RM510Q-GL
mmWave Antenna Design Note

5G Module Series

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About the Document

Revision History

Version	Date	Author	Description
1.0	2020-05-18	Yi YUAN	Initial

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1 Introduction

This document mainly introduces the antenna design note for Quectel RM510Q-GL module when it is used with the Qualcomm QTM525 series antenna BF (beamforming) module, QTM525-2 or QTM525-5. The antenna design note includes the introduction to QTM525-2/QTM525-5, design guidelines, and QTM525-2/QTM525-5 performance.

1.1. Safety Information

The following safety precautions must be observed during all phases of the operation, such as usage, service or repair of any cellular terminal or mobile incorporating RM510Q-GL module. Manufacturers of the cellular terminal should notify users and operating personnel of the following safety information by incorporating these guidelines into all manuals of the product. Otherwise, Quectel assumes no liability for customers' failure to comply with these precautions.

	Full attention must be paid to driving at all times in order to reduce the risk of an accident. Using a mobile while driving (even with a handsfree kit) causes distraction and can lead to an accident. Please comply with laws and regulations restricting the use of wireless devices while driving.
	Switch off the cellular terminal or mobile before boarding an aircraft. The operation of wireless appliances in an aircraft is forbidden to prevent interference with communication systems. If there is an Airplane Mode, it should be enabled prior to boarding an aircraft. Please consult the airline staff for more restrictions on the use of wireless devices on an aircraft.
	Wireless devices may cause interference on sensitive medical equipment, so please be aware of the restrictions on the use of wireless devices when in hospitals, clinics or other healthcare facilities.
	Cellular terminals or mobiles operating over radio signals and cellular network cannot be guaranteed to connect in all possible conditions (for example, with unpaid bills or with an invalid (U)SIM card). When emergent help is needed in such conditions, please remember using emergency call. In order to make or receive a call, the cellular terminal or mobile must be switched on in a service area with adequate cellular signal strength.
	The cellular terminal or mobile contains a transmitter and receiver. When it is ON, it receives and transmits radio frequency signals. RF interference can occur if it is used close to TV set, radio, computer or other electric equipment.
	In locations with potentially explosive atmospheres, obey all posted signs to turn off wireless devices such as mobile phone or other cellular terminals. Areas with potentially explosive atmospheres include fueling areas, below decks on boats, fuel or chemical transfer or storage facilities, areas where the air contains chemicals or particles such as grain, dust or metal powders, etc.

2 Introduction to QTM525-2/QTM525-5

The 5G NR mmWave (millimeter wave) modem system is compounded by two types of module, M.2 module (RM510Q-GL) and RF antenna modules (QTM525-2 or QTM525-5, 2–4 pieces), as shown in the following figure.

Please note that QTM525-2 and QTM525-5 cannot be used at the same time, so please select QTM525-2 or QTM525-5 according to local telecom-market requirements. Two, three, or four RF antenna modules can be used and they must be the same variant.

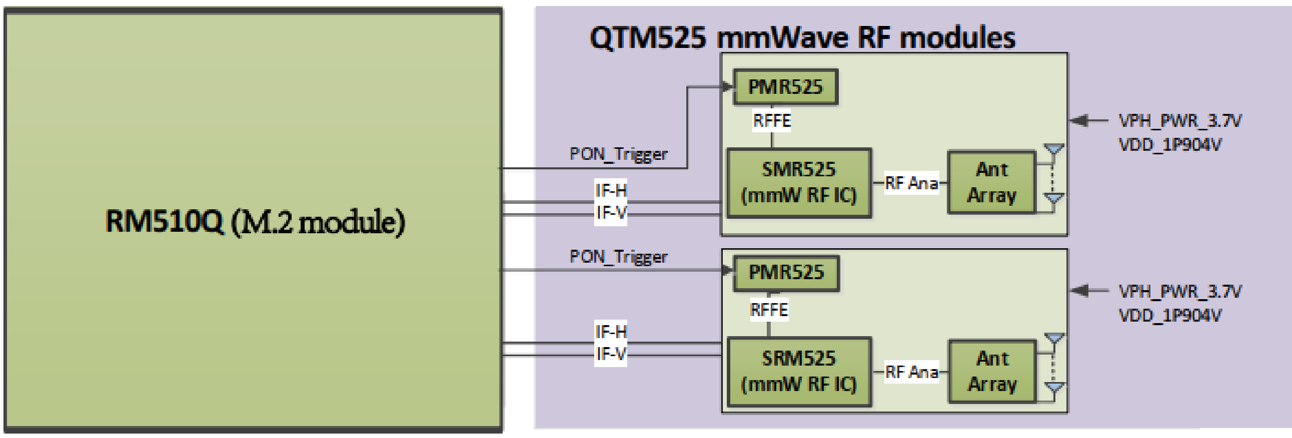

Figure 1: Modem System Diagram

In the above diagram, RM510Q-GL module works as signal baseband and IF (Intermediate Frequency) transceiver for QTM525.

2.1. QTM525-2/QTM525-5 Overview

The QTM525-2/QTM525-5 mmWave antenna module integrates RFIC SMR525, power management IC PMR525, and antenna array supporting 5G NR millimeter beamforming wave.

The following figure shows the high-level block diagram of QTM525-2/QTM525-5, in which the antenna array is 1 × 4 dual-polarized patch type matrix array.

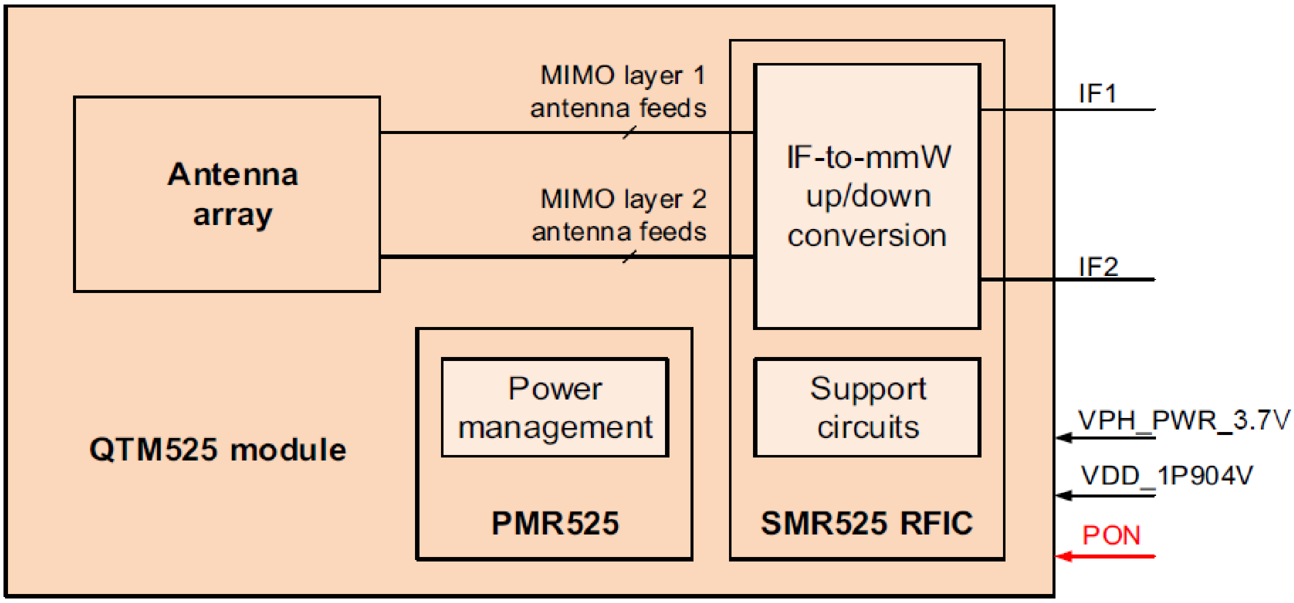

Figure 2: QTM525-2/QTM525-5 Module Block Diagram

The table below shows the key features of the antenna module.

Table 1: Key Features of QTM525-2/QTM525-5

Feature	QTM525 Series
mmWave Transceiver (Common to Rx and Tx)	
3GPP 5G NR support	5G NR Range 2 in Release 15.
RF operating bands	**QTM525-2 variant:** n257 (26.5–29.5 GHz) n258 (24.25–27.5 GHz) **QTM525-5 variant:** n258 (24.25–27.5 GHz) n260 (37–40 GHz) n261 (27.5–28.35 GHz)
MIMO support	Dual-polarization MIMO (horizontal and vertical).
Bandwidth support	Up to 800 MHz occupied bandwidth in any 1.4 GHz frequency range.
Carrier aggregation (CA) support	**DL 2 × 2 MIMO:** up to eight 100 MHz component carriers. **UL 2 × 2 MIMO:** up to four 100 MHz component carriers. **UL 1 × 1 SISO:** up to eight 100 MHz component carriers.
Beamforming support	● Independent amplitude and phase control.

	● Patch antenna elements enable broad spatial coverage.
Duplex mode of operation	TDD only.
mmWave Receiver	
Receiver paths	● One horizontal polarization (IF1) and one vertical polarization (IF2) receiver signal paths. ● Each receiver chain provides amplitude weighting, phase shifting, and I/Q quadrature mmWave-to-IF frequency translation.
mmWave Transmitter	
Transmitter paths	● One horizontal polarization (IF1) and one vertical polarization (IF2) transmitter signal path. ● Each transmitter chain provides amplitude weighting, phase shifting, and I/Q quadrature IF-to-mmWave frequency translation.
Transmit power detectors	Power detector (PDET) to sense forward power for each transmit path. Used for maximum transmit power limiting (MTPL) and factory power calibration.
Other Key Electrical Features	
Operating voltages	Two external supply voltages: VPH_PWR_3.7V and VDD_1.904V nominal.
Digital control interfaces	SMR525 control signal provided by IF signal lines. PON GPIO input signal to enable the PMR525 PMIC.
Fabrication Technology and Packaging	
Package type	QTM525-2/QTM525-5 variants (1 × 4 dual-polarized patch arrays): 23 mm × 4.2 mm × 1.86 mm nominal (1.97 mm maximum).
Package technology	● Antenna array printed on the top layers of the module substrate. ● SMR525 RFIC die, PMR525 PMIC die, and passives mounted on the bottom of the module substrate.

