UM10001

XenD101MS User Manual

Rev.1.2 User Manual

Introduction

This document introduces the reference design of ICLM intelligent space management mmWave sensor XenD101MS, including its basic functions, hardware specification, software configuration, and installing condition etc.

This document aims to guide users to get started with XenD101MS intelligent space management mmWave sensor reference design quickly and easily, so that users can sort out suitable parameters for customized scenarios, and can design precise intelligent space management sensors.

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1. XenD101MS Overview

The XenD101MS is an intelligent space management reference design of ICLM EZ Sensor series. It contains a minimalist 24 GHz radar sensor hardware XenD101 and an intelligent algorithm firmware MS01.

The XenD101 hardware incorporates an AIoT mmWave sensor SoC S3KM111L, high-performance 24 GHz 1T1R antennas, and peripheral circuits. The human detection algorithm MS01 precisely detects moving, micro-moving, and standing human target by adopting mmWave radar range measurement technology and S3KM111L specified signal processing technology.

The XenD101MS is mainly applied indoors to detect the presence of moving or micro-moving human body, and it reports the detection results in real time. The maximum detection range of the XenD101MS is 20 m[1]. Its detection range, sensibility of each range gate, and target absence report delay are easily configurable. The XenD101MS supports both GPIO and UART interfaces, and supports Plug and Play, which allows it to be applied flexibly in different smart scenarios and terminal products.

Main features of XenD101MS are listed below:

- Integrate smart mmWave sensor SoC and intelligent algorithm firmware
- Compact module size: 18 mm × 15 mm
- Load default human motion detection configuration, support Plug and Play
- 24 GHz ISM bandwidth, under FCC and CE Spectrum regulation
- 3.3 V power supply, support a wide voltage range of 3.0 V ~ 3.6 V
- Average current of 42 mA while operating consecutively
- Detecting targets include moving, micro-moving and standing human body
- Report detection results in real time
- Provide a visualization tool, support configuring detection ranges, customized sensibility of each range gate, and absence report delay
- Support detection range separation, and is able to completely prevent interferences outside of detection range
- Detect as close as 0.2 m, no non-detection zone
- Detect moving human target as far as 20 m
- Wide field of view, cover up to ±70°
- Support multiple installation methods such as top mounted and wall mounted

XenD101MS detects moving, micro-moving, and motionless standing human body, supports parameter adjustments on multiple dimensions, and can be widely applied to various AIoT scenarios, including:

- **Smart Home**

  Detect human presence, detect the direction and distance of a moving target, report results and enable the MCU to control domestic appliances accordingly.

- **Smart Business**

  Partition sensing, detect human approach or leaving in specified range so as to turn on/off devices, keep devices on when human presence is detected.

[1] The farthest detection range can reach 24 m in certain scenarios such as a long and narrow corridor, so the visualization tool's configurable range up to 24 m.

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- **Intelligent Security**

  Entrance control, building intercom, visual doorbell etc.

- **Intelligent Lighting**

  Detect human body precisely, applicable to public lighting, various motion-sensor lights, and LED bulbs etc.

2. System Characteristics

The XenD101MS is an intelligent space management reference solution developed based on ICLM S3KM111L mmWave sensor chip. It detects human in specified ranges and reports detection result in real time by integrating FMCW, radar signal process and built-in intelligent human detection algorithm. With this reference solution, users can quickly develop customized human detection and space management products with high precision.

The XenD101 hardware mainly consists of a fully integrated ICML S3KM111L smart mmWave sensor SoC, 24 GHz 1T1R antennas and an MCU. With the ICML firmware MS01 and a visualized configuration tool, users can flexibly configure detection range, sensibility and absence report delay.

The systematic characteristics of XenD101MS are shown in Table 2-1.

