E54-24LD12D Product Specifications



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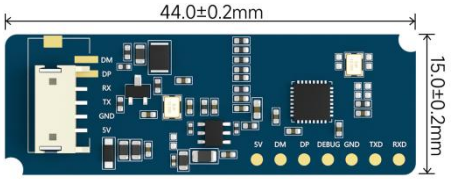
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1. Overview

1.1 Product Introduction

The E54-24LD12D is a high-precision multi-target trajectory recognition millimeter-wave radar module designed by Ebyte. It includes a minimalist 24GHz millimeter-wave sensor and intelligent algorithm firmware, equipped with an AIoT millimeter-wave sensor, a high-performance 24GHz one-transmitter-two-receiver antenna, and peripheral circuits. It is mainly used in ordinary indoor scenarios such as homes, offices, and hotels to achieve positioning and trajectory tracking of single or multiple people.



1.2 Features

- Equipped with a single-chip intelligent millimeter wave sensor SoC and intelligent algorithm firmware ;
- Ultra-small sensor size: 15 mm × 44 mm ;
- Load the default sensing configuration , plug and play;
- 24GHz ISM frequency band , can pass FCC, CE, and RF spectrum regulation certification;
- Supports real-time tracking of the target's location within the area, and realizes target trajectory tracking (distance measurement, angle measurement and speed measurement) within the area;
- DC 3.6~5.5 V power supply;
- Maximum detection range: 8m;
- Azimuth ±60°, elevation ±30 °;
- Wall mounting.

1.3 Application Scenario

The E54-24LD12D high-precision multi-target trajectory recognition millimeter-wave radar module is widely used in various AIoT scenarios, covering the following types:

- Smart Home

It senses the distance and angle of the human body and reports the detection results so that the main control module can intelligently control the operation of home appliances such as air conditioners and fans.

- Smart Business

Position sensing: It can detect when a person is approaching or leaving the device within a set range, and

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turn the screen on or off in time .

- Bathroom

The smart toilet accurately controls the automatic opening and closing of the toilet lid.

- Smart Lighting

Identify and sense the human body, accurately detect location, and can be used in home lighting equipment (induction lamps, table lamps, etc.).

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2. System Description

This high-precision, multi-target trajectory recognition millimeter-wave radar module utilizes an FMCW waveform, combined with proprietary radar signal processing and built-in intelligent positioning and tracking algorithms. It can detect multiple targets within a specified area and report the results in real time. This design enables users to quickly develop corresponding target positioning and tracking products.

Table 2-1 shows the specifications of the E54-24LD12D .

Table 2-1 E54-24LD12D specifications

Parameter	Minimum	Typical	Maximum	Unit	Remark
Hardware specifications					
Supported frequency bands	24	-	24.25	GHz	Comply with FCC , CE , and NDC certification standards
Supports maximum sweep bandwidth	-	0.25	-	GHz	-
Operating voltage	3.6	5.0	5.5	V	-
Size	-	15.0 * 44.0	-	mm	±0.2mm
Communication interface	-	UART	-	-	-
Serial port baud rate	-	256000	-	bps	-
Operating temperature	-40	25	85	℃	-
Operating humidity	5	-	95	%RH	No condensation
Storage temperature	-40	25	105	℃	-
Weight	-	2.5	-	g	±0.2 g
System performance					
Maximum sensing distance	-	8	-	m	Normal Line
Maximum number of recognized targets	-	3	-	-	Multi-target detection mode
Angle measurement range	-60	-	60	°	-
Ranging accuracy	-	0.15	-	m	Normal angle inversion test
Angle accuracy	-	2	-	°	Normal angle inversion test
Data refresh rate	-	10	-	Hz	Radar reporting frequency
Working current	-	66	-	m A	Power supply voltage: DC 5V

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3. Hardware Description

3.1 Product Dimensions

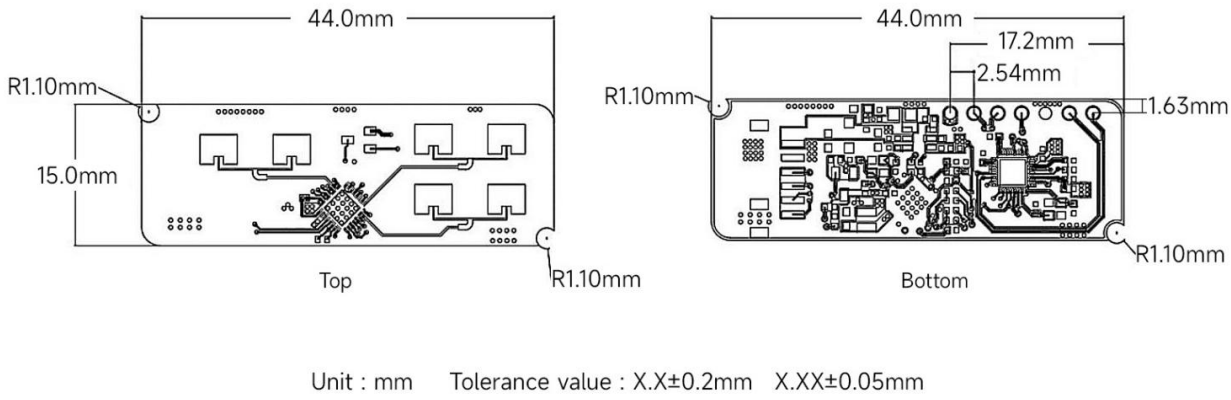
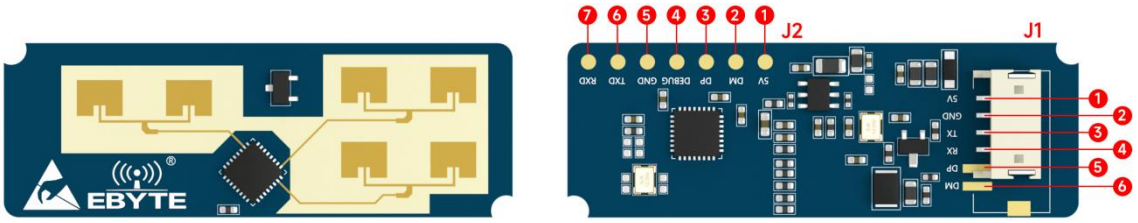


