RM520N Series

Thermal Design Guide

5G Module Series

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About the Document

Revision History

Version	Date	Author	Description
-	2023-04-03	Henry CAI/ Lucy WANG	Creation of the document
1.0	2023-04-17	Henry CAI/ Lucy WANG	First official release

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1 Introduction

This document introduces the thermal design of the RM520N series modules, including general introduction and power consumption of the modules, thermal simulation in different modes, and heat dissipation solutions based on the simulation result.

2 Product Concept

2.1. General Introduction

RM520N is a series of 5G modules, including RM520N-GL, RM520N-EU and RM520N-CN, the top views and bottom views are shown as follows:

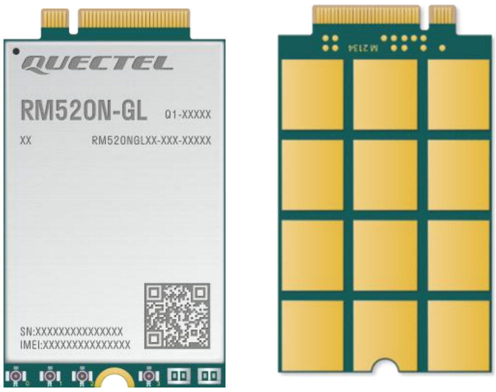

Figure 1: Top and Bottom Views of the RM520N-GL

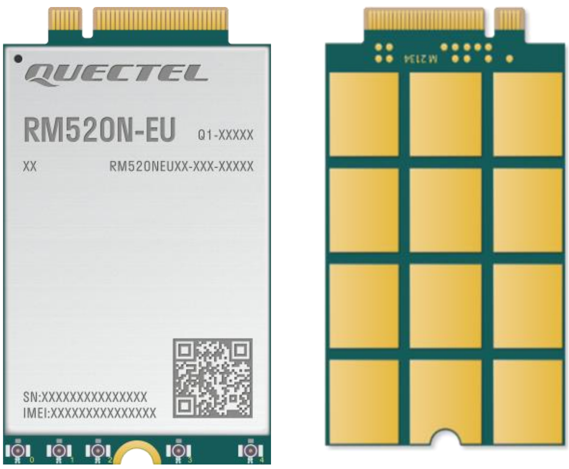

Figure 2: Top and Bottom Views of the RM520N-EU

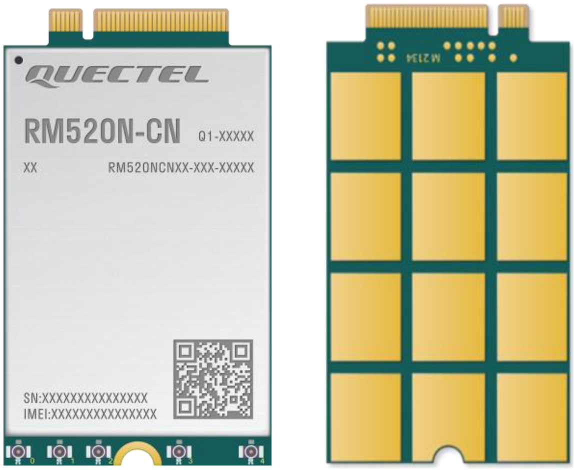

Figure 3: Top and Bottom Views of the RM520N-CN

NOTE

Images above are for illustration purpose only and may differ from the actual module. For authentic appearance and label, please refer to the module received from Quectel.

The components marked with characters shown below are heat source chips (BB, PMU, MCP, PA, etc.) with thermal gel inside the module. From left to right are RM520N-GL, RM520N-EU and RM520N-CN modules.

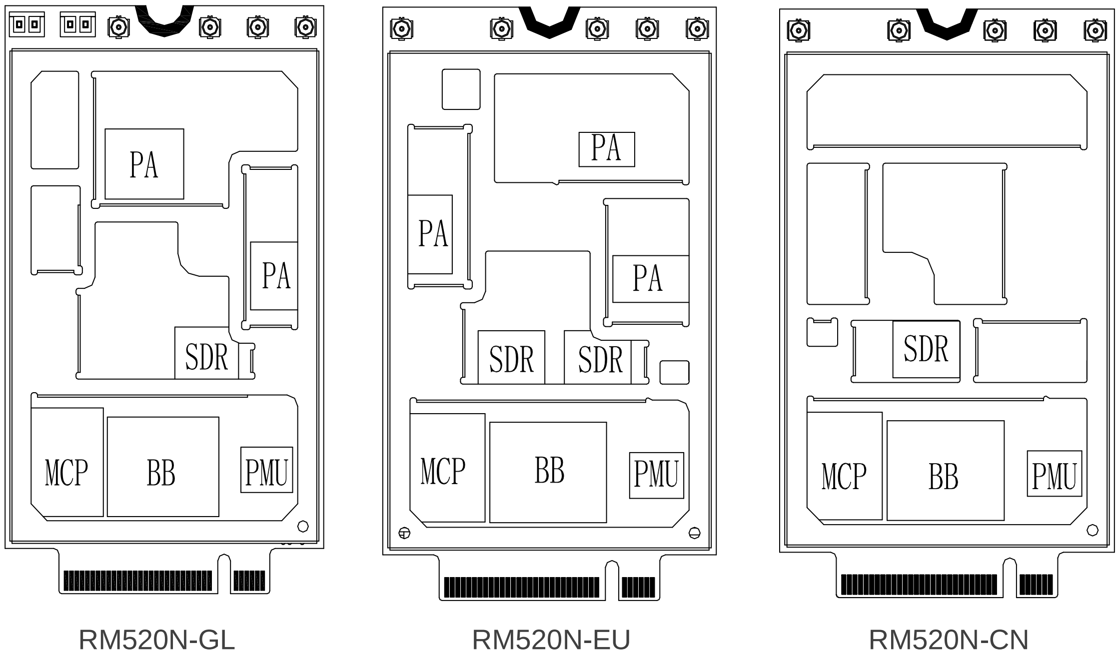

Figure 4: Distribution Diagram of Heat Source Chips Inside the Module

2.2. Key Features

This chapter mainly introduces the main features of the RM520N series modules, as shown in the following table for details:

