

LTE-Advanced PCI Express M.2 Module (LTE, UMTS)

Engineering Requirements Specification



Project code: **T77W968C9**

Solution: SDX20-2+SDR845

SKU: WW-5-S3

Foxconn PN	Customer PN
T77W968.50	NVCYP
T77W968.51	22XR0

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Modification History

Rev	Date	Originator	Comment
R1.0	2019/12/14	Shu-yu.Li	Initial release for SDX20-2 CAT9 variant SKU

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1. General Description

T77W968C9 is designed to enable wireless data connectivity for notebook computer or any other device compatible with the PCI Express M.2 Specification 3042 type Key.B slot.

T77W968C9 is the data card solution that delivers wireless wide-area network (WWAN) connectivity for the LTE, UMTS (HSDPA/HSUPA/HSPA+/DC-HSPA+) and GPS/Glonass/Beidou/ Galileo protocols in one hardware configuration.

SKU		WW-5-S3 / T77W968C9
Carrier Support		NA: AT&T, Verizon, Sprint WW: Vodafone, Orange, Telefonica-O2 EU: Deutsche Telekom, Swisscom APAC: Telstra, Optus, Docomo, KDDI China: CMCC/CUCC/CTCC * Carrier engagement based on real business agreement
QCT Solution		SDX20-2+SDR845+PMX20
4G	Mode	FDD / TDD
	Support Band	LB 26(5)/12(17)/13/14 MB 2/25/4/66 HB 7/30/38/41
	Carrier Aggregation	3xDL CA (Up to 60MHz, 64QAM)
	Cat (DL/UL Mbps)	ue-Category UL 5 (UL: 75Mbps) + ue-Category DL 9 (DL: 450Mbps) with 2X2 MIMO
3G	WCDMA	HSPA+ Rel8 (DL/UL: up to 42/11 Mbps)
	Support Band	B2/4/5
GNSS		GPS/GLONASS/Beidou/Galileo
Tunable antenna		Reserve MiPi/GPIO at M.2 interface for external antenna tuner
eSIM		Dual SIM with eSIM on board, Dual SIM and single active (DSSA)
Interface		USB2.0, USB3.0
Form factor		3042 PCIe M.2 Key.B Single side

1.1 System Main Feature

Feature	Description
Physical	PCI express M.2 module, size 3042,Key.B,75Pin golden finger
Electrical	Single VCC supply (3.135V~4.4V follow M.2 standard)
Dimension	Dimensions (L × W × H): 42 mm × 30 mm × 2.3 mm, maximum height=2.38mm (add PCB tolerance=0.08mm)
Shielding design	Shield case on board design, no additional shielding requirement
Weight	Approximately ~6g
USIM	Off-board USIM connector supported
Operating Bands	WCDMA/HSDPA/HSUPA/HSPA+ operating bands: Band 2: 1850 to 1910 MHz (UL), 1930 to 1990 MHz (DL) Band 4: 1710 to 1755 MHz (UL), 2110 to 2155 MHz (DL) Band 5: 824 to 849 MHz (UL), 869 to 894 MHz (DL)
	LTE FDD/TDD operating bands: Band 2: 1850 to 1910 MHz (UL), 1930 to 1990 MHz (DL) Band 4: 1710 to 1755 MHz (UL), 2110 to 2155 MHz (DL) Band 5: 824 to 849 MHz (UL), 869 to 894 MHz (DL) Band 7: 2500 to 2570 MHz (UL), 2620 to 2690 MHz (DL) Band 12: 699 to 716 MHz (UL), 729 to 746 MHz (DL) Band 13: 777 to 787 MHz (UL), 746 to 756 MHz (DL) Band 14: 788 to 798 MHz (UL), 758 to 768 MHz (DL) Band 17: 704 to 716 MHz (UL), 734 to 746 MHz (DL) Band 25: 1850 to 1915 MHz (UL), 1930 to 1995 MHz (DL) Band 26: 814 to 849 MHz (UL), 859 to 894 MHz (DL) Band 29: 717 to 728 MHz (DL) Band 30: 2305 to 2315 MHz (UL), 2350 to 2360 MHz (DL) Band 38: 2570 to 2620 MHz (UL/DL) Band 41: 2496 to 2690 MHz (UL/DL) Band 66: 1710 to 1800 MHz (UL), 2110 to 2200 MHz (DL)
Diversity/2nd Rx	All UMTS operating bands All LTE operating bands

