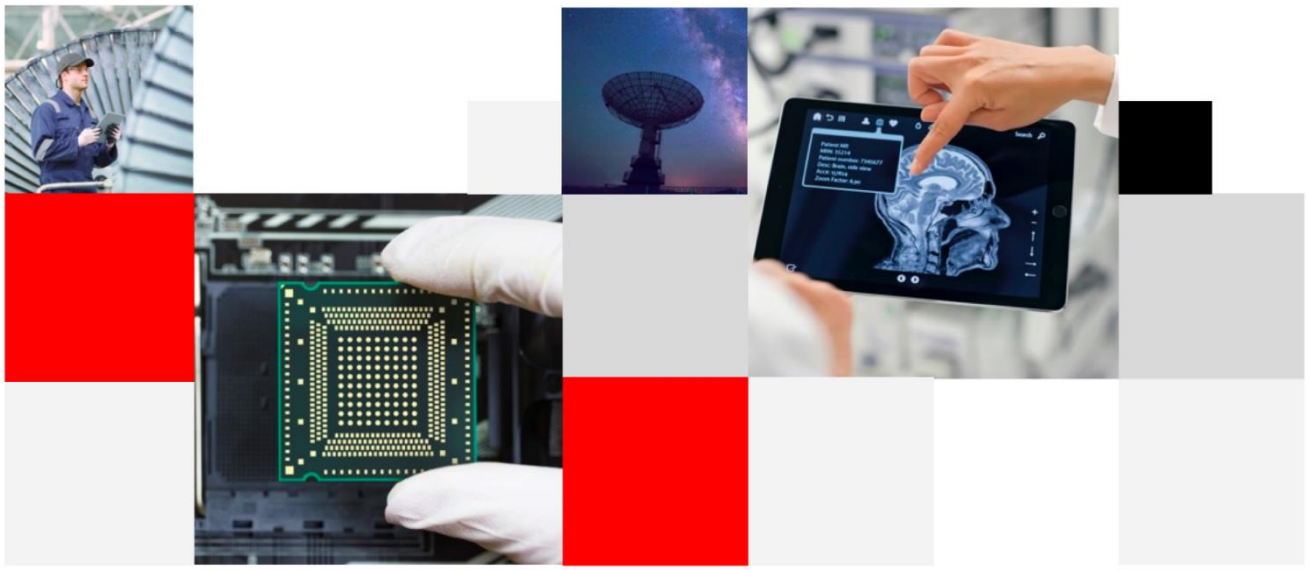
EM05-G Hardware Design

LTE Standard Module Series

Version: 1.0.0

Date: 2021-03-19

Status: Preliminary



Build a Smarter World

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 200233, China
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.

For technical support, or to report documentation errors, please visit:
http://www.quectel.com/support/technical.htm
Or email to support@quectel.com.

General Notes

Quectel offers the information as a service to its customers. The information provided is based upon customers' requirements. Quectel makes every effort to ensure the quality of the information it makes available. Quectel does not make any warranty as to the information contained herein, and does not accept any liability for any injury, loss or damage of any kind incurred by use of or reliance upon the information. All information supplied herein is subject to change without prior notice.

Disclaimer

While Quectel has made efforts to ensure that the functions and features under development are free from errors, it is possible that these functions and features could contain errors, inaccuracies and omissions. Unless otherwise provided by valid agreement, Quectel makes no warranties of any kind, implied or express, with respect to the use of features and functions under development. To the maximum extent permitted by law, Quectel excludes all liability for any loss or damage suffered in connection with the use of the functions and features under development, regardless of whether such loss or damage may have been foreseeable.

Duty of Confidentiality

The Receiving Party shall keep confidential all documentation and information provided by Quectel, except when the specific permission has been granted by Quectel. The Receiving Party shall not access or use Quectel's documentation and information for any purpose except as expressly provided herein. Furthermore, the Receiving Party shall not disclose any of the Quectel's documentation and information to any third party without the prior written consent by Quectel. For any noncompliance to the above requirements, unauthorized use, or other illegal or malicious use of the documentation and information, Quectel will reserve the right to take legal action.

Copyright

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 transceiver. When it is ON, it receives and transmits radio frequency signals. RF interference can occur if it is used close to TV sets, radios, computers or other electric equipment.
	In locations with explosive or potentially explosive atmospheres, obey all posted signs and turn off wireless devices such as mobile phone or other cellular terminals. Areas with explosive or potentially explosive atmospheres include fuelling areas, below decks on boats, fuel or chemical transfer or storage facilities, and areas where the air contains chemicals or particles such as grain, dust or metal powders.

About the Document

Revision History

Version	Date	Author	Description
-	2021-03-17	Juriyi XIE/ Ethan SHAN	Creation of the document
1.0.0	2021-03-19	Juriyi XIE/ Ethan SHAN	Preliminary

Contents

Table Index

Figure Index

1 Introduction

This document defines EM05-G module and describes its air interface and hardware interfaces which are connected with customers' applications.

This document can help customers to quickly understand the interface specifications, electrical and mechanical details, as well as other related information of EM05-G module. To facilitate its application in different fields, reference design is also provided for customers' reference. Associated with application note and user guide, customers can use the module to design and set up mobile applications easily.

Hereby, [Quectel Wireless Solutions Co., Ltd.] declares that the radio equipment type [EM05-G] is in compliance with Directive 2014/53/EU.

The full text of the EU declaration of conformity is available at the following internet address: http://www.quectel.com

The device could be used with a separation distance of 20cm to the human body.

equipment with this declaration and bearing the UKCA

[EM05-G] is in compliance with UK Radio Equipment Regulations 2017.
The full text of the UK declaration of conformity is available at the following interent address: http://www.quectel.com

FCC Certification Requirements.
According to the definition of mobile and fixed device is described in Part 2.1091(b), this device is a mobile device.

And the following conditions must be met:

1. This Modular Approval is limited to OEM installation for mobile and fixed applications only. The antenna installation and operating configurations of this transmitter, including any applicable source-based timeaveraging duty factor, antenna gain and cable loss must satisfy MPE categorical Exclusion Requirements of 2.1091.
2. The EUT is a mobile device; maintain at least a 20 cm separation between the EUT and the user's body and must not transmit simultaneously with any other antenna or transmitter.
3. A label with the following statements must be attached to the host end product: This device contains FCC ID: XMR2021EM05G
4. 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:

radiation, maximum antenna gain (including cable loss) must not exceed: Operating Band	FCC Max Antenna Gain（dBi）	IC Max Antenna Gain（dBi）
WCDMA BAND II	7.5	7.5
WCDMA BAND IV	4.5	4.5
WCDMA BAND V	8.92	7.76
LTE BAND 2	7.5	7.5
LTE BAND 4	4.5	4.5
LTE BAND 5	8.91	7.75
LTE BAND 7	7.5	7.5
LTE BAND 12	8.2	7.26
LTE BAND 13	8.66	7.56
LTE BAND 14	8.73	7.63
LTE BAND 25	7.5	7.5
LTE BAND 26(814-824)	8.91	NA
LTE BAND 26(824-849)	8.91	7.75
LTE BAND 38	7.5	7.5
LTE BAND 41	7.5	7.5
LTE BAND 66	4.5	4.5
LTE BAND 71	7.98	7.12

5. This module must not transmit simultaneously with any other antenna or transmitter
6. The host end product must include a user manual that clearly defines operating requirements and conditions that must be observed to ensure compliance with current FCC RF exposure guidelines.

For portable devices, in addition to the conditions 3 through 6 described above, a separate approval is required to satisfy the SAR requirements of FCC Part 2.1093

If the device is used for other equipment that separate approval is required for all other operating configurations, including portable configurations with respect to 2.1093 and different antenna configurations.

For this device, OEM integrators must be provided with labeling instructions of finished products.

Please refer to KDB784748 D01 v07, section 8. Page 6/7 last two paragraphs:

A certified modular has the option to use a permanently affixed label, or an electronic label. For a permanently affixed label, the module must be labeled with an FCC ID - Section 2.926 (see 2.2

Certification (labeling requirements) above). The OEM manual must provide clear instructions explaining to the OEM the labeling requirements, options and OEM user manual instructions that are required (see next paragraph).

For a host using a certified modular with a standard fixed label, if (1) the module's FCC ID is not visible when installed in the host, or (2) if the host is marketed so that end users do not have straightforward commonly used methods for access to remove the module so that the FCC ID of the module is visible; then an additional permanent label referring to the enclosed module: "Contains Transmitter Module FCC ID: XMR2021EM05G" or "Contains FCC ID: 10224A-2021EM05G" must be used. The host OEM user manual must also contain clear instructions on how end users can find and/or access the module and the FCC ID.

The final host / module combination may also need to be evaluated against the FCC Part 15B criteria for unintentional radiators in order to be properly authorized for operation as a Part 15 digital device.

The user's manual or instruction manual for an intentional or unintentional radiator shall caution the user that changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment. In cases where the manual is provided only in a form other than paper, such as on a computer disk or over the Internet, the information required by this section may be included in the manual in that alternative form, provided the user can reasonably be expected to have the capability to access information in that form.

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.

Changes or modifications not expressly approved by the manufacturer could void the user's authority to operate the equipment.

To ensure compliance with all non-transmitter functions the host manufacturer is responsible for ensuring compliance with the module(s) installed and fully operational. For example, if a host was previously authorized as an unintentional radiator under the Supplier's Declaration of Conformity procedure without a transmitter certified module and a module is added, the host manufacturer is responsible for ensuring that the after the module is installed and operational the host continues to be compliant with the Part 15B unintentional radiator requirements.

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.

IC Statement

RSS-GEN "This device complies with Industry Canada's license-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. " or "This device complies with Industry Canada RSSs applicable to license-exempt radio apparatus. Operation is permitted under the following two conditions: 1) the device must not produce interference; 2) The user of the device must accept any RFI, even if the interference could affect its operation. " RF Radiation Exposure Statement The other used for the transmitter should be installed to provide a separation distance of at least 20cm from all people and should not be co-located or work in conjunction with another antenna or transmitter. The host product shall be properly labeled to identify the modules within the host product. The Innovation, Science and Economic Development Canada certification label of a module shall

be clearly visible at all times when installed in the host product; otherwise, the host product must be labeled to display the Innovation, Science and Economic Development Canada certification number for the module, preceded by the word “Contains” or similar wording expressing the same meaning, as follows: “Contains IC: 10224A-2021EM05G” or “where: 10224A-2021EM05G is the module’s certification number”. The host product must be properly labeled to identify the modules in the host product. The Innovation, Science and Economic Development Canada certification label for a module must be clearly visible at all times when it is installed in the host product; otherwise, the host product must be labeled with the Innovation, Science and Economic Development Canada certification number for the module, preceded by the word “Contains” or similar wording with the same meaning, as follows: "Contains IC: 10224A-2021EM05G" or "where: 10224A-2021EM05G is the certification number of the module".

1.1. Reference Standard

The module complies with the following standards:

- *PCI Express M.2 Specification Revision 3.0, Version 1.2*
- *PCI Express Base Specification Revision 3.0*
- *Universal Serial Bus 3.1 Specification*
- *ISO/IEC 7816-3*
- *MIPI Alliance Specification for RF Front-End Control Interface Version 2.0*
- *3GPP TS 27.007* and *3GPP TS 27.005*

1.2. Special Marks

Table 1: Special Marks

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 pins 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

EM05-G is a series of LTE/UMTS/HSPA+ wireless communication module with receive diversity. It provides data connectivity on LTE-FDD, LTE-TDD, DC-HSDPA, HSPA+, HSDPA, HSUPA, WCDMA networks. They are standard M.2 Key-B WWAN modules. For more details, see ***document [1]***.

They support embedded operating systems such as Windows, Linux and Android, and also provide GNSS [1)] to meet specific application demands.

The following table shows the frequency bands of EM05-G module.

Table 2: Frequency Bands and GNSS Systems of EM05-G Module

Mode	EM05-G
LTE-FDD	B1/B2/B3/B4/B5/B7/B8/B12/B13/B14/B18/B19/B20/B25/B26/B28/B66/B71
LTE-TDD	B38/B39/B40/B41
WCDMA	B1/B2/B4/B5/B6/B8/B19
CDMA	/
Rx-diversity	Supported
GNSS [1)]	GPS, GLONASS, BeiDou (COMPASS), Galileo, QZSS

EM05-G can be applied in the following fields:

- Rugged tablet PC and laptop computer
- Remote monitor system
- Handheld mobile device
- Wireless POS system
- Smart metering system
- Other wireless terminal devices

NOTE

[1] GNSS function is optional.

2.2. Key Features

The following table describes the detailed features of EM05-G.