Table 1 : Key Features of RM520N Series Modules

Features	Description
CPU	● Arm Cortex-A7 up to 1.8 GHz
Size	● 30.0 × 52.0 × 2.3 mm
Power supply	● VCC supply voltage: 3.135–4.4 V ● Typical supply voltage: 3.7 V
Shielding Case	● Thermal conductivity: 16.3 W/(m·K) ● Material: SUS304 ● Size: 29.48 × 44.13 (T0.15 mm, H1.25 mm)
Shielding Frame	● Thermal conductivity: 25 W/(m·K) ● Material: C7701 ● Size: 29.1 × 43.75 (T0.2 mm, H1.25 mm)
Operating Temperature	● Operating temperature range: -30 to +75 °C [1] ● Extended temperature range: -40 to +85 °C [2] ● Storage temperature range: -40 to +90 °C

[1] To meet this operating temperature range, you need to ensure effective thermal dissipation, for example, by adding passive or active heatsinks, heat pipes, vapor chambers, etc. Within this range, the module can meet 3GPP specifications.
[2] To meet this operating temperature range, you need to ensure effective thermal dissipation, for example, by adding passive or active heatsinks, heat pipes, vapor chambers, etc. Within this range, the module remains the ability to establish and maintain functions such as voice*, SMS, emergency call*, etc., without any unrecoverable malfunction. Radio spectrum and radio network are not influenced.

2.3. Component Thermal Parameters

Taking the RM520N-GL module as an example, the max. Tj information of main heat source chips of the module is as follows.

Table 2: Max. Tj of Main Heat Source Chips of the Module (Unit: °C)

BB	MCP	PMU	Transceiver	QET_0/1	PA 1/2/3/4/5
105	90	125	105	125	115

NOTE

Please keep the temperature of BB chip below 95 °C. Otherwise, the performance of the module will be affected, resulting in limited RF output power and data transmission rate. To keep the peak temperature of BB chip below 95 °C, a heat dissipation design is necessary. For more details about temperature management mechanism, see document ***[1]***.

3 Power Consumption Test

3.1. Test Environment

5G M.2 EVB is used as the test carrier of the module. The module's RF antenna interfaces are connected to the test instrument, and place the EVB and the module in the thermostat chamber. As shown in the figure below, an external DC power supply shall be connected to the VCC pin of the module through a cable to power the module and to further obtain the total power consumption of the module.

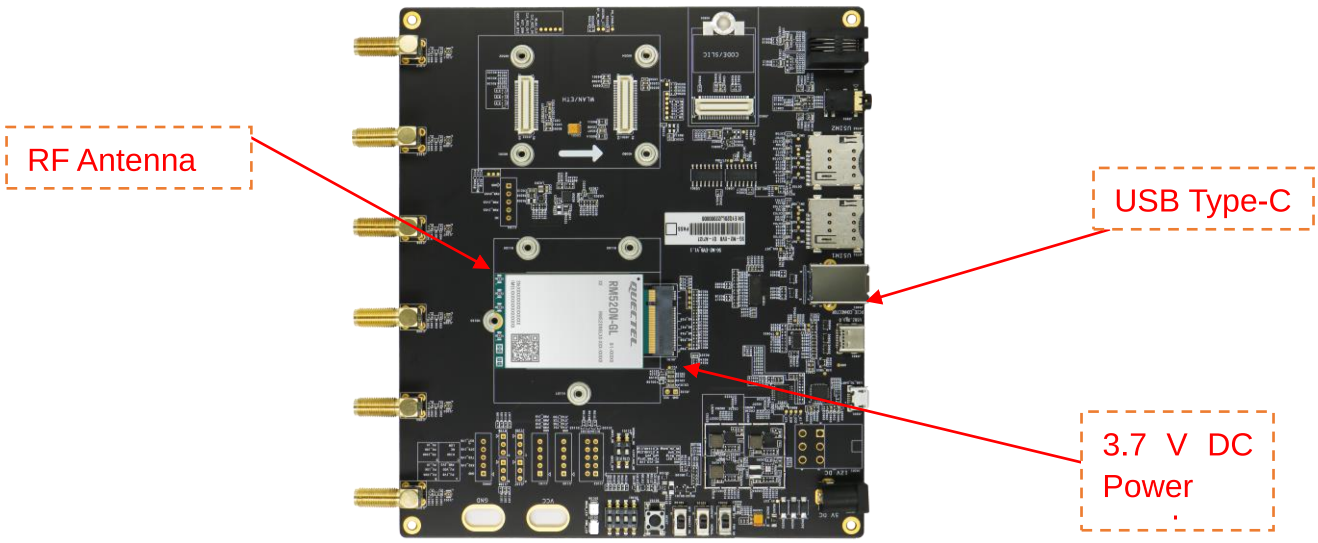

Figure 5: 5G M.2 EVB + RM520N-GL Module Assembly Diagram

The picture below shows the thermal power test environment, including computers, UXM 5G wireless test instruments, thermostats chamber, EVBs and programmable power supplies.

Figure 6: Test Environment

3.2. Test Case and Results

For RM520N series modules, the main heat source chips include the BB, PMU, MCP, and PA, etc. They consumed most thermal power of the module. Based on the above test environment, use KEYSIGHT's E7515B UXM 5G comprehensive tester to test the RM520N-GL module (test case: 66A-66A-7C_N78, application layer; data uplink transmission rate: 197.5 Mbps; data downlink transmission rate: 2.43 Gbps). Based on this test case, the module is at an ambient temperature of 25 °C, and the average current consumption of the module is about 1.768 A when the power supply is 3.8 V.

