EC2x&EG9x&EG2x-G&EM05 Series Thermal Mitigation User Guide

LTE Standard Module Series

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Our aim is to provide customers with timely and comprehensive service. For any assistance, please contact our company headquarters:

Quectel Wireless Solutions Co., Ltd.

Building 5, Shanghai Business Park Phase III (Area B), No.1016 Tianlin Road, Minhang District, Shanghai, China 200233

Tel: +86 21 5108 6236

Email: info@quectel.com

Or our local office. For more information, please visit:

http://www.quectel.com/support/sales.htm

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About the Document

Revision History

Version	Date	Author	Description
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1 Introduction

This document mainly introduces the thermal mitigation mechanism on Quectel LTE Standard EC2x&EG9x&EG2x-G&EM05 series modules.

There are two main cooling strategies to cool down the module: reduce rate and limit the transmission power, which will be described in detail in *Chapter 2* and *3* respectively, and either of the two strategies can be used or be used together according to the actual demands.

In addition, if the temperature of the module is still rising after reducing the rate and the transmission power due to some reasons, the module will enter the Limited Service State after reaching Level 3 of the temperature threshold. In this state, services such as data transmission are limited, and the temperature will drop. If the temperature of the module continues to rise and exceeds 120 ºC after entering the Limited Service State, the software will force the module to restart in order to protect the module's hardware from damage. For more details, please refer to *Chapter 4* and *5*.

1.1. Applicable Modules

Table 1: Applicable Modules

Module Series	Model
EC2x series	EC25 series
	EC21 series
	EC20 R2.1
EG9x series	EG95 series
	EG91 series
EG2x-G	EG25-G
	EG21-G
EM05 series	EM05 series

2 Limit the Data Throughput

- **Effect**

The workload of components such as CPU/PA can be reduced.

- **Limitation**

The cooling is not obvious in the case of no data or low rate.

2.1. Reduce Rate

Data throughput can be limited through reducing the data rate. The following sub-chapters illustrate the detailed information of temperature and rate thresholds concerning data rate reduction.

Thermal mitigation levels for the applicable LTE Standard modules are:
Level 0 – No mitigation.
Level 1 – Reduce uplink data.
Level 2 – Reduce the downlink rate besides reducing the uplink rate.
Level 3 – Disable services like call and data transmission.

For detailed information of the default values of the relevant AT commands used, which are recommended for thermal mitigation, please refer to the table below. For more details of these AT commands, please contact Quectel Technical Support Team.

Table 1: Default Configuration of AT Commands for Reducing Rate

AT Commands	Description
AT+QCFG="thermal/modem",1,100000,95000	Configure the temperature thresholds as 100 ºC and 95 ºC to reduce uplink rate (i.e. module enters Level 1). **1:** Level 1. **100000:** The configured temperature threshold 100 ºC. **95000:** The configured temperature threshold 95 ºC.
AT+QCFG="thermal/modem",2,105000,100000	Configure the temperature thresholds as 105 ºC and 100 ºC to reduce uplink and downlink rates simultaneously (i.e. module enters Level 2).

	2: Level 2.
	105000: The configured temperature threshold 105 ºC.
	100000: The configured temperature threshold 100 ºC.
AT+QNVFW="/nv/item_files/modem/utils/cfm/cfm_thermal_step_timer_in_sec",03	Configure the detection cycle of the temperature on sensor. **03:** Detection cycle of the temperature on sensor
AT+QNVFW="/nv/item_files/modem/lte/common/lte_fc_macul_target_rates",0A0100006A18000088130 000C4090000E2040000E80300006 B030000EE020000EE020000F4010 000F4010000	Configure the levels of reducing uplink rate. For more details of the parameter, please refer to *Table 3*.
AT+QNVFW="/nv/item_files/modem/lte/ML1/tm_mechanism",01	Enable the level configuration of reducing downlink rate.
AT+QNVFW="/nv/item_files/modem/lte/ML1/pucch_cancel",0603030 01E00AA003C008C0050007800640 06400780050008C003C000000000 00000000000000000000000001027 000090010000	Configure the levels of reducing downlink rate.

2.1.1. Temperature Thresholds

The rate can be reduced according to different temperature thresholds, which can be queried and configured as below.