2.2. Physical Dimensions

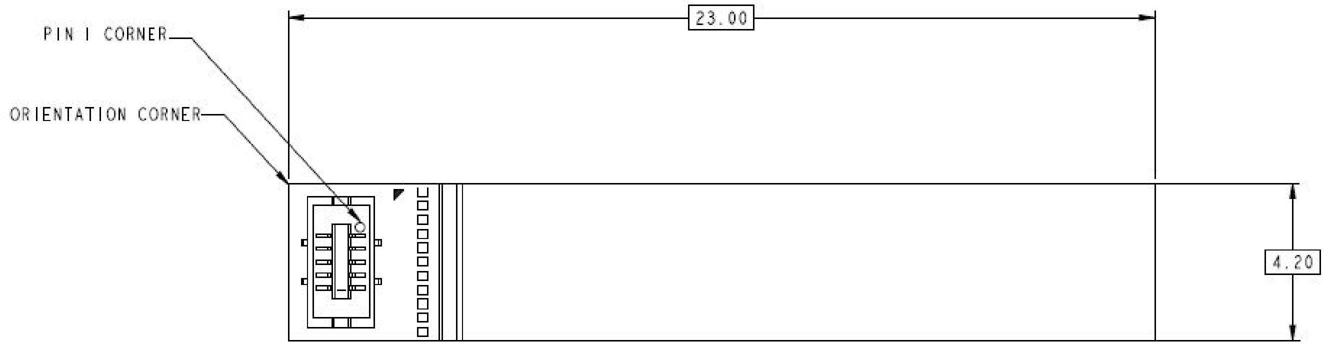

Figure 3: Front View of QTM525-2/QTM525-5

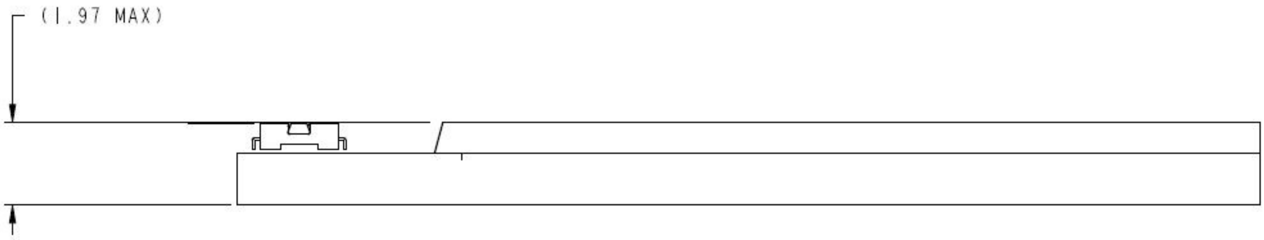

Figure 4: Side View of QTM525-2/QTM525-5

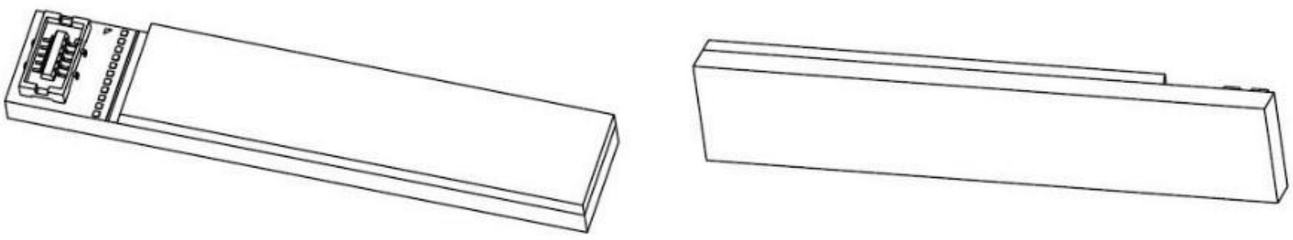

Figure 5: Package Outline Drawing of QTM525-2/QTM525-5

2.3. Pin Definition

The QTM525 series module has a board-to-board connector to provide electrical power, grounding, and IF signal connections.

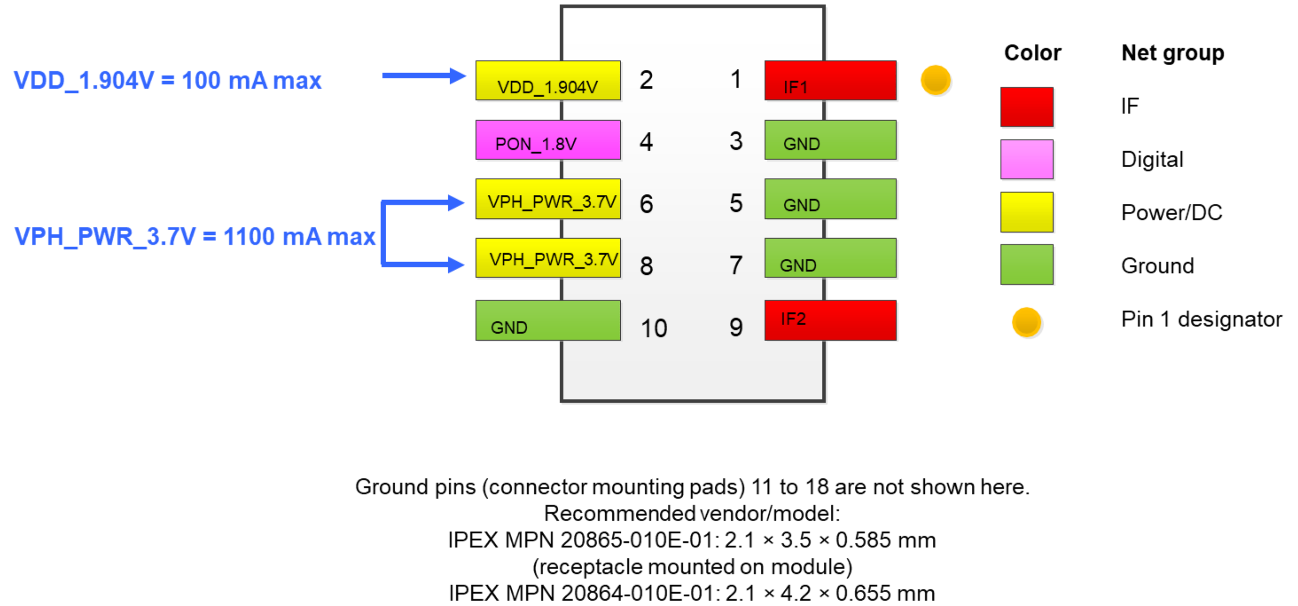

Figure 6: Pin Assignment of QTM525-2/QTM525-5

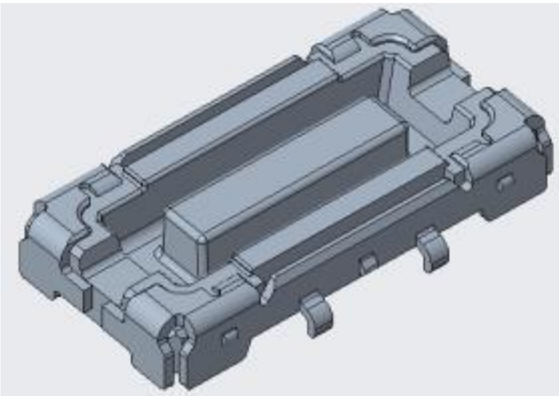

Figure 7: IPEX MPN 20865-010E-01 Mounted on QTM525

Table 2: Pin Definition of QTM525-2/QTM525-5

Pin Name	Pin No.	Description
IF1	1	IF signal input and output 1
IF2	9	IF signal input and output 2
PON_1.8V	4	PMR525 enable input signal from SDX55
VPH_PWR_3.7V	6, 8	3.7 V nominal power supply
VDD_1.904V	2	1.904 V power supply
GND	3, 5, 7, 10–18	Ground

2.4. Electrical Specifications

Table 3: Operating Conditions

Parameter	Description	Min	Typ.	Max	Unit
Power-supply Voltages					
VPH_PWR_3.7V	Power for PMR525, 3.7 V nominal power supply	2.5	3.7	4.8	V
VDD_1P904V	Power for analog and digital circuits (1.904 V)	1.85	1.904	2.04	V
Thermal Conditions					
T	Device operating temperature	Ta = -30	–	Tj = 85	°C

Table 4: Digital-logic Characteristics

Parameter	Description	Min	Typ.	Max	Unit
V_{IH}	High-level input voltage	0.65 × V_{IO}	–	V_{IO} + 0.3	V
V_{IL}	Low-level input voltage	-0.3	–	0.65 × V_{IO}	V
V_{HYS}	Schmitt hysteresis voltage	15	–	–	mV
I_{IL}	Input leakage current	-400	–	400	nA
C_{IN-D}	Input capacitance, digital input	–	–	20	pF

NOTE

V_{IO} is 1.8 V nominal.

2.5. Antenna ID Designation

Each QTM525 module has four dual-polarized patches assembled as an array. For debugging or beamforming calibration, according to the coordinate system, the antenna elements have ID designation, which will be used for configuration and later test.

Table 5: Parameter Definition

Designator	Description
a	Array
h	Horizontal
n	Array element n = 1, 2, 3, 4
P	Patch antenna
v	Vertical

Table 6: Virtual Designation

Antenna ID Designation	Description
hPn	Patch antenna, h-pol, n = 1, 2, 3, 4
vPn	Patch antenna, v-pol, n = 1, 2, 3, 4
hPa2	Patch antenna, h-pol, array of 2
hPa4	Patch antenna, h-pol, array of 4
vPa4	Patch antenna, v-pol, array of 4
hvPa4	Patch antenna, hv-dual pol, array of 4

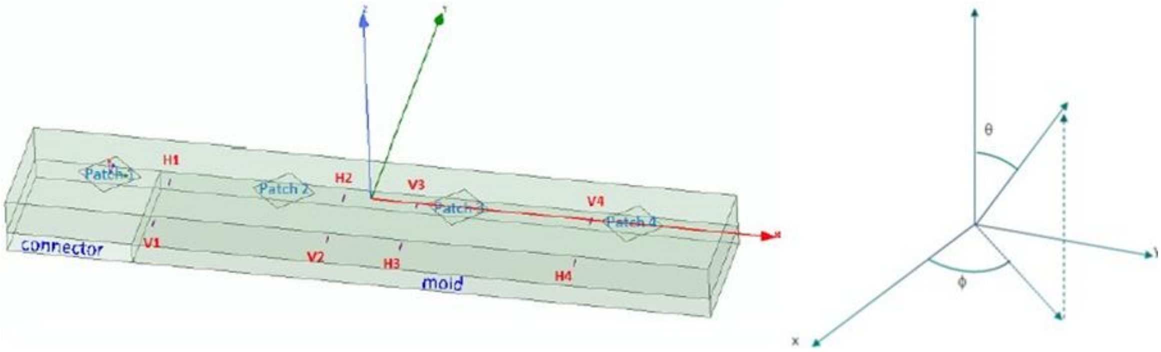

Figure 8: Coordinate System (X, Y, and Z) of QTM525-2

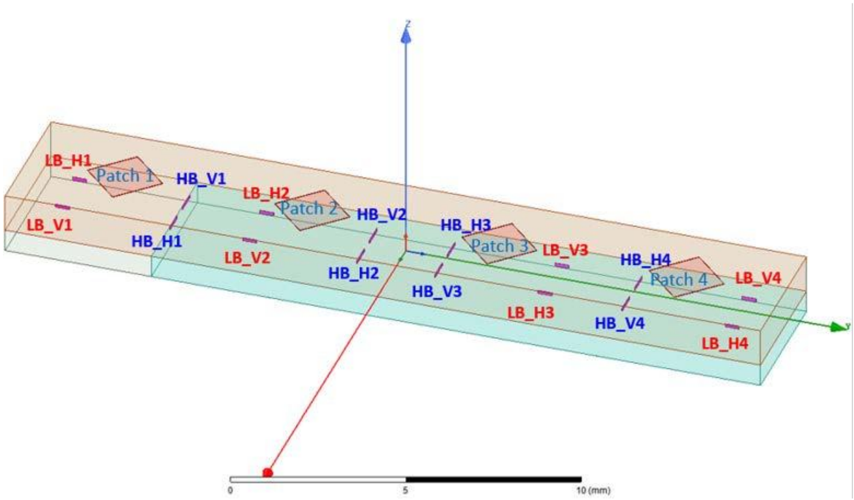

Figure 9: Coordinate System (X, Y, and Z) of QTM525-5

2.6. Other Logical Designation

Table 7: Debug Parameters Configuration

Designation	Description
Module ID	_0, _1, _2, _3 represents QTM525 module ID number, e.g. QTM525_0.
Port ID	**IF interface ID number:** IFH1/IFV4 for QTM525_0. IFH4/IFV1 for QTM525_1. IFH2/IFV3 for QTM525_2. IFH3/IFV2 for QTM525_3.
Antenna group ID	Antenna group index (AG0, AG1) for polarization
Beam ID	**Beam Identifier (0–255):** 0–127 for MIMO chain 0. 128–255 for MIMO chain 1.
Antenna element patch ID	Antenna Element Patch ID 0-3 for QTM525-2/QTM525-5
Feed point ID	Antenna signal power feeding port for H/V polarization. H1/V1. H2/V2. H3/V3. H4/V4.

