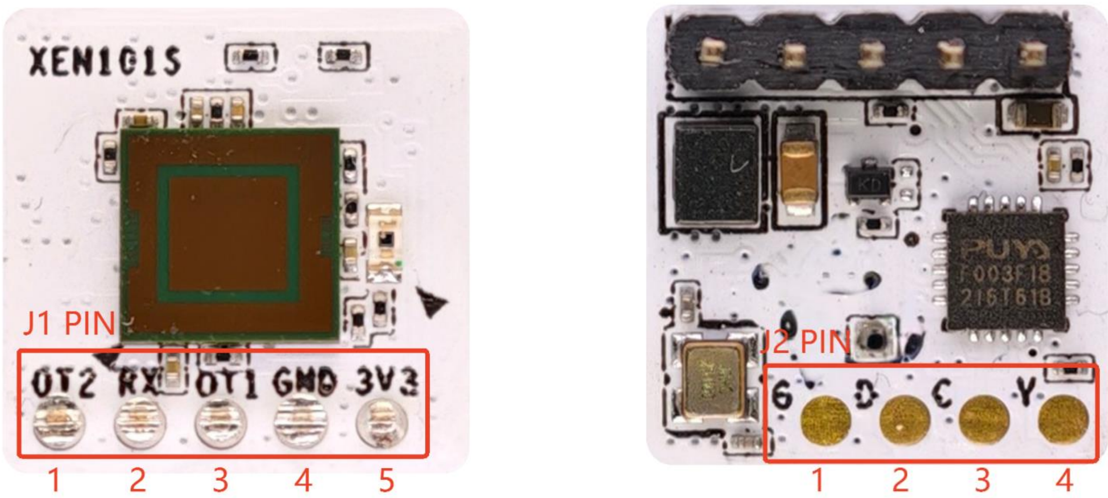

Top Bottom

Figure 3-1 Top and bottom device map of XenD101HS

The pin descriptions for J1 and J2 are listed in Table 3-1 and Table 3-2, respectively.

Table 3-1 J1 pin description

J#PIN#	Name	Function	Operating Range
J1 Pin1	OT2	Detection status reporting: High level indicates presence, low level indicates absence	0 ~ 3.3 V
J1 Pin2	RX	UART_RX	0 ~ 3.3 V
J1 Pin3	TX	UART_TX.	0 ~ 3.3 V
J1 Pin4	GND	Ground	-
J1 Pin5	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
J2 Pin1	3V3	Power input	3.0 V ~ 3.6 V, Typ. 3.3 V
J2 Pin2	CLK	Clock signal	0~3.3V
J2 Pin3	DIO	Data port	0~3.3V
J2 Pin4	GND	Ground	-

The XenD101HS supports program burning of hex files or source code projects using Keil 5 IDE and can be downloaded using burners such as J-Link (V9 or later) and CMSIS-DAP. Before burning, ensure that the Puya.PY32F0xx_DFP.1.1.0.pack has been installed.

4. Software Overview

This chapter introduces the firmware debugging methods and the usage steps of the upper computer configuration tool for the XenD101HS narrow-frame human presence mmWave sensor.

The XenD101HS sensor comes pre-loaded with system firmware from the factory. For specific firmware versions, please refer to the sensor's outer packaging. ICL provides an intuitive upper computer configuration tool software for the hardware Xen101S, enabling developers to flexibly adjust the parameter settings of the XenD103H according to their actual application scenarios, thereby optimizing its sensing effects.

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4.1 Firmware Debugging

This section describes how to debug the XenD101HS mmWave sensor firmware using third-party serial port tool software.

1) Connect the upper computer and the mmWave sensor using a USB-to-TTL serial port conversion board. The pin connection method is shown in Table 4-1.

Table 4-1 XenD101HS default parameter description

PIN	Serial Port Conversion Board
RX	TXD
OT1	RXD
GND	GND
3V3	VCCIO

2) Open the device manager on the upper computer to view the serial port number where the mmWave sensor is located.

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 equivalent) button to view the current detection results of the mmWave sensor in the tool's output interface.

4.2 Software Tool Description

This section introduces the usage of the upper computer tool specially designed for the XenD101HS mmWave sensor to help users understand the meanings of relevant parameters and methods for obtaining them.

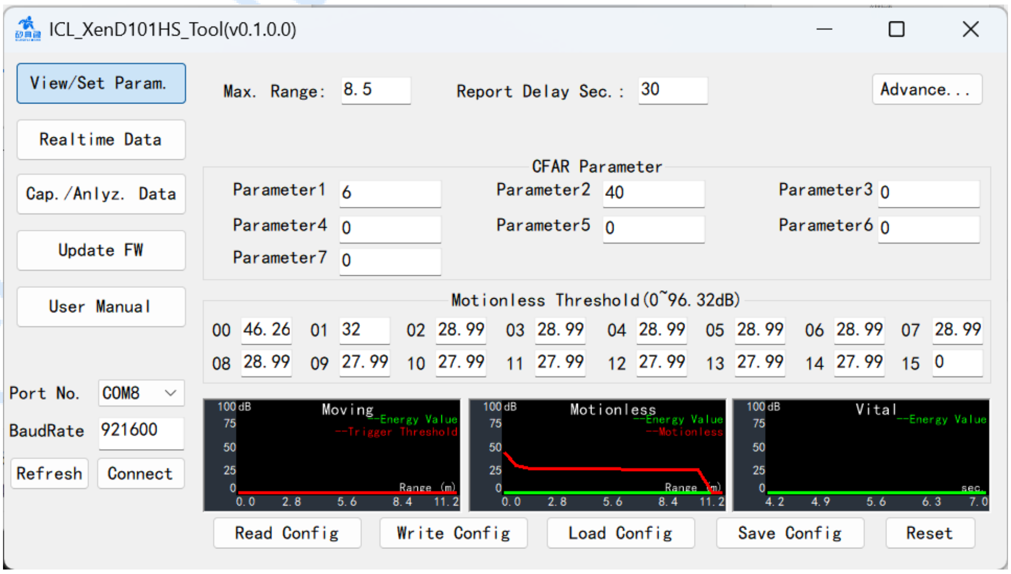
Note: The upper computer tool and third-party serial port tool cannot be used simultaneously!

Before using the various functions of the upper computer, users should first connect the XenD101HS to the upper computer using the following steps:

1) Obtain the upper computer tool "XenD101HS_Tool" for the XenD101HS from the ICL official website.

2) Connect the mmWave sensor and the upper computer using a serial port conversion board.