2.1.1.1. Query Temperature Thresholds by AT Commands

The commands for querying different temperature thresholds for the applicable modules are as follows.

```
AT+QCFG="thermal/modem"
+QCFG: "thermal/modem",1,100000,95000
+QCFG: "thermal/modem",2,105000,100000
+QCFG: "thermal/modem",3,115000,105000

OK
```

2.1.1.2. Configure Temperature Thresholds by AT Commands to Reduce Downlink/Uplink Rates

2.1.1.2.1. Reduce Uplink Rate

AT+QCFG="thermal/modem",1,100000,95000 (default configuration) is used to configure temperature thresholds as 100 ⁰C and 95 ⁰C:

- When the temperature indicated by the temperature sensor is higher than the configured temperature threshold 100 ⁰C, the uplink rate will be reduced (i.e, module enters Level 1).
- When the temperature indicated by the temperature sensor is lower than the configured temperature threshold 95 ⁰C, the module will exist from Level 1.

2.1.1.2.2. Reduce Uplink and Downlink Rates Simultaneously

AT+QCFG="thermal/modem",2,105000,100000 (default configuration) is used to configure temperature thresholds as 105 ⁰C and 100 ⁰C:

- When the temperature indicated by the temperature sensor is higher than the configured temperature threshold 105 ⁰C, the uplink rate and the downlink rates will be reduced simultaneously (i.e, module enters Level 2).
- When the temperature indicated by the temperature sensor is lower than the configured temperature threshold 100 ⁰C, module will exit Level 2.

2.1.2. Rate Thresholds

2.1.2.1. Configure the Level of Reducing Uplink Rate

1. **AT+QNVFW="/nv/item_files/modem/utils/cfm/cfm_thermal_step_timer_in_sec",03** is used to configure the detection cycle of the temperature on sensor. When the temperature is higher than 100 ⁰C, the module will enter Level 1 and set the maximum transmission rate to 40 Mbit/s (target_rate[1]). If the temperature is still at Level 1 (or higher to enter Level 2) after 3 seconds, set the transmission rate to 20 Mbit/s (target_rate[2]). Otherwise the transmission rate will be set to 50 Mbit/s (target_rate[0]).

Table 2: Detection Cycle

Parameter	Value	In Hexadecimal
Detection cycle of the temperature on sensor	3 s	03 (8 bits)

2. **AT+QNVFW="/nv/item_files/modem/lte/common/lte_fc_macul_target_rates",0A0100006A1800 0088130000C4090000E2040000E80300006B030000EE020000EE020000F4010000F4010000** configures the levels of reducing uplink rate. The parameters in this command are in hexadecimal and are configured to switch between different uplink rate levels. For more details, please refer to the following table.

Table 3: Uplink Rate Threshold Parameters

Parameter Category	Parameter ID	Value (In Decimal)	In Hexadecimal
Number of uplink rate threshold level	num_states	10	0A (8 bits)
Initial uplink rate threshold level when entering Level 1	default_state	1 (i.e. target_rate[1])	01 (8 bit)
Rate threshold levels	Reserved	0x0000	0000 (16 bits)
	target_rate[0]	6250 (50 Mbit/s)	6A180000 (32 bits)
	target_rate[1]	5000 (40 Mbit/s)	88130000 (32 bits)
	target_rate[2]	2500 (20 Mbit/s)	C4090000 (32 bits)
	target_rate[3]	1250 (10 Mbit/s)	E2040000 (32 bits)
	target_rate[4]	1000 (8 Mbit/s)	E8030000 (32 bits)
	target_rate[5]	875 (7 Mbit/s)	6B030000 (32 bits)
	target_rate[6]	750 (6 Mbit/s)	EE020000 (32 bits)
	target_rate[7]	750 (6 Mbit/s)	EE020000 (32 bits)
	target_rate[8]	500 (4 Mbit/s)	F4010000 (32 bits)
	target_rate[9]	500 (4 Mbit/s)	F4010000 (32 bits)

NOTE

The module cannot directly control the downlink rate but tries to force the network to reduce the downlink rate by not responding the network ACK at the wireless protocol stack level. This requires the support of the protocol between the module and the network, but the rate threshold is uncontrollable.