Table 2-1 XenD101MS characteristics

Parameter	Condition	Min.	Typ.	Max.	Unit
XenD101 Hardware Characteristics					
Supporting frequency		24	-	25	GHz
Max. bandwidth	Configurable on host computer side	-	-	1	GHz
Max. EIRP		-	-	15	dBm
Power supply		3.0	3.3	3.6	V
Size		-	18 × 15	-	mm × mm
Ambient temperature		-40	-	85	°C
XenD101MS System Characteristics					
Detection range	Moving human target	0.2	-	20	m
Resolution	Moving human target	0.75	-	-	m
Operating Frequency	In accordance with FCC, CE and RC certification standards	24	-	24.25	GHz
Bandwidth		-	-	0.25	GHz
Average operating current		-	42	100	mA

3. Hardware Overview

As is shown in Figure 3-1, XenD101 hardware reserves 5 pins (default without contact pin) called J1, and J2 as SWD interface for programming and debugging MCU program. Details of J1 and J2 are listed in Table 3-1 and Table 3-2.

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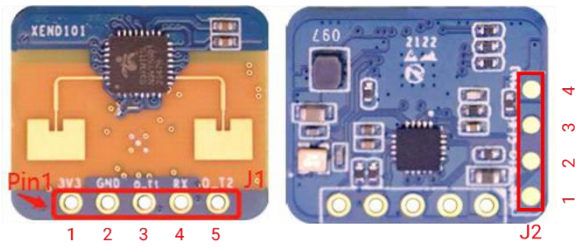

Figure 3-1 Top and bottom device map of XenD101

Table 3-1 J1 Pin description [1]

J#PIN#	Name	Function	Operating Range
J1Pin1	3V3	Power input	3.0 V ~ 3.6 V, Typ. 3.3 V
J1Pin2	GND	Ground	-
J1Pin3	O_T1	Can be configured as UART_TX or IO. Cannot be configured as UART_TX with O_T2 at the same time. Default as UART_TX.	0 ~ 3.3 V
J1Pin4	RX	UART_RX	0 ~ 3.3 V
J1Pin5	O_T2	Can be configured as UART_TX or IO. Cannot be configured as UART_TX with O_T1 at the same time. Default as IO	0 ~ 3.3 V

Table 3-2 J2 Pin description

J#PIN#	Name	Function	Operating Range
J2Pin1	GND	Ground	-
J2Pin2	SWDIO	-	0 ~ 3.3 V
J2Pin3	SWCLK	-	0 ~ 3.3 V
J2Pin4	3V3	Power supply	3.0 V ~ 3.6 V, Typ. 3.3 V

Note:

[1] J1 and J2 pitch is 2.54 mm.

4. Software Overview

XenD101MS is released with firmware MS01. For more details of the firmware version, please refer to the package of the module. ICLM provides a visualization software tool for XenD101MS, therefore users can optimize detection results by adjusting parameters according to the actual scenarios.

4.1 Firmware Description

4.1.1 Firmware Lib Structure

The structure of XenD101MS firmware is presented in Figure 4-1.

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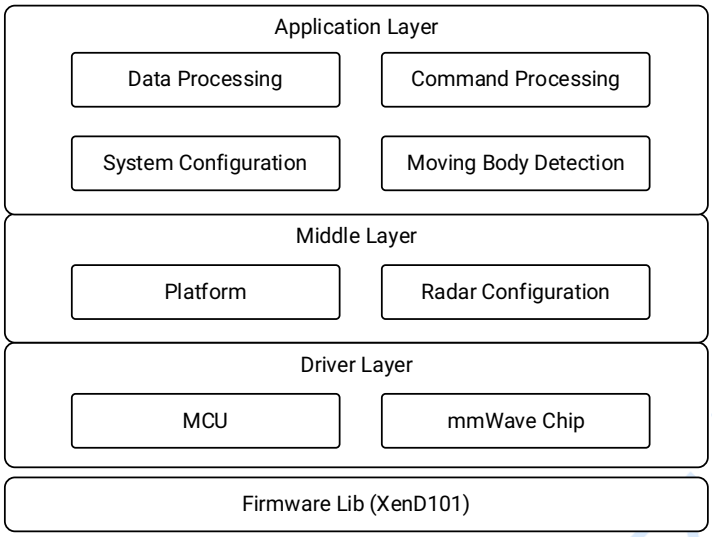

Figure 4-1 XenD101MS firmware structure

As is shown in Figure 4-1, the firmware consists of three layers, they are:

A. Application Layer: independent of platforms, provides application functions, including receiving and parsing data, and implementing algorithms;

B. Middle Layer: adapts to multiple platforms;

C. Driver Layer: official drivers for the MCU and peripherals.

In the directory of the firmware, there are folders named *App, Config, Doc Driver, Middleware, Project, Script* etc., and there is also a firmware application note *readme.txt*. *App* contains algorithms and application files; *Config* contains configuration files for the system and registers; *Driver, Middleware, Script* include platform drivers; *Project* contains project compile directory.

