BG96 Mini PCIe

Hardware Design

LPWA Module Series

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About the Document

Revision History

Revision	Date	Author	Description
1.0	2019-12-09	Lyndon LIU/ Rex WANG/ Hyman DING	Initial

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1 Introduction

This document defines BG96 Mini PCIe module, and describes its air interfaces and hardware interfaces which are connected with customers' applications.

This document helps customers to quickly understand the interface specifications, electrical and mechanical details as well as other related information of the module. To facilitate application designs, it also includes some reference designs for customers' reference. The document, coupled with application notes and user guides, makes it easy to design and set up mobile applications with BG96 Mini PCIe.

1.1. 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 BG96 Mini PCIe module. Manufacturers of the cellular terminal should notify users and operating personnel of the following safety information by incorporating these guidelines into all manuals supplied with the product. If not so, Quectel assumes no liability for any user's failure to observe these precautions.

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

2 Product Concept

2.1. General Description

BG96 Mini PCIe is an embedded IoT (LTE Cat M1, LTE Cat NB1 and EGPRS) wireless communication module. It provides data connectivity on LTE-FDD/LTE-TDD/GPRS/EGPRS networks and supports half-duplex operation with PCI Express Mini Card 1.2 standard interface. It also provides GNSS [1)] and voice [2)] functionality to meet customers' specific application demands.

BG96 Mini PCIe module can be applied in the following fields:

- Wireless POS System
- Tracking System
- Intelligent Meter Reading System
- Security System

The following table shows the product series of BG96 Mini PCIe module.

Table 1: Description of BG96 Mini PCIe

Product Series	Description
BG96 Mini PCIe	**LTE Cat M1 & Cat NB1:** LTE-FDD: B1/B2/B3/B4/B5/B8/B12/B13/B18/B19/B20/B25/B26*/B28 LTE-TDD: B39 (for Cat M1 only) GSM [3)]: GSM850/EGSM900/DCS1800/PCS1900 GNSS: GPS, GLONASS, BeiDou/Compass, Galileo, QZSS Digital Audio [4)]

NOTES

1. [1)] GNSS function is optional.
2. [2)] BG96 Mini PCIe supports VoLTE (Voice over LTE) under LTE Cat M1 network.
3. [3)] BG96 GSM only supports Packet Switch.

4. [4] Digital audio (PCM) function is only supported in **Telematics** version.
5. "*" means under development.

2.2. Key Features

The following table describes the detailed features of BG96 Mini PCIe module.

Table 2: Key Features of BG96 Mini PCIe

Feature	Details
Function Interface	PCI Express Mini Card 1.2 Standard Interface
Power Supply	Supply voltage: 3.0V~3.6V Typical supply voltage: 3.3V
Transmitting Power	Class 3 (23dBm±2dB) for LTE-FDD bands Class 3 (23dBm±2dB) for LTE-TDD bands Class 4 (33dBm±2dB) for GSM850 Class 4 (33dBm±2dB) for EGSM900 Class 1 (30dBm±2dB) for DCS1800 Class 1 (30dBm±2dB) for PCS1900 Class E2 (27dBm±3dB) for GSM850 8-PSK Class E2 (27dBm±3dB) for EGSM900 8-PSK Class E2 (26dBm±3dB) for DCS1800 8-PSK Class E2 (26dBm±3dB) for PCS1900 8-PSK
LTE Features	Support LTE Cat M1 and LTE Cat NB1 Support 1.4MHz RF bandwidth for LTE Cat M1 Support 200KHz RF bandwidth for LTE Cat NB1 Support SISO in DL direction Cat M1: Max. 375Kbps (DL)/375Kbps (UL) Cat NB1: Max. 32Kbps (DL)/70Kbps (UL)
GSM Features	**GPRS:** Support GPRS multi-slot class 33 (33 by default) Coding scheme: CS-1, CS-2, CS-3 and CS-4 Max. 107Kbps (DL), Max. 85.6Kbps (UL) **EDGE:** Support EDGE multi-slot class 33 (33 by default) Support GMSK and 8-PSK for different MCS (Modulation and Coding Scheme) Downlink coding schemes: CS 1-4 and MCS 1-9 Uplink coding schemes: CS 1-4 and MCS 1-9 Max. 296Kbps (DL), Max. 236.8Kbps (UL)

Internet Protocol Features	Support PPP/TCP/UDP/SSL/TLS/FTP(S)/HTTP(S)/NITZ/PING/MQTT protocols Support PAP (Password Authentication Protocol) and CHAP (Challenge Handshake Authentication Protocol) protocols which are usually used for PPP connections
SMS	Text and PDU mode Point to point MO and MT SMS cell broadcast SMS storage: ME by default
(U)SIM Interface	Support USIM/SIM card: 1.8V, 3.0V
UART Interfaces	Baud rate can reach up to 230400bps, 115200bps by default Used for AT command communication and data transmission
Audio Feature	Support one digital audio interface: PCM interface [1)]
USB Interface [2)]	Compliant with USB 2.0 specification (slave only) and the data transfer rate can reach up to 480Mbps 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 2.6/3.x/4.1~4.15, Android 4.x/5.x/6.x/7.x/8.x/9.x.
Antenna Interface	Include main antenna and GNSS antenna
GNSS Features	Gen8C Lite of Qualcomm Protocol: NMEA 0183
AT Commands	Compliant with 3GPP TS 27.007, 27.005 and Quectel enhanced AT commands
Physical Characteristics	Size: (51.0±0.15)mm × (30.0±0.15)mm × (4.9±0.2)mm Weight: approx. 8.0g
Temperature Range	Operation temperature range: -35°C ~ +75°C [3)] Extended temperature range: -40°C ~ +80°C [4)] Storage temperature range: -40°C ~ +90°C
Firmware Upgrade	USB interface and DFOTA
RoHS	All hardware components are fully compliant with EU RoHS directive

NOTES

1. [1)] Digital audio (PCM) function is only supported in **Telematics** version.
2. [2)] USB_VBUS has been connected to VCC_3V3, which means the USB interface is always existed.
3. [3)] Within operating temperature range, the module is 3GPP compliant.
4. [4)] Within extended temperature range, the module remains the ability to establish and maintain functions such as SMS and data transmission, without any unrecoverable malfunction. Radio spectrum and radio network will not be influenced, while one or more specifications, such as P_{out},

may exceed the specified tolerances of 3GPP. When the temperature returns to the normal operation temperature levels, the module will meet 3GPP specifications again.

2.3. Functional Diagram

The following figure shows the block diagram of BG96 Mini PCIe.

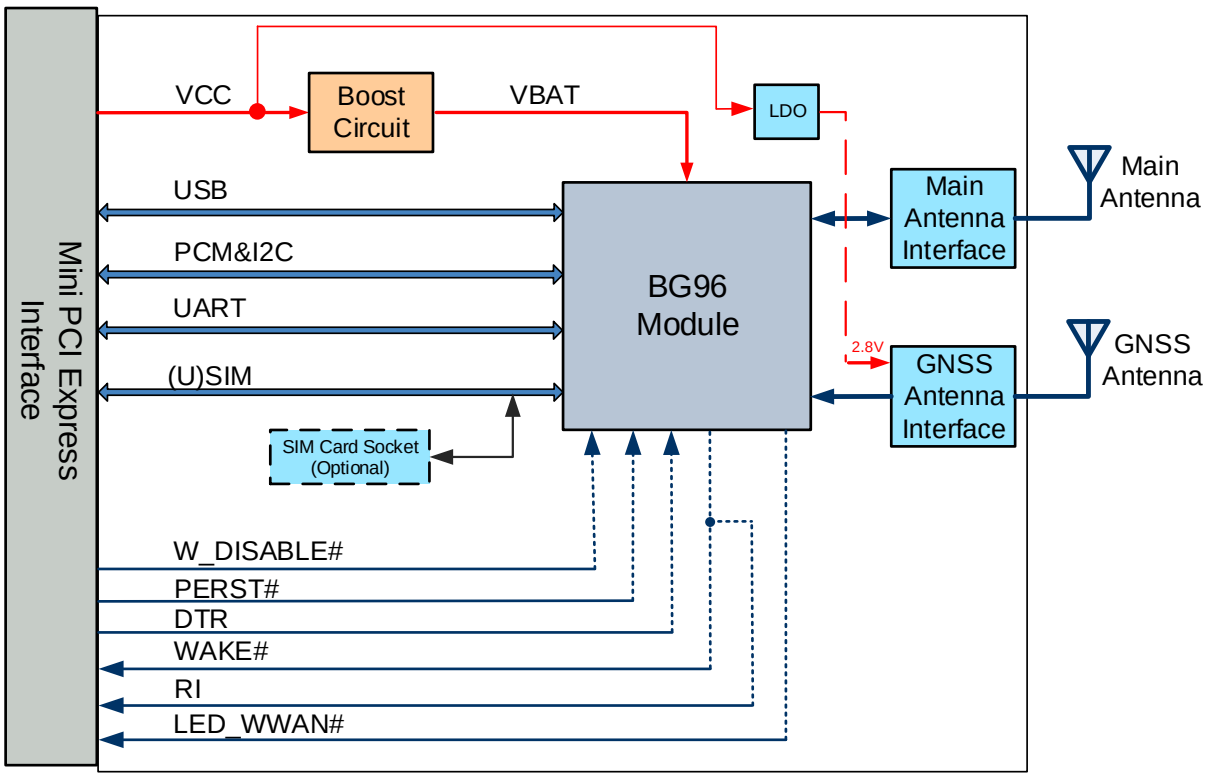


Figure 1: Functional Diagram

3 Application Interfaces

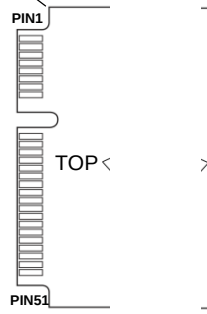
The physical connections and signal levels of BG96 Mini PCIe comply with PCI Express Mini CEM specifications. This chapter mainly describes the definition and application of the following interfaces of BG96 Mini PCIe:

- Power supply
- (U)SIM interface
- USB interface
- UART interface
- PCM and I2C interfaces
- Control and indicator signals
- Antenna interfaces

3.1. Pin Assignment

The following figure shows the pin assignment of BG96 Mini PCIe module. The top side contains BG96 module and antenna connectors.

