24GHz Microwave Intelligent Distance Measurement Sensor Module for Middle Distance (30 meter) with Low-profile

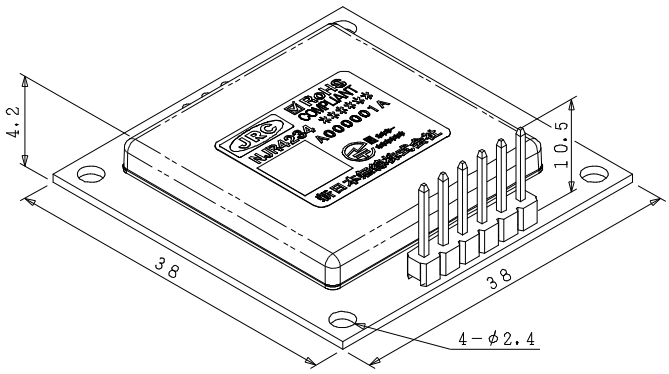
The NJR4234BV is a sensor module that can measure the distance to a moving object such as a pedestrian more than 30 m ahead and incorporates a 24 GHz band microwave circuit, antenna, and signal processing circuit in a low profile package of 38 x 38 x 4.2 mm.
As a sensor capable of distance measurement using microwave, it is possible to detect moving objects by innovative proprietary signal processing and also has the function to calculate and output the distance to the moving objects in indoor and outdoor environments. In addition, it has the unique algorithm to prevent radio interference, possible to use multiple sensors under the same location.
It can be used as a sensor front end with built-in primary signal processing for distance measurement. In addition, since it can be easily connected to other equipment via the UART interface, it can be used in a wide range of applications.

Features:

- Distance measurement sensor using the 24GHz microwave
- Measurement distance of 30 m for a pedestrian. *Note1
- Antenna, Microwave RF circuit, Base-band IF circuit, MCU and also signal processing are integrated in a low-profile package
- Low-power-consumption
  37 mA @ 3.3 V power supply*Note2
- Unique Signal Processing / Algorithm Installation
  - High sensitivity mobile object detection (Patented Technology)
  - Distance measurement signal processing
  - Automatic calibration and gain control
  - Radio interference prevention
- Adopted UART and digital CMOS output for interface
- Possible to be installed in indoor and outdoor locations

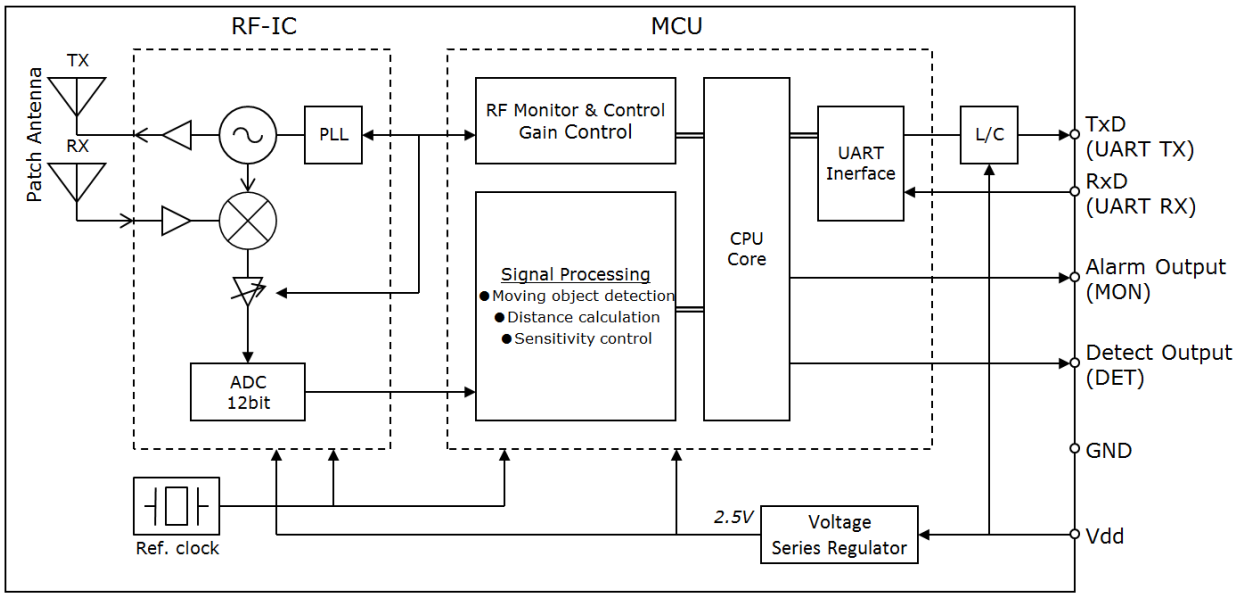
Applications:

- Various equipment control by moving objects detection and measurement
  - Security equipment
  - Traffic control system
  - FA robot
  - Industrial drone
  - Parking management system



*Note1) Distance measurement 30 m is based on evaluation results. It varies depending on the reflection intensity of the moving object.
*Note2) It is realized by intermittent operation and measurement repetition time. Please use the power supply circuit for the peak current.

Functional Brock diagram:



Products Line-up:

N J R 4 2 3 4 B V F 1 C 1

- Identity Number & Interface Type:
  - C1: Standard Model / 2.54 mme Pin-header (L:10.5mm)
- RF Frequency: *Note3
  - F1: 24.05 to 24.25 GHz / Japan
  - F2: 24.15 to 24.25 GHz / All of EU resions
  - F3: 24.075 to 24.175 GHz / United States
- Measurement Operation Mode:
  - V: Distance Measurement for Moving Objects
  - W: Distance Measurement for Moving and Stationary Objects *Note4
- Detection Distance Range
  - B: 30 m range (Detection Angle: 42°/28°) / Dimensions: 38 x 38 x 4.2 mm
- Product Series Number

Model Number List:

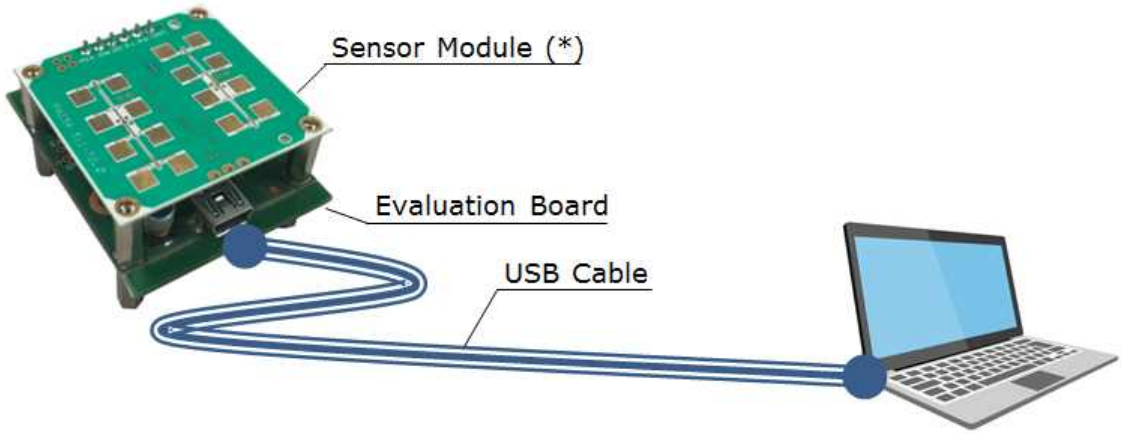
Model No.	RF Frequency	Measurement Operation Mode	Detection Distance Range	Region / Regurations
NJR4234BVF1C1	24.05~24.25 GHz (F1 type)	Distance Measurement for Moving Objects	30 m range (Angle: 42°/28°)	JAPAN / Technical Conformity ARIB STD-T73
NJR4234BVF2C1	*Note3 24.15~24.25 GHz (F2 type)			All of EU regions / RED 2014/53/EU (CE Marking)
NJR4234BVF3C1	*Note3 24.075~24.175 GHz (F3 type)			US / FCC Part 15.245

*Note3) Please contact NJRC for compliance status of RED and FCC.
*Note4) W type is under development. In this specification, only V type is described.

Evaluation Kit:

The evaluation kit is available for NJR4234 series. The contents of the evaluation kit are as follows.

- **Evaluation Kit P/N.: NJR4234K**
- **Contents**
  1. Evaluation Board (Functions are UART-to-USB convertor)
  2. GUI Software
  3. USB Cable



(*) The sensor module itself needs to be prepared separately.

1. Absolute Maximum Rating

ITEM	MIN.	TYP.	MAX.	UNITS	REMARKS
Supply Voltage	0	—	6.5	V	
MON	-5	—	5	mA	
DET	-5	—	5	mA	
UART TX	-5	—	5	mA	
UART RX	0	—	3.6	V	Do NOT exceed supply voltage
Operating Temperature	-40	—	+85	°C	
Storage Temperature	-40	—	+85	°C	

2. Electrical Characteristics

Common measure condition Ta= +25 °C

ITEM	PARAMETER MIN.	TYP.	MAX.	UNITS	REMARKS
Power Supply					
Supply Voltage	2.9	3.3	3.6	V	Vdd
Operating Current					
i) Distance Measurement mode					
Peak current	—	—	250	mA	Refer to figure 1.
Average current	—	37	50	mA	
ii) Initialization and Calibration mode					
Peak current	—	—	250	mA	Refer to figure 2.
Average current	—	—	75	mA	
iii) Sleep mode	—	—	15	mA	
Sensor RF					
Conformity Standard	● MIC Technical Conformity (Japan): ARIB STD-T73 ● EU Regulation: Radio Equipment Directive 2014/53/EU *Note1 ● FCC Regulation: Part 15.245 *Note1				
Operating Frequency					
F1 type	24.05	—	24.25	GHz	Technical Conformity
F2 type	24.15	—	24.25	GHz	EU Regulation *Note1
F3 type	24.075	—	24.175	GHz	FCC Regulation *Note1
Output Power (E.I.R.P.)	9	12	13.8	dBm	
Spurious Emission (E.I.R.P.)	—	—	-30	dBm	Wide-band including 2nd harmonics
Maximum modulation band width					
F1 type	—	—	177	MHz	
F2 & F3 type	—	—	80	MHz	
Modulation Sweep Time	—	1024	—	us	
Antenna: 2 x 4 planar antenna type					
Antenna Gain	—	13.5	—	dBi	
-3dB beam width / Horizontal	—	42	—	deg.	Refer to figure 3.
-3dB beam width / Vertical	—	28	—	deg.	
Side-lobe suppression / Horizontal	—	—	—	dB	No Side lobe
Side-lobe suppression / Vertical	—	—	—	dB	No Side lobe

*Note1) Please contact NJRC for compliance status of RED and FCC.