Table 3: Key Features of EM05-G

Feature	Details
Function Interface	PCI Express M.2 Standard Interface
Power Supply	● Supply voltage: 3.135–4.4 V ● Typical supply voltage: 3.3 V
Transmitting Power	● Class 3 (24 dBm +1.5/-3 dB) for WCDMA bands ● Class 3 (24 dBm +1.5/-3 dB) for LTE-FDD bands ● Class 3 (24 dBm +1.5/-3 dB) for LTE-TDD bands
LTE Features	● Support up to non-CA Cat 4 ● Support 1.4/3/5/10/15/20 MHz RF bandwidth ● Support MIMO in DL direction ● FDD: Max. 150 Mbps (DL), Max. 50 Mbps (UL) ● TDD: Max. 130 Mbps (DL), Max. 30 Mbps (UL)
UMTS Features	● Support 3GPP Rel-8 DC-HSDPA, HSPA+, HSDPA, HSUPA and WCDMA ● Support QPSK, 16QAM and 64QAM modulation ● Max. transmission data rates: - DC-HSDPA: 42 Mbps (DL) - HSUPA: 5.76 Mbps (UL) - WCDMA: 384 kbps (DL), 384 kbps (UL)
Internet Protocol Features	● Support Internet service protocols: TCP/UDP/PPP/FTP/HTTP/NTP/PING/QMI/NITZ/CMUX/HTTPS/SMTP/MMS/FTPS/SMTPS/SSL ● Support PAP and CHAP protocols for PPP connection
SMS	● Text and PDU mode ● Point-to-point MO and MT ● SMS cell broadcast ● SMS storage: ME by default

(U)SIM Interface	● Support (U)SIM card: 1.8/3.0 V ● Compliant with *ISO/IEC 7816-3*
USB Interface	● Compliant with USB 2.0 specification (slave only), the data transfer rate can reach up to 480 Mbps ● Used for AT command communication, data transmission, GNSS NMEA output, software debugging and firmware upgrade ● Support USB serial drivers for Windows 7/8/8.1/10, Linux 2.6–5.10, Android 4.x–10.x
Antenna Interface	● Main antenna (ANT_MAIN) ● Rx-diversity antenna/GNSS antenna (ANT_DRX/ANT_GNSS)
Rx-diversity	Support LTE/WCDMA Rx-diversity
GNSS Features	● Protocol: NMEA 0183 ● Data update rate: 1 Hz
AT Commands	● Compliant with 3GPP TS 27.007, *3GPP TS 27.005* ● Quectel enhanced AT commands
Physical Characteristics	● M.2 Key-B ● Size: (42 ±0.15) mm × (30 ±0.15) mm × (2.3 ±0.2) mm ● Weight: approx. 6.0 g
Temperature Range	● Operating temperature range: -30 °C to +70 °C [1)] ● Extended temperature range: -40 °C to +85 °C [2)] ● Storage temperature range: -40 °C to +90 °C
Firmware Upgrade	● USB interface ● DFOTA
RoHS	All hardware components are fully compliant with EU RoHS directive

NOTES

1. [1)] Within operating temperature range, the module is 3GPP compliant.
2. [2)] Within extended temperature range, the module remains the ability to establish and maintain SMS, data transmission, etc. There is no unrecoverable malfunction. There are also no effects on radio spectrum and no harm to radio network. Only one or more parameters like P_{out} might reduce in their value and exceed the specified tolerances. When the temperature returns to normal operating temperature levels, the module will meet 3GPP specifications again.

2.3. Functional Diagram

The following figure shows a block diagram of EM05-G.

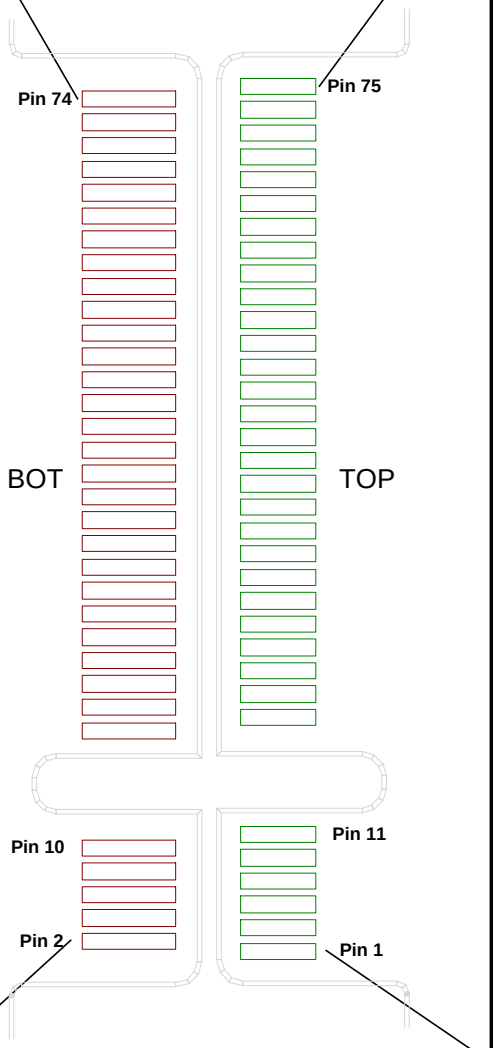
- Power management
- Baseband
- LPDDR2 SDRAM + NAND Flash
- Radio frequency
- M.2 Key-B interface

Figure 1: Functional Diagram

2.4. Pin Assignment

The following figure shows the pin assignment of EM05-G. The top side contains two antenna connectors.

No.	Pin Name
74	VCC
72	VCC
70	VCC
68	ANT_CONFIG
66	USIM1_DET
64	COEX_TXD
62	COEX_RXD
60	WLAN_PA_EN
58	RFFE_DATA
56	RFFE_CLK
54	NC
52	NC
50	NC
48	USIM2_VDD
46	USIM2_RST
44	USIM2_CLK
42	USIM2_DATA
40	USIM2_DET
38	NC
36	USIM1_VDD
34	USIM1_DATA
32	USIM1_CLK
30	USIM1_RST
28	PCM_SYNC
26	W_DISABLE2#
24	PCM_DOUT/VDDIO
22	PCM_DIN
20	PCM_CLK
	Notch
	Notch
	Notch
	Notch
10	WWAN_LED#
8	W_DISABLE1#
6	FULL_CARD_POWER_OFF#
4	VCC
2	VCC



Pin Name	No.
CONFIG_2	75
GND	73
GND	71
CONFIG_1	69
RESET#	67
ANTCTL3	65
ANTCTL2	63
ANTCTL1	61
ANTCTL0	59
GND	57
NC	55
NC	53
GND	51
NC	49
NC	47
GND	45
NC	43
NC	41
GND	39
NC	37
NC	35
GND	33
NC	31
NC	29
GND	27
DPR	25
WOWWAN#	23
CONFIG_0	21
Notch	
Notch	
Notch	
Notch	
GND	11
USB_DM	9
USB_DP	7
GND	5
GND	3
CONFIG_3	1

Figure 2: Pin Assignment

2.5. Pin Description

The following tables show the pin definition and description of EM05-G.

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

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 = 3.3 V Vmax = 4.4 V	
3	GND		Ground		
4	VCC	PI	Power supply	Vmin = 3.135 V Vnom = 3.3 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_{IH}max = 4.4 V V_{IH}min = 1.19 V V_{IL}max = 0.2 V V_{IL}min = -0.3 V	Internally pulled down with a 100 kΩ resistor.

7	USB_DP	AIO	USB 2.0 differential data (+)	
8	W_DISABLE1#	DI, OD	Airplane mode control. Active LOW.	1.8/3.3 V
9	USB_DM	AIO	USB 2.0 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	Connected to GND internally.	
22	PCM_DIN*	DI, PD	PCM data input	1.8 V
23	WOWWAN#	DO, OD	Wake up the host. Active LOW.	1.8/3.3 V
24	PCM_DOUT*/ VDD_IO [1)]	DO, PD/PO	PCM data output/Antenna tuner supply power.	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	NC		NC	
30	USIM1_RST	DO, PD	(U)SIM1 card reset	USIM1_VDD 1.8/3.0 V

31	NC		NC	
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	NC		NC	
36	USIM1_VDD	PO	(U)SIM1 card power supply	1.8/3.0 V
37	NC		NC	
38	NC		NC	
39	GND		Ground	
40	USIM2_DET	DI, PU	(U)SIM2 card hot-plug detect	1.8 V
41	NC		NC	
42	USIM2_DATA	DIO, PU	(U)SIM2 card data	USIM2_VDD 1.8/3.0 V
43	NC		NC	
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	NC		NC	
48	USIM2_VDD	PO	(U)SIM2 card power supply	1.8/3.0 V
49	NC		NC	
50	NC		NC	
51	GND		Ground	
52	NC		NC	
53	NC		NC	
54	NC		NC	

55	NC		NC	
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	Notification from WLAN to SDR while transmitting	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
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
68	ANT_CONFIG	DI, PU	Antenna configuration	1.8 V
69	CONFIG_1	DO	Connected to GND internally.	
70	VCC	PI	Power supply	Vmin = 3.135 V Vnom = 3.3 V Vmax = 4.4 V
71	GND		Ground	
72	VCC	PI	Power supply	Vmin = 3.135 V Vnom = 3.3 V Vmax = 4.4 V
73	GND		Ground	
74	VCC	PI	Power supply	Vmin = 3.135 V Vnom = 3.3 V Vmax = 4.4 V
75	CONFIG_2	DO	Not connected internally	

NOTES

1. The typical supply voltage of VCC is 3.3 V.
2. Keep all NC and unused pins open.
3. EM05-G does not support I2C interface.
4. [1] Pin function can be selected according to the actual situation.
5. [2] If this function is required, please contact Quectel for more details.

2.6. Evaluation Board

To help you develop applications conveniently with EM05-G, Quectel supplies an evaluation board (M.2 EVB), two USB type-C cables, antennas and other peripherals to control or test the module. For more details, see ***document [2]***.

3 Operating Characteristics

3.1. Operating Modes

The table below briefly summarizes the various operating modes referred in the following chapters.

Table 6: Overview of Operating Modes

Mode	Details	
Normal Operation Mode	Idle	Software is active. The module has registered to 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.
Airplane Mode	**AT+CFUN=4** or driving W_DISABLE1# pin low will set the module to airplane mode. In this mode, the RF function is invalid.	
Minimum Functionality Mode	**AT+CFUN=0** 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.	
Sleep Mode	The module keeps receiving paging messages, SMS, 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.	

3.2. Power Saving

3.2.1. Sleep Mode

DRX of the module is able to reduce the current consumption to a minimum value during the sleep mode, 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. The following section describes the power saving procedure of EM05-G module.

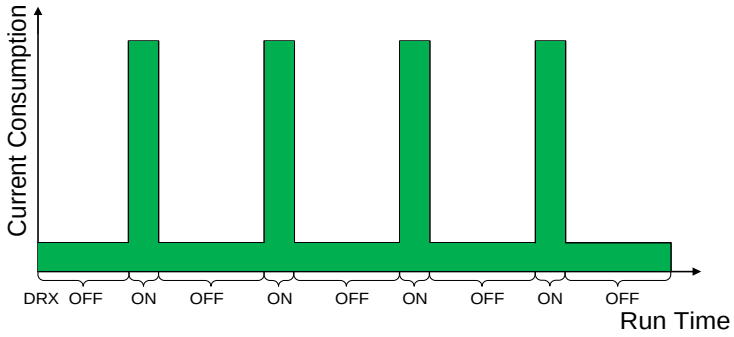


Figure 3: DRX Run Time and Current Consumption in Sleep Mode

3.2.1.1. USB Application with USB Remote Wakeup Function

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+QSCLK=1** 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.

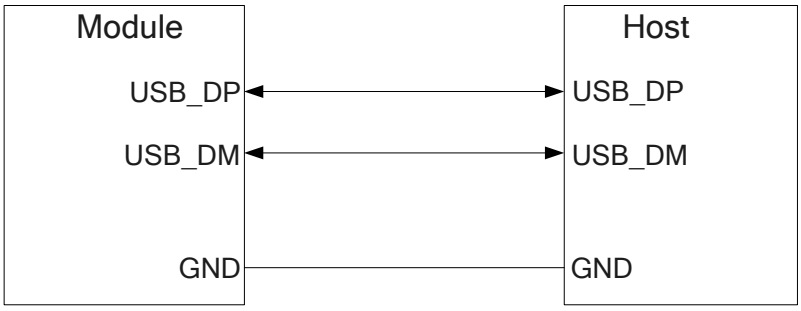


Figure 4: Sleep Mode Application with USB Remote Wakeup

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

- Sending data to EM05-G via USB will wake up the module.
- When EM05-G has a URC to report, the module will send remote wake-up signals via USB bus to wake up the host.

3.2.1.2. USB Application with USB Suspend/Resume and WOWWAN# Functions

If the host supports USB suspend/resume but does not support remote wake-up function, the WOWWAN# signal is used to wake up the host.

There are two preconditions to let the module enter sleep mode.