Pin Name	Pin No.
WAKE#	1
RESERVED	3
RESERVED	5
RESERVED	7
GND	9
UART_RX	11
UART_TX	13
GND	15
RI	17
RESERVED	19
GND	21
UART_CTS	23
UART_RTS	25
GND	27
GND	29
DTR	31
RESERVED	33
GND	35
GND	37
VCC_3V3	39
VCC_3V3	41
GND	43
PCM_CLK	45
PCM_DOUT	47
PCM_DIN	49
PCM_SYNC	51



Pin No.	Pin Name
2	VCC_3V3
4	GND
6	RESERVED
8	USIM_VDD
10	USIM_DATA
12	USIM_CLK
14	USIM_RST
16	RESERVED
18	GND
20	W_DISABLE#
22	PERST#
24	RESERVED
26	GND
28	RESERVED
30	I2C_SCL
32	I2C_SDA
34	GND
36	USB_DM
38	USB_DP
40	GND
42	LED_WWAN#
44	USIM_PRESENCE
46	RESERVED
48	RESERVED
50	GND
52	VCC_3V3

Figure 2: Pin Assignment

3.2. Pin Description

The following tables show the pin definition and description of BG96 Mini PCIe on the 52-pin application.

Table 3: Definition of I/O Parameters

Type	Description
DI	Digital Input
DO	Digital Output
IO	Bidirectional
OC	Open Collector
PI	Power Input
PO	Power Output

Table 4: Pin Description

Pin No.	Mini PCI Express Standard Name	BG96 Mini PCIe Pin Name	I/O	Description	Comment
1	WAKE#	WAKE#	OC	Output signal to wake up the host	Active low
2	3.3Vaux	VCC_3V3	PI	3.3V DC supply	
3	COEX1	RESERVED		Reserved	
4	GND	GND		Mini card ground	
5	COEX2	RESERVED		Reserved	
6	1.5V	RESERVED		Reserved	
7	CLKREQ#	RESERVED		Reserved	
8	UIM_PWR	USIM_VDD	PO	Power source for the (U)SIM card	
9	GND	GND		Mini card ground	
10	UIM_DATA	USIM_DATA	IO	Data signal of (U)SIM card	
11	REFCLK-	UART_RX	DI	UART receive data	Connect to DTE's TX.

12	UIM_CLK	USIM_CLK	DO	Clock signal of (U)SIM card	
13	REFCLK+	UART_TX	DO	UART transmit data	Connect to DTE's RX.
14	UIM_RESET	USIM_RST	DO	Reset signal of (U)SIM card	
15	GND	GND		Mini card ground	
16	UIM_VPP	RESERVED		Reserved	
17	RESERVED	RI	DO	Output signal to wake up the host	Active low
18	GND	GND		Mini card ground	
19	RESERVED	RESERVED		Reserved	
20	W_DISABLE#	W_DISABLE#	DI	Airplane mode control	Pulled up by default. Active low.
21	GND	GND		Mini card ground	
22	PERST#	PERST#	DI	Fundamental reset signal	Pulled up by default. Active low
23	PERn0	UART_CTS	DI	UART clear to send	Connect to DTE's RTS.
24	3.3Vaux	RESERVED		Reserved	
25	PERp0	UART_RTS	DO	UART request to send	Connect to DTE's CTS
26	GND	GND		Mini card ground	
27	GND	GND		Mini card ground	
28	1.5V	RESERVED		Reserved	
29	GND	GND		Mini card ground	
30	SMB_CLK	I2C_SCL	OD	I2C serial clock	Require external pull-up to 1.8V.
31	PETn0	DTR	DI	Sleep mode control	The host must support USB suspend function.
32	SMB_DATA	I2C_SDA	OD	I2C serial data	Require external pull-up to 1.8V.
33	PETp0	RESERVED		Reserved	

34	GND	GND		Mini card ground	
35	GND	GND		Mini card ground	
36	USB_D-	USB_DM	IO	USB differential data (-)	
37	GND	GND		Mini card ground	
38	USB_D+	USB_DP	IO	USB differential data (+)	
39	3.3Vaux	VCC_3V3	PI	3.3V DC supply	
40	GND	GND		Mini card ground	
41	3.3Vaux	VCC_3V3	PI	3.3V DC supply	
42	LED_WWAN#	LED_WWAN#	OC	LED signal for indicating the network status of the module	Active low
43	GND	GND		Mini card ground	
44	LED_WLAN#	USIM_PRESENCE	DI	(U)SIM card insertion detection	
45	RESERVED	PCM_CLK [1)]	DO	PCM clock signal	
46	LED_WPAN#	RESERVED		Reserved	
47	RESERVED	PCM_DOUT [1)]	DO	PCM data output	
48	1.5V	RESERVED		Reserved	
49	RESERVED	PCM_DIN [1)]	DI	PCM data input	
50	GND	GND		Mini card ground	
51	RESERVED	PCM_SYNC [1)]	DO	PCM frame synchronization	
52	3.3Vaux	VCC_3V3	PI	3.3V DC supply	

NOTES

1. Keep all reserved and unused pins unconnected.
2. [1)] The digital audio (PCM) function is only supported on **Telematics** version.

3.3. Power Supply

The following table shows pin definition of VCC_3V3 pins and ground pins.

Table 5: Definition of VCC_3V3 and GND Pins

Pin No.	Pin Name	I/O	Power Domain	Description
2, 39, 41, 52	VCC_3V3	PI	3.0V~3.6V	Typically 3.3V DC supply
4, 9, 15, 18, 21, 26, 27, 29, 34, 35, 37, 40, 43, 50	GND			Mini card ground

The typical supply voltage of BG96 Mini PCIe is 3.3V. In 2G network, the input peak current may reach 2.7A during the transmitting time. Therefore, the power supply must be able to provide enough current, and a low-ESR bypass capacitor no less than 470μF should be used to prevent the voltage from dropping.

The following figure shows a reference design of power supply. The precision of resistor R2 and R3 is 1%, and the capacitor C3 needs a low ESR.

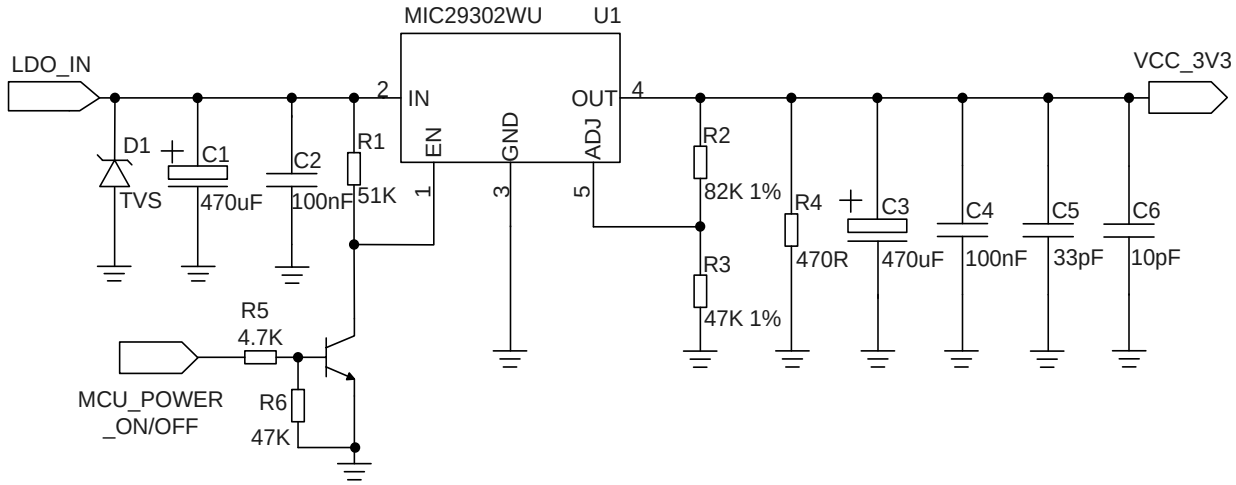


Figure 3: Reference Design of Power Supply

3.4. (U)SIM Interface

The (U)SIM interface circuitry meets ETSI and IMT-2000 requirements. Both 1.8V and 3.0V (U)SIM cards are supported. The following table shows the pin definition of (U)SIM interface.