In this scenario, the thermal power consumption of each main chip is as follows:

Table 3: RM520N-GL Module Thermal Power Consumption (unit: W)

BB	MCP	PMU	Transceiver	PA 1	QET_0	QET_1	PA 2	PA 3	PA 4	PA 5
1.80	0.074	0.696	0.767	0	0.24	0.043	0	0.469	0	2.12

NOTE

1. The total power of this test scene is 6.718 W, and the thermal power consumption is 6.209 W. The total input power of digital chips is generally considered as thermal power consumption, and only part of the input power of analog chips is converted into thermal power consumption. Based on the measured data and the working efficiency information provided by the chip supplier, the calculated thermal power consumption of each chip is shown in the table above.
2. The simulation and data analysis in this design guide are based on the RM520N-GL module and the above thermal power consumption data.

4 Thermal Simulation

4.1. Thermal Simulation Model Overview

The chip supplier provides a simulation model of these key components of the modules. During the simulation, the thermal power consumption of the heat source chips is set according to the thermal power consumption data of ***Figure 3***. At the same time, a simulation model of other components (such as the shielding frame and the shielding case, etc.) is created based on the 3D model of the module. The figure below is a simplified diagram of the simulation model:

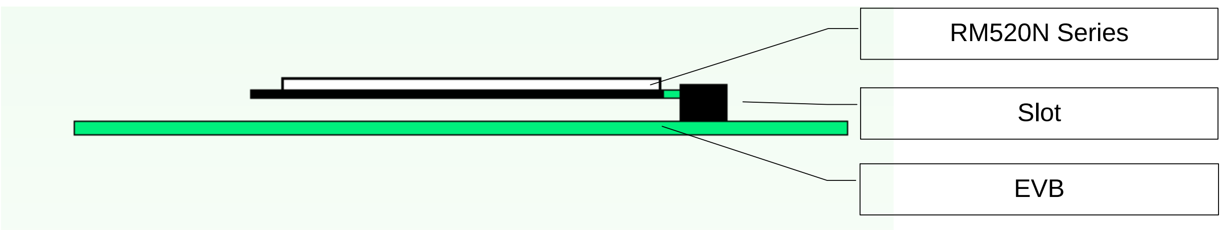

Figure 7: Simulation Model of the Module

The following 5 modes are carried out based on this model.

- **Mode 1**: At an ambient temperature of 25 °C, fill the gaps between the main heat source chips and the shielding case with thermal gel, its thermal conductivity is 3.5 W/(m·K). The module dissipates the heat through natural convection and heat radiation.
- **Mode 2**: On the basis of Mode 1, paste a 2.4 mm thermal pad between the module and the EVB, its thermal conductivity is 6 W/(m·K). The module transfers the heat generated during operation to the EVB at the bottom of the module through heat conduction and the whole module dissipates heat through natural convection and heat radiation.
- **Mode 3**: On the basis of Mode 2, add a heatsink on the top of the shielding case. The module transfers the heat generated during operation to the EVB at the bottom of the module and the heatsink at the top through heat conduction and then the whole module dissipates heat through natural convection and heat radiation.
- **Mode 4**: Based on Mode 3, change the ambient temperature to 50 °C.
- **Mode 5**: Based on Mode 3, change the ambient temperature to 85 °C.

The figure below is a component distribution diagram of the RM520N-GL thermal model. Other modules are similar to this and will not be listed one by one.

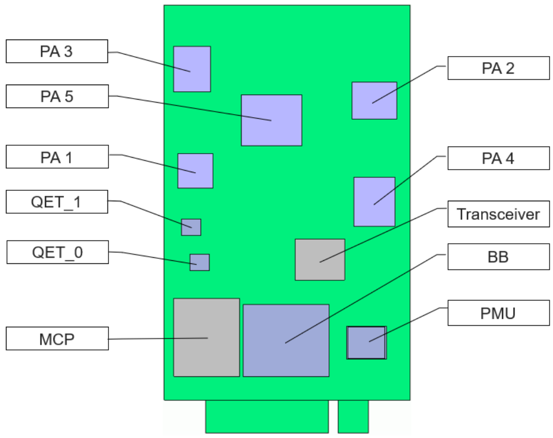

Figure 8: Component Distribution Diagram of the RM520N-GL Thermal Model

4.2. Thermal Simulation Result

This section mainly introduces the simulation results in 5 modes.

The thermal simulation is performed at an ambient temperature of 25 °C and 1 standard atmospheric pressure, and all components of the module are cooled by natural convection and thermal radiation. In the thermal simulation process, the junction temperature of each component is the temperature value after the module enters a steady state.

4.2.1. Mode 1

Mode 1: At an ambient temperature of 25 °C, fill the gaps between the main heat source chips and the shielding case with thermal gel, its thermal conductivity is 3.5 W/(m·K). The module dissipates the module through natural convection and heat radiation.

The following table shows the simulation result in **mode 1**.

Table 4: Tj of RM520N-GL Main Heat Source Chips in Simulation Mode 1 (Unit: °C)

BB	MCP	PMU	Transceiver	PA 1	QET_0	QET_1	PA 2	PA 3	PA 4	PA 5
162.5	135.6	159.6	159.4	133.7	182.5	144.2	132.8	145.0	134.8	161.3

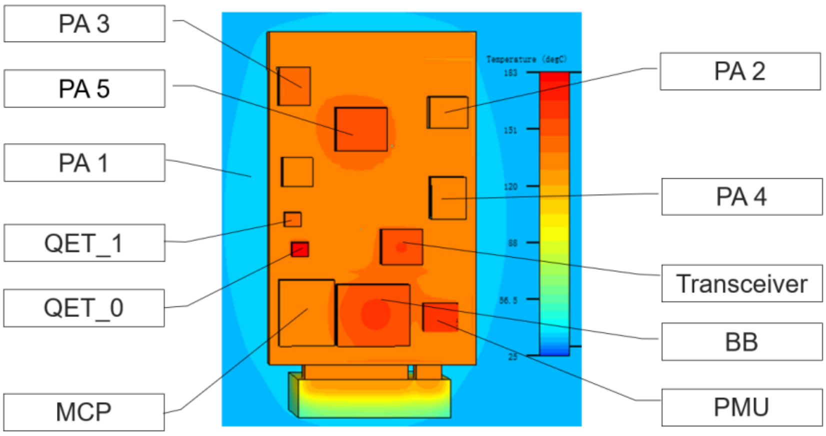

Figure 9: Cut Plane Temperature Contour in Mode 1

4.2.2. Mode 2

Mode 2: On the basis of Mode 1, paste a 2.4 mm thermal pad between the module and the EVB, its thermal conductivity is 6 W/(m·K). The module transfers the heat generated during operation to the EVB at the bottom of the module through heat conduction and the whole module dissipates heat through natural convection and heat radiation.