2.1.2.2. Configure the Level of Reducing Downlink Rate

First execute **AT+QNVFW="/nv/item_files/modem/lte/ML1/tm_mechanism",01** to enable the level configuration of reducing downlink rate.

Then execute **AT+QNVFW="/nv/item_files/modem/lte/ML1/pucch_cancel",060303001E00AA003C0 08C00500078006400640078005000 8C003C000000000000000000000000000000001027000090010 000** to configure the levels of reducing downlink rate.

The PUCCH cycle is 200 ms (Time On + Off). ACK/NACK is sent in PUCCH when the cycle is on and ACK/NACK is not sent in PUCCH when the cycle is off. After entering Level 2 of thermal mitigation, the default level of reducing downlink rate is Level 3. If the temperature is at Level 2 of thermal mitigation for 10 seconds, the level of reducing downlink rate will be limited to Level 2 (On: 80 ms; Off: 120 ms); otherwise it will rise to level 4 (On: 120 ms; Off: 80 ms), and so on. For more details, please refer to the following table.

Table 4: Downlink Rate Threshold Parameters

Parameter	Value
PUCCH cycle	200 ms
Number of states	6
Default state for thermal mitigation	3
Default state for CPU based flow control	3
Level 0 of reducing downlink rate (timer [0])	On: 30 ms; Off: 170 ms
Level 1 of reducing downlink rate (timer [1])	On: 60 ms; Off: 140 ms
Level 2 of reducing downlink rate (timer [2])	On: 80 ms; Off: 120 ms
Level 3 of reducing downlink rate (timer [3])	On: 100 ms; Off: 100 ms
Level 4 of reducing downlink rate (timer [4])	On: 120 ms; Off: 80 ms
Level 5 of reducing downlink rate (timer [5])	On: 140 ms; Off: 60 ms
Step timer for each state for thermal mitigation	10000
Default state for each CPU based flow control	400

3 Limit Transmission Power

● **Effect**

The workload of PA can be reduced.

● **Limitation**

The transmission power in field test is configured by the network. When network signal is not too bad, the transmission power is generally not high, and thus it is not obvious to limit the transmission power for cooling.

When the actual transmission power is restricted, and is lower than that of the network configured, the network may not be able to receive the signal sent by the module or to decode the signals, resulting in a decrease in the data transmission performance.

3.1. Reduce Transmission Power

The transmission power affects the power consumption and heat of the PA, and the limited transmission power can theoretically reduce the temperature. For more details of these AT commands, please contact Quectel Technical Support Team.

For EC2x&EG9x&EG2x-G&EM05 series modules, the transmission power control level is divided into eight levels from Level 0 to Level 7, which respectively correspond to different maximum transmission power ranges from 23 dBm to 16 dBm.

Table 5: Default Value Configuration of AT Commands for Reducing Transmission Power

AT Commands	Description
AT+QCFG="thermal/txpwrlmt",1,2, 105,1000,3,10	Restrict the transmission power when the temperature exceeds 105 ⁰C. For details of these parameters, please refer to **Chapter 3.1.1**.

3.1.1. AT+QCFG="thermal/txpwrlmt"   Control Transmission Power Under High Temperature

AT+QCFG="thermal/txpwrlmt" Control Transmission Power Under High Temperature	
Write Command **AT+QCFG="thermal/txpwrlmt"[,<enable>,<sensor>,<temp_threshold>,<duration>,<trig_cnt>,<clr_cnt>]**	Response If parameters **<enable>**, **<sensor>**, **<temp_threshold>**, **<duration>**, **<trig_cnt>** and **<clr_cnt>** are omitted, return current configuration: **+QCFG: "thermal/txpwrlmt",<enable>,<sensor>,<temp_threshold>,<duration>,<trig_cnt>,<clr_cnt>** **OK** If all the parameters are specified, control transmission power under the temperature thresholds that trigger the power limit or higher (default: 105 ºC): **OK** Or **ERROR**
Maximum Response Time	300 ms
Characteristics	The command takes effect immediately. The configurations will be saved automatically.