Figure 3-1 Dimensional drawing

3.2 Hardware Description

Figure 3-2 (a) and (b) are photos of the front and back of the E54-24LD12D, respectively. The E54-24LD12D hardware reserves the TXGA FWF15004 4-pin connector J1 for power and communication. J2 is for programming and testing, some of which have the same functions as those in J1.



(a) Front (b) Back

Figure 3-2 Hardware diagram

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

Table 3-1 J1 pin description

J1	Name	Function	Illustrate
1	5V	Power input	DC 3.6~5.5V
2	GND	Grounding	Power ground
3	TX	UART_TXD	Connect the serial port adapter board RXD
4	RX	UART_RXD	Connect the serial port adapter board

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			TXD
5	DP	Burning port data positive signal	No need to pay attention
6	DM	Burning port data negative signal	No need to pay attention

Table 3-2 J2 pin description

J2	Name	Function	Illustrate
1	5V	Power input	DC 3.6~5.5V
2	DM	Burning port data negative signal	-
3	DP	Burning port data positive signal	-
4	DEBUG	Debug serial port TXD	No need to pay attention
5	GND	Grounding	-
6	TXD	UART_TXD	Connect the serial port adapter board RXD
7	RXD	UART_RXD	Connect the serial port adapter board TXD

4. Software Description

The E54-24LD12D hardware has the system firmware burned in the factory. Ebyte provides a visual host computer demonstration tool software for the E54-24LD12D, which allows users to intuitively experience the positioning and tracking effect of the radar module on the target.

4.1 Introduction to host computer tools

RF_Setting_E54_D_V1.0 is a host computer tool developed specifically for the E54-24LD12D. After connecting the host computer to the E54-24LD12D hardware, the host computer tool can display, record, save, and playback radar data.

The following are the steps to connect the host computer tool and the radar module:

Step 1: Get the "RF_Setting_E54_D_V1.0" software package from the Ebyte official website, unzip the package and enter the folder directory;

Step 2: Use a cable to connect the E54-24LD12D module to the serial port tool . See Figure 4-1 for the connection method. Connect the module to the host computer through the serial port tool.

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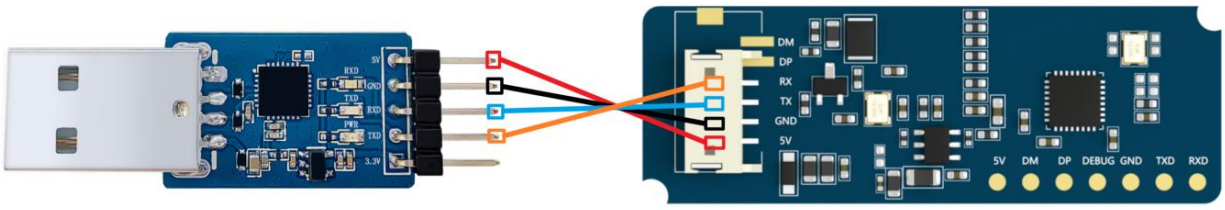


Figure 4-1 Connection between the E54-24LD12D module and the serial port tool

Step 3: Double-click the executable file "RF_Setting_E54_D_V1.0.exe" in the host computer directory path. The demonstration tool interface will pop up, as shown in Figure 4-2.

