Rd-03D Multi-Target Trajectory Tracking User Manual

Version   V1.0.0

Copyright   ©2023

Document resume

Version	Date	Develop/revise content	Edition	Approve
V1.0.0	2023.9.14	First Edition	Zhanyun Lin	Zifeng Chen

Introduction

This document describes the basic functions, hardware specifications, software usage, and installation conditions of the Rd-03D of the high-precision multi-target recognition millimeter-wave sensor (training design). It is designed to help users quickly get started Rd-03D multi-target recognition solutions.

Content

1 Rd-03D Overview

Target tracking refers to the real-time tracking of the location of the target in the region, to achieve the target in the region ranging, angle measurement and velocity measurement.

The Rd-03D is a high-precision multi-target recognition millimeter-wave sensor (finalized design) of the silicon micro-EZSensor series, which includes extremely simplified 24 GHz radar sensor hardware CS202_v2 and intelligent algorithm firmware TTO1. This solution is mainly used in common indoor scenes such as homes, offices and hotels to achieve positioning and tracking of single or multiple human bodies.

The sensor hardware consists of AIoT millimeter-wave radar chip S5KM312CL, high-performance microstrip antenna with one transmitter and two receiver, low-cost MCU and peripheral auxiliary circuit. The intelligent algorithm firmware TTO1 uses FMCW waveform and S5KM312CL chip proprietary advanced signal processing technology.

The main features of the Rd-03D are as follows:

No.	Characteristics	No.	Characteristics
1	24GHzISM band	6	5Vpower supply
2	Integrate smart millimeter-wave radar chip S5KM312CL and smart algorithm firmware	7	Max. detection distance: 8m
3	Accurate target positioning and tracking	8	Azimuth ± 60 °, Pitch ± 30 °
4	Ultra-small module size: 15mm x 44mm	9	Wall mounting
5	Ambient temperature:-20 ℃ ~ 70 ℃		

Rd-03D multi-target recognition millimeter-wave sensors can accurately locate and track targets and are widely used in various AIoT scenarios, covering the following types:

Scene	Description	Scene	Description
Smart Home	Perceive the distance and angle of the human body and report the test results for the main control module to intelligently control the operation of home appliances such as air conditioners and fans.	Bathroom	Intelligent toilet accurate control toilet lid automatic switch
Intelligent Business	Position sensing, identify the human body approaching or far away within the set position	lighting	Recognition and perception of the human body, precise position detection, can be used for home

	interval, light up or close the screen in time		lighting equipment (induction lamps, desk lamps, etc.)

2 System description

The Rd-03D is a high-precision multi-target recognition millimeter-wave sensor (stereotyped design) based on silicon micro-S5KM312CL chips. The sensor uses FMCW waveforms, combined with the MCU's proprietary radar signal processing and built-in intelligent location and tracking algorithms to detect multiple targets in a specified area and report the results in realtime. Based on this design, users can quickly develop the corresponding target location tracking products. Rd-03D specifications are shown in Table 2-1

Table 2-1 Rd-03D Specification

Parameters	Remarks	Minimum	Typical	Max.	Unit
Rd-03D Hardware Specifications					
Supported bands		24	-	24.245	GHz
Support maximum sweep bandwidth		-	0.25	-	GHz
Supply voltage		4.5	5	5.5	V
Dimensions		-	15 x 44	-	mm^2
Ambient temperature		-20	-	70	°C
Rd-03D system performance					
Maximum sensing distance		-	8	-	m
Distance resolution		-	0.75	-	m
ranging accuracy		-	0.15	-	m
Angle accuracy		2	-	20	°
Working frequency band	Comply with FCC, CE, non-committee certification standards	24	-	24.25	GHz
sweep frequency band		-	0.21	-	GHZ
Data Refresh Rate	Frequency of radar reporting results	-	10	-	Hz

Average operating current			-	110	-	mA

3 Hardware Description

Figures (a) and (b) of Figure 3-1 are photos of the front and back of the Rd-03D hardware respectively. Rd-03D FWF15004 type connector J1 of TXGA is reserved for hardware as power supply and communication interface. J2 is burning and testing contact, and the function of some contacts is consistent with that of some contacts in J1.

(a)front   (b)back

Figure 3-1 Rd-03D Hardware physical diagram

Refer to table 3-1 and 3-2 for the pin descriptions of J1 and J2

Table 3-1 J1 Pin Description

J#PIN#	Name	Function	Description
J1PIN1	5V	Power input	5V
J1PIN2	GND	Ground	Connect to serial board GND
J1PIN3	TX	UART_TX	Connect to serial board RXD
J1PIN4	RX	UART_RX	Connect to serial board TXD
J1PIN5	DP	Positive signal of programing data	Not connected when using a 4-pin serial board
J1PIN6	DM	Negative signal of programing date	Not connected when using a 4-pin serial board

Table 3-2 J2 Pin Description

J#PIN#	Name	Function	Description
J2PIN1	5V	Power input	5V
J2PIN2	DM	Negative signal of programing date	-
J2PIN3	DP	Positive signal of programing data	-
J2PIN4	DEBUG	Debug putput TXD	Serial port pin for outputting debugging log
J2PIN5	GND	Ground	-

| J2PIN6 | TX | UART_TXD | Connect to serial board RXD |
| J2PIN7 | RX | UART_RXD | Connect to serial board TXD |

Rd-03D need to use Jerry's JL USB Updater tool for image burning. Regarding the use of burning tools and the construction of Jerry MCU development environment, the official has provided detailed steps. For details, please refer to the website:

https://doc.zh-jieli.com/Tools/zh-cn/dev_tools/dev_env/index.html

4 Software Description

Rd-03D the hardware has been shipped from the factory and the system firmware has been burned. Ai-Thinker can refer to the information provided by ICLEGEND MICRO. The CSP202TT visual PC demonstration tool software is convenient for users to intuitively experience the positioning and tracking effect of the radar module on the target.

4.1 Introduction of host computer tools

PC tool ICLM_MTT.exe is a green software developed for Rd-03D. After connecting the host computer and Rd-03D hardware, the host computer tool can display, record, save and playback radar data.

Here are the steps to connect the host computer tool to the radar module:

Step 1: Use the connection line to connect the Rd-03D module and the serial port tool, the connection method is shown in Figure 4-1, through the serial port tool to connect the module and the upper computer;
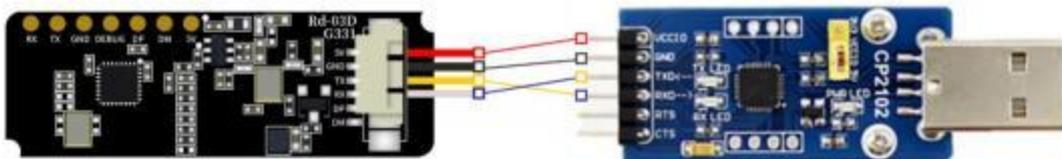
Figure 4-1 Rd-03D module and serial port tool connection

