

EM121R-GL

Hardware Design

LTE-A Module Series

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Build a Smarter World

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Safety Information

The following safety precautions must be observed during all phases of operation, such as usage, service or repair of any cellular terminal or mobile incorporating the 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 signal and cellular network cannot be guaranteed to connect in certain conditions, such as when the mobile bill is unpaid or the (U)SIM card is invalid. When emergency help is needed in such conditions, use emergency call if the device supports it. 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. In an emergency, the device with emergency call function cannot be used as the only contact method considering network connection cannot be guaranteed under all circumstances.



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 fuelling 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.

About the Document

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1 Introduction

1.1. Introduction

The hardware design defines EM121R-GL and describes the air and hardware interfaces which are connected with customers' applications.

This document helps you quickly understand the interface specifications, electrical and mechanical details, as well as other related information of EM121R-GL. To facilitate its application in different fields, reference design is also provided for reference. Associated with application notes and user guides, you can use the module to design and set up mobile applications easily.

This document is applicable to the EM121R-GL module.

1.2. Reference Standard

The module complies with the following standards:

- *PCI Express M.2 Specification Revision 2.0, Version 1.2*
- *PCI Express Base Specification Revision 2.0*
- *Universal Serial Bus Specification, Revision 3.0*
- *ISO/IEC 7816-3*
- *MIPI Alliance Specification for RF Front-End Control Interface version 2.0*
- *3GPP TS 27.007 and 3GPP 27.005*
- *3GPP TS 34.121-1*
- *3GPP TS 36.521-1*

1.3. Special Mark

Table 1: Special Mark

Mark	Definition
*	When an asterisk (*) is used after a function, feature, interface, pin name, AT command, or argument, it indicates that the function, feature, interface, pin name, AT command, or argument is under development and currently not supported, unless otherwise specified.
[...]	Brackets ([...]) used after a pin enclosing a range of numbers indicate all pin of the same type. For example, ANTCTL [0:3] refers to all four ANTCTL pins, ANTCTL0, ANTCTL1, ANTCTL2, and ANTCTL3.

2 Product Concept

2.1. General Description

EM121R-GL is a LTE-A/UMTS/HSPA+ wireless communication module with receive diversity. It provides data connectivity on LTE-FDD, LTE-TDD, DC-HSDPA, HSPA+, HSDPA, HSUPA and WCDMA networks. They are standard WWAN M.2 Key-B modules. For more details, see *PCI Express M.2 Specification Revision 2.0, Version 1.2*.

EM121R-GL is an industrial-grade module for industrial and commercial applications only.

It supports embedded operating systems such as Windows, Linux and Android, and also provide GNSS ¹⁾ and voice functionality ²⁾ to meet specific application demands.

The following table shows the frequency bands and GNSS types of the module.

Table 2: Frequency Bands and GNSS Types of EM121R-GL

Mode	Frequency Bands
LTE-FDD (with Rx-diversity)	B1/B2/B3/B4/B5/B7/B8/B12/B13/B14/ /B18/B19/B20/B25/B26/ B28/B29 ⁴⁾ /B30/B32 ⁴⁾ /B66
LTE-TDD (with Rx-diversity)	B38/B39/B40/B41/ B46 ⁴⁾ /B48
WCDMA (with Rx-diversity)	B1/B2/B3/B4/B5/B6/B8/B19
GNSS ¹⁾	GPS L1; GPS L5; GLONASS; BeiDou/COMPASS; Galileo

NOTES

- ¹⁾ GNSS function is optional.
- ²⁾ EM121R-GL contains **Telematics** version and **Data-only** version. **Telematics** version supports

voice and data functions, while **Data-only** version only supports data function.

3. ⁴⁾ LTE-FDD B29/B32 and LTE-TDD B46 support Rx only and are only for secondary component carrier.
4. For details about CA combinations, see **document [1]**.

EM121R-GL can be applied in the following fields:

- Tablet PC and Laptop
- Remote Monitor System
- Wireless POS System
- Smart Metering System
- Wireless Router and Switch
- Other Wireless Terminal Devices

2.2. Key Features

Table 3: Key Features of EM121R-GL

Feature	Details
Function Interface	PCI Express M.2 Interface
Power Supply	<ul style="list-style-type: none"> ● Supply voltage: 3.135–4.4 V ● Typical supply voltage: 3.7 V
(U)SIM Interface	<ul style="list-style-type: none"> ● Compliant with <i>ISO/IEC 7816-3</i> ● Support (U)SIM card: 1.8/3.0 V ● Support Dual SIM Single Standby
USB Interface	<ul style="list-style-type: none"> ● Compliant with USB 3.0 and 2.0 specifications, with maximum transmission rates up to 5 Gbps on USB 3.0 and 480 Mbps on USB 2.0 ● Used for AT command communication, data transmission, firmware upgrade, software debugging, GNSS NMEA sentence output, and voice over USB* ● Support USB serial drivers for: Windows 7/8/8.1/10, Linux 2.6–5.10, Android 4.x/5.x/6.x/7.x/8.x/9.x/10.x
PCIe Interface	<ul style="list-style-type: none"> ● Complaint with PCIe Gen 2 ● PCIe × 1, supporting 5 Gbps per lane ● Used for AT command communication, data transmission, firmware upgrade, software debugging, GNSS NMEA sentence output
PCM Interface*	<ul style="list-style-type: none"> ● Used for audio function with external codec ● Support 16-bit linear data format ● Support long and short frame synchronization

	<ul style="list-style-type: none"> Support master and slave modes, but must be the master in long frame synchronization
Rx-diversity	<ul style="list-style-type: none"> LTE/WCDMA
Antenna Interfaces	EM121R-GL <ul style="list-style-type: none"> Main, Rx-diversity and GNSS antenna connectors 50 Ω impedance
Transmitting Power	PCIe Interface <ul style="list-style-type: none"> WCDMA Bands: Class 3 (24 dBm +1/-3 dB) LTE-FDD: <ul style="list-style-type: none"> B30: Class 3 (20 dBm $\pm$2 dB) Other Bands: Class 3 (23 dBm $\pm$2 dB) LTE-TDD: <ul style="list-style-type: none"> B41 HPUE: Class 2 (25.5 dBm +1/-2 dB) B48: Class 3 (19 dBm $\pm$2 dB) Other Bands: Class 3 (23 dBm $\pm$2 dB) USB Interface <ul style="list-style-type: none"> WCDMA Bands: Class 3 (24 dBm +1/-3 dB) LTE-FDD Bands: Class 3 (23 dBm $\pm$2 dB) LTE-TDD: <ul style="list-style-type: none"> B41 HPUE: Class 2 (25.5 dBm +1/-2 dB) Other Bands: Class 3 (23 dBm $\pm$2 dB)
LTE Features	EM121R-GL <ul style="list-style-type: none"> Up to LTE Cat 12 1.4–60 MHz (3CA) RF bandwidth Support 2 $\times$ 2 MIMO in DL direction Support uplink QPSK, 16QAM and 64QAM modulation Support downlink QPSK, 16QAM and 64QAM and 256QAM modulation Data rate: up to 600 Mbps (DL)/150 Mbps (UL)
UMTS Features	<ul style="list-style-type: none"> 3GPP R9 DC-HSDPA, HSPA+, HSDPA, HSUPA and WCDMA Support QPSK, 16QAM and 64QAM modulation Data rate: <ul style="list-style-type: none"> DC-HSDPA: max. 42 Mbps (DL) HSUPA: max. 5.76 Mbps (UL) WCDMA: max. 384 kbps (DL)/384 kbps (UL)
GNSS Features	<ul style="list-style-type: none"> Support GPS, GLONASS, BeiDou/COMPASS and Galileo Protocol: NMEA 0183 Data update rate: 1 Hz
AT Commands	<ul style="list-style-type: none"> Compliant with 3GPP TS 27.007 and 3GPP TS 27.005 Quectel enhanced AT commands
Internet Protocol Features	QMI/MBIM/NITZ/PING/HTTP/HTTPS protocols
Firmware Upgrade	USB 2.0 interface, PCIe interface and DFOTA

SMS	<ul style="list-style-type: none"> ● Text and PDU modes ● Point-to-point MO and MT ● SMS cell broadcast ● SMS storage: ME by default
Physical Characteristics	<ul style="list-style-type: none"> ● M.2 Key-B ● Size: (30.0 ±0.15) mm × (42.0 ±0.15) mm × (2.3 ±0.2) mm ● Weight: approx. 6.8 g
Temperature Range	<ul style="list-style-type: none"> ● Operating temperature range: -25 to +75 °C ¹⁾ ● Extended temperature range: -40 to +85 °C ²⁾ ● Storage temperature range: -40 to +90 °C
RoHS	All hardware components are fully compliant with EU RoHS directive

NOTES

- 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 extended 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, while one or more specifications, such as P_{out}, may undergo a reduction in value, exceeding the specified tolerances of 3GPP. When the temperature returns to the normal operating temperature level, the module will meet 3GPP specifications again.

2.3. Functional Diagram

The following figure shows a functional diagram of EM121R-GL.

- Power management
- Baseband
- LPDDR4X SDRAM + NAND Flash
- Radio frequency
- M.2 Key-B interface

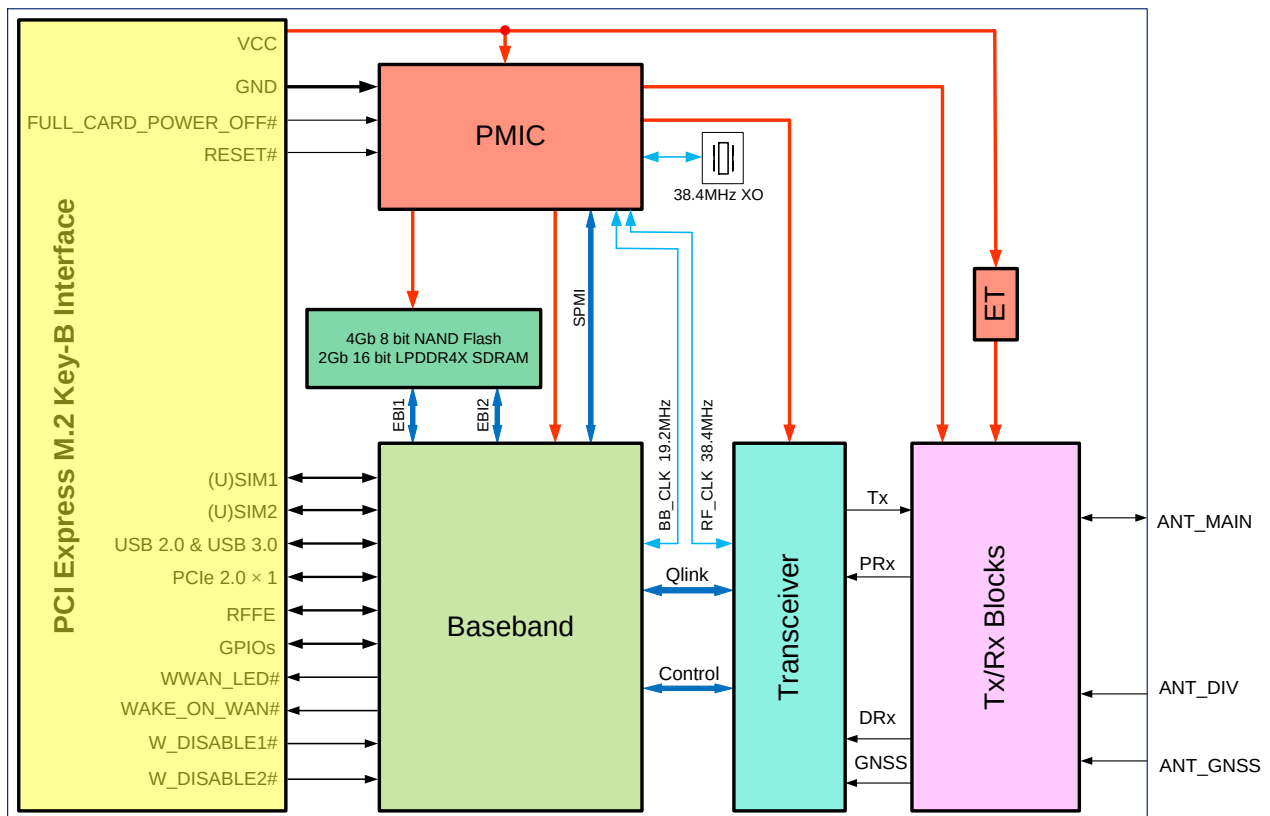


Figure 1: Functional Diagram

2.4. Pin Assignment

The following figure shows the pin assignment of the module. The top side contains module and antenna connectors.

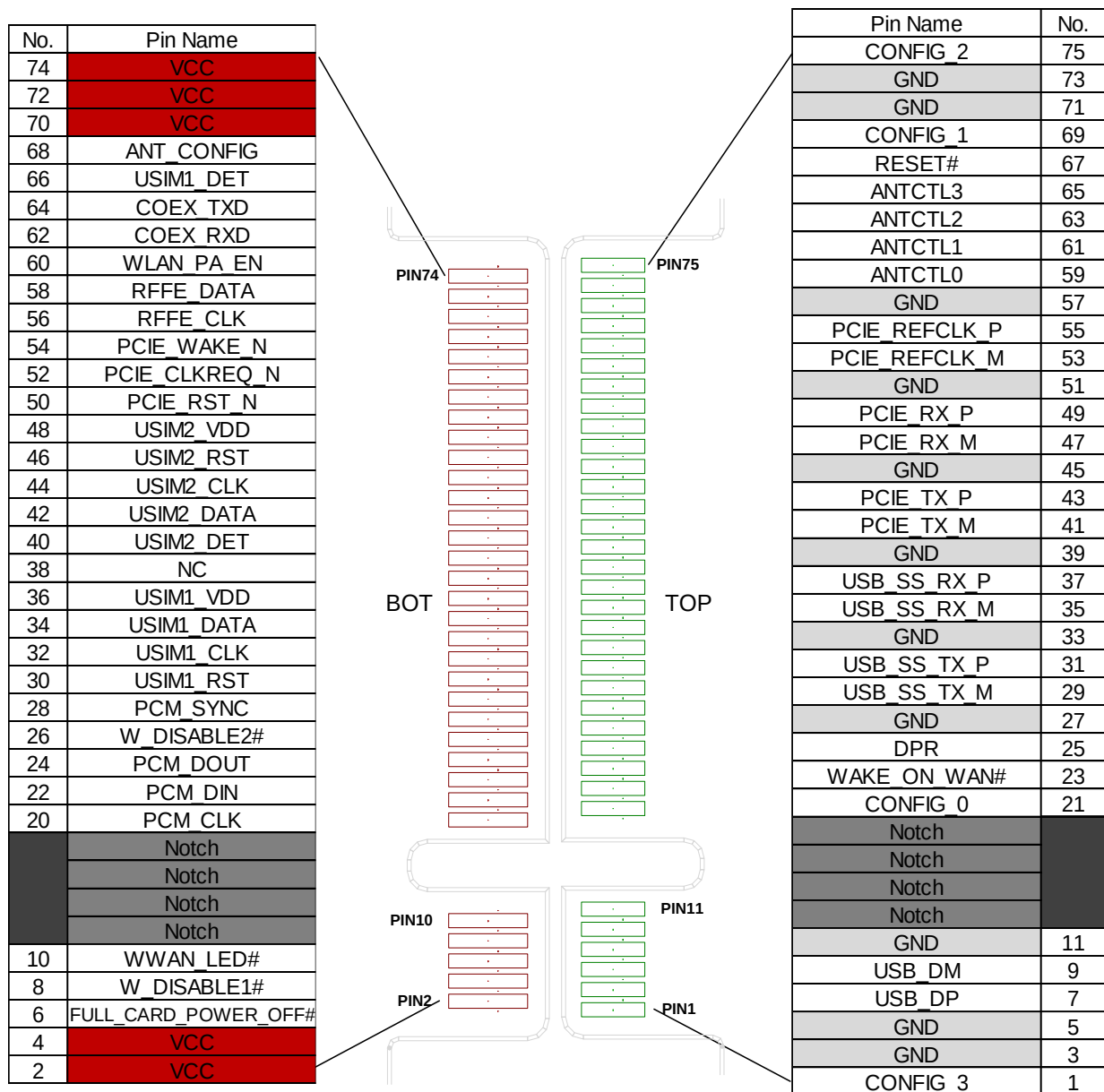


Figure 2: Pin Assignment

2.5. Pin Description

Table 4: Definition of I/O Parameters

Type	Description
AI	Analog Input
AO	Analog Output
AIO	Analog Input/Output
DI	Digital Input
DO	Digital Output
DIO	Digital Input/Output
OD	Open Drain
PI	Power Input
PO	Power Output
PU	Pull Up
PD	Pull Down

The following table shows the pin definition and description of the module.

