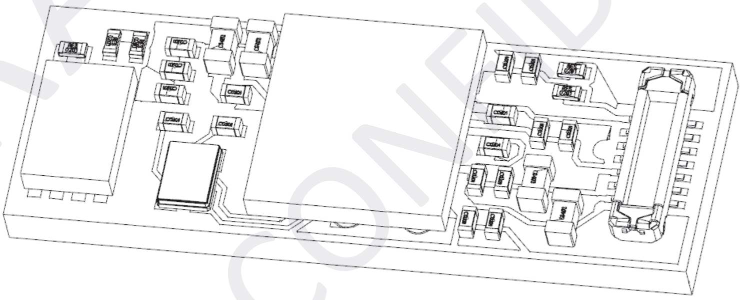
MT5C01-02R1

TI IWRL6432 WCSP

60GHz mmWave AoM



Datasheet

Draft 0.2

Index

1. INTRODUCTION

The MT5C01-02R1 module is an Antenna-on-Module (AoM) Radar device which integrate Texas Instruments mmWave FMCW single chip sensor and Jorjin high field of View (FoV) Antenna design. This module is designed for low power, self-monitored, ultra-accurate radar systems in the industrial and personal electronics space for applications such as building, factory automation, commercial, residential security, personal electronics, presence detection, motion detection, and gesture detection.

1.1. Features

- **Antenna on Module**
  - AoM include Single Chip Radar、Antenna、Crystal、16M-bit Flash、Board to Board Connector
  - Board to Board Connector: Pitch 0.35mm / 14pins / Stacking Height 0.8mm
  - Module Interface: UART、SPI、I2C、GPIOs
  - Module dimensions: 15.5x5.5 mm
  - Operating temperature: -40°C to 85°C
- **Single Chip Radar**
  - Arm® M4F® Core with Single Precision FPU (160 MHz)
  - TI Radar Hardware Accelerator (HWA 1.2) for FFT, Log Magnitude, and CFAR Operations (80MHz)
  - 1MB of On-Chip RAM
- **Radar Transceiver**
  - Integrated PLL, Transmitter, Receiver, Baseband and ADC
  - 57 to 64GHz coverage with 7-GHz
  - 3 Receive and 2 Transmit Channels
  - FMCW Operation
  - Single transmitter EIRP: 17dBm typical
- **Supports Multiple Low-power Modes**
  - Idle Mode
  - Deep Sleep Mode
- **Power Management**
  - 1V8 and 3V3 VIO support
  - BOM-Optimized or Power-Optimized design option base on Customer out of module
- **Support Algorithm from TI**
  - Presence and Motion detection
  - People Counting / Tracking
  - Gesture Recognition
  - Human vs non-human classification
- **Applications**
  - Video doorbell
  - IP network camera
  - Smart Television
  - Home theater
  - Wearable device

1.2. Block Diagram

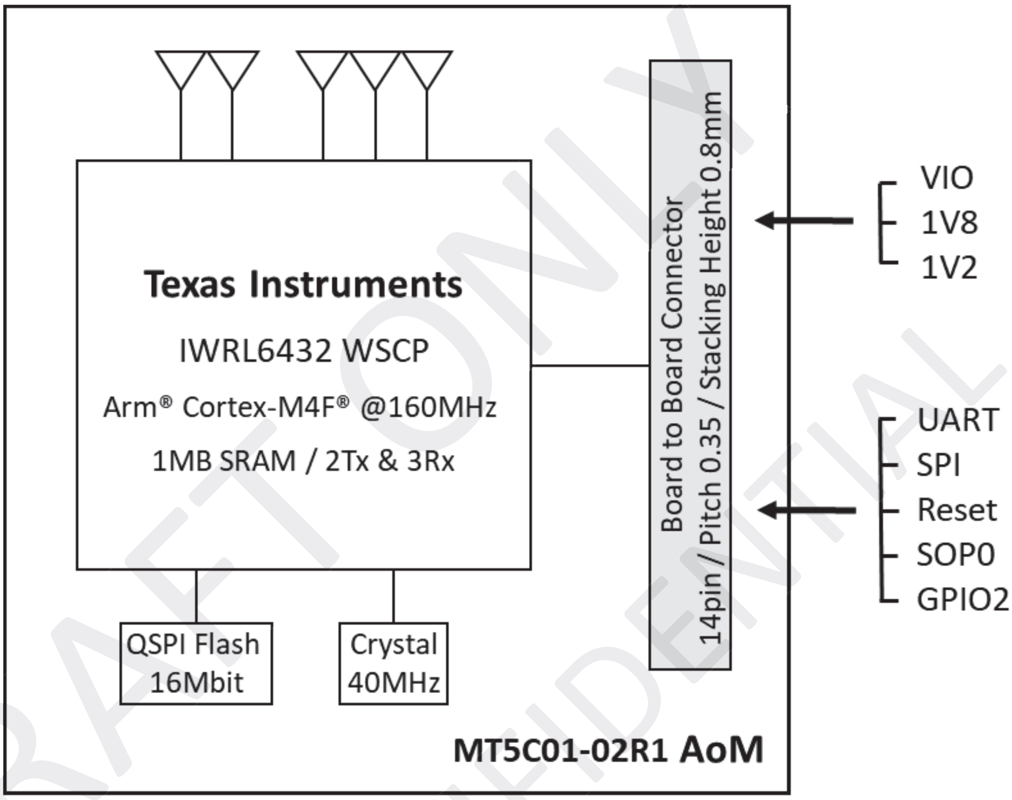
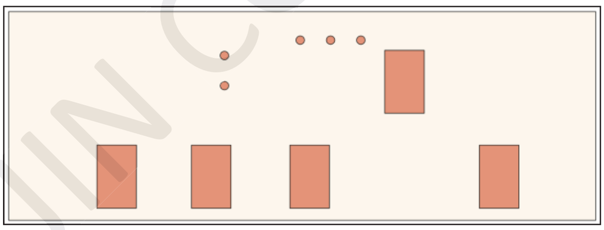
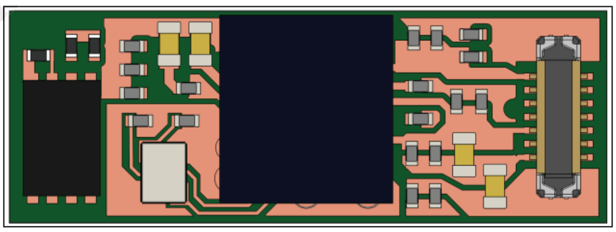