GNSS	GPS: L1 (1575.42MHz) GLONASS: L1 (1602MHz) Beidou (1561.098MHz) Galileo E1 (1575.42)
USIM Voltage	Support 1.8V and 2.85V, and auto detects follow SIM card type
Antenna connectors	MAIN: Support all LTE& UMTS bands AUX: Supports all LTE& UMTS bands Diversity and GPS simultaneously
Throughput	WCDMA CS: DL 64 kbps /UL 64 kbps WCDMA PS: DL 384 kbps /UL 384 kbps HSPA+: DL 21.6 Mbps /UL 5.76 Mbps DC-HSPA+: DL 42 Mbps/UL 5.76 Mbps LTE Cat4: DL:150 Mbps/UL 50 Mbps LTE Cat6: DL: 300 Mbps/UL 50 Mbps LTE Cat9: DL: 450 Mbps/UL 50 Mbps

LTE Air Interface

LTE Rel11

- DL - 450 Mbps / 6-layer / 60 MHz CA
- UL - 75 Mbps / None CA
- 64 QAM DL / 64 QAM UL
- FDD + TDD CA
- Advance LTE IC + NAIC (with CRS only)

WCDMA/HSPA Air Interface

- R99
All modes and data rates for WCDMA FDD
- R5 HSDPA
PS data speeds up to 7.2 Mbps on the downlink
- R6 HSUPA
E-DCH data rates of up to 5.76 Mbps for 2 ms TTI (UE category 6) uplink
- R7 HSPA+
Downlink 64 QAM SISO: up to 21 Mbps
Downlink 16 QAM 2X2 MIMO: up to 28 Mbps
- R8 DC-HSPA+
Downlink dual carrier with 64 QAM (SISO); up to 42 Mbps

GNSS

- Customizable tracking session

- Automatic tracking session on startup
- Concurrent standalone GPS, GLONASS , BeiDou and Galileo
- gpsOneXTRA with GPS + GLONASS + BeiDou + Galileo support

1.2 Carrier aggregation combination

1.2.1. Refer to Qualcomm documents 80-P8641-123 Rev. A, Published: 2017/7/31.

Remark:T77W968C9 hardware design can support follow CA combination, but the Final CA combinations plan depends on carrier engagement and Qualcomm software design.