Table 6: Pin Definition of (U)SIM Interface

Pin No.	Pin Name	I/O	Power Domain	Description
8	USIM_VDD	PO	1.8V/3.0V	Power source for (U)SIM card
10	USIM_DATA	IO	1.8V/3.0V	Data signal of (U)SIM card
12	USIM_CLK	DO	1.8V/3.0V	Clock signal of (U)SIM card
14	USIM_RST	DO	1.8V/3.0V	Reset signal of (U)SIM card
44	USIM_PRESENCE	DI	1.8V/3.0V	(U)SIM card insertion detection

BG96 Mini PCIe supports (U)SIM card hot-plug via the USIM_PRESENCE pin. The function supports low level and high level detections, and it is disabled by default. Please refer to ***document [2]*** about **AT+QSIMDET** command for details.

The following figure shows a reference design of (U)SIM interface with an 8-pin (U)SIM card connector.

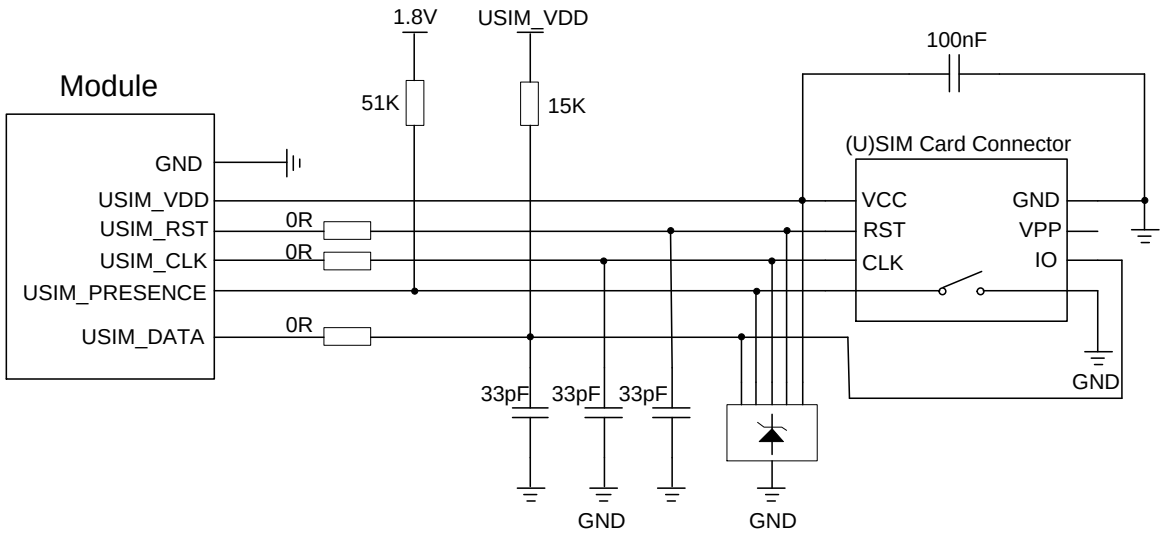


Figure 4: Reference Circuit of an 8-Pin (U)SIM Card Connector

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

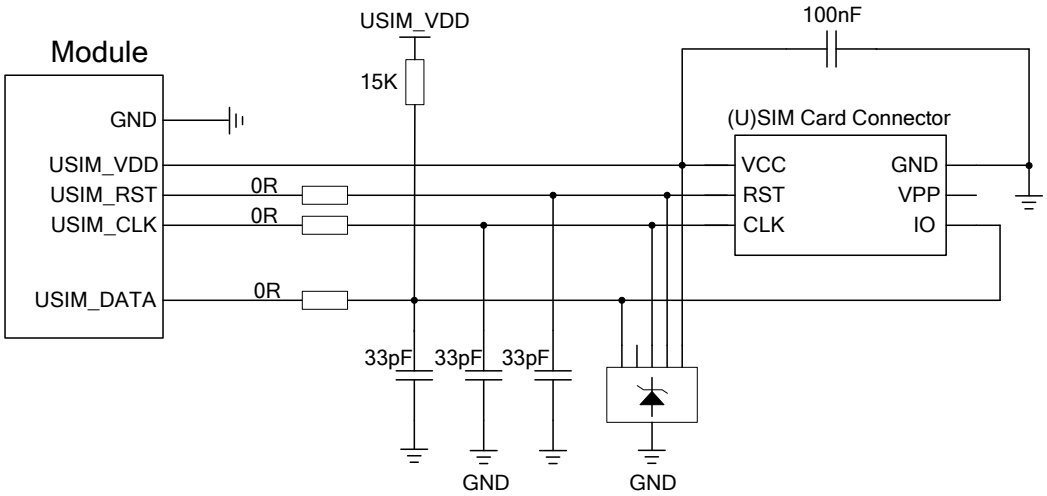


Figure 5: Reference Circuit of a 6-Pin (U)SIM Card Connector

In order to enhance the reliability and availability of the (U)SIM card in customers' applications, please follow the criteria below in (U)SIM circuit design:

- Keep placement of (U)SIM card connector to the module as close as possible. Keep the trace length as less than 200mm as possible.
- Keep (U)SIM card signals away from RF and power supply traces.
- Assure the ground between the module and the (U)SIM card connector short and wide. Keep the trace width of ground no less than 0.5mm to maintain the same electric potential. The decouple capacitor between USIM_VDD and GND should be not more than 1μF and be placed close to the (U)SIM card connector.
- To avoid cross-talk between USIM_DATA and USIM_CLK, keep them away from each other and shield them with surrounded ground.
- In order to offer good ESD protection, it is recommended to add a TVS whose parasitic capacitance should not be more than 15pF. The 0Ω resistors should be added in series between the module and the (U)SIM card so as to facilitate debugging. The 33pF capacitors are used for filtering interference of EGSM900. Please note that the (U)SIM peripheral circuit should be close to the (U)SIM card connector.
- The pull-up resistor on USIM_DATA line can improve anti-jamming capability when long layout trace and sensitive occasion are applied, and should be placed close to the (U)SIM card connector.

3.5. USB Interface

BG96 Mini PCIe is compliant with USB 2.0 specification, and supports high speed (480Mbps) mode and full speed (12Mbps) modes. It can only be used as a slave device. The USB interface is used for AT command communication, data transmission, GNSS NMEA output, software debugging, and firmware upgrade.

The following table shows the pin definition of USB interface.

Table: Pin Definition of USB Interface

Pin No.	Pin Name	I/O	Description	Comment
36	USB_DM	IO	USB differential data (-)	Require differential impedance of 90Ω
38	USB_DP	IO	USB differential data (+)	Require differential impedance of 90Ω

The following figure shows a reference circuit of USB interface.

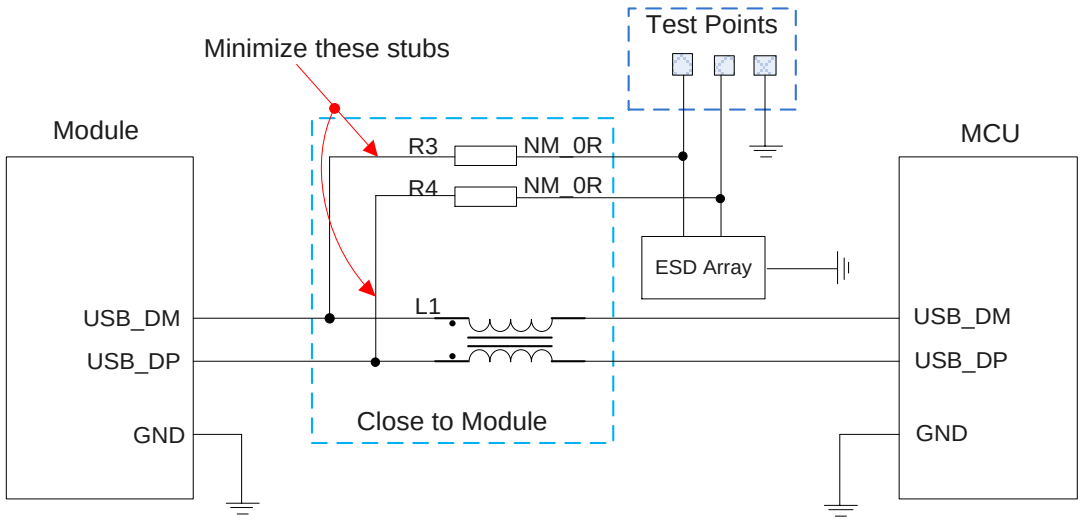


Figure 6: Reference Circuit of USB Interface

A common mode choke L1 is recommended to be added in series between the module and customer's MCU in order to suppress EMI spurious transmission. Meanwhile, the 0Ω resistors (R3 and R4) should be added in series between the module and the test points so as to facilitate debugging, and the resistors are not mounted by default. In order to ensure the integrity of USB data line signal, L1/R3/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.