Step 2: Double-click to open the upper computer tool "ICLM_MTT.exe", and the demonstration tool interface will popup, as shown in Figure 4-2.
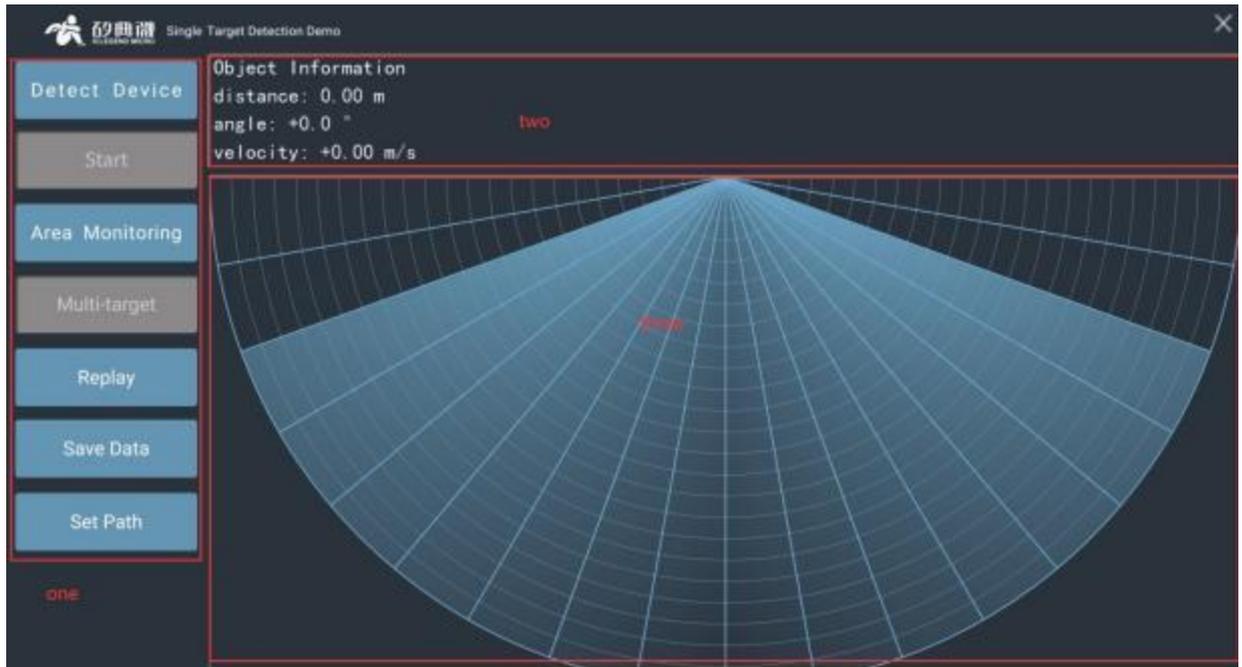
Figure 4-2 Demo Tool Interface

The visualization tool interface is mainly divided into "function button area 1", "data area 2" and "target display area 3". The functions of each area are as follows:

1. Function button area:

    ✍   The Detect Device button is used to detect whether the Rd-03D module is connected successfully

    ✍   Start/Stop toggle button to start or stop receiving radar data

    ✍   Area Monitoring button is used to set the monitoring area and set the blind area range

    ✍   Multi-target detection/single target detection" switch button is used to switch single target detection and multi-target detection mode

    ✍   Playback button for playback of recorded radar data

    ✍   Save Data button for recording radar data

    ✍   Set Patch button is used to set the path for radar data storage

2. Data area: real-time display the distance, angle and speed information of the tracked target.

3. Target display area: Visually display the position of the target being located and tracked in the detection area in the radar map.

4.2 The use of upper computer tools

4.2.1 Single target/multi-target detection

The specific operation steps of using the single-target or multi-target detection function of the upper computer are as follows:

Step 1: Connect the Rd-03D module and the serial port tool according to the steps in subsection 4.1 of this chapter, and open the host computer tool.

Step 2: Click the "Detect Device" button on the interface. If the serial port connection is correct, the interface will popup the prompt box of "Detect Serial Device", as shown in Figure 4-3. Click "OK" to continue;
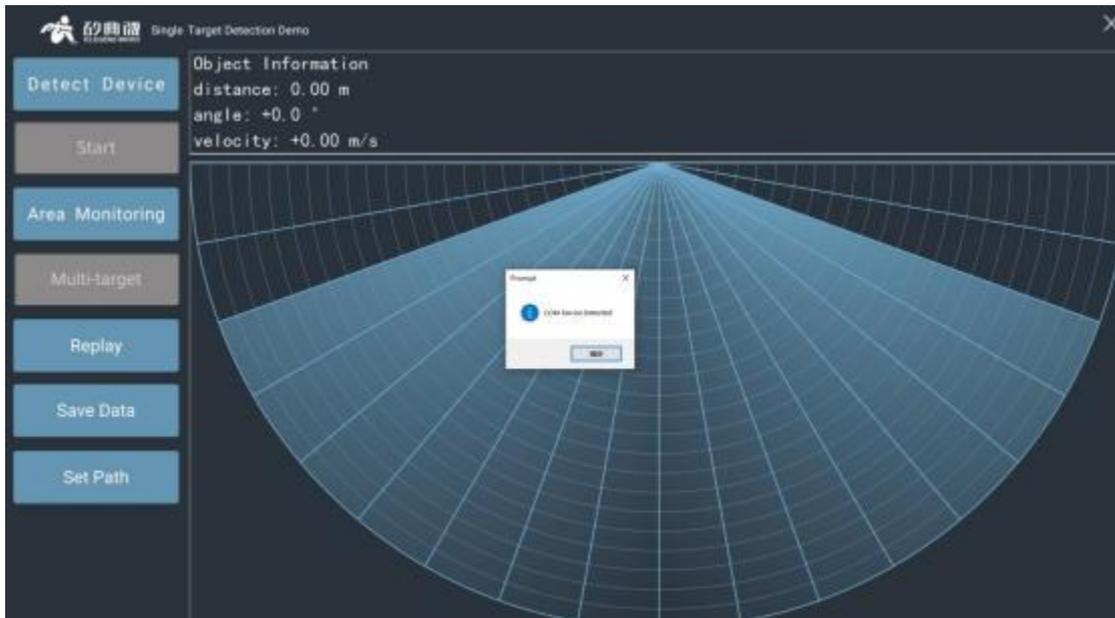
Figure 4-3 Device successfully detected