4.1.2 Firmware Parameter Description

XenD101MS allows users to optimize the performance when detecting human motion and micromotion. In common scenarios, it can detect as far as 20 m, and allows users to configure parameters of multiple dimensions according to the actual application. XenD101MS firmware is programmed with default setting when released, so that it supports Plug and Play.

Descriptions of default settings of XenD101MS are presented in Table 4-1.

Table 4-1 XenD101MS default parameter description

Parameter	Configurable Range	Default Value	Description
Max. Detect Range	0.75 ~ 24.00 m	2.25 m	
Abs. Report Delay	1 ~ 76 s	5 s	Absence report delay
Sensibility Level	Low, Middle, High	Middle	In low sensibility level, bigger motion such as normal walk can be detected.
Customized Sensibility for Each Range	1 ~ 10	5	Smaller value means lower sensibility

Serial port output data format of XenD101MS:

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- When the target is detected, serial port displays ON, GPIO (IO_OUT) Pin outputs high level.
- When no target is detected, serial port displays OFF, GPIO (IO_OUT) Pin outputs low level.

Note: The XenD101MS supports both GPIO and UART ports as reporting port, while the former outputs in real time and the latter outputs in every 0.8 s. The serial port baud rate is 256000.

4.2 Visualization Tool Description

4.2.1 Parameter Configuration

ICLM provides a visualization tool that allows users to adjust detection parameters for XenD101MS. Here are steps for using the visualization tool.

1) Connect XenD101 hardware to the host computer using a serial port tool, as shown in Figure 4-2.

Figure 4-2 Connection between XenD101 hardware and host PC

2) Obtain *XenD101 Configure Tool* from ICLM official website, unzip the pack and enter the directory.

3) Double click *ICLM_XenD101ConfigTool.exe*, the GUI (graphic user interface) of the configuration tool, which is shown in Figure 4-3, will appear.

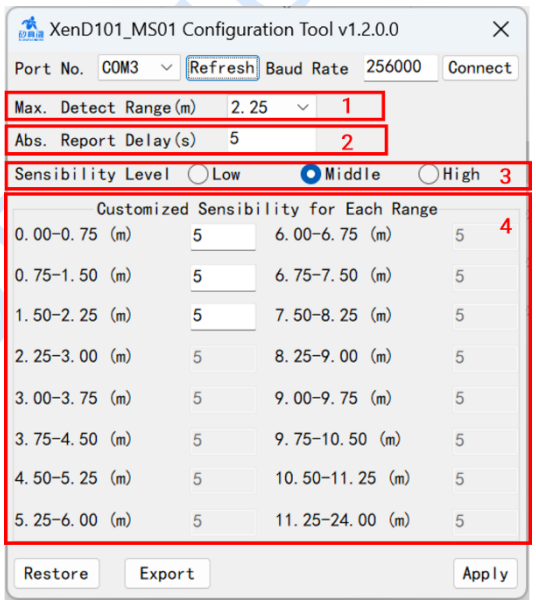

Figure 4-3 GUI of XenD101MS Configuration Tool

4) Click the **Refresh** button, choose the radar serial port number, and click the **Connect** button before

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modifying any parameter. Explanation of configurable parameters are as follows:

Max. Detect Range (maximum detection range): as is highlighted in zone 1 of Figure 4-3, maximum detection range is by default 2.25 m, and its value range is 0.75 ~ 24.00 m.

Abs. Report Delay (absence report delay): as is highlighted in zone 2 of Figure 4-3, absence report delay is by default 5 seconds, and its value range is 1 ~ 76 seconds.

Sensibility levels: as is highlighted in zone 3 of Figure 4-3, there are three optional levels for sensibility. With Low sensibility, the radar can detect moving targets such as pedestrians. With High sensibility, the radar can detect micro-motion such as a motionless standing human or finger movements. With Middle sensibility, the radar detects moderate motions between the former two occasions.