3 Antenna Design Guidelines

3.1. QTM525-2/QTM525-5 Placement

Placement of antenna modules QTM525-2/QTM525-5 in UE should meets the minimum peak EIRP and spherical coverage requirements of 3GPP protocol. Placement and number of the antenna modules affect the spherical coverage requirements.

3.1.1. 3GPP Requirements

3GPP TS 38.521 defines four types of UE on the basis of power class.

Table 8: Assumption of UE Types

UE Power Class	UE Type
1	Fixed wireless access (FWA) UE
2	Vehicular UE
3	Handheld UE
4	High power non-handheld UE

The following table shows the minimum peak EIRP requirement for different types of UE.

Table 9: Minimum Peak EIRP Requirement for UE with Different Power Class

Operating Band	Min. Peak EIRP (Unit: dBm)			
n257	40.0	29	22.4	34
n258	40.0	29	22.4	34
n260	38.0	TBD	20.6	31

n261	40.0	29	22.4	34
UE Power Class	**1**	**2**	**3**	**4**

The following table shows the spherical coverage requirement for UE with different types of power class.

Table 10: Spherical Coverage Requirement for Different Types of UE with Min. EIRP (dBm)

Operating Band	Spherical Coverage (Unit: dBm)			
	85%-tile CDF	60%-tile CDF	50%-tile CDF	20%-tile CDF
n257	32.0	18.0	11.5	25
n258	32.0	18.0	11.5	25
n260	30.0	TBD	8	19
n261	32.0	18.0	11.5	25
UE Power Class	**1**	**2**	**3**	**4**

One RM510Q-GL module works with 2, 3, or 4 QTM525-2 or QTM525-5 antenna modules in switch mode. If less than 4 antenna modules are used, please keep the unused PON pins and IFV/H ports of RM510QQ-GL unconnected.

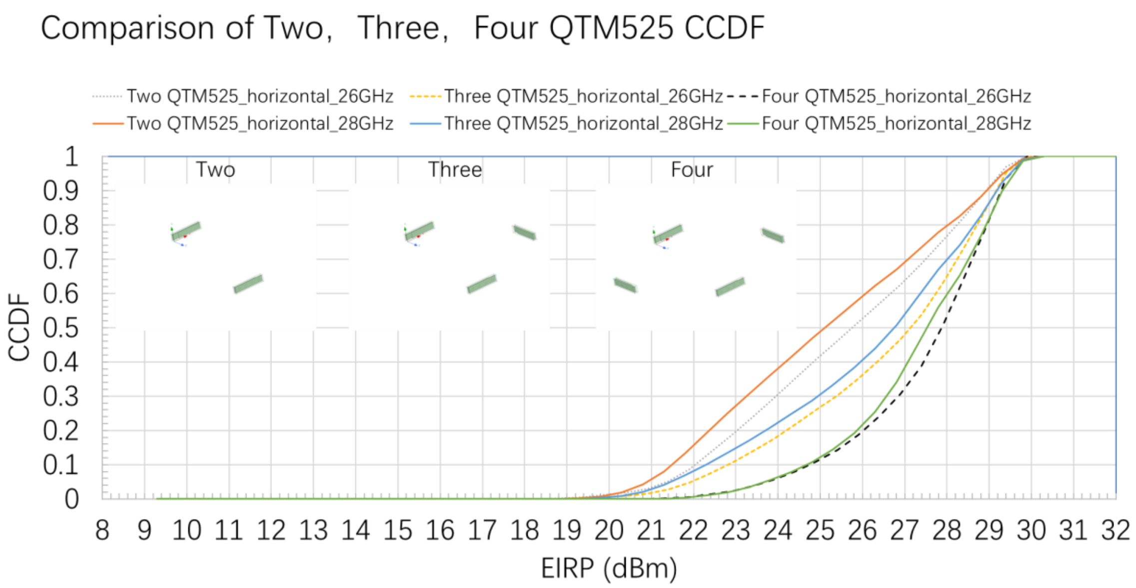

Figure 10: Comparison of Two, Three, Four Horizontal QTM525 at 26 GHz and 28 GHz with CCDF

According to the above figure, every added antenna module provides about 2 dB coverage advantage at 20%-tile.

3.1.2. Antenna Module Placement Reference

In addition to the 3GPP requirements, the antenna modules may be accommodated at the front surface or/and frame of UE (user equipment) device which can mitigate the body or hand blockage issue. The figure below shows a placement reference when the antenna modules are used in a laptop. The modules should be attached to the mechanical ambient frame or surface with different directions.

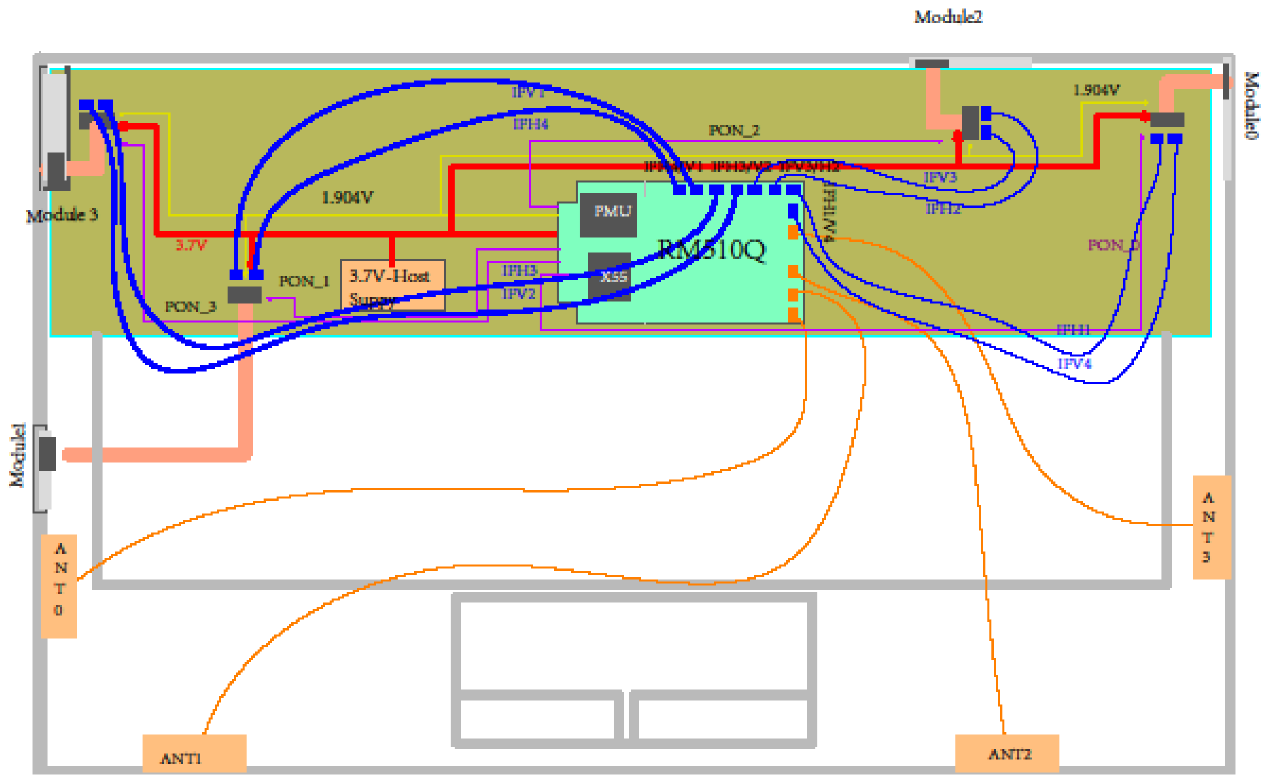

Figure 11: Used in Laptop

The figure below shows a placement reference when the antenna modules are used in phone, tablet PC, MiFi, or hotspot. In such scenario, the antenna modules could be placed at ambient frame for better coverage performance with fine turning angle in industry design.

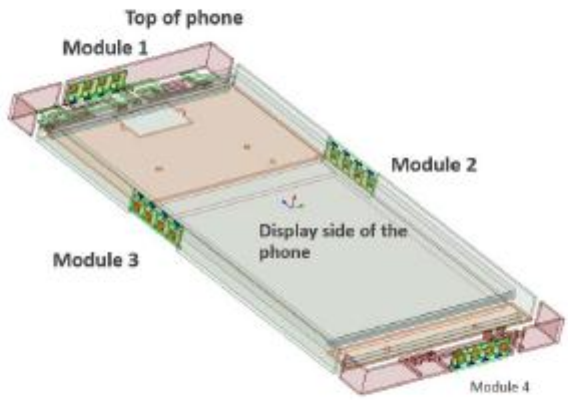

Figure 12: Used in Phone, Tablet PC, MiFi, or Hotspot

3.1.3. Antenna Module Placement Configuration

The susceptibility of mmWave signals to physical blockage presents a challenge to reliable 5G communication. Thus, special attention should be paid to the direction configuration from device antenna to the 5G base station antenna, which is related to user experiment with the UE device.