Step 3: Click the "Start/Stop" switch to display the position of the target relative to the radar, as shown in Figure 4-4:
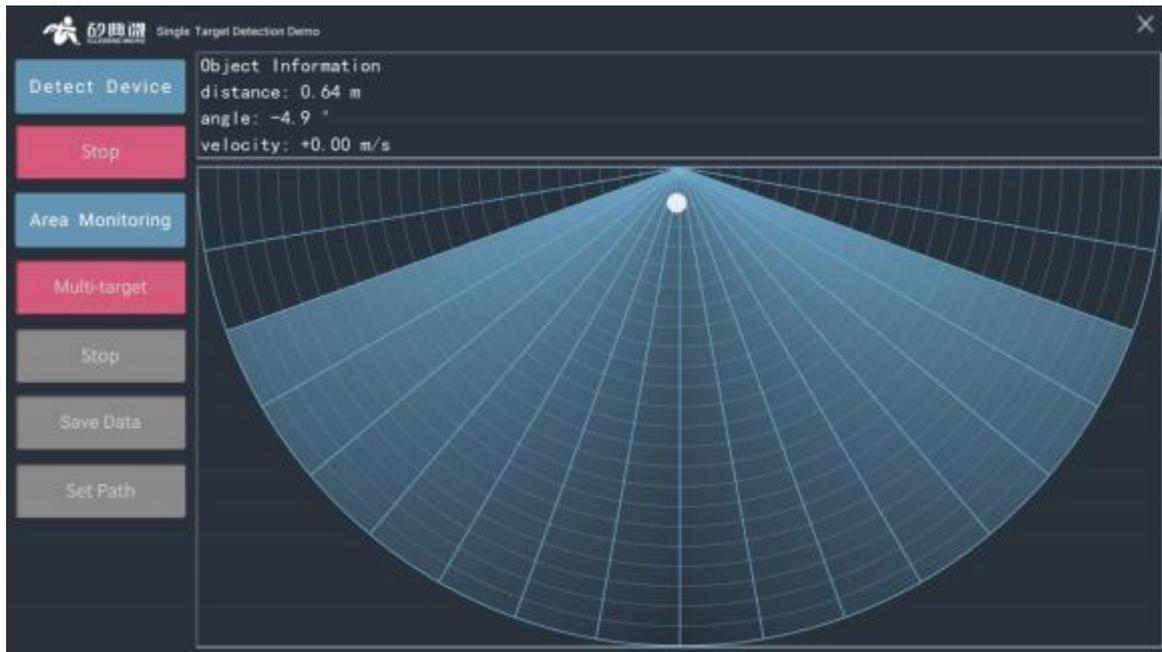
Figure 4-4 Single target detection demonstration

Step 4: After the upper computer is opened, the default is "single target detection demonstration", click the "multi-target detection/single target detection" button will switch to the "three target detection demonstration" interface, as shown in Figure 4-5, click the button again to switchback to the "single target detection demonstration interface". Note: Single Target Detection mode is not available for tracking multiple targets.
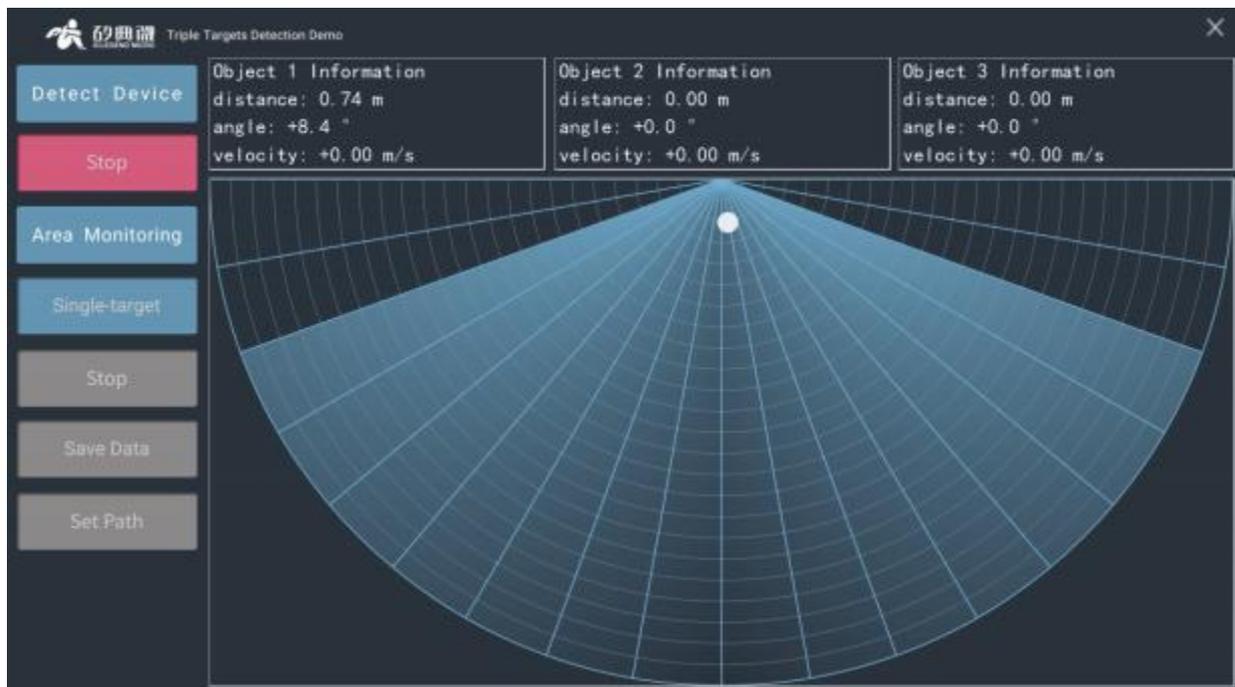
Figure 4-5 Multi-target detection demonstration

4.2.2 Regional monitoring and blind area setting

The upper computer provides regional monitoring and blind area setting functions. Area monitoring means that the user can set one or more polygonal areas of interest in the detection area, and once the human target enters the area, the color of the area changes immediately.

The blind zone setting means that the user can set the range of radar detection and tracking of interest, and turn off the detection and result display of certain distance gate areas. The operation steps of area monitoring and blind area setting are as follows:

Step 1: Connect the radar module and the upper computer according to the steps in subsection 4.2.1 and start target detection;

Step 2: Click the "Area Monitoring" button to display the interface shown in Figure 4-6. The functions of each part of the interface are described as follows:
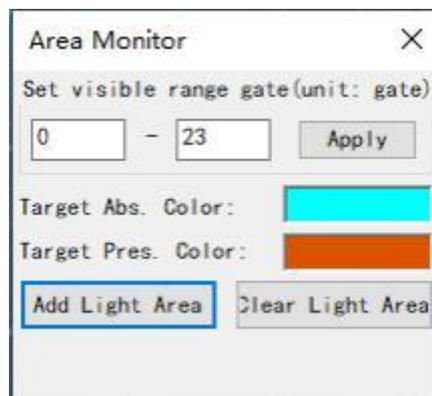
Figure 4-6 "Area Monitoring" Setting Interface