The following table shows the simulation result in **mode 2**.

Table 5: Tj of RM520N-GL Main Heat Source Chips in Simulation Mode 2 (Unit: °C)

BB	MCP	PMU	Transceiver	PA 1	QET_0	QET_1	PA 2	PA 3	PA 4	PA 5
85.0	62.0	83.9	81.6	56.5	102.2	63.2	53.1	64.5	54.7	80.1

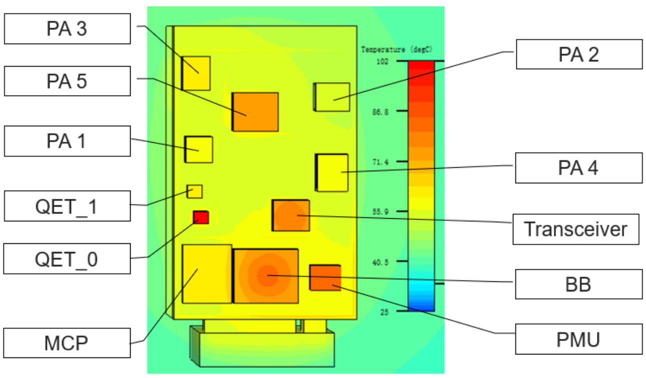

Figure 10: Cut Plane Temperature Contour in Mode 2

4.2.3. Mode 3

Mode 3: On the basis of Mode 2, add a heatsink on the top of the shielding case. The module transfers the heat generated during operation to the EVB at the bottom of the module and the heatsink at the top through heat conduction and then the whole module dissipates heat through natural convection and heat radiation.

The following are the parameters of auxiliary materials during the simulation:

- Heatsink material: aluminum 6063-T5.
- Size:
  - Base size: 40 mm (L) × 61.5 mm (W) × 2.5 mm (T);
  - Heatsink size: 40 mm (L) × 1 mm (T) × 15 mm (H）, 10 pcs;
- Surface treatment: black anodized.

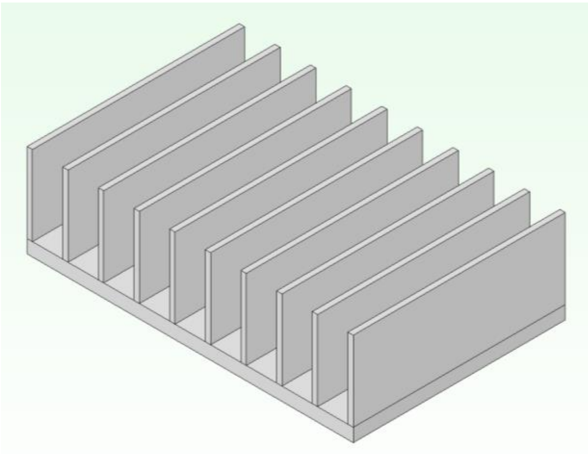

Figure 11: View of the Heatsink

The following table shows the simulation result in **mode 3**.

Table 6: Tj of RM520N-GL Main Heat Source Chips in Simulation Mode 3 (Unit: °C)

BB	MCP	PMU	Transceiver	PA 1	QET_0	QET_1	PA 2	PA 3	PA 4	PA 5
63.7	49.1	57.7	60.5	47.6	93.0	54.8	46.1	54.9	46.2	67.1

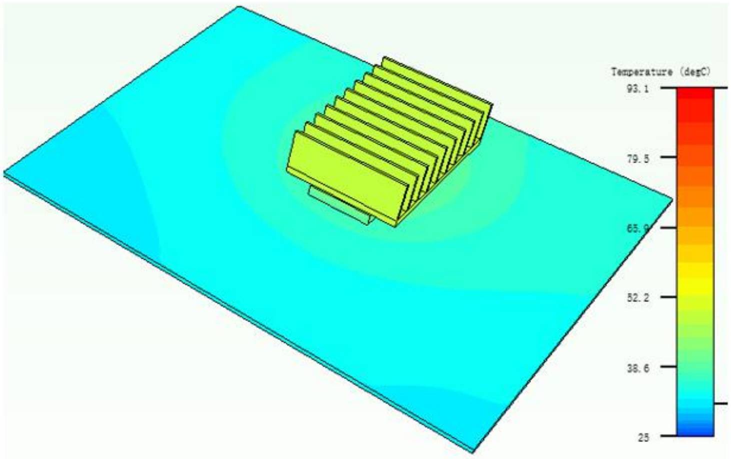

Figure 12: Thermal Simulation Temperature Profile in Mode 3

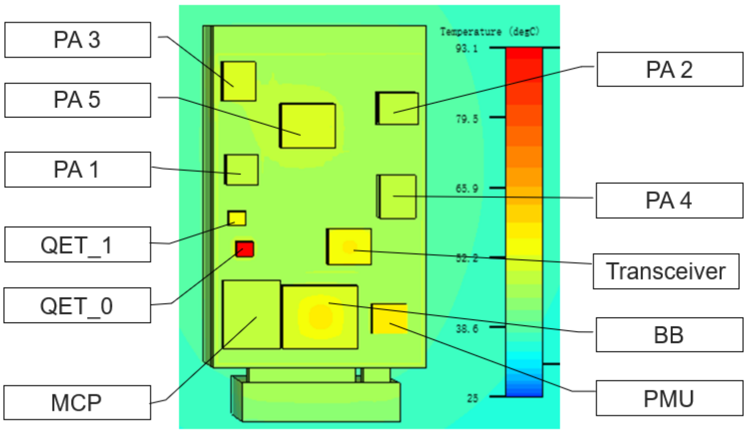

Figure 13 : Cut Plane Temperature Contour in Mode 3

4.2.4. Mode 4

Mode 4: Based on Mode 3, change the ambient temperature to 50 °C;

The following table shows the simulation result in **mode 4**.