Table 5: Pin Description

Pin No.	Pin Name	I/O	Description	DC Characteristic	Comment
1	CONFIG_3	DO	Not connected internally		
2	VCC	PI	Power supply	Vmin = 3.135 V Vnom = 3.7 V Vmax = 4.4 V	
3	GND		Ground		
4	VCC	PI	Power supply	Vmin = 3.135 V Vnom = 3.7 V Vmax = 4.4 V	

5	GND		Ground		
6	FULL_CARD_POWER_OFF#	DI, PD	Turn on/off the module. High level: Turn on Low level: Turn off	$V_{IHmax} = 4.4\text{ V}$ $V_{IHmin} = 1.19\text{ V}$ $V_{ILmax} = 0.2\text{ V}$	Internally pulled down with a 100 k Ω resistor.
7	USB_DP	AIO	USB differential data (+)		
8	W_DISABLE1#	DI, OD	Airplane mode control. Active LOW.	1.8/3.3 V	
9	USB_DM	AIO	USB differential data (-)		
10	WWAN_LED#	DO, OD	RF status indication LED. Active LOW.	VCC	
11	GND		Ground		
12	Notch		Notch		
13	Notch		Notch		
14	Notch		Notch		
15	Notch		Notch		
16	Notch		Notch		
17	Notch		Notch		
18	Notch		Notch		
19	Notch		Notch		
20	PCM_CLK*	DIO, PD	PCM clock	1.8 V	
21	CONFIG_0	DO	Not connected internally		
22	PCM_DIN*	DI, PD	PCM data input	1.8 V	
23	WAKE_ON_WAN#*	DO, OD	Wake up the host. Active LOW.	1.8/3.3 V	
24	PCM_DOUT*	DO, PD	PCM data output	1.8 V	
25	DPR	DI, PU	Dynamic power reduction. High level by default.	1.8 V	
26	W_DISABLE2#	DI, OD	GNSS disable control. Active LOW.	1.8/3.3 V	

27	GND		Ground		
28	PCM_SYNC*	DIO, PD	PCM data frame sync	1.8 V	
29	USB_SS_TX_M	AO	USB 3.0 super-speed transmit (-)		
30	USIM1_RST	DO, PD	(U)SIM1 card reset	USIM1_VDD 1.8/3.0 V	
31	USB_SS_TX_P	AO	USB 3.0 super-speed transmit (+)		
32	USIM1_CLK	DO, PD	(U)SIM1 card clock	USIM1_VDD 1.8/3.0 V	
33	GND		Ground		
34	USIM1_DATA	DIO, PU	(U)SIM1 card data	USIM1_VDD 1.8/3.0 V	
35	USB_SS_RX_M	AI	USB 3.0 super-speed receive (-)		
36	USIM1_VDD	PO	(U)SIM1 card power supply	1.8/3.0 V	
37	USB_SS_RX_P	AI	USB 3.0 super-speed receive (+)		
38	NC		NC		
39	GND		Ground		
40	USIM2_DET*	DI, PU	(U)SIM2 card hot-plug detect	1.8 V	Internally pulled up to 1.8 V ¹⁾
41	PCIE_TX_M	AO	PCle transmit (-)		
42	USIM2_DATA	DIO, PU	(U)SIM2 card data	USIM2_VDD 1.8/3.0 V	
43	PCIE_TX_P	AO	PCle transmit (+)		
44	USIM2_CLK	DO, PD	(U)SIM2 card clock	USIM2_VDD 1.8/3.0 V	
45	GND		Ground		
46	USIM2_RST	DO, PD	(U)SIM2 card reset	USIM2_VDD 1.8/3.0 V	
47	PCIE_RX_M	AI	PCle receive (-)		
48	USIM2_VDD	PO	(U)SIM2 card power supply	1.8/3.0 V	
49	PCIE_RX_P	AI	PCle receive (+)		

50	PCIE_RST_N	DI, OD	PCle reset. Active LOW.		
51	GND		Ground		
52	PCIE_CLKREQ_N	DO, OD	PCle clock request. Active LOW.		
53	PCIE_REFCLK_M	AIO	PCle reference clock (-)		
54	PCIE_WAKE_N	DO, OD	PCle wake up. Active LOW.		
55	PCIE_REFCLK_P	AIO	PCle reference clock (+)		
56	RFFE_CLK ²⁾ *	DO, PD	Used for external MIPI IC control	1.8 V	
57	GND		Ground		
58	RFFE_DATA ²⁾ *	DIO, PD	Used for external MIPI IC control	1.8 V	
59	ANTCTL0*	DO, PD	Antenna control	1.8 V	
60	WLAN_PA_EN*	DI, PD	Self-protection for QLN4650 control	1.8 V	
61	ANTCTL1*	DO, PD	Antenna control	1.8 V	
62	COEX_RXD*	DI, PD	LTE/WLAN coexistence receive	1.8 V	
63	ANTCTL2*	DO, PD	Antenna control	1.8 V	
64	COEX_TXD*	DO, PD	LTE/WLAN coexistence transmit	1.8 V	
65	ANTCTL3*	DO, PD	Antenna control	1.8 V	
66	USIM1_DET	DI, PU	(U)SIM1 card hot-plug detect	1.8 V	Internally pulled up to 1.8 V ¹⁾
67	RESET#	DI, PU	Reset the module. Active LOW.	V _{IH} max = 2.1 V V _{IH} min = 1.3 V V _{IL} max = 0.5 V	Internally pulled up to 1.8 V with a 40 kΩ resistor.
68	ANT_CONFIG ³⁾	DI, PU	Antenna configuration	1.8 V	Internally pulled up to 1.8 V
69	CONFIG_1	DO	Connected to GND internally		
70	VCC	PI	Power supply	V _{min} = 3.135 V V _{nom} = 3.7 V V _{max} = 4.4 V	

71	GND		Ground	
72	VCC	PI	Power supply	Vmin = 3.135 V Vnom = 3.7 V Vmax = 4.4 V
73	GND		Ground	
74	VCC	PI	Power supply	Vmin = 3.135 V Vnom = 3.7 V Vmax = 4.4 V
75	CONFIG_2	DO	Not connected internally	

NOTES

- ¹⁾ This pin is pulled up by software configuration when (U)SIM hot-plug is enabled by **AT+QSIMDET** (the command takes effect after the module is restarted, see **document [3]**).
- ²⁾ RFFE_CLK and RFFE_DATA are reserved only for customization.
- ³⁾ EM121R-GL does not support this function, please keep it unconnected.
- Keep all NC, reserved and unused pins unconnected.

2.6. Evaluation Board

To help you develop applications conveniently with EM121R-GL, Quectel supplies an evaluation board (PCIE-CARD-EVB). For more details, see **document [2]**.

3 Operating Characteristics

3.1. Operating Modes

The table below briefly summarizes the various operating modes of EM121R-GL.

Table 6: Overview of Operating Modes

Mode	Details
Normal Operation Mode	Idle Software is active. The module has registered on the network, and it is ready to send and receive data.
	Talk/Data Network connected. In this mode, the power consumption is decided by network setting and data transfer rate.
Minimum Functionality Mode	AT+CFUN=0 command sets the module to a minimum functionality mode without removing the power supply. In this mode, both RF function and (U)SIM card are invalid.
Airplane Mode	AT+CFUN=4 command or driving W_DISABLE1# pin low will set the module to airplane mode. In this mode, the RF function is invalid.
Sleep Mode	The module keeps receiving paging messages, SMS, voice calls and TCP/UDP data from the network with its current consumption reducing to the minimal level.
Power Down Mode	In this mode, the power management unit shuts down the power supply. Software is inactive, all interfaces are inaccessible, and the operating voltage (connected to VCC) remains applied.

3.1.1. Sleep mode

In sleep mode, DRX of the module is able to reduce the current consumption to a minimum level, and DRX cycle index values are broadcasted by the wireless network. The figure below shows the relationship between the DRX run time and the current consumption in sleep mode. The longer the DRX cycle is, the lower the current consumption will be.

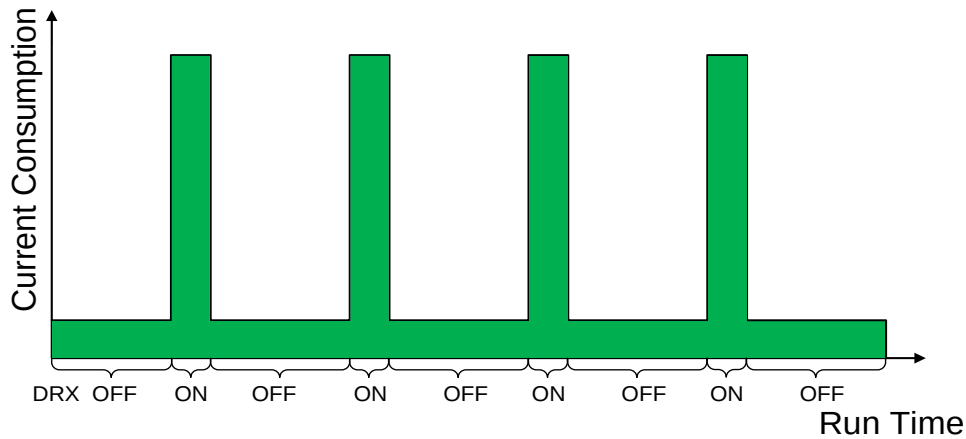


Figure 3: DRX Run Time and Current Consumption in Sleep Mode

The following part of this section describes the power saving procedure and sleep mode entrance of the module.

If the host supports USB suspend/resume and remote wakeup function, the following two conditions must be met to make the module enter sleep mode.

- Execute **AT+QSCCLK=1** command to enable the sleep mode.
- The host's USB bus, which is connected to the module's USB interface, enters suspend state.

The following figure shows the connection between the module and the host.

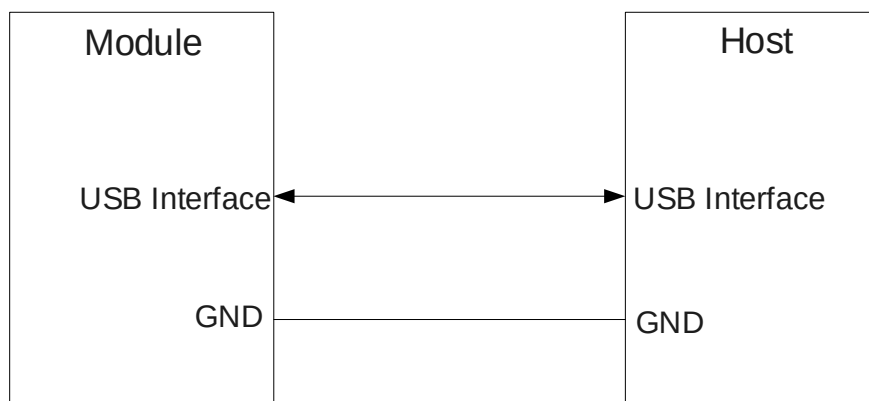


Figure 4: Sleep Mode Application with USB Remote Wakeup

The module and the host will wake up in the following conditions:

- Sending data to module through USB will wake up the module.
- When module has a URC to report, the module will send remote wake-up signals via USB bus to wake up the host.

3.1.2. Airplane mode

The module provides a W_DISABLE1# pin to disable or enable airplane mode through hardware operation. See **Chapter 4.5.1** for more details.

3.2. Communication Interface with the Host

The module supports to communicate through both USB and PCIe interfaces, respectively referring to the USB mode and the PCIe mode as described below:

USB Mode

- Support all USB 2.0/3.0 features
- Support MBIM/QMI/QRTR/AT

USB is the default communication interface between the module and the host. It is suggested that USB 2.0 interface be reserved for firmware upgrade.

PCIe Mode (eFuse-based)

- Support MBIM/QMI/QRTR/AT
- Support Non-X86 systems and X86 system (support BIOS PCIe early initial)

EM121R-GL can also be reprogrammed to PCIe mode based on eFuse. If the communication is switched to PCIe mode by burnt eFuse, the communication cannot be switched back to USB mode.

3.3. Power Supply

The following table shows pin definition of VCC pins and ground pins.

Table 7: Definition of VCC and GND Pins

Pin No.	Pin Name	I/O	Description	DC Characteristics
2, 4, 70, 72, 74	VCC	PI	Power supply	3.135–4.4 V 3.7 V typical DC supply
3, 5, 11, 27, 33, 39, 45, 51, 57, 71, 73	GND	-	Ground	-

3.3.1. Decrease Voltage Drop

The power supply range of the module is from 3.135 V to 4.4 V. Please ensure that the input voltage will never drop below 3.135 V, otherwise the module will be powered off automatically. The following figure shows the maximum voltage drop during radio transmission in 3G/4G networks.

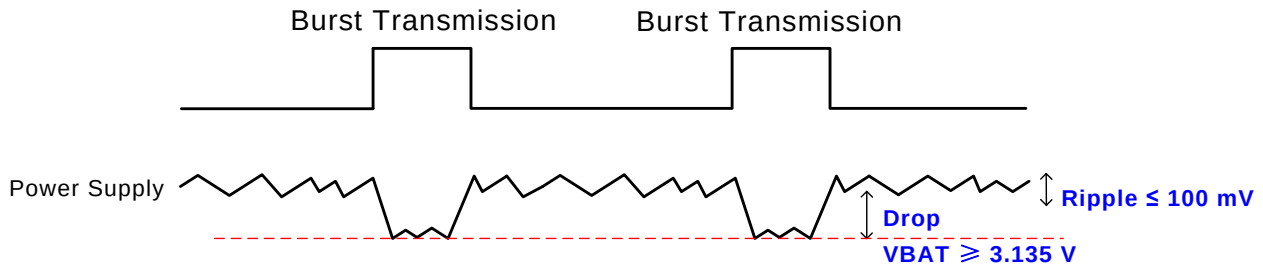


Figure 5: Power Supply Limits during Radio Transmission

Ensure the continuous current capability of the power supply is 2.0 A. To decrease the voltage drop, two bypass capacitor of about 220 μF with low ESR ($\text{ESR} = 0.7 \Omega$) should be used. To decrease the power supply is disturbed, a multi-layer ceramic chip capacitor (MLCC) array also should be used due to its ultra-low ESR. It is recommended to use four ceramic capacitors (1 μF , 100 nF, 33 pF, 10 pF) for composing the MLCC array, and place these capacitors close to VCC pins. The width of VCC trace should be no less than 2.5 mm. In principle, the longer the VCC trace is, the wider it should be.

In addition, to guarantee stability of the power supply, please use a zener diode with a reverse zener voltage of 5.1 V and a dissipation power of higher than 0.5 W. The following figure shows a reference circuit for the VCC.

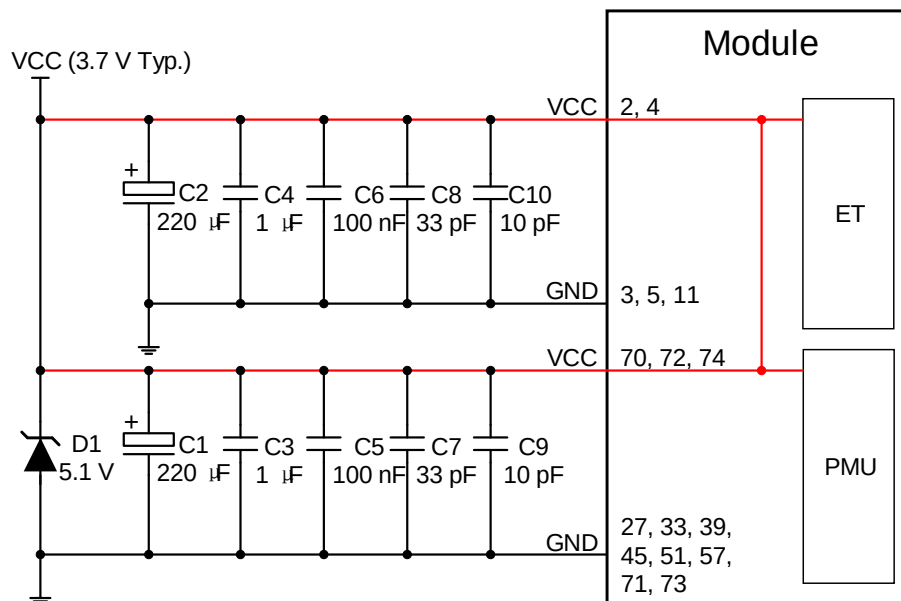


Figure 6: Reference Circuit for the VCC

3.3.2. Reference Design for Power Supply

Power design is important for the module, as the performance of the module largely depends on the power source. If the voltage difference between the input and output is not too high, it is suggested that an LDO is used when supplying power for the module. If there is a big voltage difference between the input source and the desired output (VCC = 3.7 V Typ.), a buck DC-DC converter is preferred.

The following figure shows a reference design for +5 V input power source based on the DC-DC TPS54319. The typical output of the power supply is about 3.7 V and the maximum load current is 3.0 A.

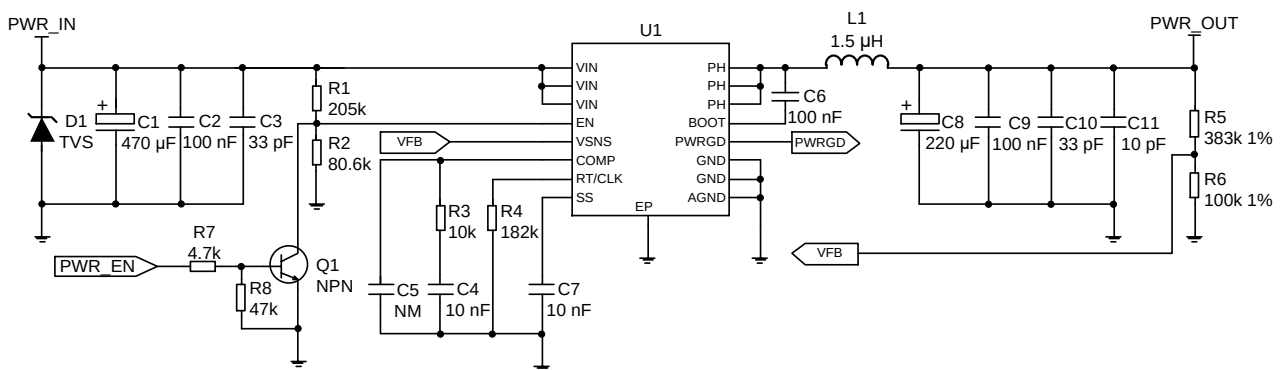


Figure 7: Reference Circuit for the Power Supply

NOTE

To avoid damaging the internal flash, do not switch off the power supply directly when the module is working.

3.4. Turn on

FULL_CARD_POWER_OFF# is used to turn on/off the module. When the input signal is asserted high (≥ 1.19 V), the module will be turned on. When the input signal is driven low (≤ 0.2 V) or Tri-stated, the module will be turned off.

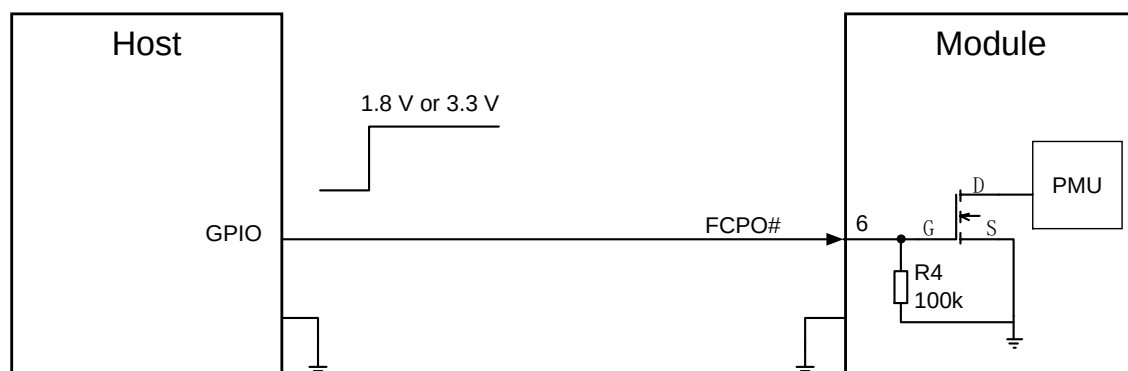
This input signal is 3.3 V tolerant and can be driven by either 1.8 V or 3.3 V GPIO. Also, it has internally pulled down with a 100 k Ω resistor.

The following table shows the definition of FULL CARD POWER OFF#.

Table 8: Pin Definition of FULL_CARD_POWER_OFF#

Pin No.	Pin Name	I/O	Description	DC Characteristics	Comment
6	FULL_CARD_POWER_OFF#	DI, PD	Turn on/off the module. High level: Turn on Low level: Turn off	$V_{IHmax} = 4.4\text{ V}$ $V_{IHmin} = 1.19\text{ V}$ $V_{ILmax} = 0.2\text{ V}$	Pull down with a 100 k Ω resistor.

It is recommended to use a host GPIO to control FULL_CARD_POWER_OFF#. A simple reference circuit is illustrated in the following figure.



Note: The voltage of pin 6 should be no less than 1.19 V when it is at HIGH level.

Figure 8: Turn on the Module with a Host GPIO

The timing of turn-on scenario is illustrated in the following figure.