Set the visible area range: the default is 0~23 distance door, that is, no blind area. The user can set the nearest and farthest blind areas by himself, for example: set 1~21, I .e. set 1 blind area from the door at the nearest end and 2 (23-21) blind areas from the door at the farthest end (36cm from the door for a single one). after clicking the "apply" button, the interface will be as shown in fig. 4-7, and the red area is the blind area position.
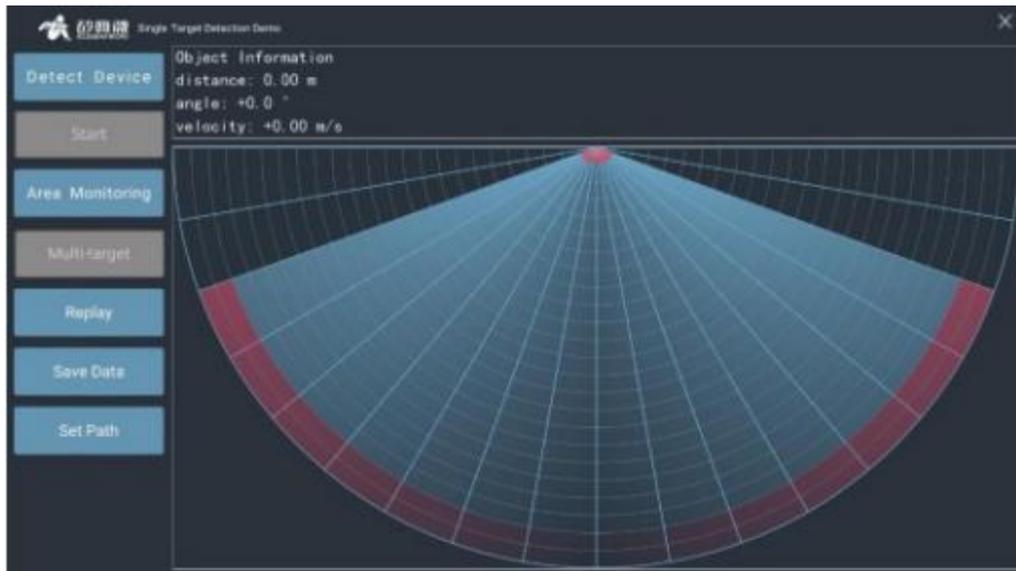
Figure 4-7 Example of setting blind area

No target color：The color displayed when there is no human target in the monitoring area.

With target color：The color displayed when a human target appears in the monitoring area.

Added lighting area：Start delimiting a monitoring area. After clicking this button, left-click the vertex of the mouse to add the area in the interface and right-click to end the delimiting process.

Remove all lighting areas: Delete all the designated monitoring areas.

Step 3: Click the "Add Lighting Area" button on the "Area Monitoring" setting page to start setting the monitoring area: left-click the mouse in the fan-shaped area on the interface to set each vertex of the monitoring area, and right-click the mouse to finish setting the monitoring area. The upper computer tool will connect each vertex into a polygon and display it in the interface according to the sequence of mouse clicks. The area surrounded by the polygon is the monitoring area. Figure 4-8 shows a quadrilateral monitoring area. When someone enters the monitoring area, the background color of the monitoring area will change to "target color"; after the human body leaves the detection area, the color of the area will change back to "no target color", as shown in Figure 4-9 and Figure 4-10;
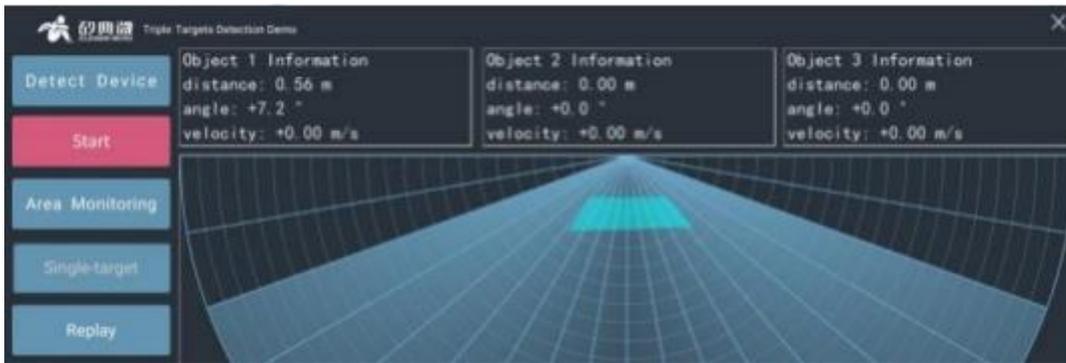
Figure 4-8 Set Monitoring Area
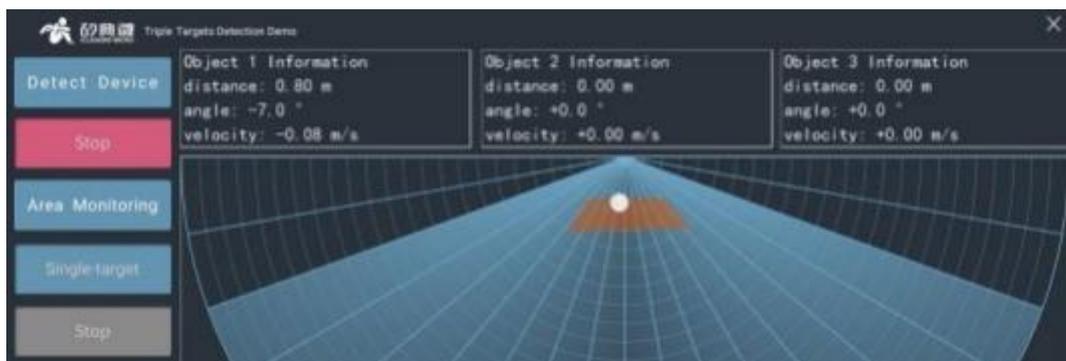
Figure 4-9 Targets in Monitoring Area
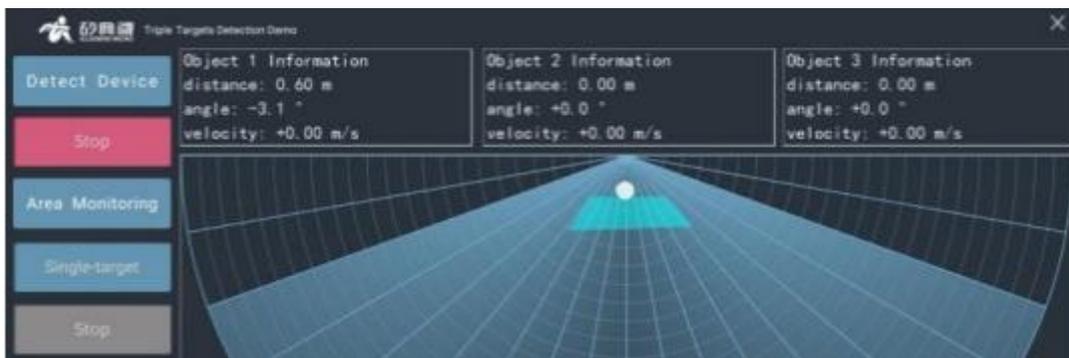
Figure 4-10 No Target in Monitoring Area

Step 4 (optional): Repeat step 3 to set multiple monitoring areas of interest;

Step 5 (optional): Click the "Area Monitoring" button, and click "Remove All Lighting Areas" in the pop-up window to delete all monitoring areas in the sector detection area.