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

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

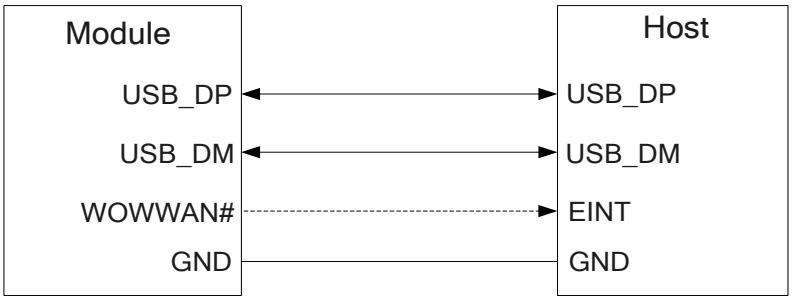


Figure 5: Sleep Mode Application with WOWWAN#

- Sending data to EM05-G via USB will wake up the module.
- When EM05-G has a URC to report, WOWWAN# signal will wake up the host.

3.2.2. Airplane Mode

When the module enters airplane mode, RF function does not work, and all AT commands correlative with RF function will be inaccessible. This mode can be set via the following ways.

Hardware:

The W_DISABLE1# pin is pulled up by default; driving it to low level will let the module enter airplane mode.

Software:

AT+CFUN provides the following choices of the functionality level.

- **AT+CFUN=0:** Minimum functionality mode; both (U)SIM and RF functions are disabled.
- **AT+CFUN=1:** Full functionality mode (by default).
- **AT+CFUN=4:** Airplane mode. RF function is disabled.

For details of related AT commands, see ***document [3]***.

NOTES

1. The W_DISABLE1# control function is disabled in firmware by default. It can be enabled by **AT+QCFG="airplanecontrol",1.**
2. Execution of **AT+CFUN** will not affect GNSS function.

3.3. Power Supply

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

Table 7: Definition of VCC and GND Pins

Pin No.	Pin Name	I/O	Description	Power Domain
2, 4, 70, 72, 74	VCC	PI	Power supply	3.135–4.4 V 3.3 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.

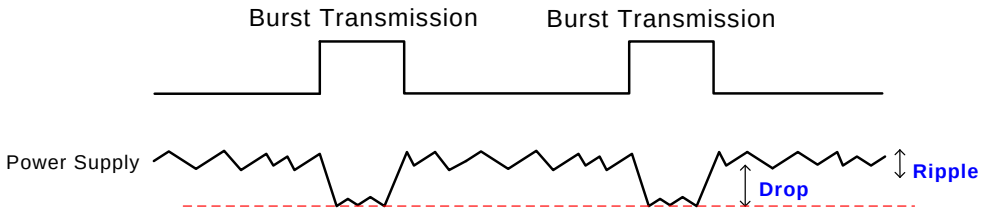


Figure 6: Power Supply Limits during Radio Transmission

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 (ESR = 0.7 Ω) 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, 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.

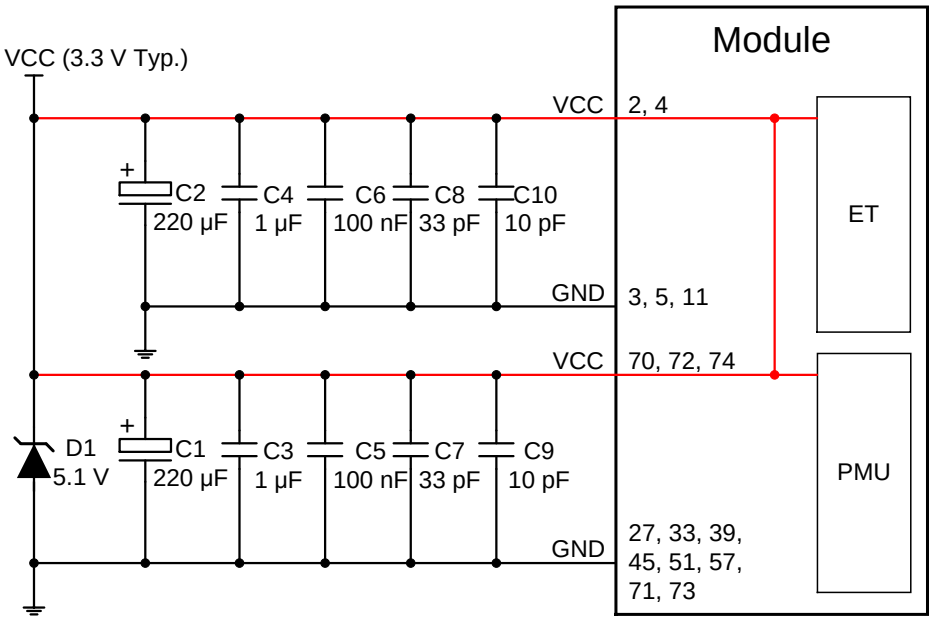


Figure 7: Reference Circuit for the VCC

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. The power supply of the module should be able to provide a sufficient current of 2.0 A at least. If the voltage drop between the input and output is not too high, it is suggested that an LDO should be used to supply power for the module. If there is a big voltage difference between the input source and the desired output (VCC = 3.3 V Typ.), a buck converter is preferred to be used as the power supply.

The following figure shows a reference design for +5 V input power source. The typical output of the power supply is about 3.3 V and the maximum load current is 2.0 A.

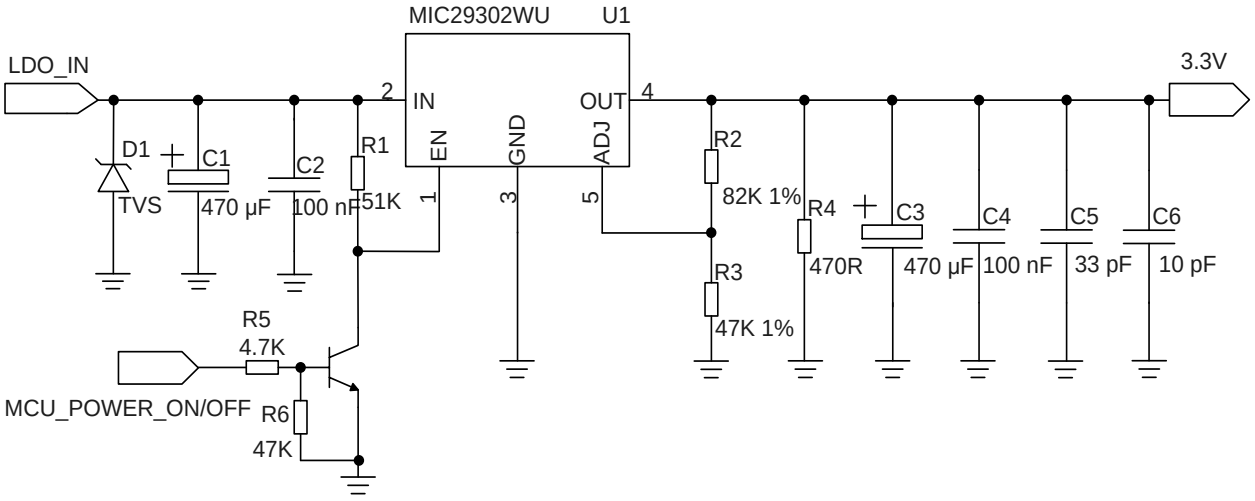


Figure 8: Reference Circuit for the Power Supply

NOTE

To avoid damaging internal flash, do not switch off the power supply when the module is working normally. It is suggested that the power supply should be cut off after pulling down RESET# for about 100 ms.

3.3.3. Monitor the Power Supply

AT+CBC can be used to monitor the voltage value of VCC. For more details, see ***document [3]***.

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 turn on.

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 kΩ resistor.

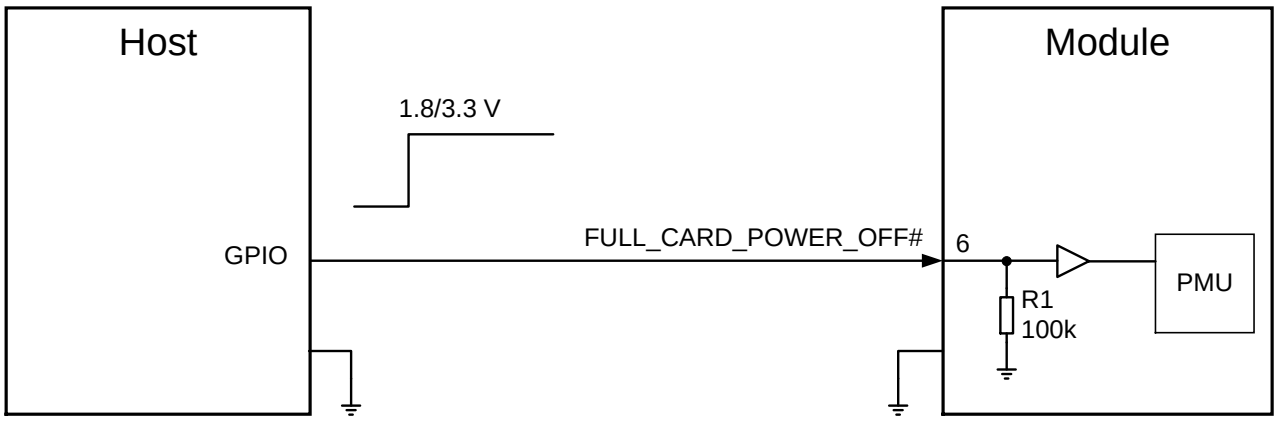
The following table shows the definition of FULL_CARD_POWER_OFF#.

Table 8: 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_{IH}max = 4.4 V V_{IH}min = 1.19 V V_{IL}max = 0.2 V V_{IL}min = -0.3 V	Pull down with a 100 kΩ resistor.

EM05-G can be turned on by driving the FULL_CARD_POWER_OFF# pin to a high level.

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 9: Turn on the Module with a Host GPIO

The module can also be turned on automatically. The FULL_CARD_POWER_OFF# should be pulled up to 1.8 V or 3.3 V (recommended) through a resistor, whose resistance should be 5–10 kΩ. In this case, when the power supply of VCC is cut off, the module will be shut down.

A reference circuit is shown in the following figure.

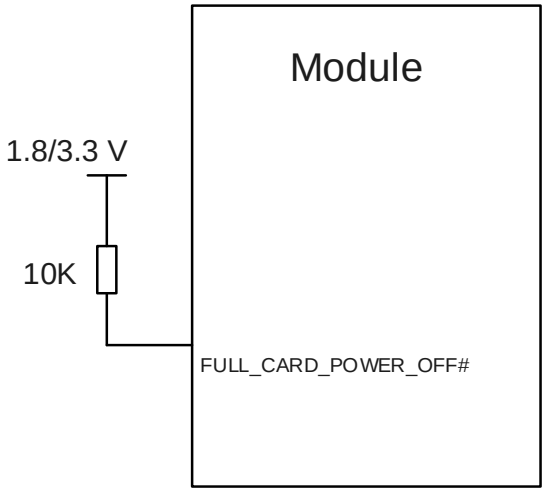


Figure 10: Turn on the Module Automatically

The timing of turning on the module is illustrated in the following figure.

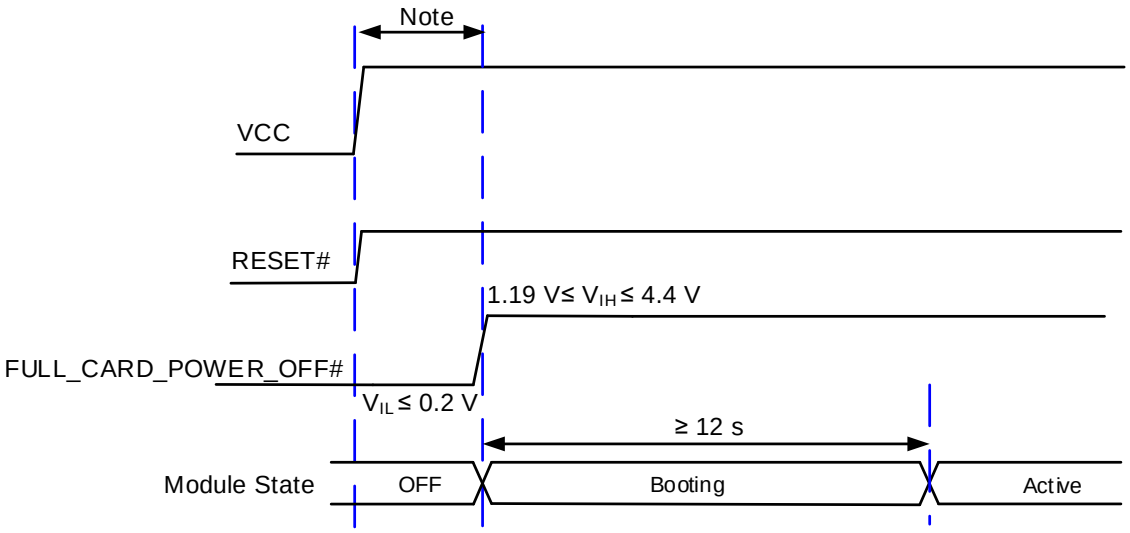


Figure 11: Timing of Turning on Module

NOTE

Make sure that VCC is stable before pulling up FULL_CARD_POWER_OFF# pin. The time between them is no less than 30 ms.