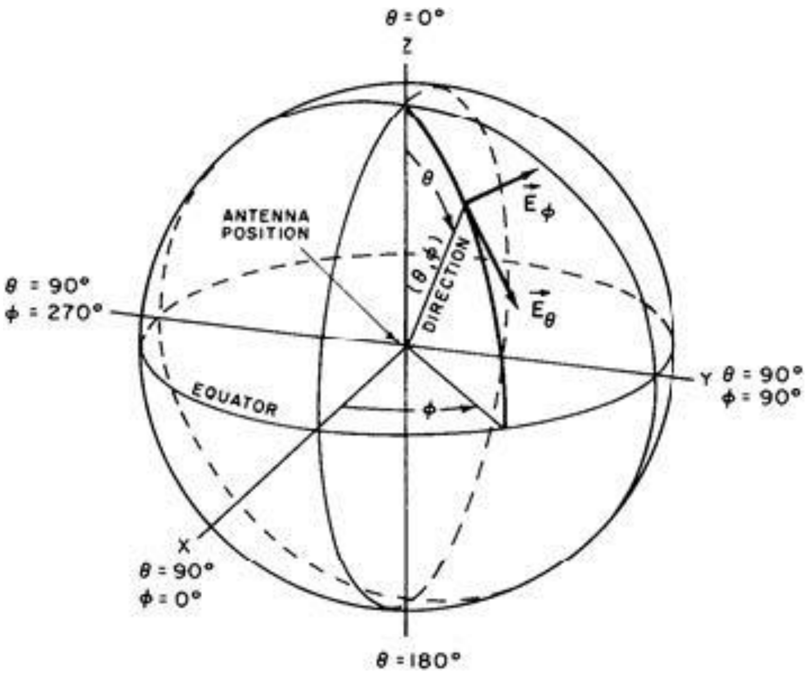

Figure 13: Spheroidal Coordinates Using for Placement

Table 11: Radiant Direction

Main Direction	Phi (φ)		Theta (Θ)	
	Azimuth (Start)	Azimuth (Stop)	Elevation (Start)	Elevation (Stop)
+X	-45	45	45	135
-X	135	225	45	135
+Y	45	135	45	135
-Y	225	315	45	135
+Z	0	359	0	45
-Z	0	359	135	180

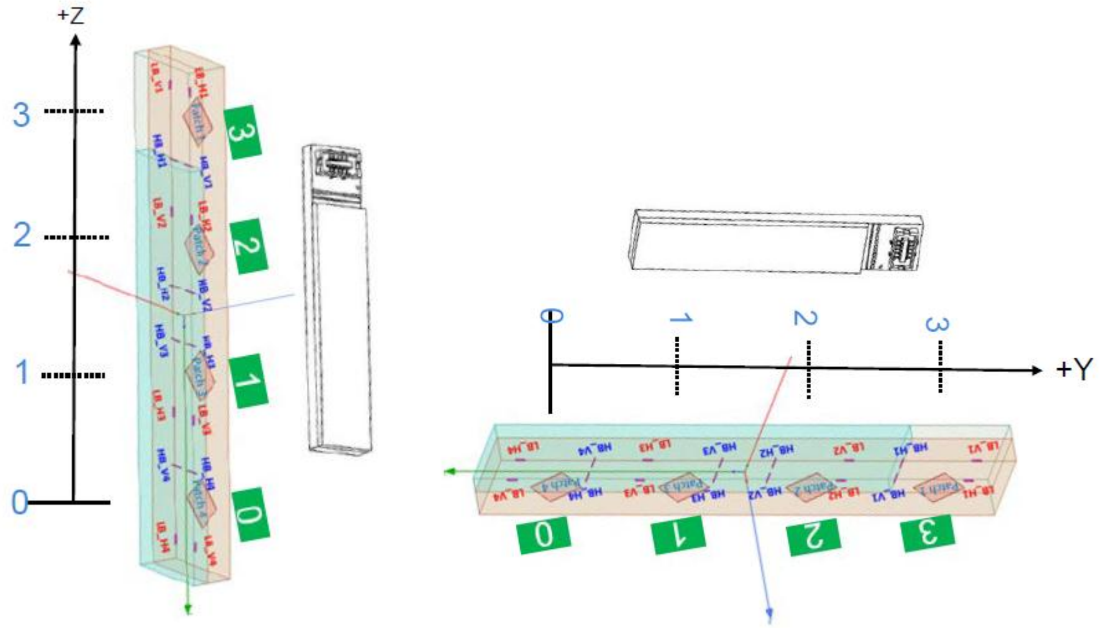

Figure 14: Position of Antenna Element in Coordinates

For the placement of the antenna modules, customer should do the configurative working according to the specific design, or abide by the following recommendation for later software maintenance and beam configuration, measurement, calibration and validation.

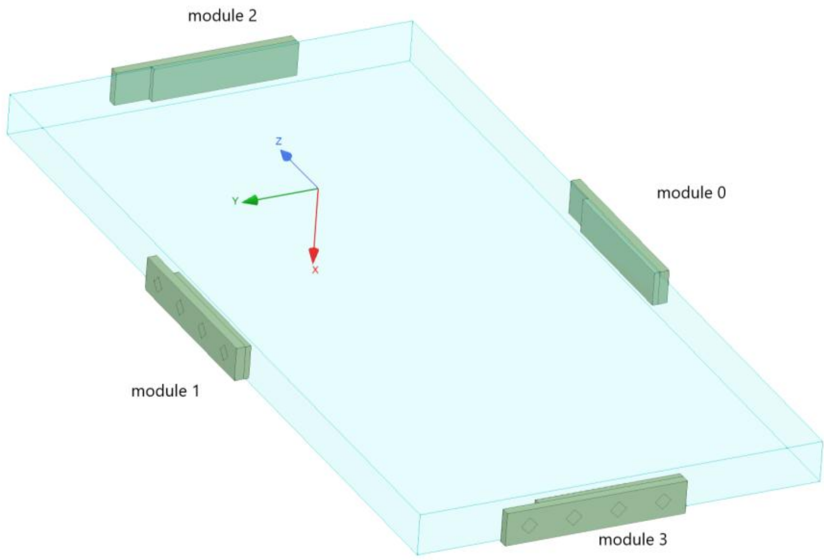

Figure 15: Recommended Positions of Antenna Modules (Option 1)

ID	Antenna Module Name	Antenna Module Instance	Ant Mod.Group ID	Antenna Port	X	Y	Z	Azimuth(Start)	Azimuth(Stop)	Elevation(Start)	Elevation(Stop)	Direction
0	QTM525_2_V2	1	0	V1 V2 V3 V4	0 0 0 0	0 0 0 0	3 2 1 0	45	135	45	135	+Y
1	QTM525_2_V2	1	1	H1 H2 H3 H4	0 0 0 0	0 0 0 0	3 2 1 0	45	135	45	135	+Y
2	QTM525_2_V2	0	0	V1 V2 V3 V4	0 0 0 0	0 0 0 0	3 2 1 0	225	315	45	135	-Y
3	QTM525_2_V2	0	1	H1 H2 H3 H4	0 0 0 0	0 0 0 0	3 2 1 0	225	315	45	135	-Y
4	QTM525_2_V2	3	0	V1 V2 V3 V4	0 0 0 0	3 2 1 0	0 0 0 0	0	359	135	180	-Z
5	QTM525_2_V2	3	1	H1 H2 H3 H4	0 0 0 0	3 2 1 0	0 0 0 0	0	359	135	180	-Z
6	QTM525_2_V2	2	0	V1 V2 V3 V4	0 0 0 0	3 2 1 0	0 0 0 0	0	359	0	45	+Z
7	QTM525_2_V2	2	1	H1 H2 H3 H4	0 0 0 0	3 2 1 0	0 0 0 0	0	359	0	45	+Z

Figure 16: Configuration Table of Option 1

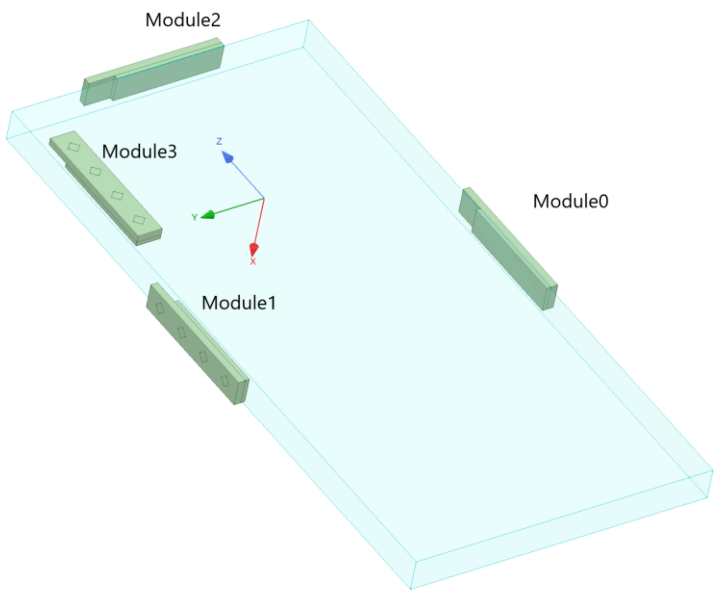

Figure 17: Recommended Positions of Antenna Modules (Option 2)

ID	Antenna Module Name	Antenna Module Instance	Ant Mod Group ID	Antenna Port	X	Y	Z	Azimuth(Start)	Azimuth(Stop)	Elevation(Start)	Elevation(Stop)	Direction
0	QTM525_5_V2	1	0	V1 V2 V3 V4	0 0 0 0	0 0 0 0	3 2 1 0	45	135	45	135	+Y
1	QTM525_5_V2	1	1	H1 H2 H3 H4	0 0 0 0	0 0 0 0	3 2 1 0	45	135	45	135	+Y
2	QTM525_5_V2	0	0	V1 V2 V3 V4	0 0 0 0	0 0 0 0	3 2 1 0	225	315	45	135	-Y
3	QTM525_5_V2	0	1	H1 H2 H3 H4	0 0 0 0	0 0 0 0	3 2 1 0	225	315	45	135	-Y
4	QTM525_5_V2	3	0	V1 V2 V3 V4	0 0 0 0	0 0 0 0	3 2 1 0	135	225	45	135	-X
5	QTM525_5_V2	3	1	H1 H2 H3 H4	0 0 0 0	0 0 0 0	3 2 1 0	135	225	45	135	-X
6	QTM525_5_V2	2	0	V1 V2 V3 V4	0 0 0 0	3 2 1 0	0 0 0 0	0	359	0	45	+Z
7	QTM525_5_V2	2	1	H1 H2 H3 H4	0 0 0 0	3 2 1 0	0 0 0 0	0	359	0	45	+Z

Figure 18: Configuration Table of Option 2

3.1.4. Antenna Performance Guidelines

3.1.4.1. Free Space Antenna Pattern

The other critical factor for coverage performance is antenna sweeping pattern.