The following principles should be complied with when design the USB interface, so as to meet USB 2.0 specification.

- It is important to route the USB signal traces as differential pairs with ground surrounded. The impedance of USB differential trace is 90Ω.
- Do not route signal traces under crystals, oscillators, magnetic devices and RF signal traces. It is important to 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 please pay attention to the selection of the device. Typically, the stray capacitance should be less than 2pF.
- Keep the ESD protection devices as close to the USB connector as possible.

3.6. UART Interface

The UART interface supports 9600bps, 19200bps, 38400bps, 57600bps, 115200bps and 230400bps baud rate. The default is 115200bps. This interface can be used for AT command communication.

The following table shows the pin definition of the UART interface.

Table 7: Pin Definition of UART Interface

Pin No.	Pin Name	I/O	Power Domain	Description
11	UART_RX	DI	3.3V	UART receive data
13	UART_TX	DO	3.3V	UART transmit data
23	UART_CTS	DI	3.3V	UART clear to send
25	UART_RTS	DO	3.3V	UART request to send

The power domain of main UART interface is 3.3V. Please pay attention to the signal direction while connecting the main UART interface to a peripheral MCU/RAM. A reference circuit is provided below:

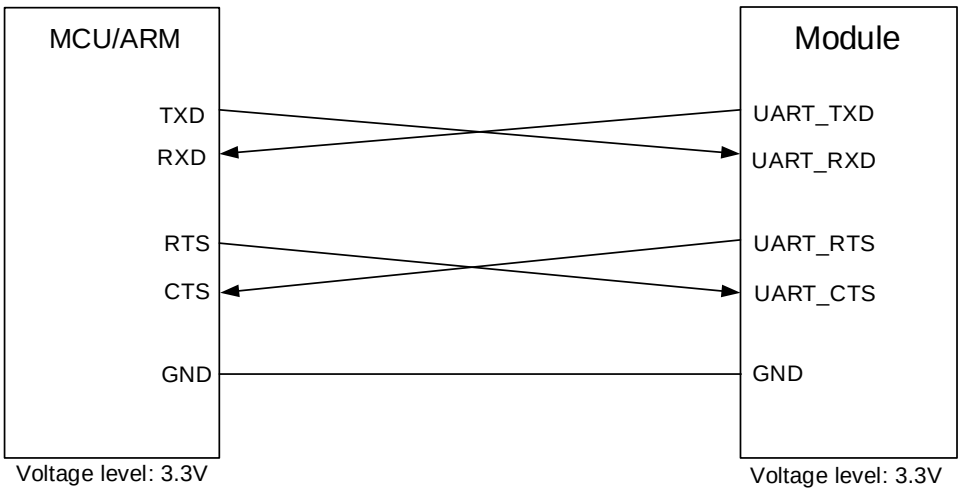


Figure 7: Reference Design of UART Interface

NOTE

AT+IPR command can be used to set the baud rate of the UART, and **AT+IFC** command can be used to set the hardware flow control (hardware flow control is disabled by default). Please refer to ***document [2]*** for details.

3.7. PCM and I2C Interfaces

BG96 Mini PCIe provides one Pulse Code Modulation (PCM) digital interface and one I2C interface.

The following table shows the pin definition of PCM and I2C interfaces that can be applied in audio codec design.

Table 8: Pin Definition of PCM and I2C Interfaces

Pin No.	Pin Name	I/O	Power Domain	Description
45	PCM_CLK [1)]	DO	1.8V	PCM clock signal
47	PCM_DOUT [1)]	DO	1.8V	PCM data output
49	PCM_DIN [1)]	DI	1.8V	PCM data input
51	PCM_SYNC [1)]	DO	1.8V	PCM frame synchronization
30	I2C_SCL	OD	1.8V	I2C serial clock. Require external pull-up to 1.8V.

32	I2C_SDA	OD	1.8V	I2C serial data. Require external pull-up to 1.8V.

NOTE

1) The digital audio (PCM) function is only supported in **Telematics** version.

The following figure shows a reference design of PCM interface with an external codec IC.

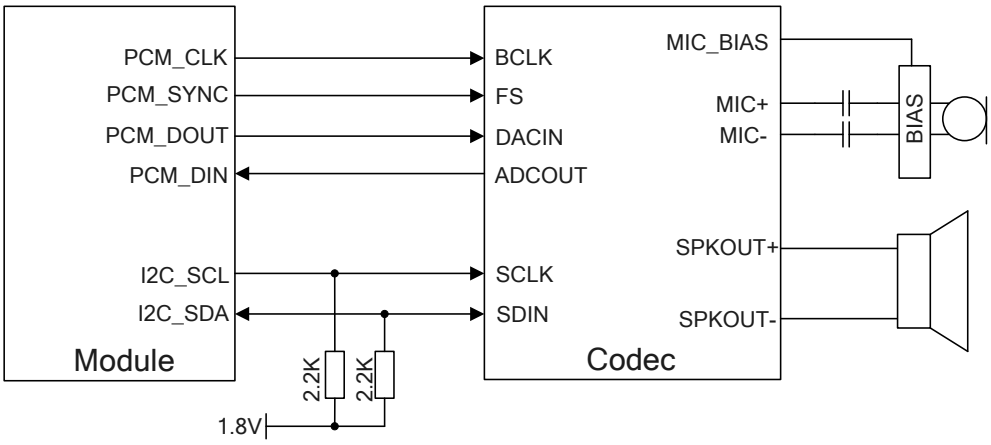


Figure 8: Reference Circuit of PCM Application with Audio Codec

3.8. Control and Indication Signals

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

Table 9: Pin Definition of Control and Indication Signals

Pin No.	Pin Name	I/O	Power Domain	Description
17	RI	DO	3.3V	Output signal to wake up the host.
31	DTR	DI	3.3V	Sleep mode control.
20	W_DISABLE#	DI	3.3V	Airplane mode control. Pulled up by default. Active low.
22	PERST#	DI	3.3V	Fundamental reset signal. Active low.
42	LED_WWAN#	OC		LED signal for indicating the network status of the module. Active low.

1	WAKE#	OC	Output signal to wake up the host.

3.8.1. RI Signal

The RI signal can be used to wake up the host. When a URC returns, there will be the following behaviors on the RI pin after executing **AT+QCFG="risignaltype","physical"** command.

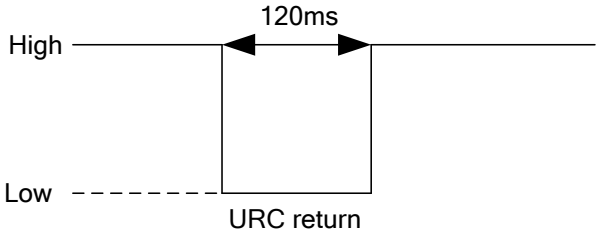


Figure 9: RI Behavior

3.8.2. DTR Signal

The DTR signal supports sleep mode control. Driving it to low level will wake up the module.

3.8.3. W_DISABLE# Signal

BG96 Mini PCIe module provides a W_DISABLE# signal to enable or disable the RF function (excluding GNSS). W_DISABLE# for RF function control is disabled by default, and **AT+QCFG="airplanecontrol",1** can be used to enable this function.

The W_DISABLE# pin is pulled up by default. Driving it low will let the module enter into airplane mode.

Table 10: Airplane Mode Control (Hardware Method)

W_DISABLE#	RF Function Status	Module Operation Mode
High level (default)	RF enabled	Normal mode
Low level	RF disabled	Airplane mode

The RF function can also be enabled/disabled with **AT+CFUN**, and the details are listed below.

Table 11: Airplane Mode Control (Software Method)

AT+CFUN=?	RF Function Status	Module Operation Mode
0	RF and (U)SIM disabled	Minimum functionality mode
1	RF enabled	Normal mode
4	RF disabled	Airplane mode

3.8.4. PERST# Signal

The PERST# signal can be used to force a hardware reset on the module. Customers can reset the module by driving PERST# low for 150ms~460ms and then releasing it. The reset timing is illustrated in the following figure.

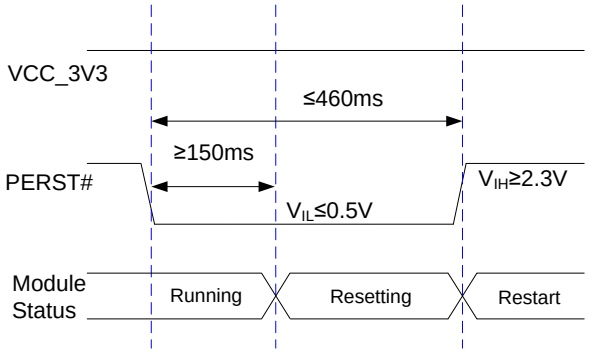


Figure 10: Timing of Resetting Module

3.8.5. LED_WWAN# Signal

The LED_WWAN# signal of BG96 Mini PCIe is used to indicate the network status of the module, and can absorb the current up to 40mA. According to the following circuit, in order to reduce the current of the LED, a resistor must be placed in series with the LED. The LED is emitting light when the LED_WWAN# output signal is active low.