Actual Operating Current (Reference)

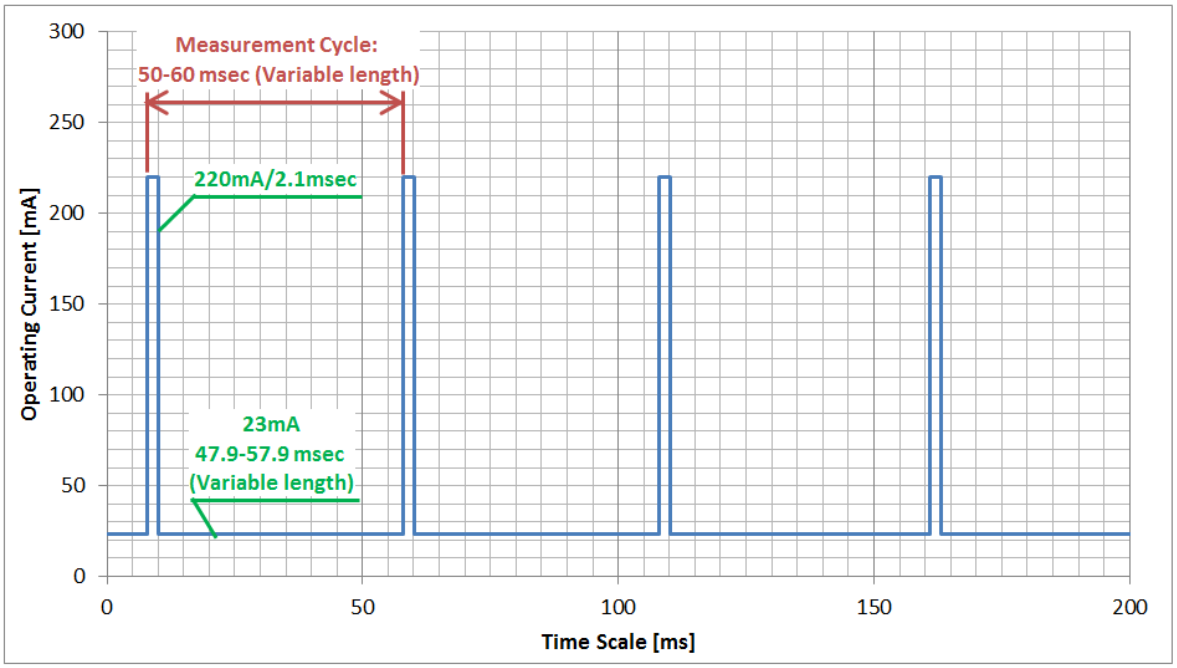


Fig. 1 Variation of Operating Current at Distance Measurement Mode

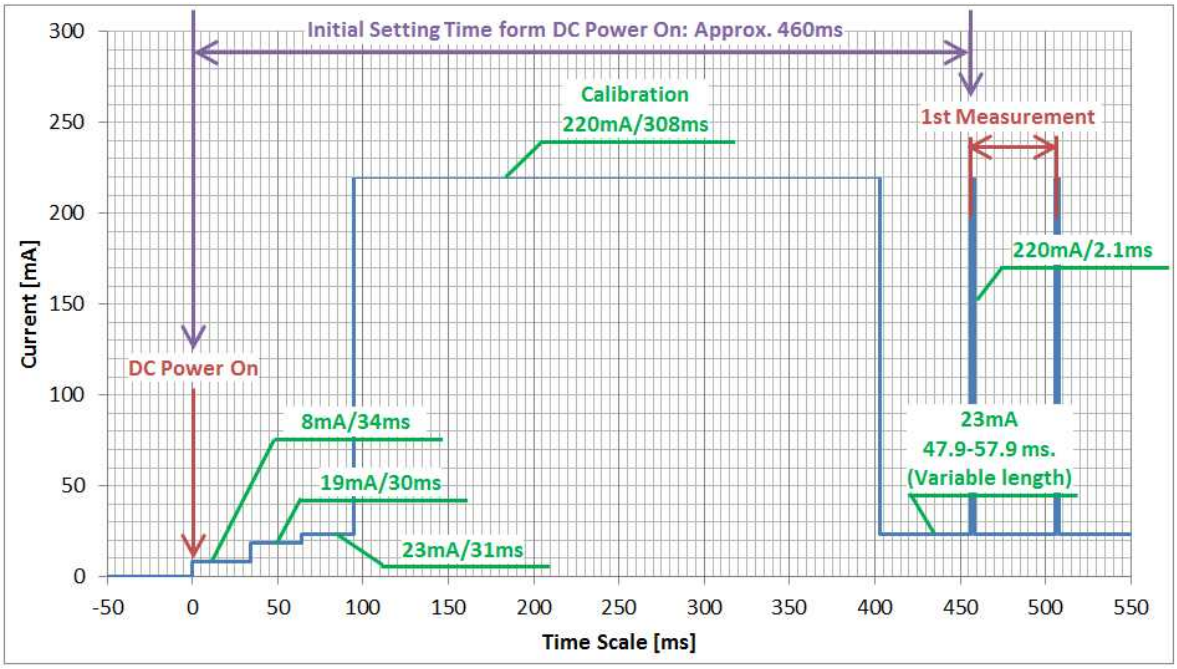


Fig. 2 Variation of Operating Current at Initialization Mode

Antenna Pattern

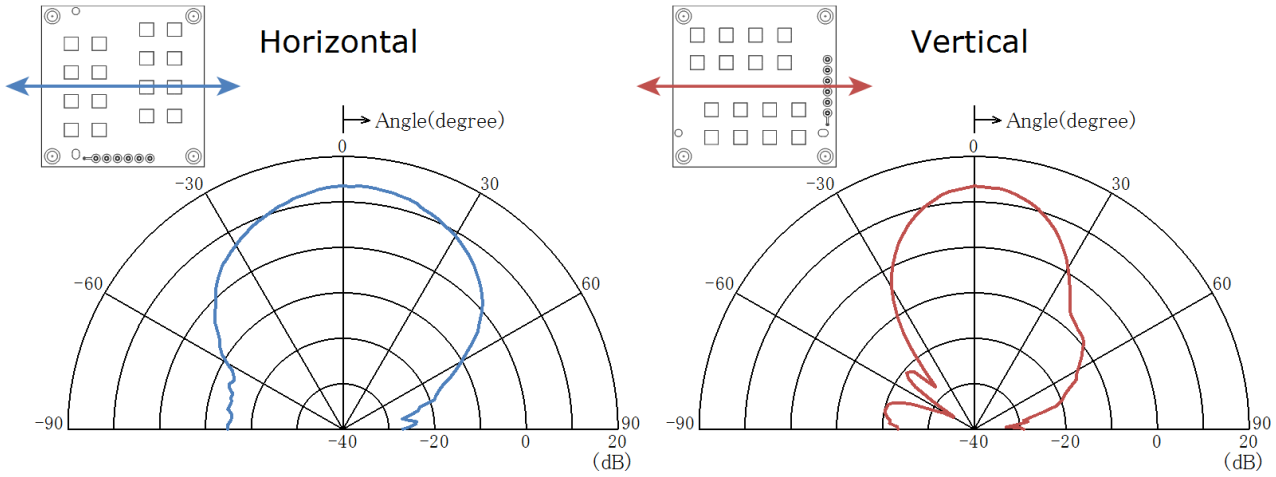


Fig. 3 Antenna Radiation Pattern

Attention point on antenna characteristics in installation

- To avoid the influence on the antenna pattern, please do not put any objects of radio reflections within 30 cm in front of the antenna surface of this sensor.
- When storing this sensor in a cover, design it appropriately to reduce the influence on the antenna pattern, and check with a demonstration experiment etc.
  Refer to Section 14 for the design of the cover.

3. Environmental Characteristics

ITEM	SPECIFICATION
Operation Temperature	-20 to +60 °C
Storage Temperature	-40 to +80 °C
Humidity	0 to 95 %RH @+30 °C
Vibration	49.03 m/s^2 (5 G), 30 to 50 Hz, 10 minutes, XYZ direction
Shock	196.13 m/s^2 (20 G), Half sine, 11 msec, XYZ direction, 3 times

4. Sensing Specifications

4.1. Sensing Performance

Common measure condition Ta= +25 °C

ITEM	PERFORMANCE	UNITS	REMARKS
Maximum Detection Distance	30	m	
Maximum Detection Distance by Nyquist			
F1 type	86	m	
F2 & F3 type	170	m	
Minimum Detection Distance			
F1 type	0.85	m	
F2 & F3 type	1.9	m	
Detectable Angle			
Horizontal	42	deg.	Depends on -3dB beam width of antenna
Vertical	28	deg.	
Distance Resolution			
F1 type	8.3	cm	
F2 & F3 type	18.75	cm	
Separation Resolution			
F1 type	1.7	m	
F2 & F3 type	3.8	m	
Measurement Time Interval	50 to 60	ms	Variable length *Note1

*Note1) When the radio interference prevention function is enabled, the measurement time interval is variable between 50 and 60 ms. It is fixed at 50 ms when it is disable.

4.1.1. Maximum Detection Distance

The detection distance is the value measured by the standard target (adult) moving towards the sensor in an open space without obstacles. The details are mentioned in below. The performance of the detection distance varies depending on installation conditions, the shape and size of the object, the angle of penetration of radio waves, and other conditions.

The detection distance is not guaranteed parameter but the performance of this product is specified by electrical characteristics.

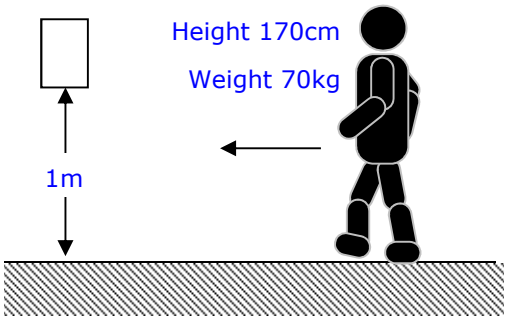


Fig. 4 Side View Image

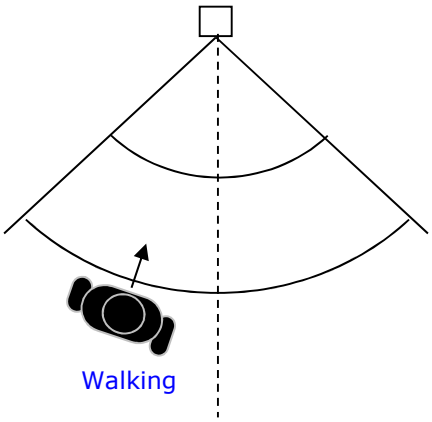


Fig. 5 Top View Image

<u>Measurement condition of detection performance</u>

* Temperature:
  Ta = +25 °C
* Target of Measurement:
  An adult of 170 cm / 70 kg is walking toward sensor.
  (Refer to figure 4 and figure 5)
* Installation of the Sensor:
  The sensor is installed as the antennas horizontal horizontally in a height of 1 m from the ground.
  (Refer to figure 4)

With respect to the accuracy of the detection distance, when measuring the object moving with high-speed, the Doppler frequency of the moving object is overlapped (Doppler shift), so an error occurs. In the case of the 80 MHz band, an error of about 1 m will result at a speed of 11 km / h.

4.1.2. Maximum Detection Distance by Nyquist

The maximum detection distance is limited by the Nyquist frequency of the AD sampling frequency inside the sensor. Depending on the reflection intensity of radio waves it may be subject to limitations on this distance.

4.1.3. Minimum Detection Distance

The minimum detection distance is determined by the value of 1/2 that is divided the speed of light by the modulation band of the frequency. Although the distance closer than the minimum detection distance is output, accuracy and stability of measurement are significantly reduced. When detecting targets that are nearer than the minimum detection distance it shall be used after sufficient evaluation.

4.1.4. Distance Resolution and Separation Resolution

The distance resolution is determined by the size of FFT analysis in signal processing of distance calculation. The size of FFT analysis is 11th power of 2.

The separation resolution is limited by the value that is divided the speed of light by the modulation band of the frequency, but if objects are moving at different speeds, the separation resolution will be equal to the distance resolution.

4.2. Measurement Time and Radio Interference Prevention Function

The measurement time is approx. 50 ms. The time which the RF circuit transmits radio waves during measurement is approx. 2 ms. The operating current is reduced by intermittently operating radio wave transmission. The measurement time is fixed length and unchangeable.

When the radio interference prevention function is enabled, the measurement time is random variable length between 50 to 60 ms.

The details of the measurement time are shown in figure 6.

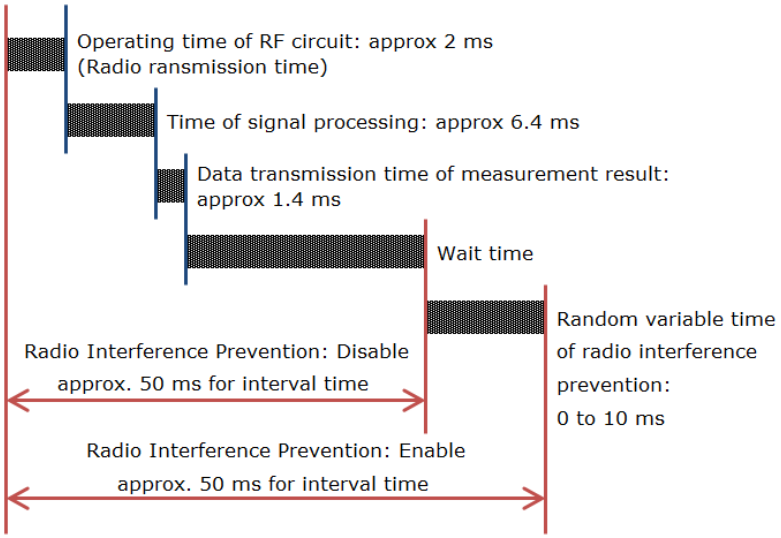


Fig. 6 Measurement Time

4.2.1. Radio Interference Prevention Function

If the same frequency at the same time is used, the radio wave sensor will become inoperable due to radio interference. This sensor has a function to probabilistically prevent radio interference. It can be enabled / disabled by command control.