3.5. Turn off

The following procedures can be applied to turn off the module normally:

- Hardware shutdown: Turn off the module using the FULL_CARD_POWER_OFF# pin.
- Software shutdown: Turn off the module using **AT+QPOWD**.

3.5.1. Turn off the Module Through FULL_CARD_POWER_OFF#

Driving the FULL_CARD_POWER_OFF# pin to low, the supply of PMIC will be powered off, then the module will be forced to shut down. But it is recommended to pull down RESET# for about 100 ms before driving the FULL_CARD_POWER_OFF# pin to low to avoid damage to the internal flash.

The timing of turning off the module via FULL_CARD_POWER_OFF# is illustrated in the following figure.

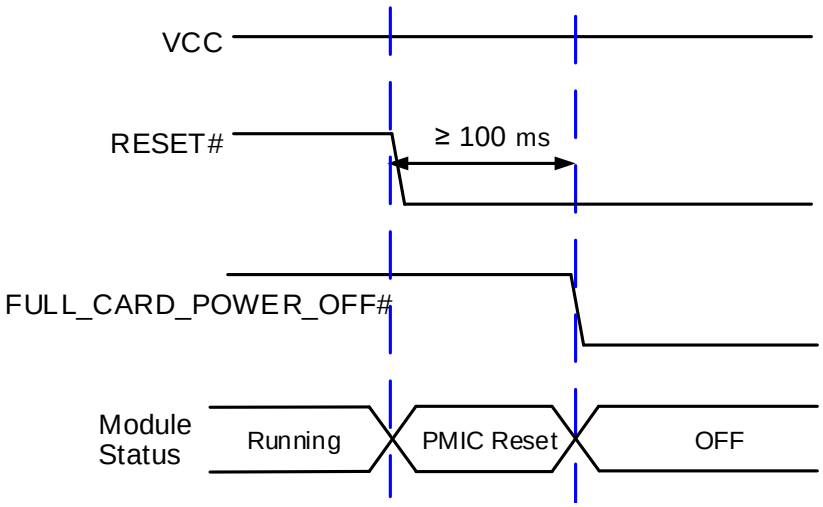


Figure 10: Turn-off Timing Through FULL_CARD_POWER_OFF#

3.5.2. Turn off the Module Through AT Command

It is also a safe method to turn off the module by **AT+QPOWD**. Pull down FULL_CARD_POWER_OFF# pin, or cut off power supply of VCC after the module is shut down, otherwise the module will be powered on again.

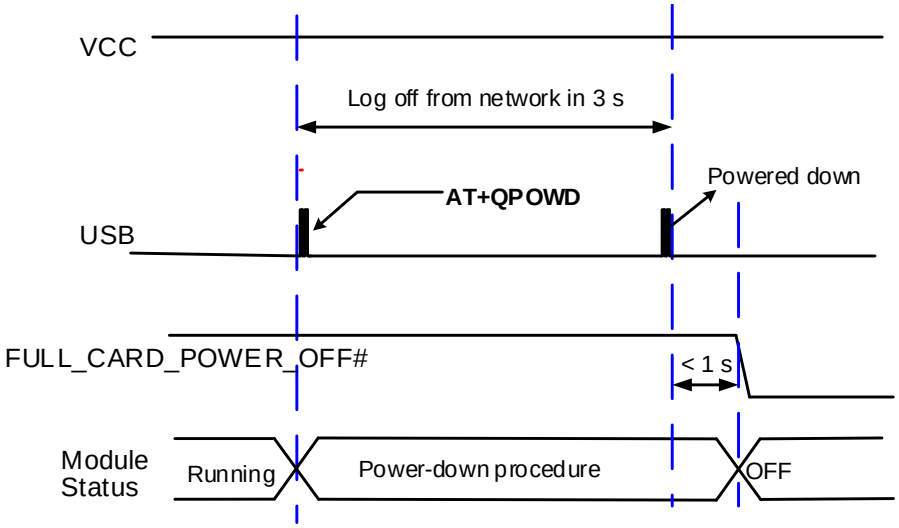


Figure 11: Turn-off Timing Through AT Command

During power-down procedure, the module will log off from network and save important data. After the module logs off, it sends URC "POWERED DOWN" and shuts down the internal power supply. If the "POWERED DOWN" URC is outputted, the power on VCC pins can be cut off.

3.6. Reset the Module

RESET# is an asynchronous and active LOW signal (1.8 V logic level). Whenever this pin is active, the module will immediately enter Power On Reset (POR) condition.

Please note that triggering the RESET# will lead to loss of all data in the modem and removal of system drivers. It will also disconnect the modem from the network.

Table 9: Definition of RESET# Pin

Pin No.	Pin Name	I/O	Description	DC Characteristic	Comment
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	

The module can enter reset state by driving RESET# low for 150–460 ms. An open collector/drain driver or button can be used to control the RESET# pin.

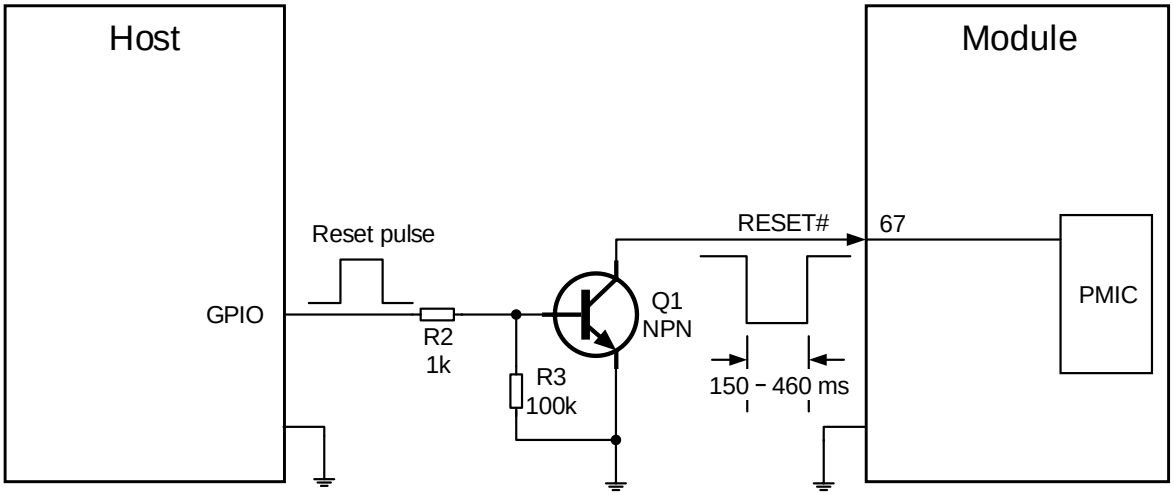
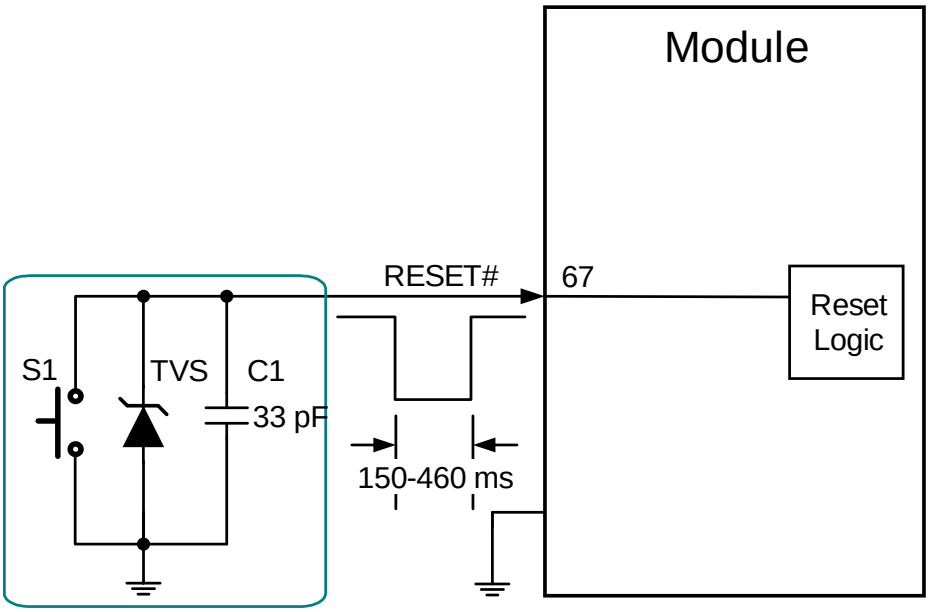


Figure 12: Reference Circuit of RESET# with NPN Driver Circuit



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

Figure 13: Reference Circuit of RESET# by Using Button

The reset timing is illustrated by the following figure.

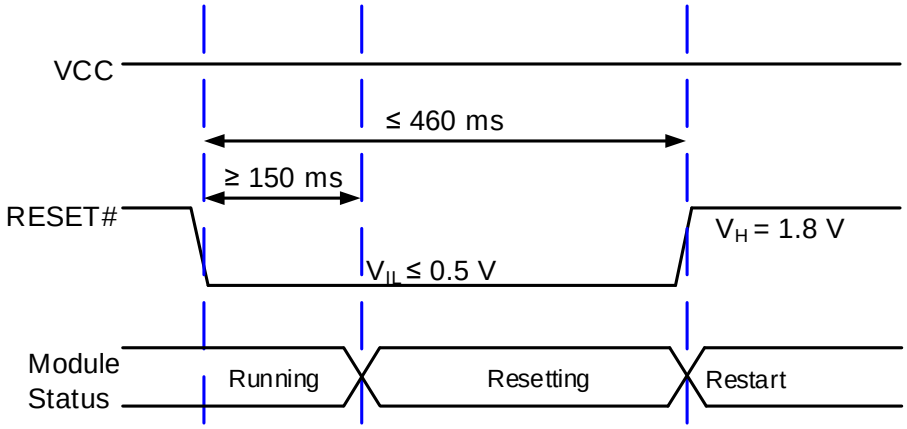


Figure 14: Reset Timing of the Module

NOTE

Ensure that there is no large capacitance on RESET# pin.

4 Application Interfaces

The physical connections and signal levels of EM05-G comply with PCI Express M.2 specifications. This chapter mainly describes the definition and application of the following interfaces of EM05-G:

- (U)SIM interface
- USB 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 interfaces circuitry meets ETSI and IMT-2000 requirements. Both Class B (3.0 V) and Class C (1.8 V) (U)SIM cards are supported.

4.1.1. Pin Definition of (U)SIM

Table 10: Pin Definition of (U)SIM Interfaces

Pin No.	Pin Name	I/O	Description	DC Characteristics
36	USIM1_VDD	PO	Power supply for (U)SIM1 card	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 [1)]	DI, PU	(U)SIM1 card hot-plug detect.	1.8 V
48	USIM2_VDD	PO	Power supply for (U)SIM2 card	USIM2_VDD 1.8/3.0 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
40	USIM2_DET [1)]	DI, PU	(U)SIM2 card hot-plug detect	1.8 V

NOTE

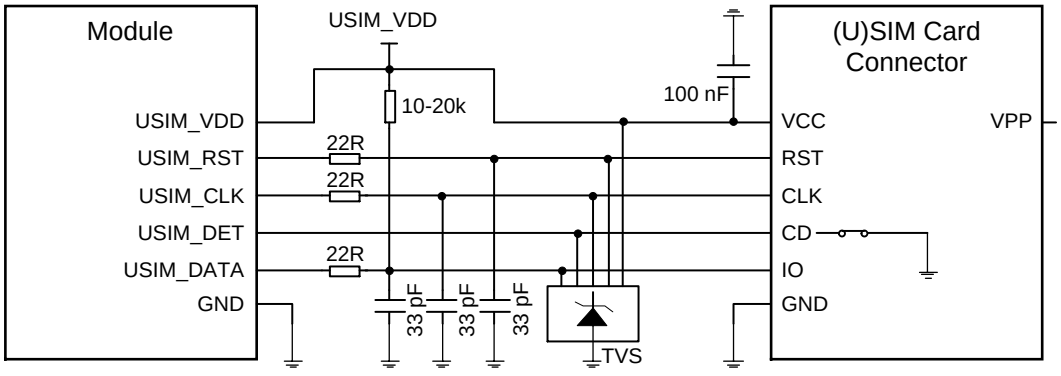
[1)] This pin is pulled LOW by default, and will be internally pulled up to 1.8 V by software configuration only when (U)SIM hot-plug is enabled by **AT+QSIMDET**.

4.1.2. Normally Closed (U)SIM Card Connector

With a normally closed (U)SIM card connector, USIM_DET pin is shorted to ground when there is no (U)SIM card 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 shorted to ground and USIM_DET is at low level.
- When the (U)SIM is present, CD is open from ground and USIM_DET is at high level.