4.2.3 Recording and playback of radar data

The steps for the user to record and playback radar data using the host computer tool are as follows:

Step 1: Connect the radar module and the upper computer software according to the steps in subsection 4.2.1, and select the appropriate target detection mode;

Step 2: When the "Start/Stop" switch button displays "Start", as shown in Figure 4-11 (b), click the "Save Path" button 3

To set the number of radars

According to the saved path, the default data save path is the SaveData folder under the tool path of the upper computer;
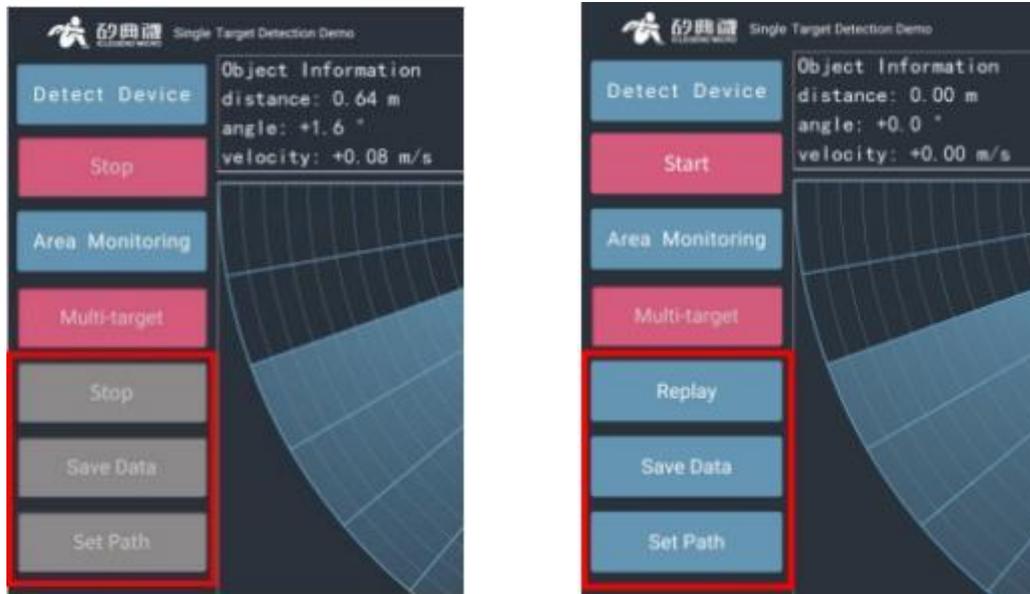
(a)Data recording/playback related buttons are clickable   (b)Data recording/playback related buttons are not clickable

Figure 4-11 Data recording/playback related buttons unavailable while radar is detecting

Step 3: The "data saving" state of the upper computer is closed by default. if the user wants to open the "data saving" mode, he should click the "data saving" button when the "data saving" button is in the clickable state (as shown in figure 4-12(a)); clicking the "data saving" button again will close this mode;

(a) The function is not turned on (the text is white) (b) The function is turned on (the text is gray) (c) It cannot be clicked

Step 4: When the "data saving" function is turned on, click the "Start" button to start detecting the target, and the area 2 and area 3 of the upper computer tool begin to display the human body information in the detection area;

Step 5: Click the "Start/Stop" switch button to stop the detection, you can find the saved radar data under the path set in step 2, the data folder naming format is timestamp "yyyy_mm_dd_hh_mm_ss";

Step 6: Click the "Detect Playback/Stop Playback" switch button, select a set of radar data of interest under the storage path, area 2 and area 3 will start playback of the target information in the radar data;

Step 7: Click the "Detect Playback/Stop Playback" switch button to stop data playback.

4.3 The firmware upgrade tool to use

Rd-03D support updating radar module firmware using the upgrade tool as follows:

Step 1: Open the Firmware Upgrade Tool: ICLM_Download_JIELI.exe

Step 2: Use the serial port adapter board to connect the upper computer and radar module according to the 4.1 sub-section step two;

Step 3: Open the firmware upgrade tool, click the "Refresh Device" button, select the serial port number of the radar module in the "Port Number" drop-down box, and the baud rate is 256000, as shown in Figure 4-13;
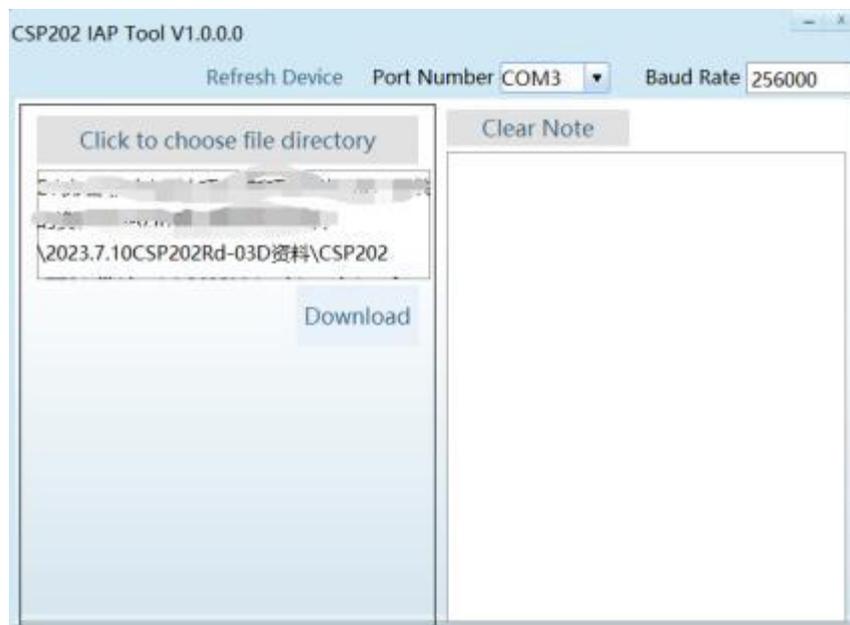
Figure 4- 13 Rd-03D the firmware upgrade tool

Step 4: click the "click to select file path" button to select the ufw file to be upgraded; click the "download" button to start the firmware upgrade, the prompt messagebox on the right will display the download result in realtime, and the download progress will be displayed below the prompt box, as shown in figure 4-14;
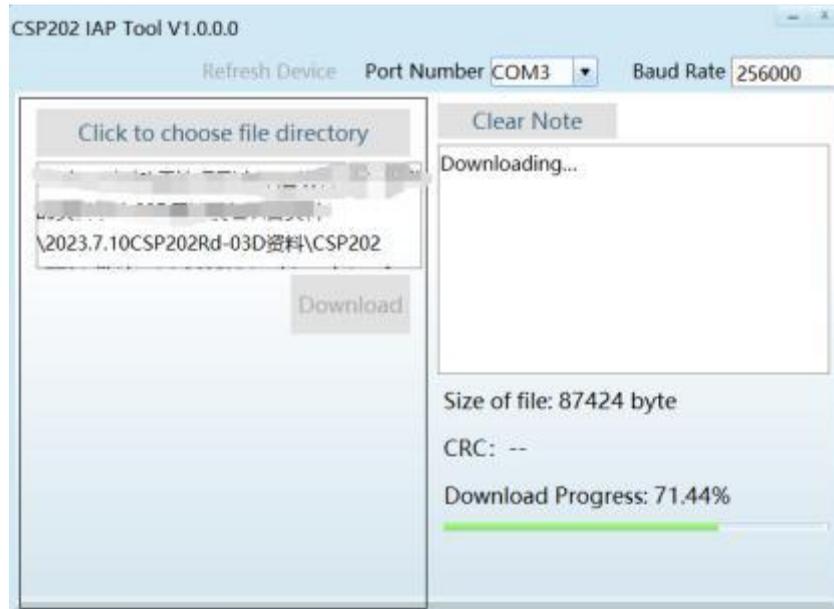
Figure 4- 14 Firmware download