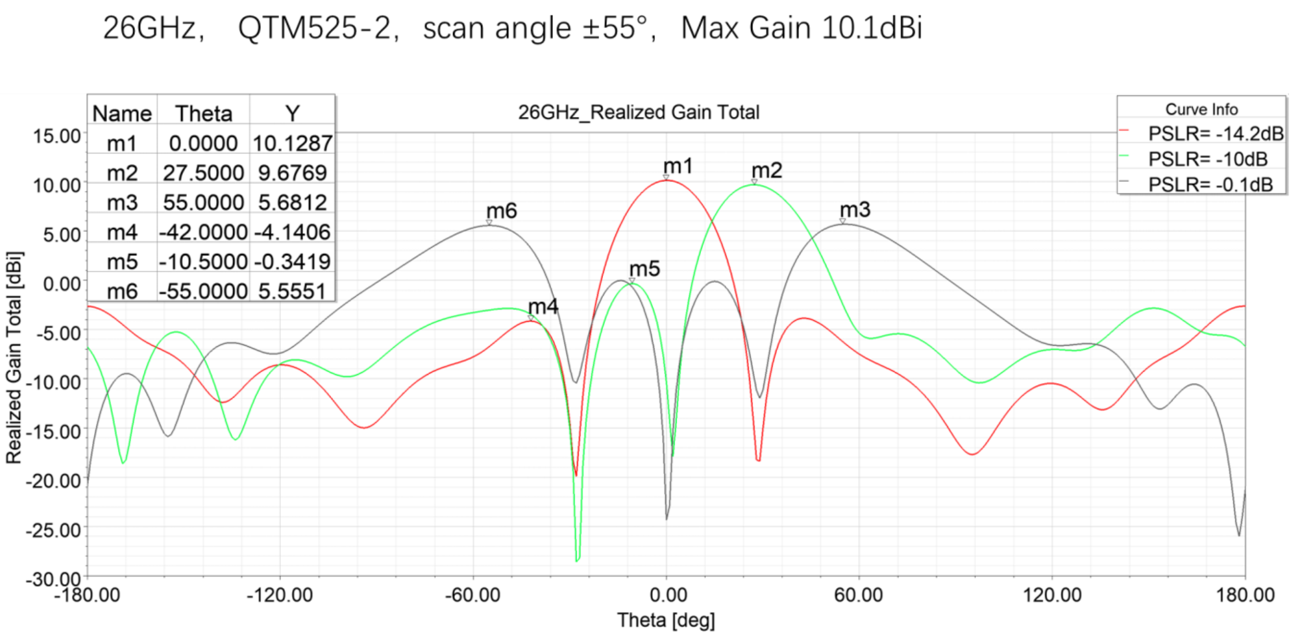

Figure 19: Free Space Beamforming Pattern in 26 GHz

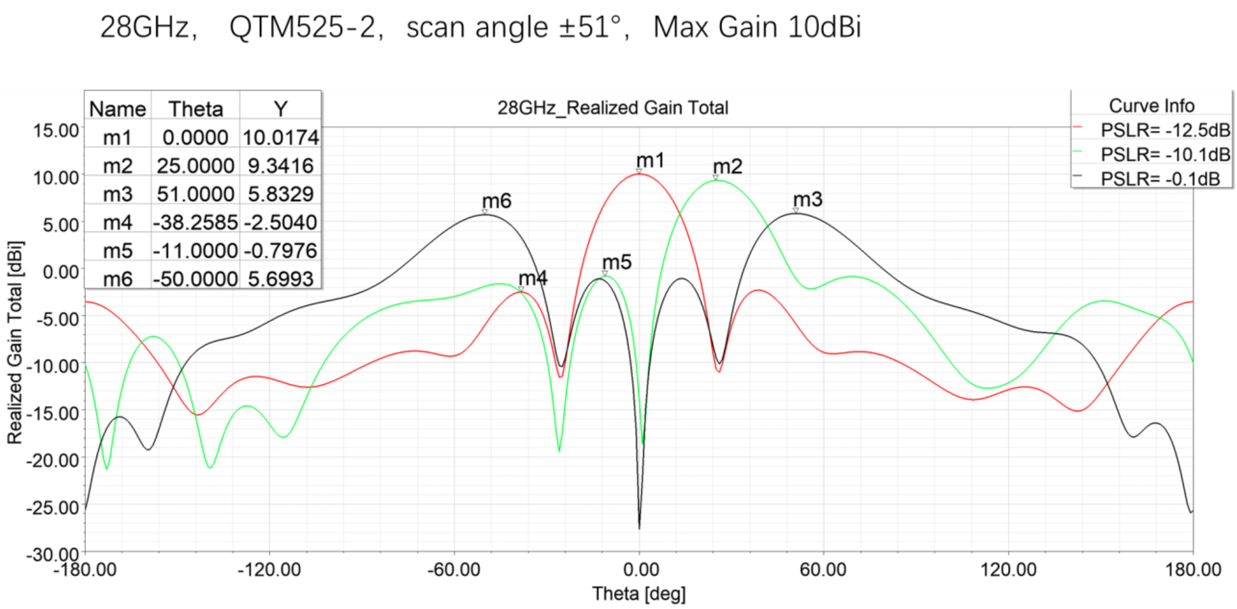

Figure 20: Free Space Beamforming Pattern in 28GHz

In the above figure, HPBW = 22°, beam angular resolution is about 12.5°, beam scan angle is less +/-50°. The pattern could be utilized to estimate the beaming performance of design.

3.1.4.2. Mechanical Design

Antenna performance is sensitive to specific industrial design of the terminal, the design includes the dimensions, device assembly, and radome (antenna housing), but the design guidelines are difficult to establish due to the competing electromagnetic effects. The following is design considerations:

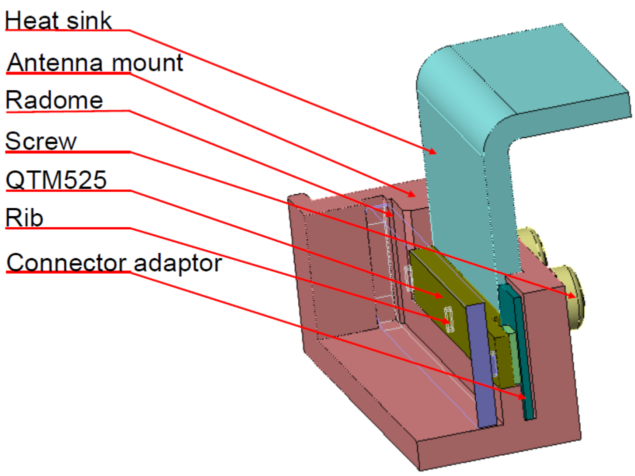

Figure 21: Mechanical Side View Reference of Radome with Antenna Mounted

1. The position and size of the radome can be changed during the test, and the final position is determined according to the test results.
2. Place the plastic ribs between the antenna module and radome.
3. The radome should have thermal constant DkDf (Df is better if less or equal than 0.003). The dielectric constant must be a known parameter before design.
4. Simulaton results show that in general the antenna performance are reasonable if the module is very close to the radome (less than 1 mm gap) or far from the radome (more than 5–10 free space wavelength apart)
5. Between air other gaps can be used but customer should verify the performance by simulation or actual measurements.
6. All metal structure of the device should be included in simulation, such as metal on the back and frame of device, as well as the PCB except the space clearance dimensions more than 1.5 mm.
7. The thickness of radome is ½ effective wavelength.

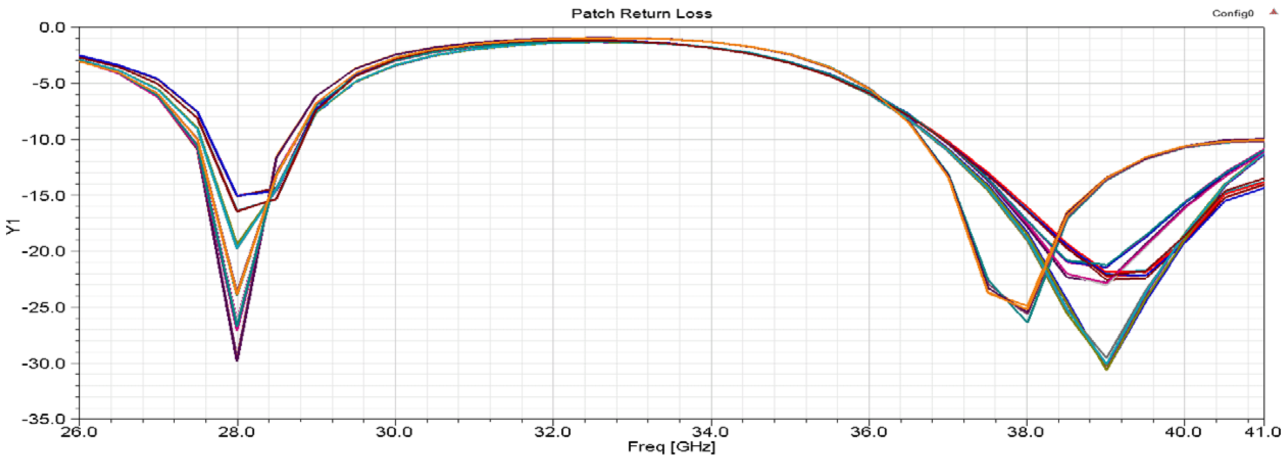

Figure 22: Return Loss Without Radome

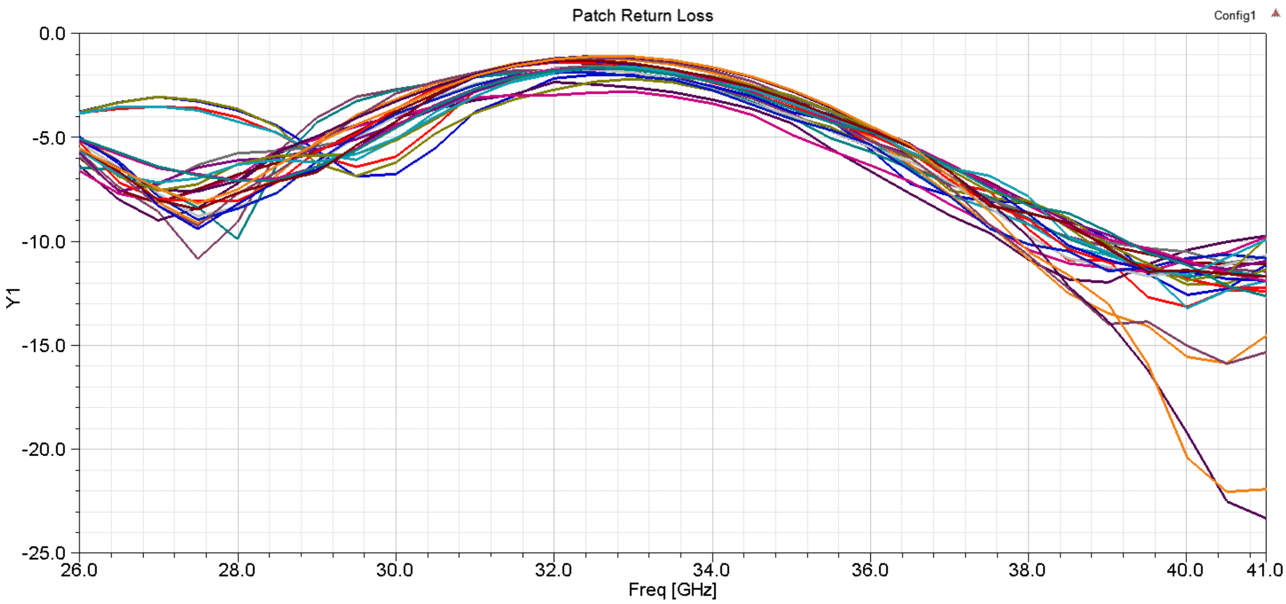

Figure 23: Degradation of Return Loss Due to Radome

The above figure shows that without careful design, the performance will be degraded.