The following figure shows a reference design for (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.

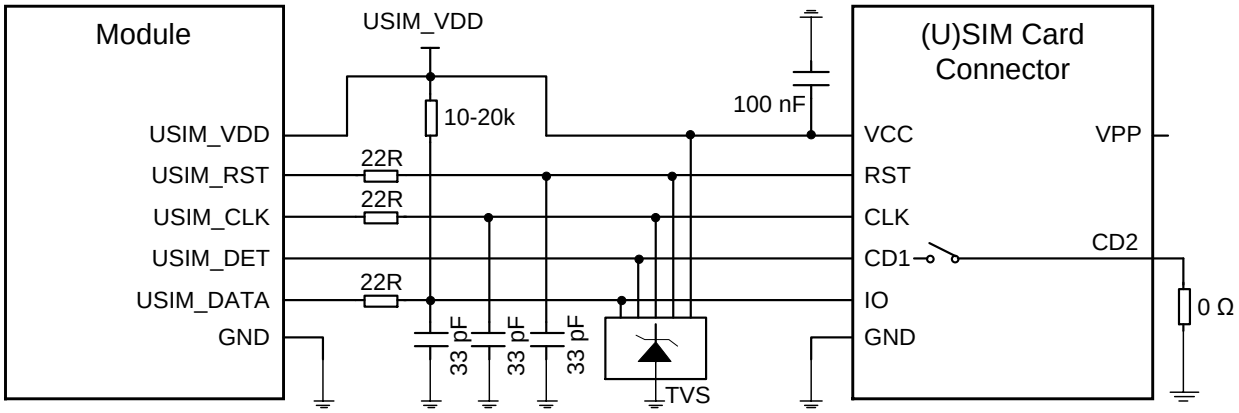
Figure 15: Reference Circuit for Normally Closed (U)SIM Card Connector

4.1.3. 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 level.
- When the (U)SIM is present, CD1 is pull down to ground and USIM_DET is at low level.

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

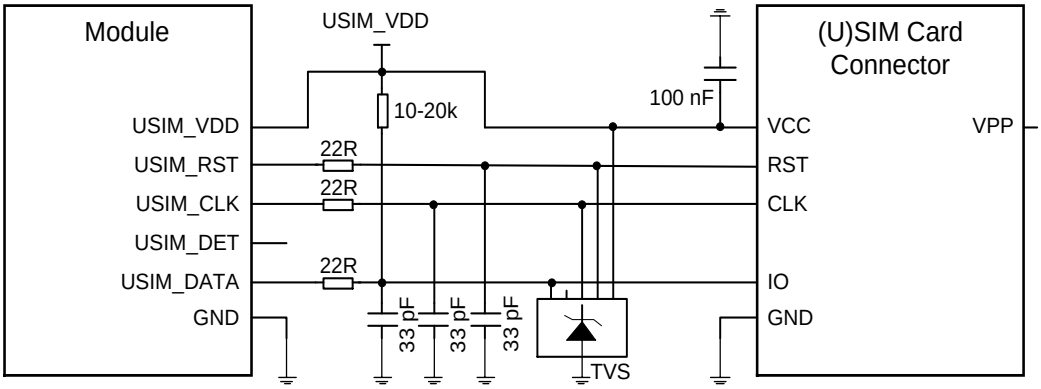


NOTE:
All these resistors, capacitors and TVS should be close to (U)SIM card connector in PCB layout.

Figure 16: Reference Circuit for Normally Open (U)SIM Card Connector

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

If (U)SIM card hot-plug is not needed, keep USIM_DET unconnected. A reference circuit for (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.

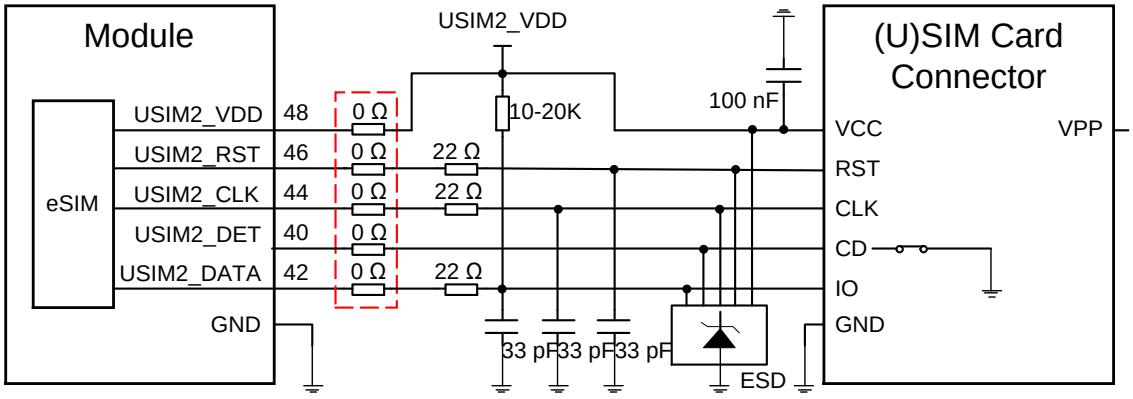
Figure 17: Reference Circuit of (U)SIM Interface with a 6-Pin (U)SIM Card Connector

4.1.5. (U)SIM 2 Card Connector

EM05-G 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. The default function is eSIM.

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 18: Recommended Compatible Design for (U)SIM2 Interface

4.1.6. (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.
- 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 kΩ pull-up resistor must be added near the (U)SIM card connector.

4.2. USB Interface

EM05-G is compliant with USB 2.0 specification. It can only be used as a slave device. Meanwhile, it supports high speed (480 Mbps) and full speed (12 Mbps) mode. The USB interface is used for AT command communication, data transmission, GNSS NMEA output, software debugging and firmware upgrade. The following figure shows the reference circuit of USB interface.

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

The following table shows the pin definition of USB interface.

Table 11: Pin Definition of USB Interface

Pin No.	Pin Name	I/O	Description	Comment
7	USB_DP	AIO	USB 2.0 differential data (+)	Requires differential impedance of 90 Ω
9	USB_DM	AIO	USB 2.0 differential data (-)	

For more details about the USB 2.0 specifications, visit http://www.usb.org/home.

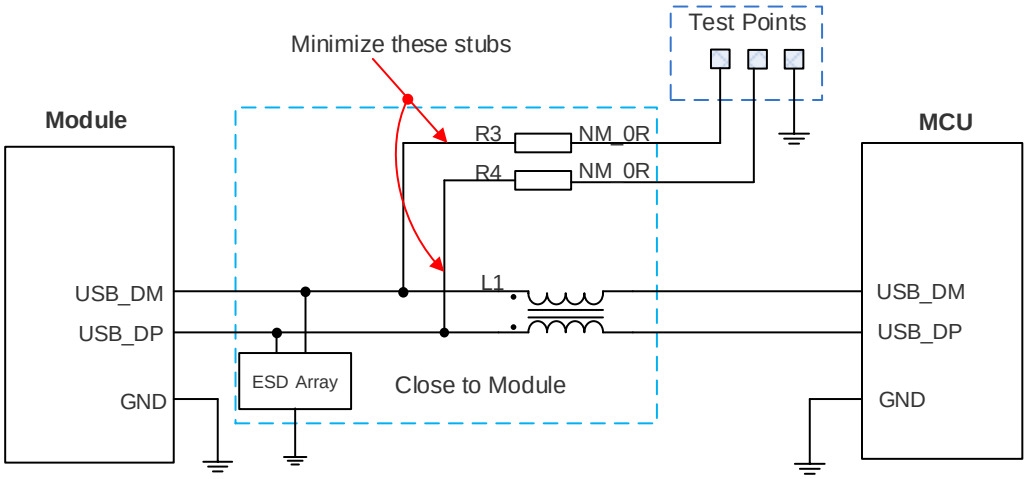


Figure 18: Reference Circuit of USB 2.0 Interface

A common mode choke L1 is recommended to be added in series between the module and customer's MCU to suppress EMI spurious transmission. Meanwhile, the 0 Ω resistors (R3 and R4) should be added in series between the module and the test points to facilitate debugging, and the resistors are not mounted by default. To ensure the integrity of USB data line signal, L1, R3 and R4 components must be placed close to the module, and also these resistors should be placed close to each other. The extra stubs of trace must be as short as possible.

To meet USB 2.0 specification, the following principles should be complied with when designing the USB interface.

- Route the USB signal traces as differential pairs with ground surrounded. The impedance of USB differential trace is 90 Ω.
- 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.
- Pay attention to the influence of junction capacitance of ESD protection components on USB data lines. Typically, the capacitance value should be less than 2 pF.
- Keep the ESD protection components as close to the USB connector as possible.

4.3. 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.

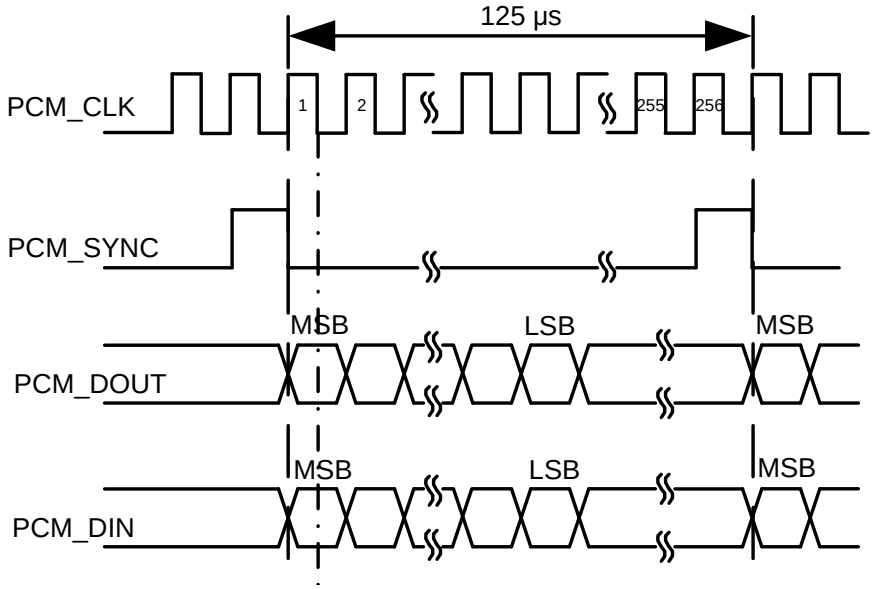


Figure 19: Primary Mode Timing

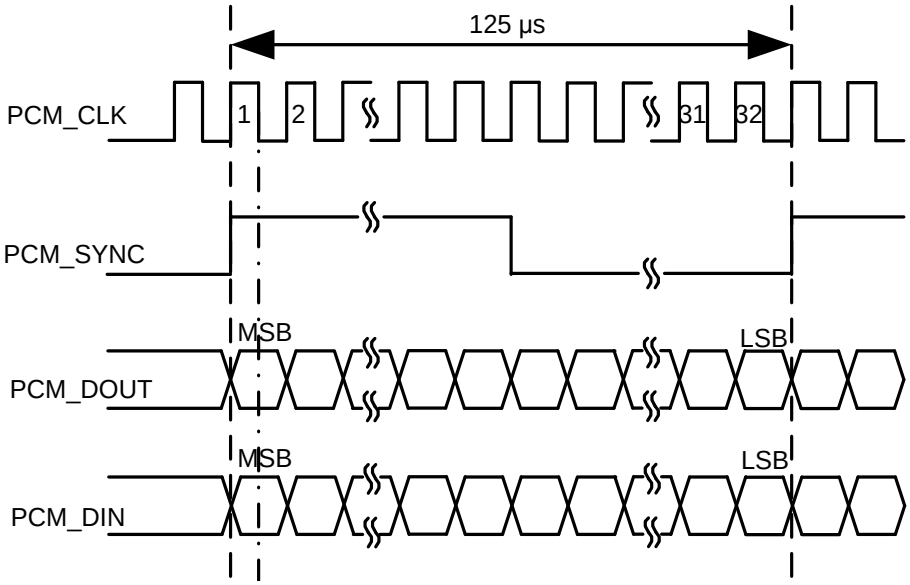


Figure 20: Auxiliary Mode Timing

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

Table 12: 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**.

4.4. Control and Indication Interfaces

The following table shows the pin definition of control and indication pins.

Table 13: Pin Definition of Control and Indication Interfaces

Pin No.	Pin Name	I/O	Description	DC Characteristic
8	W_DISABLE1#	DI, OD	Airplane mode control. Active LOW.	1.8/3.3 V
26	W_DISABLE2#*	DI, OD	GNSS disable control. Active LOW.	1.8/3.3 V
10	WWAN_LED#	DO, OD	Indicate RF status of the module. Active LOW.	VCC
23	WOWWAN#	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
68	ANT_CONFIG	DI, PU	Antenna configuration	1.8 V

4.4.1. W_DISABLE1#

EM05-G provides a W_DISABLE1# pin to disable or enable airplane mode through hardware operation. The W_DISABLE1# pin 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 AT commands. The following table shows the AT command and corresponding RF function status of the module.

