MS-RA11M User manual

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1. Product Outline

MS-RA1xM radar modules are the motion sensors that detect motion and speed of objects. As Doppler radar sensor modules, they operate in the 24 GHz ISM band.

The RA1xM series can be categorized into three product groups—MS-RA11M, MS-RA12M, and MS-RA14M—in accordance with a number of their antennas. Table 1 introduces operating ranges of three product groups, which are based on an RCS1 [1m²] (targeting an adult).

Table 1. Operating Ranges of Three Product Groups

Product group	**Operating ranges**
MS-RA11M	5 to 8 m
MS-RA12M	7 to 10 m
MS-RA14M	9 to 12 m

The range introduced in the table 1 can be adjusted by the operating environment and the gain of the digital amplifier embedded in the module.

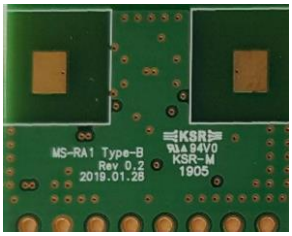
Since the MS-RA1xM module includes an exclusive transceiver for one-chip radars and an MCU for 32-bit signal processing, it has outstanding performance and provides various functions through digital signal processing.

As a one-chip device, the radar IC has almost no margin of error even at a high frequency of 24 GHz and adjusts the temperature to match the external environment with a temperature compensation circuit embedded in the IC.

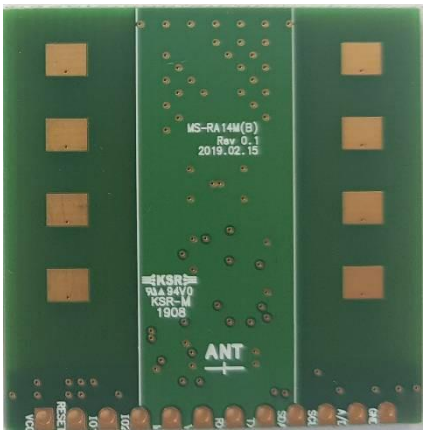
Features such as the digital amplifier, FFT signal processor, and signal comparator can be implemented by using the embedded 32-bit Cortex M0+ MCU, and the functions including fine tuning of detection range (50 stages), configuration of object speed (km/h), configuration of range of 2-stage proximity detection, and prevention of error caused by vibration are supported. These features and functions are configured and adjusted in real time via the serial communication port.

Radar modules comprised of current individual components detect motion using an analog comparator, which is not suitable for more complex situations. The MS-RA1xM module uses digital signal processing to achieve outstanding signal characteristics, and provides features that are completely differentiated from that of other radar modules.

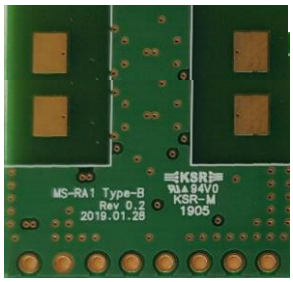
A GUI software application for PC is available to conduct performance tests when developing applications using the MS-RA1xM module, enabling users to easily assess performance and achieve target goals. With the PC software, users can develop their desired products more easily and rapidly by conducting sufficient tests in the stages prior to product development.



MS-RA11M



MS-RA14M



MS-RA12M

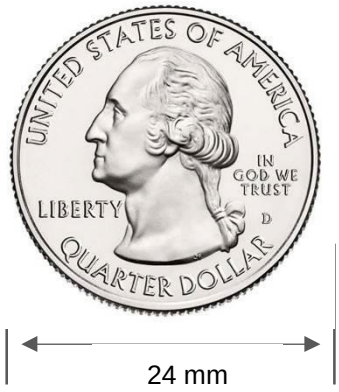


Figure 1. Real Chip Size Comparison

2. Features

- A radar module operating in K-Band of 24.05GHz–24.25GHz
- Motion and speed detection available both for indoor and outdoor use
- Product groups with various detection ranges between 5 m and 15 m (detection range is based on human motion, and the maximum range may be adjusted using the embedded digital amplifier and gain controller)
- PCB patch antenna with various operating ranges
- Small (22 x 18 mm/22 x 22.5 mm/33 x 32 mm) and low-power module (60 mA)
- Embedded 32-bit digital signal processing function
  - 8-stage digital amplifier
  - 30-stage gain controller
  - Adjustment of detection range, and detection of micro motion (240-stage fine tuning achieved by a combination of 8-stage digital amplifier and 30-stage gain controller)
  - Detection of object speed (km/h) using 256 FFT
  - Min/max speed detection
  - 2-stage proximity detection
  - Vibration error detection
- Evaluation board and GUI software for simple evaluation of module operations and easy application development
- SDK for development of dedicated software (including signal processing library)
- Temperature compensation circuit maintaining operational features even with changes in environmental conditions
- Embedded protection filter (2.4 GHz Wi-Fi noise immunity) to prevent interference from surrounding noises, especially communication noises
- The most common single power source, 3.3 V power supply operates the device.
- Same interface pins used for all modules to ensure compatibility.

3. Pin Descriptions

Table 2. Pin Descriptions

Pin number	Pin name	Type	Description
1	VCC	POWER	3.3V (Typical) (Note1)
2	GND	POWER	
3	PWM	I/O	User definition I/O (Note2)
4	nRESET	INPUT	Module reset
5	Motion out	OUTPUT	Motion detection signal output
6	IO1	I/O	User definition I/O (Note3)
7	IO2	I/O	User definition I/O (Note3)
8	Velocity out	OUTPUT	Velocity detection signal output
9	RX	INPUT	Command control port
10	TX	OUTPUT	Command control port

NOTES:

1. The MS-RA11M module operates with a precision analog circuit, and offers expected features when connected to a noise-free power supply. The noise-free power can be supplied by filtering the system or power unit using an LC filter.
2. The PWM pin is a general-purpose I/O that is programmed as an input or an output according to the user's purpose. In addition, the PWM pin is connected to the hardware PWM block of the internal MCU, and can be used in lighting control.
3. The I/O pin is a general-purpose I/O that is programmed as an input or an output according to the user's purpose. In addition, the I/O pin is connected to the A/D converter block of the internal MCU, and can be used as an analog input.