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:

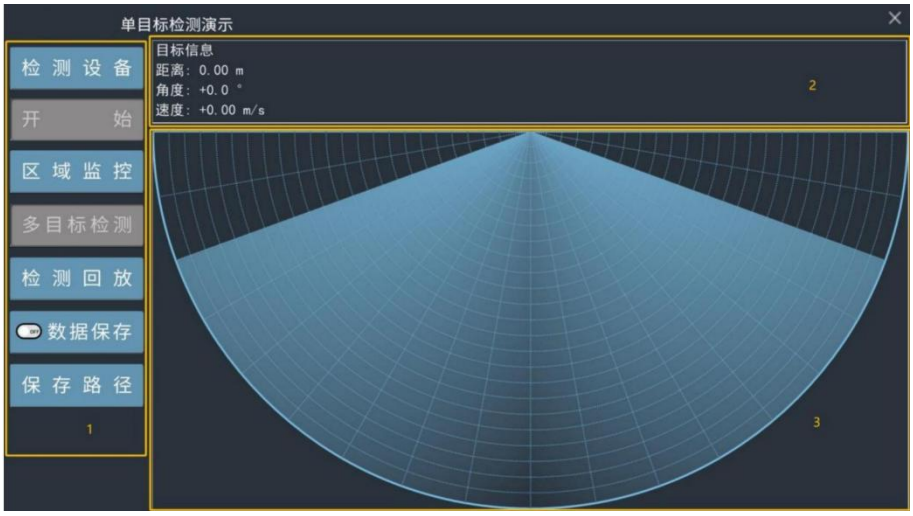


Figure 4-2 Demonstration tool interface

- Function button area:
  - The "Detect Device" button is used to detect whether the E54-24LD12D module is connected successfully;
  - The "Start/Stop" switch button is used to start or stop receiving radar data;
  - The "Area Monitoring" button is used to set the monitoring area and the blind area range;
  - The "Multi-target detection/Single target detection" switch button is used to switch between single target detection and multi-target detection mode;
  - The "Detection Playback/Stop Playback" switch button is used to play back the recorded radar data;
  - The "Data Save/Close Save" button is used to start recording radar data;
  - The "Save Path" button is used to set the storage path for recorded radar data;
- Data area: displays the distance, angle and speed information of the tracked target in real time;
- Target display area: The radar chart visually displays the position of the located and tracked target in the

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detection area.

4.2 Use of host computer tools

The host computer provides single-target and multi-target detection demonstration functions, and allows users to customize key areas on the interface for regional monitoring, while also setting detection blind areas. The host computer also allows users to record, save, and playback radar detection data.

4.2.1 Single/Multi-target Detection

The specific steps for using the single target/multi-target detection function of the host computer are as follows:

Step 1: Connect the E54-24LD12D module to the host computer according to the steps in Section 4.1 of this chapter and open the demonstration tool;

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

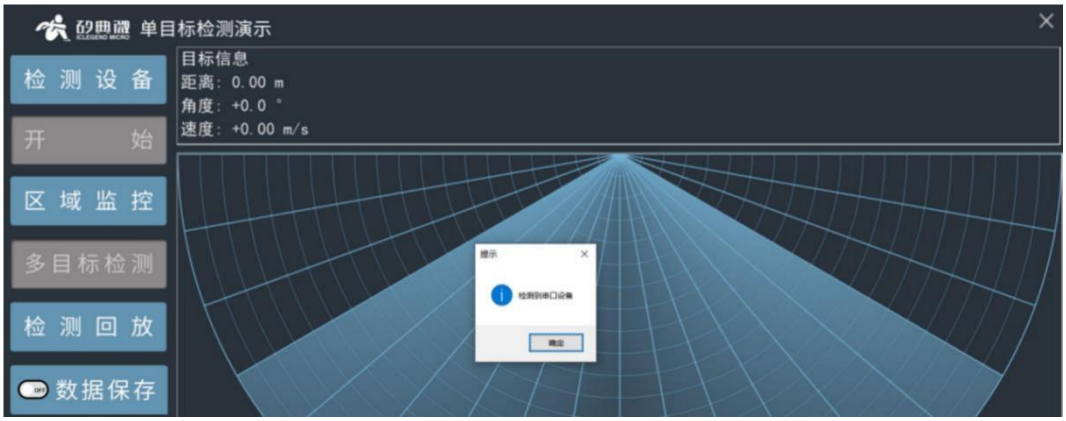


Figure 4-3 Device successfully detected

Step 3: Click the "Start/Stop" switch button to display the target's position relative to the radar, as shown in Figure 4-4;

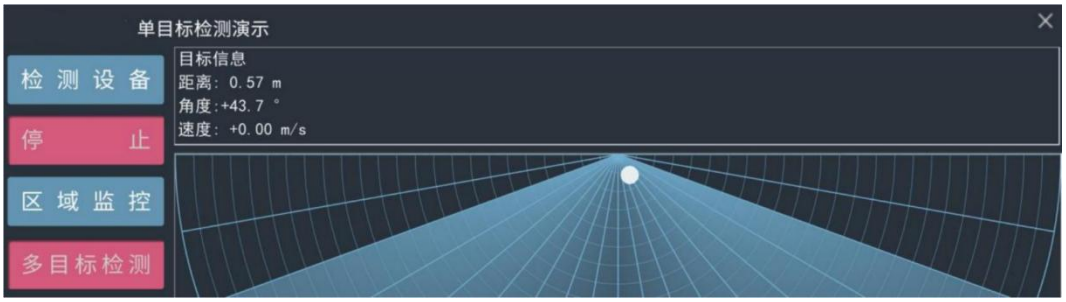


Figure 4-4 Single target detection demonstration example

Step 4: After the host computer is turned on, the default is "Single Target Detection Demonstration". Click the "Multi-target Detection/Single Target Detection" button to switch to "Three Target Detection"