Table 14: RF Function Status

W_DISABLE1# Logic 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

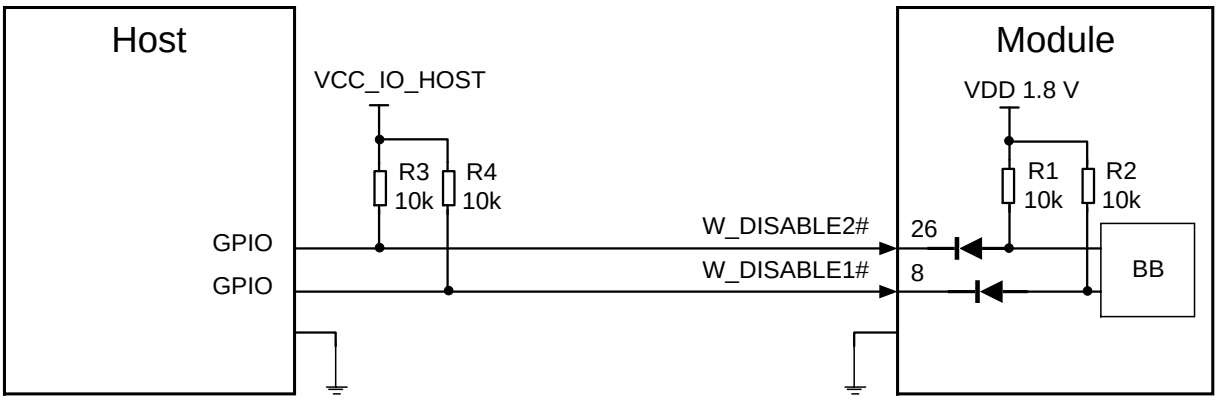
4.4.2. W_DISABLE2#*

EM05-G 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 controls the GNSS function.

Table 15: GNSS Function Status

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

A simple voltage-level translator 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 1.8 V or 3.3 V voltage level. W_DISABLE1# and W_DISABLE2# are active LOW, and a reference circuit is presented below.



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

Figure 21: W_DISABLE1# and W_DISABLE2# Reference Circuit

4.4.3. WWAN_LED#

WWAN_LED# is used to indicate the RF status of the module, and its sink current is up to 9 mA.

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

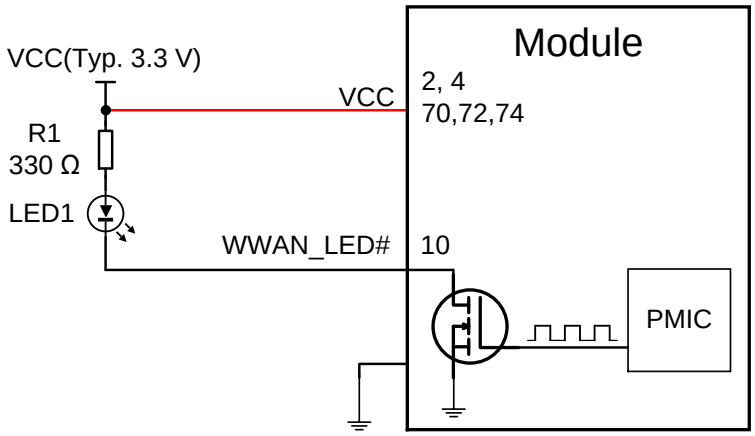


Figure 22: WWAN_LED# Reference Circuit

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

Table 16: RF Status Indications of WWAN_LED#

WWAN_LED# Logic 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: ● The (U)SIM card is not powered. ● W_DISABLE1# is at low voltage level (airplane mode enabled). ● **AT+CFUN=4** (RF function disabled).

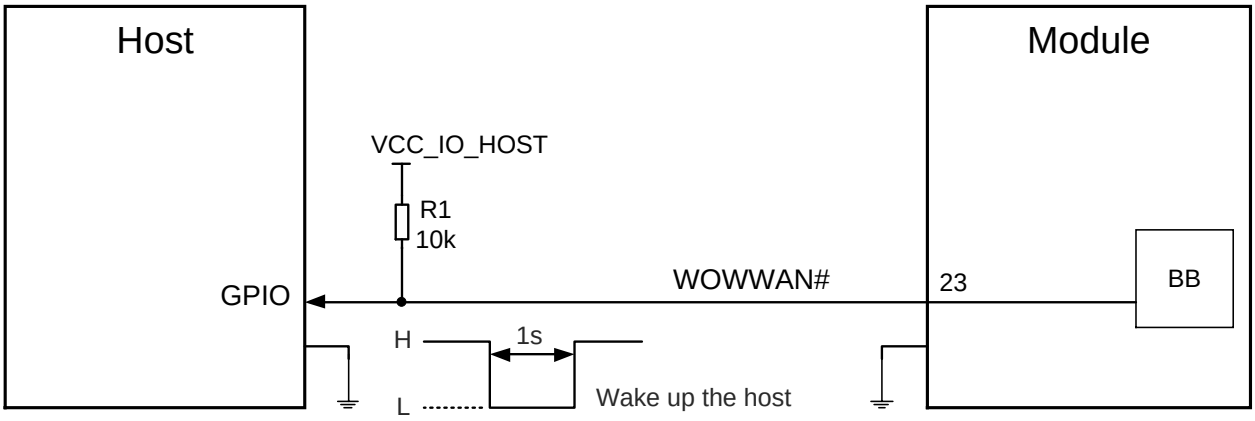
4.4.4. WOWWAN#

The WOWWAN# is an open drain pin, which requires a pull-up resistor on the host. When a URC returns, a 1s low level pulse will be outputted to wake up the host.

The state of WOWWAN# signal is shown as below.

Table 17: State of WOWWAN#

WOWWAN# State	Module Operation Status
Output a 1 s pulse signal at low level	Call/SMS/Data is incoming (to wake up the host)
Always at high voltage 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 23: WOWWAN# Reference Circuit

4.4.5. DPR*

EM05-G provides a DPR (Dynamic Power Reduction) pin for body SAR (Specific Absorption Rate) detection. The signal is sent from the proximity sensor of a host system to EM05-G module to provide an input trigger, which will reduce the output power in radio transmission.

Table 18: Function of the DPR

DPR Level	Function
High/Floating	No max. transmitting power backoff
Low	Max. transmitting power backoff by **AT+QCFG="sarcfg"**

4.5. Cellular/WLAN COEX Interface*

EM05-G provides a cellular/WLAN COEX interface, the following table shows the pin definition of this interface.

Table 19: Pin Definition of COEX Interface

Pin No.	Pin Name	I/O	Description	DC Characteristic
60	WLAN_PA_EN*	DI	Notification from WLAN to SDR while transmitting	1.8 V
62	COEX_RXD*	DI, PD	LTE/WLAN coexistence receive	1.8 V
64	COEX_TXD*	DO, PD	LTE/WLAN coexistence transmit	1.8 V

4.6. Antenna Tuner Control Interface*

The module provides ANTCTL[0:3] and RFFE pins used for antenna tuner control, which should be routed to an appropriate antenna control circuit. More details about the interface will be added in the future version of this document.

Table 20: Pin Definition of Antenna Tuner Control Interface

Pin No.	Pin Name	I/O	Description	DC Characteristic
56	RFFE_CLK [1)]	DO, PD	Used for external MIPI IC control	1.8 V
58	RFFE_DATA [1)]	DO, PD		1.8 V
24	VDD_IO	PO	Antenna tuner supply power.	1.8 V
59	ANTCTL0*	DO, PD	Antenna 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

NOTE

[1] If this function is required, please contact Quectel for more details.

4.7. Configuration Pins

EM05-G provides four configuration pins, which are defined as below.

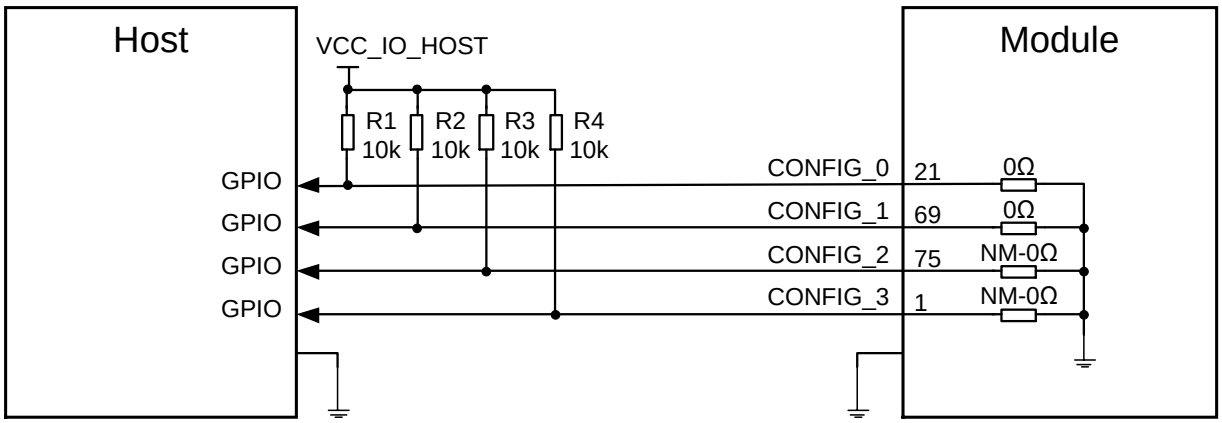
Table 21: Configuration Pins List of M.2 Specification

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	Quectel defined	NA

Table 22: Configuration Pins of the Module

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

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



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

Figure 24: Recommended Circuit for Configuration Pins

5 RF Characteristics

5.1. Cellular Antenna Interfaces

EM05-G is mounted with three 2 × 2 mm antenna connectors for external antenna connection: a main antenna connector, a Rx-diversity antenna connector, and a GNSS antenna connector. The impedance of the antenna connectors is 50 Ω.

5.1.1. Connector Definition

Table 23: EM05-G Connector Definition of Antenna Interfaces

Antenna Pin Name	I/O	Description	Comment
ANT_MAIN	AIO	Main antenna interface: ● LTE: TRx ● WCDMA: TRx	50 Ω impedance
ANT_DRX/ANT_GNSS	AI	Rx-diversity/GNSS antenna interface: ● LTE: DRx ● WCDMA: DRx ● GNSS: L1	50 Ω impedance

5.1.2. Operating Frequency

Table 24: Module Operating Frequencies

3GPP Band	Transmit	Receive	Unit
WCDMA B1	1920–1980	2110–2170	MHz
WCDMA B2	1850–1910	1930–1990	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-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 FDD B66	1710–1780	2100–2200	MHz
LTE FDD B71	663–698	617–652	MHz

5.1.3. Receiving Sensitivity

The following tables show conducted RF receiving sensitivity of EM05-G series module.

Table 25: EM05-G Conducted RF Receiving Sensitivity

Frequency Bands	Primary	Diversity	SIMO	3GPP (SIMO)
WCDMA B1	TBD	TBD	TBD	-106.7 dBm
WCDMA B2	TBD	TBD	TBD	-104.7 dBm
WCDMA B4	TBD	TBD	TBD	-106.7 dBm
WCDMA B5	TBD	TBD	TBD	-104.7 dBm
WCDMA B6	TBD	TBD	TBD	-106.7 dBm
WCDMA B8	TBD	TBD	TBD	-103.7 dBm
WCDMA B19	TBD	TBD	TBD	-106.7 dBm
LTE-FDD B1 (10 MHz)	TBD	TBD	-100.5 dBm	-96.3 dBm
LTE-FDD B2 (10 MHz)	TBD	TBD	-100.5 dBm	-94.3 dBm
LTE-FDD B3 (10 MHz)	TBD	TBD	-100.5 dBm	-93.3 dBm
LTE-FDD B4 (10 MHz)	TBD	TBD	-100.2 dBm	-96.3 dBm
LTE-FDD B5 (10 MHz)	TBD	TBD	-101.5 dBm	-94.3 dBm
LTE-FDD B7 (10 MHz)	TBD	TBD	-98.5 dBm	-94.3 dBm
LTE-FDD B8 (10 MHz)	TBD	TBD	-100.2 dBm	-93.3 dBm
LTE-FDD B12 (10 MHz)	TBD	TBD	-101.5 dBm	-93.3 dBm
LTE-FDD B13 (10 MHz)	TBD	TBD	-101.3 dBm	-93.3 dBm
LTE-FDD B14 (10 MHz)	TBD	TBD	-101.3 dBm	-93.3 dBm
LTE-FDD B18 (10 MHz)	TBD	TBD	-101.5 dBm	-96.3 dBm
LTE-FDD B19 (10 MHz)	TBD	TBD	-101.5 dBm	-96.3 dBm
LTE-FDD B20 (10 MHz)	TBD	TBD	-101.3 dBm	-93.3 dBm

LTE-FDD B25 (10 MHz)	TBD	TBD	-100.6 dBm	-92.8 dBm
LTE-FDD B26 (10 MHz)	TBD	TBD	-101.6 dBm	-93.8 dBm
LTE-FDD B28 (10 MHz)	TBD	TBD	-100.9 dBm	-94.8 dBm
LTE-TDD B38 (10 MHz)	TBD	TBD	-98.7 dBm	-96.3 dBm
LTE-TDD B39 (10 MHz)	TBD	TBD	-101 dBm	-96.3 dBm
LTE-TDD B40 (10 MHz)	TBD	TBD	-99.7 dBm	-96.3 dBm
LTE-TDD B41 (10 MHz)	TBD	TBD	-99 dBm	-94.3 dBm
LTE-FDD B66 (10 MHz)	TBD	TBD	-100.1 dBm	-95.8 dBm
LTE-FDD B71 (10 MHz)	TBD	TBD	-101.2 dBm	-93.5 dBm

5.1.4. RF Output Power

The following table shows the RF output power of EM05-G module.