3) Open the upper computer tool, click the "Refresh" button, select the serial port number of the mmWave sensor in the "Serial Port Number" dropdown box, confirm that the "Baud Rate" is set to 921600, and then click the "Connect Device" button to start connecting the upper computer and the mmWave sensor.



a) Before connection

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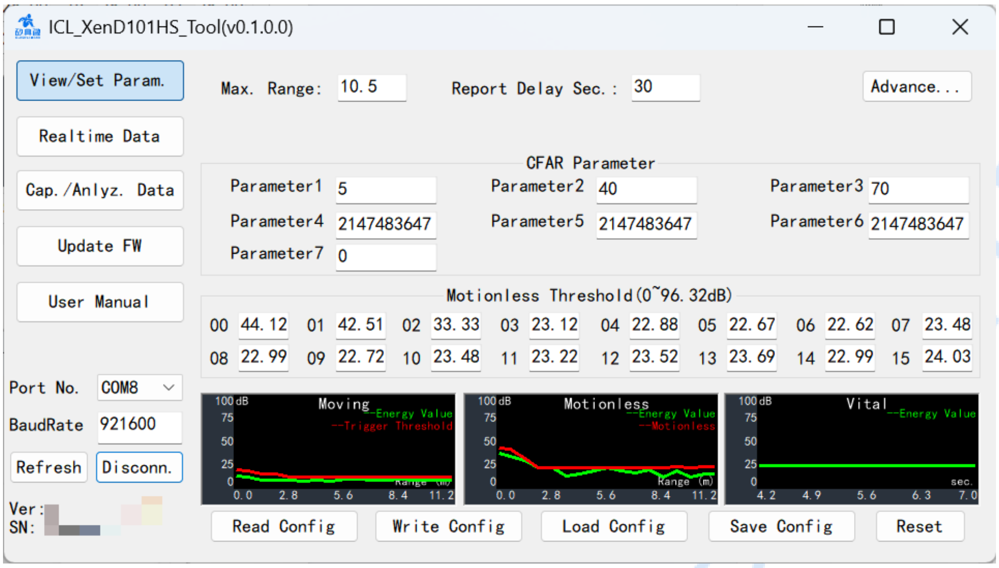

b) After connection

Figure 4-1 ICL_XenD101H_Tool

As shown in Figure 4-1(a), the upper computer tool interface can be divided into three regions: the device operation region (Zone 1), the function button region (Zone 2), and the function page region (Zone 3).

After successfully connecting the upper computer tool to the mmWave sensor, the firmware version number (format: Ver: ...) and serial number (format: SN: ...; if unburned, the upper computer software will display FFFFFFFF) of the mmWave sensor will be displayed in Zone 1 of the interface. The "Parameter View/Setup" function page region will display the current parameter values of the mmWave sensor, as shown in Figure 4-1(b).

4.2.1 Parameter View/Setup

The "Parameter View/Setup" page of the upper computer tool is shown in Figure 4-2, allowing users to view the current parameters of the mmWave sensor and modify specified parameter configurations to meet specific application scenario requirements.

Steps to Read MmWave Sensor Parameters Using the Upper Computer Tool:

- After connecting the XenD101HS to the upper computer tool, click the "Read Sensor Settings" button in the function page. A "Read Parameters Successfully" prompt window will pop up, displaying all current parameter values of the mmWave sensor. Click "OK" to close the prompt window.

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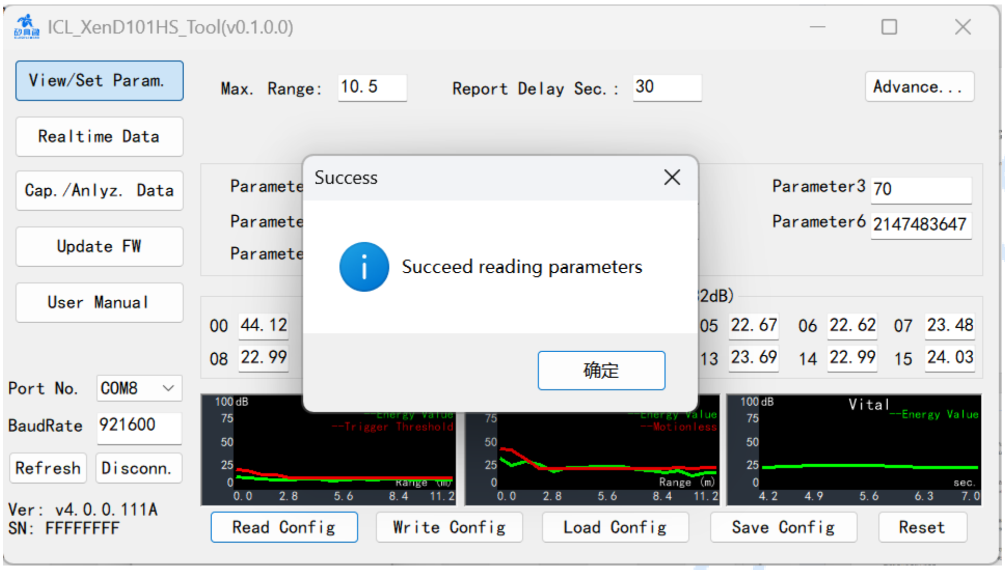

Figure 4-2 Reading mmWave Sensor Parameters Interface

Steps to Change One or More MmWave Sensor Parameters Using the Upper Computer Tool:

1) After connecting the XenD101HS to the upper computer tool, input new parameter values for all parameters that need to be changed in the function page.

2) Click the "Write Sensor Settings" button in the function page. The upper computer will write the current interface's parameter values to the mmWave sensor, and a "Write Parameters Successfully" prompt window will pop up. Click "OK" to complete the parameter settings.

The parameter explanations in the upper computer tool interface are detailed in Table 4-2.

Table 4-2 Parameter Explanations in the Upper Computer Tool Interface

Parameter Name	Description	Range
Maximum Distance	Sets the maximum effective detection distance of the mmWave sensor	0~18 m, precise to 0.1 m
Target Disappearance Delay Time (seconds)	The time delay required for the target state to switch from presence to absence: During this period, if presence is detected, the timer resets. The mmWave sensor only reports absence when no presence has been detected for a complete T time.	0~65535
Parameter 1	Life Detection Start Distance Gate	0–16
Parameter 2	Motion Detection Threshold Coefficient	10–500
Parameter 3	Life Detection Threshold Coefficient	10–500
Parameter 4	Reserved	0–65,535
Parameter 5	Reserved	0–65,535
Parameter 6	Reserved	0–65,535
Parameter 7	Installation Mode Flag: 0 = Ceiling-mounted; 1 = Wall-mounted	0, 1
Micro-Motion & Stationary Threshold (dB)	Sets the energy threshold for detecting human micro-motion and stationary states, which can be calculated using the "Generate Threshold" function	0~96.32, precise to 0.01

The upper computer tool supports saving and loading parameter configurations for the mmWave sensor:

- Click the "Save Configuration File" button and select the desired save path. The upper computer tool will save the current parameter configurations of the mmWave sensor as an .xml file on the upper computer; the default save address is the folder where the upper computer tool is located.