Customized sensibility: If users need to adjust sensibility for each individual range, as is highlighted in zone 4 of Figure 4-3, in Customized Sensibility for Each Range, the sensibility values can be manually configured. All range sensibilities are configured as 5 by default, and the value range is 1 ~ 10, while smaller value means lower sensibility.

5) After adjusting the parameters, click the **Apply** button to complete the configuration.

4.2.2 Parameter Consolidation

ICLM provides a visualization tool that is run on host computer and allows users to configure detection parameters for XenD101MS module according to applied scenarios. Users can try out parameters befit their needs and consolidate them into the firmware. Details of the consolidation process is explained below.

After setting up the parameters via the visualization tool, export the configuration file by clicking on *Export* button on the GUI, as is marked in Figure 4-4. The generated configuration file, *Setting.xml*, is saved in the same directory with the visualization tool. Figure 4-5 shows the default setting of XenD101MS firmware.

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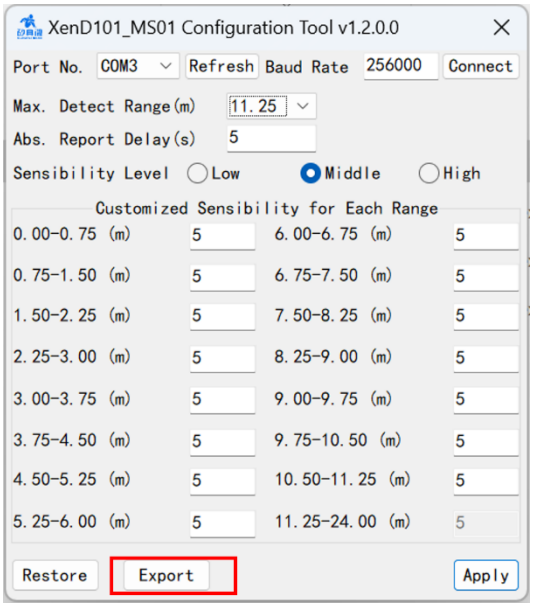

Figure 4-4 Export button on XenD101MS configuration tool

Setting.xml

```
<?xml version="1.0"?>
<Setting
    MAX_RANGE_IDX="2"
    INACTIVE_FRAME_NUM="17"
    threshold="1200, 750, 600, 600, 550, 550, 550, 450, 400, 400, 400, 400, 400, 390, 390, 290, " />
```

Figure 4-5 XenD101MS default setting

Descriptions of the parameters listed in Figure 4-5 are as follows.

- MAX_RANGE_IDX: maximum range gate index, default as 2, value ranges from 0 to 31, corresponding detection distance equals to *(MAX_RANGE_IDX+1) * 0.75* meter, hence detection distance varies from 0.75 m to 24.00 m.
- INACTIVE_FRAME_NUM: delay for reporting no-target in detection range, default as 17, value varies from 1 to 255, corresponding delay time equals to *INACTIVE_FRAME_NUM * 0.3* second, hence the time delay for reporting no-target state varies from 0.3 s to 76.5 s.
- threshold[PEAK_TH_NUM]: threshold of detection range, this parameter affects the sensibility of each detection range, value varies from 100 to 65535, the smaller the value, the higher the sensibility.
- *MAX_RANGE_IDX* and *INACTIVE_FRAME_NUM* are defined in *Middleware\common\src\radar.h*, while *threshold[PEAK_TH_NUM]* is defined in *Middleware\common\src\radar.c*. Developers can modify these variables in *radar.h* and *radar.c* using the exported configuration file shown in Figure 4-5, then re-compile the firmware and program it into XenD101 to complete the consolidation.

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5. Detection Range

There are two typical installing methods for XenD101MS, wall mounted and top mounted. XenD101MS provides precise range configuration when it is wall mounted, with a deviation of ±37.5 cm. And its FOV (field of view) within 3 meters is up to ±70°, and the maximum detectable range in radial direction is about 17 ~ 20 m. When it is top mounted, due to the variations of the installation height, the height and shape of the target, the detection range of the XenD101MS may vary accordingly.