Table 26: Conducted RF Output Power of EM05-G

Frequency Bands	Max. RF Output Power	Min. RF Output Power
LTE-FDD Bands	24 dBm ±2 dB	< -39 dBm
LTE-TDD Bands	24 dBm ±2 dB	< -39 dBm
WCDMA Bands	24 dBm +1/-3 dB	< -49 dBm

5.2. GNSS Antenna Interface

5.2.1. General Description

EM05-G includes a fully integrated Global Navigation Satellite System (GNSS) solution that supports GPS, GLONASS, BeiDou/COMPASS, Galileo and QZSS.

EM05-G supports standard NMEA-0183 protocol, and outputs NMEA sentences at 1 Hz data update rate via USB interface by default.

By default, EM05-G 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. GNSS Frequency

The following tables show the frequency specification of GNSS antenna.

Table 27: GNSS Frequency

Type	Frequency	Unit
GPS	1575.42 ±1.023	MHz
GLONASS	1597.5–1605.8	MHz
Galileo	1575.42 ±2.046	MHz
BeiDou/COMPASS	1561.098 ±2.046	MHz
QZSS	1575.42	MHz

5.2.3. GNSS Performance

The following table shows GNSS performance of EM05-G module.

Table 28: GNSS Performance

Parameter	Description	Conditions	Typ.	Unit
Sensitivity (GNSS)	Cold start	Autonomous	TBD	dBm
	Reacquisition	Autonomous	TBD	dBm
	Tracking	Autonomous	TBD	dBm
TTFF (GNSS)	Cold start @ open sky	Autonomous	TBD	s
		XTRA enabled	TBD	s
	Warm start @ open sky	Autonomous	TBD	s
		XTRA enabled	TBD	s
	Hot start @ open sky	Autonomous	TBD	s
		XTRA enabled	TBD	s
Accuracy (GNSS)	CEP-50	Autonomous @ open sky	TBD	m

NOTES

1. Tracking sensitivity: the minimum GNSS signal power at which the module can maintain locked (keep positioning for at least 3 minutes continuously).
2. Reacquisition sensitivity: the minimum GNSS signal power required for the module to maintain locked 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 25: Antenna Connectors on the EM05-G Module

5.3.2. Antenna Connector Size

EM05-G is mounted with standard 2 mm × 2 mm receptacle antenna connectors for convenient antenna connection. The antenna connector's PN is IPEX 20579-001E, and the connector dimensions are illustrated as below:

The connector dimensions are illustrated by the figure below:

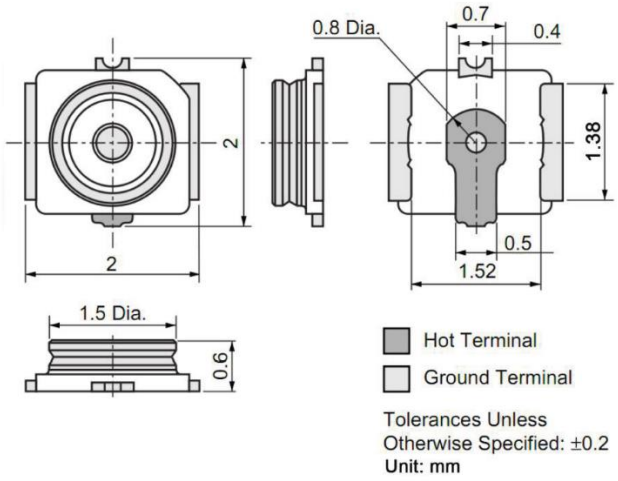


Figure 26: EM05-G RF Connector Dimensions (Unit: mm)

Table 29: Major Specifications of Antenna Connectors

Item	Specification
Nominal Frequency Range	DC to 6 GHz
Nominal Impedance	50 Ω
Temperature Rating	-40 °C to +85 °C
Voltage Standing Wave Ratio (VSWR)	Meet the requirements of: Max 1.3 (DC–3 GHz) Max 1.45 (3–6 GHz)

5.3.3. Antenna Connector Installation

The receptacle accepts two types of mating plugs to meet two maximum mated heights: 1.20 mm (using a Ø0.81 mm coaxial cable) and 1.45 mm (using a Ø1.13mm coaxial cable).

The following figure shows the specifications of mating plugs using Ø0.81 mm coaxial cables.

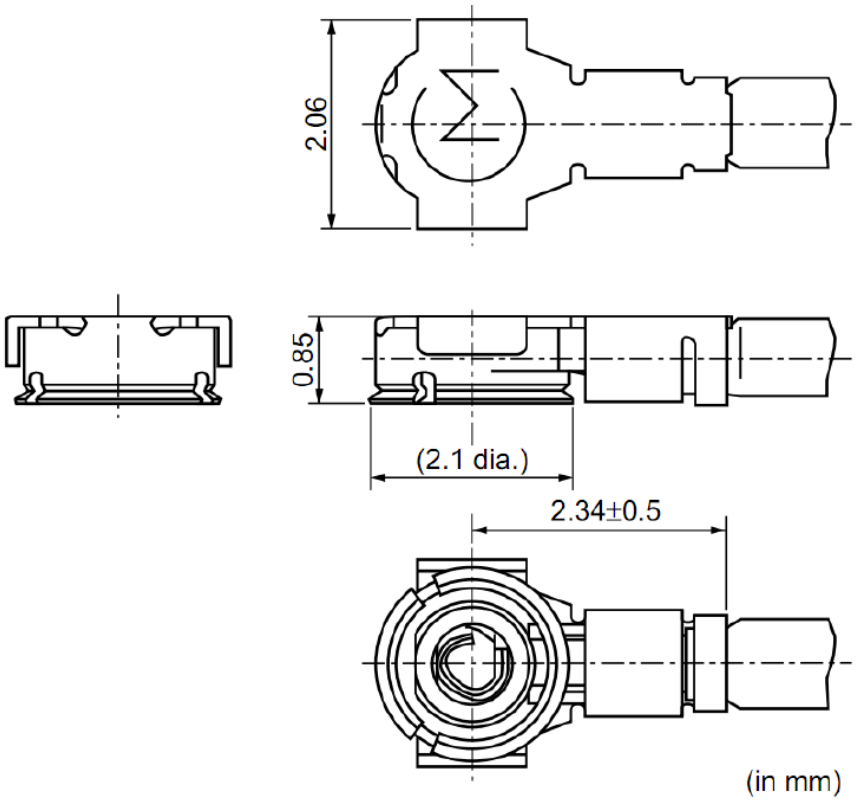


Figure 27: Specifications of Mating Plugs Using Ø0.81 mm Coaxial Cables

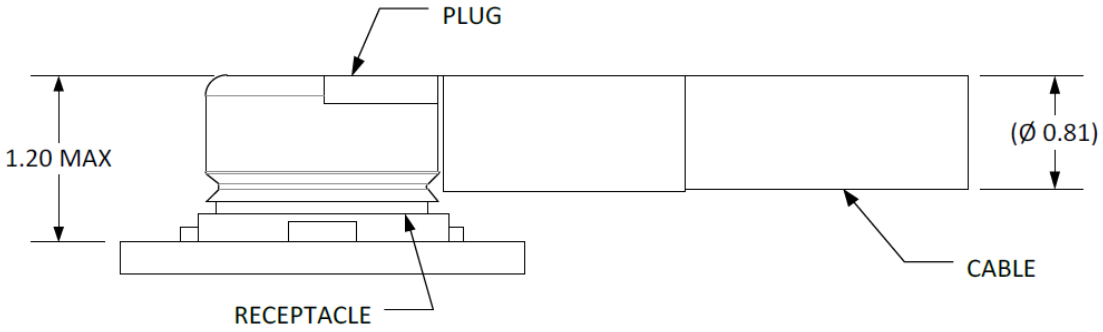


Figure 28: Connection between the RF Connector and the 0.81 mm Coaxial Cable

The following figure illustrates the connection between the receptacle antenna connector on EM05-G and the mating plug using a Ø1.13 mm coaxial cable.

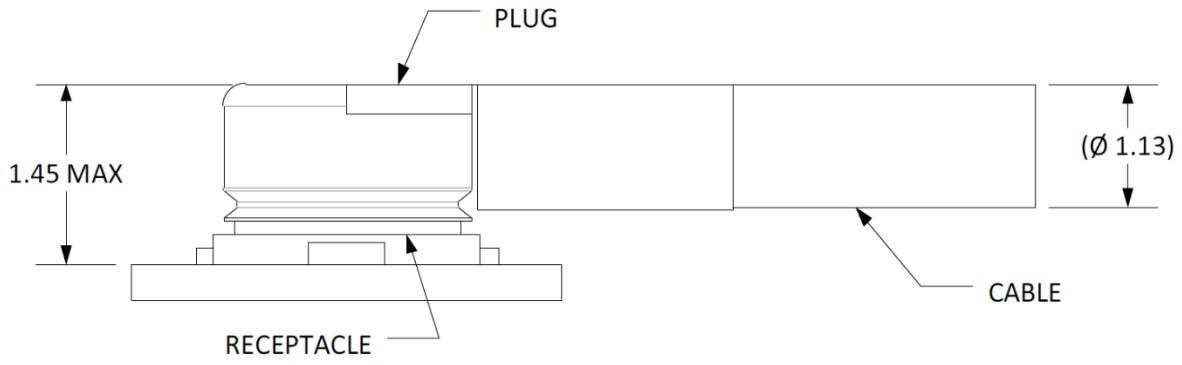


Figure 29: Connection between Receptacle and Mating Plug Using Ø1.13 mm Coaxial Cable

5.4. Antenna Requirements

The following table shows the requirements on main antenna, Rx-diversity antenna and GNSS antenna.

Table 30: Antenna Requirements

Type	Requirements
GNSS	Frequency range: 1559–1609 MHz Polarization: RHCP or linear VSWR: < 2 (Typ.) Passive antenna gain: > 0 dBi
WCDMA/LTE	VSWR: ≤ 2 Efficiency: > 30 % Max input power: 50 W Input impedance: 50 Ω Cable insertion loss: **< 1 dB:** WCDMA B5/B6/B8/B19 LTE B5/B8/B12/B13/B14/B18/B19/B20/B26/B28/B71 **< 1.5 dB:** WCDMA B1/B2/B4 LTE-FDD B1/B2/B3/B4/B25/B66 **< 2 dB:** LTE B7/B38/B40/B41

6 Reliability, Radio and Electrical Characteristics

6.1. Power Supply Requirements

The input voltage of EM05-G is 3.135–4.4 V, as specified by ***document [1]***. The following table shows the power supply requirements of EM05-G.

Table 31: Power Supply Requirements

Parameter	Description	Min.	Typ.	Max.	Unit
VCC	Power supply	3.135	3.3	4.4	V

6.2. Current Consumption

The values of current consumption are shown below.

