IRM2.31
77GHz Two-wheeler Early Warning Radar Specification

<certified version>

Nanjing Chuhang Technology Co., Ltd.

1. General description

1.1 Purpose

This document describes the IRM2.31 corner radar of Nanjing Chuhang Technology Co., Ltd. (hereinafter referred to as Chuhang Tech). It includes product specification, functional principle, product function, installation, and calibration method.

1.2 Terms and abbreviations

Abbreviation	Full name
CAN	Controller Area Network
FMCW	Frequency Modulated Continuous Wave
TTC	Time to Collision
dB	Decibel
dBm	Decibel milliwatts
dBsm	Decibel square meters
RCS	Radar Cross Section
BSD	Blind Spot Detection
LCW	Lane Change Warning
RCW	Rear Collision Warning
FCW	Front Collision Warning

2. Radar system description

2.1 Functional principle

2.1.1 FMCW radar principle of distance and speed measurement

Electromagnetic (EM) waves within frequency range between 300 MHz to 300 GHz are defined as microwaves. The propagation velocity of microwaves in the air is almost equal to the speed of light in vacuum, which is 3×10^8m/s. The straight-line distance from the antenna to the target is calculated by the time delay between the EM waves emitted by the radar transmitting antenna and the EM waves received by the receiving antenna. The measurement principle of the radial distance between radar antenna and object is shown in Figure 1. The radar emits EM waves to the target. After the EM waves encounter the target, they are reflected back to the radar. The time taken for the EM waves to go back and forth is t_d. During the time t_d, the distance the EM waves travel is 2R, the speed of light is c, $c = 3 \times 10^8$m/s; therefore, R is calculated by equation $R = \frac{1}{2} c \cdot t_d$.

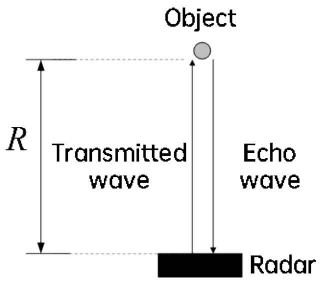


Figure 1 Radar principle of distance measurement

FMCW radar generates a frequency-modulated (FM) saw-tooth wave form through the antenna, see Figure 2. The radiated EM wave will be scattered by the target object, part of the EM wave will be captured by the receiving antenna of the radar. The echo signal and the local oscillator signal are sent to the mixer for mixing. During the period when the transmitted signal encounters the target and returns to the antenna, the frequency of the echo signal has changed compared to the frequency of the radar's transmitted signal at this time, so a signal containing the difference between the transmission frequency and the echo frequency is generated at the output of the mixer, which is called the difference frequency signal. The difference frequency signal contains the distance information of the target, so after filtering, amplification, A/D conversion and frequency measurement, the distance value from the radar antenna to the target can be obtained.

In addition, to obtain the radial velocity of the target object, the radar has to transmit the single sawtooth signal (Chirp) in a periodical way (frame). The radial velocity is calculated by in-time phase shift of the adjacent chirp signals. By equal interval sampling, the sampled data will be processed with FFT and the outcome is saved in the storage matrix in the form of consecutive line. The processor combines all received chirp signals in one frame and sequentially performs FFT to each single chirp.

The combination of distance FFT (line by line) and doppler FFT (column by column) can be considered as a 2-D (two-dimensional) FFT processing of the digital sampling data in each frame. The 2-D FFT enables the simultaneous measurement of target distance and velocity.

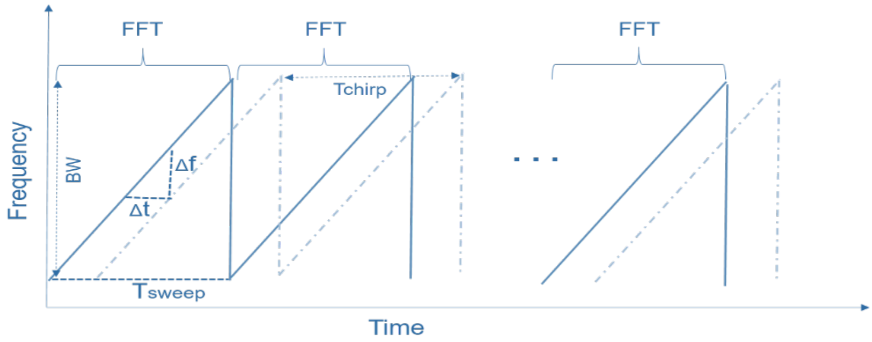


Figure 2 FM sawtooth wave

The correlation between distance and its resolution can be expressed by:

$R = \frac{cT_{sweep}}{2BW} f_{IF}$ $\qquad R_{res} = \frac{c}{2BW}$

where BW is the sweeping bandwidth, T_{sweep} is the sweeping period, f_{IF} is the difference frequency, c is the speed of light.

The correlation between velocity and its resolution can be expressed by:

$V = \frac{c}{2f} f_d$ $\qquad V_{res} = \frac{c}{2f \cdot N \cdot T_{chirp}}$

where c is the speed of light, f_d is the doppler frequency, f is the center frequency of the chirp, N is the number of chirps, T_{chirp} is the period of the chirp.

2.1.2 Angular determination by phase measurement method

The phase measurement method is used to measure the angle of the target object based on the phase difference among echo signals received by multiple antennas. As shown in Figure 3, the angle between the radar and the target object is θ. After reflection and transmission, the receiving EM wave can be considered as plane wave. Assuming the antenna spacing is d, due to the different transmitting distance ΔR, there must be a phase difference between the two receiving signals at adjacent antenna. The phase difference Δφ can be expressed by:

$$\Delta\varphi = \frac{2\pi}{\lambda}\Delta R = \frac{2\pi}{\lambda} d \sin\theta$$

where λ is the radar wavelength. In this way, the angle of the object can be derived by:

$$\theta = \arcsin\left(\frac{\Delta\varphi\lambda}{2\pi d}\right)$$

In digital signal processing of radar system, the phase difference Δφ will be obtained by orthogonal I and Q channel output signals. If φ_1, φ_2 are defined as the phases of the two receiving antenna output signals, phase difference can be derived by:

$$\begin{cases} \varphi_1 = \arctan\frac{Q_1}{I_1} \\ \varphi_2 = \arctan\frac{Q_2}{I_2} \\ \Delta\varphi = \varphi_2 - \varphi_1 \end{cases}$$