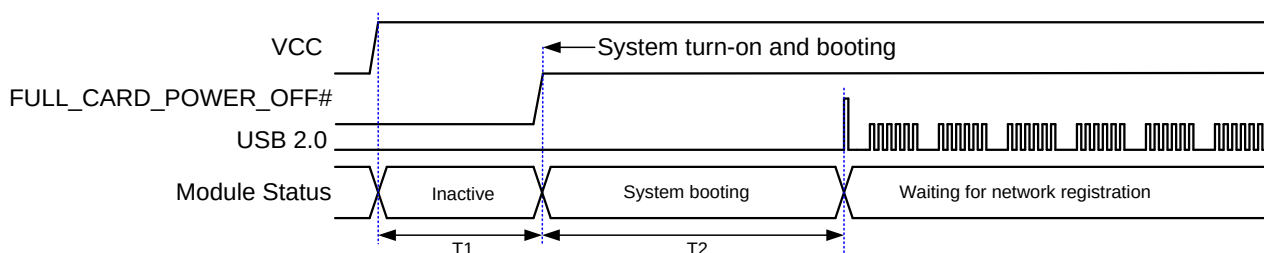


Figure 9: Turn-on Timing of the Module

Table 9: Turn-on Timing of the Module

Symbol	Min.	Typ.	Max.	Comment
T1	0 ms	50 ms	-	Module powers on
T2	9.3 s	-	-	-

3.5. Turn off

For the design that turns on the module with a host GPIO, when the power is supplied to VCC, pulling down FULL_CARD_POWER_OFF# pin will turn off the module.

The timing of turn-off scenario is illustrated in the following figure.

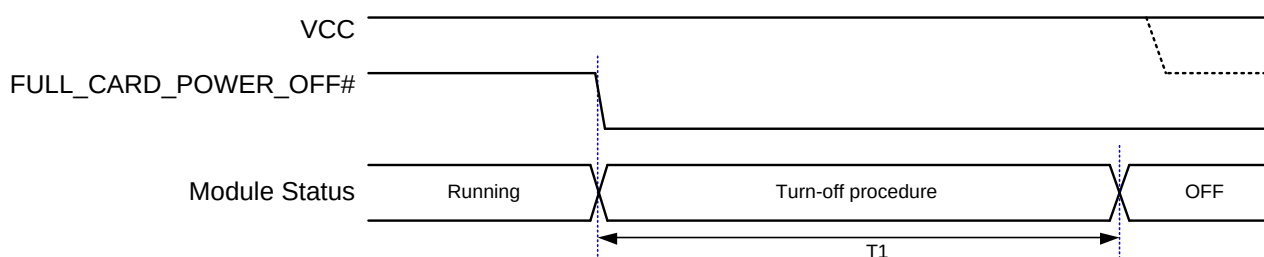


Figure 10: Turn-off Timing through FULL_CARD_POWER_OFF#

Table 10: Turn-off Timing of the Module

Symbol	Min.	Typ.	Max.	Comment
T1	3 s		-	Module turns off

3.6. Reset

The RESET# pin is used to reset the module. The module can be reset by driving RESET# low voltage for 250–600 ms.

Table 11: Pin Definition of RESET#

Pin No.	Pin Name	I/O	Description	DC Characteristics	Comment
67	RESET#	DI, PU	Reset the module Active LOW.	$V_{IHmax} = 2.1\text{ V}$ $V_{IHmin} = 1.3\text{ V}$ $V_{ILmax} = 0.5\text{ V}$	Internally pulled up to 1.8 V with a 40 kΩ resistor.

NOTE

Triggering the RESET# signal will lead to loss of all data in the modem and removal of system drivers. It will also disconnect the modem from the network.

The module can be reset by pulling down the RESET# pin for 250–600 ms. An open collector/drain driver or a button can be used to control the RESET# pin.

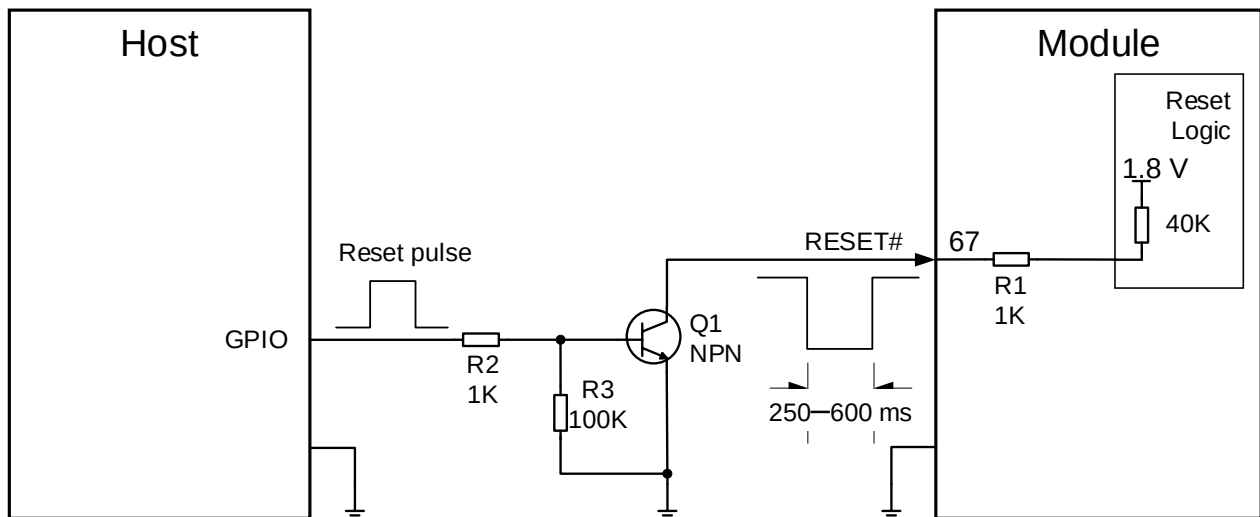
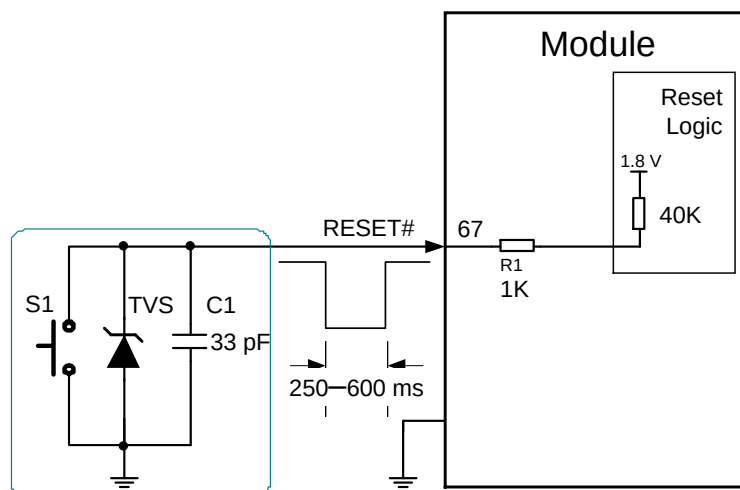


Figure 11: Reference Circuit for the RESET# with NPN Driver Circuit



Note: The capacitor C1 is recommended to be less than 47 pF.

Figure 12: Reference Circuit for the RESET# with a Button

The timing of reset scenario is illustrated in the following figure.

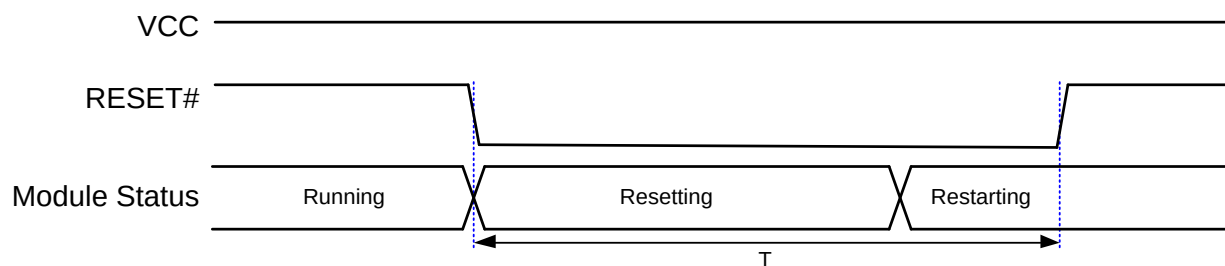


Figure 13: Reset Timing of the Module

Table 12: Reset Timing of the Module

Symbol	Min.	Typ.	Max.	Comment
T	250 ms	500 ms	600 ms	RESET# should be pulled down for 250–600 ms. An asserting time of less than 200 ms is unreliable, while that of higher than 600 ms may lead to module reset for several times.

4 Application Interfaces

The physical connections and signal levels of EM121R-GL comply with *PCI Express M.2 specification*. This chapter mainly describes the definition and application of the following interfaces/pins of the module:

- (U)SIM interfaces
- USB interface
- PCIe interface
- PCM interface*
- Control and indication interfaces
- Cellular/WLAN COEX interface*
- Antenna tuner control interface*
- Configuration pins

4.1. (U)SIM Interface

The (U)SIM interface circuitry meets ETSI and IMT-2000 requirements. Both Class B (3.0 V) and Class C (1.8 V) (U)SIM cards are supported, and Dual SIM Single Standby function is supported.

4.1.1. Pin definition of (U)SIM

Table 13: Pin Definition of (U)SIM Interfaces

Pin No.	Pin Name	I/O	Description	DC Characteristics
36	USIM1_VDD	PO	(U)SIM1 card power supply	1.8/3.0 V
34	USIM1_DATA	DIO, PU	(U)SIM1 card data	USIM1_VDD 1.8/3.0 V
32	USIM1_CLK	DO, PD	(U)SIM1 card clock	USIM1_VDD 1.8/3.0 V
30	USIM1_RST	DO, PD	(U)SIM1 card reset	USIM1_VDD 1.8/3.0 V
66	USIM1_DET	DI, PU	(U)SIM1 card hot-plug detect	1.8 V
40	USIM2_DET*	DI, PU	(U)SIM2 card hot-plug detect	1.8 V

42	USIM2_DATA	DIO, PU	(U)SIM2 card data	USIM2_VDD 1.8/3.0 V
44	USIM2_CLK	DO, PD	(U)SIM2 card clock	USIM2_VDD 1.8/3.0 V
46	USIM2_RST	DO, PD	(U)SIM2 card reset	USIM2_VDD 1.8/3.0 V
48	USIM2_VDD	PO	(U)SIM2 card power supply	1.8/3.0 V

EM121R-GL supports (U)SIM card hot-plug via the USIM1_DET pin, which is a level triggered pin. The USIM1_DET is normally short-circuited to ground when (U)SIM card is not inserted. When the (U)SIM card is inserted, the USIM1_DET will change from low to high level. The rising edge indicates an insertion of the (U)SIM card. When the (U)SIM card is removed, the USIM1_DET will change from high to low level. This falling edge indicates a removal of the (U)SIM card.

NOTE

USIM1_DET/USIM2_DET is pulled up by software configuration when (U)SIM hot-plug is enabled by **AT+QSIMDET** (the command takes effect after the module is restarted, see **document [3]**).

4.1.2. (U)SIM Hot-plug

The module supports (U)SIM card hot-plug via (U)SIM card hot-plug detection pins (USIM1_DET and USIM2_DET). (U)SIM card insertion is detected by high/low level. (U)SIM card hot-plug is disabled by default.

The following command enables (U)SIM card hot-plug function.

AT+QSIMDET (U)SIM Card Detection	
Test Command AT+QSIMDET=?	Response +QSIMDET: (list of supported <enable>s),(list of supported <insert_level>s) OK
Read Command AT+QSIMDET?	Response +QSIMDET: <enable>,<insert_level> OK
Write Command AT+QSIMDET=<enable>,<insert_level>	Response OK If there is any error: ERROR

Maximum Response Time	300 ms
Characteristics	The command takes effect after the module is restarted. The configuration will be saved to NVRAM automatically.

Parameter

<enable>	Integer type. Enable or disable (U)SIM card detection. <u>0</u> Disable 1 Enable
<insert_level>	Integer type. The level of (U)SIM detection pin when a (U)SIM card is inserted. 0 Low level <u>1</u> High level

NOTES

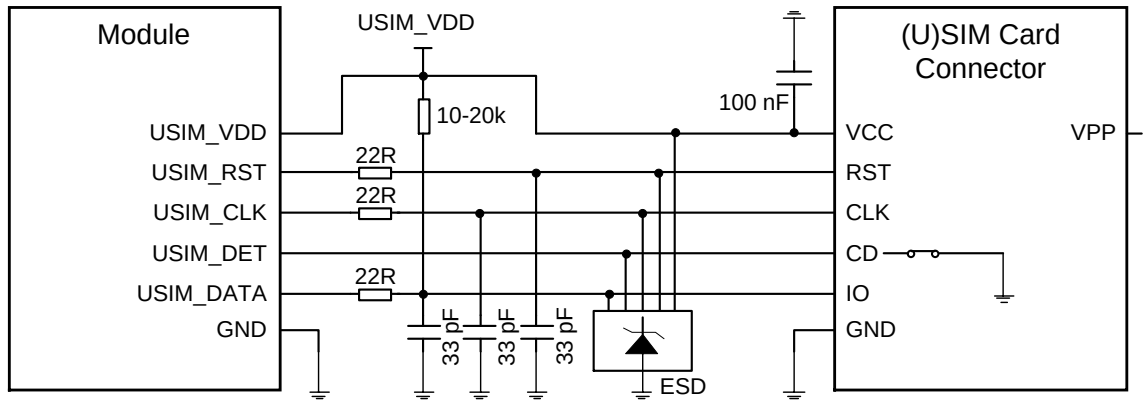
- Hot-plug function is invalid if the configured value of **<insert_level>** is inconsistent with hardware design.
- Hot-plug function setting takes effect after the module is restarted.
- The underlined value is the default parameter value.
- USIM_DET[1:2] is pulled LOW by default, and will be internally pulled up to 1.8 V by software configuration only when (U)SIM hot-plug is enabled by **AT+QSIMDET**.

4.1.3. Normally Closed (U)SIM Card Connector

With a normally closed (U)SIM card connector, the USIM_DET is normally short-circuited to ground when a (U)SIM card is not inserted, (U)SIM card detection by high level is applicable to this type of connector. After executing **AT+QSIMDET=1,1** to enable the (U)SIM hot-plug: when a (U)SIM card is inserted, USIM_DET will change from low to high level; when the (U)SIM card is removed, USIM_DET will change from high to low level.

- When the (U)SIM is absent, CD is short-circuited to ground and USIM_DET is at low voltage level.
- When the (U)SIM is inserted, CD is open from ground and USIM_DET is at high voltage level.

The following figure shows a reference design of (U)SIM interface with a normally closed (U)SIM card connector.



Note: All these resistors, capacitors and TVS should be close to (U)SIM card connector in PCB layout.

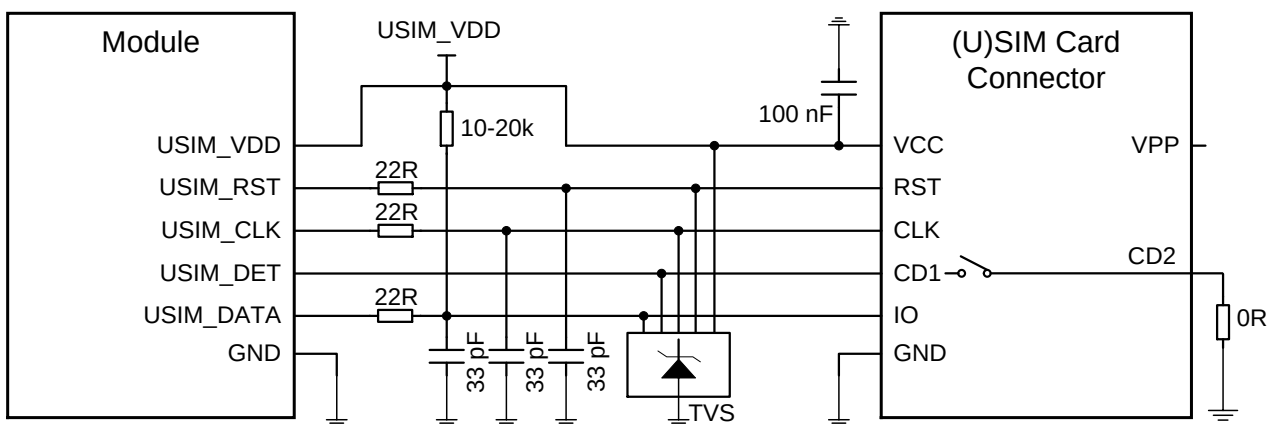
Figure 14: Reference Circuit for Normally Closed (U)SIM Card Connector

4.1.4. Normally Open (U)SIM Card Connector

With a normally open (U)SIM card connector, CD1 and CD2 of the connector are disconnected when there is no (U)SIM card inserted. (U)SIM card detection by low level is applicable to this type of connector. After executing AT+QSIMDET=1,0 to enable the (U)SIM hot-plug: when a (U)SIM card is inserted, USIM_DET will change from high to low level; when the (U)SIM card is removed, USIM_DET will change from low to high level.

- When the (U)SIM is absent, CD1 is open from CD2 and USIM_DET is at high voltage level.
- When the (U)SIM is inserted, CD1 is connected to GND and USIM_DET is at low voltage level.

The following figure shows a reference design of (U)SIM interface with a normally open (U)SIM card connector.



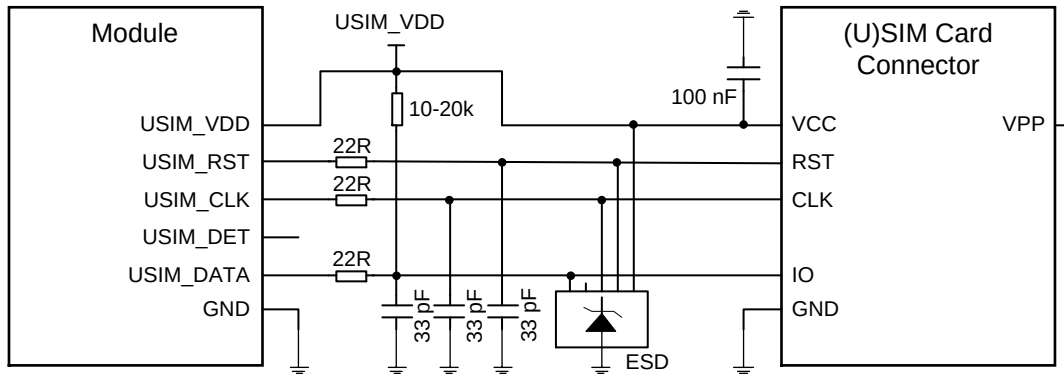
NOTE:

All these resistors, capacitors and TVS should be close to (U)SIM card connector in PCB layout.

Figure 15: Reference Circuit for Normally Open (U)SIM Card Connector

4.1.5. (U)SIM Card Connector Without Hot-plug

If the (U)SIM card detection function is not needed, please keep USIM_DET unconnected. A reference circuit for the (U)SIM card interface with a 6-pin (U)SIM card connector is illustrated by the following figure.



Note: All these resistors, capacitors and TVS should be close to (U)SIM card connector in PCB layout.