Table 32: Current Consumption of EM05-G

Description	Conditions	Typ.	Unit
OFF State	Power down	TBD	uA
Sleep State	**AT+CFUN=0** (USB disconnected)	TBD	mA
	WCDMA @ PF = 64 (USB disconnected)	TBD	mA
	WCDMA @ PF = 64 (USB suspended)	TBD	mA
	WCDMA @ PF = 128 (USB disconnected)	TBD	mA
	WCDMA @ PF = 256 (USB disconnected)	TBD	mA

	WCDMA @ PF = 512 (USB disconnected)	TBD	mA
	LTE-FDD @ PF = 32 (USB disconnected)	TBD	mA
	LTE-FDD @ PF = 64 (USB disconnected)	TBD	mA
	LTE-FDD @ PF = 64 (USB suspended)	TBD	mA
	LTE-FDD @ PF = 128 (USB disconnected)	TBD	mA
	LTE-FDD @ PF = 256 (USB disconnected)	TBD	mA
	LTE-TDD @ PF = 32 (USB disconnected)	TBD	mA
	LTE-TDD @ PF = 64 (USB disconnected)	TBD	mA
	LTE-TDD @ PF = 64 (USB suspended)	TBD	mA
	LTE-TDD @ PF = 128 (USB disconnected)	TBD	mA
	LTE-TDD @ PF = 256 (USB disconnected)	TBD	mA
Idle State	WCDMA @ PF = 64 (USB disconnected)	TBD	mA
	WCDMA @ PF = 64 (USB connected)	TBD	mA
	LTE-FDD @ PF = 64 (USB disconnected)	TBD	mA
	LTE-FDD @ PF = 64 (USB connected)	TBD	mA
	LTE-TDD @ PF = 64 (USB disconnected)	TBD	mA
	LTE-TDD @ PF = 64 (USB connected)	TBD	mA
WCDMA Data Transfer (GNSS OFF)	WCDMA B1 HSDPA @ 21dBm	TBD	mA
	WCDMA B1 HSUPA @ 20.5 dBm	TBD	mA
	WCDMA B2 HSDPA @ 21 dBm	TBD	mA
	WCDMA B2 HSUPA @ 20.5 dBm	TBD	mA
	WCDMA B4 HSDPA @ 21 dBm	TBD	mA
	WCDMA B4 HSUPA @ 20.5 dBm	TBD	mA
	WCDMA B5 HSDPA @ 21 dBm	TBD	mA
	WCDMA B5 HSUPA @ 20.5 dBm	TBD	mA
	WCDMA B6 HSDPA @ 21 dBm	TBD	mA
	WCDMA B6 HSUPA @ 20.5 dBm	TBD	mA

	WCDMA B8 HSDPA @ 21 dBm	TBD	mA
	WCDMA B8 HSUPA @ 20.5 dBm	TBD	mA
	WCDMA B19 HSDPA @ 21 dBm	TBD	mA
	WCDMA B19 HSUPA @ 20.5 dBm	TBD	mA
LTE Data Transfer (GNSS OFF)	LTE-FDD B1 @ 22.3 dBm	TBD	mA
	LTE-FDD B2 @ 22.3 dBm	TBD	mA
	LTE-FDD B3 @ 22.3 dBm	TBD	mA
	LTE-FDD B4 @ 22.3 dBm	TBD	mA
	LTE-FDD B5 @ 22.3 dBm	TBD	mA
	LTE-FDD B7 @ 22.3 dBm	TBD	mA
	LTE-FDD B8 @ 22.3 dBm	TBD	mA
	LTE-FDD B12 @ 22.3 dBm	TBD	mA
	LTE-FDD B13 @ 22.3 dBm	TBD	mA
	LTE-FDD B14 @ 22.3 dBm	TBD	mA
	LTE-FDD B18 @ 22.3 dBm	TBD	mA
	LTE-FDD B19 @ 22.3 dBm	TBD	mA
	LTE-FDD B20 @ 22.3 dBm	TBD	mA
	LTE-FDD B25 @ 22.3 dBm	TBD	mA
	LTE-FDD B26 @ 22.3 dBm	TBD	mA
	LTE-FDD B28 @ 22.3 dBm	TBD	mA
	LTE-TDD B38 @ 22.3 dBm	TBD	mA
	LTE-TDD B39 @ 22.3 dBm	TBD	mA
	LTE-TDD B40 @ 22.3 dBm	TBD	mA
	LTE-TDD B41 @ 22.3 dBm	TBD	mA
	LTE-TDD B66 @ 22.3 dBm	TBD	mA
	LTE-TDD B71 @ 22.3 dBm	TBD	mA
WCDMA Voice Call	WCDMA B1 @ 22.5 dBm	TBD	mA

	WCDMA B2 @ 22.5 dBm	TBD	mA
	WCDMA B4 @ 22.5 dBm	TBD	mA
	WCDMA B5 @ 22.5 dBm	TBD	mA
	WCDMA B6 @ 22.5 dBm	TBD	mA
	WCDMA B8 @ 22.5 dBm	TBD	mA
	WCDMA B19 @ 22.5 dBm	TBD	mA

6.3. Digital I/O Characteristic

Table 33: 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 34: (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 35: (U)SIM 3.0V I/O Requirements

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

NOTE

The maximum voltage value of V_{IL} for RESET# and W_DISABLE1# is 0.5 V.

6.4. Electrostatics 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.

The following table shows the ESD characteristics of EM05-G.

Table 36: ESD Characteristics of EM05-G (Temperature: 25 ºC, Humidity: 45 %)

Tested Interfaces	Contact Discharge	Air Discharge	Unit
Power Supply and GND	±4	±10	kV
Antenna Interface	±4	±8	kV
Others	±0.5	±1	kV

NOTE

For a good ESD performance, the module mounting holes must be used to attach the device to the main PCB ground closely.

6.5. Thermal Dissipation

EM05-G 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, etc.) 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.

There are other measures to enhance heat dissipation performance:

- Add as many ground vias as possible on the PCB.
- Maximize 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. You 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 37: Absolute Maximum Ratings

Parameter	Min.	Max.	Unit
VCC	-0.3	4.7	V
Peak Current of VCC	0	TBD	A
Voltage at Digital Pins	-0.3	2.3	V

6.7. Operating and Storage Temperatures

Table 38: Operating and Storage Temperatures

Parameter	Min.	Typ.	Max.	Unit
Operating Temperature Range [1)]	-30	+25	+70	ºC
Extended Temperature Range [2)]	-40		+85	ºC
Storage Temperature Range	-40		+90	ºC

NOTES

1. [1)] Within operation temperature range, the module is 3GPP compliant.
2. [2)] Within extended temperature range, the module remains the ability to establish and maintain SMS, data transmission, etc. There is no unrecoverable malfunction. There are also no effects on radio spectrum and no harm to radio network. Only one or more parameters like P_{out} might reduce in their value and exceed the specified tolerances. When the temperature returns to the normal operating temperature levels, the module will meet 3GPP specifications again.

7 Mechanical Dimensions and Packaging

This chapter mainly describes mechanical dimensions and packaging specifications of EM05-G module. All dimensions are measured in millimeter (mm), and the dimensional tolerances are ±0.05 mm unless otherwise specified.

7.1. Mechanical Dimensions of the Module

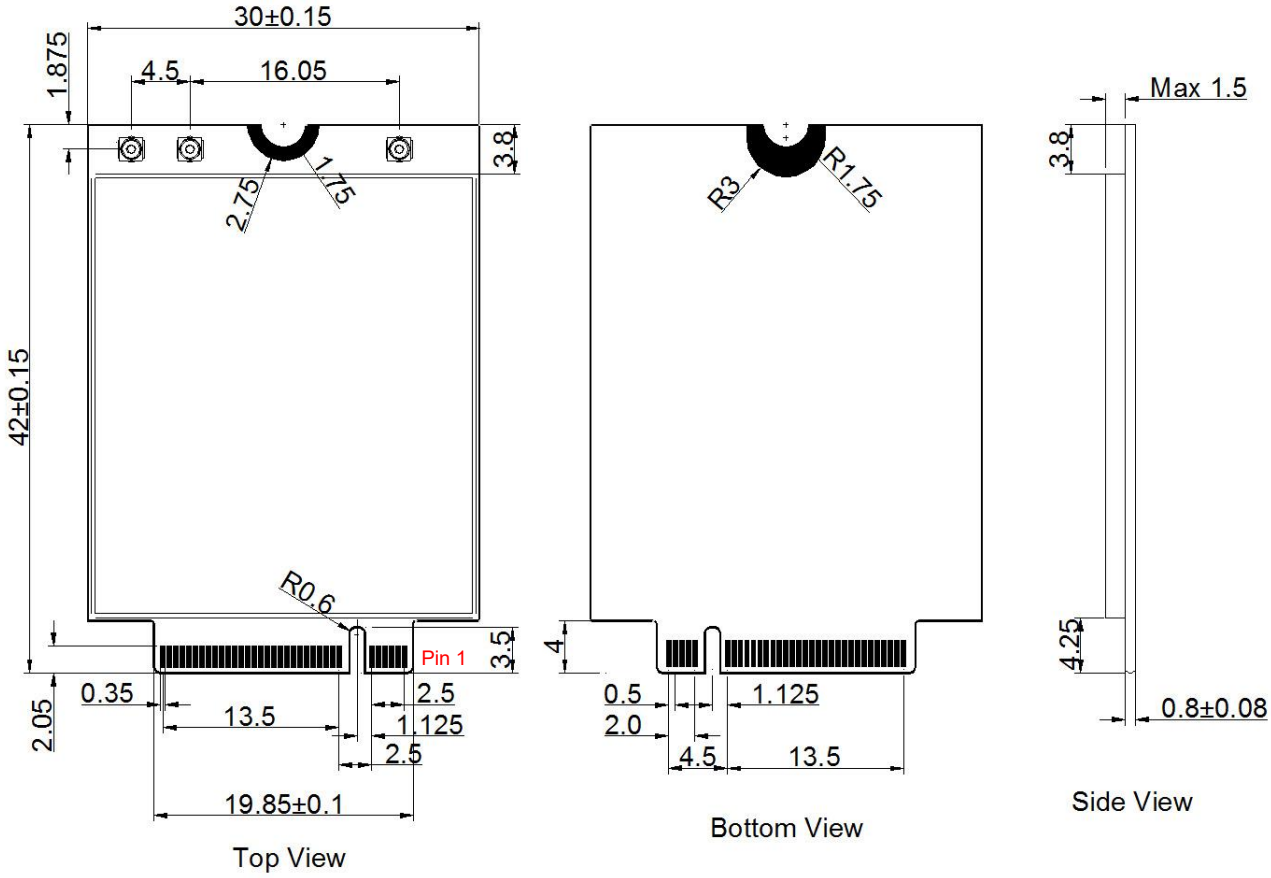


Figure 30: Mechanical Dimensions of EM05-G

7.2. Top and Bottom Views of the Module

Figure 31: Top and Bottom View of the Module

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

EM05-G adopts a standard PCI Express M.2 connector which compiles with the directives and standards listed in ***document [1]***.

7.4. Packaging

EM05-G is packaged in tray. The following figure shows the tray size.

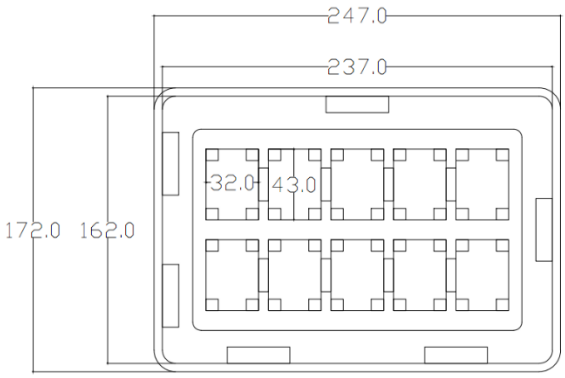


Figure 32: Tray Size (Unit: mm)

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 33: Tray Packaging Procedure

8 Appendix References

Table 39: Related Documents

SN	Document Name	Description
[1]	PCI Express M.2 Specification	PCI Express Specification
[2]	Quectel_M.2_EVB_User_Guide	M.2 EVB User Guide
[3]	Quectel_LTE_Standard_AT_Commands_Manual	AT Commands Manual for LTE Standard Modules
[4]	Quectel_LTE_Standard_GNSS_Application_Note	GNSS Application Note for LTE Standard Modules

Table 40: Terms and Abbreviations

Abbreviation	Description
bps	Bits Per Second
BW	Bandwidth
CHAP	Challenge-Handshake Authentication Protocol
COEX	Coexistence
CSQ	Cellular Signal Quality
DC-HSDPA	Double Carrier-High-Speed Downlink Packet Access
DFOTA	Delta Firmware Upgrade Over-The-Air
DL	Downlink
DPR	Dynamic Power Reduction
DRX	Discontinuous Reception (***Chapter 3.2.1***) Diversity Reception (***Chapter 5***)
ESD	Electrostatic Discharge

EMI	Electromagnetic Interference
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
HSDPA	High Speed Downlink Packet Access
HSPA	High Speed Packet Access
HSUPA	High Speed Uplink Packet Access
kbps	Kilo Bits Per Second
LED	Light Emitting Diode
LTE	Long Term Evolution
Mbps	Million Bits Per Second
ME	Mobile Equipment
MIMO	Multiple-Input Multiple-Output
MIPI	Mobile Industry Processor Interface
MLCC	Multiplayer Ceramic Chip Capacitor
MMS	Multimedia Messaging Service
MO	Mobile Originated
MSB	Most Signification Bit
MT	Mobile Terminated
PDU	Protocol Data Unit
PMIC	Power Management IC
PPP	Point-to-Point Protocol
RF	Radio Frequency

RFFE	RF Front End
Rx	Receive
SAR	Specific Absorption Rate
SDR	Software-Defined Radio
SMS	Short Message Service
Tx	Transmit
UART	Universal Asynchronous Receiver & Transmitter
UL	Uplink
URC	Unsolicited Result Code
(U)SIM	(Universal) Subscriber Identification Module
Vnom	Nominal Voltage Value
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