It is recommended that this function is enabled when using multiple in a small area.

A random variable time (10 ms / 256 steps) is added by the radio interference prevention function after 50 ms of normal measurement time. The random variable time changes for each measurement.

4.3. Detectable Area

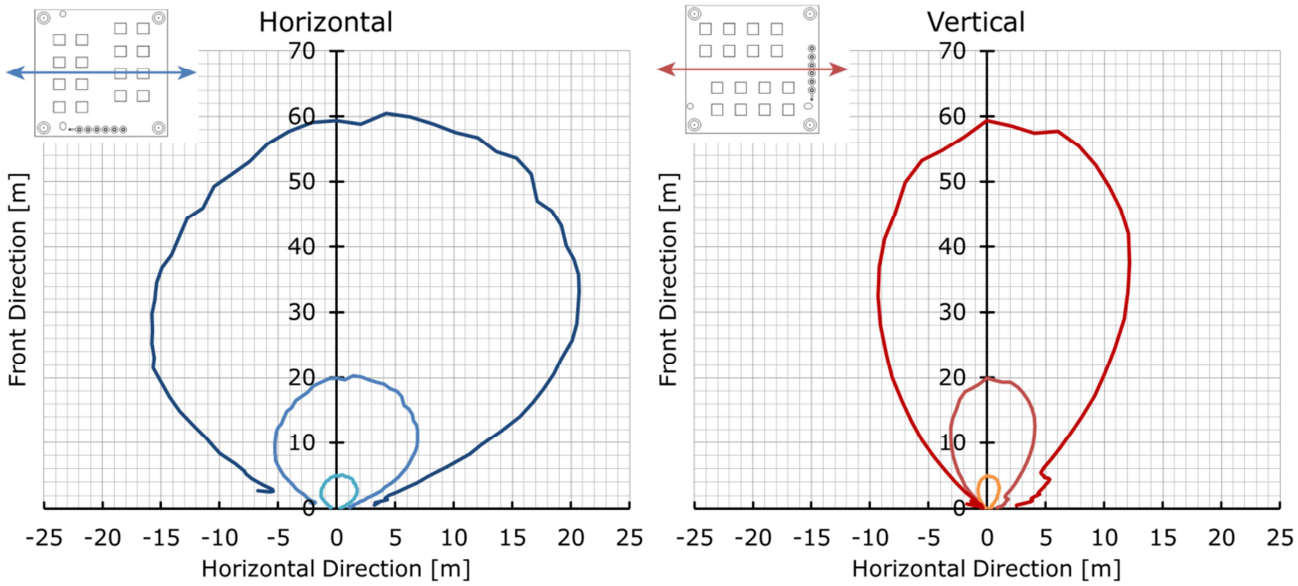


Fig. 7 Detectable Area (Reference Data form Antenna Radiation Pattern)

4.4. Signal Processing and Software

It is designed to do signal processing with the MCU inside the sensor. The details of signal processing are referred to Section 5.

Software may be upgraded due to performance improvement etc.

5. Signal Processing and Function

This sensor has the function to detect the moving body and calculate the distance to the moving body by our proprietary signal processing.
Up to three distance information is output as peak 1 / peak 2 / peak 3 in the order closer to the sensor. Only the peak 1 is output by default configuration of the distance measurement output data number.

The following signal processing and functions are loaded in order to improve the detection accuracy of moving objects and the sensitivity of distance measurement.

List of signal processing and functions

1) Calibration
2) Gain Control Function
3) Measurement Distance Range
4) Sensitivity Setting Function
5) Peak Emphasis Function
6) Moving Average Function
7) Frequency Band Switching Function(F1 type only)

5.1. Calibration

Calibration is loaded for the purpose of reducing unexpected reflection of radio waves and multipath influence. It is executed automatically when power is turned on and reset, or arbitrarily by command.
Calibration is a function to cancel DC offset and trend of internal circuit. DC offsets and trends are generated by the reflection of radio waves from short range reflectors on the front of the antenna. Also if it is put in a case and/cover it will also occur in radio wave reflection by the case. Moreover, these signals may fluctuate due to temperature fluctuation and time continuation.
It shall be performed when changing the sensor installation environment. And also it is recommended that it is performed with periodical time (about once a day).

5.2. Gain Control Function

The gain configuration can be set in two steps to detect a moving object in the range from a short distance to a long distance. There is also a configuration to control these gains automatically, and a configuration to select fixed low gain and high gain. The default co configuration is automatic control.
If there is an object near the sensor or there is a target with a large reflection area, the amplifier inside the sensor may be saturated with the received power. The gain control function is used to avoid this saturation.
The basic gain at automatic control configuration is high gain. The sensor checks the saturation of the signal once every 1.5 seconds and changes it to low gain when saturated. If saturation does not exist, it returns to high gain. When using this sensor in a narrow area such as indoor room, it is recommended to set a fixed low gain.

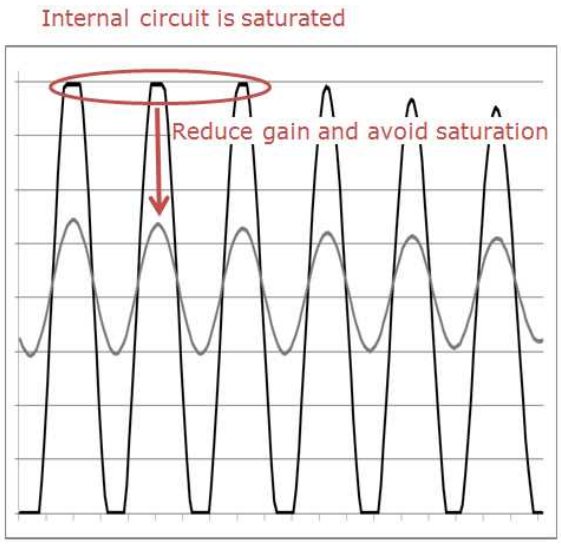


Fig. 8 Image of Gain Control

5.3. Measurement Distance Range

The measurement distance range is a function that can specify the range of distance to be measured, and use it when there is a range that is wanted to detect. The configurable range is between 0 m and the maximum detection distance by Nyquist. The maximum detection distance by Nyquist is 86 m for F 1 type and 170 m for F 2 and F 3 Type.

When measurement distance range is configured, up to three distance information within this range is output. The distance of the peak outside this range is not output. Also, if there is no peak within this range, non-detection (0xFFFF) is output.

5.4. Sensitivity Setting Function

The sensitivity setting is a function to reduce the possibility of erroneous detection and failure. This function is used to distinguish between signal and noise. The larger the configuration value, the lower the sensitivity. Also, this function affects the maximum detectable distance.

This sensitivity setting is not a threshold value for a specific peak value but by the integration power in the whole band of the received signal. When the integration power exceeds the sensitivity setting configuration, the distance information of peaks is output. If it does not exceed it, it outputs non-detection (0xFFFF). The integration power is output together with the distance information as the signal level regardless of the state of sensitivity setting. The sensitivity setting also combines with setting of the DET terminal. When integration power exceeds the sensitivity setting, the output of the DET terminal changes "H", and when it does not exceed "L".

The figure 9 is the measured value of the signal level (integration power) indicated by the standard target shown in Section 4.11 in an environment with very little reflection. Based on the target detection distance, it can be used as a reference value for sensitivity setting configuration.

The recommendation value of sensitivity setting is shown in following chart. The default configuration is 100.

- Fixed High Gain Setting

Sensitivity Setting	Detection Distance (Standard Target)
100	20 m and more
200	20 m and less
500	5 m and less

- Fixed Low Gain Setting

Sensitivity Setting	Detection Distance (Standard Target)
30	20 m and less
50	8 m and less
100	5 m and less

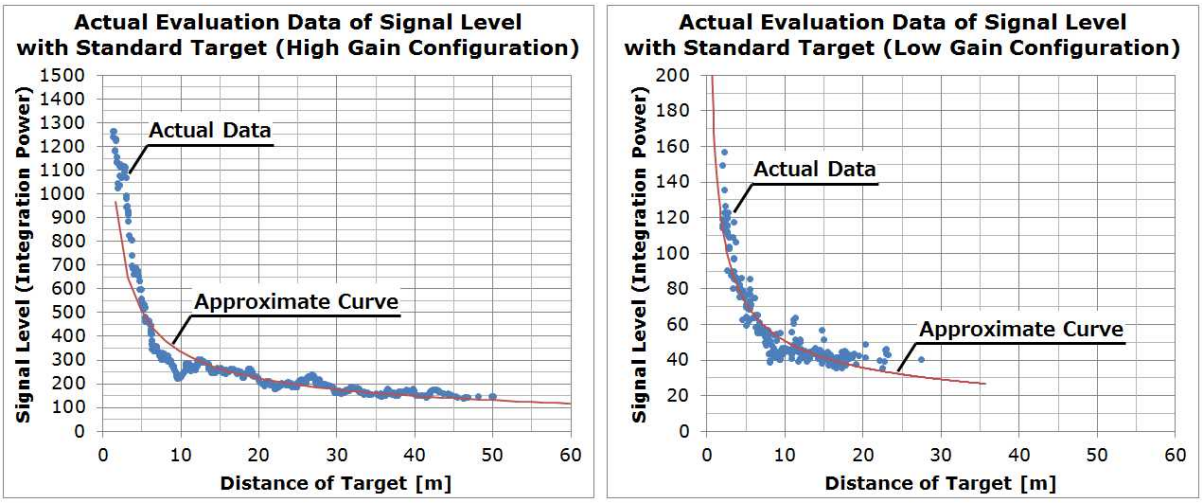


Fig. 9 Actual Evaluation Data of Signal Level

5.5. Peak Emphasis Function

The sensor outputs up to three distance information which means Peak 1, Peak 2 and Peak 3 in order of closer to the sensor. The peak emphasis is a function not to select peaks smaller than the configuration value in order to emphasize the largest peak among these three peak values. The default configuration is valid.

In a generic peak search, very small peaks may be selected as compared with the largest peak. In order to avoid this phenomenon, the small peaks are not intentionally selected by setting the ratio with the largest peak value. The peak selection range is set between the largest peak and the value which the largest peak is divided by the configuration value. For example, if the configuration is 4, the peak selection range will be from 25 % to 100%. The explanation of this function is shown in figure 10.

Even when the measurement distance range is configured, peak outside the range is also selected for the largest peak. The image of this description is shown in figure 11.