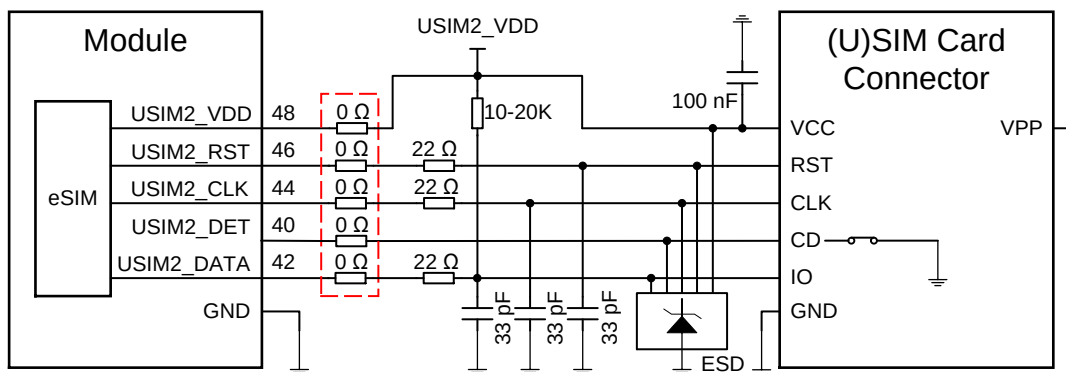
Figure 16: Reference Circuit for a 6-Pin (U)SIM Card Connector

4.1.6. (U)SIM2 Card Connector

EM121R-GL provides two (U)SIM interfaces. (U)SIM1 interface is used for external (U)SIM card only, and (U)SIM2 interface is used for external (U)SIM card or internal eSIM card.

It should be noted that, when the (U)SIM2 interface is used for an external (U)SIM card, the circuits are the same as those of (U)SIM1 interface. When the (U)SIM2 interface is used for the internal eSIM card, pins 40, 42, 44, 46 and 48 of the modules must be kept open.

A recommended compatible design for the (U)SIM2 interface is shown below.



Note: The five 0 Ω resistors must be close to M.2 socket connector, and all other components should be close to (U)SIM card connector in PCB layout.

Figure 17: Recommended Compatible Design for (U)SIM2 Interface

4.1.7. (U)SIM Design Notices

To enhance the reliability and availability of the (U)SIM card in applications, please follow the criteria below in (U)SIM circuit design.

- Place the (U)SIM card connector as close to the module as possible. Keep the trace length less than 200 mm.
- Keep (U)SIM card signals away from RF and VCC traces.
- Make sure the ground between the module and the (U)SIM card connector is short and wide. Keep the trace width of ground and USIM_VDD no less than 0.5 mm to maintain the same electric potential.
- To avoid cross-talk between USIM_DATA and USIM_CLK, keep them away from each other and shield them with surrounded ground.
- To offer better ESD protection, add a TVS diode array of which the parasitic capacitance should be not higher than 10 pF. Add 22 Ω resistors in series between the module and the (U)SIM card connector to suppress EMI such as spurious transmission, and to enhance ESD protection. The 33 pF capacitors are used to filter out RF interference.
- For USIM_DATA, a 10–20 k Ω pull-up resistor must be added near the (U)SIM card connector.

4.2. USB Interface

The module provides one integrated Universal Serial Bus (USB) interface which complies with the USB 3.0 & 2.0 specifications and supports super speed (5 Gbps) on USB 3.0 and high speed (480 Mbps) and full speed (12 Mbps) modes on USB 2.0. The USB interface is used for AT command communication, data transmission, GNSS NMEA sentence output, software debugging, firmware upgrade and voice over USB*.

Please note that only USB 2.0 can be used for firmware upgrade currently.

Table 14: Pin Definition of USB Interface

Pin No.	Pin Name	I/O	Description	Comment
7	USB_DP	AIO	USB differential data bus (+)	
9	USB_DM	AIO	USB differential data bus (-)	
29	USB_SS_TX_M	AO	USB 3.0 super-speed transmit (-)	Require differential impedance of 90 Ω
31	USB_SS_TX_P	AO	USB 3.0 super-speed transmit (+)	
35	USB_SS_RX_M	AI	USB 3.0 super-speed receive (-)	

37 USB_SS_RX_P AI USB 3.0 super-speed receive (+)

For more details about the USB 3.0 & 2.0 specifications, please visit <http://www.usb.org/home>.

The USB 2.0 interface is recommended to be reserved for firmware upgrade in designs. The following figure presents a reference circuit for the USB 3.0 & 2.0 interface.

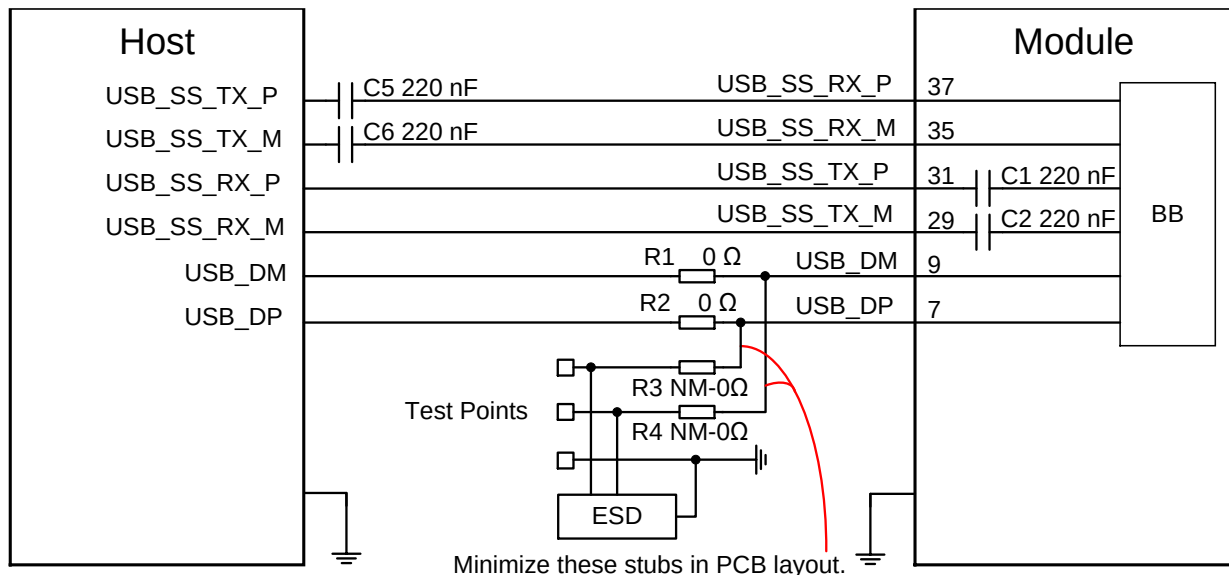


Figure 18: Reference Circuit for the USB 3.0 & 2.0 Interface

AC coupling capacitors C5 and C6 must be placed close to the host and close to each other. C1 and C2 have been integrated inside the module, so do not place these two capacitors on your schematic and PCB. To ensure the signal integrity of USB 2.0 data traces, R1, R2, R3 and R4 must be placed close to the module, and the stubs must be minimized in PCB layout.

Please follow the principles below when designing for the USB interface to meet USB 3.0 and 2.0 specifications:

- Route the USB signal traces as differential pairs with ground surrounded. The impedance of differential trace of USB 2.0 and USB 3.0 is 90 Ω.
- For USB 2.0 signal traces, the trace length should be less than 120 mm, and the differential data pair matching should be less than 2 mm. For USB 3.0 signal traces, length matching of each differential data pair (Tx/Rx) should be less than 0.7 mm, while the matching between Tx and Rx should be less than 10 mm.
- Do not route signal traces under crystals, oscillators, magnetic devices, PCIe and RF signal traces. Route the USB differential traces in inner-layer of the PCB, and surround the traces with ground on that layer and with ground planes above and below.
- Junction capacitance of the ESD protection device might cause influences on USB data lines, so you should pay attention to the selection of the device. Typically, the stray capacitance should be less

than 1.0 pF for USB 2.0, and less than 0.15 pF for USB 3.0.

- Keep the ESD protection devices as close to the USB connector as possible.
- If possible, reserve 0 Ω resistors on USB_DP and USB_DM lines respectively.

4.3. PCIe Interface

The module provides one integrated PCIe interface, featuring as follows:

- *PCI Express Base Specification Revision 2.0* compliant
- Data rate up to 5 Gbps per lane

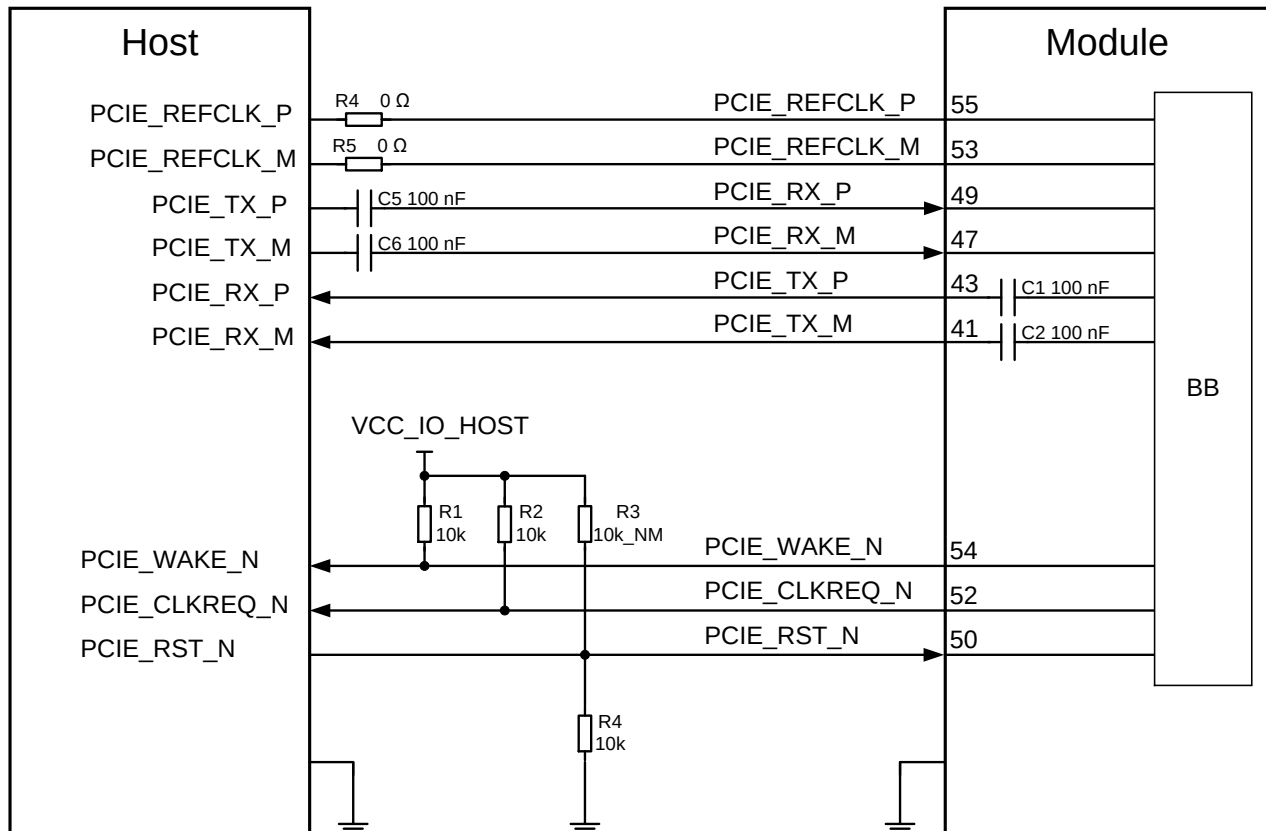
4.3.1. Pin definition of PCIe

Table 15: Pin Definition of PCIe Interface

Pin No.	Pin Name	I/O	Description	Comment
55	PCIE_REFCLK_P	AIO	PCIe reference clock (+)	100 MHz clock frequency.
53	PCIE_REFCLK_M	AIO	PCIe reference clock (-)	Require differential impedance of 95 Ω
49	PCIE_RX_P	AI	PCIe receive (+)	Require differential impedance of 95 Ω
47	PCIE_RX_M	AI	PCIe receive (-)	
43	PCIE_TX_P	AO	PCIe transmit (+)	Require differential impedance of 95 Ω
41	PCIE_TX_M	AO	PCIe transmit (-)	
50	PCIE_RST_N	DI, OD	PCIe reset. Active LOW.	
52	PCIE_CLKREQ_N	DO, OD	PCIe clock request. Active LOW.	
54	PCIE_WAKE_N	DO, OD	PCIe wake up. Active LOW.	

4.3.2. Reference Design for PCIe

The following figure shows a reference circuit for the PCIe interface.



Note. The voltage level VCC_IO_HOST of these three signals depend on the host side due to open drain.

Figure 19: PCIe Interface Reference Circuit

To ensure the signal integrity of PCIe interface, AC coupling capacitors C5 and C6 should be placed close to the host on PCB. C1 and C2 have been integrated into the module, so do not place these two capacitors on your schematic and PCB.

The following principles of PCIe interface design should be complied with, to meet the PCIe specification.

- Keep the PCIe data and control signals away from sensitive circuits and signals, such as RF, audio, crystal and oscillator signals.
- Add a capacitor in series on Tx/Rx traces to prevent any DC bias.
- Keep the maximum trace length less than 300 mm.
- Keep the length matching of each differential data pair (Tx/Rx) less than 0.7 mm for PCIe routing traces.
- Keep the differential impedance of PCIe data trace as $95 \Omega \pm 10 \%$.
- You must not route PCIe data traces under components or cross them with other traces.

4.3.3. PCIe Timing

The following figure is PCIe power-on timing sequence for an adapter powered from system power rail in PCI Express M.2 specification.

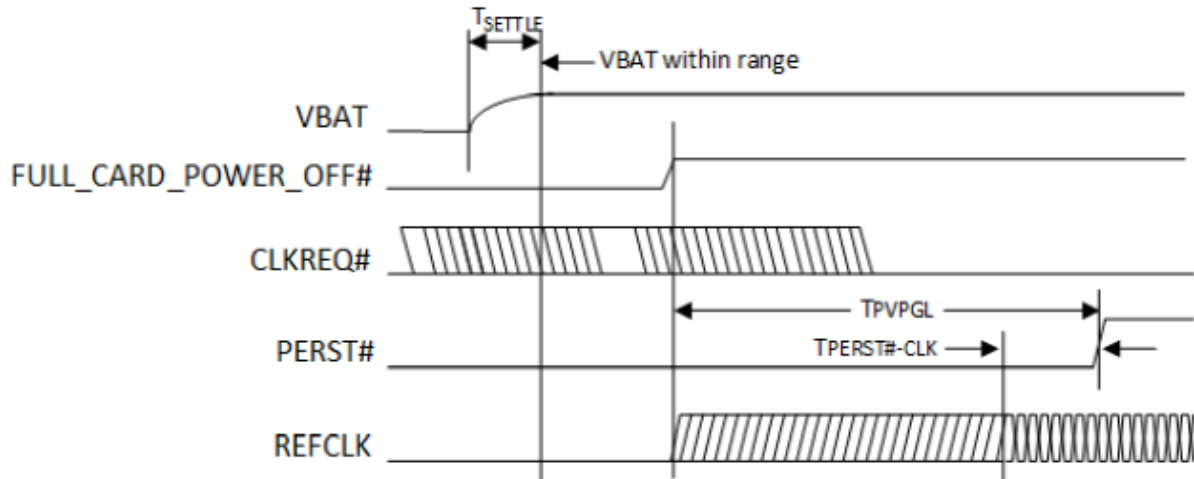


Figure 20: PCIe Power-on Timing Requirements of M.2 Specification

The following table is power-on timing variables in PCI Express M.2 specification.

Table 16: Power-up Timing of M.2 Specification

Symbol	Min.	Typ.	Max.	Comment
$TPVPGl$	50 ms	-	-	Power valid to PERST# input inactive
$TPERST\#-CLK$	100 μs	-	-	REFCLK stable before PERST# inactive

4.3.3.1. PCIe Turn-on Timing

If FULL_CARD_POWER_OFF# is de-asserted, the module will turn on. RESET# is pulled up inside the module. Keep RESET# floating or at high level during module power-on.

PCIe turn-on timing is illustrated by the following figure.

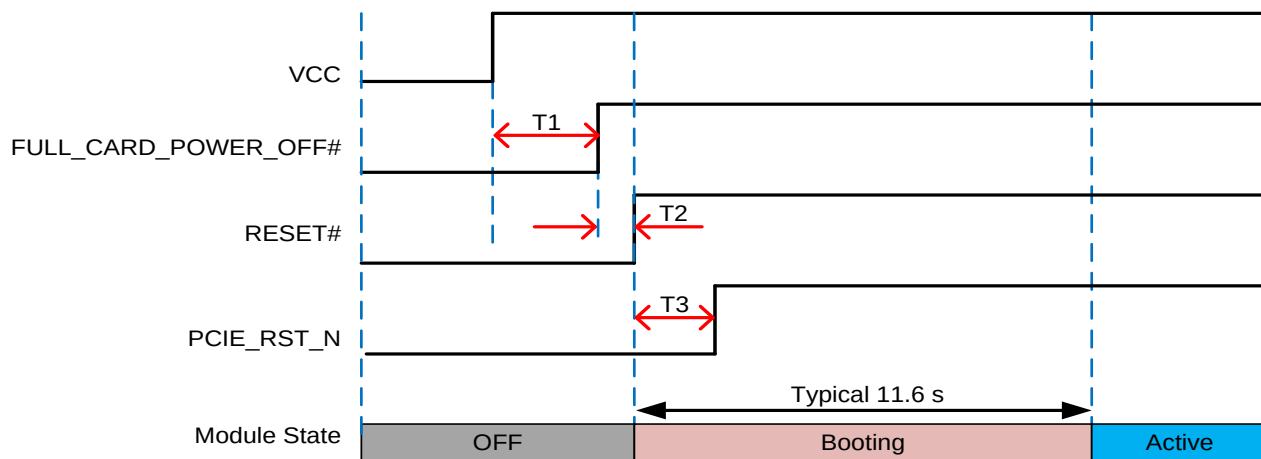


Figure 21: PCIe Turn-on Timing of the Module

Table 17: PCIe Turn-on Timing of the Module

Index	Min.	Typ.	Max.	Comment
T1	0 ms	50 ms	-	The module is turning on.
T2	0 ms	-	200 ms	De-assert RESET# after de-asserting FULL_CARD_POWER_OFF#.
T3	100 ms	-	-	De-assert PCIE_RST_N 100 ms after de-asserting RESET#.

4.3.3.2. PCIe Turn-off Timing

The module will be powered off by cutting off the VCC after pulling down RESET# and FULL_CARD_POWER_OFF#.

The module is turned off when FULL_CARD_POWER_OFF# is driven low. This is a way to power off the module via software.

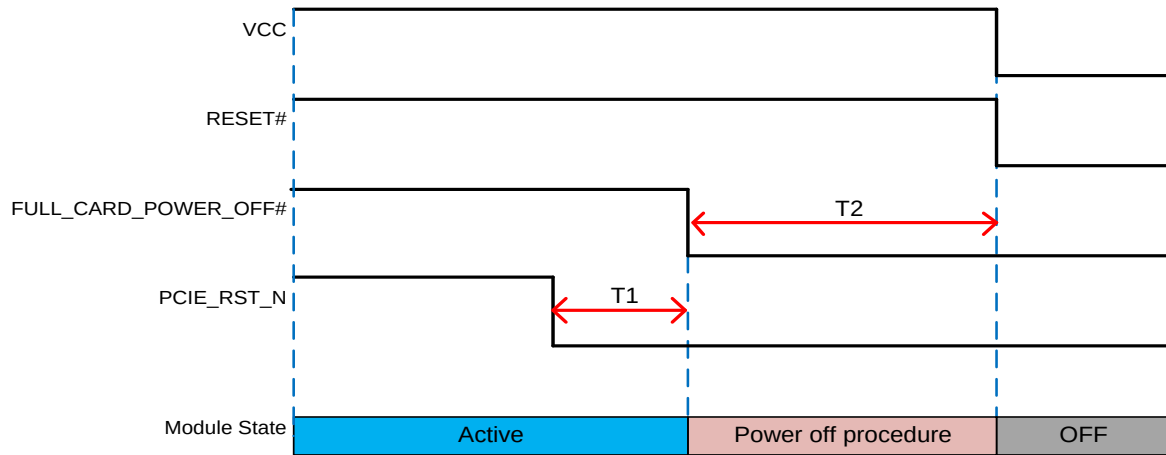


Figure 22: PCIe Turn-off Timing through FULL_CARD_POWER_OFF#

Table 18: PCIe Turn-off Timing through FULL_CARD_POWER_OFF#

Index	Min.	Typ.	Max.	Comment
T1	20 ms	-	-	PCIe interface is disabled by asserting PCIE_RST_N.
T2	3 s	-	-	Module is powering off and it stops reading and writing Flash, data protection, etc. If the power is always on, T2 could be ignored.