Table 7: Tj of RM520N-GL Main Heat Source Chips in Mode 4 (Unit: °C)

BB	MCP	PMU	Transceiver	PA 1	QET_0	QET_1	PA 2	PA 3	PA 4	PA 5
87.3	72.7	81.3	84.1	71.2	116.7	78.5	69.8	78.6	69.8	90.8

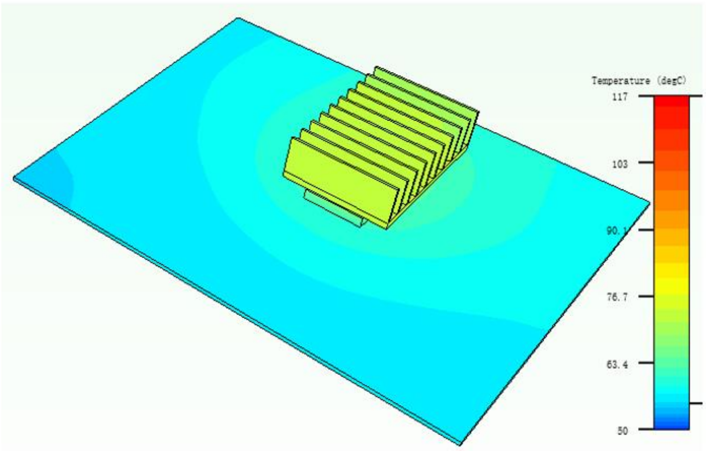

Figure 14: Thermal Simulation Temperature Profile in Mode 4

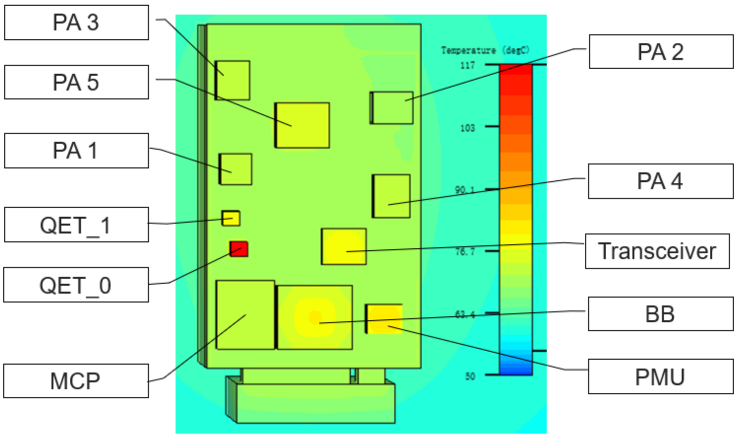

Figure 15: Cut Plane Temperature Contour in Mode 4

4.2.5. Mode 5

Mode 5: Based on Mode 3, change the ambient temperature to 85 °C;

The following table shows the simulation result in **mode 5**.

Table 8: Tj of RM520N-GL Main Heat Source Chips in Mode 5 (Unit: °C)

BB	MCP	PMU	Transceiver	PA 1	QET_0	QET_1	PA 2	PA 3	PA 4	PA 5
120.5	114.4	105.8	117.2	104.4	149.9	111.8	103.0	111.8	103.1	124.0

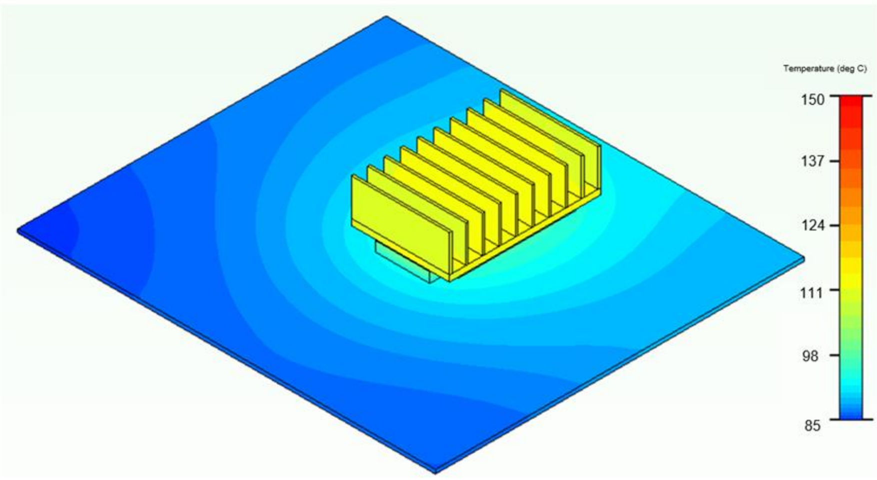

Figure 16: Thermal Simulation Temperature Profile in Mode 5

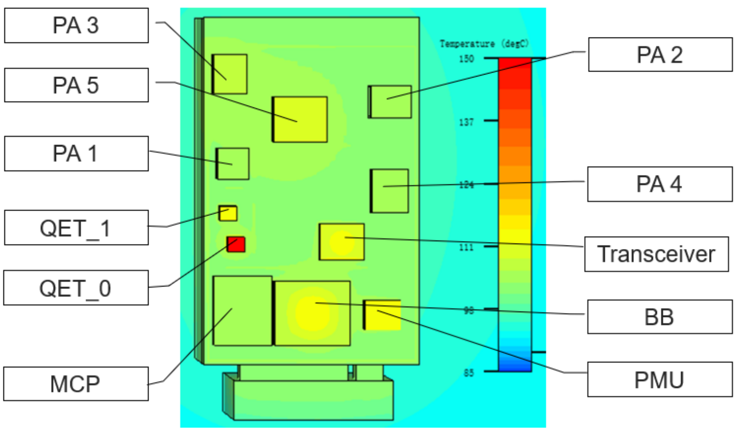

Figure 17: Cut Plane Temperature Contour in Mode 5

4.3. Thermal Simulation Summary

According to the five modes listed above, the simulation results are as follows：

Table 9: RM520N-GL Thermal Simulation Tj Summary (Unit: ºC)