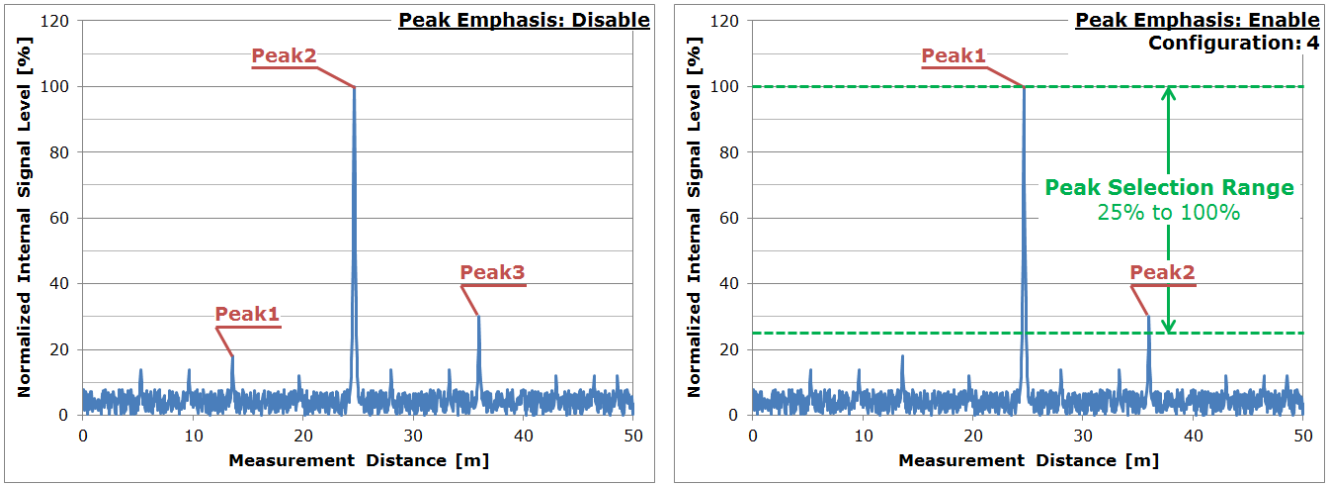


Fig. 10 Explanation of Peak Emphasis Function

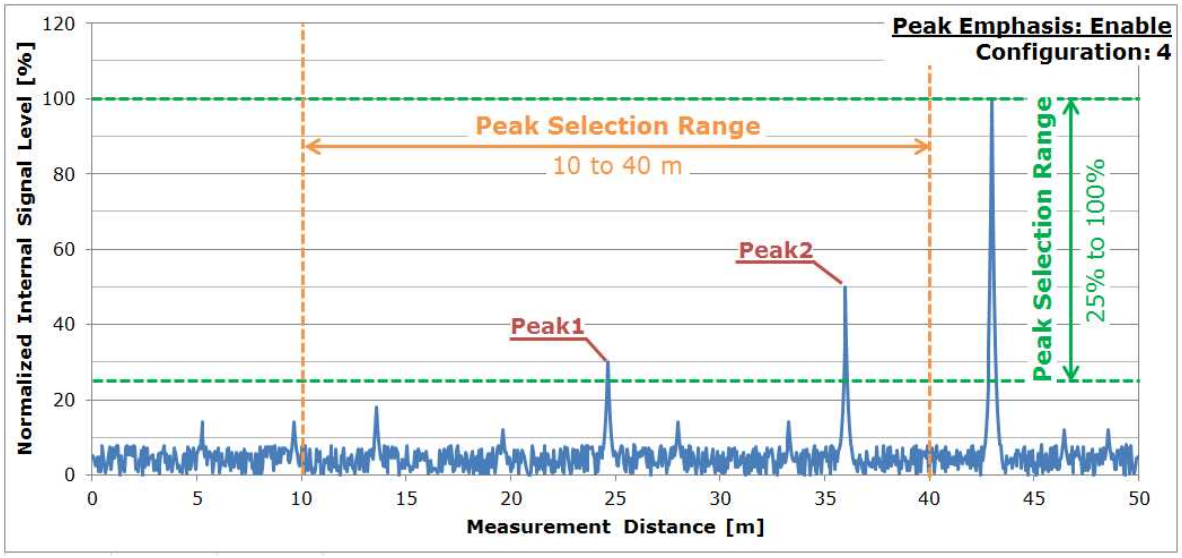


Fig. 11 Explanation of Peak Emphasis Function with Measurement Distance Range

5.6. Moving Average Function

The moving average is a function that performs moving average processing on distance measurement results and can be used to reduce false detection. The default configuration is valid and 4 times of moving average. The configurable is disable of this function, 2 times and 4 times.
If the detection target moves at high speed (10 km/h and more), it is recommended to configure 2 times of the moving average.

5.7. Frequency Band Switching Function(F1 type only)

This sensor adopts a PLL (Phase Lock Loop) type oscillator and controls the frequency.
In this function, it is possible to set it to 80 MHz on the lower side, 80 MHz on the upper side and the 177 MHz band. The default configuration is 177 MHz band.
The band is managed by the frequency plan of Fig. 12 and it is not available to be changed from outside.

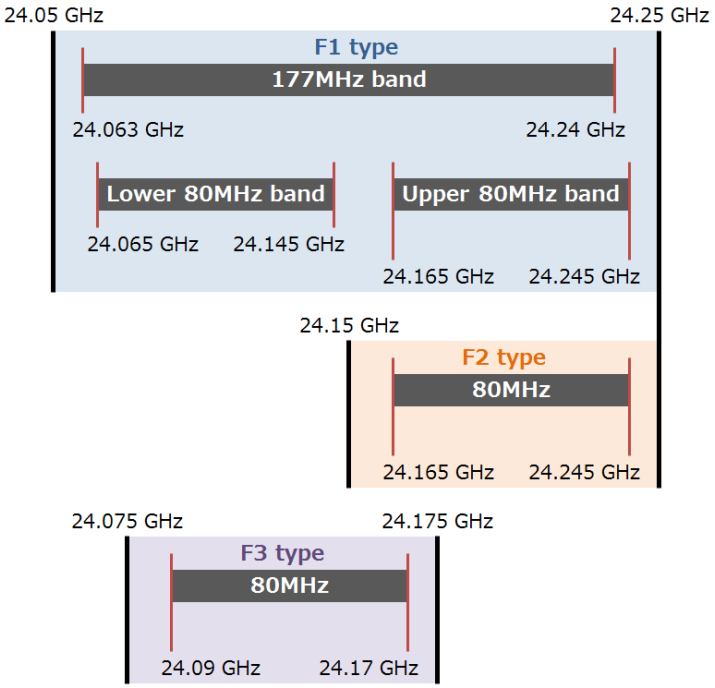


Fig. 12 Frequency Plan

6. Interface

6.1. Pin Assignment

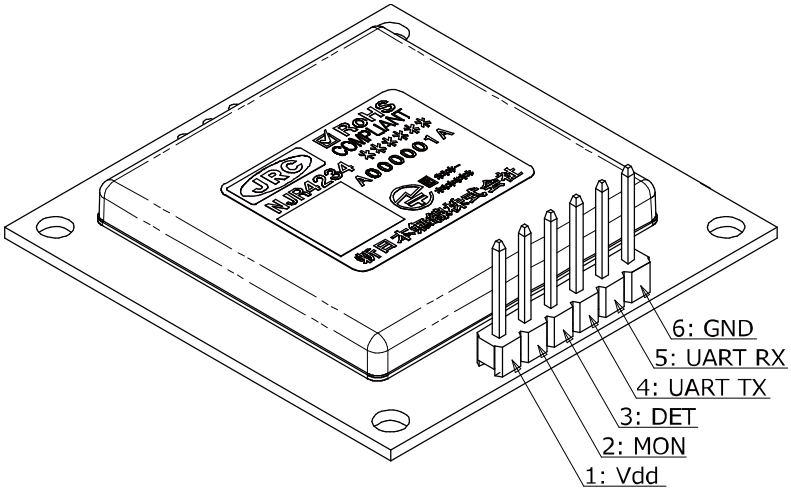


Fig. 13 Pin Diagram

#	NAME	I/O	DESCRIPTION
1	Vdd	I	Power Supply: 2.9 to 5.25 V *Note1
2	MON	O	Notice of abnormal condition (alarm) *Note2 The alarm is output when the internal PLL circuit is unlocked. The state is checked every measurement. H: Normal / L: Alarm Output current < +/-5 mA max.
3	DET	O	Digital output of CMOS level for detection result *Note2 Detection result is output when the signal level exceeds the sensitivity setting. The details are referred to Section 5.4. H: Detect / L: No detect Output current < +/-5 mA max.
4	UART TX	O	UART TX *Note3
5	UART RX	I	UART RX *Note4
6	GND	—	GND Pin

Connector: Pin-header of 2.54mm pitch

*Note1) Applied voltage must be paid attention because there is no reverse connection protection circuit at the Vdd pin.
The applied voltage should be the same voltage as the power supply of the connected equipment.

*Note2) The logic voltage of those pin is 0 V low level and 2.5 V high level. The voltage for the receiving circuit of the connected equipment should be the same voltage as this logic

*Note3) This pin (UART TX) outputs using the internal level conversion IC. High level voltage is same as Vdd voltage.

*Note4) The input voltage of high level input for this pin (UART RX) must not exceed the voltage of Vdd.

6.2. UART Communication Interface

This sensor has a built-in MCU, it is possible to control various configurations and to acquire distance information from external MCU by UART.

ITEM	FORMAT	UNITS	REMARKS
Signal Level	CMOS	—	Refer to Section 6.1.
Communication Parameters			
Baud Rates	115200	bps	
Data Bits	8	bits	
Stop Bits	1	bits	
Parity	no	—	
Handshake	no	—	
Byte Order	LBS	—	

7. Operational Mode

MODE	DESCRIPTION
Power ON / Reset	CPU Reset.
Initialization Mode	Initialization and default configuration for RF-IC. (approx. 70 ms)
Calibration Mode	Performing calibration. The details are referred to Section 5.1 (approx. 350 ms)
Distance Measurement Mode	Measure the distance of the moving objects periodically (50 to 60 ms) and output the distance measurement result. The following items can be set. Configurations settings are accepted in this mode and sleep mode. • Radio Interference Prevention Function: Default – Enable (Refereed to Section 4.2.1) • Number of Distance Measurement Output Data: Default – Peak 1 • Gain Control: Default – Automatic Control (Refereed to Section 5.2) • Measurement Distance Range: Default - 0 m and Maximum Measurement Distance by Nyquist (Refereed to Section 5.3) • Sensitivity Setting Function: Default – 100 (Refereed to Section 5.4) • Peak Emphasis Function: Default – 4 (Refereed to Section 5.5.) • Moving Average Function: Default – 4 times (Refereed to Section 5.6) • Frequency Band Switching Function (only F1 type): Default – 177 MHz band (Refereed to Section 5.7) An example other than the default configurations is referred to Configurations Example of Control Command of Section 8.1.3.
Sleep Mode	Stop the distance measurement and put the built-in RF-IC and MCU to sleep state. Transit to calibration after returning. The configurations of distance measurement after returning are the same as the state before sleep mode.

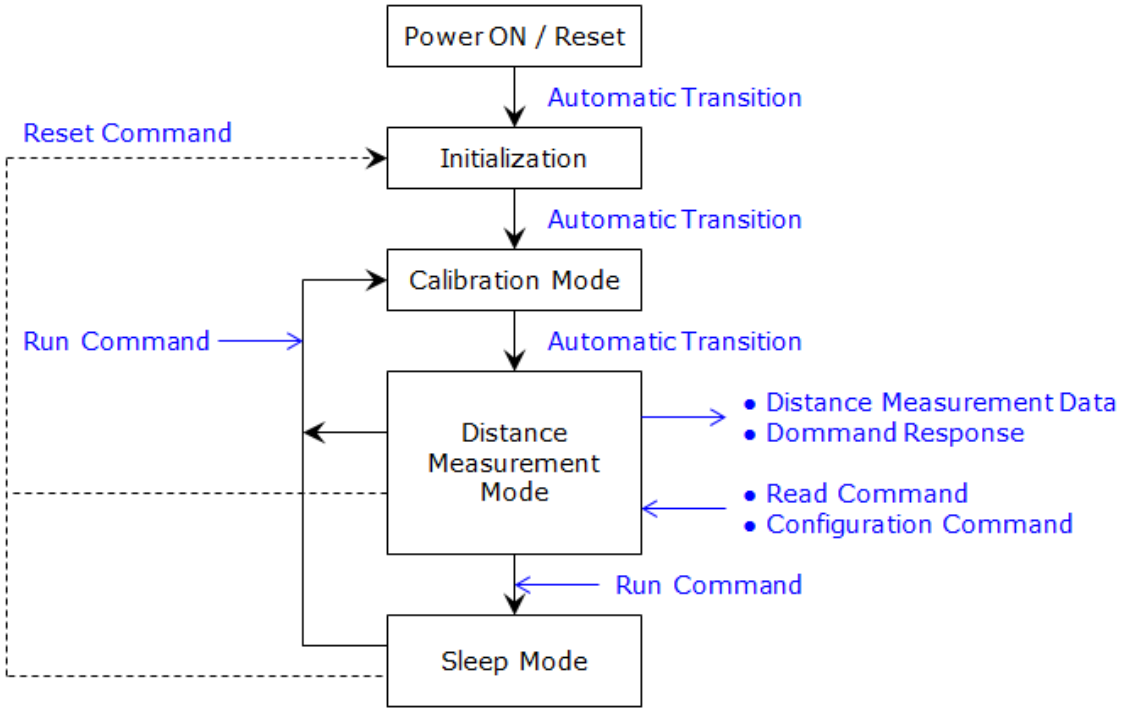


Fig.14 State Transition Diagram

8. Communication Command

8.1. Control Command

The configurations setting at startup of distance measurement mode is always the default value. It is possible to control and change the configurations by UART when using other than the default configurations or changing the mode. It is recommended to change the configurations setting according to the conditions to be used. If restart of the power supply or reset, it must be set again. The format of the control command is as follows.