4.3.3.3. PCIe Reset Timing

RESET# pin is used to reset the module. FULL_CARD_POWER_OFF# is driven low during system reset.

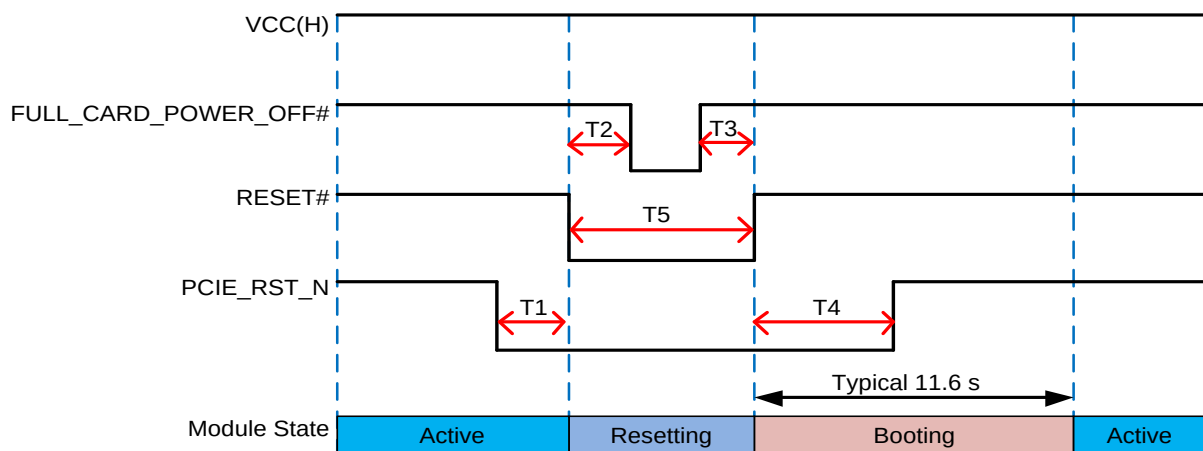


Figure 23: PCIe Reset Timing

Table 19: PCIe Reset Timing

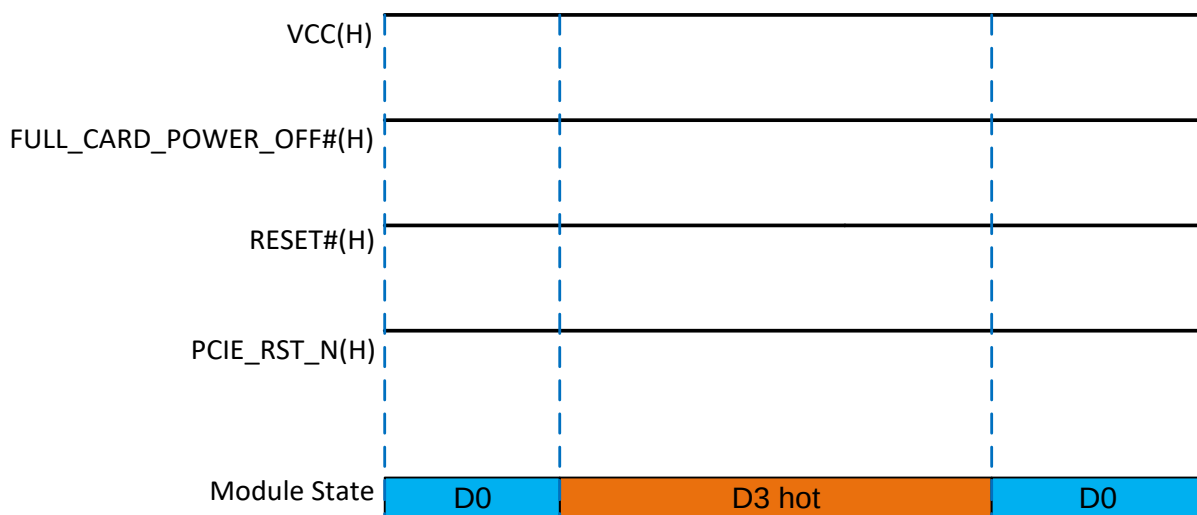
Index	Min.	Typ.	Max.	Comment
T1	20 ms	-	-	PCIe interface is disabled by asserting PCIE_RST_N.
T2	0 ms	-	-	Module is reset by asserting RESET#.
T3	0 ms	-	-	T3 could be ignored.
T4	100 ms	-	-	De-assert PCIE_RST_N 100 ms after de-asserting RESET#.
T5	250 ms	500 ms	-	

4.3.3.4. PCIe Modern Standby Timing

EM121R-GL supports D3 Hot and D3 Cold state in Win 10 system. When the module enters D3 Hot or D3 Cold state, the timing is shown below:

● D3 Hot Timing

In D3 Hot state, PCIE_RST_N remains at high level.


Figure 24: PCIe D3 Hot State Timing

● D3 Cold Timing

The module must go through D3 Hot before entering D3 Cold state. In D3 Hot state, PCIE_RST_N remains at high level, then in D3 cold state, PCIE_RST_N should be pulled down.

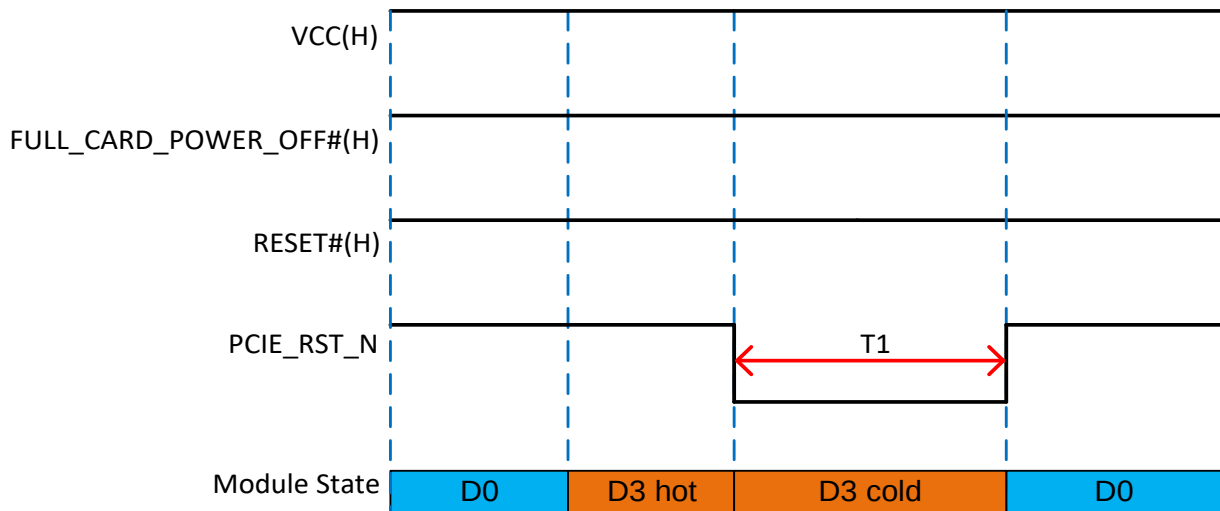


Figure 25: PCIe D3 Cold Timing

4.4. PCM Interface*

The module supports audio communication via Pulse Code Modulation (PCM) digital interface. The PCM interface supports the following modes:

- Primary mode (short frame synchronization): the module works as both master and slave
- Auxiliary mode (long frame synchronization): the module works as master only

In primary mode, the data is sampled on the falling edge of the PCM_CLK and transmitted on the rising edge. The PCM_SYNC falling edge represents the MSB. In this mode, the PCM interface supports 256 kHz, 512 kHz, 1024 kHz or 2048 kHz PCM_CLK at 8 kHz PCM_SYNC, and also supports 4096 kHz PCM_CLK at 16 kHz PCM_SYNC.

In auxiliary mode, the data is sampled on the falling edge of the PCM_CLK and transmitted on the rising edge. The PCM_SYNC rising edge represents the MSB. In this mode, PCM interface operates with a 256 kHz PCM_CLK and an 8 kHz, 50 % duty cycle PCM_SYNC only.

The module supports 16-bit linear data format. The following figures show the primary mode's timing relationship with 8 kHz PCM_SYNC and 2048 kHz PCM_CLK, as well as the auxiliary mode's timing relationship with 8 kHz PCM_SYNC and 256 kHz PCM_CLK.

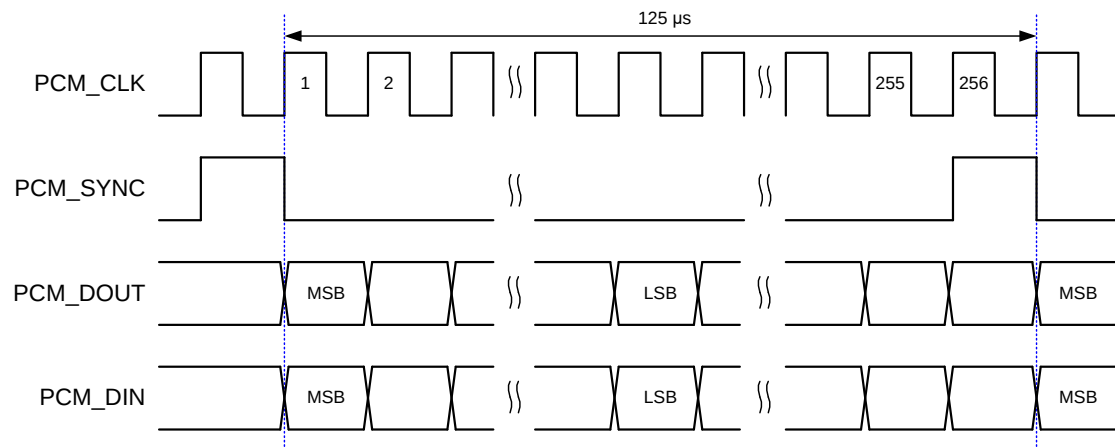


Figure 26: Primary Mode Timing

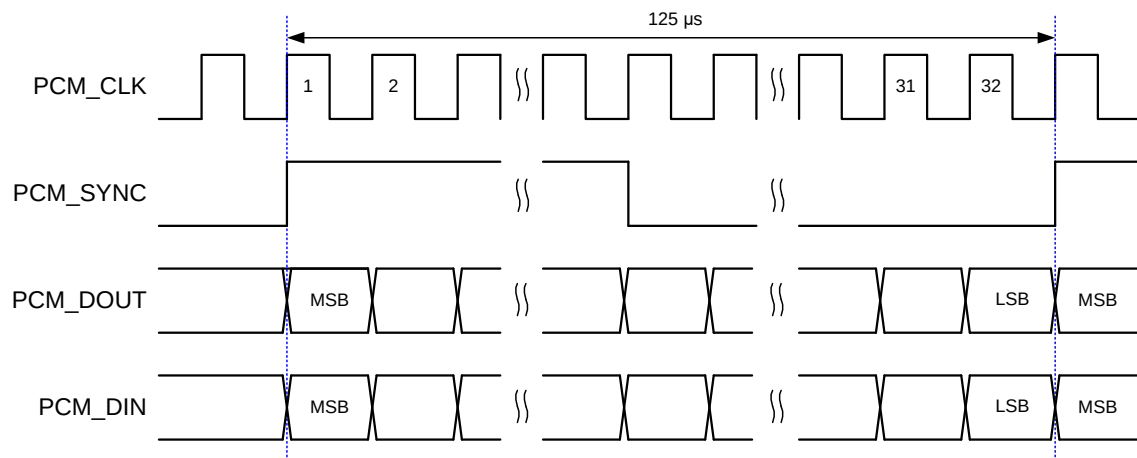


Figure 27: Auxiliary Mode Timing

The following table shows the pin definition of PCM interface which can be applied to audio codec design.

Table 20: Pin Definition of PCM Interface

Pin No.	Pin Name	I/O	Description	DC Characteristics
20	PCM_CLK	DIO, PD	PCM clock	1.8 V
22	PCM_DIN	DI, PD	PCM data input	1.8 V
24	PCM_DOUT	DO, PD	PCM data output	1.8 V
28	PCM_SYNC	DIO, PD	PCM data frame sync	1.8 V

The clock and mode can be configured by AT command, and the default configuration is master mode using short frame synchronization format with 2048 kHz PCM_CLK and 8 kHz PCM_SYNC. See [document \[3\]](#) for details about **AT+QDAI** command.

4.5. Control and Indication Interfaces

Table 21: Pin Definition of Control and Indication Interfaces

Pin No.	Pin Name	I/O	Description	DC Characteristics
8	W_DISABLE1#	DI, OD	Airplane mode control. Active LOW.	1.8/3.3 V
10	WWAN_LED#	DO, OD	RF status indication LED. Active LOW.	VCC
23	WAKE_ON_WAN#*	DO, OD	Wake up the host. Active LOW.	1.8/3.3 V
25	DPR	DI, PU	Dynamic power reduction. High voltage level by default.	1.8 V
26	W_DISABLE2#	DI, OD	GNSS disable control. Active LOW.	1.8/3.3 V
60	WLAN_PA_EN*	DI, PD	Self-protection of QLN4650 control	1.8 V
68	ANT_CONFIG	DI, PU	Antenna configuration	1.8 V

4.5.1. W_DISABLE1#

The module provides a W_DISABLE1# pin to disable or enable airplane mode through hardware operation. W_DISABLE1# is pulled up by default. Driving it low will set the module to airplane mode. In airplane mode, the RF function will be disabled.

The RF function can also be enabled or disabled through software AT commands. The following table shows the RF function status of the module.

Table 22: RF Function Status

W_DISABLE1# Level	AT Commands	RF Function Status
High Level	AT+CFUN=1	Enabled

High Level	AT+CFUN=0 AT+CFUN=4	Disabled
Low Level	AT+CFUN=0 AT+CFUN=1 AT+CFUN=4	Disabled

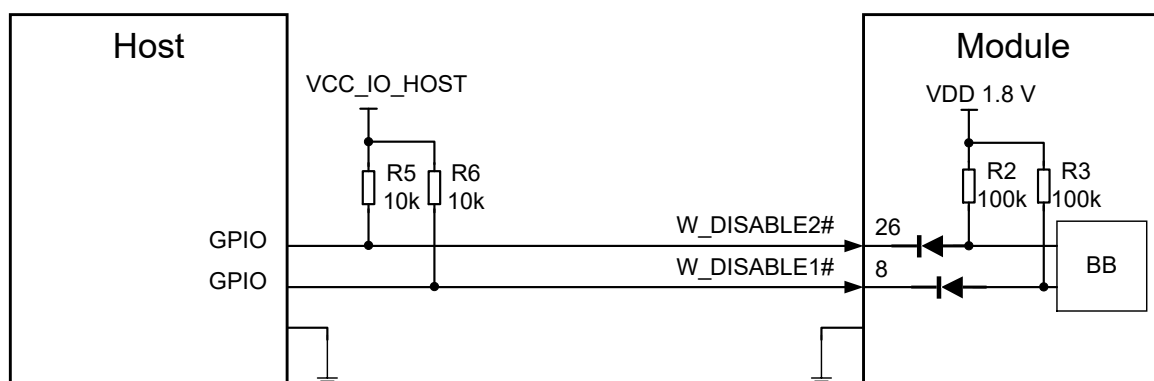
4.5.2. W_DISABLE2#

The module provides a W_DISABLE2# pin to disable or enable the GNSS function. The W_DISABLE2# pin is pulled up by default. Driving it low will disable the GNSS function. The combination of W_DISABLE2# pin and AT commands can control the GNSS function.

Table 23: GNSS Function Status

W_DISABLE2# Level	AT Commands	GNSS Function Status
High Level	AT+QGPS=1	Enabled
High Level	AT+QGSEND	
Low Level	AT+QGPS=1	Disabled
Low Level	AT+QGSEND	

A simple level shifter based on diodes is used on W_DISABLE1# pin and W_DISABLE2# pin which are pulled up to a 1.8 V voltage in the module, as shown in the following figure. So, the control signals (GPIO) of the host device could be at 1.8 V or 3.3 V voltage level. W_DISABLE1# and W_DISABLE2# are active low signals, and a reference circuit is shown as below.



Note: The voltage level of VCC_IO_HOST could be 1.8 V or 3.3 V typically.

Figure 28: W_DISABLE1# and W_DISABLE2# Reference Circuit

4.5.3. WWAN_LED#

The WWAN_LED# signal is used to indicate RF status of the module, and its sink current is up to 10 mA.

To reduce current consumption of the LED, a current-limited resistor must be placed in series with the LED, as illustrated in the figure below. The LED is ON when the WWAN_LED# signal is at low level.

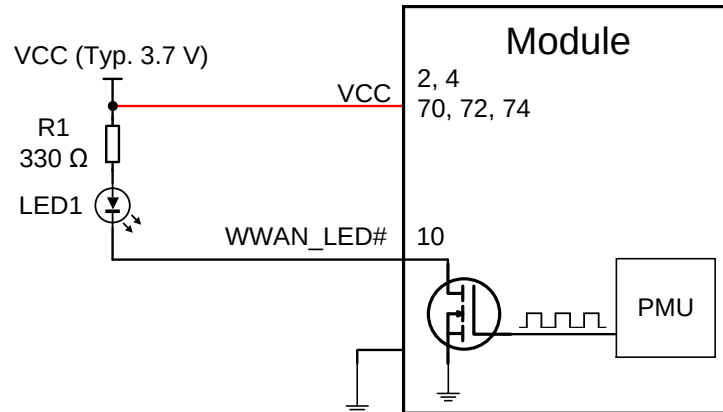


Figure 29: WWAN_LED# Reference Circuit

The following table shows the RF status indicated by WWAN_LED#.