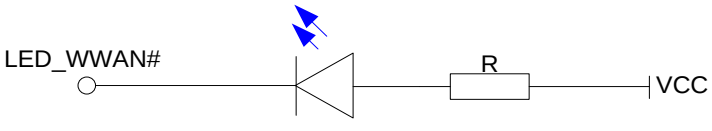


Figure 11: LED_WWAN# Signal Reference Circuit Diagram

There are two indication modes for LED_WWAN# signal to indicate network status, which can be switched through following AT commands:

- **AT+QCFG="ledmode",0 (Default setting)**
- **AT+QCFG="ledmode",1**

The following tables show the detailed network status indications of the LED_WWAN# signal.

Table 12: Indications of Network Status (AT+QCFG="ledmode",0, Default Setting)

Pin Status	Description
Flicker slowly (200ms High/1800ms Low)	Network searching
Flicker slowly (1800ms High/200ms Low)	Idle
Flicker quickly (125ms High/125ms Low)	Data transfer is ongoing

Table 13: Indications of Network Status (AT+QCFG="ledmode",1)

Pin Status	Description
Low Level (Light on)	Registered on network
High-impedance (Light off)	• No network coverage or not registered • W_DISABLE# signal is at low level. (Disable the RF) • **AT+CFUN=0**, **AT+CFUN=4**

3.8.6. WAKE# Signal

The WAKE# signal is an open collector signal which is similar to RI signal, but a host pull-up resistor and **AT+QCFG="risignaltype","physical"** command are required. When a URC returns, a 120ms low level pulse will be outputted. The state of WAKE# signal is shown as below.

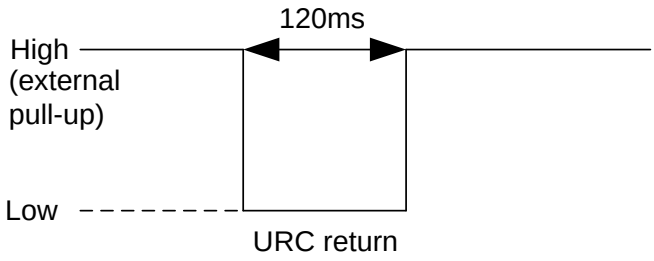


Figure 12: WAKE# Behavior

3.9. Antenna Interfaces

BG96 Mini PCIe antenna interfaces include a main antenna interface and a GNSS antenna interface.

3.9.1. Antenna Requirements

The following table shows the requirements on main antenna and GNSS antenna.

Table 14: Antenna Requirements

Type	Requirements
GNSS [1)]	Frequency range: 1559MHz ~1609MHz Polarization: RHCP or linear VSWR: < 2 (Typ.) Passive antenna gain: > 0dBi Active antenna noise figure: < 1.5dB Active antenna gain: > 0dBi Active antenna embedded LNA gain: < 17dB
LTE/GSM	VSWR: ≤ 2 Efficiency: > 30% Max Input Power (W): 50 Input Impedance (Ω): 50 Cable Insertion Loss: < 1dB (LTE B5/B8/B12/B13/B18/B19/B20/B26/B28, GSM850/EGSM900) Cable Insertion Loss: < 1.5dB (LTE B1/B2/B3/B4/B25/B39, DCS1800/PCS1900)

NOTE

[1)] It is recommended to use a passive GNSS antenna when LTE B13 or B14 is supported, as the use of active antenna may generate harmonics which will affect the GNSS performance.

3.9.2. Antenna Connectors and Mating Plugs

BG96 Mini PCIe is mounted with receptacle antenna connectors with dimensions shown as below.

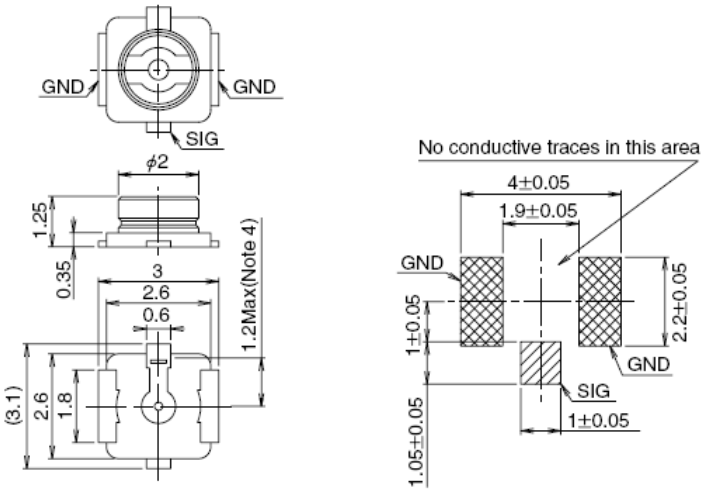


Figure 13: Dimensions of Antenna Connector (Unit: mm)

It is recommended to use U.FL-LP serial connectors listed in the following figure to match the receptacle connectors.

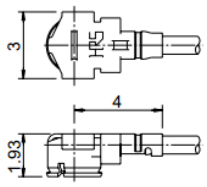
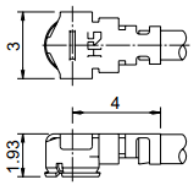
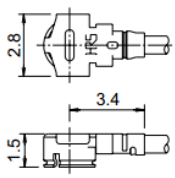
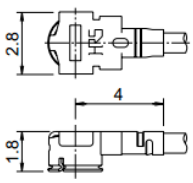
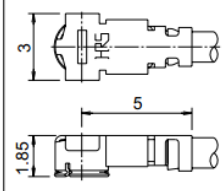
Part No.	U.FL-LP-040	U.FL-LP-066	U.FL-LP(V)-040	U.FL-LP-062	U.FL-LP-088
					
Mated Height	2.5mm Max. (2.4mm Nom.)	2.5mm Max. (2.4mm Nom.)	2.0mm Max. (1.9mm Nom.)	2.4mm Max. (2.3mm Nom.)	2.4mm Max. (2.3mm Nom.)
Applicable cable	Dia. 0.81mm Coaxial cable	Dia. 1.13mm and Dia. 1.32mm Coaxial cable	Dia. 0.81mm Coaxial cable	Dia. 1mm Coaxial cable	Dia. 1.37mm Coaxial cable
Weight (mg)	53.7	59.1	34.8	45.5	71.7
RoHS	YES				

Figure 14: Mechanicals of U.FL-LP Connectors

The following figure describes the space factor of mated connector.

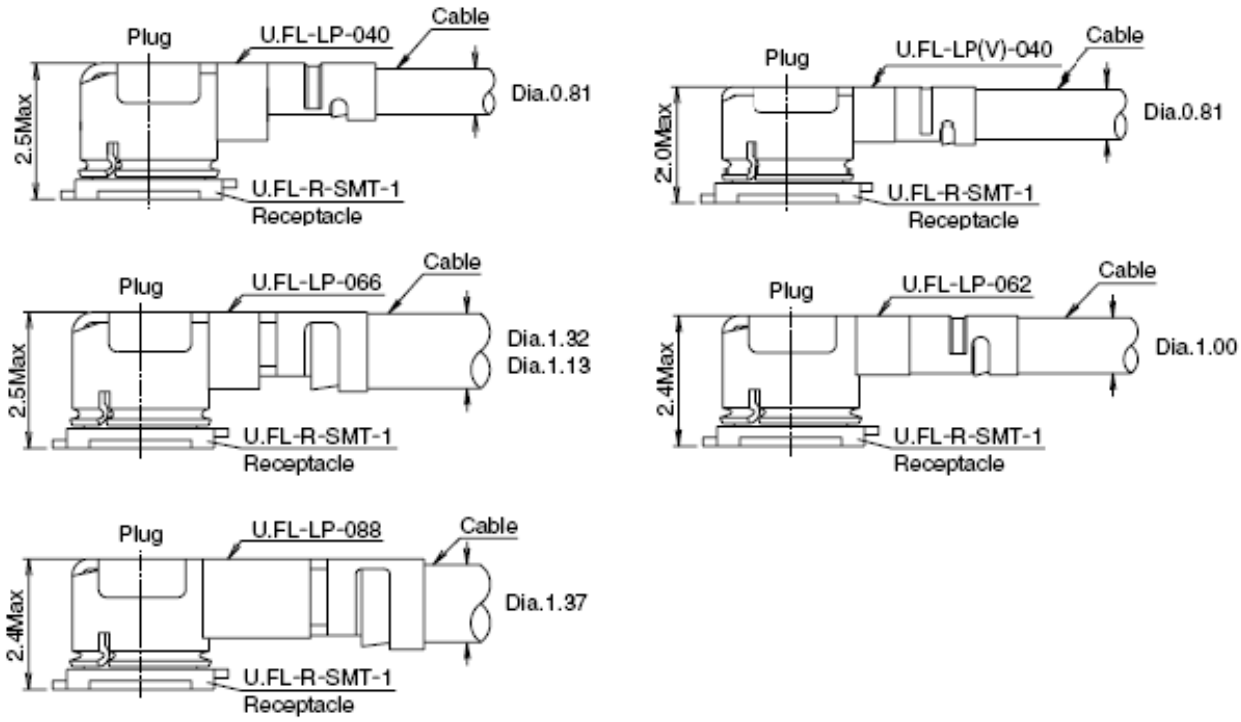


Figure 15: Space Factor of Mated Connector (Unit: mm)

For more details, please visit http://www.hirose.com.