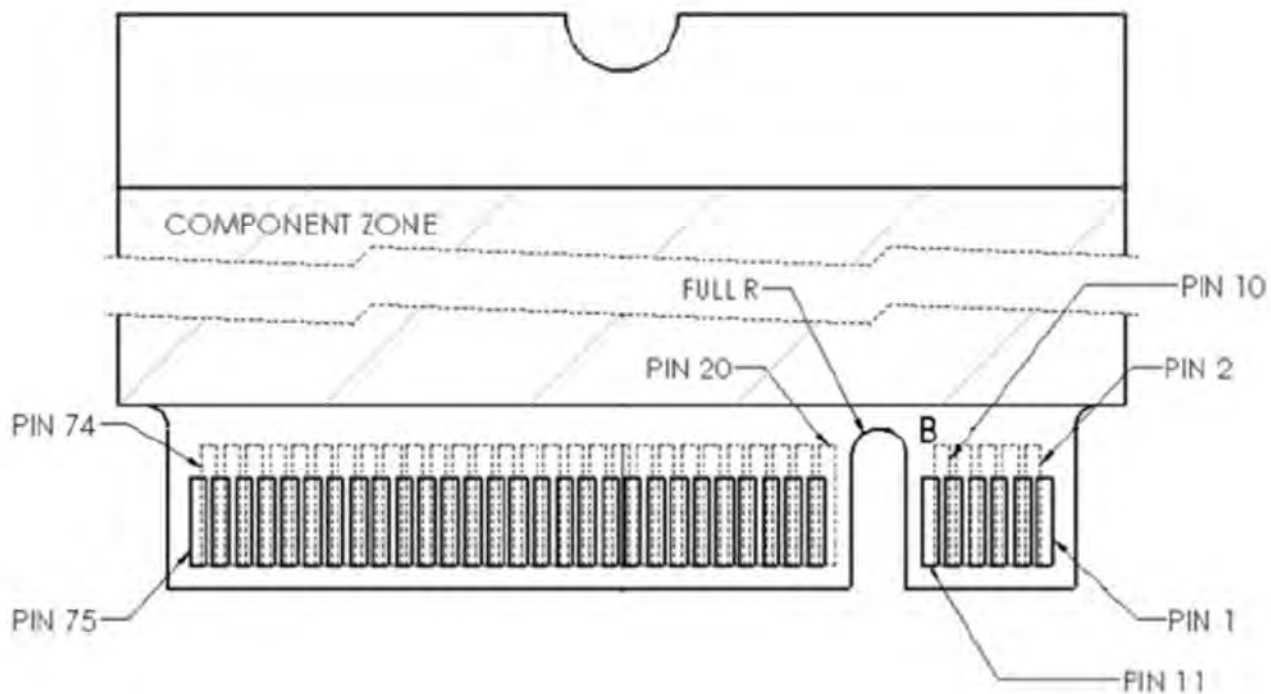
1.2.2. Qualcomm SDX20-2 support 2CA+64QAM (up to Cat9) and Rel11 (FDD+TDD CA) which is mandatory for NA/AU/JP carriers.

Region	Carriers	2CCs DL CA Combinations
NA	AT&T	CA_12A-30A; CA_12A-66A; CA_14A-30A; CA_14A-66A; CA_2A-12A; CA_2A-14A; CA_2A-29A; CA_2A-30A; CA_2A-5A; CA_2A-66A; CA_29A-30A; CA_29A-66A; CA_30A-66A; CA_5A-30A; CA_5A-66A; CA_5B
NA	Verizon	CA_13A-66A; CA_2A-13A; CA_2A-2A; CA_2A-4A; CA_2A-5A; CA_2A-66A; CA_4A-13A; CA_4A-4A; CA_4A-5A; CA_5A-66A; CA_5B; CA_66A-66A; CA_66B; CA_66C
NA	Sprint	CA_25A-25A; CA_25A-26A; CA_41C;
AU	Telstra	CA_1A-3A; CA_3A-28A; CA_3A-7A; CA_3A-8A; CA_3C; CA_7A-28A; CA_7C;
JP	Docomo	CA_1A-19A; CA_1A-26A; CA_1A-28A; CA_1A-41A; CA_1A-5A; CA_1C; CA_26A-41A; CA_38C; CA_39A-41A; CA_39C; CA_3A-19A; CA_3A-26A; CA_3A-28A; CA_3A-5A; CA_3A-7A; CA_3C; CA_40C; CA_41C; CA_5A-7A; CA_7A-28A; CA_7C;
JP	KDDI	CA_1A-18A; CA_1A-26A; CA_41C
EU	Vodafone	CA_1A-20A; CA_1A-3A; CA_1A-7A; CA_20A-32A; CA_3A-20A; CA_3A-28A; CA_3A-38A; CA_3A-3A; CA_3A-5A; CA_3A-7A; CA_3C; CA_7A-20A; CA_7A-28A;
Region	Carriers	3CCs DL CA Combinations