Table 24: Network Status Indications of WWAN_LED#

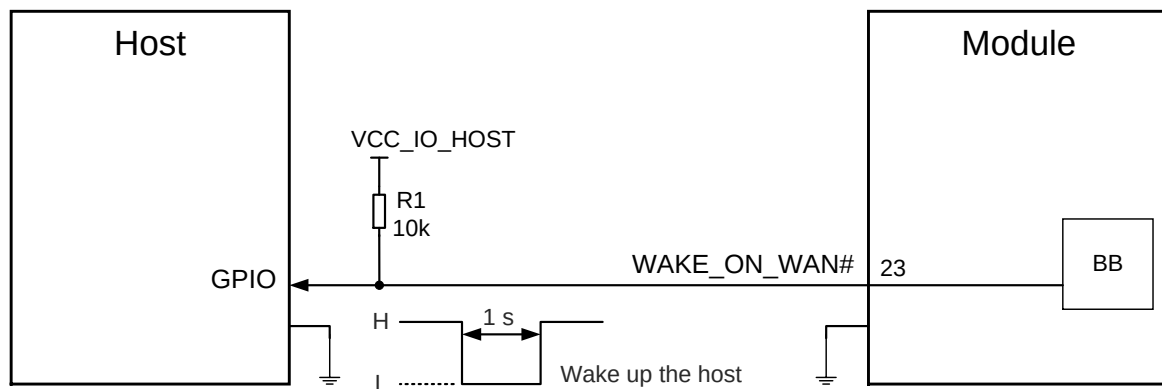
WWAN_LED# Level	Description
Low Level (LED On)	RF function is turned on
High Level (LED Off)	RF function is turned off if any of the following occurs: <ul style="list-style-type: none"> ● The (U)SIM card is not powered. ● W_DISABLE1# is at low level (airplane mode enabled). ● AT+CFUN=4 (RF function disabled).

4.5.4. WAKE_ON_WAN#

The WAKE_ON_WAN# is an open drain pin, which requires a pull-up resistor on the host. When a URC returns, a 1 s low level pulse signal will be outputted to wake up the host. The module operation status indicated by WAKE_ON_WAN# is shown below.

Table 25: State of the WAKE_ON_WAN#

WAKE_ON_WAN# State	Module Operation Status
Output a 1 s low level pulse signal	Call/SMS/Data is incoming (to wake up the host)
Always at high level	Idle/Sleep



Note: The voltage level on VCC_IO_HOST depends on the host side due to the open drain in pin 23.

Figure 30: WAKE_ON_WAN# Signal Reference Circuit

4.5.5. DPR

The module provides the DPR pin for body SAR detection. The signal is sent from a host system proximity sensor to the module to provide an input trigger, which will reduce the output power in radio transmission.

Table 26: Function of the DPR Signal

DPR Level	Function
High/Floating	Max transmitting power will NOT backoff.
Low	Max transmitting power backoff by SAR efs file configure.

4.5.6. WLAN_PA_EN*

QLN4650 enables self-protection circuit (integrated inside QLN4650) when WLAN_PA_EN is ON.

- In LTE mode, the default WLAN_PA_EN is set to 0.
- When WLAN_PA_EN = 1, the LNA will be in self-protection mode.

Table 27: Pin definition of WLAN_PA_EN for EM121R-GL

Pin No.	Pin Name	I/O	Description	Comment
60	WLAN_PA_EN	DI, PD	Self-protection of QLN4650 control	1.8 V

4.6. Cellular/WLAN COEX Interface*

The module provides the cellular/WLAN COEX interface, the following table shows the pin definition of this interface.

Table 28: Pin Definition of COEX Interface

Pin No.	Pin Name	I/O	Description	DC Characteristics
62	COEX_RXD	DI, PD	LTE/WLAN coexistence receive	1.8 V
64	COEX_TXD	DO, PD	LTE/WLAN coexistence transmit	1.8 V

4.7. Antenna Tuner Control Interface*

ANTCTL [0:3] and RF FE interface are used for antenna tuner control and should be routed to an appropriate antenna control circuit. More details about the interface will be added in the future version of this document.

4.7.1. Antenna Tuner Control Interface through GPIOs

Table 29: Pin Definition of Antenna Tuner Control Interface through GPIOs

Pin No.	Pin Name	I/O	Description	DC Characteristics
59	ANTCTL0	DO, PD	Antenna GPIO Control	1.8 V
61	ANTCTL1	DO, PD		1.8 V
63	ANTCTL2	DO, PD		1.8 V
65	ANTCTL3	DO, PD		1.8 V

4.7.2. Antenna Tuner Control Interface through RFFE

Table 30: Pin Definition of Antenna Tuner Control Interface through RFFE

Pin No.	Pin Name	I/O	Description	DC Characteristics
56	RFFE_CLK	DO, PD	Used for external MIPI IC control	1.8 V
58	RFFE_DATA	DIO, PD	Used for external MIPI IC control	1.8 V

NOTE

RFFE_CLK and RFFE_DATA are reserved only for customization.

4.8. Configuration Pins

The module provides four configuration pins, which are defined as below.

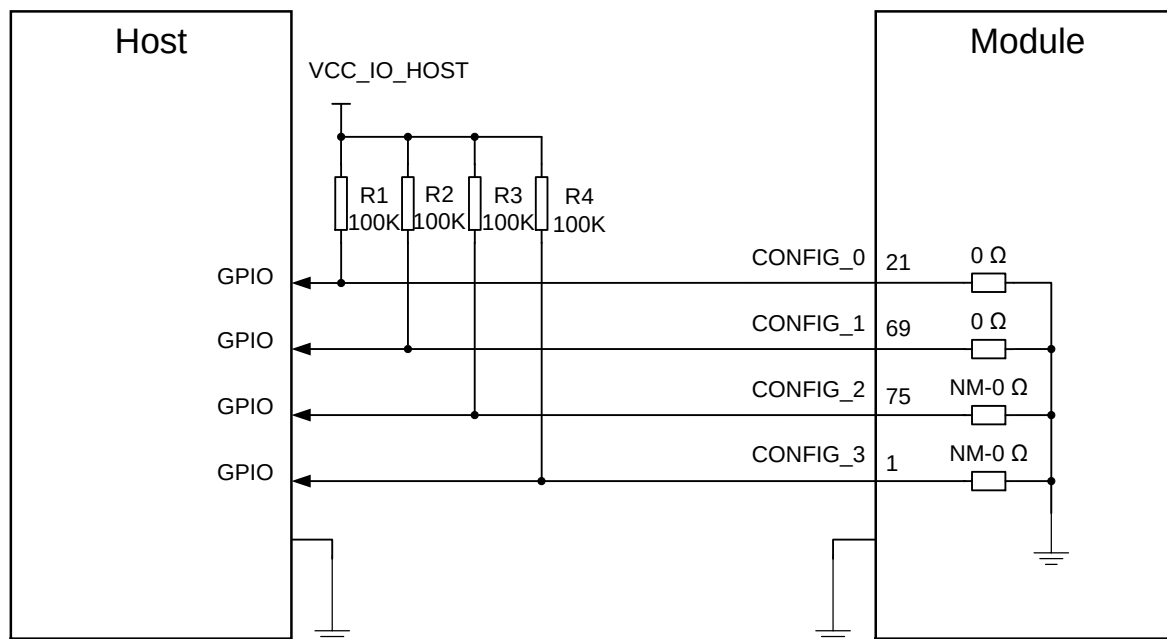
Table 31: List of EM121R-GL Configuration Pins

Config_0 (Pin 21)	Config_1 (Pin 69)	Config_2 (Pin 75)	Config_3 (Pin 1)	Module Type and Main Host Interface	Port Configuration
GND	GND	NC	NC	WWAN–USB3.0	2

Table 32: Pin Definition of EM121R-GL Configuration Pins

Pin No.	Pin Name	I/O	Description
21	CONFIG_0	DO	Connected to GND internally.
69	CONFIG_1	DO	Connected to GND internally
75	CONFIG_2	DO	Not connected internally
1	CONFIG_3	DO	Not connected internally

The following figure shows a reference circuit for these four pins.



Note: The voltage level VCC_IO_HOST depends on the host side, and could be a 1.8 V or 3.3 V voltage level.

Figure 31: Recommended Circuit of EM121R-GL Configuration Pins

5 RF Characteristics

5.1. Cellular Antenna Interfaces

EM121R-GL provides Main, Rx-diversity and GNSS antenna connectors which are used to resist the fall of signals caused by high-speed movement and multipath effect. The impedance of antenna ports is 50 Ω .

5.1.1. Connector Definition

Table 33: EM121R-GL Connector Definition of Antenna Interfaces

Connector Name	I/O	Description	Comment
Main Antenna	AIO	Main Antenna connector: <ul style="list-style-type: none"> ● LTE: TRx ● WCDMA: TRx 	50 Ω impedance
Rx-diversity	AI	Rx-diversity Antenna connector: <ul style="list-style-type: none"> ● LTE: DRx ● WCDMA: DRx 	50 Ω impedance

5.1.2. Operating Frequency

Table 34: Operating Frequency of EM121R-GL

3GPP Band	Transmit	Receive	Unit
WCDMA B1	1920–1980	2110–2170	MHz
WCDMA B2	1850–1910	1930–1990	MHz
WCDMA B3	1710–1785	1805–1880	MHz
WCDMA B4	1710–1755	2110–2155	MHz
WCDMA B5	824–849	869–894	MHz

WCDMA B6	830–840	875–885	MHz
WCDMA B8	880–915	925–960	MHz
WCDMA B19	830–845	875–890	MHz
LTE-FDD B1	1920–1980	2110–2170	MHz
LTE-FDD B2	1850–1910	1930–1990	MHz
LTE-FDD B3	1710–1785	1805–1880	MHz
LTE-FDD B4	1710–1755	2110–2155	MHz
LTE-FDD B5	824–849	869–894	MHz
LTE-FDD B7	2500–2570	2620–2690	MHz
LTE-FDD B8	880–915	925–960	MHz
LTE-FDD B12	699–716	729–746	MHz
LTE-FDD B13	777–787	746–756	MHz
LTE-FDD B14	788–798	758–768	MHz
LTE-FDD B18	815–830	860–875	MHz
LTE-FDD B19	830–845	875–890	MHz
LTE-FDD B20	832–862	791–821	MHz
LTE-FDD B25	1850–1915	1930–1995	MHz
LTE-FDD B26	814–849	859–894	MHz
LTE-FDD B28	703–748	758–803	MHz
LTE-FDD B29 ¹⁾	-	717–728	MHz
LTE-FDD B30	2305–2315	2350–2360	MHz
LTE-FDD B32 ¹⁾	-	1452–1496	MHz
LTE-TDD B38	2570–2620	2570–2620	MHz
LTE-TDD B39	1880–1920	1880–1920	MHz
LTE-TDD B40	2300–2400	2300–2400	MHz

LTE-TDD B41	2496–2690	2496–2690	MHz
LTE-TDD B46 ¹⁾	-	5150–5925	MHz
LTE-TDD B48	3550–3700	3550–3700	MHz
LTE-FDD B66	1710–1780	2110–2200	MHz

NOTE

¹⁾ LTE-FDD B29/32 and LTE-TDD B46 support Rx only and are only for secondary component carrier.

5.1.3. Receiving Sensitivity

Table 35: EM121R-GL Dual-Antenna Conducted Receiving Sensitivity

Frequency Bands	RX Sensitivity ¹⁾ (Typical) (dBm)	3GPP (dBm)	Comment ²⁾
WCDMA B1	-110.5	-106.7	
WCDMA B2	-110	-104.7	
WCDMA B3	-111	-103.7	
WCDMA B4	-110.5	-106.7	
WCDMA B5	-111	-104.7	
WCDMA B6	-111	-106.7	
WCDMA B8	-110.5	-103.7	
WCDMA B19	-111	-106.7	
LTE-FDD B1	-100.5	-96.3	10 MHz
LTE-FDD B2	-100	-94.3	10 MHz
LTE-FDD B3	-100.5	-93.3	10 MHz
LTE-FDD B4	-100.5	-96.3	10 MHz
LTE-FDD B5	-101.5	-94.3	10 MHz
LTE-FDD B7	-99	-94.3	10 MHz

LTE-FDD B8	-101	-93.3	10 MHz
LTE-FDD B12	-102	-93.3	10 MHz
LTE-FDD B13	-102	-93.3	10 MHz
LTE-FDD B14	-101.5	-93.3	10 MHz
LTE-FDD B18	-102	-96.3	10 MHz
LTE-FDD B19	-102	-96.3	10 MHz
LTE-FDD B20	-102	-93.3	10 MHz
LTE-FDD B25	-100.5	-92.8	10 MHz
LTE-FDD B26	-101.9	-93.8	10 MHz
LTE-FDD B28	-102	-94.8	10 MHz
LTE-FDD B30	-99	-95.3	10 MHz
LTE-TDD B38	-100.1	-96.3	10 MHz
LTE-TDD B39	-100.5	-96.3	10 MHz
LTE-TDD B40	-99.2	-96.3	10 MHz
LTE-TDD B41	-100.7	-94.3	10 MHz
LTE-TDD B48	-100.6	-95.0	10 MHz
LTE-FDD B66	-100.4	-95.8	10 MHz

NOTES

- ¹⁾ Rx Sensitivity values are measured in dual antennas condition (Primary + Diversity). For single primary antenna (without Diversity), the sensitivity will drop around 3 dBm for each LTE band.
- ²⁾ The RB configure follows 3GPP specification.

5.1.4. Output Power

Table 36: EM121R-GL RF Output Power of PCIe Only Version

Frequency Bands	Modulation	Max.	Min.	Comment
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WCDMA B1	BPSK	24 dBm +1/-3 dB	< -50 dBm	
WCDMA B2	BPSK	24 dBm +1/-3 dB	< -50 dBm	
WCDMA B3	BPSK	24 dBm +1/-3 dB	< -50 dBm	
WCDMA B4	BPSK	24 dBm +1/-3 dB	< -50 dBm	
WCDMA B5	BPSK	24 dBm +1/-3 dB	< -50 dBm	
WCDMA B6	BPSK	24 dBm +1/-3 dB	< -50 dBm	
WCDMA B8	BPSK	24 dBm +1/-3 dB	< -50 dBm	
WCDMA B19	BPSK	24 dBm +1/-3 dB	< -50 dBm	
LTE-FDD B1	QPSK	23 dBm ± 2 dB	< -40 dBm	10 MHz, 1RB
LTE-FDD B2	QPSK	23 dBm ± 2 dB	< -40 dBm	10 MHz, 1RB
LTE-FDD B3	QPSK	23 dBm ± 2 dB	< -40 dBm	10 MHz, 1RB
LTE-FDD B4	QPSK	23 dBm ± 2 dB	< -40 dBm	10 MHz, 1RB
LTE-FDD B5	QPSK	23 dBm ± 2 dB	< -40 dBm	10 MHz, 1RB
LTE-FDD B7	QPSK	23 dBm ± 2 dB	< -40 dBm	10 MHz, 1RB
LTE-FDD B8	QPSK	23 dBm ± 2 dB	< -40 dBm	10 MHz, 1RB
LTE-FDD B12	QPSK	23 dBm ± 2 dB	< -40 dBm	10 MHz, 1RB
LTE-FDD B13	QPSK	23 dBm ± 2 dB	< -40 dBm	10 MHz, 1RB
LTE-FDD B14	QPSK	23 dBm ± 2 dB	< -40 dBm	10 MHz, 1RB
LTE-FDD B18	QPSK	23 dBm ± 2 dB	< -40 dBm	10 MHz, 1RB
LTE-FDD B19	QPSK	23 dBm ± 2 dB	< -40 dBm	10 MHz, 1RB
LTE-FDD B20	QPSK	23 dBm ± 2 dB	< -40 dBm	10 MHz, 1RB
LTE-FDD B25	QPSK	23 dBm ± 2 dB	< -40 dBm	10 MHz, 1RB
LTE-FDD B26	QPSK	23 dBm ± 2 dB	< -40 dBm	10 MHz, 1RB
LTE-FDD B28	QPSK	23 dBm ± 2 dB	< -40 dBm	10 MHz, 1RB
LTE-FDD B30	QPSK	20 dBm ± 2 dB	< -40 dBm	10 MHz, 1RB

LTE-TDD B38	QPSK	23 dBm ± 2 dB	< -40 dBm	10 MHz, 1RB
LTE-TDD B39	QPSK	23 dBm ± 2 dB	< -40 dBm	10 MHz, 1RB
LTE-TDD B40	QPSK	23 dBm ± 2 dB	< -40 dBm	10 MHz, 1RB
LTE-TDD B41	QPSK	23 dBm ± 2 dB	< -40 dBm	10 MHz, 1RB
LTE-TDD B41 HPUE	QPSK	25.5 dBm $+1/-2$ dB	< -40 dBm	10 MHz, 1RB
LTE-TDD B48	QPSK	19 dBm ± 2 dB	< -40 dBm	10 MHz, 1RB
LTE-FDD B66	QPSK	23 dBm ± 2 dB	< -40 dBm	10 MHz, 1RB

Table 37: EM121R-GL RF Output Power of USB Version

Frequency Bands	Modulation	Max.	Min.	Comment
WCDMA B1	BPSK	24 dBm $+1/-3$ dB	< -50 dBm	
WCDMA B2	BPSK	24 dBm $+1/-3$ dB	< -50 dBm	
WCDMA B3	BPSK	24 dBm $+1/-3$ dB	< -50 dBm	
WCDMA B4	BPSK	24 dBm $+1/-3$ dB	< -50 dBm	
WCDMA B5	BPSK	24 dBm $+1/-3$ dB	< -50 dBm	
WCDMA B6	BPSK	24 dBm $+1/-3$ dB	< -50 dBm	
WCDMA B8	BPSK	24 dBm $+1/-3$ dB	< -50 dBm	
WCDMA B19	BPSK	24 dBm $+1/-3$ dB	< -50 dBm	
LTE-FDD B1	QPSK	23 dBm ± 2 dB	< -40 dBm	10 MHz, 1RB
LTE-FDD B2	QPSK	23 dBm ± 2 dB	< -40 dBm	10 MHz, 1RB
LTE-FDD B3	QPSK	23 dBm ± 2 dB	< -40 dBm	10 MHz, 1RB
LTE-FDD B4	QPSK	23 dBm ± 2 dB	< -40 dBm	10 MHz, 1RB
LTE-FDD B5	QPSK	23 dBm ± 2 dB	< -40 dBm	10 MHz, 1RB
LTE-FDD B7	QPSK	23 dBm ± 2 dB	< -40 dBm	10 MHz, 1RB
LTE-FDD B8	QPSK	23 dBm ± 2 dB	< -40 dBm	10 MHz, 1RB
LTE-FDD B12	QPSK	23 dBm ± 2 dB	< -40 dBm	10 MHz, 1RB

LTE-FDD B13	QPSK	23 dBm $\pm$ 2 dB	< -40 dBm	10 MHz, 1RB
LTE-FDD B14	QPSK	23 dBm $\pm$ 2 dB	< -40 dBm	10 MHz, 1RB
LTE-FDD B18	QPSK	23 dBm $\pm$ 2 dB	< -40 dBm	10 MHz, 1RB
LTE-FDD B19	QPSK	23 dBm $\pm$ 2 dB	< -40 dBm	10 MHz, 1RB
LTE-FDD B20	QPSK	23 dBm $\pm$ 2 dB	< -40 dBm	10 MHz, 1RB
LTE-FDD B25	QPSK	23 dBm $\pm$ 2 dB	< -40 dBm	10 MHz, 1RB
LTE-FDD B26	QPSK	23 dBm $\pm$ 2 dB	< -40 dBm	10 MHz, 1RB
LTE-FDD B28	QPSK	23 dBm $\pm$ 2 dB	< -40 dBm	10 MHz, 1RB
LTE-FDD B30	QPSK	23 dBm $\pm$ 2 dB	< -40 dBm	10 MHz, 1RB
LTE-TDD B38	QPSK	23 dBm $\pm$ 2 dB	< -40 dBm	10 MHz, 1RB
LTE-TDD B39	QPSK	23 dBm $\pm$ 2 dB	< -40 dBm	10 MHz, 1RB
LTE-TDD B40	QPSK	23 dBm $\pm$ 2 dB	< -40 dBm	10 MHz, 1RB
LTE-TDD B41	QPSK	23 dBm $\pm$ 2 dB	< -40 dBm	10 MHz, 1RB
LTE-TDD B41 HPUE	QPSK	25.5 dBm +1/-2 dB	< -40 dBm	10 MHz, 1RB
LTE-TDD B48	QPSK	23 dBm $\pm$ 2 dB	< -40 dBm	10 MHz, 1RB
LTE-FDD B66	QPSK	23 dBm $\pm$ 2 dB	< -40 dBm	10 MHz, 1RB

5.2. GNSS Antenna Interface

5.2.1. General Description

EM121R-GL includes a fully integrated global navigation satellite system solution.