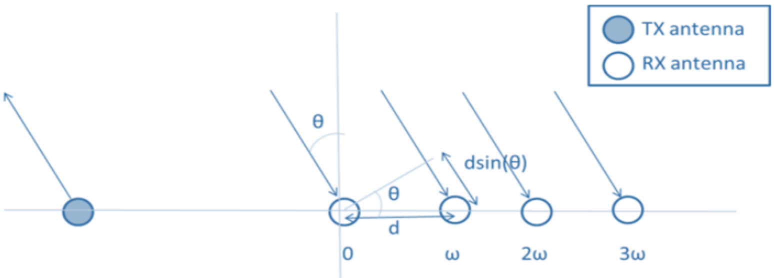


Figure 3 Angular determination by phase measurement method

2.2 System structure

The system structure of IRM2.31 corner radar is shown in Figure 4. There are 2 TX antennas and 3 RX antennas for RF antenna. It also has horizontal azimuth detection and pitch height detection

The radar adopts a separate power supply design, with two LDOs in series with DCDC, and supports KL15 (start-up power supply). The built-in IMU chip is used to estimate car body posture.

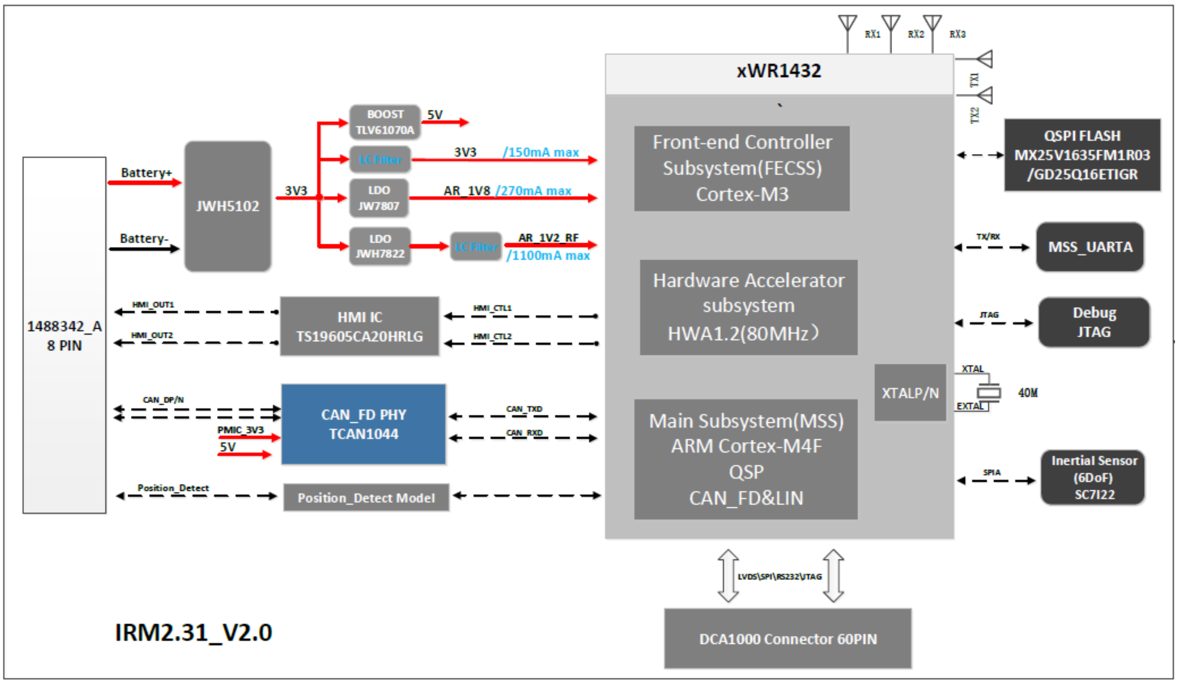


Figure 4 System hardware structure

Main component model:

Chip type	Type
SOC	AWRL1432
Flash	GD25Q16ETIGR
CAN	TCAN1044
IMU	SC7122
DCDC	JWH5102
LDO	JWH7822

2.3 Mechanical structure

2.3.1 Radar exploded view

IRM2.31 adopts an integrated cable design. The whole machine is connected to the cable and connector, which is convenient for vehicle installation. The connector supports other models. Please see Figure 5.

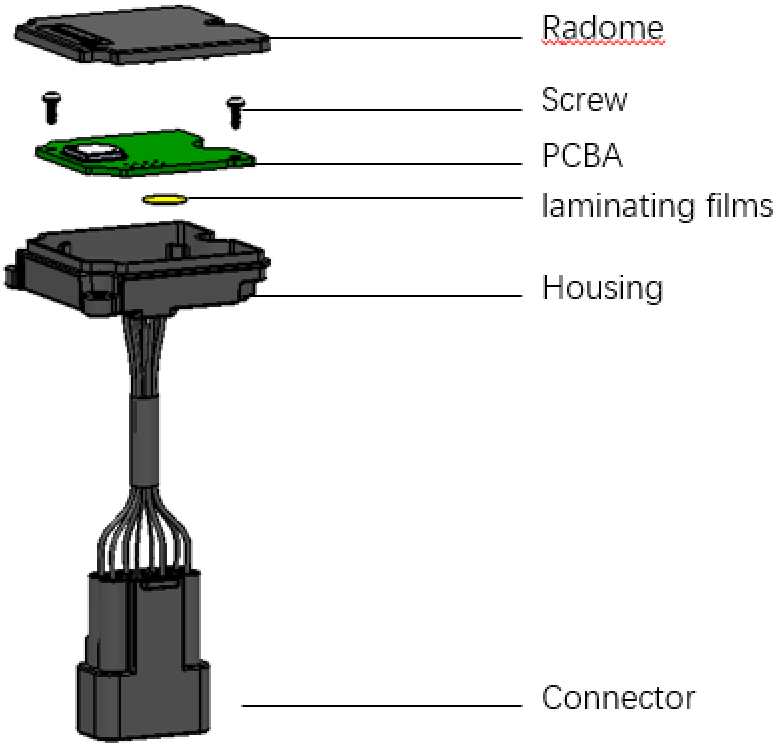


Figure 5 Radar structure

2.3.2 Radar dimension

Figure 6 shows the dimension of radar housing. Chuhang Tech supports radar bracket design.