After the firmware upgrade is successful, the page message prompt box will display "Download successfully!", As shown in Figure 4-15, when the firmware upgrade fails, the corresponding error message will be displayed in the prompt messagebox.
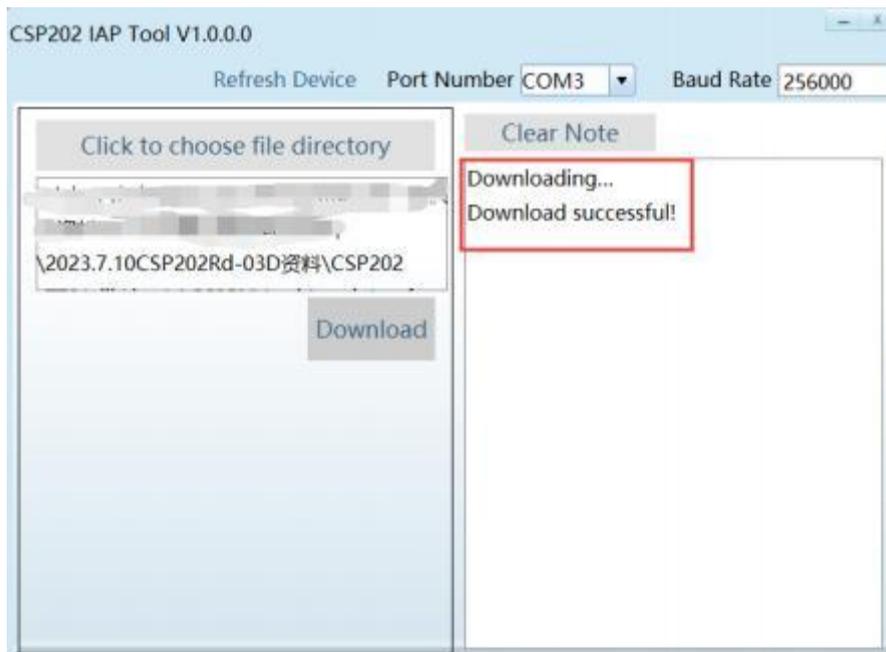
Figure 4- 15 Successful firmware download

5 Communication protocol

The Rd-03D is designed for high-precision multi-target recognition millimeter-wave sensors and is not recommended for secondary development; if the user insists on development, refer to this chapter and Chapter 6.

This communication protocol is mainly used by users who are separated from the upper

computer demonstration tool for secondary development. The Rd-03D module communicates with the outside world through the serial port (TTL level). The default baud rate of the radar serial port is 256000,1 stop bit and no parity bit. The radar outputs the detected target information, including the x-coordinate in the area, they-coordinate (the definition of the x-axis and they-axis is shown in Figure 5-1, and the direction indicated by the arrow is the positive direction of the coordinate), and the speed value of the target. The format of the data frame reported by the radar is shown in Table 5-1.

Table 5-1 Reporting Data Frame Format

Frame Header	Intra-frame data	Frame Tail
AA FF 03 00	Objective 1 Information Objective 2 Information Objective 3 Information	55 CC

The information specifically contained in a single target is shown in Table 5-2.

Table 5-2 Intra-frame data frame format

Target x coordinate	Target y coordinate	Target Speed	Pixel distance value
signed int16 type; The highest bit 1 corresponds to the positive coordinate, and 0 corresponds to the negative coordinate; The remaining 15 bits represent the absolute value of x coordinate, unit: mm	signed int16 type; The highest bit 1 corresponds to the positive coordinate, and 0 corresponds to the negative coordinate; the remaining 15 bits represent the absolute value of they coordinate, in mm.	signed int16 type; The highest bit 1 corresponds to the positive speed, and 0 corresponds to the negative speed; the remaining 15 bits represent the absolute value of the speed, in cm/s.	Uint16 type; single pixel distance value in mm.
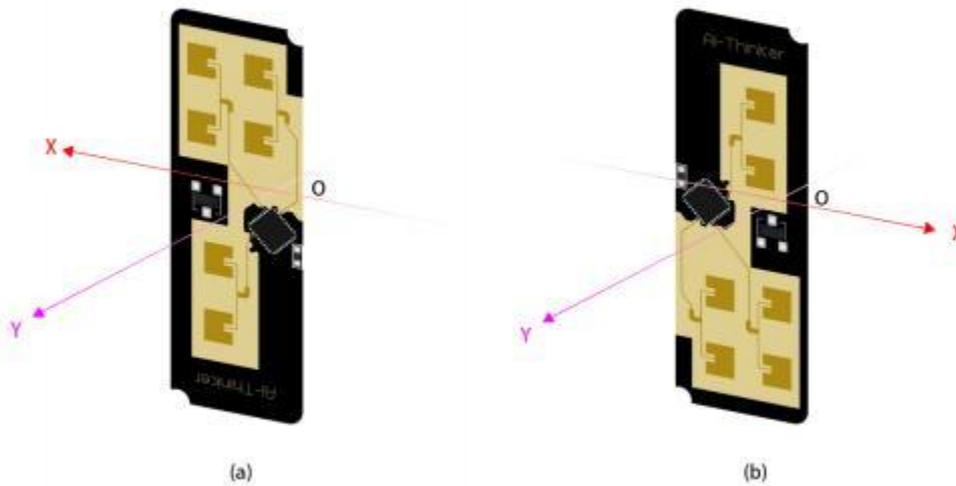
Figure 5-1 Schematic Diagram of Target Position Coordinate System under Recommended Installation Mode

Data example: AA FF 03 00 OE 03 B186 10 00 68 0100 00 00 00 00 00 00 00 0000 00 00 00 00 00 00 00 00 55 CC

This set of data indicates that the radar has tracked a target, namely Target 1 (blue field in the example), and Target 2 and Target 3 (corresponding to red and black fields in the example, respectively) do not exist, so their corresponding data segments are 0x00. The process by which the module converts the data of target 1 into related information is shown below:

Target 1x coordinate: OxOE+Ox03*256= 782

$\qquad$ 0-782= -782 mm;

Target 1y coordinate: OxB1+Ox86*256 = 34481

$\qquad$ 34481-2^15= 1713 mm;

Target 1 speed: 0x10 + OxO0 * 256= 16

$\qquad$ 0-16=-16 cm/s;

Target 1 Distance Resolution: Ox68+Ox01*256= 360 mm。

6 Firmware parameter configuration

6.1 Data reporting interval settings

If you need to modify the radar data reporting rate, you can find the Set_AlgoPara function in the project directory \Applalgo\srclalgopara.c file, which calls the function that sets the data reporting interval: Set_ReportIntervalTime, the parameter of the function is the interval time, in seconds, and the default value is 0.1 seconds. Currently, the interval that can be set cannot be

less than 0.1 seconds.

6.2 Target Hold Interval

In a specific application scenario, the radar is required to keep tracking the target for a certain period of time after the human target is stationary without losing it, and this time is the target holding time. For the setting of the holding time, you can find the Set_AlgoPara function in the project directory VApplalgolsrclalgopara.c file, which calls the function Set_HoldCntTime. the parameter of the function is the holding time, in seconds, and the default value is 37 seconds.

6.3 Detection range setting

The user can set the scope of target detection and tracking: find the Set_AlgoPara function in the project directory \Applalgolsrclalgopara.c file, which calls the function Set_RectRange and Set_SectorArea, which are used to frame the scope of radar detection and tracking.