Figure 1-1. MT5C01-02R1 Block Diagram



Top View



Bottom View

Figure 1-2. MT5C01-02R1 Drawing

1.3. Module Pin Define

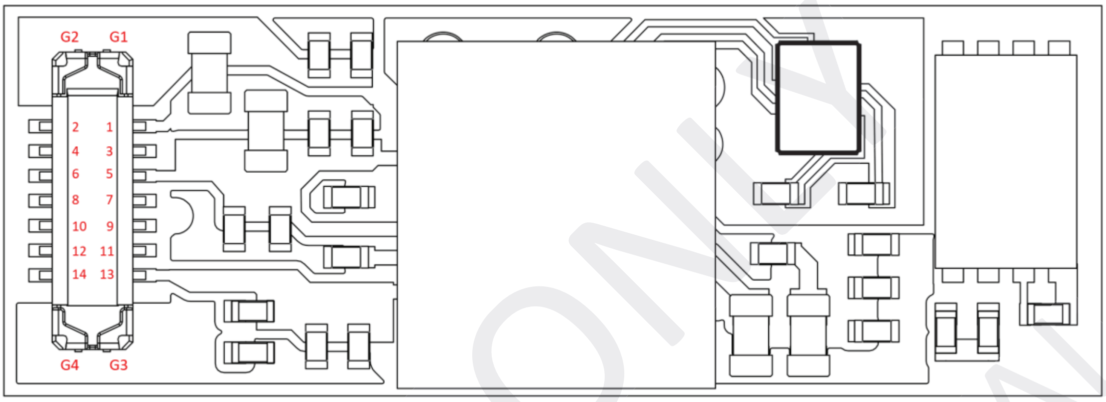


Figure 1-3. MT5C01-02R1 Bottom View

Pin define of Board to Board Connector

Pin No.	Signal Name	Description
1	GND	Ground.
2	RADAR_SPI_MOSI	SPI Master Out Slave In.
3	RADAR_1V8	Module 1V8 Supply.
4	RADAR_SPI_MISO	SPI Master In Slave Out.
5	RADAR_1V8	Module 1V8 Supply.
6	RADAR_SPI_CS	SPI Chip Select.
7	RADAR_NRST	Power on reset for chip. Active low.
8	RADAR_SPI_CLK	SPI Clock.
9	RADAR_HOST_INTR	Out of Band Interrupt to an external host communicating over SPI.
10	RADAR_RS232_RX	Debug UART (Operates as Bus Main) – Receive Signal.
11	RADAR_GPIO2	General purpose I/O.
12	RADAR_RS232_TX	Debug UART (Operates as Bus Main) – Transmit Signal.
13	RADAR_VIO	Module VIO Supply. Support 1.8V or 3.3V.
14	RADAR_SOP0	Module functional mode default. Pull-down if need to set to flash mode.
G1	RADAR_1V2	Module 1V2 Supply.
G2	RADAR_1V2	Module 1V2 Supply.
G3	GND	Ground.
G4	GND	Ground.

2. SPECIFICATIONS

2.1. Recommended Operating Conditions

PARAMETER		Min	Typ	Max	Units
RADAR_1V8	1.8V power supply input	1.71	1.8	1.89	V
RADAR_1V2	1.2V power supply input	1.14	1.2	1.26	V
RADAR_VIO	3.3V power supply input for module IO	3.135	3.3	3.465	V
	1.8V power supply input for module IO	1.71	1.8	1.89	V
V_{IH}	Voltage Input High (VIO=3.3V)	2.25			V
	Voltage Input High (VIO=1.8V)	1.17			V
V_{IL}	Voltage Input Low (VIO=3.3V)			0.62	V
	Voltage Input Low (VIO=1.8V)			0.57	V
RADAR_NRST RADAR_SOP0	V_{IH} (VIO=3.3V)	1.57			V
	V_{IL} (VIO=3.3V)			0.3	V
	V_{IH} (VIO=1.8V)	0.96			V
	V_{IL} (VIO=1.8V)			0.2	V
Phase noise	At 1-MHz offset		-89		dBc/Hz
Operating temperature		-40		85	°C

2.2. RF and Antenna Specification

PARAMETER	Min	Typ	Max	Unit
RF frequency range (1)	57		64	GHz
Single transmitter output power EIRP		+17		dBm
Antenna gain of single transmitter		5		dBi
Field of View of Azimuth		150		degree
Field of View of Elevation		120		degree
Detection Range (2)			20	meters

(1) The module RF frequency range is 57-64GHz. Based on application and certification of end product, the use range will be changed.

(2) Based on motion detection application, the detection range is 20m at Boresight and 15m at FOV Edges for Human.

2.3. Typical Power Consumption Numbers

Below table lists the typical power consumption for each power save modes in different power topologies and antenna configurations.

Estimated Power Consumed

Power Mode		Power Consumption (mW)	
		Power Optimized Mode	BOM Optimized Mode
Active (2TX, 3RX)	Sampling: 12.5 MSps, Continuous Streaming Mode Freq =60 GHz TX Power = 10dBm RX gain = 30 dB	987	1334
Active (1TX, 1RX)		655	986
Processing		159	233
Idle	APPSS CM4 = 20MHz, FECSS, HWA powered off, SPI Interface active	13.8	23.13
Deep sleep (VIO=3V3)	Memory Retained = 114KB	1.38	1.34
Deep sleep (VIO=1V8)		0.64	0.78

Use Case Power Consumed (VIO=3.3V, Power optimized mode)

Parameter		Condition	mW
Average Power Consumption (Presence Detection)	RF Front End Configuration :2TX, 3RX 5MHz Sampling Rate Num of ADC samples = 64 Ramp End time = 19us Chirp Idle Time = 6us Chirp Slope = 32MHz/us Number of chirps per burst = 8 Burst Periodicity = 300us Number of bursts per frame = 1 Device configured to go to deep sleep state after active operation. Memory Retained in deep sleep = 900KB	1Hz Update Rate	2.52

3. ANTENNA RADIATION PATTERNS

3.1. Antenna Positions

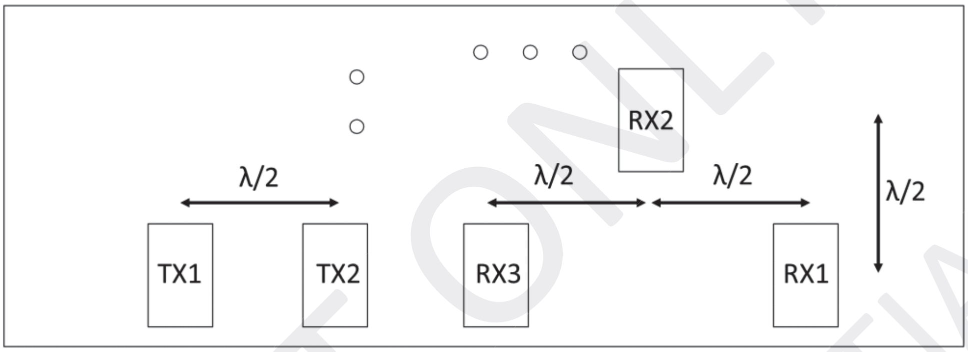


Figure 3-1. Antenna position of module

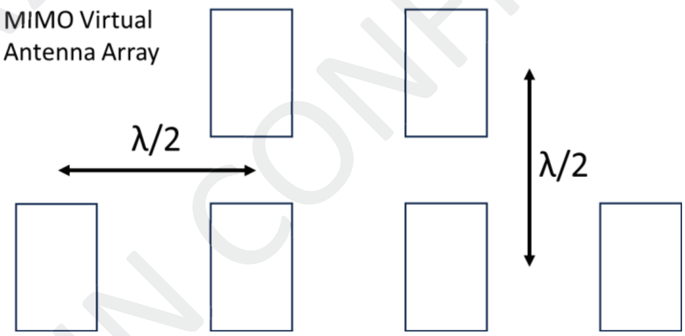


Figure 3-2. 2x4 MIMO Virtual Antenna Array

3.2. Radiation Patterns Simulation

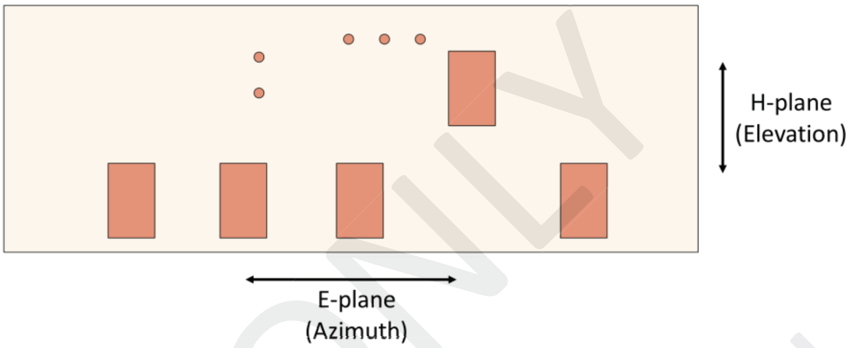
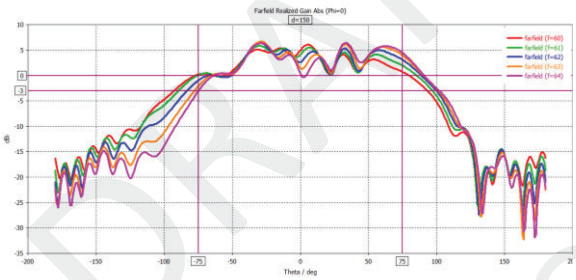
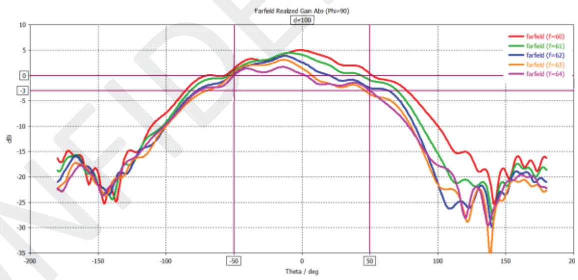