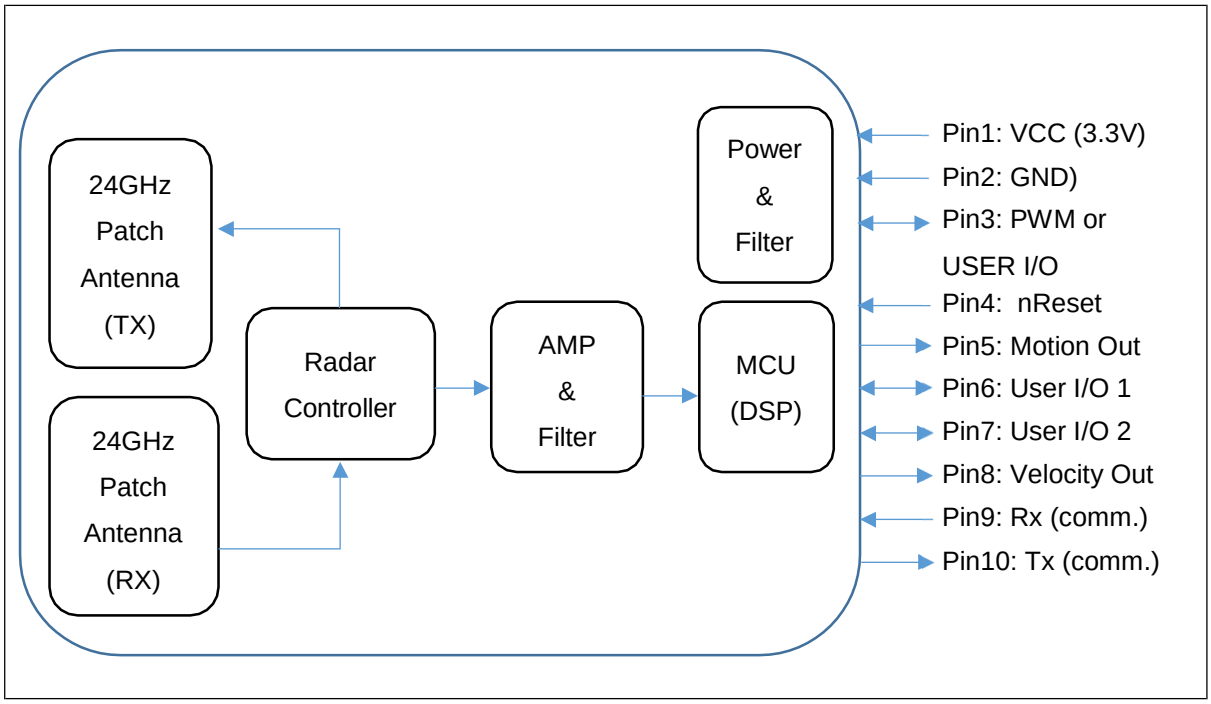


Figure 2. Blocks and Pin Descriptions

Pin 1: VCC

Power noise should be removed as much as possible to ensure normal analog operations of the radar on a 3.3 V operating voltage.

Pin 2: GND

Pin 3: PWM or User I/O

The PWM is connected to the dedicated PWM port of the embedded MCU, and thus can be used as a dimming control port for LED lighting. If the pin 3 is not used as a PWM port, it can be used as a general-purpose I/O.

Pin 4: nReset

Low active reset signal

Pin 5: Motion Out

Motion detection signal output detected by the radar. A motion output signal is produced when motion is detected within the motion detection range set by a user.

Pin 6 / Pin 7: I/O1 / I/O 2

Pin 6 and pin 7 are used for general-purpose user I/O interface signals. These pins are connected to the A/D converter, and thus can be used for analog input signal interface. For instance, pin 6 and pin 7 can be used for temperature measurement with a thermistor or other analog devices.

Pin 8: Velocity Out

A signal is produced if the speed of a detected object falls within the velocity range set by the user. The velocity range can be adjusted from the provided GUI interface. The default value ranges from 1 km/h to 6 km/h.

Pin 9/ Pin 10: Tx/ Rx for Command Control Interface

The MS-RA1xM module is capable of interfacing various information with external MCUs through serial communication. Pin 9 and pin 10 support this interaction. Information about the motion and speed of detected objects can be exchanged in real time with external MCUs, and the range of detection can also be configured in real time.

4. Electrical Characteristics

Table 3. Electrical Characteristics

Parameter	Conditions	Symbol	Min.	Typ.	Max.	Units
RADAR						
Transmit Frequency	KR-frequency @ 25°C	fc	24.050	24.125	24.250	GHz
Tx Tune up Power (Note1)						
RA11M	@ 25°C	Pout	-1	3	7	dBm
RA12M	@ 25°C	Pout	7	11	15	dBm
RA14M	@ 25°C	Pout	9	13	17	dBm
SENSOR						
Detection distance for person working (RCS 1m²) (Note2)						
RA11M				5	7	m
RA12M				7	10	
RA14M				10	15	
Detection speed range (Note3)			0.3	30	100	Km/h
Detection angle for person working (@ -3dB for RCS 1m²) (Note3)						
RA11M		Horizontal		±70		°
		Vertical		±50		°
RA12M		Horizontal		±60		°
		Vertical		±35		°
RA14M		Horizontal		±55		°
		Vertical		±25		°
POWER SUPPLY						
Supply voltage		Vcc	3.2	3.3	3.4	V
Supply current (Note4)		Icc		70mA	75mA	mA

Table 3. Electrical Characteristics (continued)

Parameter	Conditions	Symbol	Min.	Typ.	Max.	Units
OPERATION						
Start-up time	After power on	Ts		10		msec
Interface signal	Digital Signal	I/O		3.3		V
ENVIRONMENT						
Operation temperature			-30		60	°C
Storage temperature			-40		80	°C

NOTES:

1. The Tx output power is a theoretical figure obtained from summing the output of the radar IC and the actual antenna gain of the model.
2. The detection distance can vary significantly with the testing environment and detection goal, and may be increased or decreased by changing the gain controller value.
3. Speed detection is related to the performance of the MCU used in signal processing. The maximum value is based on A31G111 40MHz operations. Please contact ABOV's Technical Support if you need to make changes to EVB's maximum detection speed of 30 km/h.