- Byte Length: 3 bytes (fixed)
- Command Interval: minimum 100 ms
- Command Code: binary

Configuration change and mode change are executed within 100 ms after receiving the control command.

8.1.1. Control Command List

Command	1st Byte								2nd Byte								3rd Byte							
Run Command																								
Run of Software Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Run of Calibration	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Change to Sleep Mode	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Change to Distance Measurement Mode	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Read Command																								
Read of Software Version	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Configuration Command																								
Configuration of Radio Interference Prevention	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	X	0	0	0	0	0	0	0	0
Configuration for Number of Distance Measurement Output Data	0	0	1	0	0	0	0	0	1	0	0	0	0	X	X	X	0	0	0	0	0	0	0	0
Configuration of Gain Control	0	0	0	0	0	0	1	0	0	0	0	0	0	0	X	X	0	0	0	0	0	0	0	X
Configuration of Measurement Distance Range	0	0	1	0	1	0	1	1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Configuration of Sensitivity Setting	0	0	1	0	1	1	0	1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Configuration of Peak Emphasis	0	0	1	0	1	1	1	0	0	0	0	0	X	X	X	X	0	0	0	0	0	0	0	0
Configuration of Moving Average	0	0	1	0	0	1	0	1	0	0	0	0	0	0	X	X	0	0	0	0	0	0	0	0
Configuration of Frequency Band Switching (only F1 type)	0	0	1	0	1	0	0	1	0	0	0	0	0	0	X	X	0	0	0	0	0	0	0	0

8.1.2. Description of Control Command

8.1.2.1. Run of Software Reset

This is a command to reset by software. After reset, calibration is performed and all configurations return to the default. There is no response to this command.

- Run Command:

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(0x00)								(0x00)								(0x00)							

8.1.2.2. Run of Calibration

This is a command to perform calibration. It is recommended to perform periodically. The details are referred to Section 5.1.

- Run Command:

0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(0x28)								(0x00)								(0x00)							

8.1.2.3. Change to Sleep Mode

This is a command to change form distance measurement mode to sleep mode.

- Run Command:

0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
(0x05)								(0x01)								(0x00)							

8.1.2.4. Change to Distance Measurement Mode

This is a command to change from sleep mode to distance measurement mode. Before transmitting distance measurement mode, calibration is performed.

- Run Command:

0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(0x05)								(0x00)								(0x00)							

8.1.2.5. Read of Software Version

This is a command to check the software version.

- Read Command:

0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(0x01)								(0x00)								(0x00)							

8.1.2.6. Configuration of Radio Interference Prevention

This is a command to configure the radio interference prevention function. The default configuration is "enable". The details are referred to Section 4.2.1.

0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	X	0	0	0	0	0	0	0	0
(0x2C)								(0x00)								(0x00)							

2nd Byte [0] - Configuration of radio interference prevention, 1: enable / 0: disable

- Command for Enable (Default):

0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
(0x2C)								(0x01)								(0x00)							

- Command for Disable:

0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(0x2C)								(0x00)								(0x00)							

8.1.2.7. Configuration for Number of Distance Measurement Output Data

This is a command to configure number of distance measurement output data. The default configuration is "Peak 1". Only the closest peak 1 is output with default against the three peaks (Peak1 / Peak2 / Peak3).

0	0	1	0	0	0	0	0	0	0	0	0	0	X	X	X	0	0	0	0	0	0	0	0

2nd Byte [2] - Configuration for "Peak 3" of output data, 1: enable / 0: disable

2nd Byte [1] - Configuration for "Peak 2" of output data, 1: enable / 0: disable

2nd Byte [0] - Configuration for "Peak 1" of output data, 1: enable / 0: disable

- Command for Output of only Peak1 (Default):

0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
(0x20)								(0x01)								(0x00)							

- Command for Output of Peak1 / Peak2:

0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
(0x20)								(0x01)								(0x00)							

- Command for Output of Peak1 / Peak2 / Peak3:

0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0
(0x20)								(0x01)								(0x00)							

8.1.2.8. Configuration of Gain Control

This is a command to configure the gain control function. The default configuration is "Automatic Control". The details are referred to Section 5.2.

0	0	0	0	0	0	1	0	0	0	0	0	0	0	X	X	0	0	0	0	0	0	0	X

2nd Byte [1:0] - Configuration between high and low gain,
10: high gain / 00: low gain

3rd Byte [0] - Configuration between automatic and fixed control,
1: automatic control / 0: fixed control

- Command for Automatic Control (Default):

0	0	0	0	0	0	1	0	0	0	0	0	0	0	N	N	0	0	0	0	0	0	0	1
(0x02)								(0x0N)								(0x01)							

- Command for High Gain of Fixed Control:

0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
(0x02)								(0x02)								(0x00)							

- Command for Low Gain of Fixed Control:

0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(0x02)								(0x00)								(0x00)							

8.1.2.9. Configuration of Measurement Distance Range

This is a command to configure the distance range of output measurement data. The default configuration is 0 m as minimum distance and maximum distance measurement by Nyquist as maximum distance. The details are referred to Section 5.3.

0	0	1	0	1	0	1	1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

2nd Byte [7:0] - Configuration for minimum distance of output measurement data
3rd Byte [7:0] - Configuration for maximum distance of output measurement data
The configuration range is 0 to 86 for F1 type and 0 to 170 for F2 type and F3 type.

- Command for Configuration of 0 to 86 m (Default for F1 type):

0	0	1	0	1	0	1	1	0	0	0	0	0	0	0	0	0	1	0	1	0	1	1	0
(0x2B)								(0x00)								(0x56)							

- Command for Configuration of 0 to 170 m (Default for F2 type and F3 type):

0	0	1	0	1	0	1	1	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1	0
(0x2B)								(0x00)								(0xAA)							

- Command for Configuration of 5 to 25 m (Example):

0	0	1	0	1	0	1	1	0	0	0	0	0	1	0	1	0	0	0	1	1	0	0	1
(0x2B)								(0x05)								(0x19)							

- Command for Configuration of 15 to 50 m (Example):

0	0	1	0	1	0	1	1	0	0	0	0	1	1	1	1	0	0	1	1	0	0	1	0
(0x2B)								(0x0F)								(0x32)							

8.1.2.10. Configuration of Sensitivity Setting

This is a command to configure the sensitivity of the sensitivity setting function. The default configuration is "100". The details are referred to Section 5.4.

0	0	1	0	1	1	0	1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

2nd Byte [7:0] : 3rd Byte [7:0] – Configuration of sensitivity, Range: 1 to 65535

- Command for Configuration of 100 (Default):

0	0	1	0	1	1	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0
(0x2D)								(0x00)								(0x64)							

- Command for Configuration of 50:

0	0	1	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0
(0x2D)								(0x00)								(0x32)							

- Command for Configuration of 300:

0	0	1	0	1	1	0	1	0	0	0	0	0	0	0	1	0	0	1	0	1	1	0	0
(0x2D)								(0x01)								(0x2C)							

8.1.2.11. Configuration of Peak Emphasis

This is a command to configure the peak selection range of the peak emphasis function. The default configuration is "4". The details are referred to Section 5.5.

0	0	1	0	1	1	1	0	0	0	0	0	X	X	X	X	0	0	0	0	0	0	0	0

2nd Byte [3:0] – Configuration of peak selection range,

Range: 0 to 15 / 0: disable

- Command for Configuration of 4 (Default):

0	0	1	0	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
(0x2E)								(0x04)								(0x00)							

- Command for Configuration of 15:

0	0	1	0	1	1	1	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0
(0x2E)								(0x0F)								(0x00)							

- Command for Disable:

0	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(0x2E)								(0x00)								(0x00)							

8.1.2.12. Configuration of Moving Average

This is a command to configure moving average function. The default configuration is "Average of 4 Times". The details are referred to Section 5.6.

0	0	1	0	0	1	0	1	0	0	0	0	0	0	X	X	0	0	0	0	0	0	0	0

2nd Byte [1:0] – Configuration of moving average,

10: average of 4 times / 01: average of 2 times / 00: disable

- Command for Configuration of "Average of 4 times" (Default):

0	0	1	0	0	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
(0x25)								(0x02)								(0x00)							

- Command for Configuration of "Average of 2 times" (Default):

0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
(0x25)								(0x01)								(0x00)							

- Command for Disable:

0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(0x25)								(0x00)								(0x00)							

8.1.2.13. Configuration of Frequency Band Switching (only F1 type)

This is a command to configure band of the frequency band switching function. The default configuration is "177 MHz Band". Since this function is not implemented in F2 type and F3 type, this command is not accepted. The details are referred to Section 5.7.

0	0	1	0	1	0	0	1	0	0	0	0	0	0	X	X	0	0	0	0	0	0	0	0

2nd Byte [1:0] – Configuration of frequency band,

11: 177 MHz band / 01: lower 80 MHz band / 10: upper 80 MHz band

- Command for Configuration of 177 MHz Band (Default):

0	0	1	0	1	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
(0x29)								(0x03)								(0x00)							

- Command for Configuration of Lower 80 MHz Band:

0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
(0x29)								(0x01)								(0x00)							

- Command for Configuration of Upper 80 MHz Band:

0	0	1	0	1	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
(0x29)								(0x02)								(0x00)							

8.1.3. Configurations Example of Control Command

Configuration Item	Default	Indoor (5m Room)	Outdoor Few Obstacles	Outdoor Few Obstacles	Outdoor Multi Obstacles
Radio Interference Prevention	Enable	Enable	Enable	Enable	Enable
Number of Distance Measurement Output Data	1	1	1 to 3	1 to 3	1
Gain Control Function	Automatic Cont.	Low Gain (Fixed)	Automatic Cont.	Automatic Cont.	High Gain (Fixed)
Sensitivity Setting Function	100	150	100	200	200
Peak Emphasis Function	4	1	4	5 to 8	1
Moving Average Function	4 times	4 times	4 times	2 times	4 times
Detection Target	Pedestrian	Pedestrian	Pedestrian	vehicle	Pedestrian

8.2. Notification Command (Response)

There are only three notification commands (responses) as fallows

1) Output Data of Measurement Distance:
   Preamble (4 bytes) + Header (4 bytes) + Distance data (8 bytes)
2) Command Response: Preamble (4 bytes) + Header (4 bytes)
3) Alarm Notice: Preamble (4 bytes) + Header (4 bytes)

The format of the notification command is as follows.

- Byte Length: 8 to 16 bytes (variable by notification command)
- Command Code: binary

8.2.1. Output Data of Measurement Distance

This output data is automatically sent for each measurement.

The format of the output data to be sent is as follows.

Preamble (4 bytes)	Header (4 bytes)				Distance Data (8 bytes)			
0xCCCC5555	H1 [7:0] (0x21)	H2 [7:0] (0xX2)	H3 [7:0] (0x0X)	H4 [7:0] (0xXX)	Data1 (0xXXXX)	Data2 (0xXXXX)	Data3 (0xXXXX)	Data4 (0xXXXX)

H1 [7:0] - Fixed value: 0010 0001 (0x21)
H2 [7:4] - Gain control information / 0000: low gain, 0010: high gain
[3:0] - Fixed value: 0010
H3 [7:4] - Fixed value: 0000
[3:0] - Notification of the number of peaks within the measurement distance range
Range: 0 to 16 (Reference)
H4 [7:0] - Information for the random variable time of the measurement cycle
0 to 256: 0 corresponds to 50 ms and 256 corresponds to 60 ms
Data 1 (2 bytes) - Notify the value of 10 times the distance information of Peak 1
Range: 0 to 1700 (170 m).
Data 2 (2 bytes) - Notify the value of 10 times the distance information of Peak 2
Range: 0 to 1700 (170 m).
Data 3 (2 bytes) - Notify the value of 10 times the distance information of Peak 3
Range: 0 to 1700 (170 m).
Data 4 (2 bytes) - Notifies the integrated power in the whole band of the received signal as the signal level. It is a value used for sensitivity setting function. The details are referred to Section 5.4.
Range: 0 to 65535

8.2.2. Command Response

The command response is sent after the sensor receives the control command. If incorrect control commands or no configuration range exists, an error response is sent.

8.2.2.1. Response for Run Command

This response is sent after receiving a correct run command in the control command. There is no response to run command of software reset.

The format of this response to be sent is as follows.