Figure 3-3. Azimuth and Elevation of module

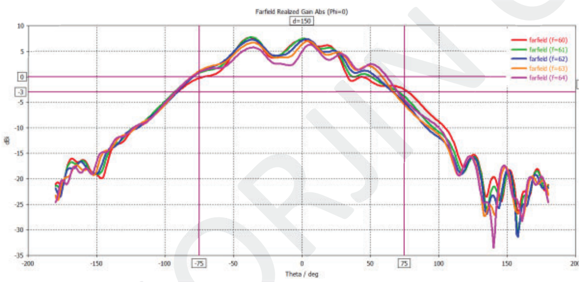
TX1 E-Plane



TX1 H-plane



TX2 E-Plane



TX2 H-plane

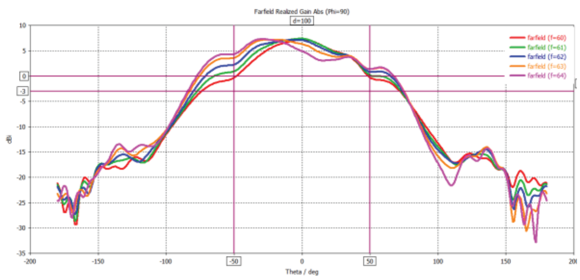
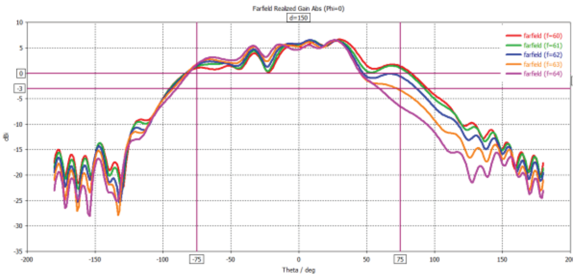
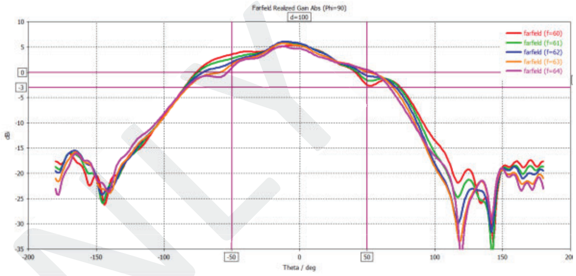


Figure 3-4. Transmitter Antenna Radiation Pattern

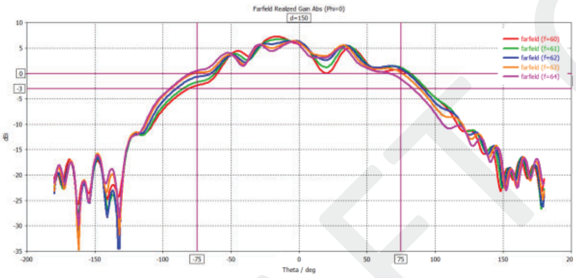
RX1 E-Plane



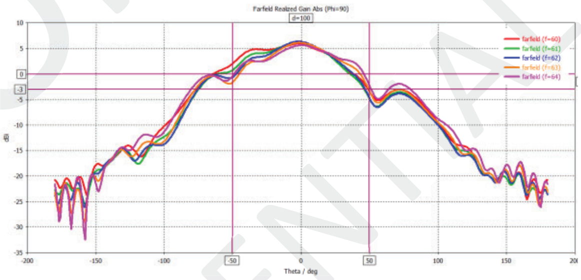
RX1 H-plane



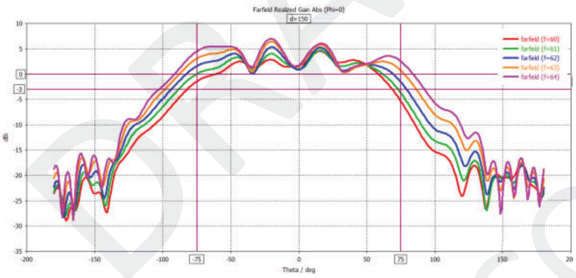
RX2 E-Plane



RX2 H-plane



RX3 E-Plane



RX3 H-plane

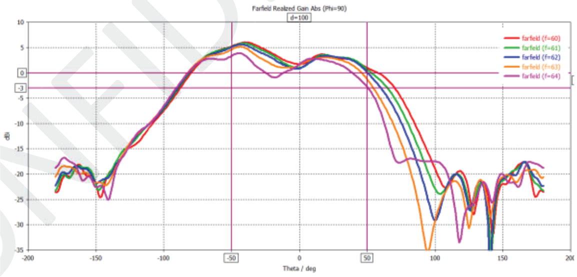


Figure 3-5. Receiver Antenna Radiation Pattern

4. MMWAVE RADOME DESIGN GUIDE

4.1. Radome Material

In order to minimize 60 GHz signal attenuation at the radome, we need to minimize the dielectric loss at the radome. Materials with low dielectric constant (Dk, εr) and low tangent loss (Df, tanδ) value, will have smaller dielectric losses.

The following are common plastic materials that have acceptable permittivity and loss tangent properties.

Material	Dielectric constant (εr)	Loss tangent (tanδ)
ABS [1]	2.0-3.5	0.005-0.019
Teflon (PTFE)	2.0	< 0.0002
Polypropylene (PP)	2.2	0.0005
Polyethylene (PE)	2.3	0.0003
Polystyrene (PS)	2.5	0.0004
Polycarbonate (PC)	2.9	0.012

Note:

1. In the market, plastic might be called ABS, but it could contain additives. (e.g. fire retardants)

The additives could cause changes in the dielectric constant because in chemical terms they are **polar materials**, and these polar materials will cause an increase in dielectric constant.

4.2. Radome simulations

In general, radome performance depends mainly on the frequency of use, thickness, Dk/Df, air gap, shape and size. This section used radome designs and simulations performed with the Jorjin antenna using a rectangular radome as a case. And compared the far-field antenna radiation patterns with and without radome.