4. Antenna Characteristics

The MS-RA1xM radar module has 1T1R PCB patch antennas with a peak gain of approximately 1 dBi to 8 dBi, and each module is comprised of 1 to 4 arrays. A higher number of array components leads to a concentration of antenna energy forward—the detection range increases in front, but decreases in the horizontal/vertical direction.

Performance can be maximized with a better understanding of the antenna characteristics of the MS-RA1xM radar module and the positioning of antennas in actual applications. The patch antennas embedded in the RA1xM module require accurate allocation due to their different antenna beam widths in the horizontal and vertical directions. As shown in the figure 3 below, the beam width in the horizontal direction is wider than the beam width in the vertical direction. This characteristic must be taken into account when positioning the antennas.

Figure. 3 shows the directionality in relation to antenna position of MS-RA11M. The antenna gain and beam width values in Table 4 were obtained based on the directionality of figure. 3.

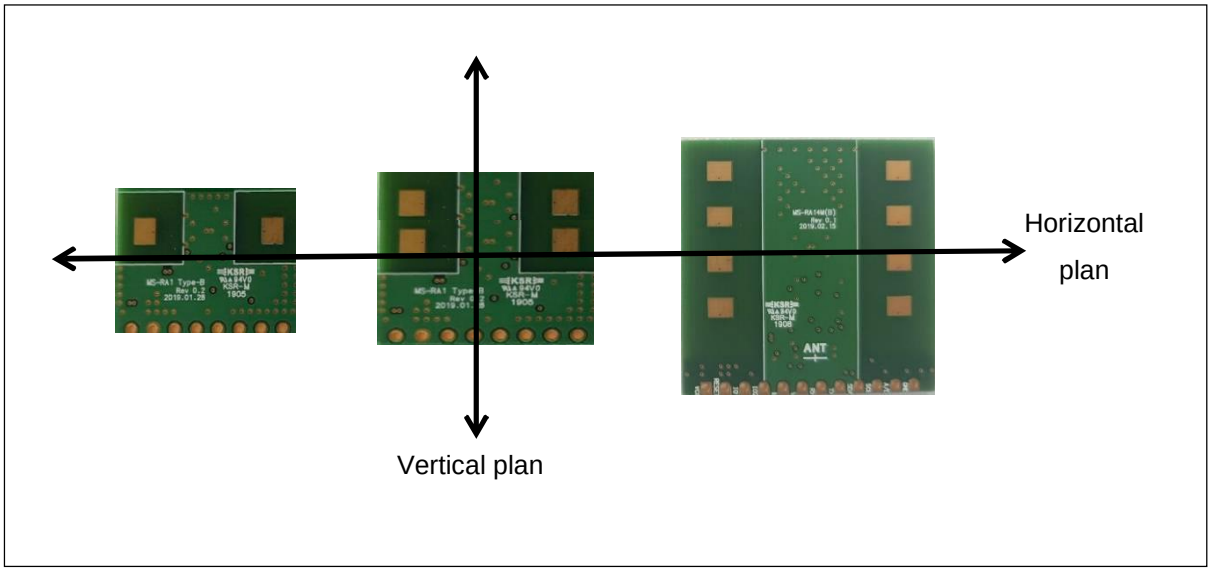


Figure 3. Antenna Directionality

In figure 3, the horizontal plan refers to the azimuth direction in the antenna system, while the vertical plan refers to the elevation direction.

Table 4. Antenna Gain and Directionality

Model	Parameter	Horizontal plan	Vertical plan
RA11M	Peak Gain @ 24.15GHz	2.91 dBi	3.47 dBi
	Beam width @ -3.0 dB	78°	70°
	Beam width @ -10.0 dB	160°	140°
RA12M	Peak Gain @ 24.15GHz	4.07 dBi	4.07 dBi
	Beam width @ -3.0 dB	80°	38°
	Beam width @ -10.0 dB	150°	90°
RA14M	Peak Gain @ 24.15GHz	6.94 dBi	6.74 dBi
	Beam width @ -3.0 dB	75°	24°
	Beam width @ -10.0 dB	140°	50°

NOTES:

1. Gain of each antenna includes the cable loss of approximately 2.5 dB that occurred during measurement.
2. Gain of each antenna was measured using separate antenna equipment, and may differ from actual operation.