Preamble (4 bytes)	Header (4 bytes)			
0xCCCC5555	H1 [7:0] (0xE0)	H2 [7:0] (0xXX)	H3 [7:0] (0xXX)	H4 [7:0] (0xXX)

H1 [7:0] - Fixed value: 1110 0000 (0xE0)
H2 [7:0] - Same as 1st byte of the control command
H3 [7:0] - Same as 2nd byte of the control command
H4 [7:0] - Same as 3rd byte of the control command

8.2.2.2. Response for Read Command

This response is sent including response data after receiving a correct read command in the control command.

The format of this response to be sent is as follows.

Preamble (4 bytes)	Header (4 bytes)			
0xCCCC5555	H1 [7:0] (0xE0)	H2 [7:0] (0xXX)	H3 [7:0] (0xXX)	H4 [7:0] (0xXX)

H1 [7:0] - Fixed value: 1110 0000 (0xE0)
H2 [7:0] - Same as 1st byte of the control command
H3 [7:0] - Response data
H4 [7:0] - Response data

8.2.2.3. Response for Configuration Command

This response is sent after changed configuration at receiving a correct configuration command in the control command.

The format of this response to be sent is as follows.

Preamble (4 bytes)	Header (4 bytes)			
0xCCCC5555	H1 [7:0] (0xE0)	H2 [7:0] (0xXX)	H3 [7:0] (0xXX)	H4 [7:0] (0xXX)

H1 [7:0] - Fixed value: 1110 0000 (0xE0)
H2 [7:0] - Same as 1st byte of the control command
H3 [7:0] - Same as 2nd byte of the control command
H4 [7:0] - Same as 3rd byte of the control command

8.2.2.4. Error of Control Command

This response is sent when receiving an incorrect control command.
The format of this response to be sent is as follows.

Preamble (4 bytes)	Header (4 bytes)			
0xCCCC5555	H1 [7:0] (0xE0)	H2 [7:0] (0xFF)	H3 [7:0] (0xFF)	H4 [7:0] (0x00)

H1 [7:0] - Fixed value: 1110 0000 (0xE0)
H2 [7:0] - Fixed value: 1111 1111 (0xFF)
H3 [7:0] - Fixed value: 1111 1111 (0xFF)
H4 [7:0] - Fixed value: 0000 0000 (0x00)

8.2.2.5. Error of Control Command

This response is sent when receiving an invalid configuration range of correct control command.
The format of this response to be sent is as follows.

Preamble (4 bytes)	Header (4 bytes)			
0xCCCC5555	H1 [7:0] (0xE0)	H2 [7:0] (0xXX)	H3 [7:0] (0xFF)	H4 [7:0] (0x00)

H1 [7:0] - Fixed value: 1110 0000 (0xE0)
H2 [7:0] - Same as 1st byte of the control command
H3 [7:0] - Fixed value: 1111 1111 (0xFF)
H4 [7:0] - Fixed value: 0000 0000 (0x00)

8.2.3. Alarm Notice

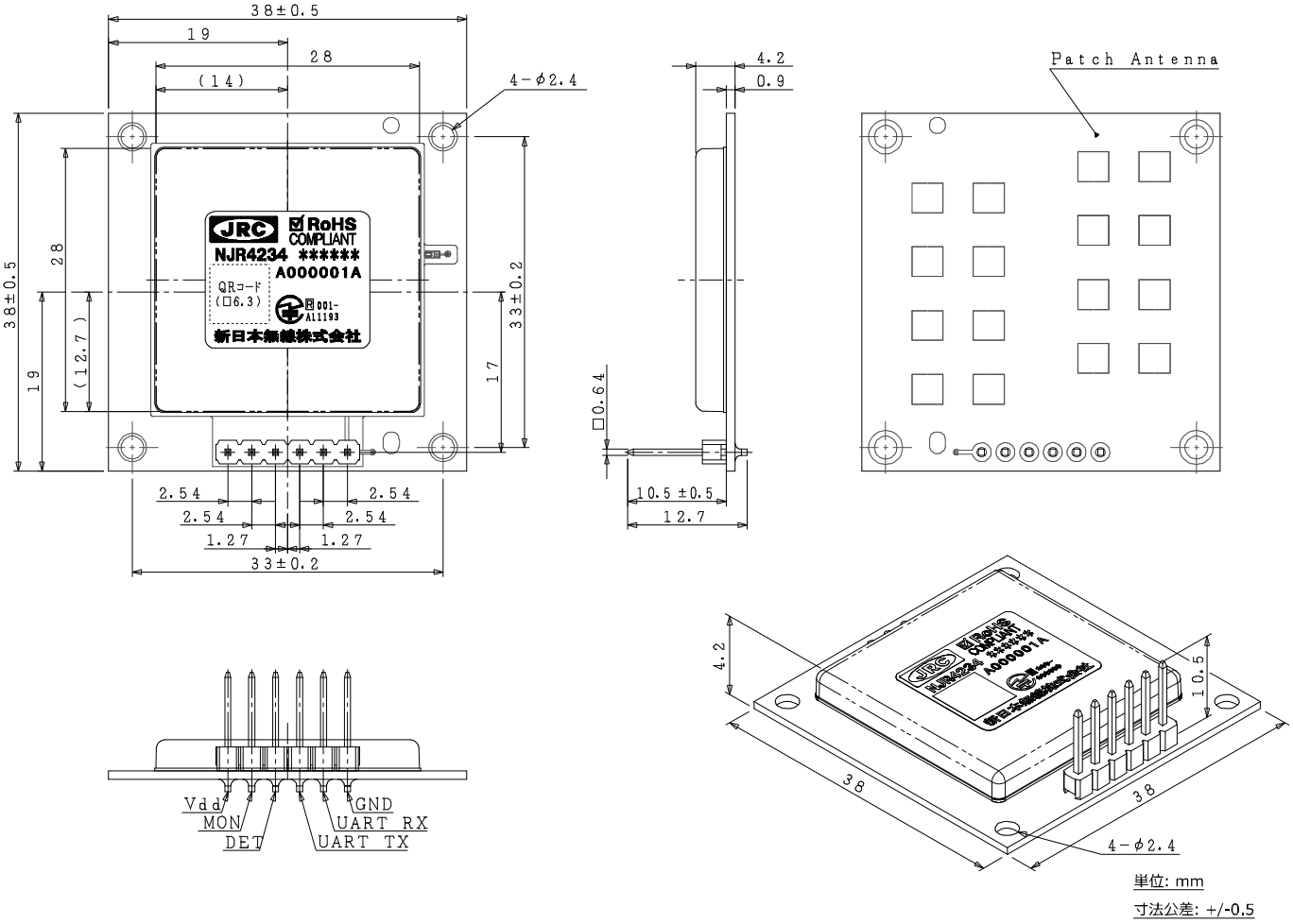
This notice is sent when the sensor becomes abnormal. The abnormal means the internal PLL circuit is unlocked. The state is checked every measurement. There is a possibility of sensor failure.
The format of this notice to be sent is as follows.

Preamble (4 bytes)	Header (4 bytes)			
0xCCCC5555	H1 [7:0] (0x00)	H2 [7:0] (0x01)	H3 [7:0] (0x00)	H4 [7:0] (0x00)

H1 [7:0] - Fixed value: 0000 0000 (0x00)
H2 [7:0] - Fixed value: 0000 0001 (0xFF)
H3 [7:0] - Fixed value: 0000 0000 (0x00)
H4 [7:0] - Fixed value: 0000 0000 (0x00)

9. Drawing

9.1. Outline



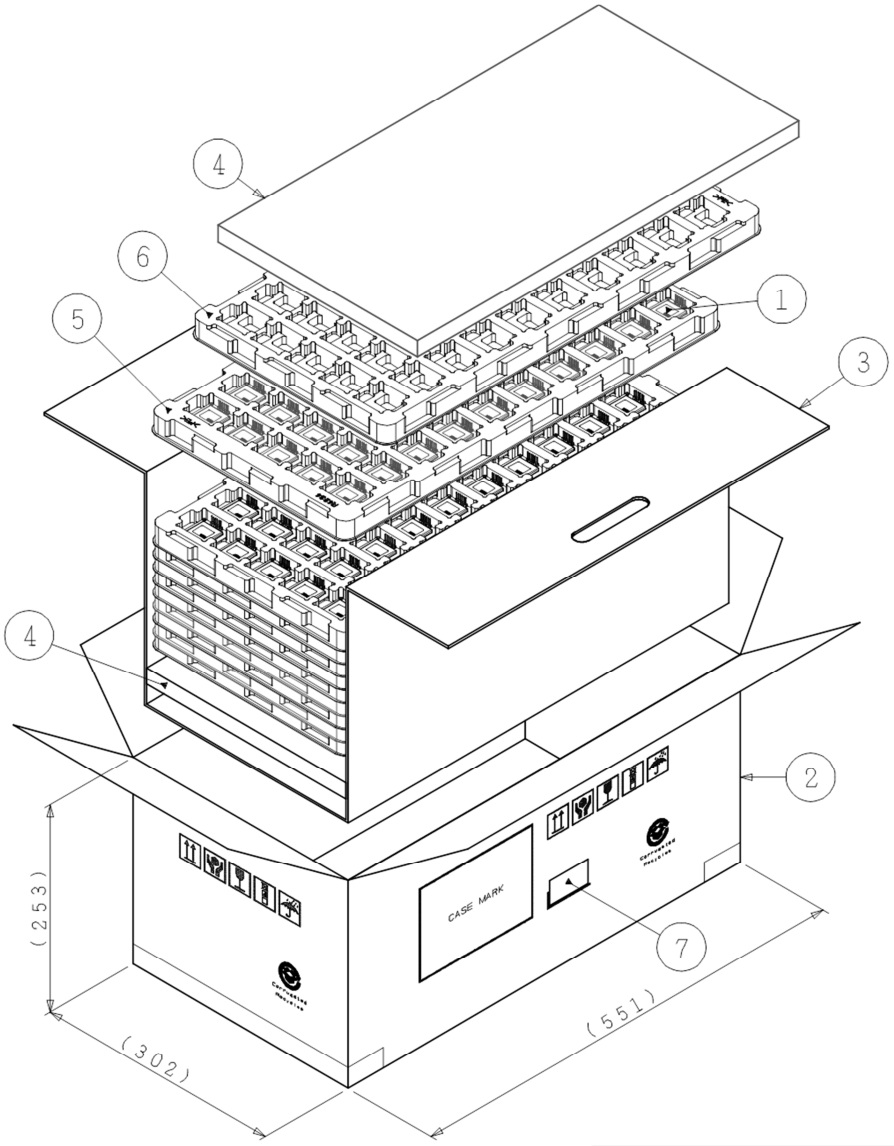
9.2. Label

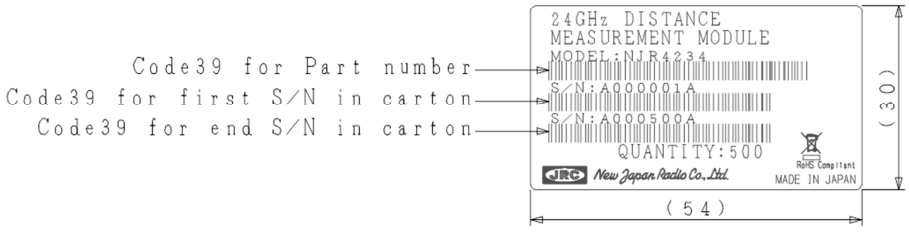
ex) NJR4234BVF1C1

10. Package

Standard Package

Packing Quantity: 500 pieces per shipping box



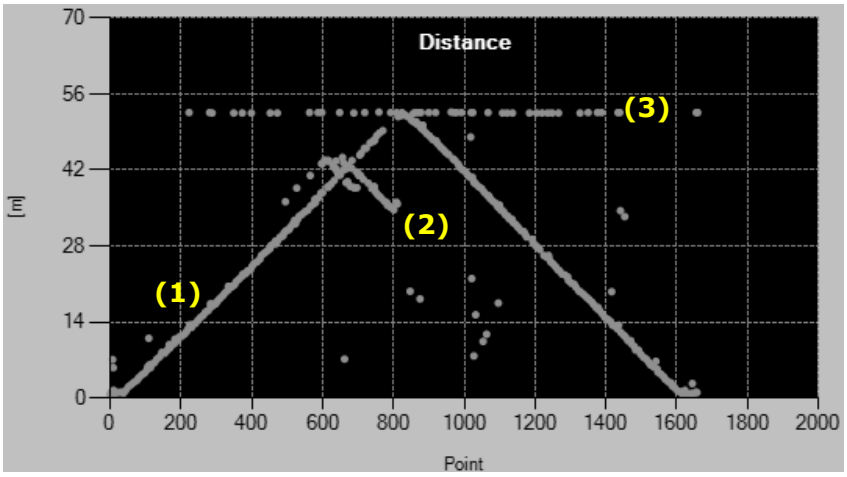


⑦:Package label

①NJR4234 24GHz Distance Measurement module
②Outer packaging:double wall corrugated fiberboard
③Inner packaging:single wall corrugated fiberboard
④Package cushioning:polyethylene foam
⑤Tray for modules (50 pcs×10 trays):conductive polystyrene
⑥Dummy tray:conductive polystyrene
⑦Package label