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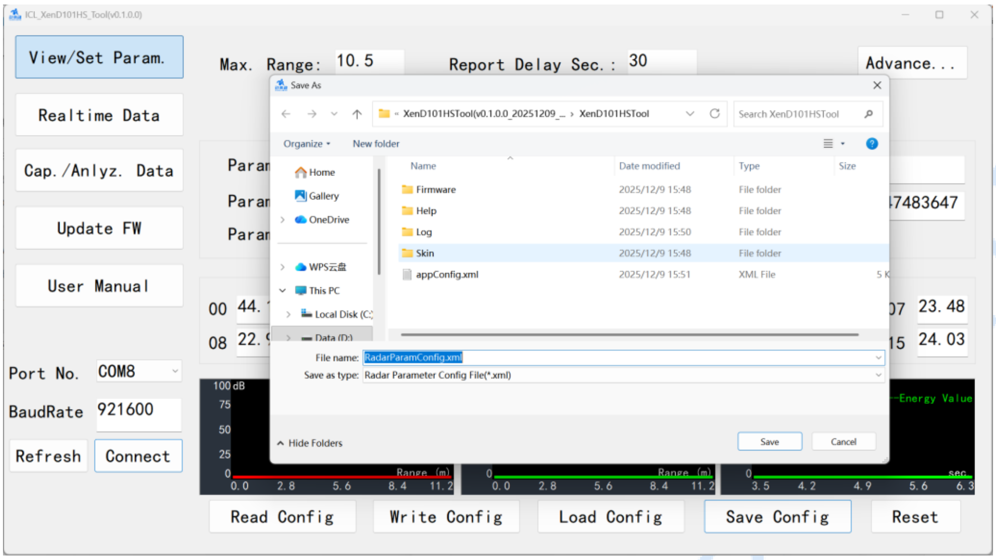

Figure 4-3 Saving Configuration File Interface

- Click the "Load Configuration File" button. The upper computer tool will open the specified parameter configuration file for the mmWave sensor and read in the mmWave sensor parameters. Click the "Write Sensor Settings" button to write the parameters from the configuration file to the mmWave sensor.

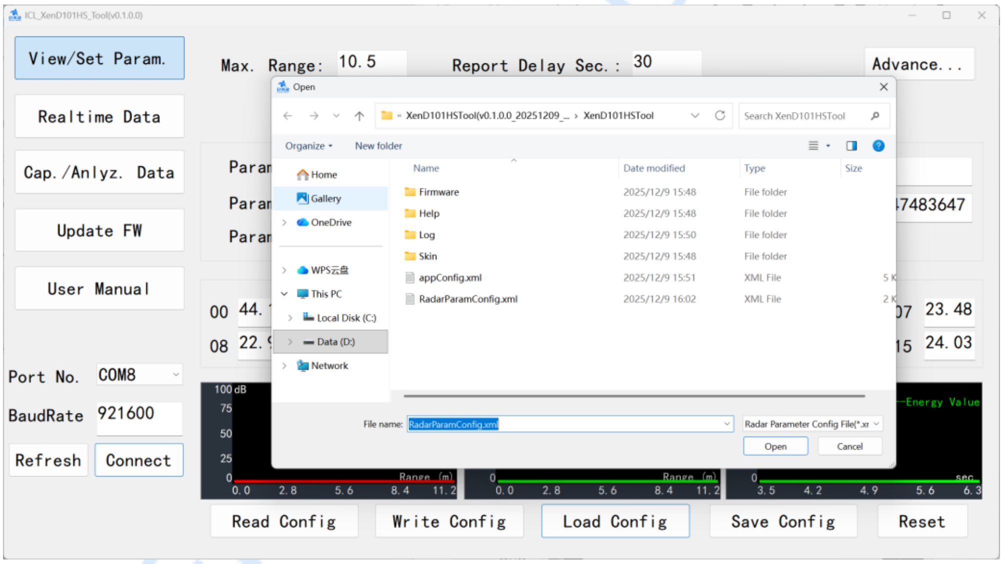

Figure 4-4 Loading Configuration File Interface

4.2.2 Real-Time Data

The "Real-Time Data" page of the upper computer is shown in Figure 4-5, and its function page is mainly divided into the target information area (a), the function button area (b), and the real-time data area (c), with detailed introductions in Table 4-3.

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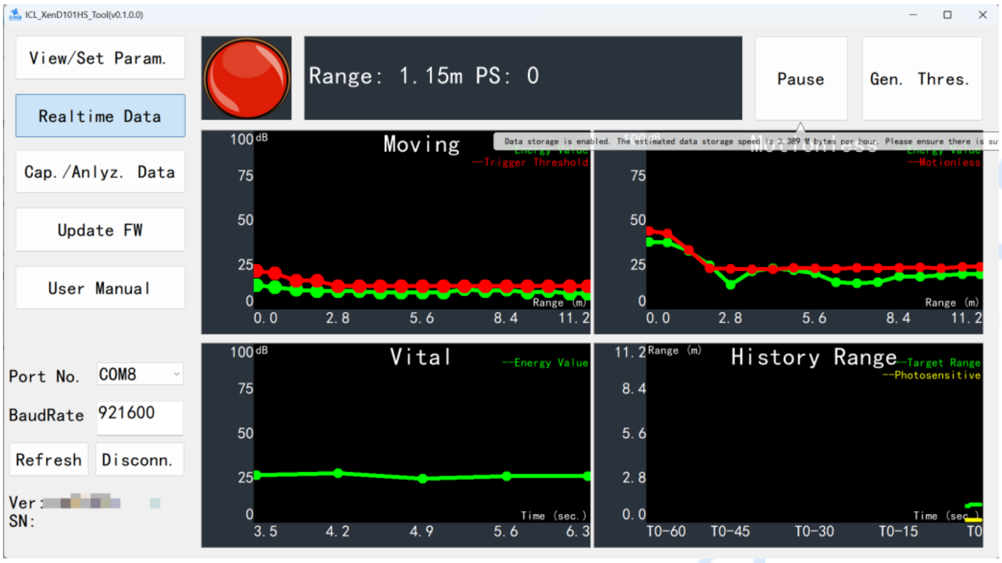

Figure 4-5 Real-Time Data Page

Table 4-3 Functional Area Descriptions of the "Real-Time Data" Page

Page Area		Function	Description
a	Color Lamp Icon	The color of the lamp indicates the presence of human targets in the detection area	Red = Target present; Green = Target absent.
a	Target Information Text Box	Displays the detected target distance information	Shows the straight-line distance between the human target and the sensor.
b	"Start/Pause" Toggle Button	Starts/stops the human presence sensing detection of the sensor	-
b	"Generate Threshold" Button	Scans environmental noise and generates coefficient-based calculations for "Trigger Threshold" and "Hold Threshold" for each distance gate	Refer to Table 4-2 for threshold definitions.
c	"Motion Information/Micro-Motion & Stationary Information" Real-Time Detection Data Display	Displays the real-time motion energy values (green) and threshold values (red)) for each distance gate	Black background = Valid detection range; Gray background = Invalid detection range.
c	"Distance vs. Time" Real-Time Detection Data Display	Displays the distance changes of the target human detected by the mmWave sensor over the past 60 seconds in real-time	Gray background areas indicate that the sensor detected human targets during this time period, while black background areas indicate no human target detection by the sensor during this time period.

Steps to View Real-Time Data Using the Upper Computer:

1) After connecting the XenD101HS to the upper computer tool, click the "Real-Time Data" button to switch to this function page. The upper computer tool automatically enables the detection function of the mmWave sensor, and the "Start/Pause" toggle button displays "Pause". The color lamp icon, target information text box, and two broken line graphs in the function page start displaying corresponding real-time data information.