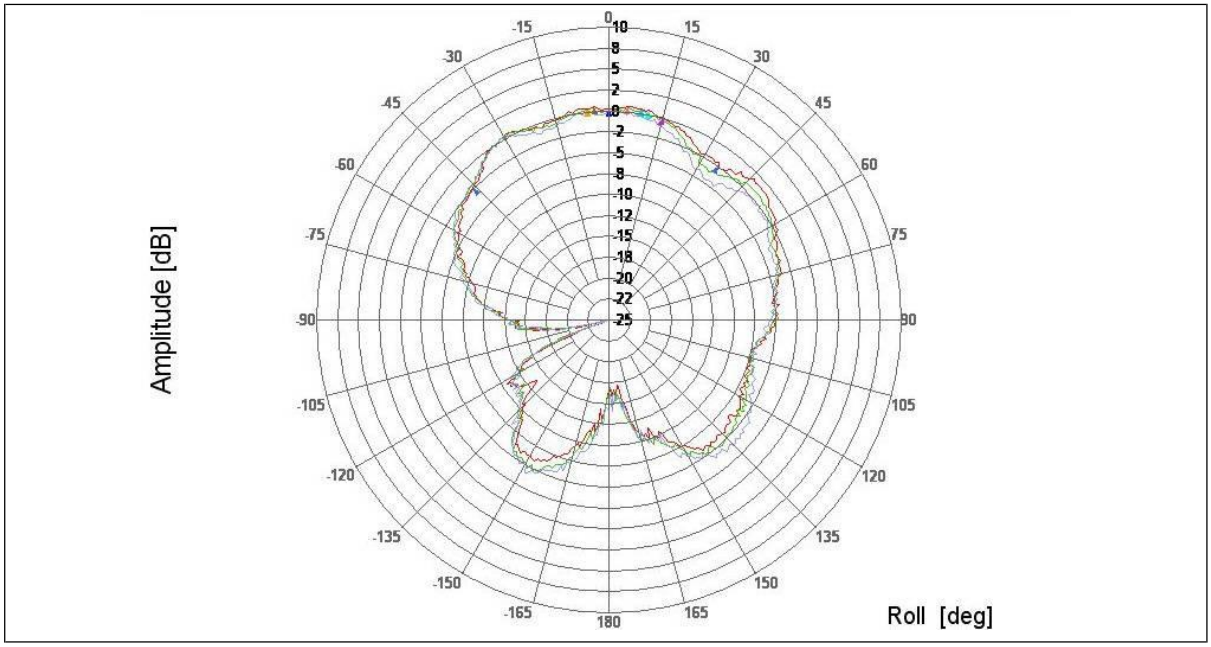


Figure 4. Radiation Pattern of MS-RA11M (Horizontal Direction)

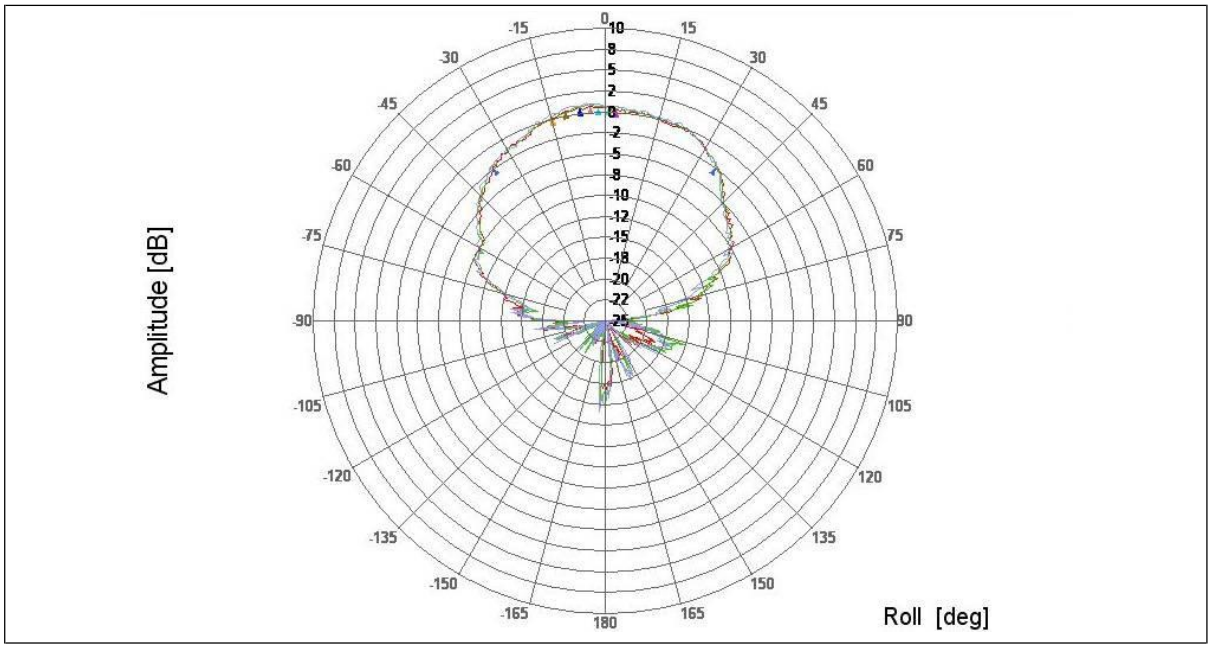


Figure 5. Radiation Pattern of MS-RA11M (Vertical Direction)

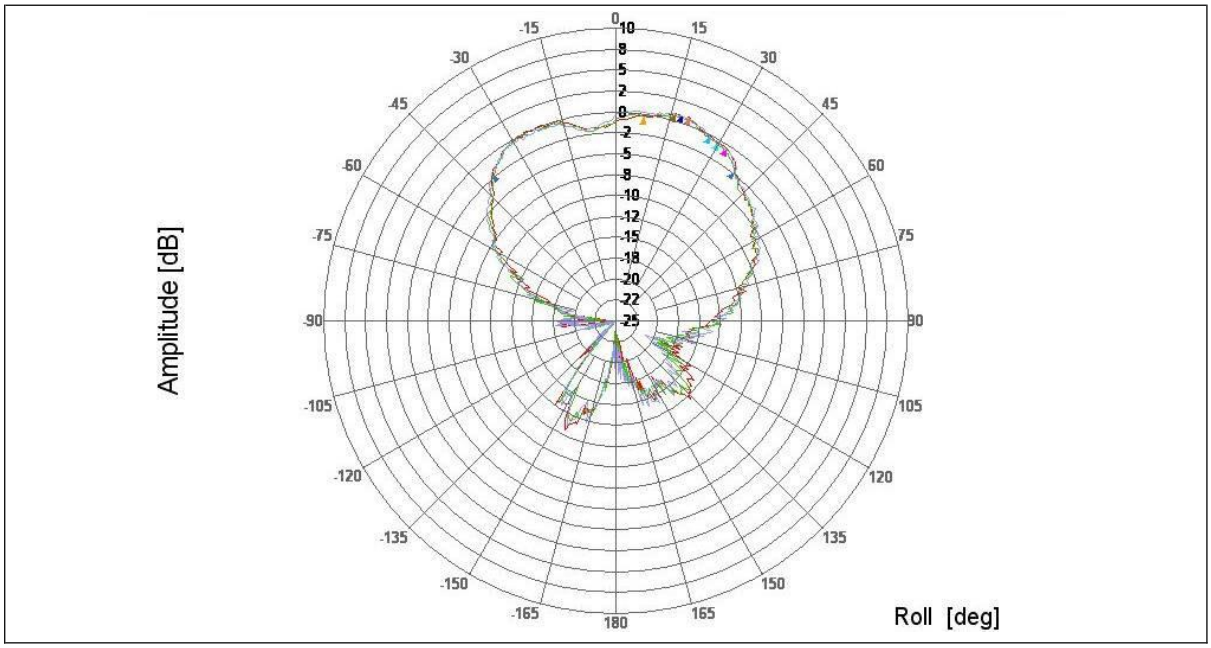


Figure 6. Radiation Pattern of MS-RA12M (Horizontal Direction)