11. Actual Measurement Result (Reference)

11.1. Measurement of person walking in corridor



Measurement Result

Measurement Condition

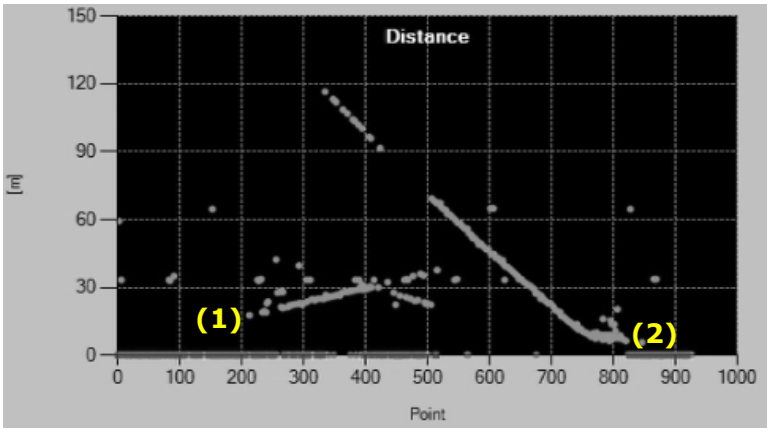
Measurement Objects:

(1) Person walking from the front of the sensor to the wall at the end after that walking toward the sensor again.

(2) Person different from (1) coming out of the door and walking toward the sensor

(3) The wall at the end

11.2. Measurement of people walking and moving vehicle outdoors



Measurement Result

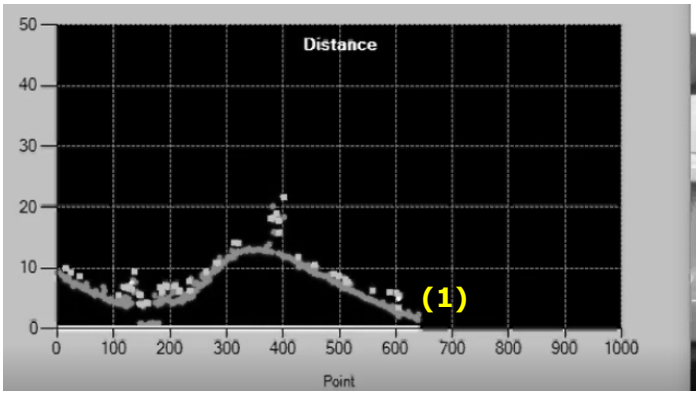
Measurement Condition

Measurement Objects:

(1) People walking away from the front of the sensor

(2) Vehicle approaching the sensor from a distance

11.3. Measurement of vehicle repeating approach and leave



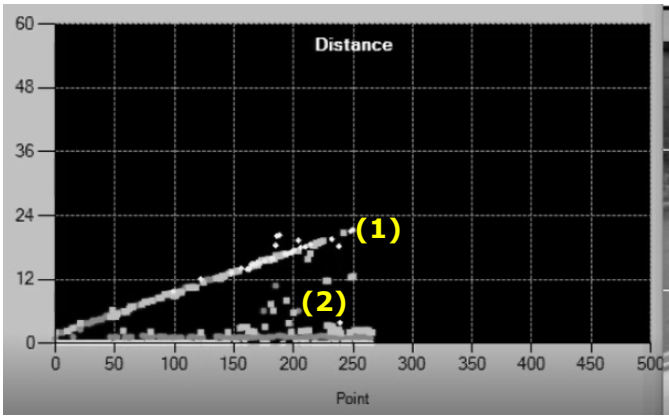
Measurement Result　　Measurement Condition

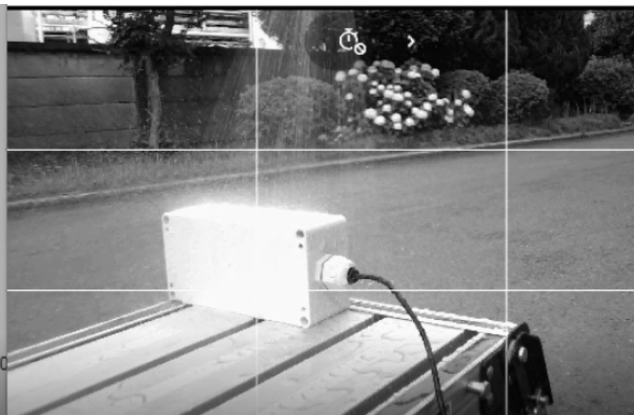
Measurement Object:

(1) Vehicle repeatly approaching and leaving from the sensor

11.4. Effect of rainfall

After mounting the sensor on the case, the pedestrian measurement is tested with water shower applied to the case.





Measurement Result　　Measurement Condition

Measurement Objects:

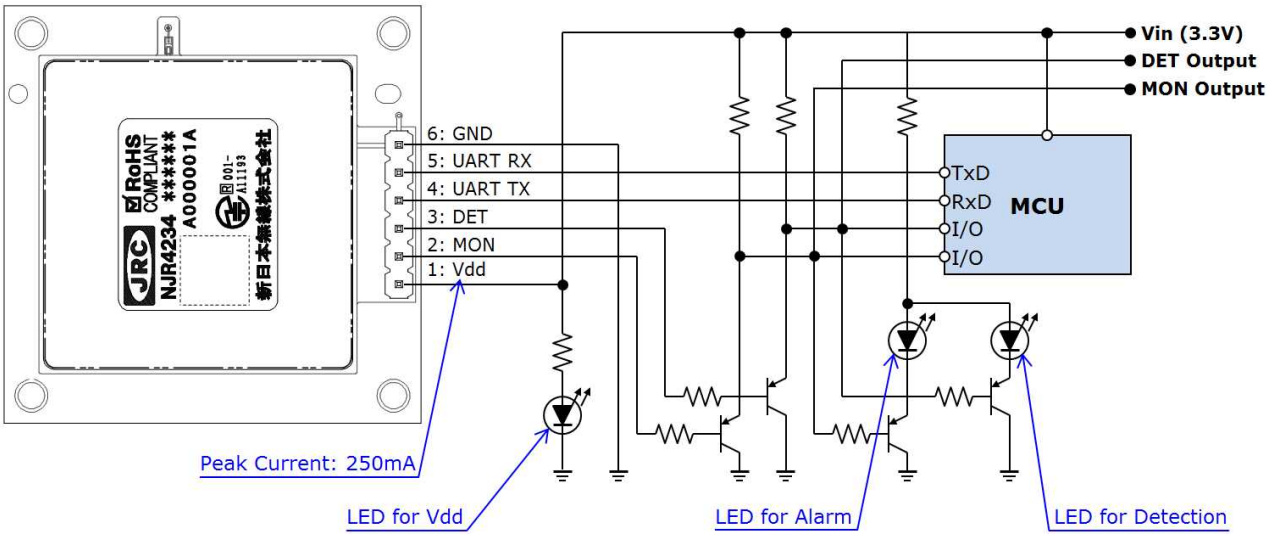
(1) People walking away from the front of the sensor

(2) The effect of rainfall on the distance measurement of pedestrian is small, but the raindrop on the front of the case has a slight influence.

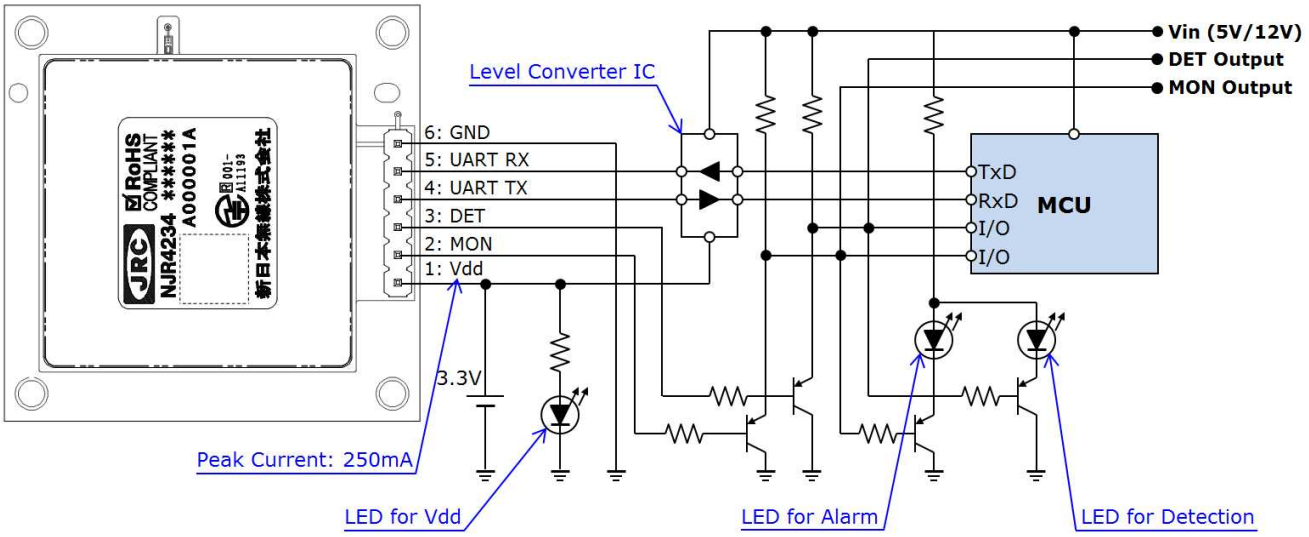
12. Reference Circuit

12.1. Control Circuit / Secondary Circuit

1) When the power supply voltage between the sensor and connection circuit are the same

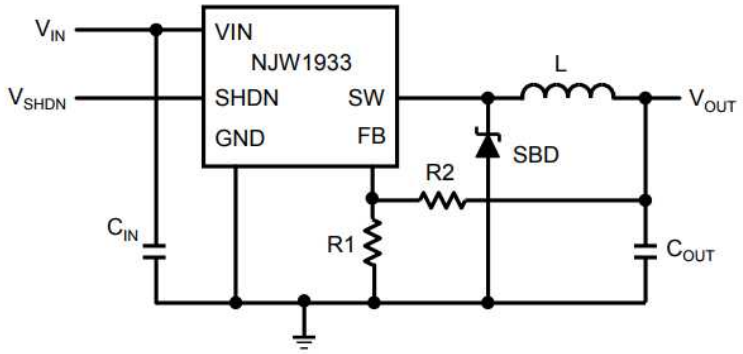


2) When the power supply voltage between the sensor and connection circuit are different



12.2. Recommendation Power Supply Circuit

IC : NJW1933F1-AT
Input Voltage : V_{IN}=12V
Output Voltage : V_{OUT}=3.3V
Output Current : I_{OUT}=0.6A
Oscillation Frequency : fosc=500kHz

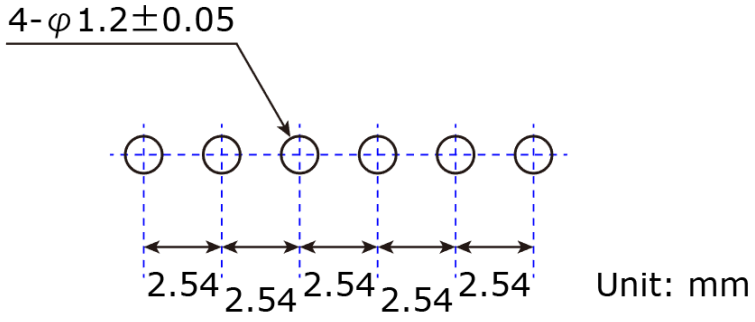


SYMBOL	QTY.	PART NUMBER	DESCRIPTION	MFR.
IC	1	NJW1933F1-AT	0.6A MOSFET built-in SW.REG. IC	New JRC
L	1	CDRH6D28NP-220NC	Inductor 22μH, 1.2A	Sumida
SBD	1	MBRM140T3G	Schottky Diode 40V, 1A	ON Semiconductor
C_{IN1}	1	GRM31CB31H225KA87	Ceramic Capacitor 3216 2.2μF, 50V, B	Murata
C_{OUT}	1	GRM32EB31C476ME15	Ceramic Capacitor 3225 47μF, 16V, B	Murata
R1	1	3.3kΩ	Resistor 1608 3.3kΩ, ±1%, 0.1W	Std.
R2	1	5.6kΩ	Resistor 1608 5.6kΩ, ±1%, 0.1W	Std.