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Click the button again to switch back to the "Single Target Detection Demonstration Interface [1]" ;

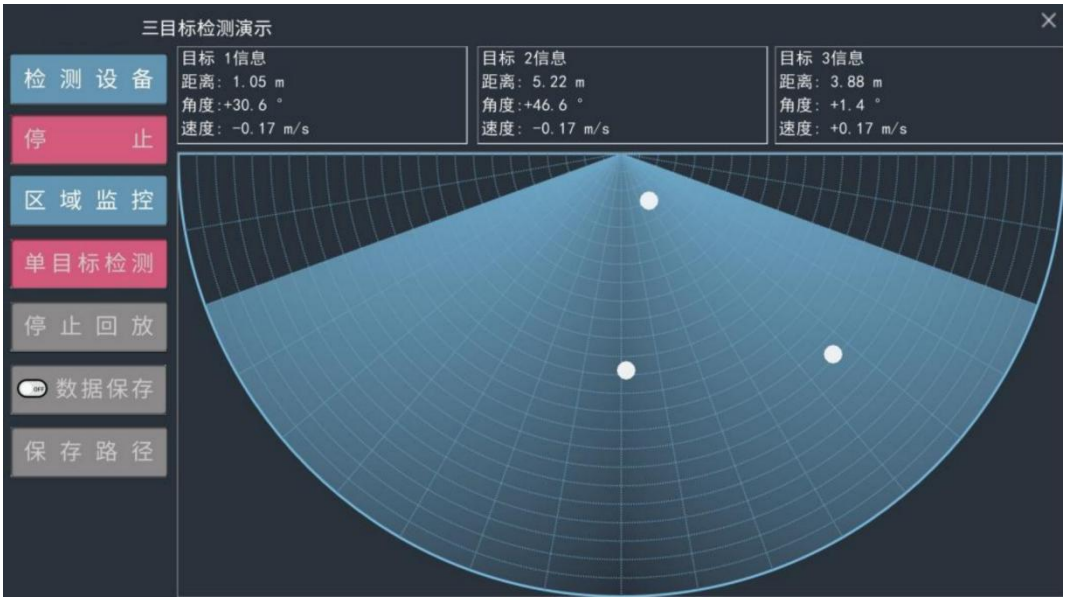


Figure 4-5 Three-target detection demonstration example

4.2.2 Regional monitoring and blind spot setting

The host computer provides regional monitoring and blind spot setting functions.

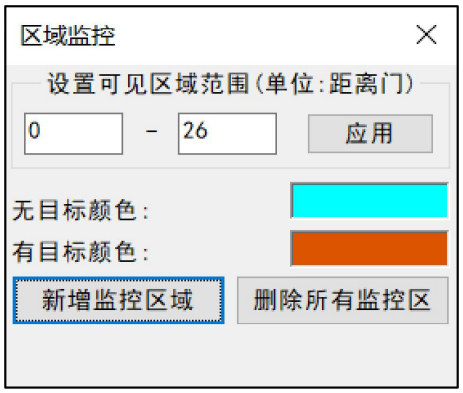
"Regional Monitoring" allows users to define one or more polygonal areas of interest within the detection area. Once a human target enters the area, the area's color changes immediately. This feature allows the software to selectively display the data uploaded by the sensor in a way that suits the user's interests.

Blind Zone Settings allow users to define the radar detection and tracking range of interest, disabling detection and display of results for certain range gate areas. This feature allows the software to block specific detection areas based on user-defined parameters.

The steps for area monitoring and blind zone setting are as follows:

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

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



[1] Note: The "Single Target Detection" mode is not suitable for tracking and detecting multiple targets.

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Figure 4-6 “Region Monitoring” settings page

Set the visible area range: The default is 0 to 26 range gates, meaning there are no blind spots. Users can also customize the nearest and farthest blind spots. For example, setting 1 to 24 would create one range gate blind spot at the nearest end and two (26-24) range gate blind spots at the farthest end (a single range gate is 33 cm). After clicking "Apply," the interface will appear as shown in Figure 4-7, with the red area indicating the blind spot.