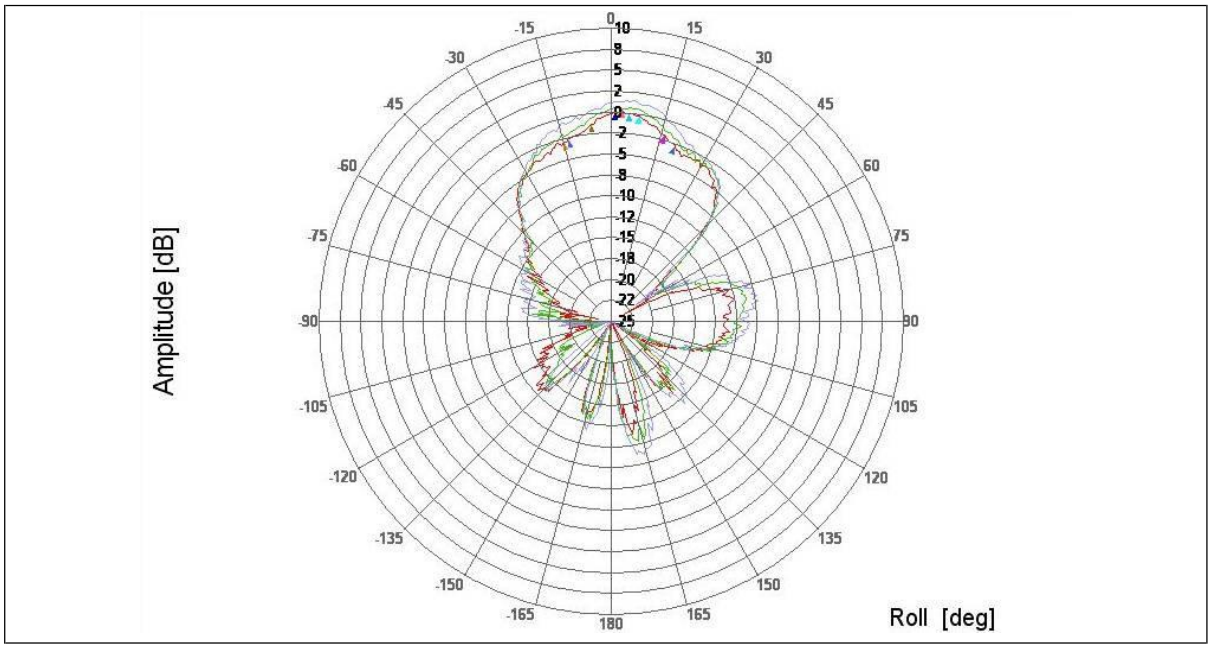


Figure 7. Radiation Pattern of MS-RA12M (Vertical Direction)

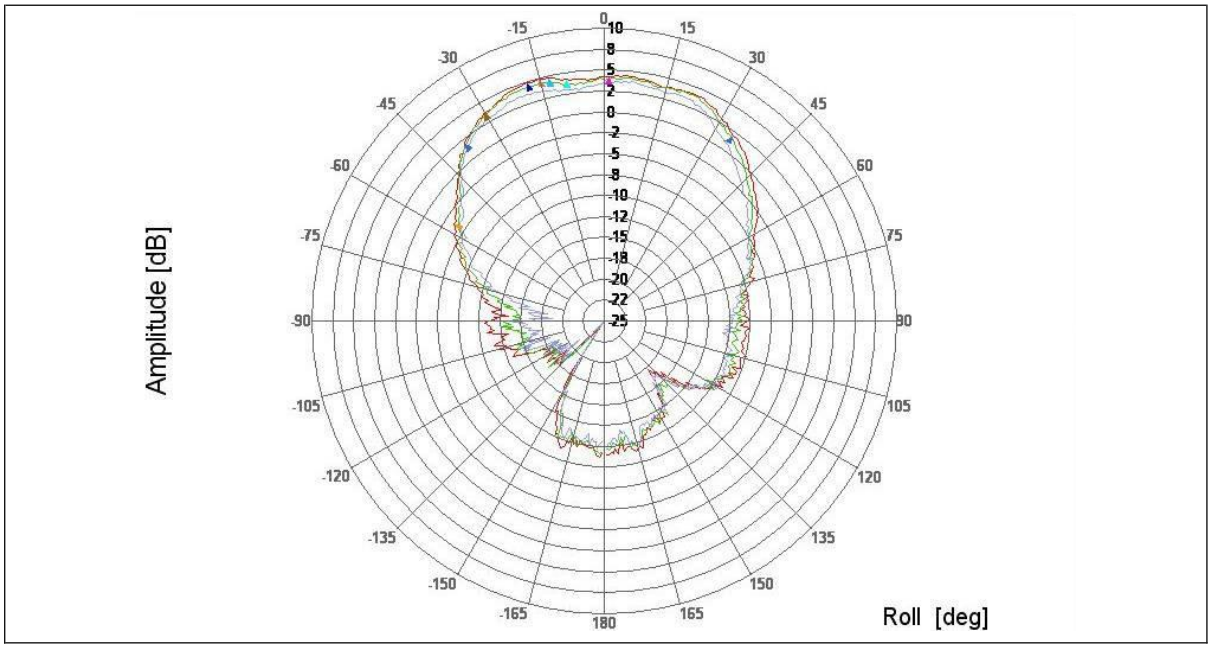


Figure 8. Radiation Pattern of MS-RA14M (Horizontal Direction)