2) (Optional) Click the "Start/Pause" toggle button to pause the detection function of the mmWave sensor. The function page's color lamp turns green, the target distance displays "0.00 meters", and the two broken line graphs stop updating.

4.2.3 Firmware Update

The "Firmware Update" page of the upper computer is shown in Figure 4-6. The steps to update the mmWave

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sensor firmware using the upper computer are as follows:

1) After connecting the XenD101HS to the upper computer tool, click the "Firmware Update" function button to switch to this function page.

2) Click the "Get Firmware Information" button in the function page. The right-side information prompt box will display the current device's ID information.

3) Click the "Select .bin File Path" button, select the desired .bin file, and click the "Download" button to start upgrading the firmware. The right-side information prompt box will display the download result in real-time, and the bottom will display the .bin file information and the current download progress.

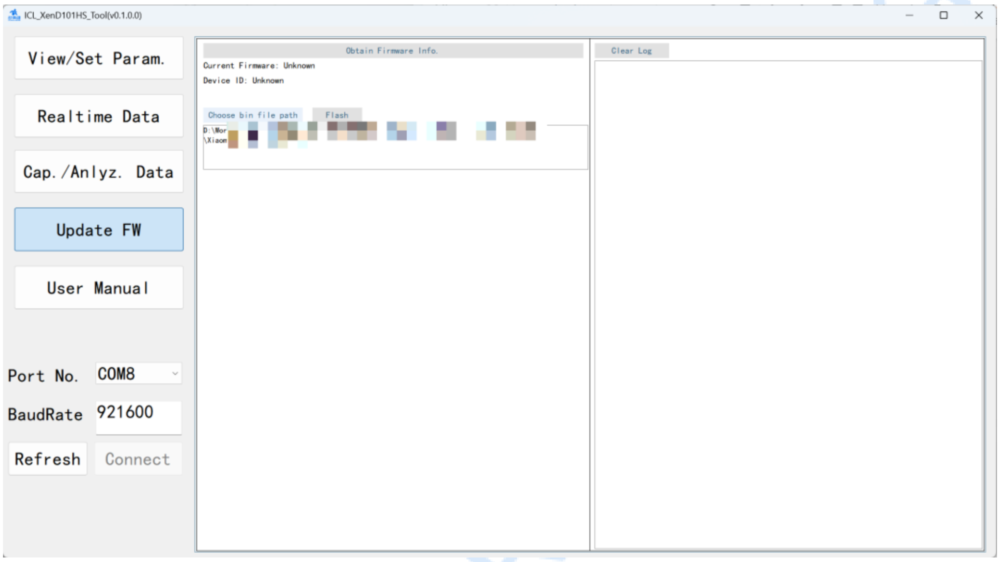

Figure 4-6 Firmware Upgrade Page

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

5. Communication Protocol

This communication protocol is primarily intended for users who need to perform secondary development without relying on visualization tools. The XenD101HS narrow-frame human presence mmWave sensor communicates with the external world through a serial port (TTL level). Data output and parameter configuration commands for the mmWave sensor are conducted under this protocol. The default baud rate for the mmWave sensor's serial port is 921600, with 1 stop bit and no parity bit.

This chapter mainly introduces this communication protocol from three parts:

- Protocol Format: Includes protocol data format and command frame format.
- Configuration Command Packet Format: Includes command packet format and command response packet format.
- Upload Data Frame Format: Includes debug mode upload data frame format and report mode upload data frame format.

The basic process for using commands to configure parameters is:

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

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5.1 Protocol Format

5.1.1 Protocol Data Format

The data communication of XenD101HS uses the little-endian format, and all data in the following tables is in hexadecimal.

5.1.2 Command Protocol Frame Format

The formats of sensor configuration commands and ACK commands defined in the protocol are shown in Table 5-1 to Table 5-4.

Table 5-1 Format of transmission command frame

Head	Data Length	Data Value	Tail
FD FC FB FA	2 bytes	Refer to Table 5-2	04 03 02 01

Table 5-2 Format of data inside the transmission command

Command Word	Command Value
2 bytes	N bytes

Table 5-3 ACK frame format

Head	Data Length	Data Value	Tail
FD FC FB FA	2 bytes	Refer to Table 5-4	04 03 02 01

Table 5-4 Format of data inside the ACK

Command Word & 0x0100	Command Execution Status	Return Value
2 bytes	2 bytes	N bytes

5.2 Transmission Command and ACK

5.2.1 Read Firmware Version

This command reads the firmware version information.

Command Word: 0x0000

Command Value: None

Return Value: 2 bytes major revision number + revision number byte string

Sending data:

Head	In-frame Data Length	Command Word	Tail
FD FC FB FA	02 00	00 00	04 03 02 01

ACK from sensor(succeed):

Head	In-frame Data Length	Command Word	ACK	Version Number Length	Version Number	Tail
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

Any other commands issued to the mmWave sensor must be executed after this command is issued; otherwise, they will be invalid.

Command word: 0x00FF

Command value: 0x0001

Return value: 2 bytes ACK state (0-succeed, 1-fail) + 2 bytes protocol revision (0x0002) + 2 bytes

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buffer size(0x0020)

Sending data:

Head	In-frame Data Length	Command Word	Command Value	Tail
FD FC FB FA	04 00	FF 00	01 00	04 03 02 01

ACK from sensor(succeed):

Head	In-frame Data Length	Command Word	ACK	Protocol Version	Buffer Size	Tail
FD FC FB FA	08 00	FF 01	00 00	02 00	20 00	04 03 02 01

5.2.3 End Configuration

This command is used to end the configuration mode and restore the sensor to its operational mode. If further commands need to be issued, the enable configuration command must be sent first.

Command word: 0x00FE

Command value: None

Return value: 2 bytes ACK state (0-succeed, 1-fail)

Sending data:

Head	In-frame Data Length	Command Word	Tail
FD FC FB FA	02 00	FE 00	04 03 02 01

ACK from sensor(succeed):

Head	In-frame Data Length	Command Word	ACK	Tail
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: None
- Return Value: 2-byte ACK Status (0 for success, 1 for failure) + SN Length (2 bytes) + SN (2 bytes)

Sending data:

Head	In-frame Data Length	Command Word	Tail
FD FC FB FA	02 00	11 00	04 03 02 01

ACK from sensor(succeed):

Head	In-frame Data Length	Command Word	ACK	SN Length	SN	Tail
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 to the mmWave sensor.

Command Word: 0x0010

Command Value: SN Length (2 bytes) + SN Byte String (2 bytes)

Return Value: 2-byte ACK Status (0 for success, 1 for failure)

Sending data:

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Head	In-frame Data Length	Command Word	SN Length	SN	Tail
FD FC FB FA	06 00	10 00	02 00	CD AB	04 03 02 01

ACK from sensor(succeed):

Head	In-frame Data Length	Command Word	ACK	Tail
FD FC FB FA	04 00	10 01	00 00	04 03 02 01

5.2.6 Read Sensor Register Parameter

This command reads the registers of the mmWave sensor.