3.2. IF Routing

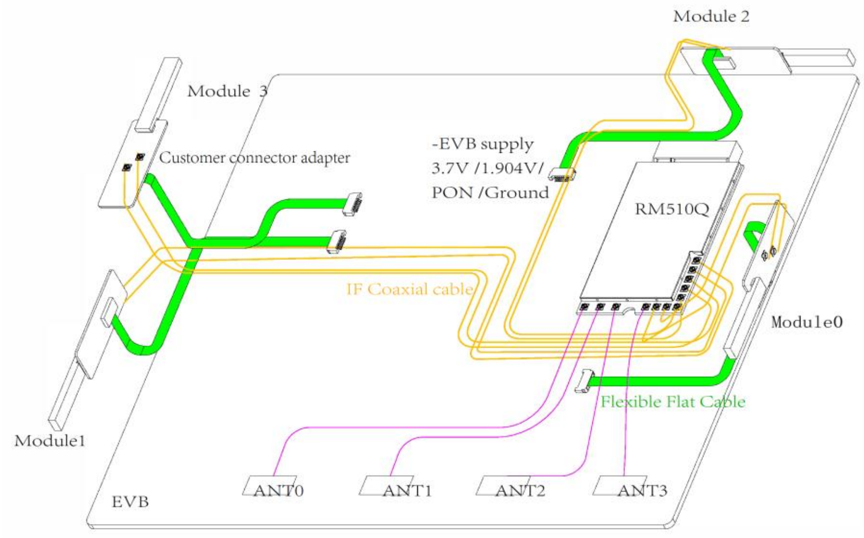

Figure 24: RM510Q-GL IF Port Identification

The relationship between RM510Q-GL and QTM525-2/QTM525-5 modules is shown in the above figure. The most important connection between RM510Q-GL and RF antenna modules QTM525-2/QTM525-5 are IF ports.

Figure 25: RM510Q-GL IF Port Identification

Please note that antenna modules should be connected to the appointed IF interface.

Table 12: Relationship between RM510Q-GL and QTM525-2/QTM525-5 Modules

Antenna Module	IF ←→RF	
Identification	**Interface**	
QTM525_0	IFH1	IFV4
QTM525_1	IFH4	IFV1
QTM525_2	IFH2	IFV3
QTM525_3	IFH3	IFV2

RM510Q-GL connector type:

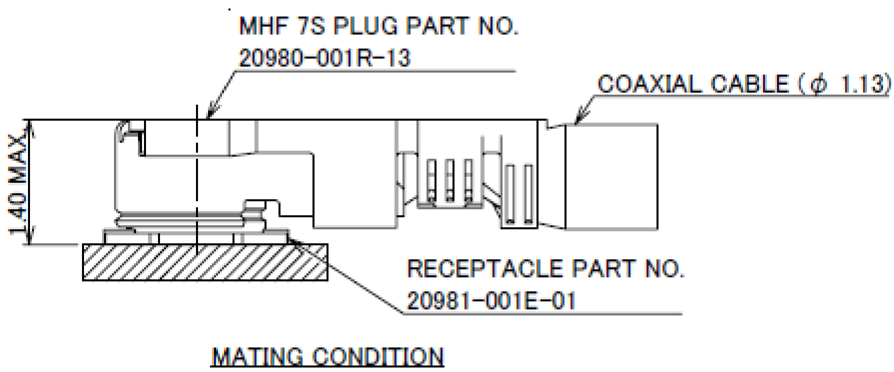

Figure 26: MHF 7S Receptacle, Plug and Coaxial Cable

- IPEX (vendor name) MPN 20981-001E-01: 2.1 × 3.5 × 0.585 mm (receptacle connector is mounted on RM510Q-GL).
- IPEX (vendor name) MPN 20980-001R-01: 2.1 × 4.2 × 0.655 mm (plug connector with coaxial cable).
- IPEX (vendor name) MHF 7S is assembled by MPN20980 connector and 1.13 mm coaxial cable, and the length of the cable is decided by the insertion loss budget.

The connector mounted on QTM525-2/QTM525-5 is different with the connector mounted on RM510Q-GL. Regarding MPN 20865-010E-01 vs MPN 20981-001E-01, customers should design their own IF connector adaptor between QTM525 and RM510Q-GL modules using the appointed connector pair.

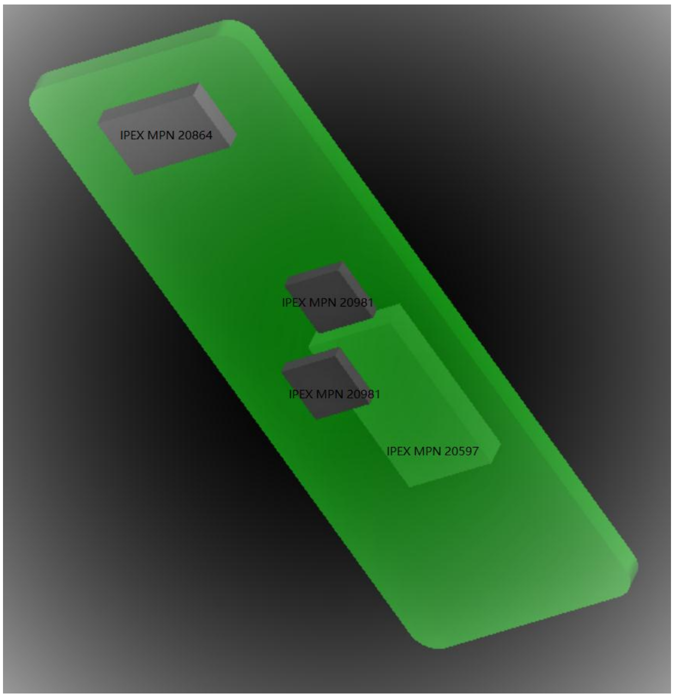

Figure 27: Customer connector adaptor reference with size 28x 10 (H x W unit: mm)

In the adaptor reference, except the IF connector, the connector of IPEX MPN 20597 is used for power supply (3.7V and 1.904V) and PON signal, customer could choose their own suitable connector.

Total system isolation between IF paths (combined PCB, cables, connectors, and so on) to the same module should be > 40 dB from 6 GHz to 10 GHz for proper operation. For different modules with different polarization, the isolation specification should be > 35 dB; for those with the same polarization, it can be relaxed to > 20 dB.

Isolation Requirement		40dB	35dB	20dB				
	IFV1	IFV2	IFV3	IFV4	IFH1	IFH2	IFH3	IFH4
IFV1		20	20	20	35	35	35	40
IFV2	20		20	20	35	35	40	35
IFV3	20	20		20	35	40	35	35
IFV4	20	20	20		40	35	35	35
IFH1	35	35	35	40		20	20	20
IFH2	35	35	40	35	20		20	20
IFH3	35	40	35	35	20	20		20
IFH4	40	35	35	35	20	20	20	

Figure 28: Isolation Requirement

The IF paths to the same antenna module should be routed with approximately the same insertion loss. The delta value should be < 1dB.

IF path VSWR should meet the following requirements.

Table 13: VSWR Requirement

Range	VSWR Requirement
10 MHz to 1.2 GHz	Better than 1.2:1
1.2–3.6 GHz	Better than 2:1
6–10 GHz	Better than 2:1; variation over frequency width 1.4 GHz < 0.5

IF path insertion loss should meet the following requirements.

Table 14: Insertion Loss Requirement

Range	Insertion Loss Requirement
6–10 GHz	< 4 dB (from the RM510Q-GL coaxial connector to the QTM525 IPEX connector)

For 10 GHz frequency range, the maximum insertion loss on the IF path should not exceed 4 dB on all eight IF paths. The formulation is:

IF path insertion loss = IF co-axial cable [MHF7S cable + 2 × plug + 2 × receptacle] loss + Adaptor PCB trace loss

The following table shows insertion loss budget.

Table 15: Insertion Loss Example

Case	Cable w/o PCB	IL (Insertion Loss) dB
Adapter PCB + Coaxial cable	≈ 0.6 (26 mm adaptor PCB) + 2.2 (360 mm coaxial) + (0.2 + 0.2) connectors	3.2

- Adaptor PCB: IL ≈ 2.3 dB/ 100 mm.
- Coaxial Cable: IL ≈ 0.6 dB/ 100 mm; Coaxial mated connectors IL 0.2 dB.

3.3. Thermal Definitions

High-speed data operation and low PAE of mmWave tend to generate heat, mitigating this heat requires a careful approach to thermal design to prevent the antenna modules from overheating.

Table 16: Parameter Definition

Parameter	Definition
Ta	The temperature of the surrounding environment (typically air) of the device under test.
Tj	The maximum allowed temperature of the silicon in an Integrated Circuit.
Tc	The maximum allowed temperature of the antenna module case.

1. QTM525-2/QTM525-5 semiconductor temperature limits: Tj typically value, 85 °C.
2. QTM525-2/QTM525-5 module case temperature limits: Tc typically value, 40 °C for metal cover; 45 °C for plastic cover.
3. The average power dissipation of QTM525-2/QTM525-5 module is 1.23 W: IC PMR525: 0.2 W + IC SMR 525: 1.28 W × 0.8 (peak power 1.28 W).
4. It is optional to have one external thermistor for each QTM525 module. The thermistor should be placed close to the corresponding antenna module, so the thermistor reading is well correlated with Tc hotspot caused by QTM525 module.
5. Using a gel/grease type thermal interface material (TIM) between the module and a heatsink to evacuate the air.
6. Recommended gel/grease type TIM vendors:
   - Parker Chomerics GEL 30: 3.5 W/m-K thermal conductivity, soft, and compliant with low required compressive force.
   - Shin-Etsu – X-23-7868-2D: 6.2 W/m-K thermal conductivity, highest thermal conductivity or X-23-8117 –6.0 W/m-K thermal conductivity, pump-out resistant due to high viscosity.
7. Metal heatsink: Aluminum 6063T5 with surface treatment, such as nano carbon coating, to enhance thermal radiation under natural convection heat transfer. The size of the heatsink with sufficient cooling capacity is shown below.