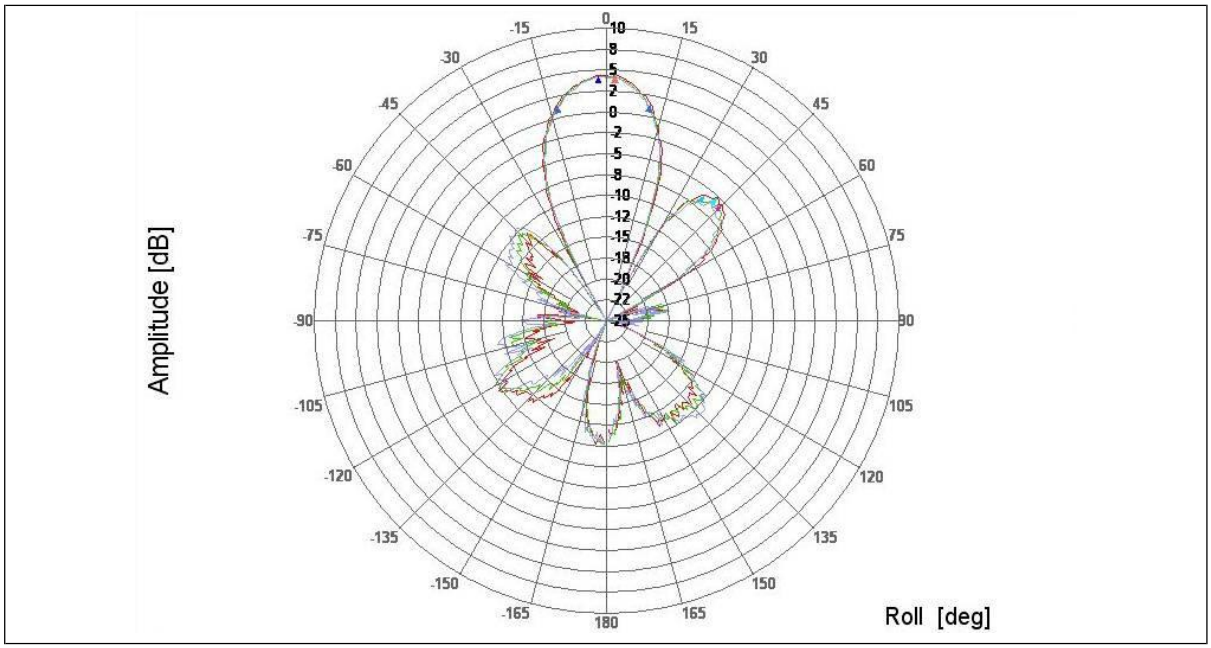


Figure 9. Radiation Pattern of MS-RA14M (Vertical Direction)

NOTES:

1. Antenna radiation patterns may differ from actual operation due to the cable loss during measurement and the mismatching with the measurement system.
2. In the actual module, the backside radiation pattern is limited by the shield can.