The Set_RectRange(int16_txn, int16_t xp, int16_ty) function is used to frame a rectangular detection tracking range, as shown in Figure 6-1.
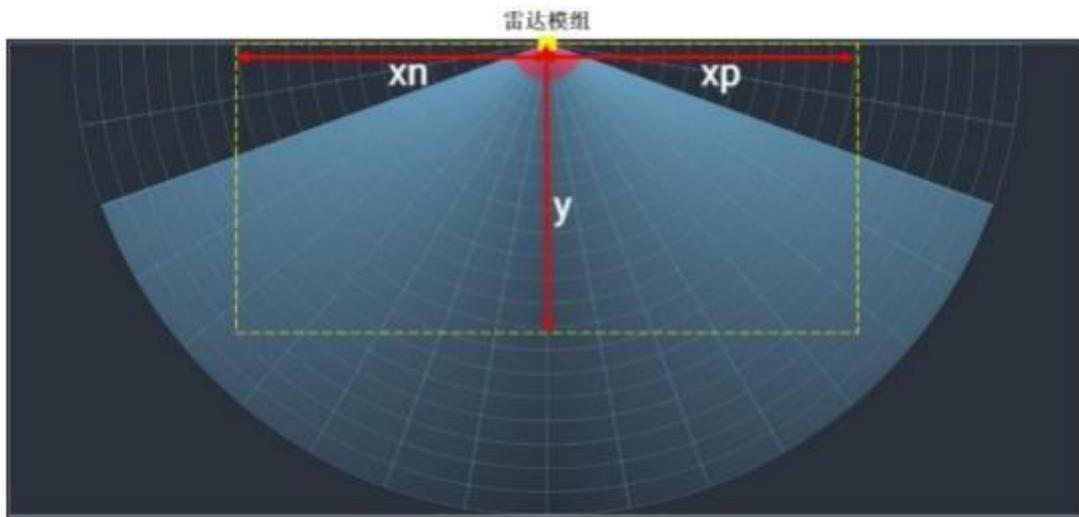
Figure 6-1 Square Detection and Tracking Range

The Set_SectorArea(uint16_t distance, uint8_t angle) function is used to frame the tracking and monitoring range of a sector, as shown in Figure 6-2.

Figure 6-2 Sector detection and tracking range

7 Installation and detection range

The typical installation method of the Rd-03D is wall-hanging installation, as shown in Figure 7-1, and the farthest positioning and tracking distance is 8 m. Wall-hanging installation needs to consider the occlusion in the application scene and the interference on the top, and the recommended installation height range is 1.5~2 m.
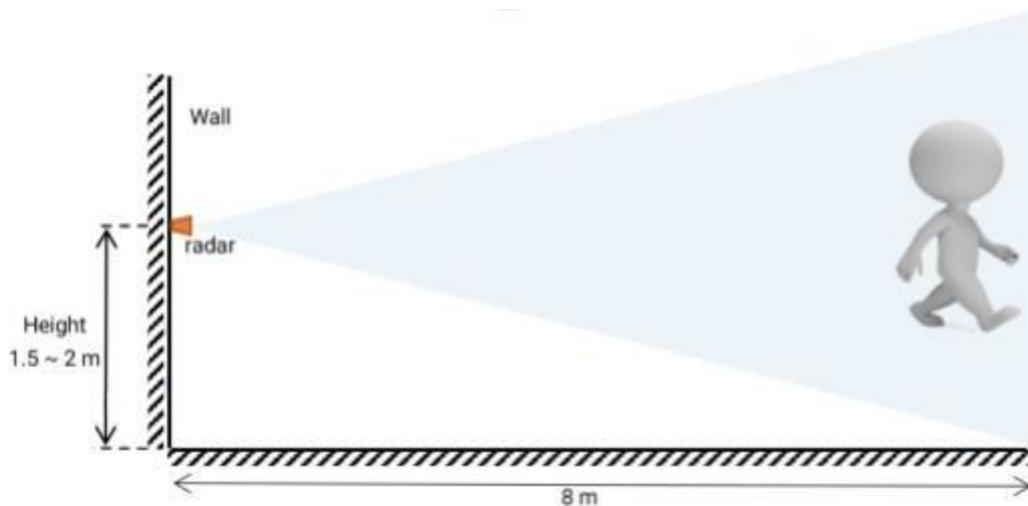
Figure 7- 1 Schematic Diagram of Wall Hanging Installation

When installing the wall, the recommended radar installation posture is shown in Figure 7-2(a) and (B). The normal direction of the radar antenna plane is 0 °.

(a)   (b)
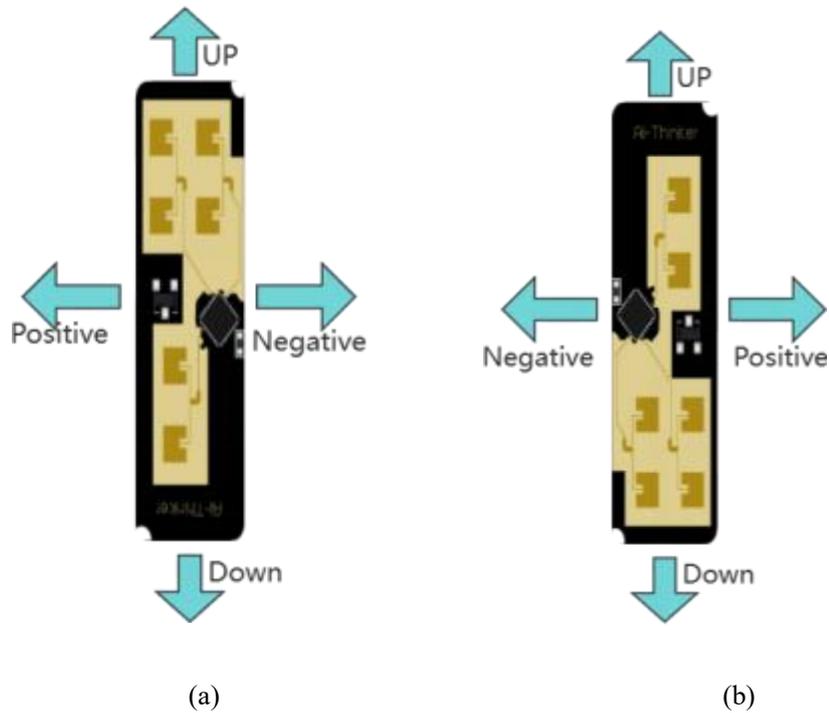
Figure 7-2 Identification of radar wall mounting angle

Figure 7-3 shows the positioning and tracking range of this stereotyped design at a wall height of 1.5 m. The tester is 1.75 m tall and of medium build. When the wall is installed, the Rd-03D detection angle range is ± 60 ° centered on the normal direction of the radar antenna plane; the maximum detection distance in the normal direction can reach 8 m.
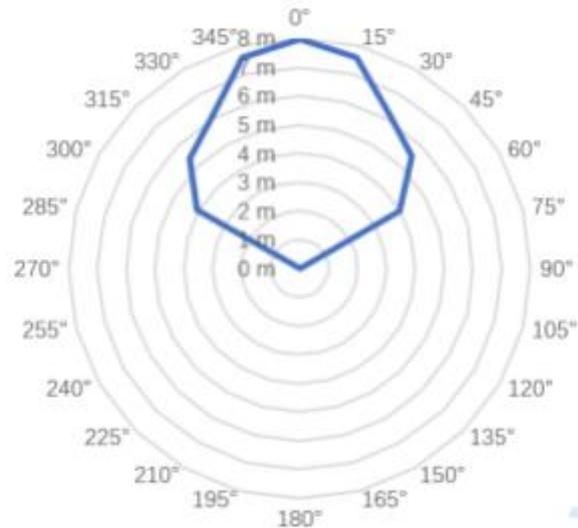
Figure 7-3 Schematic diagram of radar tracking range during wall mounting