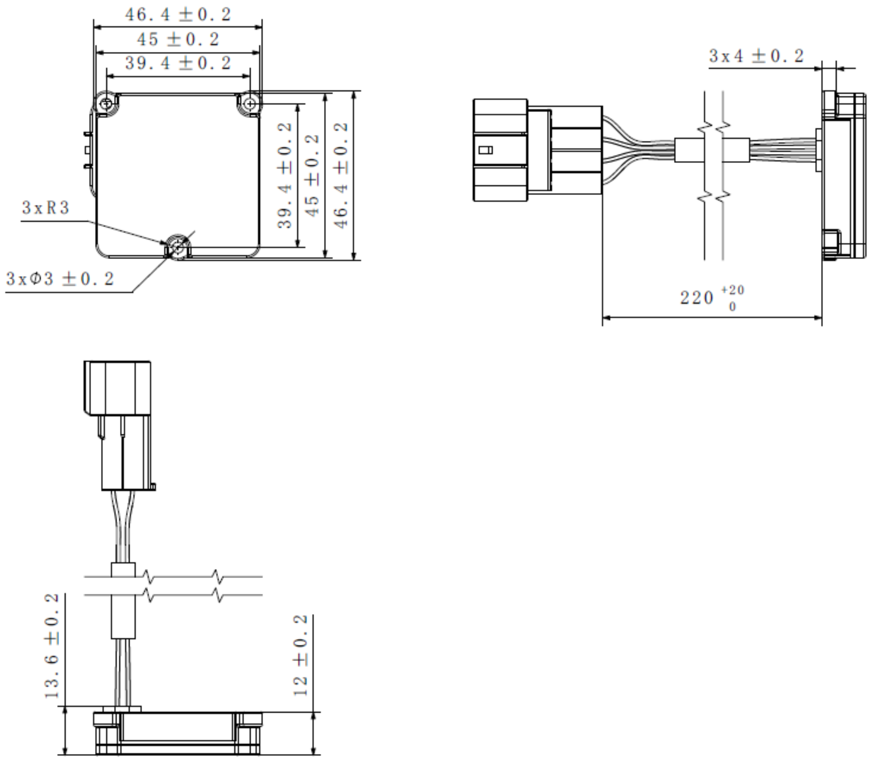


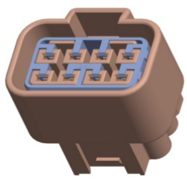
Figure 6 Radar 2D dimension drawing

2.3.3 Product materials

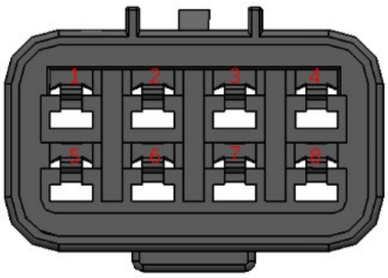
Name	Quantity	Material
Radar housing	1	PBT-GF30
Antenna case	1	PBT-GF30
Laminating film	1	/
Shielding cover	1	Copper-nickel-zinc alloy C7521

2.3.4 Connector definition

Specification and type of connectors to cables are as follows:

	**Housing type**	DJ7081Y-2.3-21
	Supplier	ZEET
	Protect level	IP67

Radar pin definition is shown as follows:



Number	Radar pin	Function
1	DC12V+	Power input positive
2	L-LED driver I/O	Driver LED DC 12V
3	CANH	Connect vehicle communication
4	Location identification address line	Identify assembly status and automatically configure parameters (suspended: high, grounded: low)
5	R-LED driver I/O	Driver LED DC 12V
6	DC12V-	Power input negative
7	CANL	Connect vehicle communication
8	NA	NA

2.4 Software architecture

The operation software of IRM2.31 radar is developed based on ASPICE Level2 requirements. By using AutoSAR architecture as seen in Figure 7, the modular design not only realizes an agile development, but also makes further maintenance and upgrade very easy.

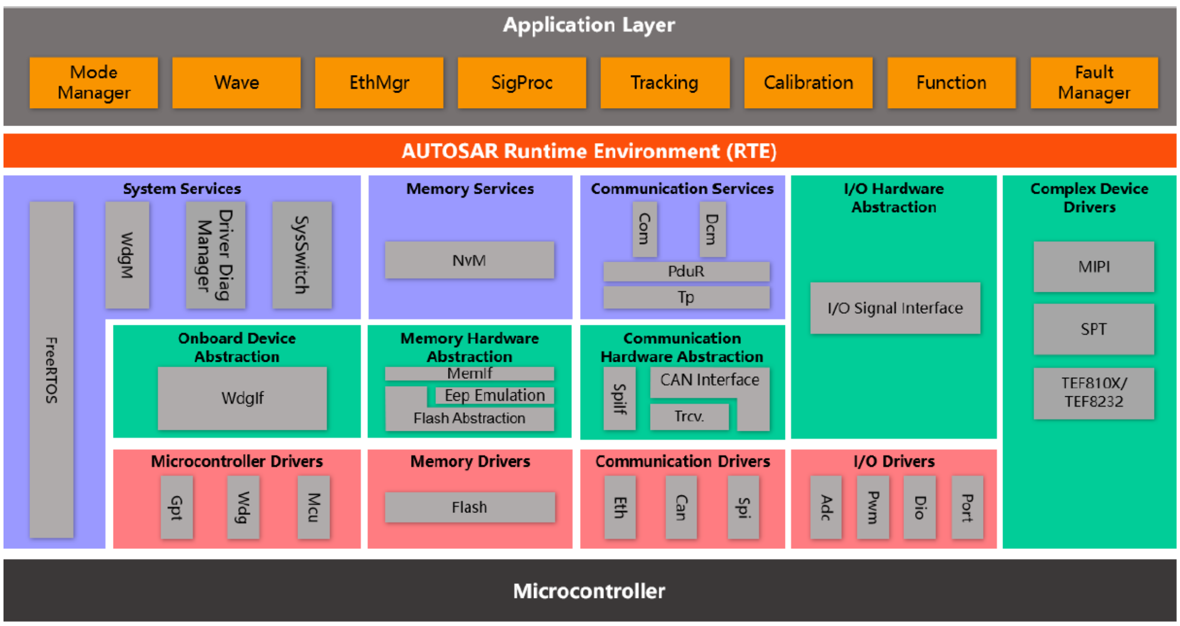


Figure 7 Software architecture

2.5 Algorithm structure

The software module in application layer mainly includes signal processing, data processing and function application.