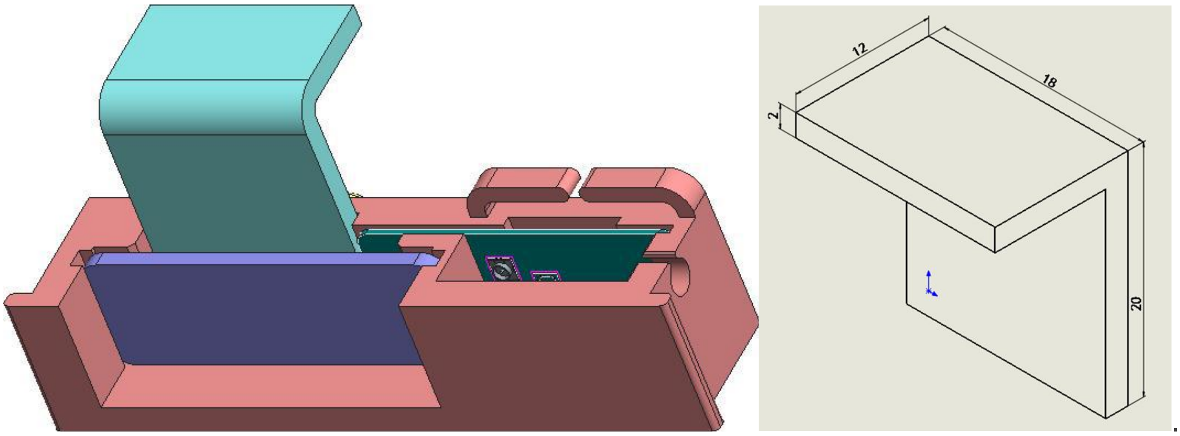

Figure 29: Heatsink Mounted with QTM525 Module and Antenna Radome (Unit: mm)

3.4. Power Consumption (Estimation)

The antenna modules also require enough wattage in switch mode. Otherwise, the performance will be throttled.

Table 17: Power Requirements

Test Case 50%-tile	RM510Q-GL Power	QTM525-2/QTM525-5 Power
PDCCH 1CC Mode	2.0	0.55
75% DL 7 Gbps + 25% UL 3.5 Gbps	10.0	1.20
25% DL 7 Gbps + 75% UL 3.5 Gbps	10.0	1.48
75% DL 0.8 Gbps + 25% UL 0.4 Gbps	3.4	0.85
25% DL 0.8 Gbps + 75% UL 0.4 Gbps	3.4	1.00

4 QTM525-2/QTM525-5 Performance

4.1. Transmitter Performance

Table 18: QTM525-2 Band n258 Tx Performance (26 GHz)

Parameter	Antenna ID [2]	Scan Angle	Measurement Coordinates [3] [Θ, Φ] deg	Condition	Min	Typ.	Max	Unit
The frequency range is 24.25 GHz (minimum) to 27.5 GHz (maximum) for these specifications.								
Maximum EIRP [4]	hPn, vPn	0	[0, 0]	Peak beam = measurement angle; full RB; 1 CC/1 CW; SCFDMA/QPSK	–	14.7	–	dBm
	hPa4, vPa4				–	26.7	–	
	hvPa4				–	29.7	–	
Maximum TRP	hvPa4	0	[0, 0]	Full RB; 1CC; QPSK	–	–	20.7	dBm
Scan angle EIRP [4]	hPa4, vPa4	22.5	[22.5, 0]	Peak beam = measurement angle; full RB; 1 CC/1 CW; SCFDMA/QPSK	–	25.1	–	dBm
		22.5	[22.5, 180]		–	25.1	–	
		45	[45, 0]		–	22.7	–	
		45	[45, 180]		–	22.7	–	
	hvPa4	22.5	[22.5, 0]		–	28.1	–	
		22.5	[22.5, 180]		–	28.1	–	
		45	[45, 0]		–	25.7	–	
		45	[45, 180]		–	25.7	–	
ACLR [5]	hPa4, vPa4	0	[0, 0]	POUT = TRP; SCFDMA/QPSK [ch_BW/2] ±ch BW 100 MHz offset	–	–	-17.0	dBc
	hvPa4				–	–	-17.0	
EVM (RMS) [6]	hPa4, vPa4	0	[0, 0]	Full RB; 1 CC; QPSK	–	–	-15.2	dBc

	hvPa4				–	–	-15.2	
	hPa4, vPa4	0, 0	[90, 90]	Full RB; 1 CC, 64 QAM	–	–	-22.5	
	hvPa4				–	–	-22.5	
Spurious emissions [7]	hPn, vPn	0.0	[0, 0]	Single tone/CW	–	–	-36.0	dBc
	hPa4, vPa4				–	–	-36.0	
	hvPa4				–	–	-36.0	
Minimum output power	–	–	–	Peak beam = measurement angle	–	–	-13.0	dBm

Table 19: QTM525-2 band n257 Tx performance (28 GHz)

Parameter	Antenna ID [1]	Scan Angle	Measurement Coordinates [2] [Θ, Φ] deg	Condition	Min	Typ.	Max	Unit
The frequency range is 24.25 GHz (minimum) to 27.5 GHz (maximum) for these specifications.								
Maximum EIRP [3]	hPn, vPn	0	[0, 0]	Peak beam = measurement angle; full RB; 1 CC/1 CW; SCFDMA/QPSK	–	14.7	–	dBm
	hPa4, vPa4	0	[0, 0]		–	26.7	–	
	hvPa4	0	[0, 0]		–	29.7	–	
Maximum TRP	hvPa4	0	[0, 0]	Full RB; 1CC; QPSK	–	–	20.7	dBm
Scan angle EIRP [3]	hPa4, vPa4	22.5	[22.5, 0]	Peak beam = measurement angle; full RB; 1 CC/1 CW; SCFDMA/QPSK	–	25.1	–	dBm
		22.5	[22.5, 180]		–	25.1	–	
		45	[45, 0]		–	22.7	–	
		45	[45, 180]		–	22.7	–	
	hvPa4	22.5	[22.5, 0]		–	28.1	–	
		22.5	[22.5, 180]		–	28.1	–	
		45	[45, 0]		–	25.7	–	
		45	[45, 180]		–	25.7	–	
ACLR [4]	hPa4, vPa4	0	[0, 0]	POUT = TRP; SCFDMA/QPSK [ch_BW/2] ±ch BW 100 MHz offset	–	–	-17.0	dBc
	hvPa4				–	–	-17.0	
EVM (RMS) [5]	hPa4, vPa4	0	[0, 0]	Full RB; 1 CC; QPSK	–	–	-15.2	dBc

	hvPa4				–	–	-15.2	
	hPa4, vPa4	0		Full RB; 1 CC, 64 QAM	–	–	-22.5	
	hvPa4				–	–	-22.5	
Spurious emissions 6	hPn, vPn	0.0	[0, 0]	Single tone/CW	–	–	-36.0	dBc
	hPa4, vPa4				–	–	-36.0	
	hvPa4				–	–	-36.0	
Minimum output power	–	–	–	Peak beam = measurement angle	–	–	-13.0	dBm

Table 20: QTM525-5 Band n258 Tx Performance (26 GHz)

Parameter	Antenna ID 2	Scan Angle	Measurement Coordinates 3 [Θ, Φ] deg	Condition	Min	Typ.	Max	Unit
The frequency range is 24.25 GHz (minimum) to 27.5 GHz (maximum) for these specifications.								
Maximum EIRP 4	hPn, vPn	0	[0, 0]	Peak beam = measurement angle; full RB; 1 CC/1 CW; SCFDMA/QPSK	–	14.7	–	dBm
	hPa4, vPa4				–	26.7	–	
	hvPa4				–	29.7	–	
Maximum TRP	hvPa4	0	[0, 0]	Full RB; 1CC; QPSK	–	–	20.7	dBm
Scan angle EIRP 4	hPa4, vPa4	22.5	[22.5, 0]	Peak beam = measurement angle; full RB; 1 CC/1 CW; SCFDMA/QPSK	–	25.1	–	dBm
		22.5	[22.5, 180]		–	25.1	–	
		45	[45, 0]		–	22.7	–	
		45	[45, 180]		–	22.7	–	
	hvPa4	22.5	[22.5, 0]		–	28.1	–	
		22.5	[22.5, 180]		–	28.1	–	
		45	[45, 0]		–	25.7	–	
		45	[45, 180]		–	25.7	–	
ACLR 5	hPa4, vPa4	0	[0, 0]	POUT = TRP; SCFDMA/QPSK [ch_BW/2] ±ch BW 100 MHz offset	–	–	-17.0	dBc
	hvPa4				–	–	-17.0	
EVM (RMS) 6	hPa4, vPa4	0	[0, 0]	Full RB; 1 CC; QPSK	–	–	-15.2	dBc

	hvPa4				–	–	-15.2	
	hPa4, vPa4	0, 0	[90, 90]	Full RB; 1 CC, 64 QAM	–	–	-22.5	
	hvPa4				–	–	-22.5	
Spurious emissions [7]	hPn, vPn	0.0	[0, 0]	Single tone/CW	–	–	-36.0	dBc
	hPa4, vPa4				–	–	-36.0	
	hvPa4				–	–	-36.0	
Minimum output power	–	–	–	Peak beam = measurement angle	–	–	-13.0	dBm

Table 21: QTM525-5 Band n261 Tx Performance (28 GHz)

Parameter	Antenna ID [2]	Scan Angle	Measurement Coordinates [3] [Θ, Φ] deg	Condition	Min	Typ	Max	Unit
The frequency range is 24.25 GHz (minimum) to 27.5 GHz (maximum) for these specifications.								
Maximum EIRP [4]	hPn, vPn	0	[0, 0]	Peak beam = measurement angle; full RB; 1 CC/1 CW; SCFDMA/QPSK	–	14.7	–	dBm
	hPa4, vPa4	0	[0, 0]		–	26.7	–	
	hvPa4	0	[0, 0]		–	29.7	–	
Maximum TRP	hvPa4	0	[0, 0]	Full RB; 1CC; QPSK	–	–	20.7	dBm
Scan angle EIRP [4]	hPa4, vPa4	22.5	[22.5, 0]	Peak beam = measurement angle; full RB; 1 CC/1 CW; SCFDMA/QPSK	–	25.1	–	dBm
		22.5	[22.5, 180]		–	25.1	–	
		45	[45, 0]		–	22.7	–	
		45	[45, 180]		–	22.7	–	
	hvPa4	22.5	[22.5, 0]		–	28.1	–	
		22.5	[22.5, 180]		–	28.1	–	
		45	[45, 0]		–	25.7	–	
		45	[45, 180]		–	25.7	–	
ACLR [5]	hPa4, vPa4	0	[0, 0]	POUT = TRP; SCFDMA/QPSK [ch_BW/2] ±ch BW 100 MHz offset	–	–	-17.0	dBc
	hvPa4				–	–	-17.0	
EVM (RMS) [6]	hPa4, vPa4	0	[0, 0]	Full RB; 1 CC; QPSK	–	–	-15.2	dBc

	hvPa4				–	–	-15.2	
	hPa4, vPa4	0		Full RB; 1 CC, 64 QAM	–	–	-22.5	
	hvPa4				–	–	-22.5	
Spurious emissions [7]	hPn, vPn	0.0	[0, 0]	Single tone/CW	–	–	-36.0	dBc
	hPa4, vPa4				–	–	-36.0	
	hvPa4				–	–	-36.0	
Minimum output power	–	–	–	Peak beam = measurement angle	–	–	-13.0	dBm