(*) The details of power supply circuit is referred to datasheet of NJW1933.

13. Recommendation Mounting Conditions

13.1. Footprint dimensions *Note1



13.2. Soldering conditions

- Soldering way: Solder iron *Note2
- Solder iron temperature: 350 °C or less
- Soldering time: in below

Pin #	Soldering time
1 to 5	3 second or less
6 (GND)	6 second or less

*Note1) In actual design, please optimize in accordance with the situation of your board design and soldering condition.

*Note2) The soldering iron to be used must be grounded via a resistance of about 1 MΩ.

14. Recommendation Condition for Cover Design

DISCLAIMER OF WARRANTY:
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Microwave sensor is possible to detect by passing through glass or plastic, pottery, etc. Therefore, there are advantages such as hiding properties and a high degree of freedom in the cover design when it incorporated into a product. However, the cover is the reflecting object which is located in closest to the sensor. If it is not made by a suitable material and a suitable shape, it will adversely affect the sensor characteristics. It will be helpful to prevent trouble such that the performance of the sensor can not be obtained, by understanding about the important parameters for designing the cover.

Role of Cover

Protecting the sensor from rain and dust is important object of cover. Therefore, the appropriate material for your use should be selected as the cover material. On the other hand, since the cover is located in closest position to the sensor, the reflection by the cover affect to the sensor performance. Therefore, the cover should be designed to reduce the reflection by it as much as possible.

Key Points in Cover Design

- The cover shall be selected the material with the low dielectric constant and low insertion loss, such as polycarbonate.
- Do not select the material of the cover including some of the conductive such as metal or carbon.
- Do not coat with paint that contains some of the conductive such as metal or carbon.
- The thickness of cover is approx. 3 to 4 mm generally for plastic materials in 24 GHz microwave. However, it varies depending on the dielectric constant of the material.
- The distance between cover and antenna of the sensor is approx. 6.2 mm or more generally in 24 GHz microwave. However, it is recommended to test the sensor performance by changing the distance to the sensor with a plate material to use.
- The design against vibration of both cover and sensor must be paid careful attention.

14.1. Material of Cover

In regards to the cover materials, the cover shall be selected the material as follows.

- Electrically non-conductive material
- Low dielectric constant (εr) and low dielectric loss (tanδ) at transmit frequency.
- Shape must be stable in used temperature range and pressure range.
- No water absorption and no hygroscopic. Water-repellent is desirable.
  Water is a material that has high dielectric loss and large dielectric constant. Therefore, the dry cloth and wood are pass the microwaves well but when those absorb moisture, those attenuation is greatly increase.
- Other environmental performance, that is, light resistance, chemical resistance, flame retardant may be required by the situation of the product.

Table: Example of Material used for the Cover *Note1

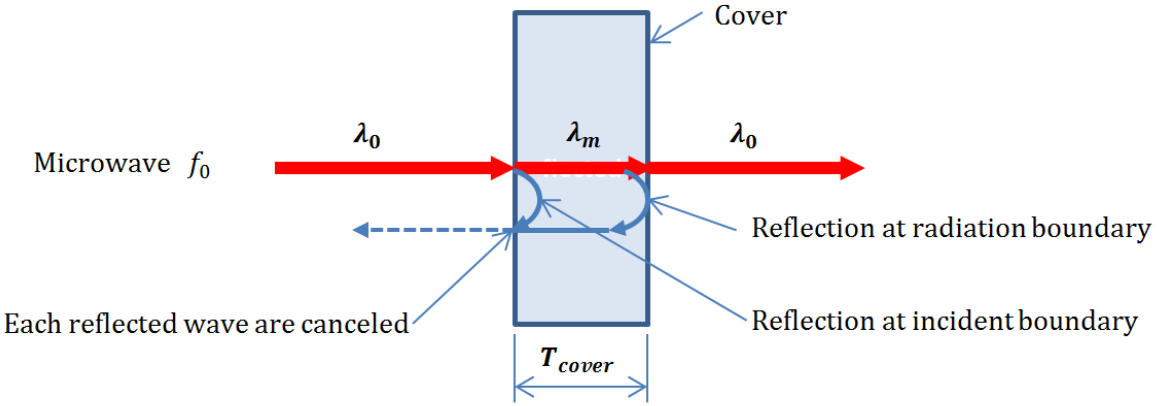
Material	Dielectric Constant (εr)	Dielectric Loss (tanδ)	Feature
Polycarbonate	2.9	0.012	Shock Resistance / Heat Resistance / Flame Retardant
ABS Reain	2.5 – 3.5	0.001 – 0.02	Excellent moldability Characteristics may be different due to the composition *Note2
PTFE (Teflon®)	2.0	0.0002	Electrical Characteristics at High frequency is excellent.

*Note1) Characteristic values showing in the table are typical values that are published on the web or documents. When you actually design a cover, it is better to ask the manufacturer about the characteristics of material. However, please take care about the measured frequency of dielectric constant / dielectric loss of manufacturer data.
To design a microwave cover, It is necessary the value of the frequency (10 / 24GHz) to be used, but in many cases data of manufacturer is the data measured at 1MHz or at lower than 1GHz.

*Note2) Engineering plastics such as ABS resin requires a separate confirmation because there are many kinds of changing the composition and additives. Also, please avoid coating with paint containing the metal or carbon.

14.2. Thickness of Cover

Cover is designed to minimize microwave reflection in order to reduce the influence to the sensor performance. Some part of microwaves incident into the cover is reflected at the boundary between the air and the cover. Further, some part of the microwaves that was inserted into the cover will be reflected again at the boundary of the cover and the air. When the thickness of the cover is about half of the wavelength in the cover material, the reflected wave of the incident boundary and the radiation boundary is canceled and it will become the minimum loss.



Reflection of microwave at the Cover

Ex.) Polycarbonate (εr=2.9)| Frequency(f_0) = 24.15 GHz

Wavelength in the air (λ_0) = c_0/f_0 ≈ 12.4 mm

Wavelength in Cover material (λ_m) = $\lambda_0/\sqrt{\varepsilon r}$ ≈ 7.3 mm

Thickness of Cover for minimum loss (T_{cover}) = $\lambda_m/2$ ≈ 3.6 mm

c_0: Speed of light (3 x 10^8 m/s)

εr: Dielectric Constant of Cover material

14.3. Distance between Cover and Antenna

The distance between the antenna of the sensor and the cover is also important parameter to reduce the effect of the cover.

Reflected wave by the cover will affect the receiving noise characteristics by the phase of incident into the receiving antenna as following figure is an example of actually measured in our sensor.

Dashed line is the noise level without cover

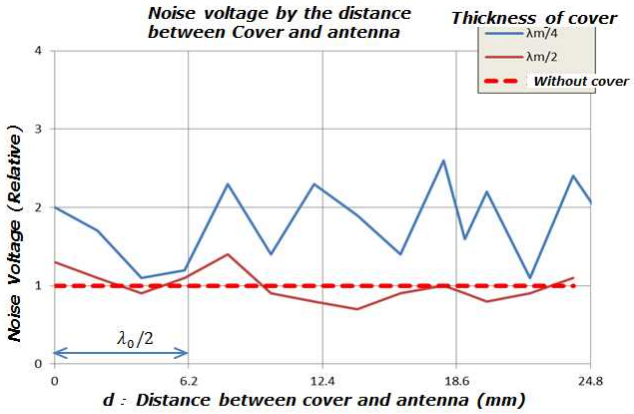
- In case thickness $\lambda_m/2$ (red): reflection at the cover is small, not much change in the noise in the distance.
- In case thickness $\lambda_m/4$ (blue): reflection at the cover is large, the noise has changed significantly in the distance.
- In either case, noise at the distance about $\lambda_0/2$ is low.
- Noise becomes worse in excessively close distance ($<\lambda_0/4$)

Ex.) Frequency(f_0) = 24.15 GHz

Wavelength in the air (λ_0) = c_0/f_0
≈ 12.4 mm

Distance between cover and antenna (d)
= $\lambda_0/2$ ≈ 6.2 mm

c_0: Speed of light (3 x 10^8 m/s)



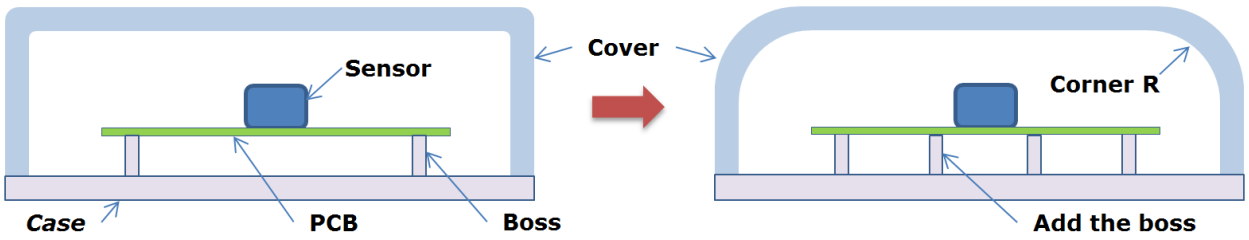
Changes in the noise voltage due to the distance between cover and antenna

Actually distance for the minimum noise might be shifted from $\lambda_0/2$. It is recommended to confirm the optimal value of the thickness and the distance using the cover material to be actually used by this measurement.

14.4. Consideration to the vibration

It would appear as increase of noise when the distance of the cover and the sensor is relatively changed by the vibration. Therefore, cover needs a mechanically sufficient strength to avoid the moving by vibration. Mounting of the sensor also need to be careful to the motion by vibration.

The following figure is example of weak structure to vibration and the example of counter measure to the vibration. If using the sensor in locations there is a vibration, it is strongly recommended that the natural vibration of the structure and consider the adoption of the damper to reduce the vibration.



In case of the cover is flat and wide, it is a possibility to sway the cover by vibration.
If the PCB is supported only around of large Board, it is also a possibility to swaying by the vibration.

By increasing the corner R, sway of the cover will be able to reduce.
By supporting the PCB in the vicinity of the sensor, sway of the sensor will be able to reduce.

Example of mechanical vibration measures

Caution

1. NJRC strives to produce reliable and high quality microwave components. NJRC's microwave components are intended for specific applications and require proper maintenance and handling. To enhance the performance and service of NJRC's microwave components, the devices, machinery or equipment into which they are integrated should undergo preventative maintenance and inspection at regularly scheduled intervals. Failure to properly maintain equipment and machinery incorporating these products can result in catastrophic system failures.

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3. NJRC offers a variety of microwave components intended for particular applications. It is important that you select the proper component for your intended application. You may contact NJRC's sales office or sales representatives, if you are uncertain about the products listed in the catalog and the specification sheets.

4. Special care is required in designing devices, machinery or equipment, which demand high levels of reliability. This is particularly important when designing critical components or systems whose foreseeable failure can result in situations that could adversely affect health or safety. In designing such critical devices, equipment or machinery, careful consideration should be given to, amongst other things, their safety design, fail-safe design, back-up and redundancy systems, and diffusion design.

5. The products listed in the catalog and specification sheets may not be appropriate for use in certain equipment where reliability is critical or where the products may be subjected to extreme conditions. You should consult our sales office or sales representatives before using the products in any of the following types of equipment.
   * Aerospace Equipment
   * Equipment Used in the Deep Sea
   * Power Generator Control Equipment (nuclear, steam, hydraulic)
   * Life Maintenance Medical Equipment
   * Fire Alarm/Intruder Detector
   * Vehicle Control Equipment (automobile, airplane, railroad, ship, etc.)
   * Various Safety Equipment

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