The signal processing module processes the original ADC signal of the radar and converts it into point cloud data using TDMA standard. The IMU body attitude estimation module is added for body attitude information compensation and for subsequent data processing module. Data processing transforms it into a target through a clustering tracking algorithm, and outputs a series of kinematic and non-kinematic attribute values, such as position, speed, acceleration, orientation, classification (truck, car, two-wheeler, pedestrian), as shown in Figure 8.

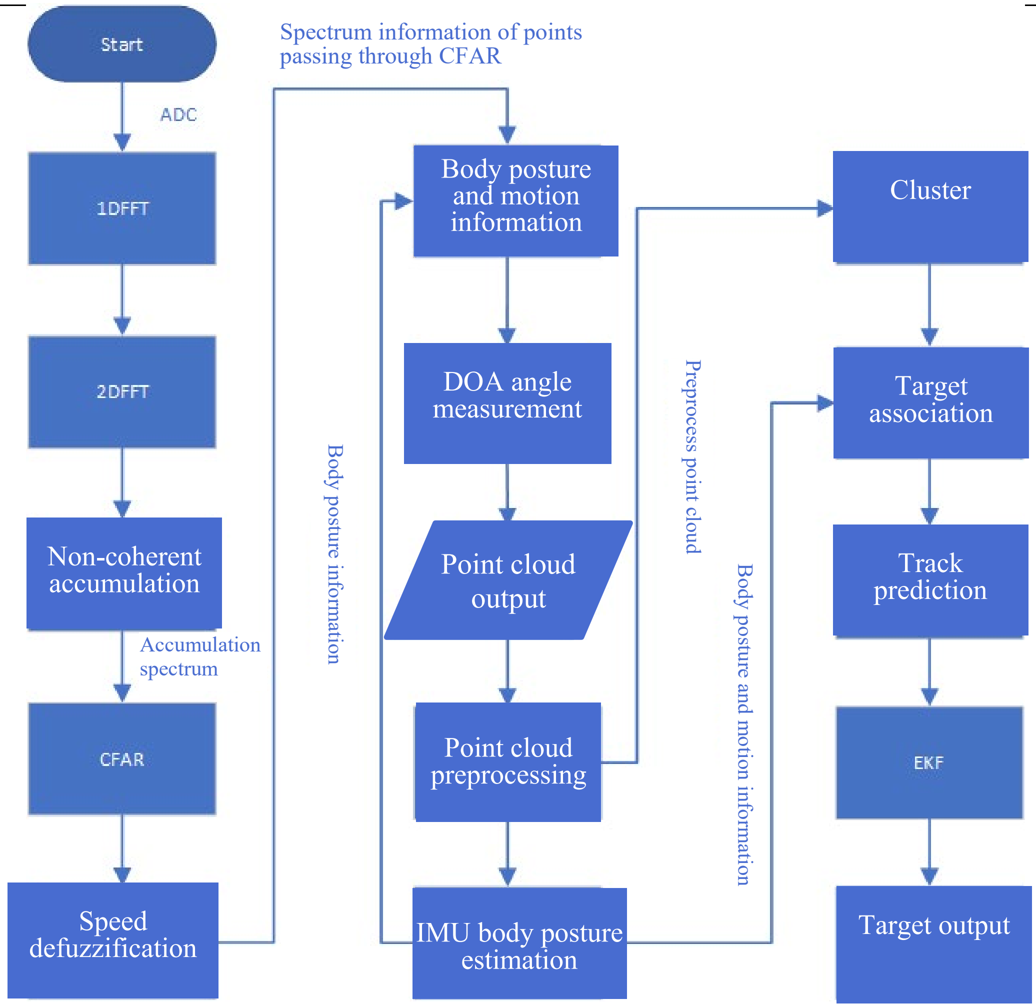


Figure 8. Algorithm flow

Finally, the functional application module processes the target data and develops BSD, LCW, RCW and other applications according to the functional requirements. See Chapter 3 for detailed function introduction.

2.6 Radar characteristics

2.6.1 General characteristics

Operating frequency		76 GHz to 77 GHz
Data cycle		100 ms
Distance	Range	0.5 m~80 m
	Accuracy	±0.1m
	Resolution	0.5 m
Velocity	Range	-35～+35 m/s
	Accuracy	±0.1 m/s
	Resolution	0.4 m/s
Angle	Range	-75° ~ +75° (Horizontal) -15° ~ +15° (Vertical)
	Accuracy	±0.5° ±0.1°@0° Normal direction
	Resolution	7°
Antenna channel		2Tx 3Rx

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Number of detectable objects	≤16
Operating voltage	9.0 V ~ 16 V DC
Power consumption	≤2.0 W
Operating temperature	- 40℃ ~ +85℃
Protection level	IP67
Sleep wakeup	No
Wireless transmission power	29dBm

2.6.2 Operating voltage

The table below shows the communication status of the radar system at different voltage ranges.

Rated voltage 12V state	Operating mode	Performance
<6.5V (± 0.3V hysteresis)	Safe mode	- No communication with vehicle interface - No fault detection
6.5V – 9V (±0.3V hysteresis)	Low voltage mode	- Normal communication with vehicle interface - Normal hardware monitoring - Partial fault monitoring, low voltage fault memory - Restricted functionality
9V – 16V (± 0.3V hysteresis)	Normal voltage mode	- Normal communication with vehicle interface - Normal hardware monitoring - Full fault monitoring
16V – 18.5V (± 0.3V hysteresis)	High voltage mode	- Normal communication with vehicle interface - Normal hardware monitoring, not including body related DTC - High voltage fault only - Restricted functionality
>18.5V (± 0.3V hysteresis)	Safe mode	- No communication with vehicle interface - No fault detection

2.6.3 Supplementary information

Hereby, Nanjing Chuhang Technology Co., Ltd. declares that the radio equipment type IRM2.31 is in compliance with Directive 2014/53/EU.