Parameter

<enable>	Integer type. Enable/disable to control transmission power reduction under high temperature. 1 Enable 0 Disable
<sensor>	Integer type. Temperature sensor ID. It corresponds to the sensor temperature value returned by **AT+QTEMPDBG=0**. For more details of the AT command, please contact Quectel Technical Support Team. Range: 0-7. Default: 2 (Recommend not to modify this value). 2 Modem temperature sensor 5 PA temperature sensor 7 XO temperature sensor Other parameters are not necessary to be paid attention to.
<temp_threshold>	Integer type. The temperature thresholds that trigger the power limit. Range: -150–150. Default: 105. Unit: ºC.
<duration>	Integer type. Temperature detection cycle. Range: 1000–360000. Default: 1000 (Recommend not to modify this value). Unit: ms.

<trig_cnt>	Integer type. The number of triggering power limit detection threshold. Range: 1-1000. Default: 3 (Recommend not to modify this value).
<clr_cnt>	Integer type. The number of triggering power recovery detection threshold. Range: 1-10000. Default: 10 (Recommend not to modify this value).

4 Enter Limited Service State

AT+QCFG="thermal/modem",3,115000,105000 (default configuration) is used to configure the temperature thresholds as 115 ⁰C and 105 ⁰C to enable module to enter Limited Service State (i.e. Level 3). For more details of the AT command, please contact Quectel Technical Support Team.

Table 6: Default Configuration of AT Command for Entering Limited Service State

AT Command	Description
AT+QCFG="thermal/modem",3,11 5000,105000	Configure the temperature thresholds as 115 ⁰C and 105 ⁰C to enable module to enter Limited Service State (i.e. Level 3). **3:** Level 3. **115000:** The configured temperature threshold 115 ⁰C. **105000:** The configured temperature threshold 105 ⁰C.

- When the temperature indicated by the temperature sensor is higher than the configured temperature threshold 115 ⁰C, the module will enter Limited Service State.
- When the temperature indicated by the temperature sensor is lower than the configured temperature threshold 105 ⁰C, the module will exit Limited Service State.

- **Effect**

Module can be cooled down rapidly.

- **Limitation**

Once the module enters limited service state, it will be out of service immediately.

5 Reboot the Module

When the temperature of the baseband chipset is over 120 ºC, rebooting will occur automatically.

- **Effect**

Module's hardware can be protected.

- **Limitation**

None.

6 Auto-configure Thermal Mitigation

When thermal mitigation is enabled (When **<enable>**=1 in the command below) and the temperature reaches the set thresholds, the thermal mitigation will be adjusted according to the corresponding default values. For default values, please refer to *Table 4*, *5* and *6*.

6.1.　AT+QCFG="thermal/limit_rates"　Enable/Disable Thermal Mitigation

AT+QCFG="thermal/limit_rates"　Enable/Disable Thermal Mitigation	
Write Command **AT+QCFG="thermal/limit_rates"[,<enable>]**	Response If **<enable>** is omitted, return current configuration: **+QCFG: "thermal/limit_rates",<enable>** **OK** If **<enable>** is specified, control rate and transmission power reduction under specified high temperature of each level of thermal mitigation: **OK** Or **ERROR**

Parameter

<enable>	Integer type. Enable/disable thermal mitigation.
	<u>1</u>　Auto-configure temperature thresholds
	Level 1　Enter Level 1 when temperature reaches 100 ⁰C and exits from Level 1 when temperature is lower than 95 ⁰C
	Level 2　Enter Level 2 when temperature reaches 105 ⁰C and exits from Level 2 when temperature is lower than 100 ⁰C
	Limited Service State　Enter Level 3 when temperature reaches 115 ⁰C and exits from Level 3 when temperature is lower than 105 ⁰C
	0　Disable thermal mitigation.

7 Appendix A Reference

Table 7: Terms and Abbreviations

Abbreviation	Description
ACK	Acknowledgement
BB	Baseband
CPU	Central Processing Unit
GMSK	Gaussian Filtered Minimum Shift Keying
GSM	Global System for Mobile Communications
NACK	Negative Acknowledgement
NVM	Non-volatile Memory
PA	Power Amplifier
PUCCH	Physical Uplink Control Channel
WCDMA	Wideband Code Division Multiple Access
XO	Crystal Oscillators