Command word: 0x0002

Command value: 2-byte Chip Address + (2-byte Register Address) * N

Return value: (2-byte Register Data) * N

Sending data:

Head	In-frame Data Length	Command Word	Chip Address	Register Address	Tail
FD FC FB FA	06 00	02 00	40 00	40 00	04 03 02 01

ACK from sensor: (succeed)

Head	In-frame Data Length	Command Word	ACK	Register Data	Tail
FD FC FB FA	06 00	02 01	00 00	07 02	04 03 02 01

5.2.7 Configure Sensor Register

This command writes to the registers of the mmWave sensor.

Command Word: 0x0001

Command Value: 2-byte Chip Address + (2-byte Register Address + 2-byte Register Data) * N

Return Value: 2-byte ACK Status (0-success, 1-failure)

Sending data:

Head	In-frame Data Length	Command Word	Chip Address	Register Address	Register Data	Tail
FD FC FB FA	08 00	01 00	40 00	40 00	07 42	04 03 02 01

ACK from sensor: (succeed)

Head	In-frame Data Length	Command Word	ACK	Tail
FD FC FB FA	04 00	01 01	00 00	04 03 02 01

5.2.8 Read Sensor Parameter Configuration

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

Sending data:

Head	In-frame Data Length	Command Word	Parameter ID	Tail
FD FC FB FA	04 00	08 00	01 00	04 03 02 01

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ACK from sensor: (succeed)

Head	In-frame Data Length	Command Word	ACK	Parameter Value	Tail
FD FC FB FA	08 00	08 01	00 00	0C 00 00 00	04 03 02 01

5.2.9 Configure Sensor Parameters

This command sets the parameters of the mmWave sensor. For specific parameter details, refer to Table 5-5, which adds micro-motion & static threshold parameters and power interference alarm parameters.

Table 5-5 Sensor Parameter Table

Parameter	Parameter Word	Range
Maximum Distance Gate	0x0001	0~15
Target Absence Delay	0x0004	0~65535 s
Micro-motion & Static Threshold	0x0030 ~ 0x003F	0~2^32, squared modulus value
Power Interference Alarm	0x0005	Lower 16 bits: 0: Not performed; 1: No interference; 2: Interference exists. Upper 16 bits: Interference frequency, range 0~256 kHz; valid only when the lower 16 bits are 2. 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)

Sending data:

Head	In-frame Data Length	Command Word	ACK	Parameter Value	Tail
FD FC FB FA	08 00	07 01	01 00	0C 00 00 00	04 03 02 01

ACK from sensor: (succeed)

Head	In-frame Data Length	Command Word	Parameter ID	Tail
FD FC FB FA	04 00	07 01	00 00	04 03 02 01

5.2.10 Save Sensor Parameters

After this command is sent, the sensor will save its current parameters.

- Command Word: 0x00FD
- Command Value: None
- Return Value: 2-byte ACK status (0 for success, 1 for failure) + SN length (2 bytes) + SN (2 bytes)

Sending data:

Head	In-frame Data Length	Command Word	Tail
FD FC FB FA	02 00	FD 00	04 03 02 01

ACK from sensor(succeed):

Head	In-frame Data Length	Command Word	ACK	Tail
FD FC FB FA	04 00	FD 01	00 00	04 03 02 01

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5.2.11 Configure System Parameters

This command allows for the configuration of mmWave sensor system parameters.

- Command Word: 0x0012
- Command Value: (2-byte parameter ID + 4-byte parameter value) * N
- Return Value: 2-byte ACK status (0 for success, 1 for failure)
- Sending data:

Head	In-frame Data Length	Command Word	ACK	Parameter Value	Tail
FD FC FB FA	08 00	12 01	00 00	04 00 00 00	04 03 02 01

The parameter values correspond to the following modes:

No.	Parameter Value	Description
1	04 00 00 00	Debug Mode
2	64 00 00 00	Reporting Mode

ACK from sensor(succeed):

Head	In-frame Data Length	Command Word	ACK	Tail
FD FC FB FA	04 00	12 01	00 00	04 03 02 01

5.2.12 Reporting Automatic Threshold Interference

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

Sending data:

Head	In-frame Data Length	Command Word	Tail
FD FC FB FA	02 00	FD 00	04 03 02 01

ACK from sensor(succeed):

Head	In-frame Data Length	Command Word	Parameter Value	Tail
FD FC FB FA	06 00	14 01	2-byte status byte + 2-byte distance gate status Status Byte: 0000: Success, no interference; 0001: Failure, interference present Distance Gate Status: Example: 0x8402, converted to binary as 1000_0100_0000_0010, indicating interference in distance gates 1, 10, and 15.	04 03 02 01

5.3 Report Data

The factory firmware of XenD101HS normally operates in a mode where it outputs detection results via the serial port. There are two output modes: debug mode and reporting mode.

When configured in reporting mode, it outputs the string "OFF" when no target is detected and the string "distance: target distance" when a target is detected. When configured in debug mode, the data format is as shown in Table 5-6.

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Table 5-6 Data Frame Format in Debug Mode

<table>
<tr><th>Head</th><th colspan="2">Length</th><th>Detection Result</th><th>Target Distance</th><th>Light Sensitivity Value</th><th>Motion Energy</th></tr>
<tr><td>F4 F3 F2 F1</td><td colspan="2">2 bytes, total number of bytes for detection result, target distance, and energy values for each distance gate</td><td>1 byte, 00 for no person, 01 for person present</td><td>2 bytes</td><td>2 bytes</td><td>16 distance gates * 4 bytes</td></tr>
<tr><th colspan="2">Motion Trigger Threshold</th><th>Static Energy</th><th>2DFFT Data Head</th><th colspan="2">2DFFT Data</th><th>Tail</th></tr>
<tr><td colspan="2">16 distance gates * 4 bytes</td><td>16 distance gates * 4 bytes</td><td>1 byte: 0xAA</td><td colspan="2">4 distance gates * 4 bytes</td><td>F8 F7 F6 F5</td></tr>
</table>

6. Installation and Detection Range

The XenD101HS narrow-bezel mmWave sensor for human presence detection supports two installation methods: ceiling-mounted and wall-mounted, with wall-mounted installation being the recommended approach.

6.1 Ceiling-Mounted Installation

When the XenD101HS is installed on the ceiling at a height of 3 m, its maximum motion sensing range forms a conical space with a bottom radius of 4.5 m, as illustrated in Figure 6-1.