NA	AT&T	CA_12A-30A-66A; CA_12A-66A-66A; CA_14A-66A-66A; CA_2A-12A-66A; CA_2A-12A-30A; CA_2A-14A-30A; CA_2A-2A-30A; CA_2A-2A-5A; CA_2A-2A-66A; CA_2A-5A-66A; CA_2A-5A-30A; CA_2A-5B; CA_2A-30A-66A; CA_2A-66A-66A; CA_30A-66A-66A; CA_5A-30A-66A; CA_5A-66A-66A; CA_5B-30A; CA_5B-66A
NA	Verizon	CA_13A-66A-66A; CA_13A-66C; CA_2A-13A-66A; CA_2A-2A-13A; CA_2A-2A-4A; CA_2A-2A-5A; CA_2A-2A-66A; CA_2A-4A-13A; CA_2A-4A-4A; CA_4A-4A-5A; CA_2A-4A-5A; CA_2A-5A-66A; CA_2A-66A-66A; CA_2A-66C; CA_2A-4A-13A; CA_5A-66A-66A; CA_5A-66C; CA_66A-66B; CA_66A-66C; CA_66D; CA_13A-66B; CA_2A-66B; CA_5A-66B
AU	Telstra	CA_3A-7A-28A; CA_3C-28A; CA_7C-28A;
JP	Docomo	CA_1A-3A-19A
WW	Vodafone	CA_1A-3A-20A; CA_1A-3A-28A; CA_1A-3A-7A; CA_1A-7A-20A; CA_3A-7A-20A; CA_3A-7A-28A; CA_3C-20A; CA_3C-5A;
WW	Telefonica	CA_3A-7A-20A;

1.3.1 Golden finger Pin sequence

Figure 1-2 shows the sequence of pins on the 75-pin signal interface of M.2 3042 Key.B.



1.4.2 Pin definition

Table 1-1 M.2 Pin definition.

			CONFIG_2 (GND)	75	
74	3.3V		GND	73	
72	3.3V		GND	71	
70	3.3V		CONFIG_1 (GND)	69	
68	ANT_CONFIG (I)(0/1.8V)	See item 1.5.10	RESET# (I)(0/1.8V)	67	
66	SIM DETECT (I)		ANTCTL3 (O)(0/1.8V)	65	1. Pin59~65 for external GPIO antenna tuner control 2. Pin 59 reserve for PCM interface (PCM_Out) 3. Pin 61 reserve for PCM interface (PCM_CLK) 4. Configure by SW
64	COEX_TXD (O)(0/1.8V)	Dual layout 3GPIOs and UART I/F for LTE / Wi-Fi coexistence	ANTCTL2 (O)(0/1.8V)	63	
62	COEX_RXD(I)(0/1.8V)		ANTCTL1 (O)(0/1.8V)	61	
60	COEX3(I/O)(0/1.8V)		ANTCTL0 (O)(0/1.8V)	59	
58	MIPI_CLK (0/1.8V)	For external tunable antenna (MIPI)	GND	57	
56	MIPI_DATA (0/1.8V)		Not connect (Reserve as REFCLKP)	55	Without PCIe support
54	PEWAKE# (IO)(0/3.3V)		Not connect (Reserve as REFCLKN)	53	
52	CLKREQ# (IO)(0/3.3V)		GND	51	
50	PERST# (I)(0/3.3V)		Not connect (Reserve as PERp0)	49	Without PCIe support
48	UIM_2 - PWR (O)	USIM_2 for on board eSIM and reserve for external 2 nd USIM	Not connect (Reserve as PERn0)	47	
46	UIM_2 - RESET (O)		GND	45	
44	UIM_2 - CLK (O)		Not connect (Reserve as PETp0)	43	Without PCIe support
42	UIM_2 - DATA (IO)		Not connect (Reserve as PETn0)	41	
40	SIM DETECT (2)		GND	39	
38	Not connect		USB3.0 - Rx+	37	
36	UIM_1 - PWR (O)	USIM_1 connect to external SIM socket	USB3.0 - Rx -	35	
34	UIM_1 - DATA (IO)		GND	33	
32	UIM_1 - CLK (O)		USB3.0 - Tx+	31	
30	UIM_1 - RESET (O)		USB3.0 - Tx -	29	
28	GPIO_8 - AUDIO_3 (IO) (0/1.8V)	Reserve PCM interface (PCM_Sync)	GND	27	
26	GPIO_10 - W_DISABLE2# (I) (0/3.3V)	3.3V I/O	DPR (I)(0/1.8V)	25	1.8V I/O
24	GPIO_7 - AUDIO_2 (IO) (0/1.8V)	Antenna tuner power (1.8V)	GPIO_11 - WoWWA N# (O)(0/1.8V)	23	
22	ANT_TUNER_CONFIG(I)(0/1.8V)	Antenna tuner mode control	CONFIG_0 (GND)	21	
20	GPIO_5 - AUDIO_0 (IO)(0/2.7V)	Antenna tuner power (2.7V)	Module Key	13~19	
12~18	Module Key		GND	11	
10	GPIO_9 - LED#1 (O)(Open drain)		USB_D -	9	
8	W_DISABLE1# (I)(0/3.3V)	3.3V I/O	USB_D+	7	
6	FULL_CARD_POWER_OFF# (I)(0/3.3V)	3.3V I/O	GND	5	
4	3.3V		GND	3	
2	3.3V		CONFIG_3 (N/C)	1	