4 Electrical, Reliability and Radio Characteristics

4.1. General Description

This chapter mainly describes the following electrical and radio characteristics of BG96 Mini PCIe:

- Power supply requirements
- I/O requirements
- RF characteristics
- GNSS receiver
- ESD characteristics
- Current consumption
- Thermal consideration

4.2. Power Supply Requirements

The input voltage of BG96 Mini PCIe is 3.3V±9%, as specified by *PCI Express Mini CEM Specifications 1.2*. The following table shows the power supply requirements of BG96 Mini PCIe.

Table 15: Power Supply Requirements

Parameter	Description	Min.	Typ.	Max.	Unit
VCC_3V3	Power Supply	3.0	3.3	3.6	V

4.3. I/O Requirements

The following table shows the I/O requirements of BG96 Mini PCIe.

Table 16: 3.3V power domain of I/O Requirements

Parameter	Description	Min.	Max.	Unit
V_{IH}	Input High Voltage	0.7 × VCC_3V3	VCC_3V3 + 0.3	V
V_{IL}	Input Low Voltage	-0.3	0.3 × VCC_3V3	V
V_{OH}	Output High Voltage	VCC_3V3 - 0.5	VCC_3V3	V
V_{OL}	Output Low Voltage	0	0.4	V

Table 17: 1.8V Power Domain of I/O Requirements

Parameter	Description	Min.	Max.	Unit
V_{IH}	Input High Voltage	1.2	2.0	V
V_{IL}	Input Low Voltage	-0.3	0.6	V
V_{OH}	Output High Voltage	1.35	1.8	V
V_{OL}	Output Low Voltage	0	0.45	V

NOTES

1. The PCM and I2C interfaces belong to 1.8V power domain and other I/O interfaces belong to VCC_3V3 power domain.
2. The maximum voltage value of V_{IL} for PERST# signal and W_DISABLE# signal is 0.5V.

4.4. RF Characteristics

The following tables show the conducted RF output power and receiving sensitivity of BG96 Mini PCIe module.

Table 18: BG96 Mini PCIe Conducted RF Output Power

Frequency	Max.	Min.
GSM850/EGSM900	33dBm±2dB	5dBm±5dB
DCS1800/PCS1900	30dBm±2dB	0dBm±5dB
GSM850/EGSM900 (8-PSK)	27dBm±3dB	5dBm±5dB
DCS1800/PCS1900 (8-PSK)	26dBm±3dB	0dBm±5dB
LTE-FDD B1/B2/B3/B4/B5/B8/B12/B13/B18/B19/B20/B26/B28	23dBm±2dB	< -39dBm
LTE-TDD B39	23dBm±2dB	< -39dBm

Table 19: BG96 Mini PCIe Conducted RF Receiving Sensitivity

Network	Band	Primary	Diversity	Sensitivity (dBm)	
				Cat M1/3GPP	Cat NB1[1)]/3GPP
LTE	LTE-FDD B1	Supported	Not Supported	-106.4/-102.3	-112/-107.5
	LTE-FDD B2			-106 /-100.3	-112/-107.5
	LTE-FDD B3			-106.4/-99.3	-112/-107.5
	LTE-FDD B4			-106.9/-102.3	-113/-107.5
	LTE-FDD B5			-107/-100.8	-114/-107.5
	LTE-FDD B8			-107.4/-99.8	-113/-107.5
	LTE-FDD B12			-107/-99.3	-113/-107.5
	LTE-FDD B13			-106/-99.3	-112.5/-107.5
	LTE-FDD B18			-107/-102.3	-114/-107.5
	LTE-FDD B19			-107/-102.3	-114/-107.5
	LTE-FDD B20			-107/-99.8	-113/-107.5
	LTE-FDD B25			-106/-99.8	-112/-107.5
	LTE-FDD B26			-107/-100.3	-112/-107.5

	LTE-FDD B28			-107/-100.8	-112.5/-107.5
	LTE-TDD B39			TBD /-103	Not Supported

Network	Band	Primary	Diversity	Sensitivity (dBm)
				GSM/3GPP
GSM	GSM850/GSM900	Supported	Not Supported	-109/-102
	DCS1800/PCS1900			-108.5/-102

NOTE

1) LTE Cat NB1 receiving sensitivity without repetitions.

4.5. GNSS Receiver

BG96 Mini PCIe integrates a GNSS receiver that supports IZat Gen 8C Lite of Qualcomm (GPS, GLONASS, BeiDou, Galileo, QZSS). Meanwhile, it supports Qualcomm gpsOneXTRA technology (one kind of A-GNSS). This technology will download XTRA file from the internet server to enhance the TTFF. XTRA file contains predicted GPS and GLONASS satellites coordinates and clock biases valid for up to 7 days. It is best if XTRA file is downloaded every 1-2 days. Additionally, BG96 Mini PCIe can support standard NMEA-0183 protocol and output NMEA messages with 1Hz via USB NMEA interface.

BG96 Mini PCIe GNSS engine is switched off by default. Customers must switch on it by AT command. Please refer to ***document [3]*** for more details about GNSS engine technology and configurations. A passive antenna should be used for the GNSS engine.

4.6. ESD Characteristics

The following table shows the ESD characteristics of BG96 Mini PCIe.

Table 20: ESD Characteristics of BG96 Mini PCIe

Part	Contact Discharge	Air Discharge	Unit
GND	±8	±12	kV
VCC_3V3	±6	±12	kV

Main antenna interface	±5	±10	kV
GNSS antenna interface	±2	±4	kV

4.7. Current Consumption

The following tables describe the current consumption of BG96 Mini PCIe series module.

Table 21: Current Consumption of BG96 Mini PCIe

Parameter	Description	Conditions	Typ. [1)]	Unit
	Idle State	DRX=0.32s @ Instrument (LTE Cat M1) with USB connected	19	mA
		DRX=1.28s @ Instrument (LTE Cat NB1) with USB connected	19	mA
	LTE Cat M1 data transfer (GNSS OFF)	LTE-FDD B1 @ 23.15dBm	323	mA
		LTE-FDD B2 @ 22.98dBm	302	mA
		LTE-FDD B3 @ 22.79dBm	302	mA
		LTE-FDD B4 @ 23.08dBm	306	mA
		LTE-FDD B5 @ 23.14dBm	302	mA
		LTE-FDD B8 @ 22.77dBm	281	mA
		LTE-FDD B12 @ 22.69dBm	317	mA
		LTE-FDD B13 @ 22.88dBm	290	mA
		LTE-FDD B18 @ 23.05dBm	286	mA
		LTE-FDD B19 @ 23.36dBm	283	mA
		LTE-FDD B20 @ 23.04dBm	308	mA
		LTE-FDD B25 @ TBD	TBD	mA
		LTE-FDD B26 @ 22.81dBm	303	mA
		LTE-FDD B28 @ 22.93dBm	326	mA
		LTE-TDD B39 @ TBD	TBD	mA

LTE Cat NB1 data transfer (GNSS OFF)		LTE-FDD B1 @ 23.1dBm	312	mA
		LTE-FDD B2 @ 23.07dBm	282	mA
		LTE-FDD B3 @ 23.25dBm	278	mA
		LTE-FDD B4 @ 23.28dBm	289	mA
		LTE-FDD B5 @ 23.2dBm	289	mA
		LTE-FDD B8 @ 23.1dBm	284	mA
		LTE-FDD B12 @ 22.62dBm	317	mA
		LTE-FDD B13 @ 22.83dBm	295	mA
		LTE-FDD B18 @ 22.89dBm	290	mA
		LTE-FDD B19 @ 23.28dBm	292	mA
		LTE-FDD B20 @ 23.15dBm	286	mA
		LTE-FDD B25 @ TBD	TBD	mA
		LTE-FDD B26 @ 23.51dBm	292	mA
		LTE-FDD B28 @ 23.14dBm	314	mA
GPRS data transfer (GNSS OFF)		GSM850 4UL1DL @ 29dBm	809	mA
		GSM850 3UL2DL @ 31dBm	721	mA
		GSM850 2UL3DL @ 32dBm	616	mA
		GSM850 1UL4DL @ 32dBm	385	mA
		EGSM900 4UL1DL @ 29dBm	809	mA
		EGSM900 3UL2DL @ 30dBm	710	mA
		EGSM900 2UL3DL @ 31dBm	600	mA
		EGSM900 1UL4DL @ 32dBm	375	mA
		DCS1800 4UL1DL @ 28dBm	737	mA
		DCS1800 3UL2DL @ 28dBm	591	mA
		DCS1800 2UL3DL @ 29dBm	448	mA