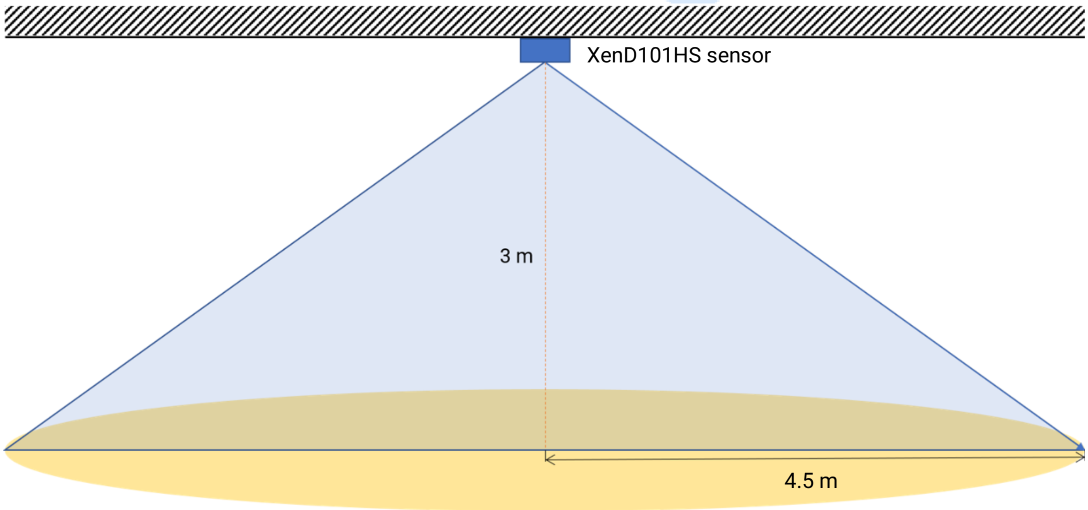

Figure 6-1 Schematic Diagram of the Detection Range for XenD101HS Ceiling-Mounted Installation

It should be noted that as the installation height decreases, the maximum sensing range gradually narrows, as depicted in Figure 6-2.

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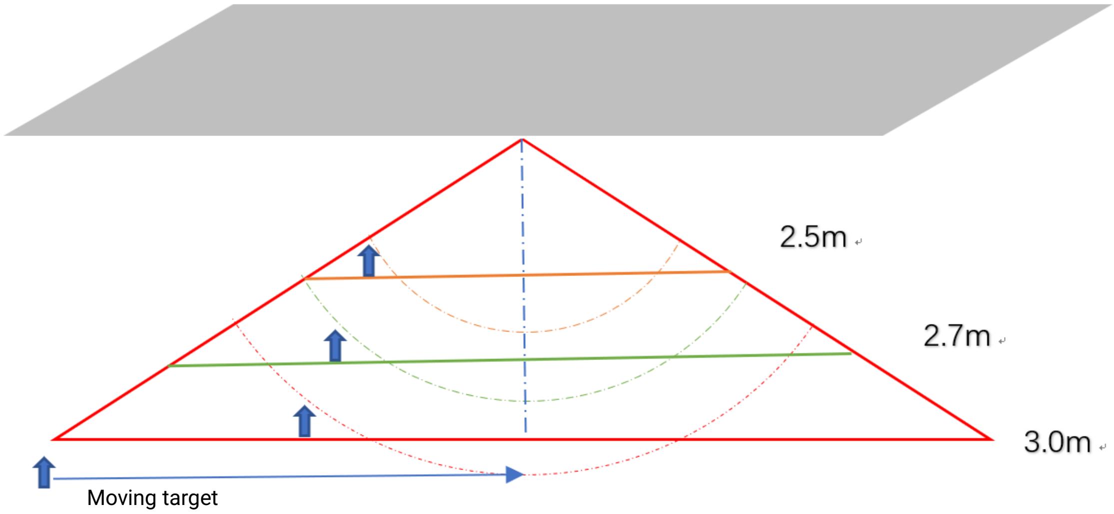

Figure 6-2 Relationship Between Installation Height and Detection Range for XenD101HS Ceiling-Mounted Installation

The schematic diagram of the motion and micromotion detection range for this reference solution when the ceiling-mounted installation height is 2.7 m is shown in Figure 6-3.

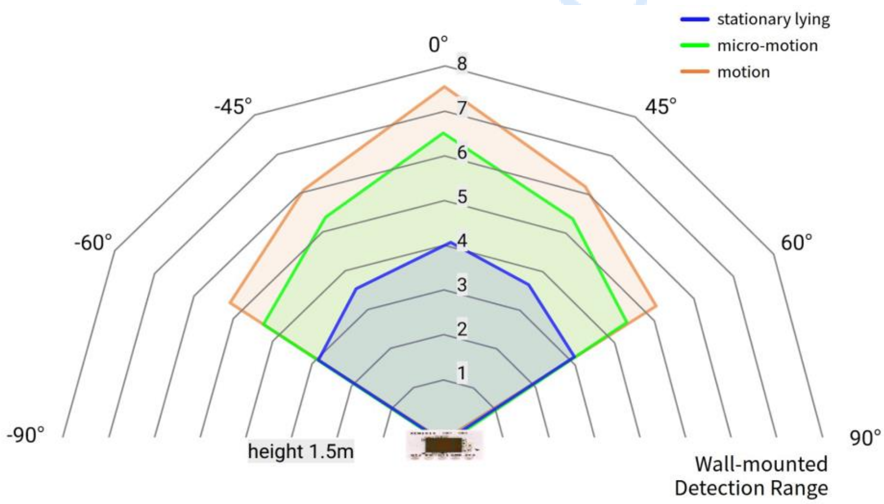

Figure 6-3 Sensing Range of XenD101HS Ceiling-Mounted Installation

6.2 Wall-Mounted Installation

The recommended wall-mounted installation height ranges from 1.5 m to 2.0 m. During wall-mounted installation, the X-axis (reference) of the mmWave sensor points horizontally, the Z-axis points upwards, and the Y-axis points towards the detection area. In its default configuration, the XenD101HS wall-mounted installation has a maximum motion sensing range that forms a conical space extending 8 m in the normal direction of the sensor and within an angle of ±60° in both the horizontal and pitch directions, as shown in Figure 6-4.

The schematic diagram of the detection range for this reference solution when the wall-mounted installation height is 1.5 m is presented in Figure 6-5.

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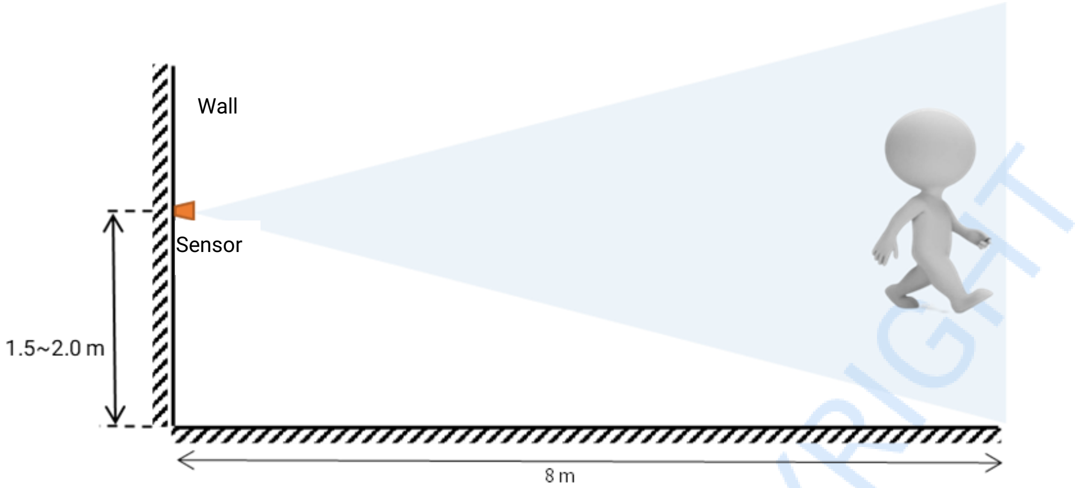