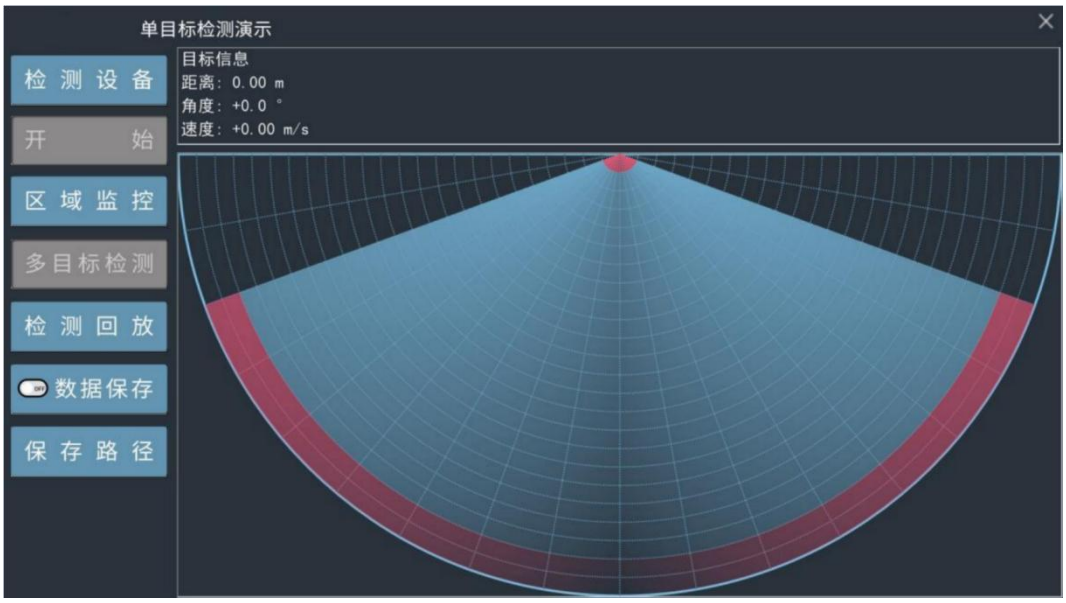


Figure 4-7 Blind zone setting example

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

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

Add a new monitoring area: Start to delineate a monitoring area. After clicking this button, left-click the mouse on the interface to add the vertices of the area, and right-click to end the delineation process.

Delete all monitoring areas: Delete all designated monitoring areas.

Step 3: Click the "Add Monitoring Area" button on the "Region 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 end the setting of the monitoring area. The host computer tool will connect each vertex into a polygon in the order of mouse clicks and display it on the interface. The area enclosed 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 area color will change back to "no target color", as shown in Figures 4-9 and 4-10 ;

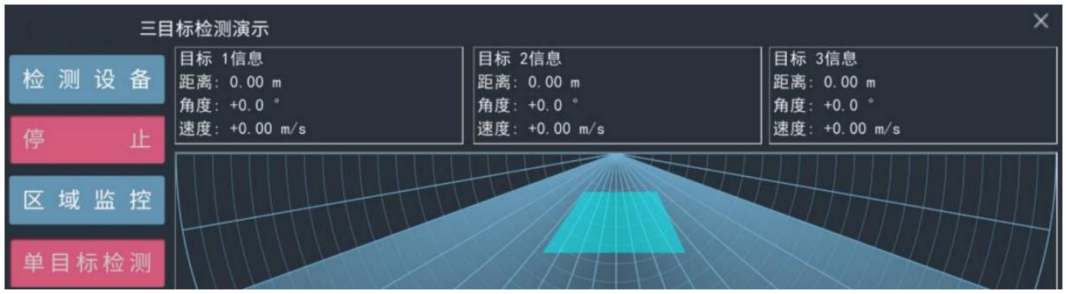


Figure 4-8 Set monitoring area

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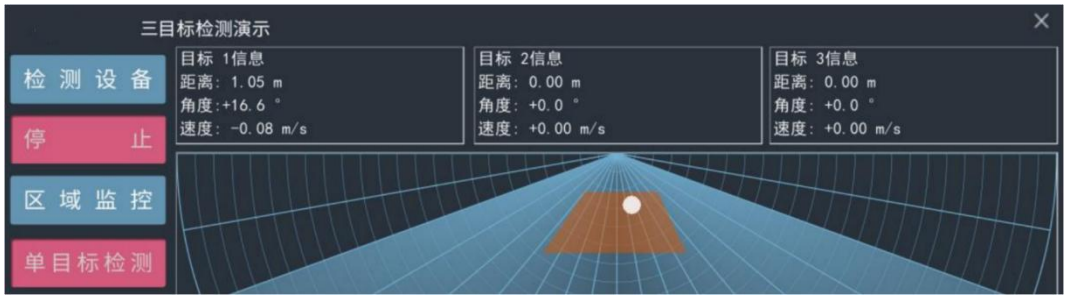


Figure 4-9 Target in the monitoring area

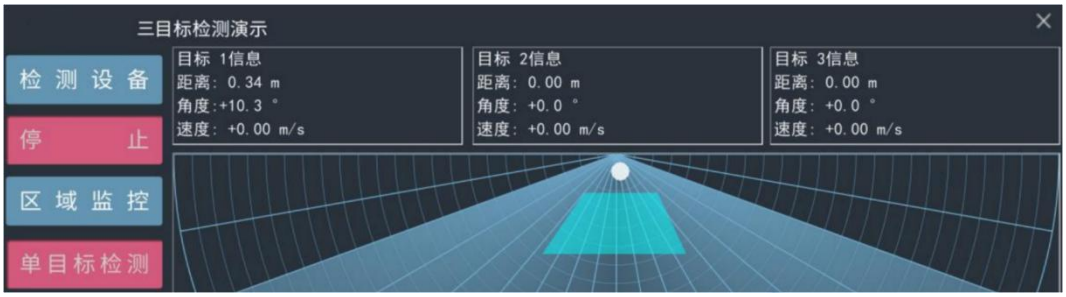


Figure 4-10 No target in the monitoring area

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

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

4.2.3 Recording and Playback of Radar Data

Users can use the software to record and replay sensor data. The communication format of sensor data is detailed in Chapter 5 , Communication Protocol. The software operation steps are as follows:

Step 1: Connect the radar module and host computer software according to the steps in Section 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 [2]to set the path for saving radar data. The default data save path is the SaveData folder under the host computer tool path;

[2] When the "Start/Stop" switch button displays "Stop", the "Detection Playback", "Data Save" and "Save Path" buttons are all unclickable.