		DCS1800 1UL4DL @ 29dBm	298	mA
		PCS1900 4UL1DL @ 29dBm	854	mA
		PCS1900 3UL2DL @ 30dBm	705	mA
		PCS1900 2UL3DL @ 29dBm	505	mA
		PCS1900 1UL4DL @ 29dBm	311	mA
	EDGE data transfer (GNSS OFF)	GSM850 4UL1DL @ 25dBm	563	mA
		GSM850 3UL2DL @ 25dBm	458	mA
		GSM850 2UL3DL @ 26dBm	352	mA
		GSM850 1UL4DL @ 26dBm	250	mA
		EGSM900 4UL1DL @ 25dBm	553	mA
		EGSM900 3UL2DL @ 25dBm	444	mA
		EGSM900 2UL3DL @ 25dBm	348	mA
		EGSM900 1UL4DL @ 26dBm	246	mA
		DCS1800 4UL1DL @ 24dBm	537	mA
		DCS1800 3UL2DL @ 24dBm	439	mA
		DCS1800 2UL3DL @ 24dBm	337	mA
		DCS1800 1UL4DL @ 25dBm	224	mA
		PCS1900 4UL1DL @ 25dBm	545	mA
		PCS1900 3UL2DL @ 25dBm	439	mA
		PCS1900 2UL3DL @ 25dBm	345	mA
		PCS1900 1UL4DL @ 25dBm	219	mA
	LTE Voice (GNSS OFF)	Voice @ LTE Cat M1 network	TBD	mA

NOTE

[1)] means the average value.

Table 22: GNSS Current Consumption of BG96 Mini PCIe

Parameter	Description	Conditions	Typ.	Unit
I_{VBAT} (GNSS)	Searching (AT+CFUN=0)	Cold start @ Passive Antenna	50	mA
		Lost state @ Passive Antenna	50.38	mA
	Tracking (AT+CFUN=0)	Instrument environment	24	mA
		Open Sky @ Passive Antenna	TBD	mA
		Open Sky @ Active Antenna	TBD	mA

5 Dimensions and Packaging

5.1. General Description

This chapter mainly describes mechanical dimensions as well as packaging specification of BG96 Mini PCIe module. All dimensions are measured in millimeter (mm), and the dimensional tolerances are ±0.05mm unless otherwise specified.

5.2. Mechanical Dimensions of BG96 Mini PCIe

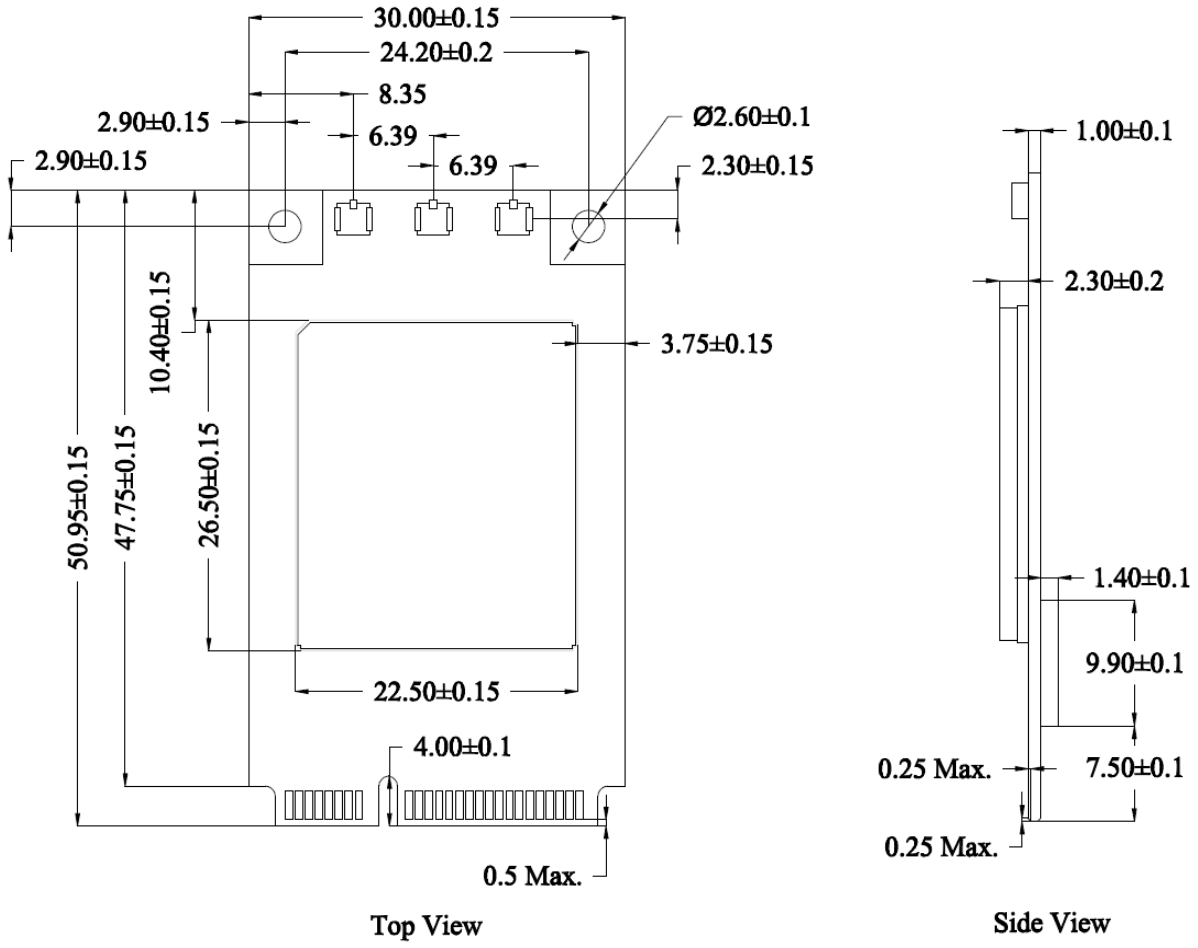


Figure 16: Mechanical Dimensions of BG96 Mini PCIe

5.3. Standard Dimensions of Mini PCI Express

The following figure shows the standard dimensions of Mini PCI Express. Please refer to ***document [1]*** for detailed A and B.

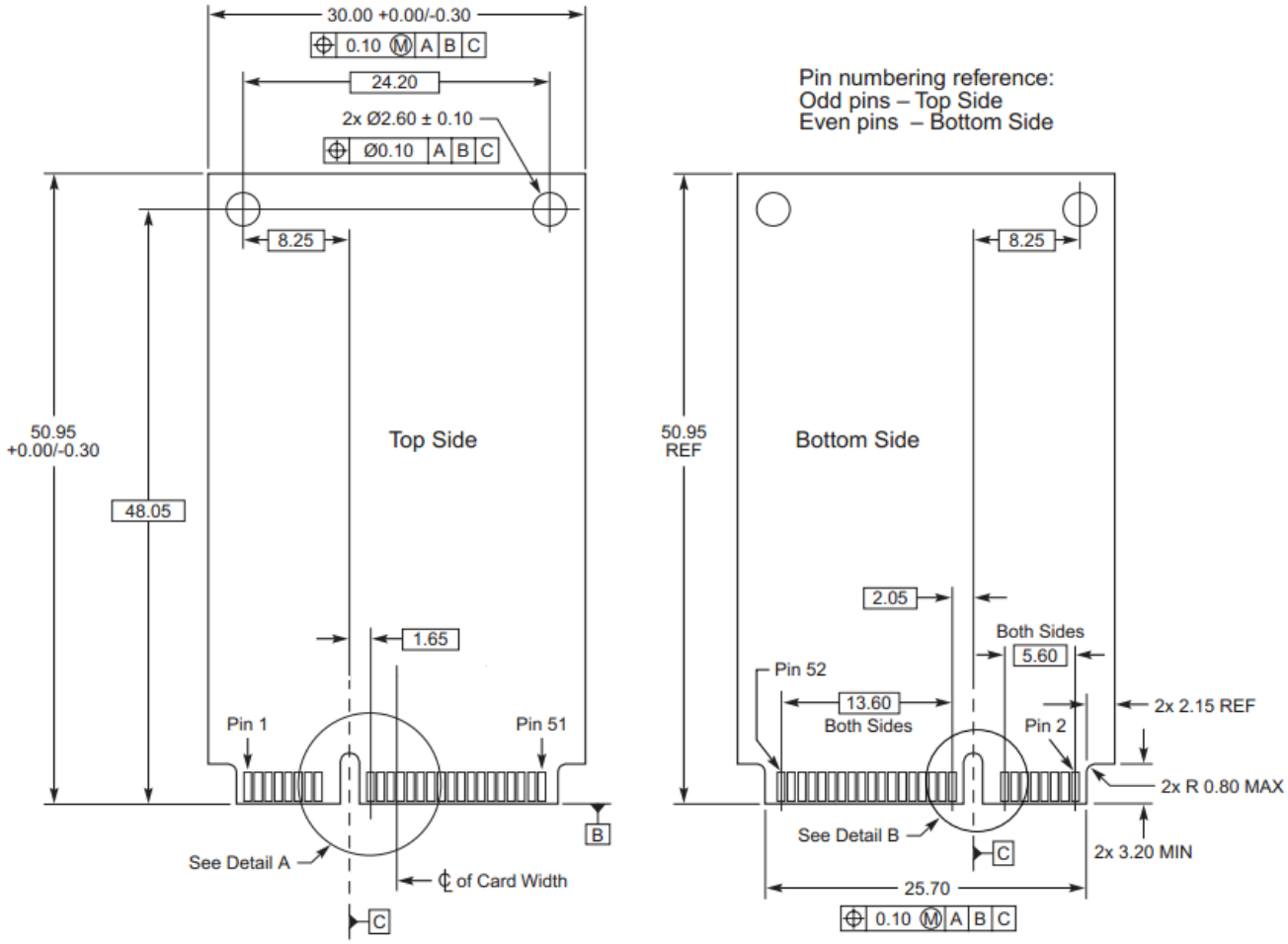


Figure 17: Standard Dimensions of Mini PCI Express

BG96 Mini PCIe adopts a standard Mini PCI Express connector which compiles with the directives and standards listed in the ***document [1]***. The following figure takes the Molex 679105700 as an example.