Notes: Foxconn will provide one excel file to explain the PCIe M.2 Pin connection after project award.

1.4 Platform connection design

1.5.1 Configuration Pins

The M.2 module provides 4 configuration pins. T77W968C9 is configured as WWAN-USB3.0- 0, refer to PCIe M.2_Rev 1.1.

Item	Module configuration decodes				Module type	Port configuration
Config	Config_0	Config_1	Config_2	Config_3	WWAN-USB3.0	0
Pin No.	21	69	75	1		
State	GND	GND	GND	NC		

1.5.2 Power and ground

(1) Power Rail Parameters

Parameter	Min	Type	Max	Units
Operating voltage	3.135	3.3	4.4	Vdc

The operating voltage was defined in PCIe M.2_Rev 1.1 standard as 3.135V~4.4V.

(2) 3.135 V is the minimum voltage supplied to LTE M.2 card by the host platform, and VCC must never be under 3.135 V in any case. As our experiment, if we set the VCC=3.0V, the M.2 card will power off possibly when M.2 card working at +23dBm continue mode.

(3) The LTE M.2 module provides 5 power pins and 11 Ground pins. To ensure that the LTE module works normally, all the pins must be connected.

1.5.3 Full_Card_Power_Off

The M.2 LTE module can be controlled to power on/off by the Full_Card_Power_Of pin.

Item	State	M.2 card state
1	Low	Powers off, It's internally pulled down by 100K ohm resistor
2	High	Powers on, it is 3.3V tolerant but can be driven by either 1.8V or 3.3V GPIO.