2.6.3.1 Manufacturer's name and address

Nanjing Chuhang Technology Co., Ltd.
12th Floor, Inter-Space, No. 9, Yunzheng Street,
Jiangbei New Area, Nanjing,
P.R. China

2.6.3.2 Importer's name and address

Importer: xxxx
Address: xxxx

2.6.3.3 FCC compliance statement

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions:
(1) This device may not cause harmful interference, and
(2) this device must accept any interference received, including interference that may cause undesired operation.

Please note that changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

Note: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

—Reorient or relocate the receiving antenna.

—Increase the separation between the equipment and receiver.

—Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.

—Consult the dealer or an experienced radio/TV technician for help.

This equipment complies with radio frequency exposure limits set forth by the FCC for an uncontrolled environment.
This equipment should be installed and operated with a minimum distance of 20 cm between the device and the user or bystanders.
This device must not be co-located or operating in conjunction with any other antenna or transmitter.

3. System functions

IRM2.31 supports two wheeler's backward warning function including BSD, LCW and RCW, and forward warning function such as FCW.

3.1 Blind Spot Detection (BSD)

Blind spot detection assists the driver in monitoring the traffic situation at the blind spot of vehicle's rear side. Its functional area is shown in Figure 9.

Function description:

When a target vehicle is detected in the rear of subject vehicle, the first-level alarm will be triggered on human-machine interface (LED warning light is always on and it can be distinguished between left and right). When a target vehicle is detected in the rear of subject vehicle, and the driver gives a steering command to the same side, the second-level alarm will be triggered on human-machine interface (LED warning light flashes and it can be distinguished between left and right). If the turn signal on the corresponding side of the vehicle returns to the positive position, the system will jump to the first level alarm state on the corresponding side. When the target vehicle moves away from or overtakes the subject vehicle, the alarm will be cleared.

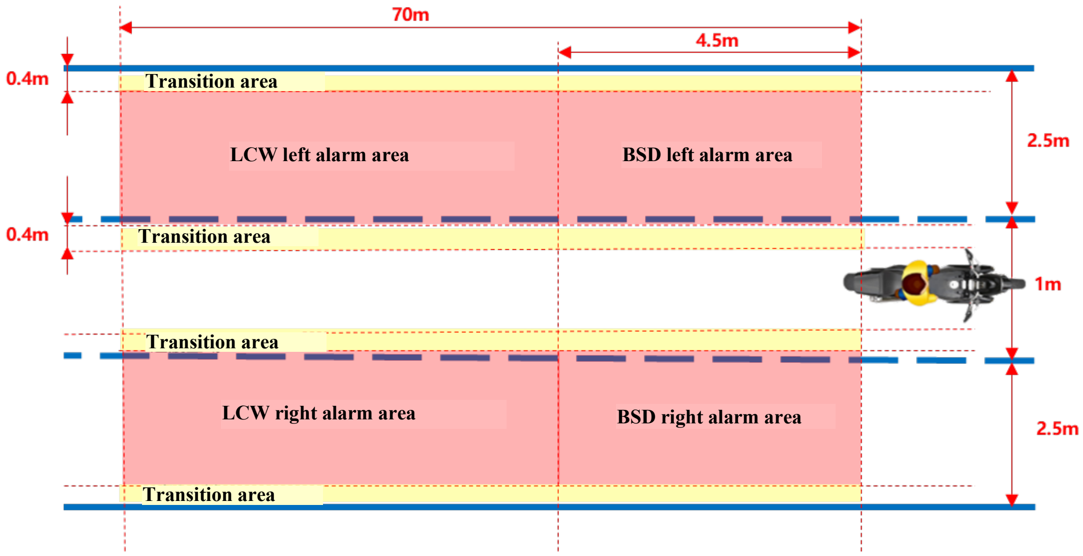

Figure 9 BSD/LCW Functional Area Diagram

3.2 Lane Change Assistant (LCA)

Lane change warning assists the driver in monitoring the traffic situation from the blind spot of vehicle's rear side. Its functional area is shown in Figure 9.

Function description:

When a target vehicle is detected following the rear of the vehicle and the target vehicle enters the LCW blind spot alarm area, the first-level function alarm will be triggered on human-machine interface (LED warning light is always on and it can be distinguished between left and right). When the LCW level 1 alarm conditions are met and the turn signal on the same side is turned on, the second-level function alarm will be triggered on human-machine interface (LED warning light flashes and it can be distinguished between left and right). If the turn signal on the corresponding side of the vehicle returns to the positive position, the system will jump to the first level alarm state on the corresponding side. When the target vehicle moves away from or overtakes the subject vehicle, the alarm will be cleared.

3.3 Rear Collision Warning (RCW)

Rear collision warning assists the driver to monitor approaching vehicles in the rear. The alarm area is shown in Figure 10.

Function description:

When the subject vehicle is moving on the road with a target vehicle approaching rapidly from the rear, the RCW function will determine the severity of a rear-end collision. Based on the severity, the subject vehicle will send RCW signals to alert the driver to take measures to avoid collisions or mitigate the consequence (Both left and right LED warning lights flash). The function can also be used to warn the rear vehicles.

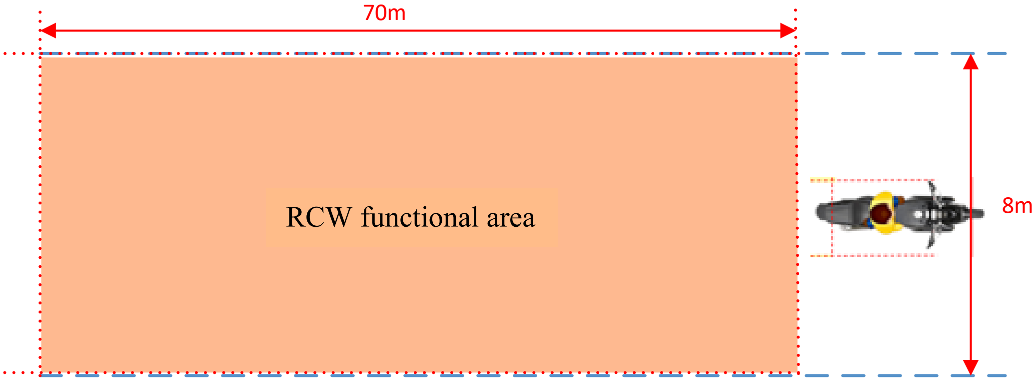

Figure 10 RCW Functional Area Diagram

3.4 Front Collision Warning (FCW)

Front Collision Warning (FCW) assists the driver in monitoring the situation of vehicles coming directly behind the vehicle on the highway.