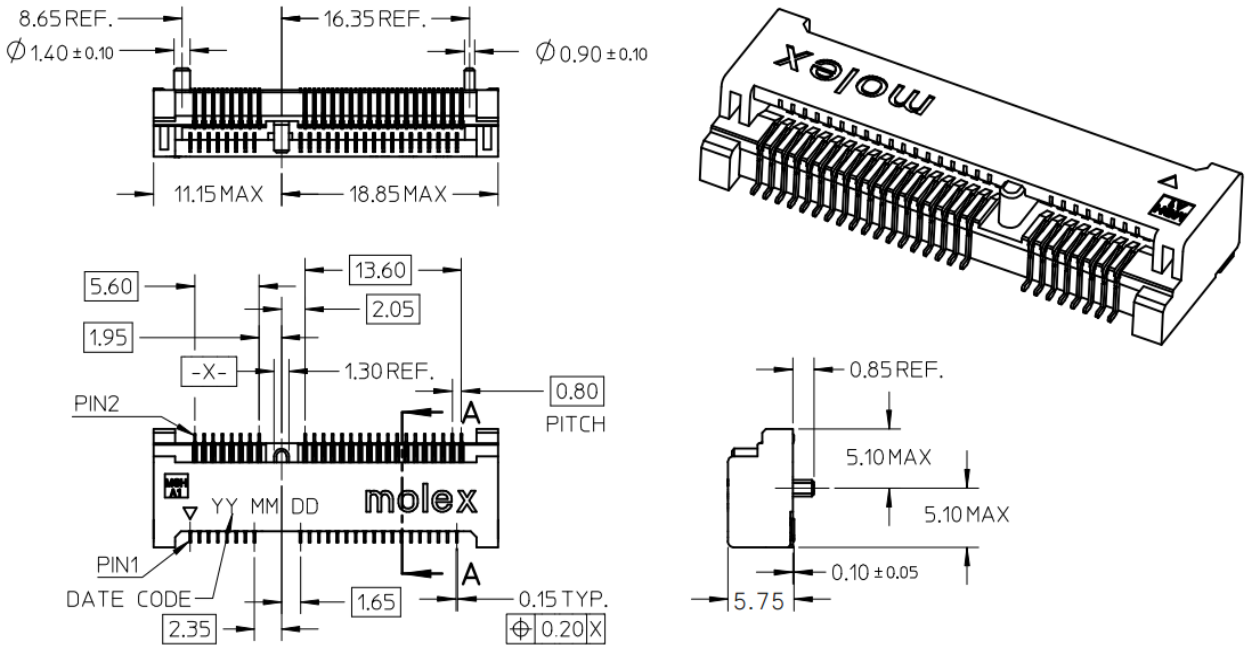


Figure 18: Dimensions of the Mini PCI Express Connector (Molex 679105700)

5.4. Packaging Specification

BG96 Mini PCIe is packaged in a tray. Each tray contains 10 modules. The smallest package contains 100 modules.

6 Appendix A References

Table 23: Related Documents

SN	Document Name	Remark
[1]	PCI Express Mini Card Electromechanical Specification Revision 1.2	Mini PCI Express specification
[2]	Quectel_BG96_AT_Commands_Manual	BG96 AT commands manual
[3]	Quectel_BG96_GNSS_AT_Commands_Manual	BG96 GNSS AT commands manual

Table 24: Terms and Abbreviations

Abbreviation	Description
bps	Bits Per Second
CS	Coding Scheme
CTS	Clear to Send
DFOTA	Delta Firmware upgrade Over The Air
DL	Downlink
DTE	Data Terminal Equipment
DTR	Data Terminal Ready
EMI	Electromagnetic Interference
ESD	Electrostatic Discharge
ESR	Equivalent Series Resistance
FDD	Frequency Division Duplexing
GLONASS	GLObalnaya Navigatsionnaya Sputnikovaya Sistema, the Russian Global Navigation Satellite System
GMSK	Gaussian Minimum Shift Keying

GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GSM	Global System for Mobile Communications
kbps	kilobits per second
LED	Light Emitting Diode
LTE	Long Term Evolution
Mbps	Million Bits Per Second
MCU	Micro Control Unit
ME	Mobile Equipment
NMEA	National Marine Electronics Association
PCM	Pulse Code Modulation
PDA	Personal Digital Assistant
PDU	Protocol Data Unit
POS	Point of Sale
PPP	Point-to-Point Protocol
RF	Radio Frequency
RTS	Ready To Send
Rx	Receive Direction
SMS	Short Message Service
TX	Transmitting Direction
TVS	Transient Voltage Suppressor
UART	Universal Asynchronous Receiver & Transmitter
UL	Uplink
URC	Unsolicited Result Code
USB	Universal Serial Bus
(U)SIM	(Universal) Subscriber Identification Module

7 Appendix B GPRS Coding Schemes

Table 25: Description of Different Coding Schemes

Scheme	CS-1	CS-2	CS-3	CS-4
Code Rate	1/2	2/3	3/4	1
USF	3	3	3	3
Pre-coded USF	3	6	6	12
Radio Block excl.USF and BCS	181	268	312	428
BCS	40	16	16	16
Tail	4	4	4	-
Coded Bits	456	588	676	456
Punctured Bits	0	132	220	-
Data Rate Kb/s	9.05	13.4	15.6	21.4

8 Appendix C GPRS Multi-slot Classes

Twenty-nine classes of GPRS multi-slot modes are defined for MS in GPRS specification. Multi-slot classes are product dependent, and determine the maximum achievable data rates in both the uplink and downlink directions. Written as 3+1 or 2+2, the first number indicates the amount of downlink timeslots, while the second number indicates the amount of uplink timeslots. The active slots determine the total number of slots the GPRS device can use simultaneously for both uplink and downlink communications.

The description of different multi-slot classes is shown in the following table.

Table 26: GPRS Multi-slot Classes

Multislot Class	Downlink Slots	Uplink Slots	Active Slots
1	1	1	2
2	2	1	3
3	2	2	3
4	3	1	4
5	2	2	4
6	3	2	4
7	3	3	4
8	4	1	5
9	3	2	5
10	4	2	5
11	4	3	5
12	4	4	5
13	3	3	NA
14	4	4	NA

15	5	5	NA
16	6	6	NA
17	7	7	NA
18	8	8	NA
19	6	2	NA
20	6	3	NA
21	6	4	NA
22	6	4	NA
23	6	6	NA
24	8	2	NA
25	8	3	NA
26	8	4	NA
27	8	4	NA
28	8	6	NA
29	8	8	NA
30	5	1	6
31	5	2	6
32	5	3	6
33	5	4	6

9 Appendix D EDGE Modulation and Coding Schemes

Table 27: EDGE Modulation and Coding Schemes

Coding Schemes	Modulation	Coding Family	1 Timeslot	2 Timeslot	4 Timeslot
CS-1:	GMSK	/	9.05kbps	18.1kbps	36.2kbps
CS-2:	GMSK	/	13.4kbps	26.8kbps	53.6kbps
CS-3:	GMSK	/	15.6kbps	31.2kbps	62.4kbps
CS-4:	GMSK	/	21.4kbps	42.8kbps	85.6kbps
MCS-1	GMSK	C	8.80kbps	17.60kbps	35.20kbps
MCS-2	GMSK	B	11.2kbps	22.4kbps	44.8kbps
MCS-3	GMSK	A	14.8kbps	29.6kbps	59.2kbps
MCS-4	GMSK	C	17.6kbps	35.2kbps	70.4kbps
MCS-5	8-PSK	B	22.4kbps	44.8kbps	89.6kbps
MCS-6	8-PSK	A	29.6kbps	59.2kbps	118.4kbps
MCS-7	8-PSK	B	44.8kbps	89.6kbps	179.2kbps
MCS-8	8-PSK	A	54.4kbps	108.8kbps	217.6kbps
MCS-9	8-PSK	A	59.2kbps	118.4kbps	236.8kbps