The setting of the simulation:

- TX2 E-plan at 62GHz
- DK=2.7 / Df=0.003
- Air Gap 2.5mm (λ/2 at 60GHz)
- Thickness from 1.1 to 2.5mm

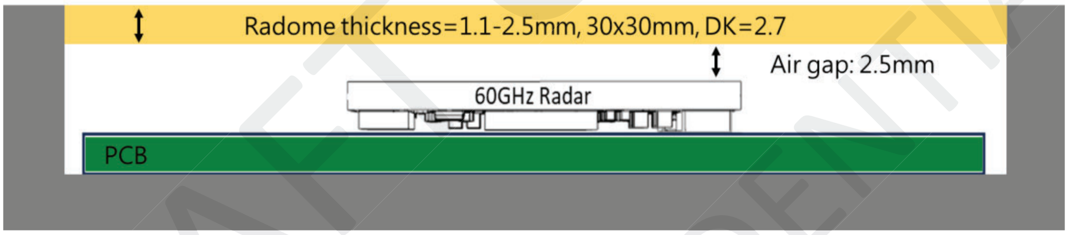


Figure 4-1. Simulation model of Radome

TX1+RX3 E-plan at 62GHz / Air Gap of Radome=2.5mm

Radome thickness (mm)	Gain difference between with Radome and no Radome (dBm)					Notes
	-70°	-60°	0°	+60°	+70°	
1.1mm	-0.5	-0.3	+2.7	-1.7	+0.2	
1.5mm	+3.1	-0.4	-2.8	-1.5	+3.1	
1.8mm	+3.2	+1.0	-1.1	+1.5	+4.0	Width FOV
2.5mm	+0.8	+2.9	+3.1	-7.7	-3.2	

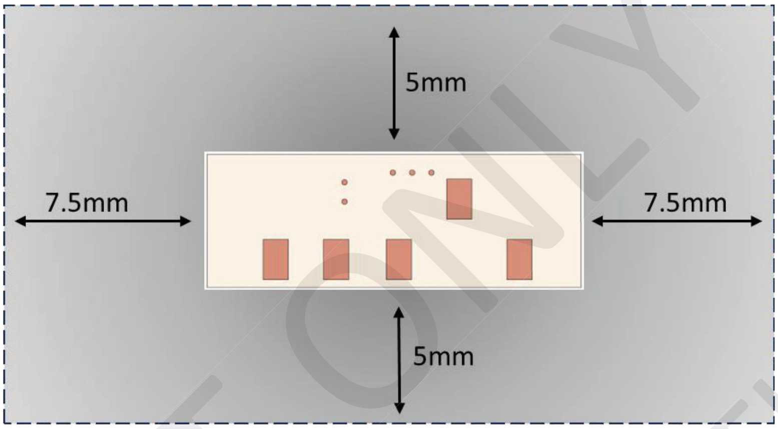
TX2+RX3 E-plan at 62GHz / Air Gap of Radome=2.5mm

Radome thickness (mm)	Gain difference between with Radome and no Radome (dBm)					Notes
	-70°	-60°	0°	+60°	+70°	
1.1mm	-0.2	+0.3	+2.2	+0.8	+1.7	
1.5mm	+2.1	-0.4	+0.5	+0.9	+6.1	
1.8mm	+3.2	+0.7	+1.6	+2.7	+6.8	Width FOV
2.5mm	-1.8	0	+1.7	+0.1	+5.6	

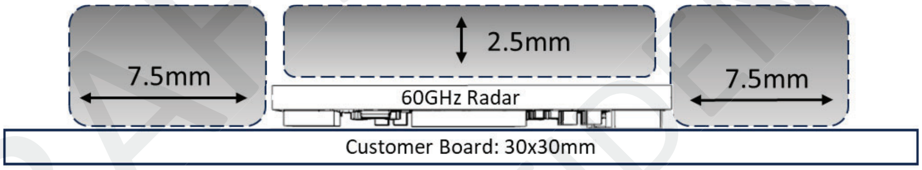
Figure 4-2. FOV simulation with difference radome thickness

4.3. Clearance Area Recommendation of Module

Recommended clear area of MT5C01-02R1 AoM module with no components over the module as below.



Top View



Front View

Figure 4-3. Recommend Clear Area of Radar module

4.4. Radome Recommendation of Module

According to Radome simulation in section 4-2, we assume your product has a planar flat surface above the radar. In this case, the radome thickness would give a good signal.

- **Radome thickness:** 1.8mm, if used PC (Dk=2.7 , Df=0.003) for radome.
- **Air Gap:** 2.5mm (λ/2 at 60GHz)
- **Radome size:** 30x30mm

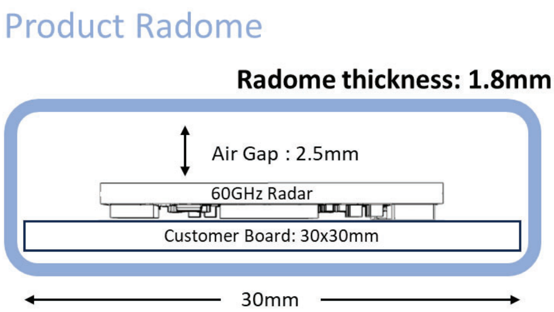


Figure 4-4 . Recommend design of Radome

5. MODULE REFERENCE DESIGN

5.1. Reference Schematic

<u>Power Optimized mode</u> ***(Recommended)***

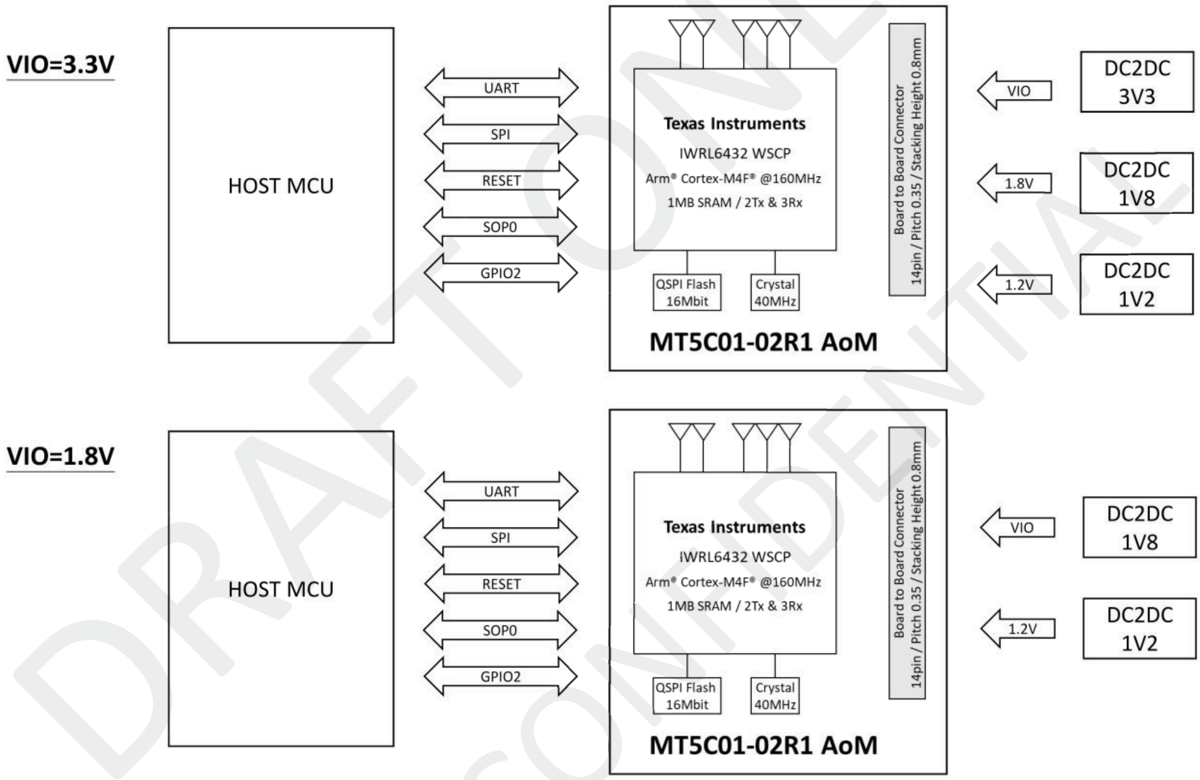
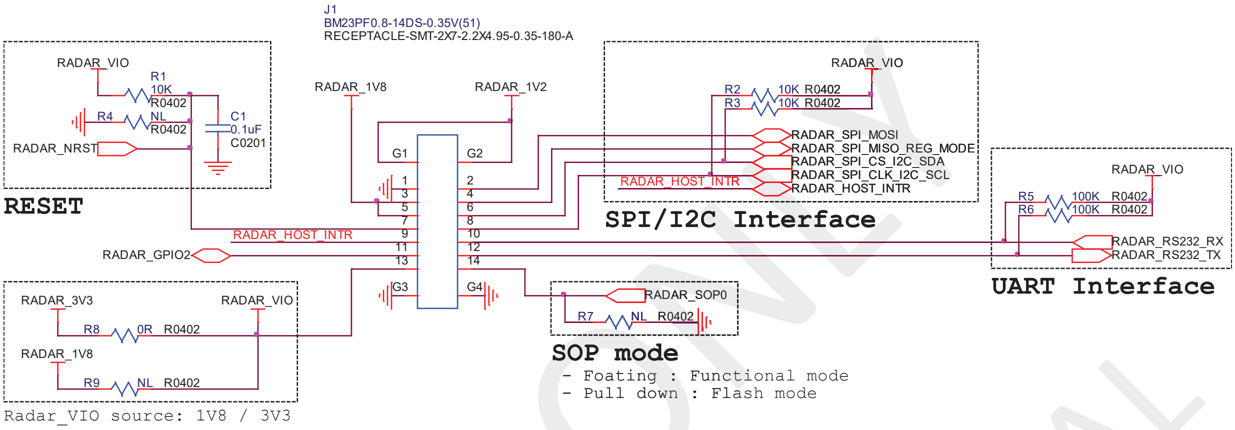