The module supports standard NMEA-0183 protocol, and outputs NMEA sentences at 1 Hz data update rate via USB interface by default.

By default, the module GNSS engine is switched off. It has to be switched on via AT command. For more details about GNSS engine technology and configurations, see **document [4]**.

5.2.2. Connector Definition

Table 38: EM121R-GL Connector Definition of Antenna Interfaces

Connector Name	I/O	Description	Comment
GNSS Antenna	AI	GNSS Antenna connector: ● GNSS: L1, L5	50 Ω impedance

5.2.3. GNSS Frequency

Table 39: GNSS Frequency

Type	Frequency	Unit
GPS L1/Galileo	1575.42 $\pm$ 1.023	MHz
GPS L5	1176.45 $\pm$ 1.023	MHz
GLONASS	1601.65 $\pm$ 4.15	MHz
BeiDou/COMPASS	1561.098 $\pm$ 2.046	MHz

Internal circuit for active antenna DC bias is shown as below.

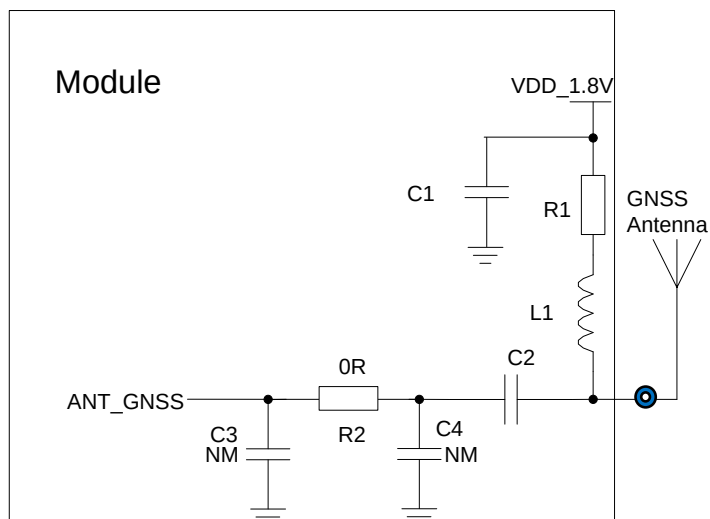


Figure 32: Internal circuit for Active Antenna DC Bias

5.2.4. GNSS Performance

Table 40: EM121R-GL GNSS Performance

Parameter	Description	Conditions	Typ.	Unit
Sensitivity (GNSS)	Cold start	Autonomous	-148	dBm
	Reacquisition	Autonomous	-160	dBm
	Tracking	Autonomous	-159	dBm
TTFF (GNSS)	Cold start @ open sky	Autonomous	27.46	s
		XTRA enabled	17.07	s
	Warm start @ open sky	Autonomous	26.45	s
		XTRA enabled	1.53	s
	Hot start @ open sky	Autonomous	1.02	s
		XTRA enabled	1.03	s
Accuracy (GNSS)	CEP-50	Autonomous @ open sky	2.08	m

NOTES

1. Tracking sensitivity: the minimum GNSS signal power at which the module can maintain lock (keep positioning for at least 3 minutes continuously).
2. Reacquisition sensitivity: the minimum GNSS signal power required for the module to maintain lock within 3 minutes after the loss of lock.
3. Cold start sensitivity: the minimum GNSS signal power at which the module can fix position successfully within 3 minutes after executing cold start command.

5.3. Antenna Connectors

5.3.1. Antenna Connector Location

The antenna connector locations are shown below.



Figure 33: Antenna Connectors on the EM121R-GL Module

5.3.2. Antenna Connector Size

Standard 2 mm × 2 mm receptacle antenna connectors are mounted for convenient antenna connection. The antenna connector's PN is IPEX 20449-001E, and the connector dimensions are illustrated as below:

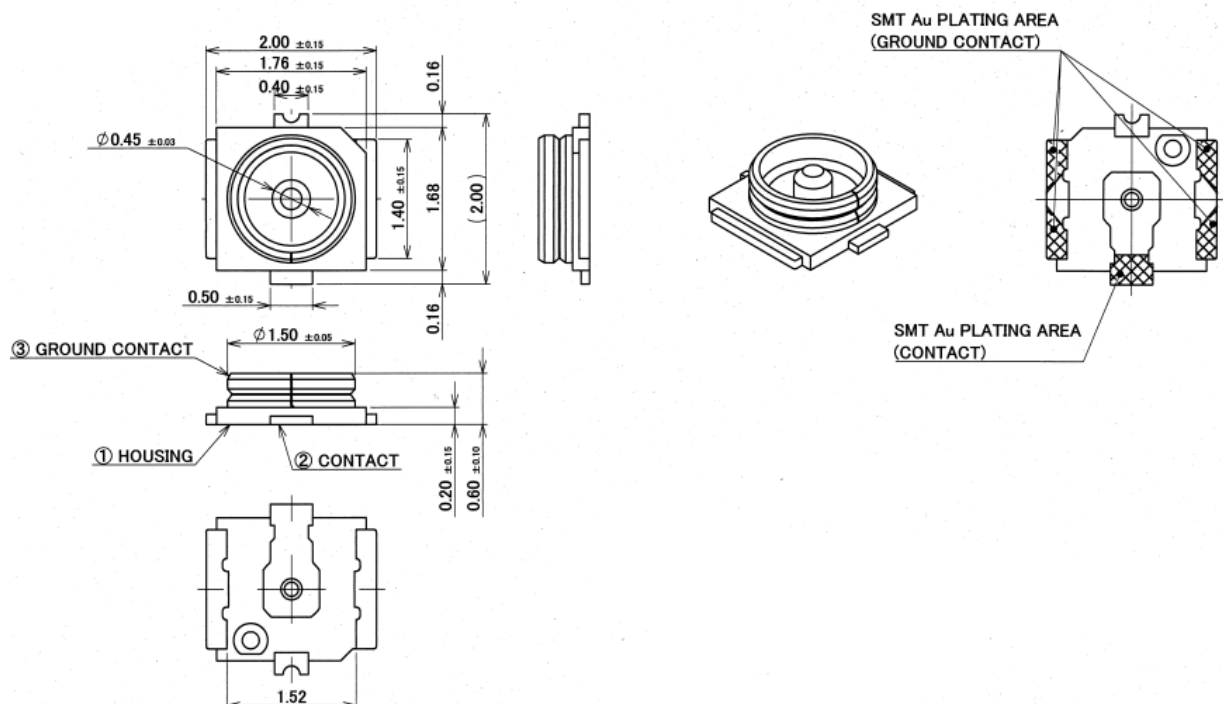


Figure 34: EM121R-GL RF Connector Dimensions (Unit: mm)

Table 41: Major Specifications of the RF Connector

Item	Specification
Nominal Frequency Range	DC to 6 GHz
Nominal Impedance	50 Ω
Temperature Rating	-40 to +85 °C
Voltage Standing Wave Ratio (VSWR)	Meet the requirements of: Max. 1.3 (DC–3 GHz) Max. 1.4 (3–6 GHz)

5.3.3. Antenna Connector Installation

The 2 mm × 2 mm connector dimensions are illustrated below:

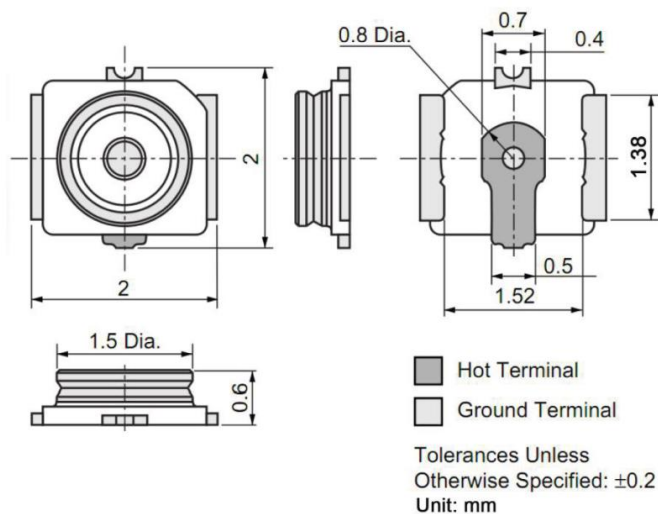


Figure 35: EM121R-GL RF Connector Dimensions (Unit: mm)

The receptacle RF connector used in conjunction with the module will accept two types of mating plugs that will meet a maximum height of 1.2 mm using a $\varnothing$ 0.81 mm coaxial cable or a maximum height of 1.45 mm utilizing a $\varnothing$ 1.13 mm coaxial cable.

The following figure shows the specifications of mating plugs using $\varnothing$ 0.81 mm coaxial cables.

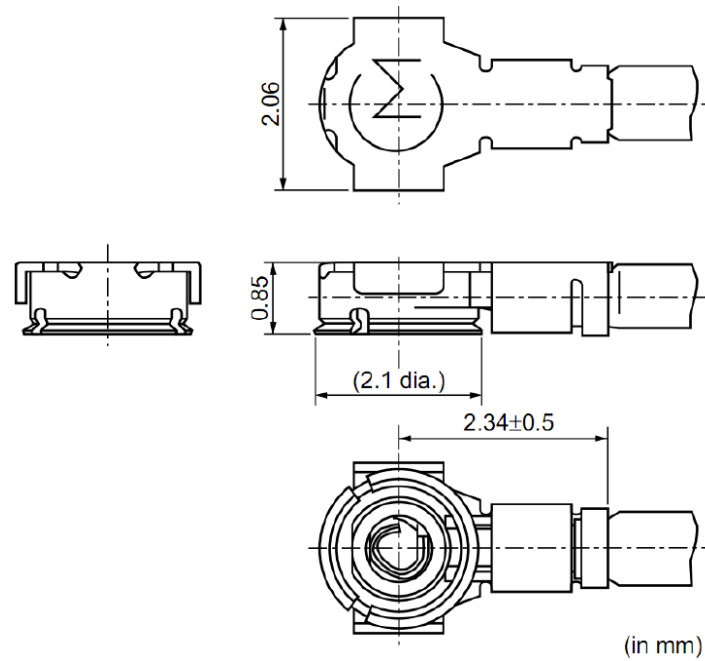


Figure 36: Specifications of Mating Plugs Using Ø 0.81 mm Coaxial Cables

The following figure illustrates the connection between the receptacle RF connector on the module and the mating plug using a Ø 0.81 mm coaxial cable.

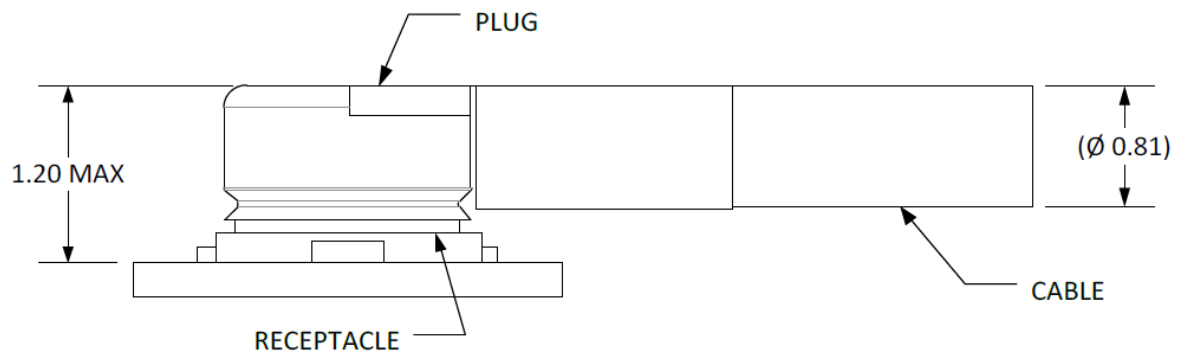


Figure 37: Connection between RF Connector and Mating Plug Using Ø 0.81 mm Coaxial Cable

The following figure illustrates the connection between the receptacle RF connector on the module and the mating plug using a Ø 1.13 mm coaxial cable.

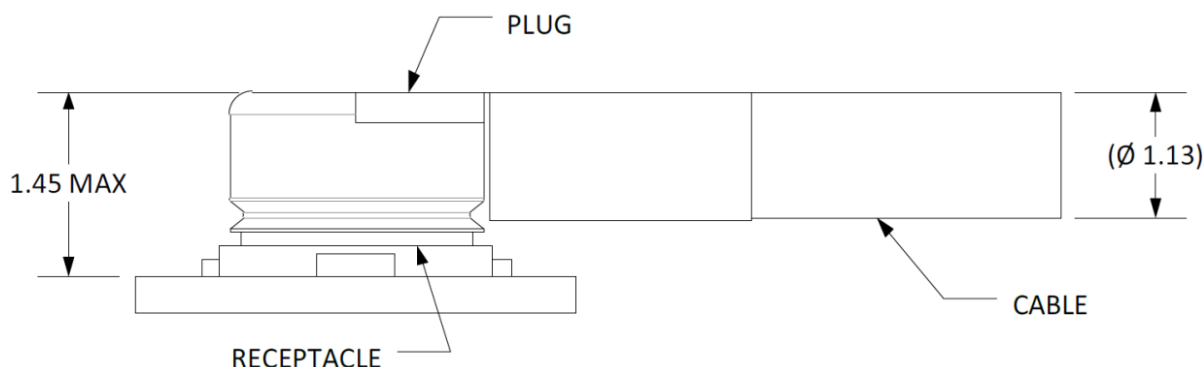


Figure 38: Connection between RF Connector and Mating Plug Using Ø 1.13 mm Coaxial Cable

5.4. Antenna Requirements

Table 42: Antenna Requirements of EM121R-GL

Type	Requirements	Supported Bands
Main Antenna (Tx/Rx)	VSWR: ≤ 2 Efficiency: $> 30\%$ Max Input Power: 50 W Input Impedance: 50 Ω Cable Insertion Loss: < 1 dB (699–960 MHz) Cable Insertion Loss: < 1.5 dB (1710–2200 MHz) Cable Insertion Loss: < 2 dB (2300–2690 MHz)	LTE: B1/B2/B3/B4/B5/B7/B8/B12/B13/ B14/B17/B18/B19/B20/B25/B26/ B28/B29/B30/B32/B38/B39/B40/ B41/B42/B43/B46/B48/B66 WCDMA: B1/B2/B3/B4/B5/B6/B8/B19
Rx-diversity	VSWR: ≤ 2 Efficiency: $> 30\%$ Max Input Power: 50 W Input Impedance: 50 Ω Cable Insertion Loss: < 1 dB (699–960 MHz) Cable Insertion Loss: < 1.5 dB (1559–2200 MHz) Cable Insertion Loss: < 2 dB (2300–2690 MHz)	LTE: B1/B2/B3/B4/B5/B7/B8/B12/B13/ B14/B17/B18/B19/B20/B25/B26/ B28/B29/B30/B32/B38/B39/B40/ B41/B42/B43/B46/B48/B66 WCDMA: B1/B2/B3/B4/B5/B6/B8/B19
GNSS Antenna ¹⁾	Active Antenna Frequency range: 1175–1610 MHz VSWR: < 1.5 (Typ.) Efficiency: $> 50\%$	GNSS: GPS L1; GPS L5; GLONASS;

LNA Noise Figure: < 1.5 dB
LNA Gain: 14.5 ±5 dB
Input Impedance: 50 Ω

BeiDou/COMPASS;
Galileo

NOTE

¹⁾ VDD voltage is 1.8 V.

6 Electrical Characteristics and Reliability

6.1. Power Supply Requirements

The typical input voltage of the module is 3.7 V. The following table shows the power supply requirements of the module.

Table 43: Power Supply Requirements

Parameter	Description	Min.	Typ.	Max.	Unit
VCC	Power Supply	3.135	3.7	4.4	V
Voltage Ripple	-	-	30	100	mV
Voltage Drop	-	-	-	165	mV

6.2. Current Consumption

6.2.1. PCIe Only Version

Table 44: EM121R-GL Current Consumption (PCIe Only Version, 3.3 V Power Supply)

Description	Conditions	Typ.	Unit
OFF state	Power down	66	μA

6.2.2. USB Version

Table 45: EM121R-GL Current Consumption (USB Only Version, 3.7 V Power Supply)

Description	Conditions	Typ.	Unit
OFF state	Power down	66	μA

6.3. Digital I/O Characteristic

Table 46: Logic Levels of Digital I/O (1.8 V)

Parameter	Description	Min.	Max.	Unit
V _{IH}	Input high voltage	1.65	2.1	V
V _{IL}	Input low voltage	-0.3	0.54	V
V _{OH}	Output high voltage	1.3	1.8	V
V _{OL}	Output low voltage	0	0.4	V

Table 47: (U)SIM 1.8 V I/O Requirements

Parameter	Description	Min.	Max.	Unit
USIM_VDD	Power supply	1.65	1.95	V
V _{IH}	Input high voltage	0.7 × USIM_VDD	USIM_VDD + 0.3	V
V _{IL}	Input low voltage	-0.3	0.2 × USIM_VDD	V
V _{OH}	Output high voltage	0.8 × USIM_VDD	USIM_VDD	V
V _{OL}	Output low voltage	0	0.4	V

Table 48: (U)SIM 3.0 V I/O Requirements

Parameter	Description	Min.	Max.	Unit
USIM_VDD	Power supply	2.7	3.05	V

V_{IH}	Input high voltage	$0.7 \times USIM_VDD$	$USIM_VDD + 0.3$	V
V_{IL}	Input low voltage	-0.3	$0.2 \times USIM_VDD$	V
V_{OH}	Output high voltage	$0.8 \times USIM_VDD$	$USIM_VDD$	V
V_{OL}	Output low voltage	0	0.4	V

6.4. Electrostatic Discharge

The module is not protected against electrostatic discharge (ESD) in general. Consequently, it is subject to ESD handling precautions that typically apply to ESD sensitive components. Proper ESD handling and packaging procedures must be applied throughout the processing, handling and operation of any application that incorporates the module.

Table 49: Electrostatic Discharge Characteristics (Temperature: 25 °C, Humidity: 40 %)

Tested Interfaces	Contact Discharge	Air Discharge	Unit
VCC, GND	± 5	± 10	kV
Antenna Interfaces	± 4	± 8	kV
Other Interfaces	± 0.5	± 1	kV

6.5. Thermal Dissipation

EM121R-GL is designed to work over an extended temperature range. To achieve a maximum performance while working under extended temperatures or extreme conditions (such as with maximum power or data rate) for a long time, it is strongly recommended to add a thermal pad or other thermally conductive compounds between the module and the main PCB for thermal dissipation.