The recommended connections as below



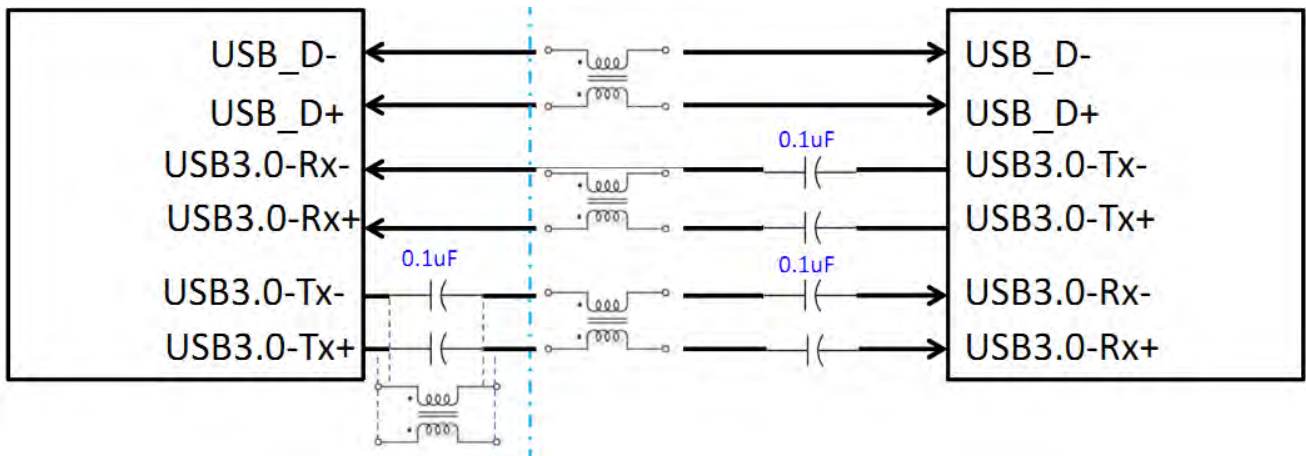
1.5.4 USB3.0 interface

T77W968C9 module is compliant with USB3.0 in all modes. When two devices are connected via a USB3.0 interface, one of the devices must act as a host, and the other device must act as a peripheral. The host is responsible for initiating and controlling traffic on the bus.

Figure 1-3 USB3.0 interface.

1. Reserve choke on all the USB signals in platform for noise debug.
2. Reserve 0.1uF capacitor on USB3.0 TX/Rx paths.
3. Co-layout USB3 choke and 0.1uF capacitor on module side for noise debug

Notes: All the above components should be covered by shielding cover.



Remark:

USB configuration the module supports

Win7: DIAG, RmNet, Modem, NMEA

Win10: MBIM, GNSS

Linux: DIAG, RmNet, Modem, NMEA

1.5.5 W_DISABLE#

This control setting is implementation-specific and represents the collective intention of the host software to manage radio operation. T77W968C9 provides a hardware pin (W_DISABLE#) to disable or enable the radio. Besides, the radio can also be enabled or disabled through software AT commands.

Item	State	Function (WWAN state)
W_DISABLE#1	Low	WWAN Disabled (no RF operation allowed)
	High	WWAN Enabled (RF operation allowed), internally pull up
W_DISABLE#2	Low	GPS Disabled (no RF operation allowed)
	High	GPS Enabled (RF operation allowed), internally pull up

Note: W_Disable# is connected to configurable GPIO pin from PMIC, which can support either 3.3V VIO or 1.8V VIO. The default configuration is 3.3V VIO with interrupt function (low active), 1.8V will not disable RF function.

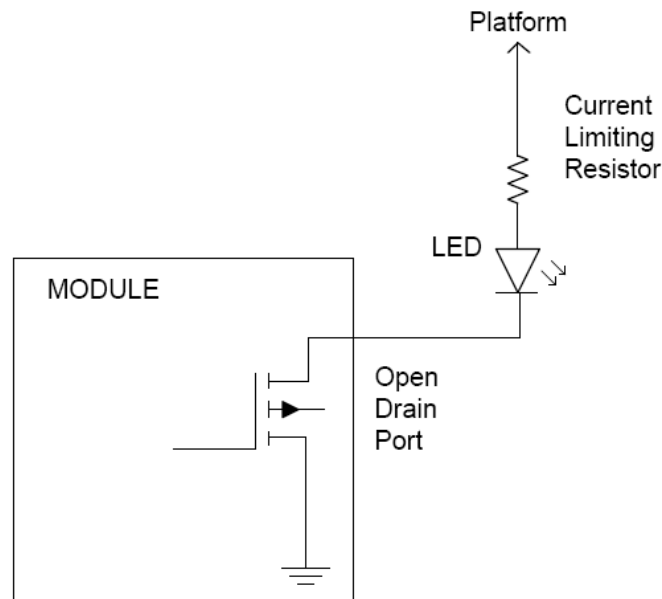
1.5.6 LED Indication

The LED signal is provided to enable wireless communication add-in cards to provide status indications to users via system provided indicators

(1) State of the LED# pin

Item	State	Definition	Interpretation
1	Low	The LED is emitting light.	Radio is capable of transmitting.
2	High	The LED is emitting no light.	Radio is incapable of transmitting.