The detection range of the radar sensor is configurable by adjusting the parameters. The maximum detectable range is 20 m, while the actual detectable range can be adjusted according to customized requirements.

Figure 5-1 shows the detection range of a wall mounted radar. The detection range varies in accordance with sensibility levels. There are three different detection ranges, representing target state of motion, micro-motion and motionless sitting. The dark blue area is of high sensibility, where a motionless sitting human can be detected. The medium blue area is of medium sensibility, where a motionless standing human in occasions like a corridor can be detected. The light blue area is of low sensibility, where moving human can be detected under various occasions.

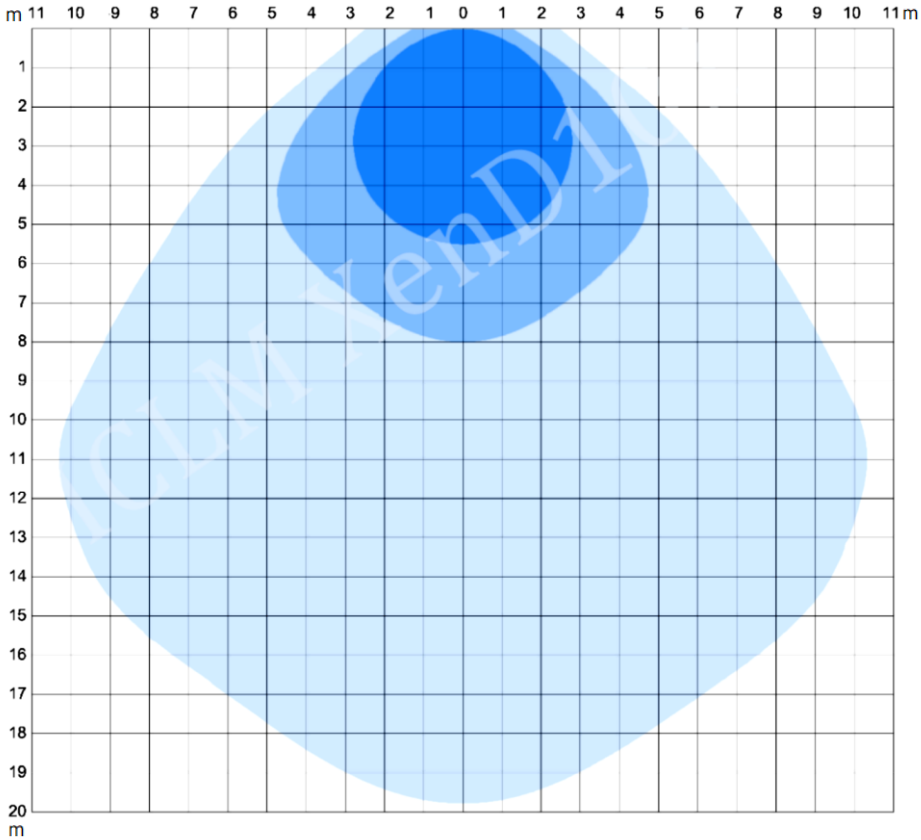

Figure 5-1 Detection range (wall mounted)

When installing XenD101MS using top mounted method, the typical height is 2.7 m. Both moving and motionless standing human targets can be detected within different ranges, detailed detection range in different angles are shown in Figure 5-2.

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In Figure 5-2, the numbers 1 to 7 indicate the direct distance to the radar. In the dark blue area, motionless standing human targets can be precisely detected, while in light blue area, moving human targets can be precisely detected.