The thermal dissipation area on the bottom (i.e. the area for adding thermal pad) is shown in the following figure. The dimensions are measured in mm.

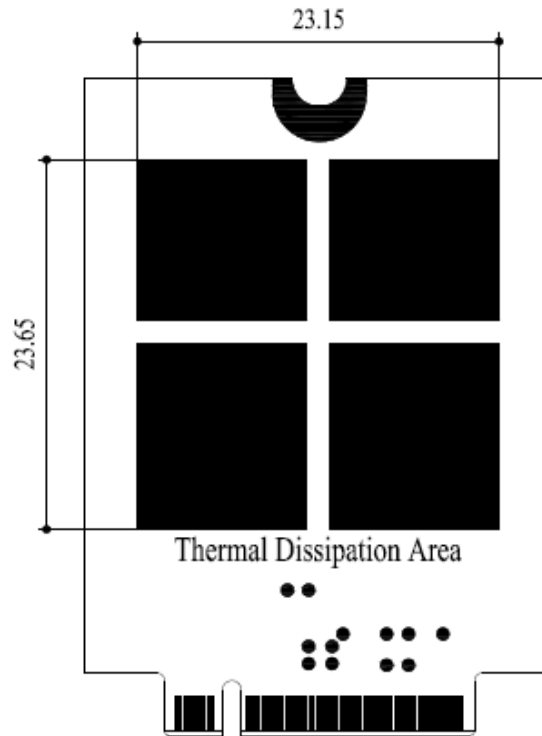


Figure 39: Thermal Dissipation Area on Bottom Side of Module

There are other measures to enhance the heat dissipation performance:

- Add as many ground vias as possible on PCB.
- Maximize the airflow over/around the module.
- Place the module away from other heating sources.
- Module mounting holes must be used to attach (ground) the device to the main PCB ground.
- It is NOT recommended to apply solder mask on the main PCB where the module's thermal dissipation area is located.
- Select appropriate material, thickness and surface for the outer housing of the application device that integrates the module (i.e. the mechanical enclosure) to enhance thermal dissipation ability. Customers may also need active cooling to dissipate heat of the module.
- If possible, add a heatsink on the top of the module. A thermal pad should be used between the heatsink and the module, and the heatsink should be designed with as many fins as possible to increase heat dissipation area.

NOTE

If a conformal coating is necessary for the module, do NOT use any coating material that may chemically react with the PCB or shielding cover, and prevent the coating material from flowing into the module.

6.6. Absolute Maximum Ratings

Absolute maximum ratings for power supply and voltage on digital and analog pins of the module are listed in the following table.

Table 50: Absolute Maximum Ratings

Parameter	Min.	Max.	Unit
VCC	-0.3	4.7	V

6.7. Operating and Storage Temperatures

Table 51: Operating and Storage Temperatures

Parameter	Min.	Typ.	Max.	Unit
Operating Temperature Range ¹⁾	-25	+25	+75	°C
Extended Temperature Range ²⁾	-40	-	+85	°C
Storage temperature Range	-40	-	+90	°C

NOTES

- 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 meets 3GPP specifications.
- ²⁾ To meet this extended 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, etc., without any unrecoverable malfunction. Radio spectrum and radio network are not influenced, while one or more specifications, such as P_{out} , may undergo a reduction in value, exceeding the specified tolerances of 3GPP. When the temperature returns to the normal operating temperature level, the module will meet 3GPP specifications again.

7 Mechanical Dimensions and Packaging

This chapter mainly describes mechanical dimensions and packaging specifications of EM121R-GL. All dimensions are measured in mm, and the tolerances are ± 0.2 mm unless otherwise specified.

7.1. Mechanical Dimensions of the Module

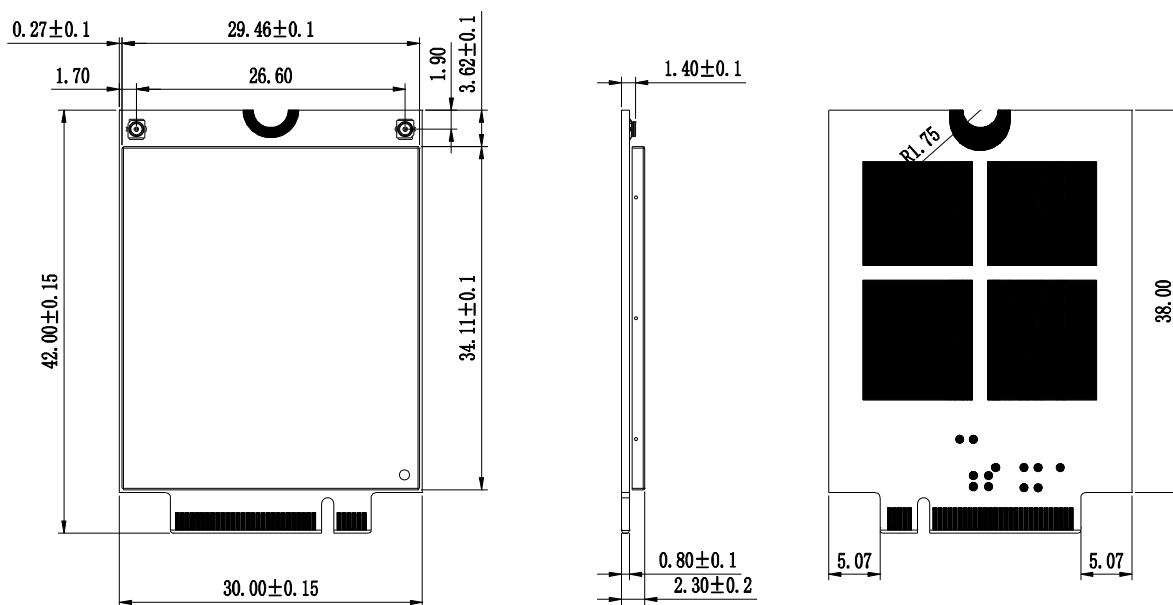


Figure 40: Mechanical Dimensions of the Module (Unit: mm)

7.2. Top and Bottom Views of the Module



Figure 41: EM121R-GL Top View and Bottom View

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.

7.3. M.2 Connector

EM121R-GL adopts a standard PCI Express M.2 connector which compiles with the directives and standards listed in *PCI Express M.2 Specification*.

7.4. Packaging

Modules are packaged in trays. The following figure shows the tray size.

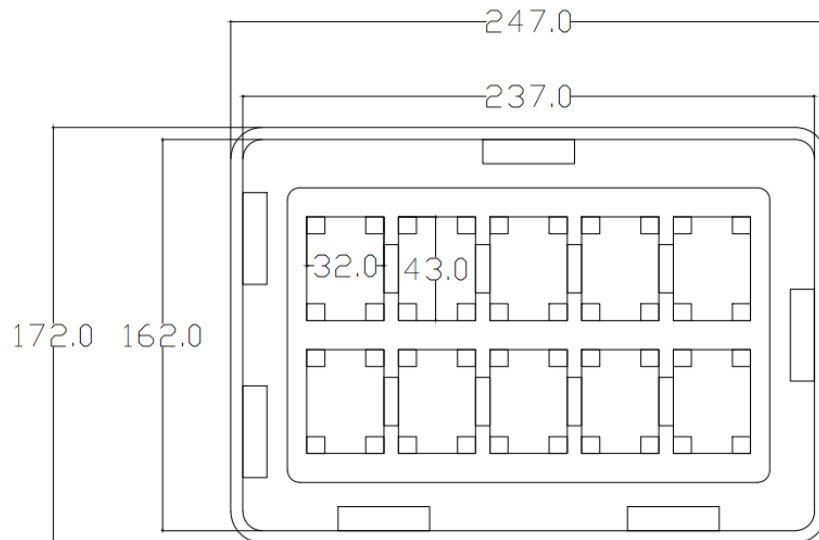


Figure 42: Tray Size (Unit: mm)

Each tray contains 10 modules. The smallest package contains 100 modules. Tray packaging procedures are as below.

1. Use 10 trays to package 100 modules at a time (tray size: 247 mm × 172 mm).
2. Place an empty tray on the top of the 10-tray stack.
3. Fix the stack with masking tape in “#” shape as shown in the following figure.
4. Pack the stack with conductive bag, and then fix the bag with masking tape.
5. Place the list of IMEI No. into a small carton.
6. Seal the carton and then label the seal with sealing sticker (small carton size: 250 mm × 175 mm × 128 mm).



Figure 43: Tray Packaging Procedure

8 Appendix References

Table 52: Related Documents

SN.	Document Name	Description
[1]	Quectel_EM121R-GL_CA_Feature	EM121R-GL CA Feature
[2]	Quectel_PCle_Card_EVB_User_Guide	PCIE card EVB user guide
[3]	Quectel_EG512R&EM1x0R_Series_AT_Commands_Manual	AT commands manual for EG512R and EM1x0R-GL series and EM121R-GL.
[4]	Quectel_EM1x0R-GL&EG512R_Series_GNSS_Application_Note	The GNSS application note for EM1x0R-GL & EG512R_Series and EM121R-GL.

Table 53: Terms and Abbreviations

Abbreviation	Description
BIOS	Basic Input Output System
bps	Bit Per Second
BPSK	Binary Phase Shift Keying
CPE	Customer Premise Equipment
COEX	Coexistence
DFOTA	Delta Firmware Upgrade Over-The-Air
DL	Downlink
DPR	Dynamic Power Reduction
DRX	Discontinuous Reception
DRx	Diversity Receive

EIRP	Equivalent Isotropically Radiated Power
ESD	Electrostatic Discharge
FDD	Frequency Division Duplexing
GLONASS	Global Navigation Satellite System (Russia)
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GSM	Global System for Mobile Communications
HSPA	High Speed Packet Access
HSUPA	High Speed Uplink Packet Access
kbps	Kilo Bits Per Second
LAA	License Assisted Access
LED	Light Emitting Diode
LTE	Long Term Evolution
Mbps	Mega Bits Per Second
ME	Mobile Equipment
MIMO	Multiple-Input Multiple-Output
MLCC	Multiplayer Ceramic Chip Capacitor
MO	Mobile Originated
MSB	Most Significant Bit
MT	Mobile Terminated
PAP	Password Authentication Protocol
PCB	Printed Circuit Board
PCIe	Peripheral Component Interconnect Express
PCM	Pulse Code Modulation
PDU	Protocol Data Unit

PME	Power Management Event
PPP	Point-to-Point Protocol
QPSK	Quadrature Phase Shift Keying
RB	Resource Block
RF	Radio Frequency
RFFE	RF Front-End
R.H	Relative humidity
Rx	Receive
SAR	Specific Absorption Rate
SMS	Short Message Service
TCP	Transmission Control Protocol
TRx	Transmit & Receive
Tx	Transmit
UART	Universal Asynchronous Receiver & Transmitter
UDP	User Datagram Protocol
UL	Uplink
URC	Unsolicited Result Code
USB	Universal Serial Bus
(U)SIM	(Universal) Subscriber Identity Module
V_{IH}	Input High Voltage Level
V_{IL}	Input Low Voltage Level
V_{OH}	Output High Voltage Level
V_{OL}	Output Low Voltage Level
WCDMA	Wideband Code Division Multiple Access

OEM/Integrators Installation Manual

Important Notice to OEM integrators 1. This module is limited to OEM installation ONLY. 2. This module is limited to installation in mobile or fixed applications, according to Part 2.1091(b). 3. The separate approval is required for all other operating configurations, including portable configurations with respect to Part 2.1093 and different antenna configurations 4. For FCC Part 15.31 (h) and (k): The host manufacturer is responsible for additional testing to verify compliance as a composite system. When testing the host device for compliance with Part 15 Subpart B, the host manufacturer is required to show compliance with Part 15 Subpart B while the transmitter module(s) are installed and operating. The modules should be transmitting and the evaluation should confirm that the module's intentional emissions are compliant (i.e. fundamental and out of band emissions). The host manufacturer must verify that there are no additional unintentional emissions other than what is permitted in Part 15 Subpart B or emissions are complaint with the transmitter(s) rule(s). The Grantee will provide guidance to the host manufacturer for Part 15 B requirements if needed.

Important Note

notice that any deviation(s) from the defined parameters of the antenna trace, as described by the instructions, require that the host product manufacturer must notify to Quectel that they wish to change the antenna trace design. In this case, a Class II permissive change application is required to be filed by the USI, or the host manufacturer can take responsibility through the change in FCC ID (new application) procedure followed by a Class II permissive change application

End Product Labeling

When the module is installed in the host device, the FCC/IC ID label must be visible through a window on the final device or it must be visible when an access panel, door or cover is easily re-moved. If not, a second label must be placed on the outside of the final device that contains the following text: "Contains FCC ID: XMR2020EM120RGL" "Contains IC:10224A-2020EM120GL". The FCC ID/IC ID can be used only when all FCC/IC compliance requirements are met.

Antenna

- (1) The antenna must be installed such that 20 cm is maintained between the antenna and users,
- (2) The transmitter module may not be co-located with any other transmitter or antenna.

In the event that these conditions cannot be met (for example certain laptop configurations or co-location with another transmitter), then the FCC/IC authorization is no longer considered valid and the FCC ID/IC ID cannot be used on the final product. In these circumstances, the OEM integrator will be responsible for re-evaluating the end product (including the transmitter) and obtaining a separate FCC/IC authorization.

To comply with FCC regulations limiting both maximum RF output power and human exposure to RF radiation, maximum antenna gain (including cable loss) must not exceed

Test Mode	Antenna Gain (dBi)	Test Mode	Antenna Gain (dBi)
WCDMA B2	8.00	LTE B14	5.00
WCDMA B4	8.00	LTE B25	8.00
WCDMA B5	5.00	LTE B26	5.00
LTE B2	8.00	LTE B30*	5.00
LTE B4	8.00	LTE B38	8.00
LTE B5	5.00	LTE B41	6.50
LTE B7	8.00	LTE B48*	5.00
LTE B12	5.00	LTE B66	8.00
LTE B13	5.00		

Note: “*” means when using these maximum gain antenna, the host manufacturer should reduce the conducted power to meet the FCC maximum RF output power limit.

Manual Information to the End User

The OEM integrator has to be aware not to provide information to the end user regarding how to install or remove this RF module in the user’s manual of the end product which integrates this module. The end user manual shall include all required regulatory information/warning as show in this manual

Federal Communication Commission Interference Statement

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions:

(1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

Any changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate this equipment. This transmitter must not be co-located or operating in conjunction with any other antenna or transmitter.

List of applicable FCC rules

This module has been tested and found to comply with part 22, part 24, part 27, part 90 requirements for Modular Approval.

The modular transmitter is only FCC authorized for the specific rule parts (i.e., FCC transmitter rules) listed on the grant, and that the host product manufacturer is responsible for compliance to any other FCC rules that apply to the host not covered by the modular transmitter grant of certification. If the grantee markets their product as being Part 15 Subpart B compliant (when it also contains unintentional-radiator digital circuitry), then the grantee shall provide a notice stating that the final host product still requires Part 15 Subpart B compliance testing with the modular transmitter installed.

This device is intended only for OEM integrators under the following conditions: (For module device use)

- 1) The antenna must be installed such that 20 cm is maintained between the antenna and users, and
- 2) The transmitter module may not be co-located with any other transmitter or antenna.

As long as 2 conditions above are met, further transmitter test will not be required. However, the OEM integrator is still responsible for testing their end-product for any additional compliance requirements required with this module installed.

Radiation Exposure Statement

This equipment complies with FCC radiation exposure limits set forth for an uncontrolled environment. This equipment should be installed and operated with minimum distance 20 cm between the radiator & your body.

Industry Canada Statement

This device complies with Industry Canada's licence-exempt RSSs. Operation is subject to the following two conditions:

- (1) This device may not cause interference; and
- (2) This device must accept any interference, including interference that may cause undesired operation of the device.

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes:

- (1) l'appareil ne doit pas produire de brouillage, et
- (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement."

Radiation Exposure Statement

This equipment complies with IC radiation exposure limits set forth for an uncontrolled environment. This equipment should be installed and operated with minimum distance 20 cm between the radiator & your body

Déclaration d'exposition aux radiations:

Cet équipement est conforme aux limites d'exposition aux rayonnements ISED établies pour un environnement non contrôlé. Cet équipement doit être installé et utilisé avec un minimum de 20 cm de distance entre la source de rayonnement et votre corps.

This device is intended only for OEM integrators under the following conditions: (For module device use)

- 1) The antenna must be installed such that 20 cm is maintained between the antenna and users, and
- 2) The transmitter module may not be co-located with any other transmitter or antenna. As long as 2 conditions above are met, further transmitter test will not be required. However, the OEM integrator is still responsible for testing their end-product for any additional compliance requirements required with this module installed.

Cet appareil est conçu uniquement pour les intégrateurs OEM dans les conditions suivantes: (Pour utilisation de dispositif module)

- 1) L'antenne doit être installée de telle sorte qu'une distance de 20 cm est respectée entre l'antenne et les utilisateurs, et
- 2) Le module émetteur peut ne pas être coïmplanté avec un autre émetteur ou antenne.

Tant que les 2 conditions ci-dessus sont remplies, des essais supplémentaires sur l'émetteur ne seront pas nécessaires. Toutefois, l'intégrateur OEM est toujours responsable des essais sur son produit final pour toutes exigences de conformité supplémentaires requis pour ce module installé.

IMPORTANT NOTE:

In the event that these conditions cannot be met (for example certain laptop configurations or colocation with another transmitter), then the Canada authorization is no longer considered valid and the IC ID cannot be used on the final product. In these circumstances, the OEM integrator will be responsible for re-evaluating the end product (including the transmitter) and obtaining a separate Canada authorization.

NOTE IMPORTANTE:

Dans le cas où ces conditions ne peuvent être satisfaites (par exemple pour certaines configurations d'ordinateur portable ou de certaines co-localisation avec un autre émetteur), l'autorisation du Canada n'est plus considéré comme valide et l'ID IC ne peut pas être utilisé sur le produit final. Dans ces circonstances, l'intégrateur OEM sera chargé de réévaluer le produit final (y compris l'émetteur) et l'obtention d'une autorisation distincte au Canada.

End Product Labeling

This transmitter module is authorized only for use in device where the antenna may be installed such that 20 cm may be maintained between the antenna and users. The final end product must be labeled in a visible area with the following: "Contains IC: 10224A-2020EM120GL".

Plaque signalétique du produit final

Ce module émetteur est autorisé uniquement pour une utilisation dans un dispositif où l'antenne peut être installée de telle sorte qu'une distance de 20cm peut être maintenue entre l'antenne et les utilisateurs. Le produit final doit être étiqueté dans un endroit visible avec l'inscription suivante: "Contient des IC: 10224A-2020EM120GL".

Manual Information to the End User

The OEM integrator has to be aware not to provide information to the end user regarding how to install or remove this RF module in the user's manual of the end product which integrates this module.

The end user manual shall include all required regulatory information/warning as show in this manual.

Manuel d'information à l'utilisateur final

L'intégrateur OEM doit être conscient de ne pas fournir des informations à l'utilisateur final quant à la façon d'installer ou de supprimer ce module RF dans le manuel de l'utilisateur du produit final qui intègre ce module.

Le manuel de l'utilisateur final doit inclure toutes les informations réglementaires requises et avertissements comme indiqué dans ce manuel.