Main Chip	Ambient temperature 25 °C Original state	Ambient temperature 25 °C Add a thermal pad to the bottom	Ambient temperature 25 °C Place heatsink on top and add thermal pad to the bottom	Ambient temperature 50 °C Place heatsink on top and add a thermal pad to the bottom	Ambient temperature 85 °C Place heatsink on top and add a thermal pad to the bottom
BB	162.5	85.0	63.7	87.3	120.5
MCP	135.6	62.0	49.1	72.7	114.4
PMU	159.6	83.9	57.7	81.3	105.8
Transceiver	159.4	81.6	60.5	84.1	117.2
PA 1	133.7	56.5	47.6	71.2	104.4
QET_0	182.5	102.2	93.0	116.7	149.9
QET_1	144.2	63.2	54.8	78.5	111.8
PA 2	132.8	53.1	46.1	69.8	103.0
PA 3	145.0	64.5	54.9	78.6	111.8
PA 4	134.8	54.7	46.2	69.8	103.1
PA 5	161.3	80.1	67.1	90.8	124.0

Conclusions based on the above simulation results are listed below:

1. No thermal pad between the module and the PCB results in poor heat dissipation effect; after adding thermal pad, the heat dissipation effect of the module is greatly improved.
2. After adding a thermal pad of appropriate thickness between the bottom of the module and the PCB, and adding a heatsink on the top of the module, the heat dissipation effect of the module is greatly improved, and the junction temperature of the BB chip can drop to 67.1 °C under the same environment. The improvement is obvious.

NOTE

The above thermal simulation temperature values are for reference only, it is recommended to refer to the actual thermal test data.

5 Thermal Design Scheme

To ensure the module works as long as possible under the premise of ensuring the overall performance of the module (such as maximum power or maximum data transmission rate, etc.) under high temperature or extreme conditions, the following thermal design schemes are recommended.

5.1. Device Housing Design

1. In the case of ensuring the mechanical reliability of the device, please choose a thinner housing to reduce thermal resistance.
2. Enlarge the internal space as much as possible for better air convection.
3. Sufficient space needs to be reserved inside the device for placing a heatsink to improve heat dissipation.
4. Use metal housings for the device for better thermal conductivity .

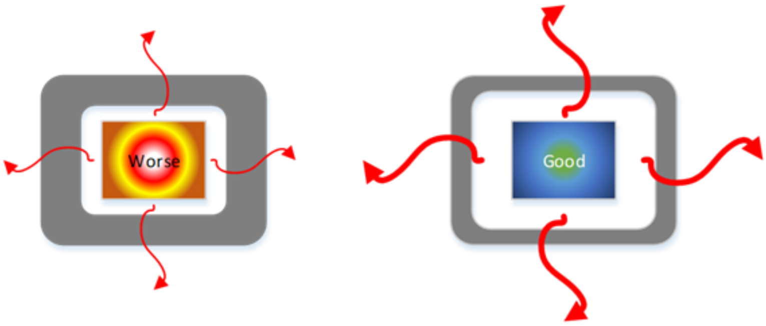

Figure 18: Housing Wall Thickness Design

Figure 19: Suggestions on Internal Space Design

5.2. Place Design of Terminal PCBA

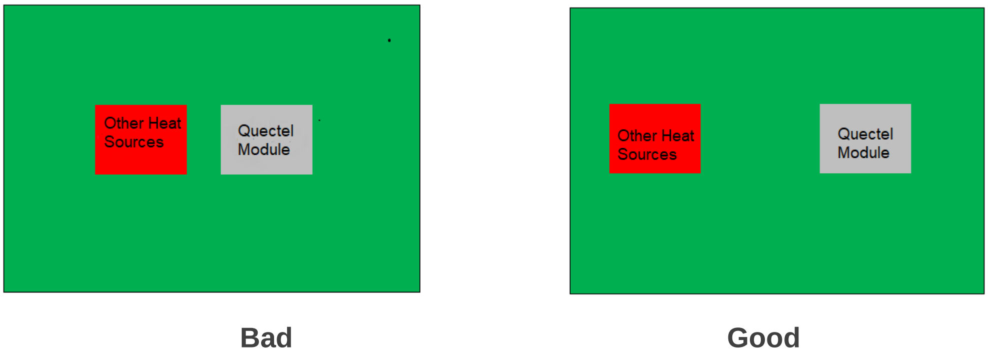

Figure 20: Schematic Diagram of the Module and Other Heat Sources

When placing RM520N series modules, try to keep a distance of more than 6 mm from other heat sources on the mainboard. Especially for high-power components such as PA, the distance can be increased appropriately to prevent heat superposition.

5.3. Design of Terminal PCB

The impact of different PCB sizes, layers, and thermal vias on the module heat dissipation is listed below.