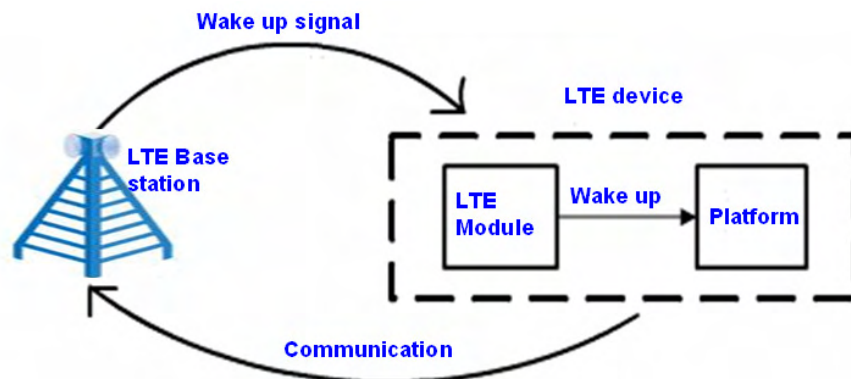
(2) Typical LED Connection in Platform/System



1.5.7 WoWWAN

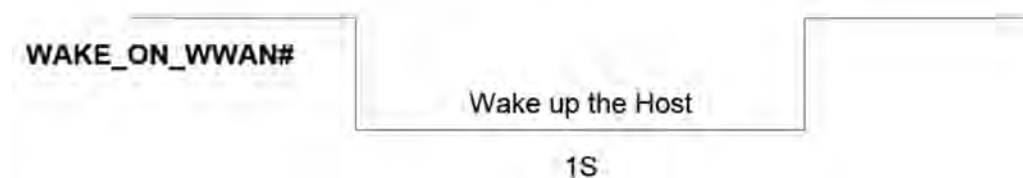
The WAKE_ON_WWAN# signal is for power saving.

- LTE module always listening at very low power in idle mode
- LTE module will wake up mother board via 'WoWWAN' signal.
- The platform will power on when triggered by the LTE module.

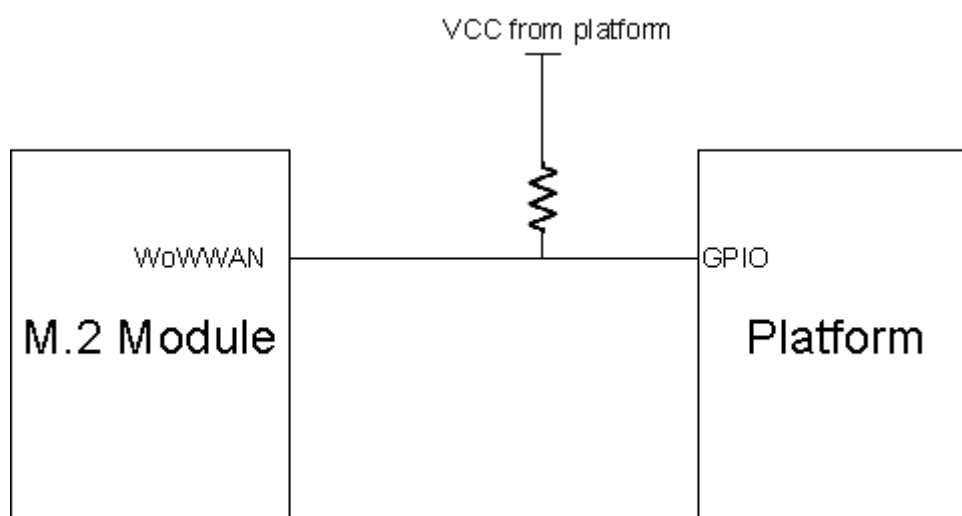


The WAKE_ON_WWAN# signal is used to wake up the host. It is open drain and should be

pulled up at the host side. When the WWAN needs to wake up the host, it will output a one second low pulse, shown in Figure 1-4.



Typical Connection in Platform/System



1.5.8 DPR (Dynamic Power Reduction)

The optional DPR signal is used by wireless devices to assist in meeting regulatory SAR (Specific Absorption Rate) requirements for RF exposure. The signal is provided by a host system proximity sensor to the wireless device to provide an input trigger causing a reduction in the radio transmit output power.