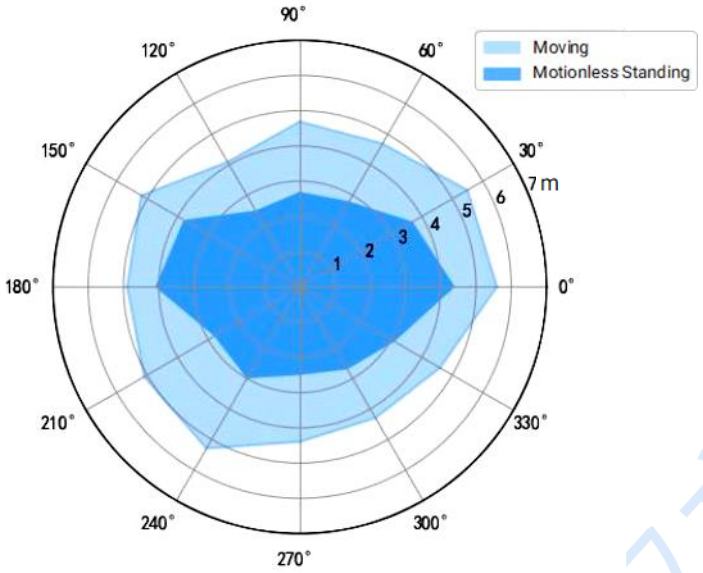
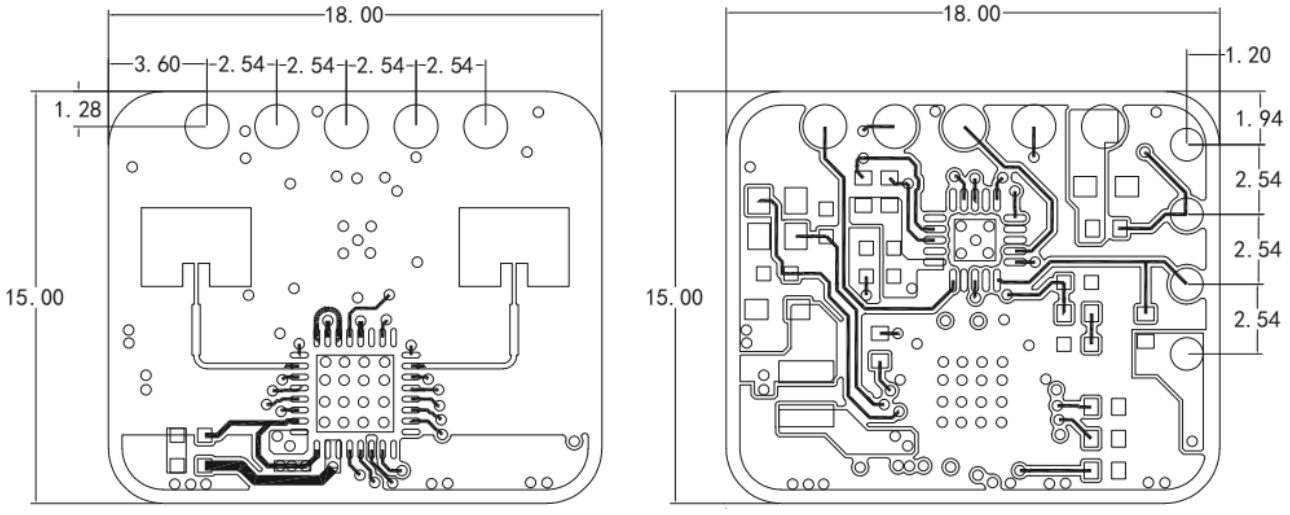


Figure 5-2 Detection range (top mounted)

6. Mechanical Size

Figure 6-1 shows the mechanical size of XenD101 PCB. The unit for all the data is mm. The board thickness is 1.6mm with ±10% tolerance.



(a) Top (b) Bottom

Figure 6-1 Top and bottom view of XenD101 hardware (mm)

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7. Installation Requirements

Minimum Mounting Clearances

If there is a need to install a radome, the material selected must have good transparency for 24 GHz electromagnetic wave, and do not contain any material that may block electromagnetic wave such as metal. More details please refer to Guide of mmWave Sensor Antenna Radome Design[2].

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

Installation Environment

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

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

Important Requirements

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

[2] Currently, only Chinese version is available.

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8. Revision History

Revision	Date	Modification
1.0	2022/2/24	Initial release.
1.1	2022/10/31	Update document structure; Add J2 Pin description, firmware Lib introduction, and Parameter Consolidation.
1.2	2023/6/7	Change the product name from XenD101MS01 to XenD101MS according to the latest product naming rule; Add EULA to the visualization tool, and update the figures of the visualization tool; Add a Refresh button on the visualization tool to better connect the radar with the tool.

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