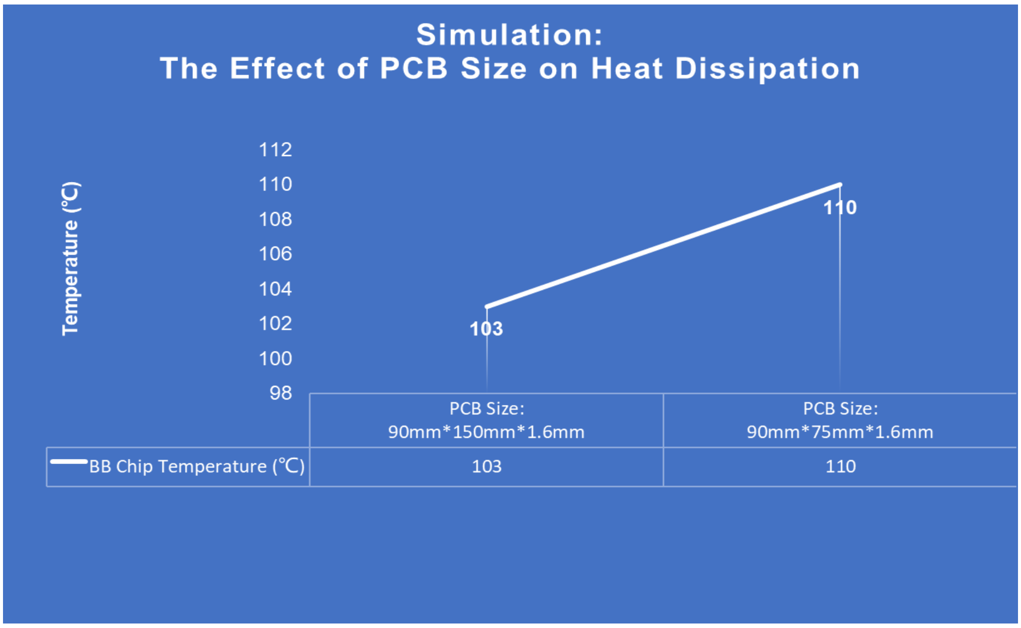

Figure 21: Thermal simulation comparison of different PCB sizes

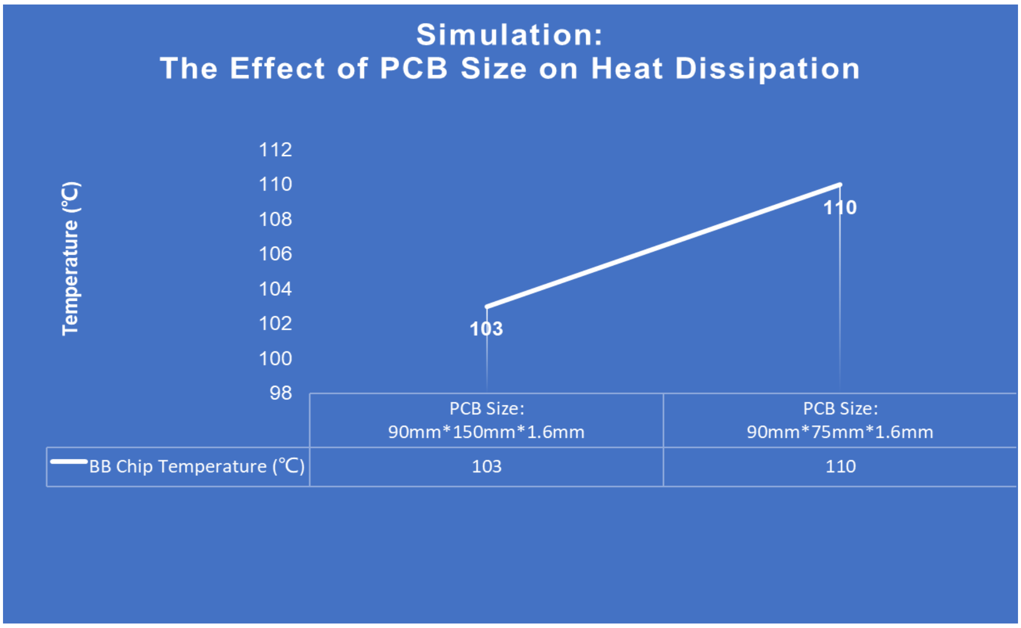

Figure 22: Simulation comparison of different PCB layers and thermal vias

Combining the above content, the design of terminal PCB is summarized as follows:

1. In the same scenario, the larger the area of the PCB, the better the cooling performance of the module.
2. In the same scenario, the more layers the PCB has with the same thickness, the better the heat dissipation performance of the module is; For the PCB with the same thickness and number of layers, the more thermal vias under the module, the better the heat dissipation performance of the module.
3. It is suggested that you should make solder mask opening (copper exposed) directly on the front of the PCB where the module is installed and on the back of the PCB to increase the heat dissipation performance on the back of the PCB, as shown in the figure below.

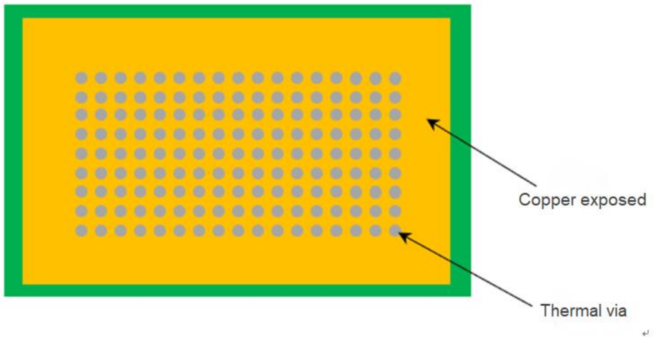

Figure 23: Copper Exposed on the Back of the Bottom PCB

5.4. Suggestions for External Heat Dissipation of Terminals

5.4.1. External Heat Dissipation Scheme 1

Place the heatsink on top of the shielding case as shown below. The TIM (Thermal Interface Material) with high conductivity is filled between the module shielding case and the heatsink to facilitate the complete contact between the module and the heatsink. It is recommended to choose 6063-T5 aluminum heatsink. The surface of it can be black anodized and nano-carbon coated to enhance the heat dissipation capability. Additionally, add as many thermal vias as possible in the mainboard PCB where the module is installed to facilitate heat dissipation.