Figure 5-1. System Hardware Topology - Power Optimized mode



DC2DC Circuit

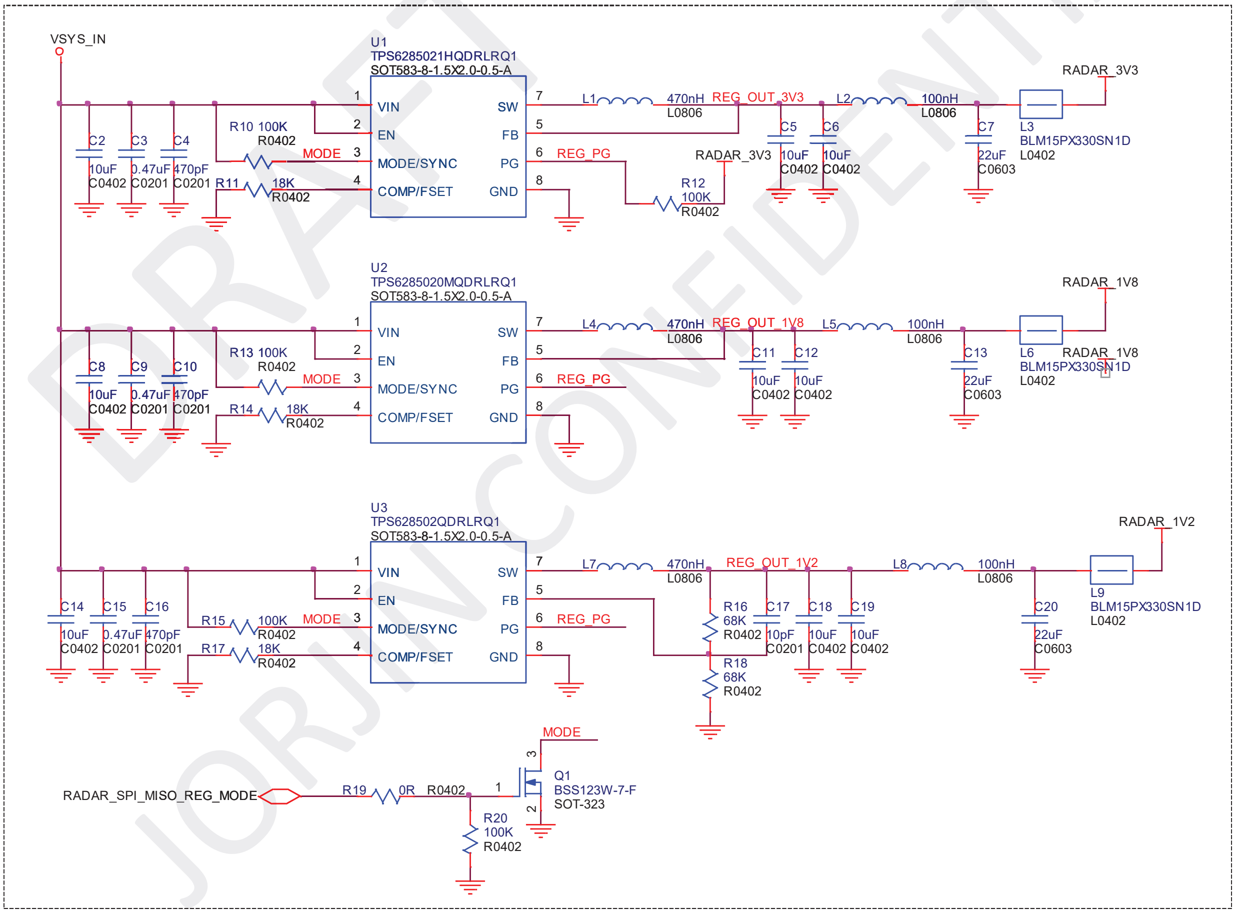


Figure 5-2. Reference Schematic - Power Optimized mode

BOM Optimized mode [1]