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(a) Data recording/playback related buttons are not clickable. (b) Data recording/playback related buttons are clickable.

Figure 4-11 Data recording/playback buttons are unavailable when the radar is detecting.

Step 3: The "Data Save" mode of the host computer is disabled by default. If the user wants to enable the "Data Save" mode , click the "Data Save" button when it is clickable (as shown in Figure 4-12 (a)). Clicking the "Data Save" button again will disable this mode.







(a) Function is not enabled (displays OFF) (b) Function is enabled (displays ON) (c) Unclickable

Figure 4-12 Three states of the "Save Data" button

Step 4: When the "Data Save" function is turned on, click the "Start" button to start detecting the target. Area 2 and Area 3 of the host computer tool will begin to display the human body information within the detection area;

Step 5: Click the "Start/Stop" switch button to stop the detection. You can find the saved radar data in the path set in step 2. The data folder is named in the format of the timestamp "yyyy_mm_dd_hh_mm_ss";

Step 6: Click the "Playback/Stop Playback" switch button and select a set of radar data of interest in the storage path. Areas 2 and 3 will then start playing back the target information in the radar data.

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

4.3 Firmware Upgrade Tool Usage

The E54-24LD12D supports updating the radar module firmware using the upgrade tool. The specific steps are as follows:

Step 1: Get the E54-24LD12D upgrade tool "Ebyte IAPTool" from the Ebyte official website, unzip it and enter the software directory;

Step 2: Follow step 2 in section 4.1 to connect the host computer and radar module using the serial port adapter board;

Step 3: Open the firmware upgrade tool, click the "Refresh Device" button, and select the radar module's serial port number in the "Port Number" drop-down box. The baud rate is 256000 bps, as shown in Figure 4-13.

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Figure 4-13 E54-24LD12D firmware upgrade tool

Step 4: Click the "Click to select file path" button and select the ufw file to be upgraded. Click the "Download" button to start upgrading the firmware. The prompt box on the right will display the download results in real time, and the download progress will be displayed below the prompt box, as shown in Figure 4-14.



Figure 4-14 Downloading

After the firmware upgrade is successful, the page information prompt box will display "Download Successful!", as shown in Figure 4-15; if the firmware upgrade fails, the corresponding error message will be displayed in the prompt box.

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Figure 4-15 Download successful

5. Communication Protocol

This communication protocol is primarily intended for users who require secondary development independent of a host computer demonstration tool. The E54-24LD12D module communicates with the outside world via a serial port (TTL level). The default baud rate of the radar serial port is 256,000 bps, with 1 stop bit and no parity.

The E54-24LD12D uses the little-endian format for data communication. All data in the following table are in hexadecimal.

5.1 Reporting Data Format

The radar outputs detected target information, including the x- and y-coordinates within the area (the x- and y-axes are defined as shown in Figure 5-1; the arrow indicates the positive direction of the coordinates), as well as the target's speed. The data frame format 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	Target 1 information Target 2 information Target 3 information	55 CC

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

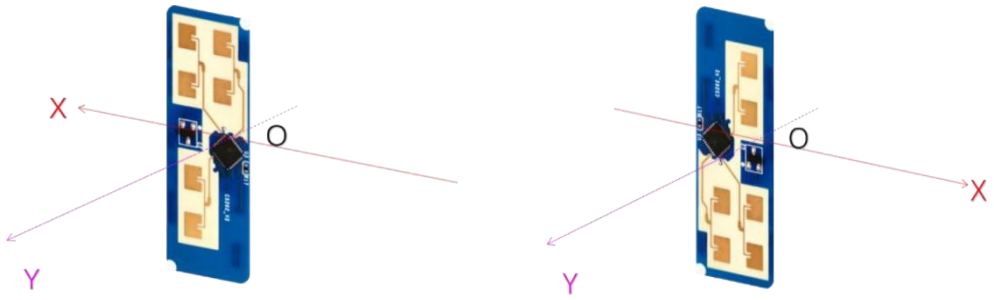
Table 5-2 Intra-frame data format

Target x-coordinate	Target y coordinate	Target speed	Pixel distance value
signedint16 type; The highest bit 1 corresponds to the positive coordinate, 0 corresponds to negative coordinates;	signedint16 type; The highest bit 1 corresponds to positive coordinates, and 0 corresponds to negative coordinates;	signedint16 type; The highest bit 1 corresponds to positive speed, and 0 corresponds to negative speed. Toward speed, negative when approaching the radar;	uint16 type; Single pixel distance value, single mm