6. Mechanical Outlines

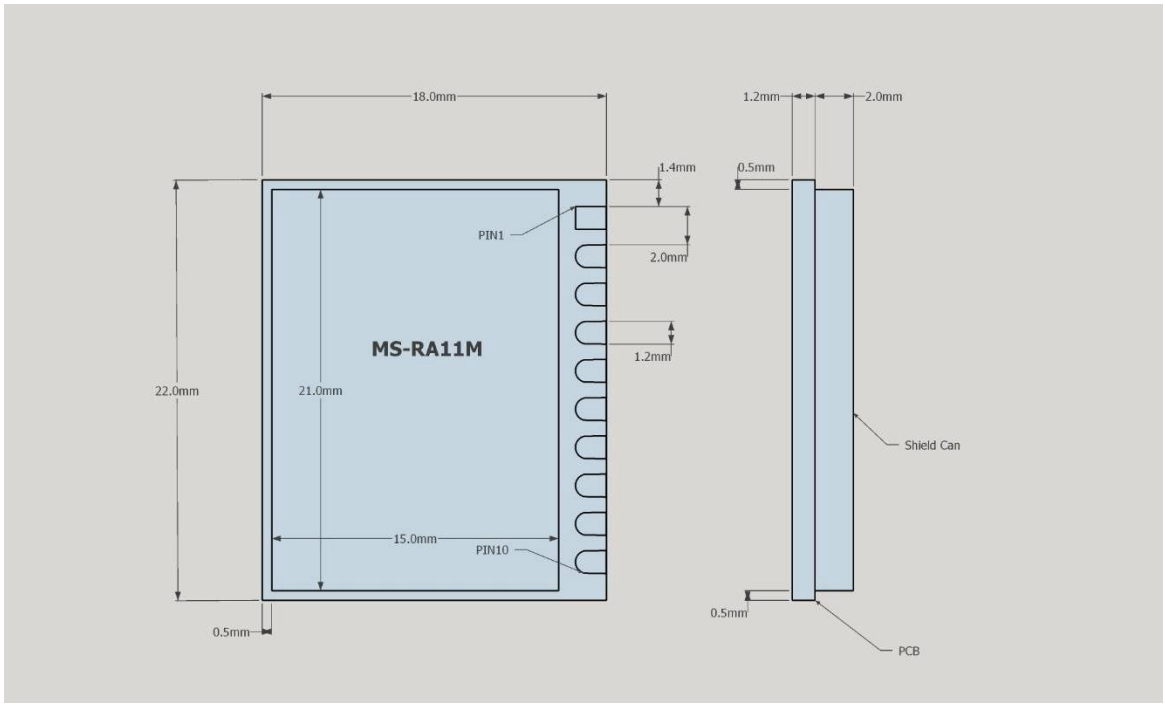


Figure 10. MS-RA11M Mechanical Outline

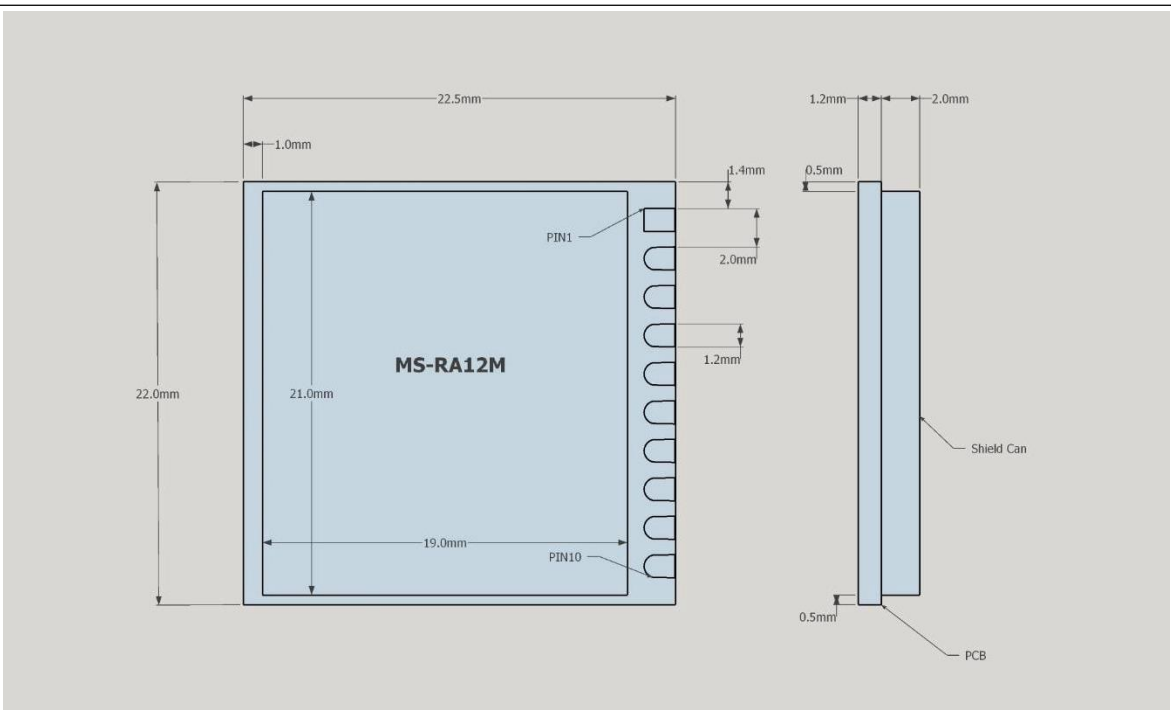


Figure 11. MS-RA12M Mechanical Outline

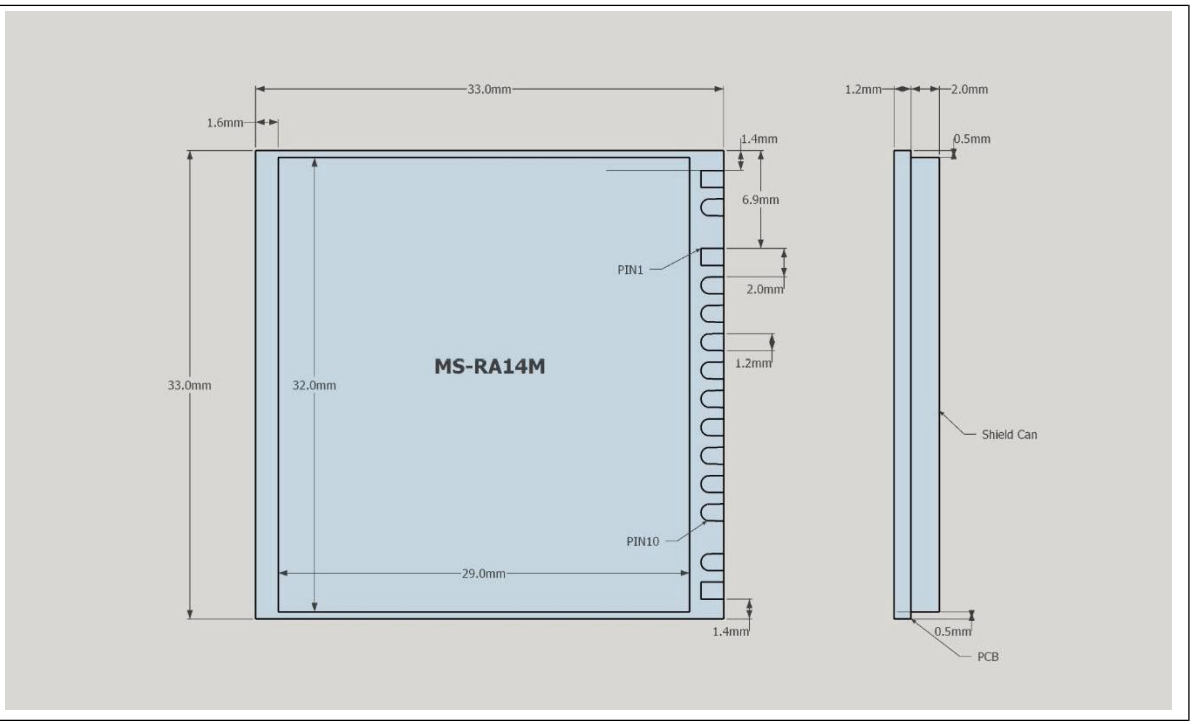


Figure 12. MS-RA14M Mechanical Outline

7. GUI Software

MS-RA1xM provides a module evaluation board and GUI software, enabling users to configure the desired functions and easily conduct performance tests. Users can make direct adjustments to radar modules using the GUI software to obtain the desired results.

As a result, each module is updated with these user-configured values, and the individual module maintains its expected performance.

For further details on operations and functions, please see the evaluation board user manual.

Figure 13. GUI Software

8. Performance Test

Figure 14 shows test result of the detection performance of MS-RA11M. The size of the target object was measured at an RCS of 1 m^2. The results may vary with testing environment, and can be increased or decreased by adjusting values such as amplifier gain and control threshold. The results below were obtained at amplifier gain = 1 and control threshold = 8.