Function description:

When the driver drives the vehicle normally on the road and quickly approaches the target in the front lane, the danger level of the rear-end collision is judged. Depending on the danger level at this time, the vehicle sends an FCW signal to prompt the driver to take measures to avoid or mitigate the collision (the dashboard warning light flashes). FCW collision warning can also be used to warn vehicles behind.

4. Installation specification

4.1 Installation requirements

The installation position of the two-wheeler forward and backward early warning radar is shown in Figure 11.

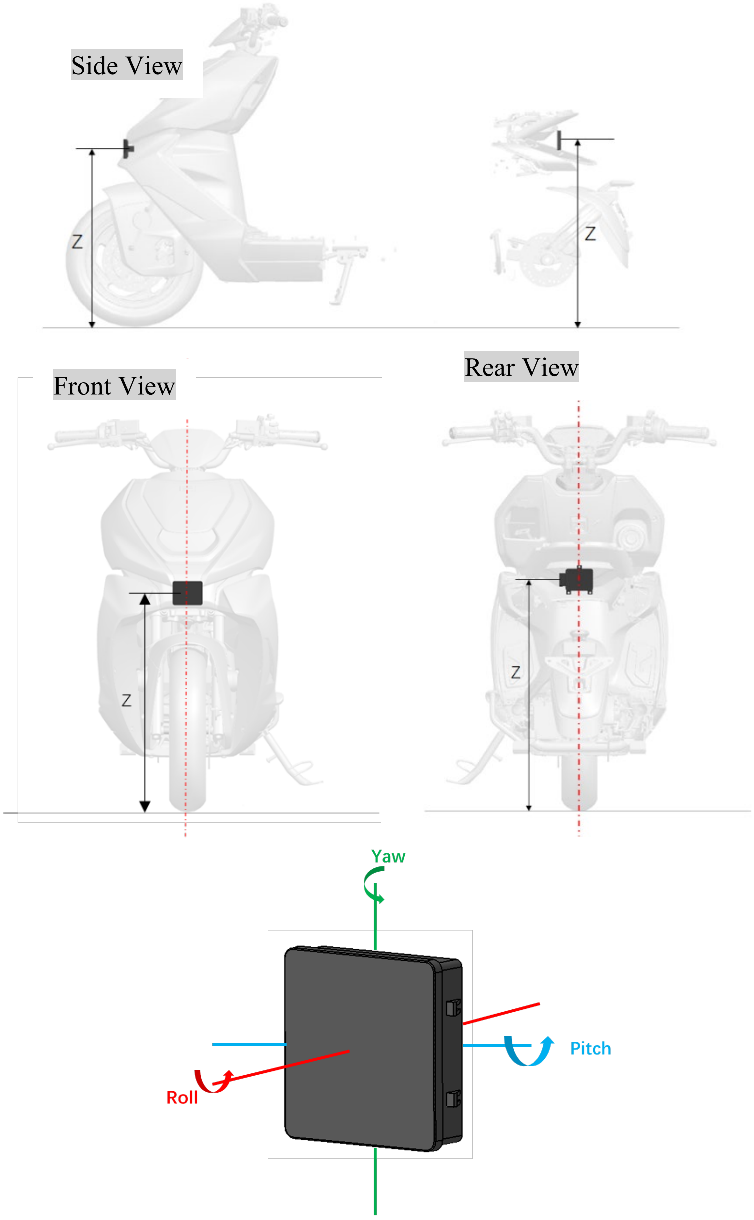

Figure 11 Installation diagram

Parameter name	**Parameter value**	**Tolerance**	**Remark**
Z Installation height	50~70 cm (Configurable)	±5cm (Configurable)	Layout position is above fender
Center offset	0	±5cm (Configurable)	Vehicle Y direction
Yaw angle	0° (Configurable)	±3° (Configurable)	Radar normal and vehicle X direction
Pitch angle	0°	±2°	/

Roll angle	0°	±2°	/
Connector orientation	Can be installed forward or reverse	/	/

Notes for installation:

1. The radar shall be installed in a relatively spacious area (preferably exposed installation) and a specific distance shall be retained between the radar and the decorative cover;
2. There should not be any metal objects nor protruding structural components near the radar to avoid electromagnetic wave reflection;
3. There are no interventions from other sensors and beams.

4.2 Bumper requirements

Radar and the second surface outside the body should fulfill the following requirements:

- **Thickness**

The front and rear bumpers should be as thick as or multiple times as thick as half wave length of the radar. The thicker the bumper, the greater impact to the penetration of the radar waves, see Figure 12.