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The remaining 15 bits represent the x-coordinate Absolute value, unit: mm	The remaining 15 bits represent the absolute value of the y coordinate. Unit: mm	The remaining 15 bits represent the absolute value of the speed, in units of cm/s	



(a) (b)

Figure 5-1 Schematic diagram of the target position coordinate system under the recommended installation method

Data example: AA FF 03 00 0E 03 B1 86 10 00 4A 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 55 CC

This set of data indicates that the radar has tracked a target, target 1 (the blue field in the example). Targets 2 and 3 (the red and black fields in the example, respectively) do not exist, so their corresponding data segments are 0x00. The module converts target 1 data into related information as follows:

Target 1x coordinate: 0x0E + 0x03 * 256 = 782

0 - 782 = -782mm;

Target 1 y coordinate: 0xB1 + 0x86 * 256 = 34481

34481 - 2^15 = 1713 mm;

Target 1 speed: 0x10 + 0x00 * 256 = 16

0 - 16 = -16 cm/s;

Target 1 distance resolution: 0x4A + 0x01 * 256 = 330 mm.

5.2 Sending Commands and ACK

5.2.1 Entering single target detection mode

This command is used to switch the sensor's target detection mode to single target detection mode, and the mode will not be saved after power failure.

Command word : 0x00 80

Command value : 2 bytes

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

Sending data :

Frame header	Data length in frame	Command word	Frame tail

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FD FC FB FA	0 2 00	80 00	04 03 02 01

ACK (success):

Frame header	Data length in frame	Command word	ACK	Frame tail
FD FC FB FA	0 4 00	80 01	01 00	04 03 02 01

5.2.2 Entering multi-target detection mode

This command is used to switch the sensor's target detection mode to multi-target detection mode, and the mode will not be saved after power failure.

Command word : 0x00 9 0

Command value : 2 bytes

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

Sending data :

Frame header	Data length in frame	Command word	Frame tail
FD FC FB FA	02 00	9 0 00	04 03 02 01

ACK (success):

Frame header	Data length in frame	Command word	ACK	Frame tail
FD FC FB FA	04 00	9 0 01	01 00	04 03 02 01

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6. Installation and Detection Range

The E54-24LD12D is typically mounted on a wall, as shown in Figure 6-1. Its maximum tracking distance is 8 meters. When mounting on a wall, consider the application scenario's obstructions and overhead interference. The recommended mounting height is 1.4 to 1.7 meters.

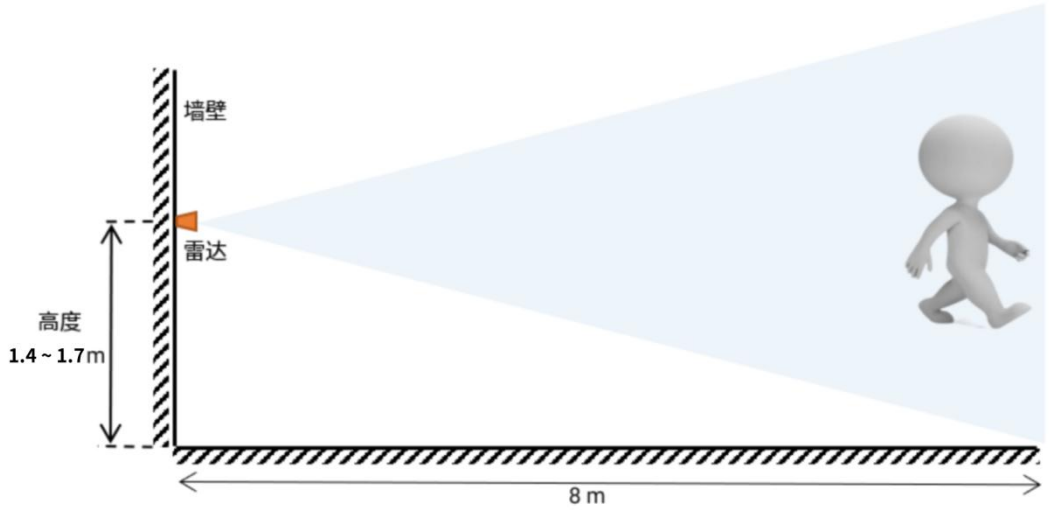
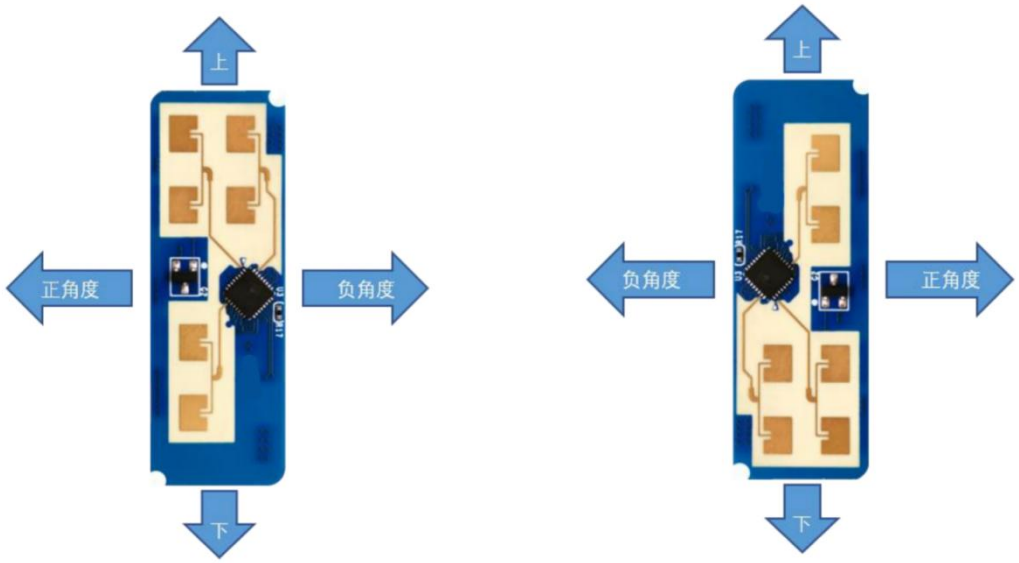