Figure 6-4 Schematic Diagram of the Detection Range for XenD101HS Wall-Mounted Installation

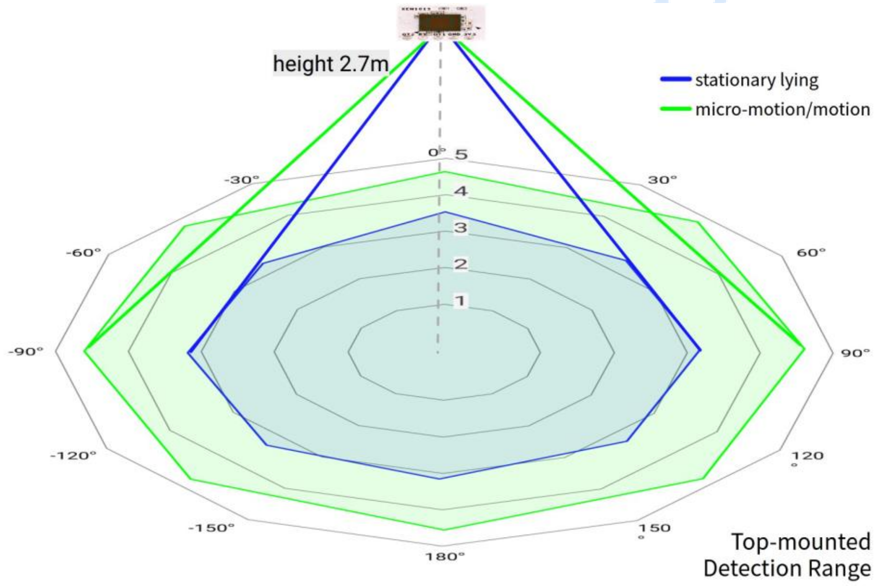

Figure 6-5 Sensing Range of XenD101HS Wall-Mounted Installation

6.3 Detection Range Testing

The testing methods for the triggering and maintaining detection ranges of the mmWave sensor are described separately as follows:

- **Triggering Range**: With the target human approaching the mmWave sensor from a distance while the sensor reports no one present, the target stops advancing when the sensor begins to report the presence of a person. The current position marks the boundary of the triggering detection range of the mmWave sensor. The area enclosed by the detection boundaries in all directions constitutes the triggering detection range of the mmWave sensor.
- **Maintaining Range**: While the mmWave sensor reports the presence of a person, the target human remains at the position to be tested and performs minor movements, such as shrugging or raising their hands. If the mmWave sensor continues to report the presence of a person for 60 s, the current position is within the maintaining detection range of the mmWave sensor; otherwise, the detection position is outside the maintaining detection range.

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7. Mechanical Size

Figure 7-1 illustrates the mechanical dimensions of the hardware Xen101S. All dimensions are in millimeters (mm). The board thickness of the hardware Xen101S is 1 mm, with a tolerance of ±10%.

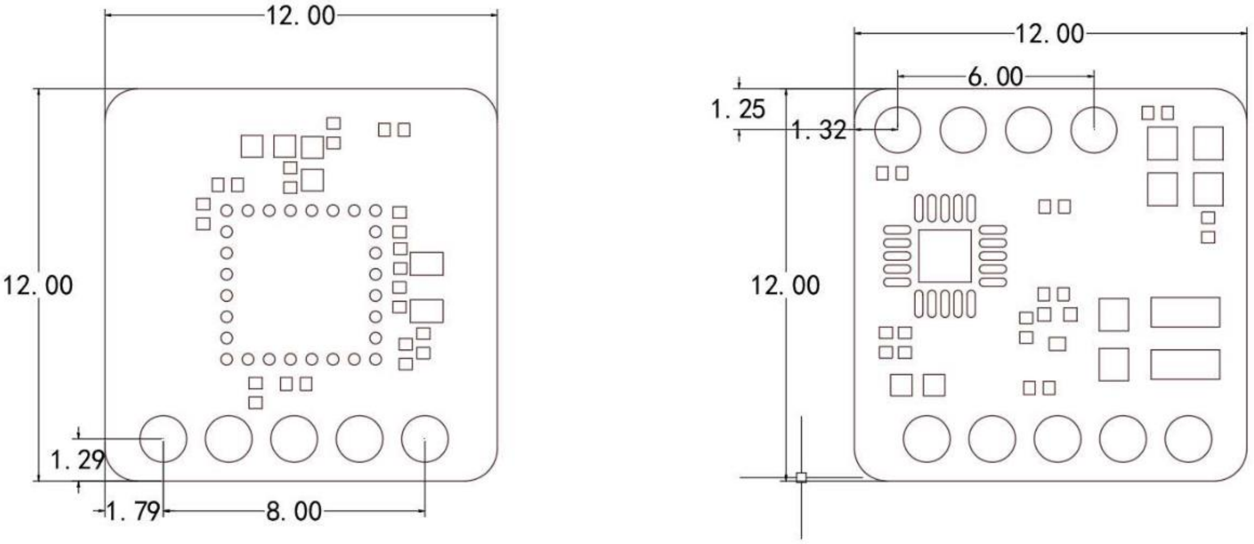

Figure 7-1 Mechanical Dimensions of Hardware Xen101S

8. Installation Requirement

8.1 Radome Requirements

If an enclosure is required for the sensor, ensure that the enclosure has good transmission characteristics at the 24 GHz frequency band and does not contain any materials with metal or electromagnetic wave shielding properties. For more recommendations on enclosure design, please refer to mmWave Sensor Radome Design Guide.

8.2 Installation Environment

To ensure optimal detection performance, avoid using this product in the following environments:

- Presence of non-human objects with continuous movement in the sensing area, such as animals, swinging curtains, and large plants directly facing air vents.
- Presence of large reflective surfaces in the sensing area, as direct reflection onto the sensor antenna may cause interference.
- When installing on a wall, consider external interference factors such as indoor ceiling-mounted air conditioners, fans, etc.

8.3 Important Requirements

- Ensure that the sensor antenna is directly facing the detection area and is unobstructed on all sides.
- The sensor should be installed in a firm and stable position to avoid impact on detection performance due to shaking.
- To prevent objects behind the sensor from affecting detection, a metal shielding cover or backplate can be used to shield the sensor back lobe. Due to the penetrating nature of sensor waves, the antenna back lobe may detect moving objects behind the sensor.
- When multiple sensors operating at the 24 GHz frequency band are present, avoid aligning the beams directly and install them as far apart as possible to reduce potential mutual interference.