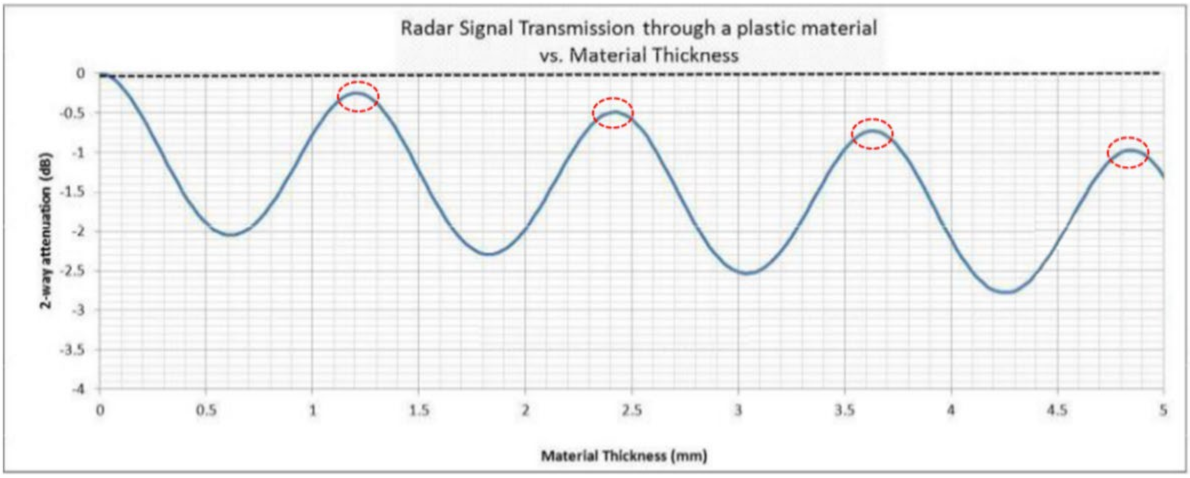

Figure 12 The relationship between bumper thickness and radar wave attenuation

- **Material**

All metal material in the front and rear bumper coatings will affect the performance of the radar; therefore, metal coating material should be avoided as much as possible. The correlation between the material dielectric constant and the optimal bumper thickness at 77 GHz frequency is as follows.

Material thickness (mm)	Optimal thickness 1 ±0.1mm	Optimal thickness 2 ±0.1mm	Optimal thickness 3 ±0.1mm	Optimal thickness 4 ±0.1mm
Polypropylene	1.28	2.55	3.83	5.1
ABS	1.19	2.39	3.58	4.77
Polyamide	1.18	2.36	3.54	4.72
Polycarbonate	1.16	2.33	3.49	4.66
SMC	0.88	1.77	2.65	3.54

- **Shape**

For the front and rear bumpers which cover the radar front, its radius of curvature should be ≥200mm. If the radius of curvature is too small, it will cause multipath reflection and increase the blurred area of radar wave, see Figure 13.

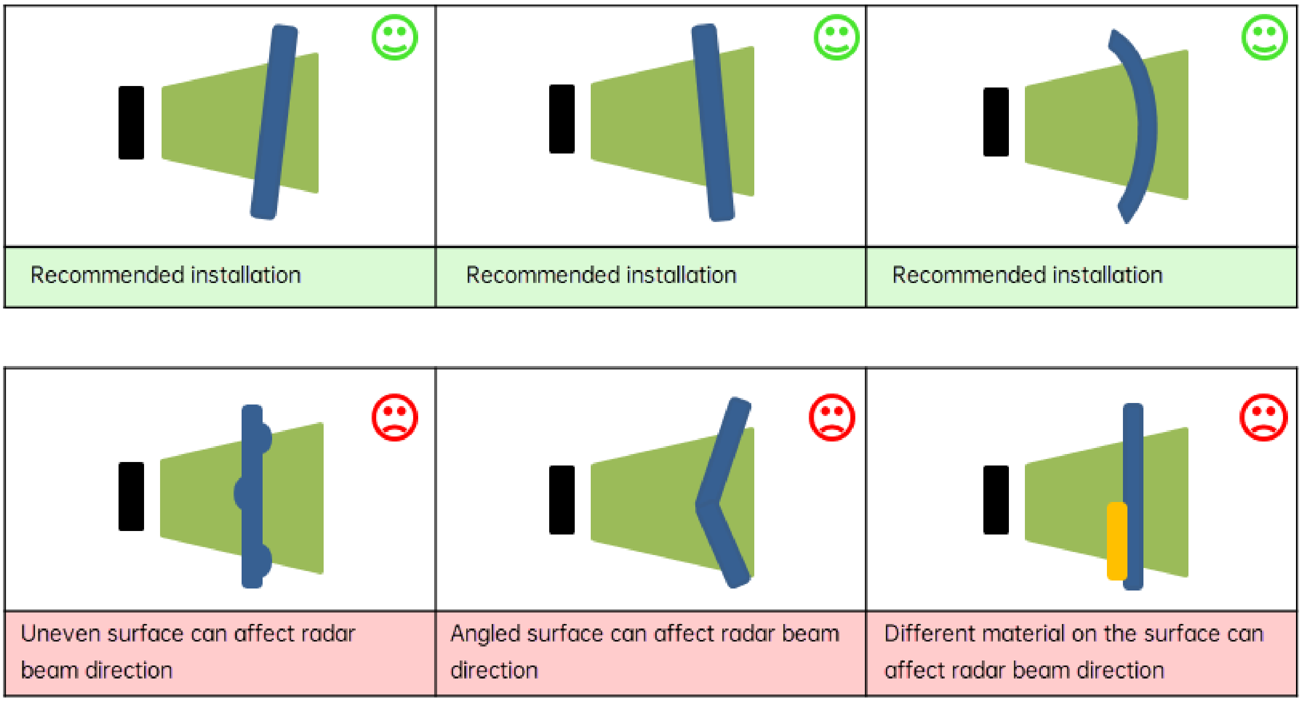

Figure 13 Recommended bumper shape

- **Distance**

  Keep a certain distance (>10mm) between the front/rear bumper and radar front surface to avoid mechanical interference due to vibration and thermal deformation. See Figure 14.

- **Uniformity**

  The front and rear bumpers should have uniform thickness and material property.

- **Angle**

  The angle between radar and bumper should be $|\alpha| > 5°$, see Figure 14.