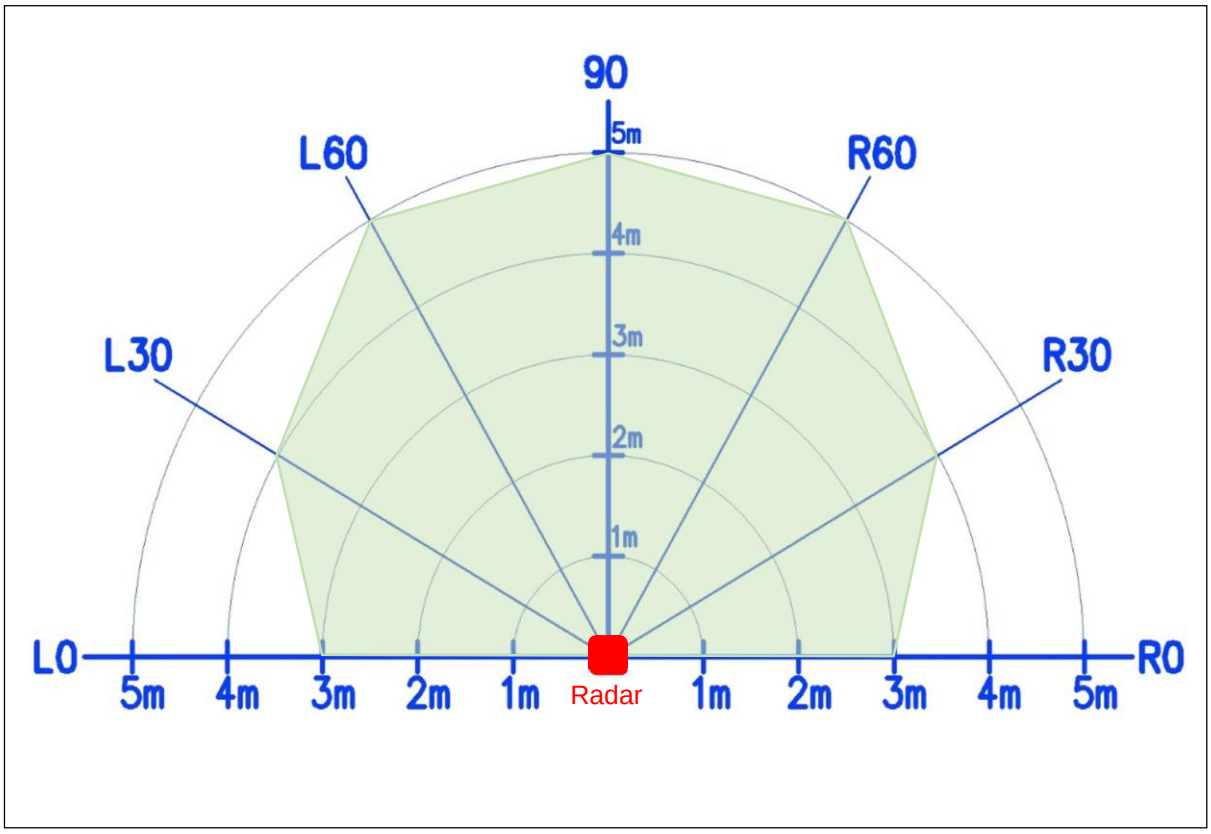


Figure 14. Detection Performance of MS-RA11M

Table 5. Detection Performance of MS-RA11M

Angle/ Distance	**L-0°**	**L- 30°**	**L- 60°**	**F-90°**	**R-60°**	**R-30°**	**R-0°**
5m	X	X	O	O	O	X	X
4m	X	O	O	O	O	O	X
3m	O	O	O	O	O	O	O
2m	O	O	O	O	O	O	O
1m	O	O	O	O	O	O	O

Model Number Naming Rule

M S – R A 1 1 M

MS: Motion Sensor

RA: Radar

1: Modulation type

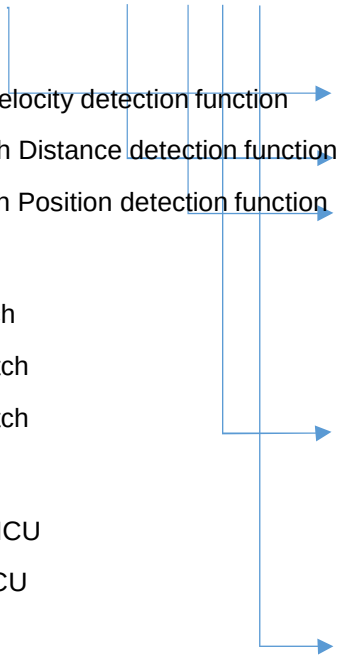
1) 1: CW with Velocity detection function
2) 2: FMCW with Distance detection function
3) 3: FMCW with Position detection function

1: Antenna type

1) 1: single patch
2) 4: 4 array patch
3) 8: 8 array patch

N: Built-in MCU

1) N: external MCU
2) M: built-in MCU



FCC Statement

FCC Part 15.19 Statements
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.

FCC Part 15.21 statement
Any changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate this equipment.

Regulatory notice to host manufacturer according to KDB 996369 D03 OEM Manual

List of applicable FCC rules
This module has been granted modular approval as below listed FCC rule parts.
- FCC Rule parts 15C(15.249)

Summarize the specific operational use conditions
The OEM integrator should use equivalent antennas which is the same type and equal or less gain then an antenna listed in this instruction manual.

RF exposure considerations
The module has been certified for integration into products only by OEM integrators under the following condition:
- The antenna(s) must be installed such that a minimum separation distance of at least 20 cm is maintained between the radiator (antenna) and all persons at all times.
- The transmitter module must not be co-located or operating in conjunction with any other antenna or transmitter except in accordance with FCC multi-transmitter product procedures.
- Mobile use

As long as the three conditions above are met, further transmitter testing will not be required.
OEM integrators should provide the minimum separation distance to end users in their end-product manuals.

Antennas list
This module is certified with the following integrated antenna.
- Type: Patch ANTENNA
- Antenna gain: 0.97 dBi

Any new antenna type, higher gain than listed antenna should be met the requirements of FCC rule 15.203 and 2.1043 as permissive change procedure.

End Product Labeling
The module is labeled with its own FCC ID. If the FCC ID is not visible when the module is installed inside another device, then the outside of the device into which the module is installed must also display a label referring to the enclosed module. In that case, the final end product must be labeled in a visible area with the following:

"Contains FCC ID: 2VAQO-RA11M"

Information on test modes and additional testing requirements
OEM integrator is still responsible for testing their end-product for any additional compliance requirements required with this module installed (for example, digital device emissions, PC peripheral requirements, additional transmitter in the host, etc.).

Additional testing, Part 15 Subpart B disclaimer
The final host product also requires Part 15 subpart B compliance testing with the modular transmitter installed to be properly authorized for operation as a Part 15 digital device.