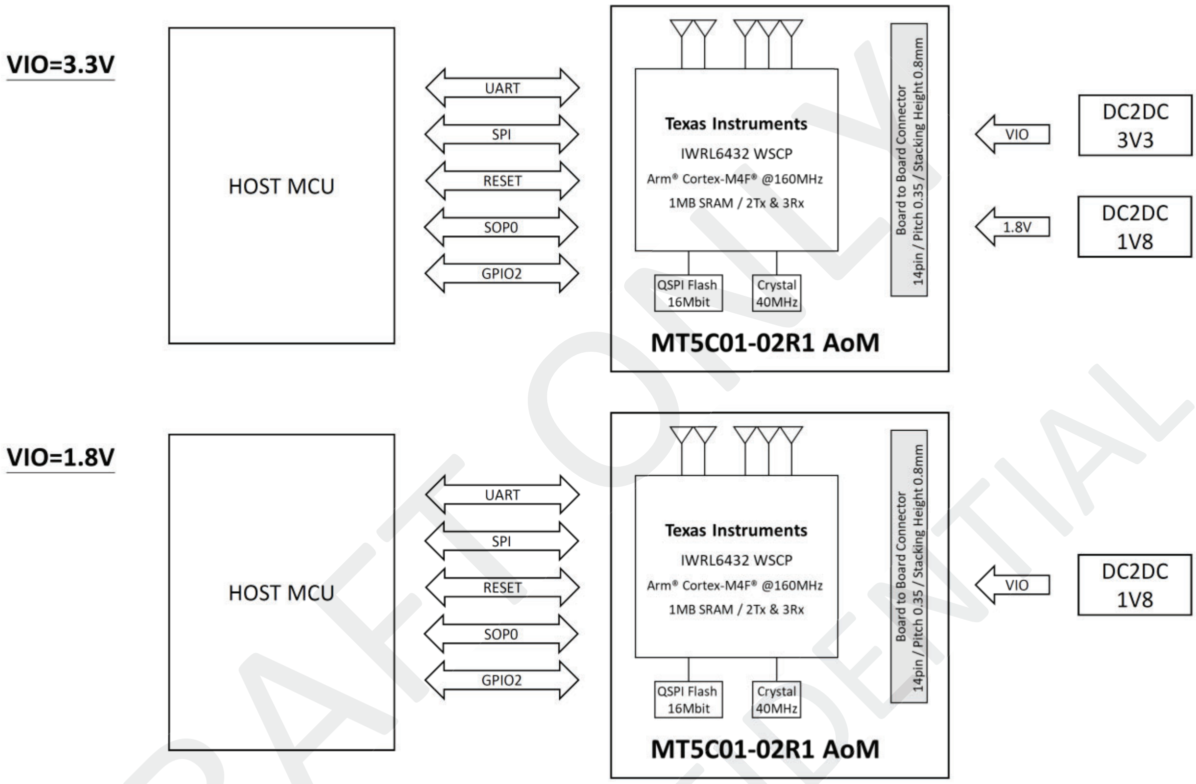
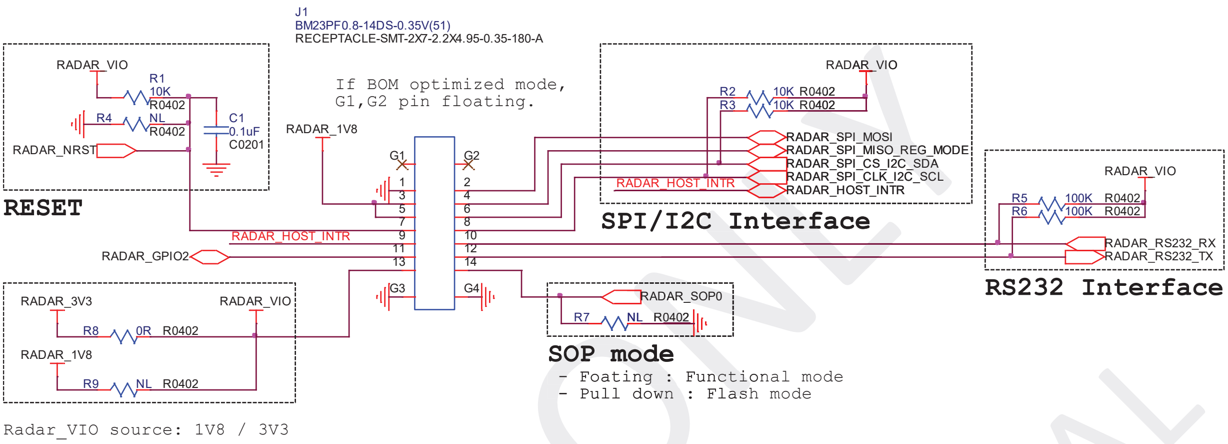


Figure 5-3. System Hardware Topology - BOM Optimized mode

(1) If need to use this mode, please check with Jorjin FAE for review.



DC2DC Circuit

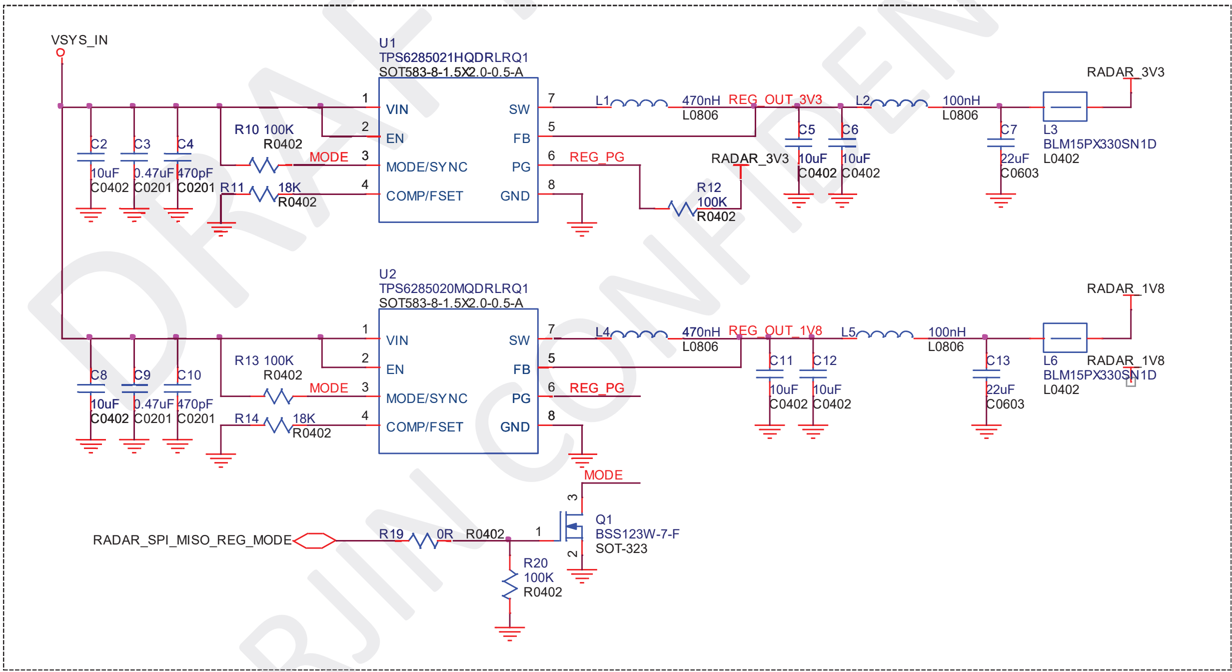


Figure 5-4. Reference Schematic - BOM Optimized mode

5.2. Connector Recommendation for Customer

The Board to Board Connector plug of Hirose BM23PF0.8-14DP-0.35V(51) is be used in the MT5C01-02R1 Module. Please ensure that must be used Receptacle type of Hirose BM23PF0.8-14DS-0.35V(51) to correct positioning the module on board.