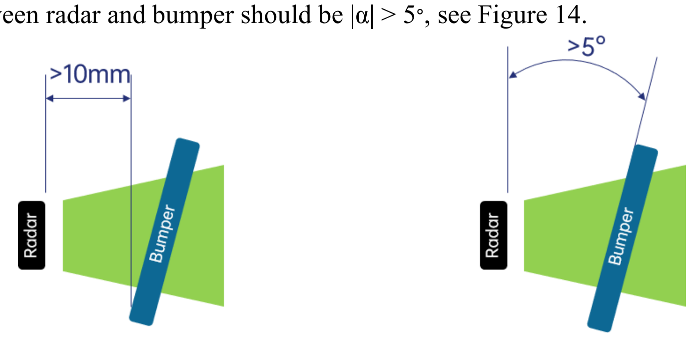

Figure14 Side view to show the angle

5. Design verification

5.1 Design standards

Standard	Standard name
GB/T 28046.1-2011	Road vehicles - Environmental conditions and testing for electrical and electronic equipment - Part 1: General
GB/T 28046.2-2011	Road vehicles - Environmental conditions and testing for electrical and electronic equipment - Part 2: Electrical loads

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GB/T 28046.3-2011	Road vehicles - Environmental conditions and testing for electrical and electronic equipment - Part 3: Mechanical loads
GB/T 28046.4-2011	Road vehicles - Environmental conditions and testing for electrical and electronic equipment - Part 4: Climatic loads
GB/T 2423.1-2008	Environmental testing for electric and electronic products - Part 2: Test methods - Tests A: Cold
GB/T 2423.2-2008	Environmental testing for electric and electronic products - Part 2: Test methods - Tests B: Dry heat
GB/T 2423.4-2008	Environmental testing for electric and electronic products - Part 2: Test methods - Test Db: Damp heat, cyclic (12h+12h cycle)
GB/T 2423.10-2008	Environmental testing for electric and electronic products - Part 2: Test methods - Test Fc: Vibration (sinusoidal)
GB/T 2423.18-2012	Environmental testing - Part 2: Test methods - Test Kb: Salt mist, cyclic (sodium chloride solution)
GB/T 2423.22-2012	Environmental testing - Part 2: Test methods - Test N: Change of temperature
GB/T 30038-2013	Road vehicles - Degrees of electrical equipment protection (IP-Code)
GB/T 33014.2-2016	Road vehicles - Component test methods for electrical/electronic disturbances from narrowband radiated electromagnetic energy - Part 2: Absorber-lined shielded enclosure
GB/T 21437.3-2008	Road vehicles - Electrical disturbances from conduction and coupling - Part 3: Electrical transient transmission by capacitive and inductive coupling via lines other than supply lines
GB/T 19951-2019	Road vehicles - Disturbances test methods for electrical/electronic component from electrostatic discharge
GB/T 18655-2018	Vehicles, boats and internal combustion engines - Radio disturbance characteristics - Limits and methods of measurement for the protection of on-board receivers
GB 8410	Flammability of automotive interior materials
GMW3172-2018	General Specification for Electrical/Electronic Components – Environmental/Durability

5.2 DV test verification

IRM2.31 product DV test plan.

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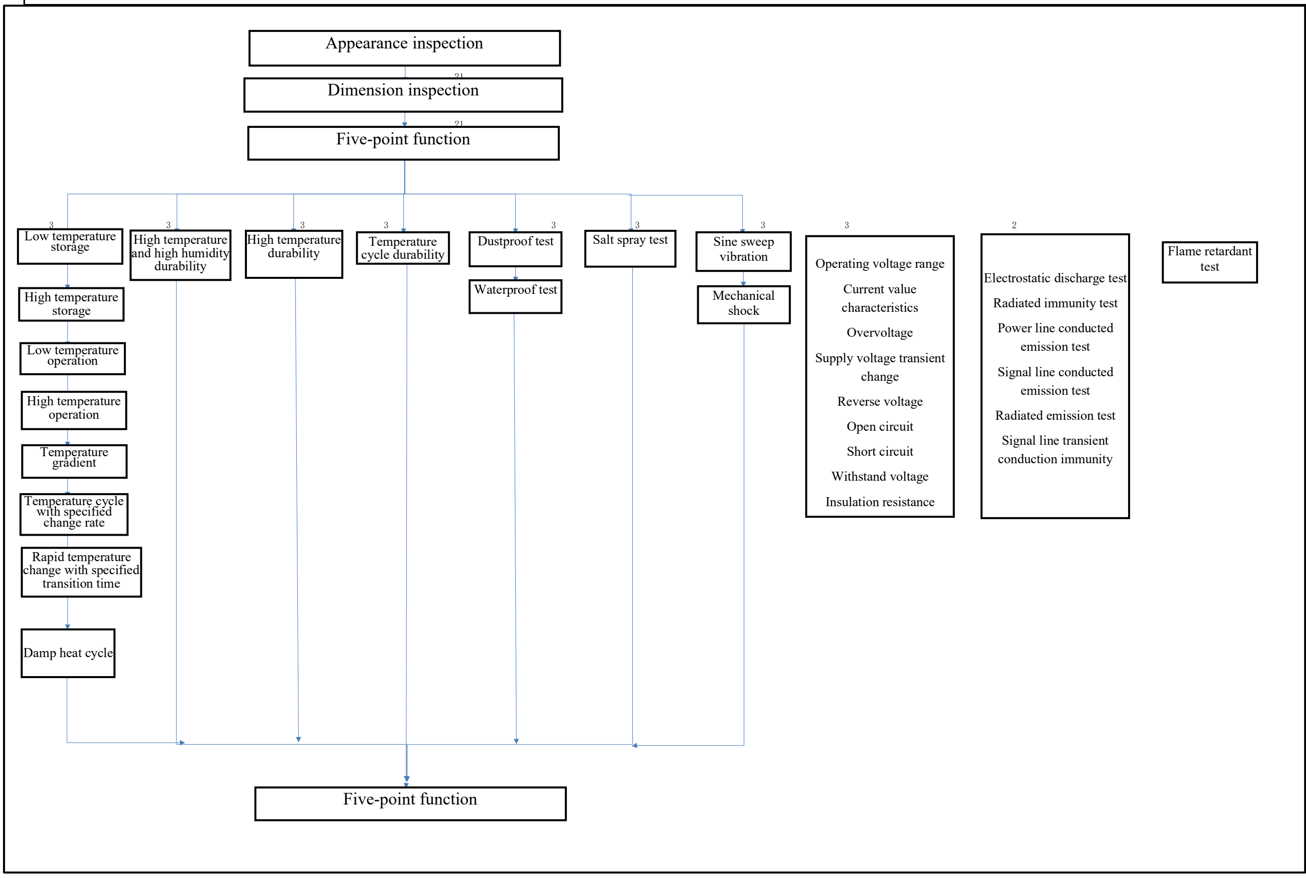

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