Table 22: QTM525-5 Band 260 Tx Performance (39 GHz)

Parameter	Antenna ID [2]	Scan Angle	Measurement Coordinates [3] [Θ, Φ] deg	Condition	Min	Typ	Max	Unit
The frequency range is 24.25 GHz (minimum) to 27.5 GHz (maximum) for these specifications.								
Maximum EIRP [4]	hPn, vPn	0	[0, 0]	Peak beam = measurement angle; full RB; 1 CC/1 CW; SCFDMA/QPSK	–	13.2	–	dBm
	hPa4, vPa4	0	[0, 0]		–	25.2	–	
	hvPa4	0	[0, 0]		–	28.2	–	
Maximum TRP	hvPa4	0	[0, 0]	Full RB; 1CC; QPSK	–	–	19.2	dBm
Scan angle EIRP [4]	hPa4, vPa4	22.5	[22.5, 0]	Peak beam = measurement angle; full RB; 1 CC/1 CW; SCFDMA/QPSK	–	23.6	–	dBm
		22.5	[22.5, 180]		–	23.6	–	
		45	[45, 0]		–	21.2	–	
		45	[45, 180]		–	21.2	–	
	hvPa4	22.5	[22.5, 0]		–	26.6	–	
		22.5	[22.5, 180]		–	26.6	–	
		45	[45, 0]		–	24.2	–	
		45	[45, 180]		–	24.2	–	
ACLR [5]	hPa4, vPa4	0	[0, 0]	POUT = TRP; SCFDMA/QPSK [ch_BW/2] ±ch BW 100 MHz offset	–	–	-17.0	dBc
	hvPa4				–	–	-17.0	
EVM (RMS) [6]	hPa4, vPa4	0	[0, 0]	Full RB; 1 CC; QPSK	–	–	-15.2	dBc

	hvPa4				–	–	-15.2	
	hPa4, vPa4			Full RB; 1 CC, 64 QAM	–	–	-22.5	
	hvPa4				–	–	-22.5	
	hPn, vPn				–	–	-36.0	dBc
Spurious emissions 7	hPa4, vPa4	0.0	[0, 0]	Single tone/CW	–	–	-36.0	
	hvPa4				–	–	-36.0	
Minimum output power	-	-	-	Peak beam = measurement angle	–	–	-13.0	dBm

4.2. Receiver Performance

Table 23: QTM525-2 Band n258 Rx Performance (26 GHz)

Antenna ID	Gain State	Scan Angle	Measurement Coordinates [Θ, Φ] deg	Pin Amplitude 4	Unit	Gain 5				SNR 6				OIP3 7			
						Min	Typ.	Max	Unit	Min	Typ.	Max	Unit	Min	Typ.	Max	Unit
The frequency range is 24.25 GHz (minimum) to 27.5 GHz (maximum) for these specifications.																	
	G0			-76.0			55.7				15.0						
hPn, vPn	G5	0	[0, 0]	-49.0	dBm	–	28.7	–	dB	–	41.1	–	dB	14	–	–	dBm
	G10			-37.0			-1.3				32.6						
	G0			-88.0			67.7				9.0						
	G5	0	[0, 0]	-61.0			40.7				35.1						
	G10			-37.0			10.7				38.6						
hPa4, vPa4		22.5	[22.5, 0]		dBm	–	66.1	–	dB	–	7.3	–	dB	14	–	–	dBm
			[22.5, 180]														
	G0			-88.0													
		45	[45, 0]				63.7				5.0						
			[45, 180]														
hvPa4	G0	0	[0, 0]	-88.0	dBm	–	67.7	–	dB	–	9.0	–	dB	14	–	–	dBm
	G5		[0, 0]	-61.0			40.7				35.1						

	G10		[0, 0]	-37.0	10.7	38.6
	G0	22.5	[22.5, 0]	-88.0	66.1	7.3
			[22.5, 180]			
		45	[45, 0]		63.7	5.0
			[45, 180]			

- Pin amplitude is only applicable in the gain and SNR measurements.
- Main is measured at the IF output with the pin (amplitude) at the QTM525 module patch antenna.
- SNR is measured in 100 MHz BW.
- Test conditions for the third-order output intercept point (OIP3) measurement: one signal tone and two-equal CW tone of amplitude -79 dBm (G0), referenced to the QTM525 module input.

Table 24: QTM525-2 Band n257 Rx Performance (28 GHz)

Antenna ID [2]	Gain state	Scan Angle	Measurement Coordinates [Θ, Φ] deg	Pin Amplitude [4]	Unit	Gain [5]				SNR [6]				OIP3 [7]			
						Min	Typ.	Max	Unit	Min	Typ.	Max	Unit	Min	Typ.	Max	Unit
The frequency range is 24.25 GHz (minimum) to 27.5 GHz (maximum) for these specifications.																	
hPn, vPn	G0	0	[0, 0]	-76.0	dBm	–	55.7	–	dB	–	15.0	–	dB	14	–	–	dBm
	G5			-49.0			28.7				41.1						
hPa4, vPa4	G0	0	[0, 0]	-88.0	dBm	–	67.7	–	dB	–	9.0	–	dB	14	–	–	dBm
	G5			-61.0			40.7				35.1						
	G0	22.5	[22.5, 0]	-88.0			66.1				7.3						
			[22.5, 180]														
		45.0	[45, 0]				63.7				5.0						
			[45, 180]														
hvPa4	G0	0	[0, 0]	-88.0	dBm	–	67.7	–	dB	–	9.0	–	dB	14	–	–	dBm
	G5		[0, 0]	-61.0			40.7				35.1						
	G0	22.5	[22.5, 0]	-88.0			66.1				7.3						
			[22.5, 180]														
		45	[45, 0]				63.7				5.0						

			[45, 180]		

Table 25: QTM525-5 Band n258 Rx Performance (26 GHz) [1]

Antenna ID [2]	Gain State	Scan Angle	Measurement Coordinates [3] [Θ, Φ] deg	Pin Amplitude [4]	Unit	Gain [5]				SNR [6]				OIP3 [7]			
						Min	Typ.	Max	Unit	Min	Typ.	Max	Unit	Min	Typ.	Max	Unit
The frequency range is 24.25 GHz (minimum) to 27.5 GHz (maximum) for these specifications.																	
hPn, vPn	G0	0	[0, 0]	-76.0	dBm	–	55.7	–	dB	–	15.0	–	dB	14	–	–	dBm
	G5			-49.0			28.7				41.1						
hPa4, vPa4	G0	0	[0, 0]	-88.0	dBm		67.7				9.0						
	G5			-61.0			40.7				35.1						
	G0	22.5	[22.5, 0]	-88.0	dBm	–	66.1	–	dB	–	7.3	–	dB	14	–	–	dBm
			[22.5, 180]														
		45	[45, 0]				63.7				5.0						
			[45, 180]														
hvPa4	G0	0	[0, 0]	-88.0	dBm	–	67.7	–	dB	–	9.0	–	dB	14	–	–	dBm
	G5		[0, 0]	-61.0			40.7				35.1						
	G0	22.5	[22.5, 0]	-88.0			66.1				7.3						
			[22.5, 180]														
		45	[45, 0]				63.7				5.0						
			[45, 180]														

Table 26: QTM525-5 Band n261 Rx Performance (28 GHz)

Antenna ID [2]	Gain State	Scan Angle	Measurement Coordinates [3] [Θ, Φ] deg	Pin Amplitude [4]	Unit	Gain [5]				SNR [6]				OIP3 [7]			
						Min	Typ.	Max	Unit	Min	Typ.	Max	Unit	Min	Typ.	Max	Unit
The frequency range is 24.25 GHz (minimum) to 27.5 GHz (maximum) for these specifications.																	
hPn, vPn	G0	0	[0, 0]	-76.0	dBm	–	55.7	–	dB	–	15.0	–	dB	14	–	–	dBm

	G5			-49.0			28.7				41.1						
	G0	0	[0, 0]	-88.0			67.7				9.0						
	G5			-61.0			40.7				35.1						
hPa4, vPa4	G0	22.5	[22.5, 0]	-88.0	dBm	–	66.1	–	dB	–	7.3	–	dB	14	–	–	dBm
			[22.5, 180]														
		45.0	[45, 0]				63.7				5.0						
			[45, 180]														
	G0	0	[0, 0]	-88.0			67.7				9.0						
	G5			-61.0			40.7				35.1						
hvPa4	G0	22.5	[22.5, 0]	-88.0	dBm	–	66.1	–	dB	–	7.3	–	dB	14	–	–	dBm
			[22.5, 180]														
		45.0	[45, 0]				63.7				5.0						
			[45, 180]														

Table 27: QTM525-5 Band n260 Rx Performance (39 GHz)

Antenna ID [2]	Gain State	Scan Angle	Measurement Coordinates [3] [Θ, Φ] deg	Pin Amplitude [4]	Unit	Gain [5]				SNR [6]				OIP3 [7]			
						Min	Typ.	Max	Unit	Min	Typ.	Max	Unit	Min	Typ.	Max	Unit
The frequency range is 37 GHz (minimum) to 40 GHz (maximum) for these specifications.																	
hPn, vPn	G0	0	[0, 0]	-76.0	dBm	–	55.7	–	dB	–	13.9	–	dB	14	–	–	dBm
	G5			-49.0			28.7				40.2						
	G0	0	[0, 0]	-88.0			67.7				7.9						
	G5			-61.0			40.7				34.2						
hPa4, vPa4	G0	22.5	[22.5, 0]	-88.0	dBm	–	66.1	–	dB	–	6.2	–	dB	14	–	–	dBm
			[22.5, 180]														
		45.0	[45, 0]				63.7				3,9						
			[45, 180]														

hvPa4	G0	0	[0, 0]	-88.0	dBm	–	67.7	–	dB	–	7.9	–	dB	14	–	–	dBm
	G5			-61.0			40.7				34.2						
	G0	22.5	[22.5, 0]	-88.0			66.1				6.2						
			[22.5, 180]														
		45.0	[45, 0]				63.7				3.9						
			[45, 180]														

5 Appendix A References

Table 28: Related Documents

SN	Document Name	Remark
[1]	Quectel_RM510Q-GL_Hardware_Design	RM510Q-GL Hardware Design

Table 29: Terms and Abbreviations

Abbreviation	Description
3GPP	Third Generation Partnership Project
5G	Fifth Generation
BB	Baseband
BF	Beamforming
CCDF	Coverage Cumulative Distribution Function
CDF	Cumulative Distribution Function
DUT	Device Under Test
EIRP	Effective Isotropic Radiated Power
FWA	Fixed Wireless Access
HPBW	Half Power Band Width
IF	Intermediate Frequency
LCP	Liquid Crystal Polymer
NR	New Radio
MiFi	Mobile Wi-Fi

MIMO	Multiple Input Multiple Output
mmWave	Millimeter wave
PMU	Power Management Unit
RFIC	Radio Frequency Integrated Circuit
Ta	Ambient temperature
Tc	Case temperature
TIM	Thermal Interface Material
Tj	Junction temperature
UE	User Equipment