8 Rendering

Figure 8-1 shows a rendering of the Rd-03D hardware, measuring 44mm x 15mm.
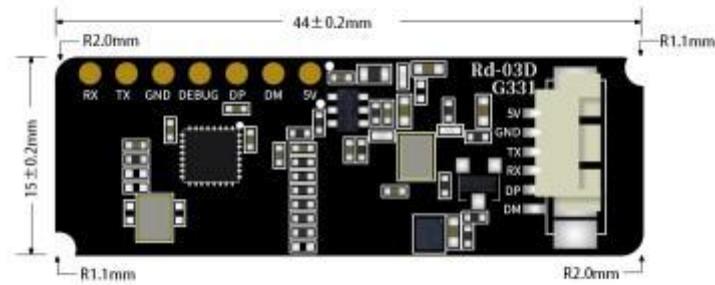
Figure 8- 1 Rd-03D rendering

9 Installation instructions

9.1 Radar Enclosure Requirements

If the radar requires an enclosure, the enclosure must have good permeability in the 24 GHz band and must not contain metal or materials that shield against electromagnetic waves. For more information, please refer to the   《Millimeter Wave Sensor Radome Design Guide》 。

9.2 Environmental requirements for installation

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

There are non-human objects with continuous movement in the sensing area, such as animals, continuous swinging curtains and large green plants facing the tuyere;

There is a large area of strong reflection plane in the sensing area, and the strong reflector will cause interference to the radar antenna;

When installing the wall, it is necessary to consider the external interference factors such as the air conditioner and electric fan at the top of the room.

9.3 Precautions for installation

✎ Try to ensure that the radar antenna is facing the area to be detected, and the antenna is open and unobstructed, and the detection area is relatively open.

✎ To ensure that the installation position of the sensor is firm and stable, the shaking of the radar itself will affect the detection effect.

✎ Make sure that there is no movement or vibration on the back of the radar. Due to the penetrating nature of radar waves, the back flap of the antenna may detect moving objects on the back of the radar. A metal shield or a metal back plate can be used to shield the back flap of the radar to reduce the impact of objects on the back of the radar.

✎ When there are multiple 24 GHz band radars, please do not install them in the opposite direction of the beam, and install them as far as possible to avoid possible mutual interference.

10 Considerations

10.1 Firmware baud rate

The default baud rate of the radar serial port is 256000. You can find the directory CSP202_TT01_lib\XenP202_App\Middleware\platform\AC6956C\inc\ac695x_uart.h to modify the baud rate by modifying the CS202_USART_BAUDRATE macro definition.

Note: When the baud rate is set to a low level, it takes longer for the radar to report one frame of data. In order to prevent the data from being overwritten and modified during the reporting process, it is recommended to extend the data reporting interval accordingly.

10.2 Maximum distance, accuracy and angular accuracy

Due to the different size, state and RCS of the target, the ranging accuracy, the farthest ranging and the angle accuracy will have certain fluctuations.

10.3 Power Considerations

This scheme is a stereotyped design, and designers need to consider the corresponding ESD and lightning surge electromagnetic compatibility design of the power supply during development.

Contact us

Ai-Thinker official website   Official Forum   Develop DOCS   LinkedIn

Tmall shop   Taobao shop   Alibaba shop

Technical support Email: support@aithinker.com

Domestic business cooperation: sales@aithinker.com

Overseas business cooperation：overseas@aithinker.com

Company address: Room 403,408-410, Block C, Huafeng Smart Innovation Port, Gushu 2nd Road, Xixiang, Baoan District, Shenzhen.

Tel: 0755-29162996

WeChat mini   WeChat official

Disclaimer and copyright notice

The information in this article, including the URL address for reference, is subject to change without notice.

The document is provided "as is" without any guarantee responsibility, including any guarantee for merchantability, suitability for a specific purpose, or non-infringement, and any guarantee mentioned elsewhere in any proposal, specification or sample. This document does not bear

any responsibility, including the responsibility for infringement of any patent rights arising

from the use of the information in this document. This document does not grant any license for the use of intellectual property rights in estoppel or other ways, whether express or implied.

The test data obtained in the article are all obtained from Ai-Thinker's laboratory tests, and the actual results may vary slightly.

All brand names, trademarks and registered trademarks mentioned in this article are the property of theirrespective owners, and it is hereby declared.

The final interpretation right belongs to Shenzhen Ai-Thinker Technology Co., Ltd.

Notice

Due to product version upgrades or other reasons, the contents of this manual maybe changed.

Shenzhen Ai-Thinker Technology Co., Ltd. reserves the right to modify the contents of this manual without any notice or prompt.

This manual is only used as a guide. Shenzhen Ai-Thinker Technology Co., Ltd. makes every effort to provide accurate information in this manual. However, Shenzhen Ai-Thinker

Technology Co., Ltd. does not guarantee that the contents of the manual are completely free of errors. All statements and information in this manual. And the suggestion does not constitute

any express or implied guarantee.

Statement

Ai-Thinker may provide technical and reliability data (including data sheets), design resources (including reference designs), application or other design recommendations, network tools,

safety information and other resources (the "Resources") "as is" without warranties of any kind, express or implied. Including, but not limited to, express or implied warranties of suitability,

fitness for a particular use, or non-infringement of any third party's intellectual property rights. And specifically declares that it is not liable for any necessary or incidental losses, including

but not limited to, arising from the application or the use of any of our products and circuits.

Ai-Thinker reserves the right to release information in this document (including but not limited to metrics and product descriptions) and any changes to our products without prior notice. This document automatically supersedes and replaces all information provided in previous versions of the same document number file.

These resources are available to skilled developers who design with Ai-Thinker products. You are solely responsible for: (1) Selecting the appropriate Ai-Thinker products for your

application; (2) Design, validate, and run your application and product throughout its life cycle; (3) Ensure that your application meets all applicable standards, codes and laws, as well as any other functional security, information security, regulatory or other requirements.

Ai-Thinker may authorize you to use these resources only for the development of applications

of Essence Products described in this Resource. Without the permission of Ai-Thinker, any unit or individual shall not extract or copy part or all of these resources, and shall not be transmitted in any form. You are not entitled to use any other Ai-Thinker intellectual property rights or any third party intellectual property rights. You shall indemnify you in full for any claims, damages, costs, losses and liabilities arising against Ai-Thinkeror its representatives in connection with

the use of these resources, for which Ai-Thinker is not liable.

The products offered by Ai-Thinker are subject to the terms of sale of Ai-Thinker or other

applicable terms attached to Essence's products. Essence's availability of these resources does not extend or otherwise change the warranties or warranties disclaimers applicable to product releases.