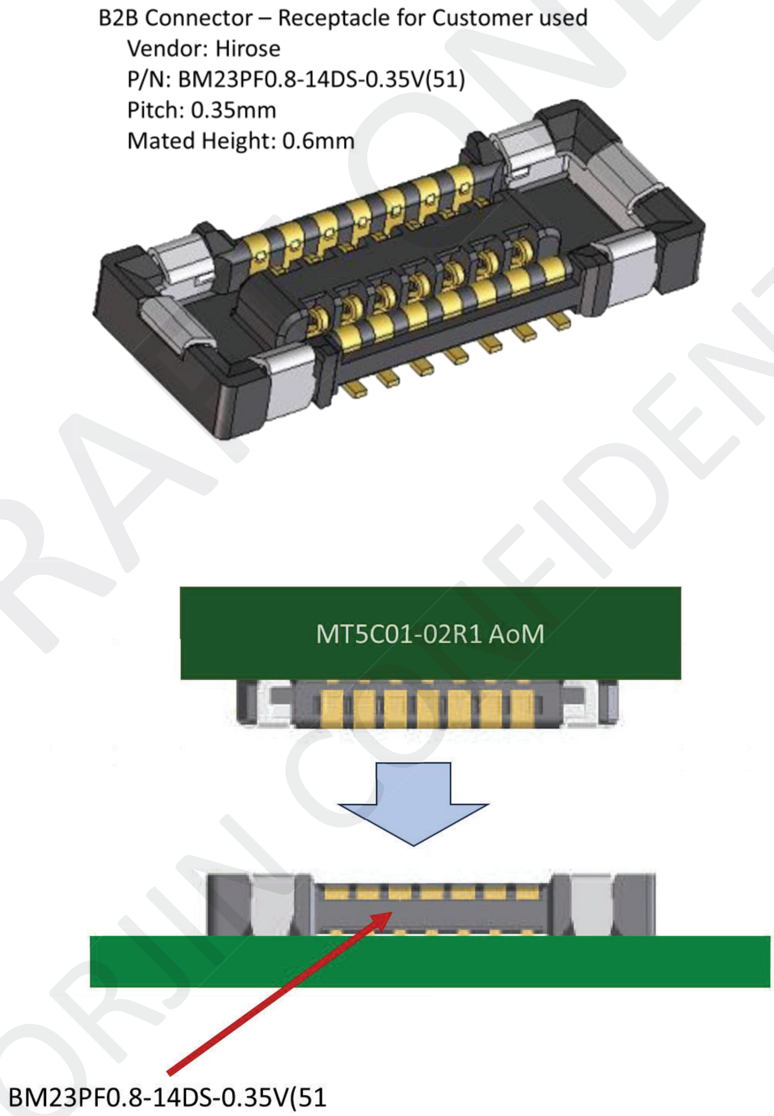
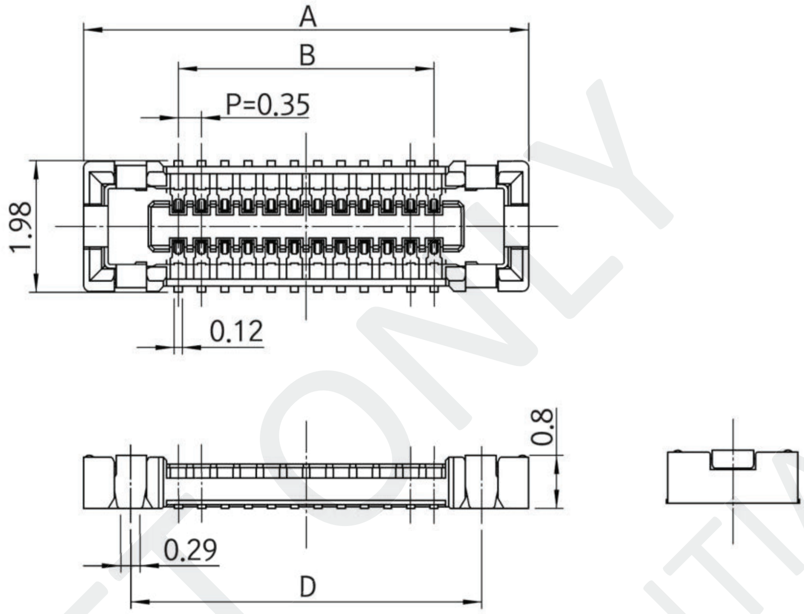
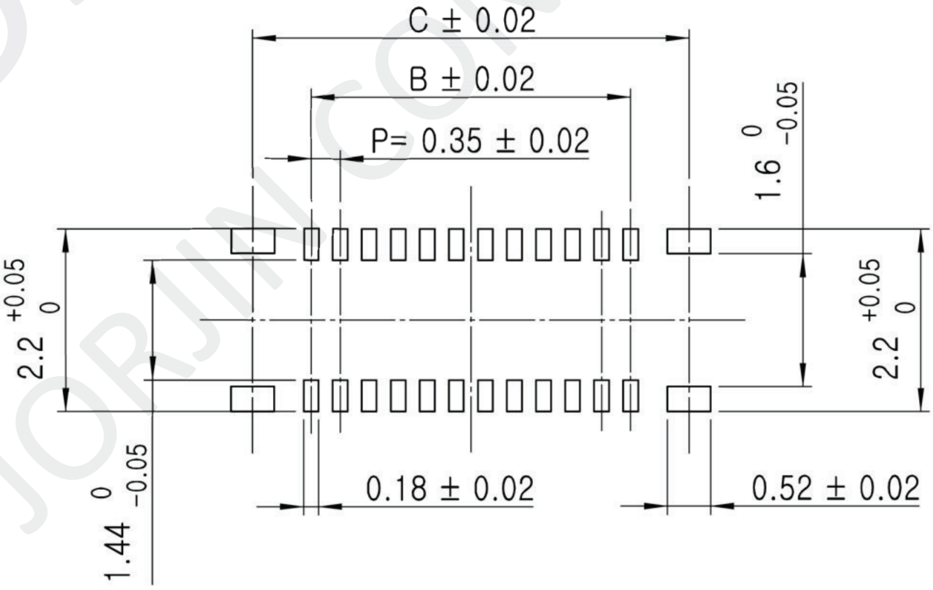


Figure 5-5. Board to Board Connector for Customer



Part No.	HRS No.	No. of contacts	A	B	C	D
BM23PF0.8-14DS-0.35V(***)	480-0367-0 **	14	4.95	2.10	3.51	3.54

Figure 5-6. Connector Dimensions of Hirose BM23PF series

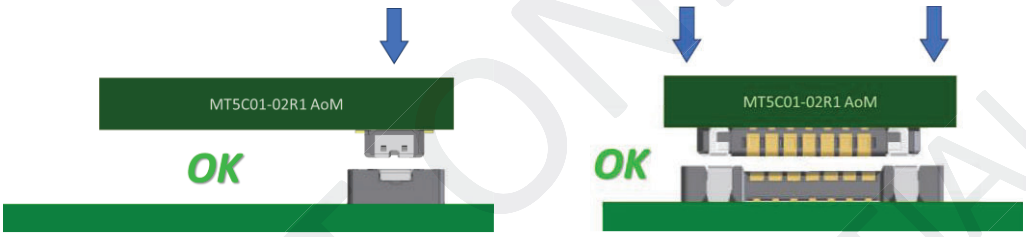


Part No.	HRS No.	No. of contacts	A	B	C	D
BM23PF0.8-14DS-0.35V(***)	480-0367-0 **	14	4.95	2.10	3.51	3.54

Figure 5-7. Recommended PCB Layout of Hirose BM23PF series

Notice for Connector Handling

When aligning, look for the guide port without applying excessive force.
When guided, the connectors are aligned parallel to each other with longitudinal and lateral movements restricted. Mate them parallel to each other.



Un-mate connectors parallel to each other.