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8.4 Power Supply

- The power input voltage range is 3.0~3.6 V, and with an LDO attached, it is 4.5~5.5 V. The power supply ripple should not have significant spectral peaks within 100 kHz. This solution is a reference design, and users need to consider corresponding electromagnetic compatibility designs such as ESD and lightning surge protection.

9. Important Tips

9.1 Maximum Detection Range

The maximum range for the mmWave sensor to detect a target is a radial distance of 8 m. Within this detection range, the mmWave sensor reports the straight-line distance between the target and itself.

9.2 Range Accuracy

Theoretically, the ranging accuracy of the mmWave sensor in this reference solution is ±0.15 m. Due to variations in the size, state, and Radar Cross Section (RCS) of human targets, the ranging accuracy may fluctuate, as well as the maximum detection range.

9.3 Target Absence Delay Time

When the mmWave sensor detects that there is no human presence in the target area, it does not immediately report an "unoccupied" status but introduces a delay. The mechanism for delayed reporting is as follows: Once no human target is detected within the test range, the mmWave sensor starts a timer, which represents the duration of the unoccupied status. If no human presence is continuously detected during the timer's duration, the sensor reports an "unoccupied" status after the timer expires. If human presence is detected during this period, the timer is immediately reset and updated, and the target information is reported.

9.4 Micromotion Detection Range

The detection range of the mmWave sensor for human micromotions is inversely proportional to the angle between the normal direction of the human body and the normal direction of the sensor. Therefore, in micromotion detection scenarios, it is recommended to adjust the position and angle of the mmWave sensor during installation to minimize the angle between its normal direction and that of the detected human body, thereby improving detection accuracy and range.

9.5 Optimization of Automatic Threshold Generation Function

The optimization of the automatic threshold generation function has enhanced the overall performance of the XenD101HS, providing users with a better experience. The specific optimizations are as follows:

- **Reduced On-Site Debugging Workload**

  Through the automatic threshold generation function, the system can automatically calculate and set appropriate threshold values, significantly reducing the on-site debugging workload. This avoids the drawback of engineers needing to manually adjust the threshold values of each mmWave sensor during traditional product deployment, making large-scale deployments more efficient and convenient. It improves deployment efficiency and reduces the risk of human errors.

- **Improved Detection Accuracy**

  The automatic threshold generation function can accurately perceive the environment and analyze data to automatically calculate the most suitable threshold values for the current environment. This method reduces interference from human factors in manual adjustments and ensures that the sensor maintains optimal detection accuracy in various complex environments. Whether detecting static targets stably or responding quickly to dynamic targets, the XenD101HS (Note: Corrected from XenD103H to maintain consistency with the context) can provide accurate and reliable results, offering users an exceptional experience.

- **Simplified Installation Process**

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The automatic threshold generation function simplifies the sensor installation process. Users only need to complete basic installation steps, and the sensor can automatically optimize the threshold settings without complex manual debugging.

- **Reduced Maintenance Costs**

  The sensor can automatically adjust threshold values in real-time based on environmental changes, reducing the need for periodic manual adjustments due to environmental variations. This reduces the workload of maintenance personnel, improves system operational efficiency and stability, and saves maintenance costs for users.

- **Flexible Triggering Methods**

  To meet the needs of different users and application scenarios, we provide two flexible methods for automatically generating triggering thresholds: external triggering and sensor automatic judgment of start conditions.

  - External Triggering: Users can trigger the automatic generation of thresholds through external signals. This method allows users to manually control the timing of threshold generation based on the needs of the actual application scenario.
  - Sensor Automatic Judgment of Start Conditions: For users requiring a higher degree of automation, we offer a function where the sensor automatically judges the start conditions for generating threshold values. This function is based on intelligent algorithms built into the sensor and can automatically determine when to begin 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 Explanation of Ceiling-Mounted Static Lying Test

The sensor can detect stationary lying states, with higher sensitivity in the tangential direction compared to the radial direction. Examples of tangential and radial stationary lying states are shown in Figure 9-1.

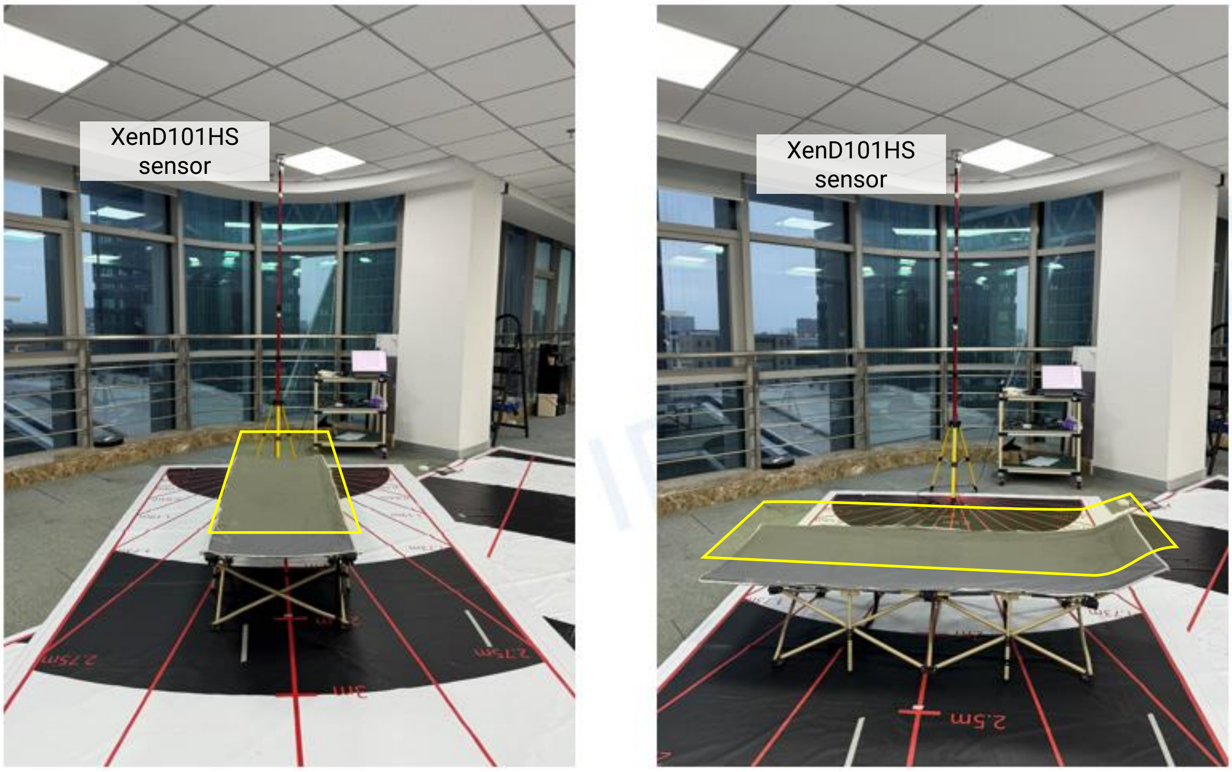

Figure 9-1 Examples of Tangential and Radial Stationary lying states

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10. Revision History

Revision	Date	Modification
1.0	2025/12/10	Initial release.

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