Figure 6-1 Schematic diagram of wall installation

When wall-mounted, the recommended radar installation posture is shown in Figures 6-2 (a) and (b). The normal to the radar antenna plane is 0°.



(a) (b)

Figure 6-2 Radar wall-mounted installation angle identification

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Figure 6-3 shows the positioning and tracking range of this finalized design when mounted on a wall at a height of 1.5 meters. The tester was 1.75 meters tall and of medium build. When wall-mounted, the E54-24LD12D's detection angle range is ±60° centered on the normal to the radar antenna plane; the maximum detection range in the normal direction is 8 meters.

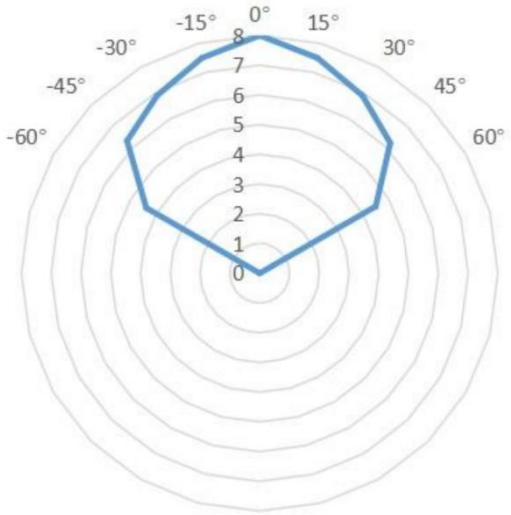


Figure 6-3 Schematic diagram of tracking range when radar is wall-mounted

7. Installation Instructions

Radar enclosure requirements

If the radar requires an enclosure, it must have good wave transmission characteristics in the 24 GHz band and must not contain metal or other materials that shield electromagnetic waves. For more information, please refer to Ebyte's "Millimeter Wave Sensor Radome Design Guide . "

Installation environment requirements

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

- There are non-human objects in continuous motion within the sensing area, such as animals, swaying curtains, and large green plants facing the wind;
- There is a large area of strong reflective surface in the sensing area. Strong reflective objects facing the radar antenna will cause interference;
- When wall-mounted, external interference factors such as air conditioners and electric fans on the ceiling need to be considered.

Notes on installation

- Try to ensure that the radar antenna is facing the area to be detected, and the area around the antenna is open and unobstructed, and the detection area is relatively open.
- It is necessary to ensure that the sensor is installed firmly and stably. The shaking of the radar itself will affect the detection effect.

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- Ensure that there is no movement or vibration behind the radar. Because radar waves are penetrating, the antenna backlobe may detect moving objects behind the radar. A metal shield or backplate can be used to shield the radar backlobe and reduce the impact of objects behind the radar.
- When there are multiple 24GHz radars, do not install them in the direction of the beam and install them as far away from each other as possible to avoid possible mutual interference.

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8. Notes

Firmware baud rate

The default serial port baud rate of the radar is 256000bps.

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

Maximum distance, accuracy, and angular accuracy

Please note that due to differences in the target's body shape, condition, radar cross section (RCS), etc., the ranging accuracy, maximum range, and angle accuracy will fluctuate to a certain extent.

Target hold time

In specific application scenarios, the radar is required to track the human target for a certain period of time without losing the target after the human target stops. This time is the target holding time , and the default value is 37 seconds.

Power Supply Considerations

Power Input Selection: The sensor supports DC 3.6V~5V power input. Please refer to the Hardware Description section in Chapter 3 for detailed information.

Electromagnetic compatibility design: During the development process, developers need to fully consider the electromagnetic compatibility design of the power supply, including electrostatic discharge (ESD) protection and lightning surge protection, to ensure the stable operation of the sensor.

Revision History

Version	Revision Date	Revision Notes	Maintainer
1.0	2025-10-23	Initial version	Bin

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