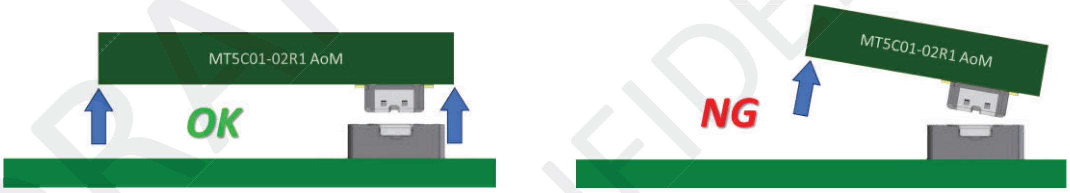


Figure 5-8. Correct Handle when mating a connector

6. PACKAGE INFORMATIION

6.1. Module Dimension

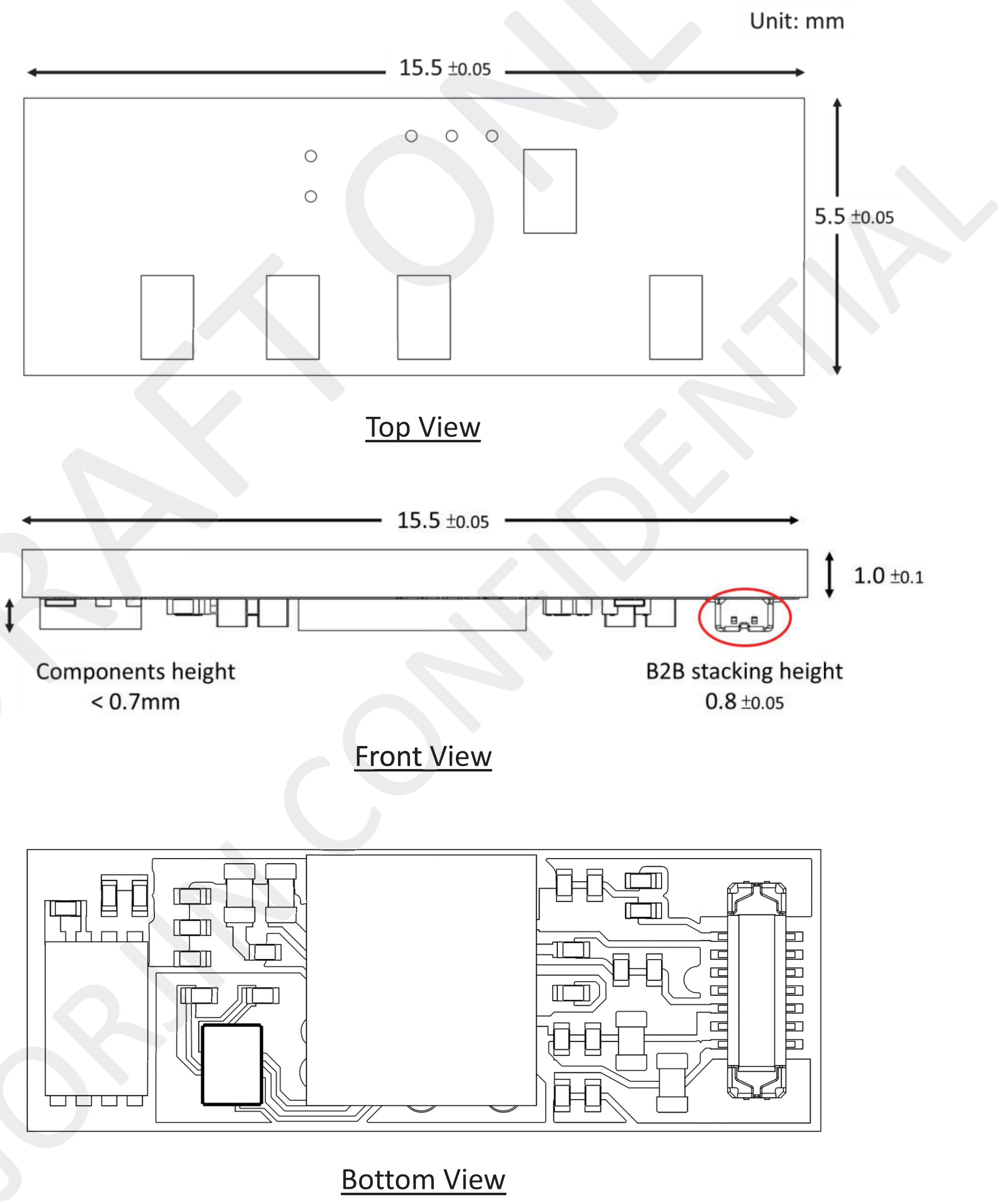
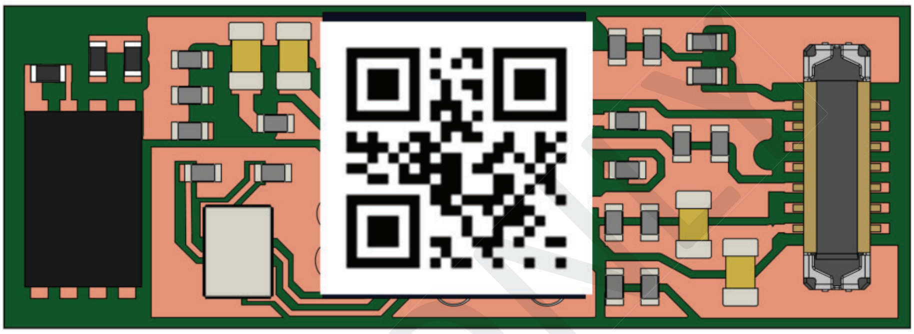


Figure 6-1. MT5C01-02R1 Module Dimension

6.2. Device Label



Code information	Description
YYWW,CXXXXXX	YY : Digit of the year, ex: 2023=23 WW : Week (01~52) C : Product Number, ex: C=MT5C01-02R1 XXXXXX : Series number.

Figure 6-2. Code label on Bottom of module

6.3. Tape Reel information

TBD

7. EVALUATION KIT

The Jorjin mmWave Radar evaluation kit MT5C01E02R1 show as below. Based on the MT5C01-02R1 Radar sensor module. This evaluation kit easy to demo and development for customer.

7.1. Evaluation Hardware Description

The following figure and table describe physical sections of the board.

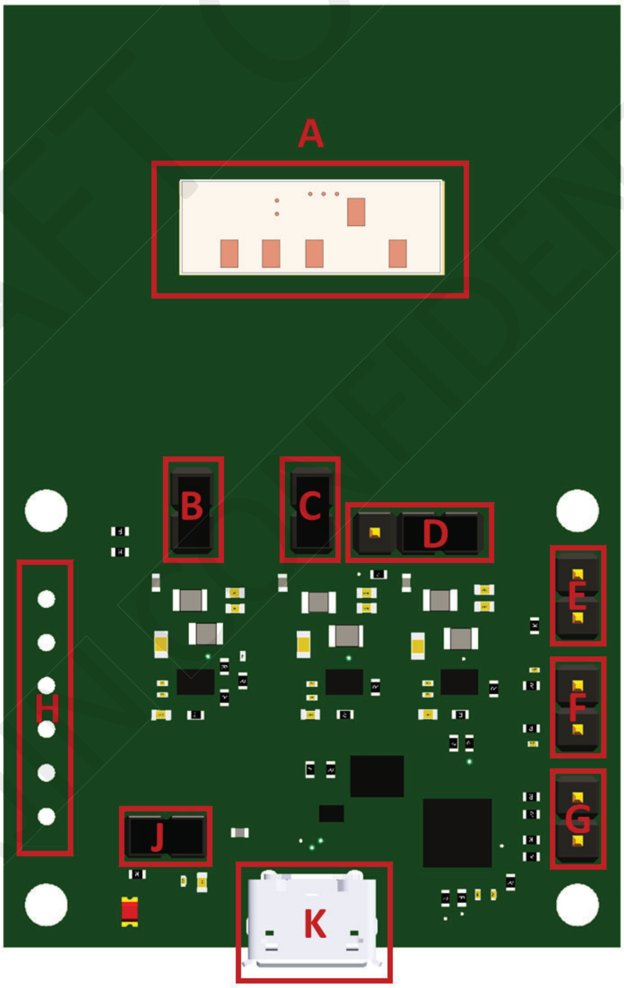


Figure 7-1. MT5C01E02R1 mmWave Radar Evaluation Kit

Table 7-1. Evaluation Kit component descriptions list

Region	Description
A	Jorjin MT5C01-02R1 mmWave Radar module.
B	1V2 power source of Module.
C	1V8 power source of Module.
D	VIO power source selection of Module: - 3.3V: Jumper to right. (Default) - 1.8V: Jumper to left.
E	SOP0 selection: - Functional mode: Jumper open. (Pull-up) - Flash mode: Jumper short. (Pull-down)
F	Reset pin of Radar module: - Module working: Jumper open. (Pull-up) - Module reset: Jumper short. (Pull-down)
G	Module RS232 interface reserved.
H	Module SPI interface reserved.
J	5V Power supply to evaluation kit form micro-USB.
K	Micro-USB for function demo and power supply of module.

8. ORDERING INFORMATION

Order number	Description
MT5C01-02R1	60GHz mmWave Radar AoM Module

9. HISTORY CHANGE

Revision	Date	Description
Draft 0.1	2023-12-19	Draft version.
Draft 0.2	2024-02-01	Modify Radome information in Section 4.2~4.4.