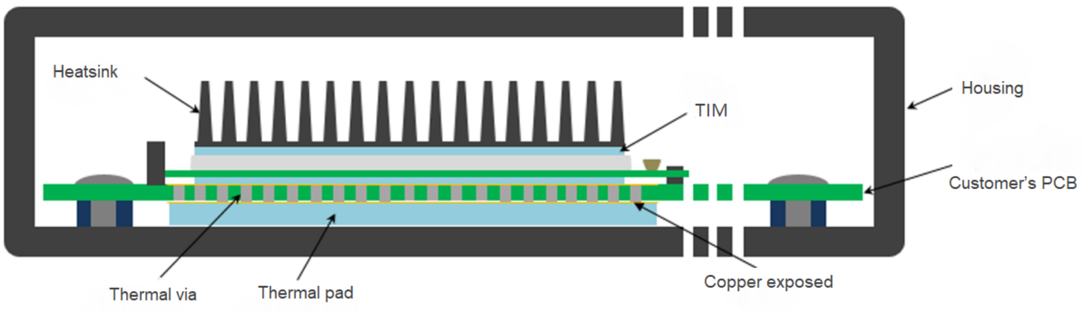

Figure 24: View of External Heat Dissipation Design Scheme 1

NOTE

The TIM thermal material and heatsink specifications mentioned in the following chapters are consistent with the scheme 1, and the mainboard PCB area where the module is installed needs to add as many thermal vias as possible. It is a general measure and we will not repeat this in each of the measure scheme in the following chapters.

5.4.2. External Heat Dissipation Scheme 2

Use two heatsinks. One is placed on the top of the module's shielding case, and the other is placed on the back of the mainboard PCB. Fill the gaps between the shielding case, mainboard PCB and the heatsink with TIM so that it is in full contact with the heatsink.

Remove the solder mask on both sides of the mainboard PCB and expose as much copper as possible to reduce thermal resistance and facilitate heat dissipation.

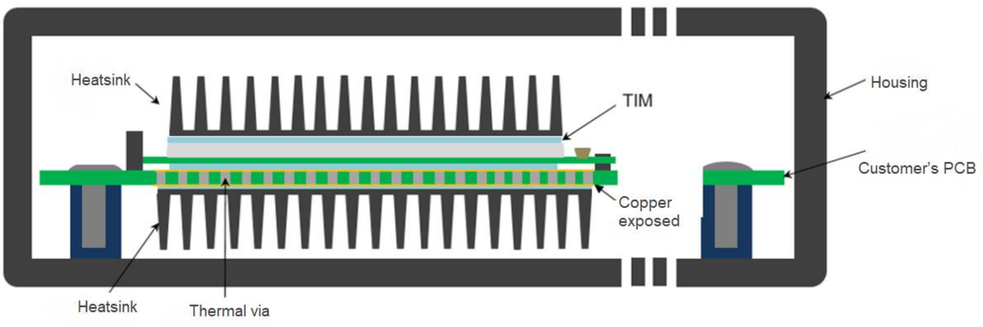

Figure 25: View of External Heat Dissipation Design Scheme 2

5.4.3. External Heat Dissipation Scheme 3

Use a metal housing with a heatsink, and fill the gap between the module's shielding case and the device housing with TIM to make close contact with heatsink.

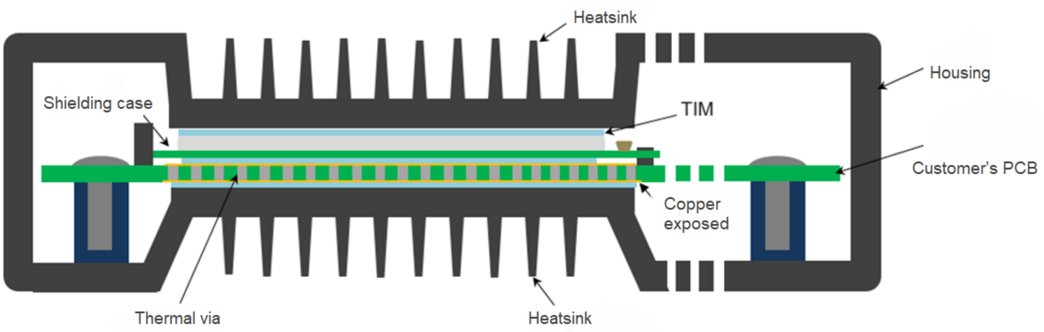

Figure 26: View of External Heat Dissipation Design Scheme 3

6 Summary

In view of the above thermal test, thermal simulation and cooling measures for the module, the following principles are concluded:

1. Due to the size limitation, the temperature rise problem cannot be solved completely from the module's side, an effective and reliable systematic heat dissipation solution is necessary.
2. Thermal vias need to be designed in the mainboard PCB area under the module, the solder mask layer on both sides of the PCB in the module area needs to be opened to expose the copper, and a heatsink should be used to improve the heat dissipation effect of the module. Additionally, select the appropriate heatsink and housing according to the structure of the product, and conduct the heat generated by the module to the device housing for heat dissipation;
3. Try to keep a certain distance (more than 6 mm) between other heat sources on the PCB where the module is installed and the module to prevent heat superposition. It is required to avoid the heat superposition between the heat sources on the front and back of the PCB and the module.
4. Choose suitable thermal pads, thermal gel and thermal silicone grease, and avoid using thicker thermal pads. The recommended thickness is less than 3 mm;
5. For devices whose thermal dissipation relies on natural convection, it is necessary to improve the heat transfer performance from structural parts and housing to air, In the case that natural heat dissipation is not satisfied, we can make forced heat dissipation measures to improve the heat dissipation effect of the whole device.

7 Related Documents

Table 10: Related Documents

Document Name
[1] Quectel_RG520N&RG5x0F&RM5x0N_Series_Software_Thermal_Management_Guid
[2] Quectel_RM520N_Series_Hardware_Design
[3] Quectel_Module_Thermal_Design_Guide

Table 11: Terms and Abbreviations

Terms and Abbreviations	Description
BB	Baseband
CPU	Central Processing Unit
DC	Direct Current
EVB	Evaluation Board
MCP	Multiple Chip Package
PA	Power Amplifier
PCB	Printed Circuit Board
PCBA	Printed Circuit Board Assembly
PMU	Power Management Unit
TIM	Thermal Interface Materials
Tj	Junction Temperature
USB	Universal Serial Bus