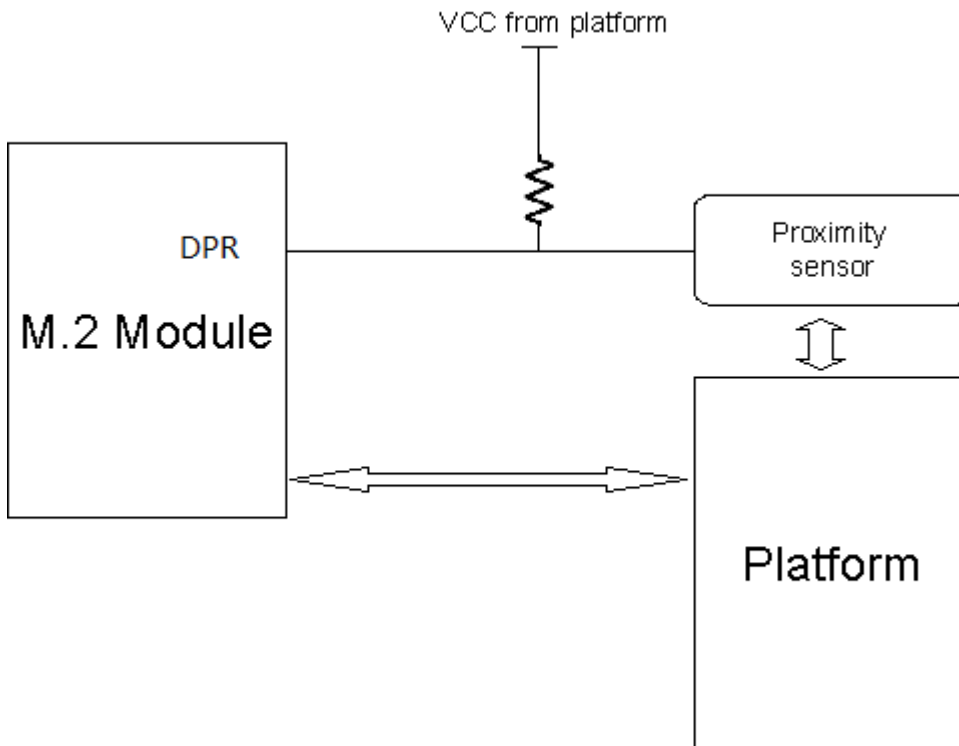
The required value of the power reduction will vary between different host systems and is left to the host platform OEM and card vendor to determine, along with the specific implementation details. The assertion and de-assertion of DPR is asynchronous to any system clock. All transients resulting from the proximity sensor need to be de-bounced by system circuitry.

(1) State of the DPR

Item	State	Definition
1	Low	Enable the SAR power back off.
2	High	Disable the SAR power back off, internally pull up

Note: DPR is connected to configurable GPIO pin from PMIC, which can support either 3.3V VIO or 1.8V VIO. The default configuration is 1.8V VIO with interrupt function (low active)

(2) Typical Connection in Platform/System



(3) DPR table by different Platform requirement

Refer the detail DPR table base on different platform requirement and implement into FW setting

(Waiting customer provide)

Remark:

- a. The platform (system) side needs design a proximity sensor connect to platform system side, while the sensor be triggered then pull low the DPR pin to enable SAR power back off mechanism
- b. After DPR pin becomes low level, you can set the MAX TX power by AT commands.

1.5.9 USIM& eSIM

The UIM contains parameters necessary for the WWAN device's operation in a wireless wide area network radio environment. The UIM signals are described in the following paragraphs for M.2 add-in cards that support the off-card UIM interface.

(1) 2 USIM interface

Design 2 USIM interface on M.2 connector; USIM _1 (Pin 30/32/34/36/66) dedicate for external USIM socket; USIM_2 connect to on board e-SIM chip; Put Pin 40/42/44/46/48 as NC and reserved for 2nd external USIM socket

(2) USIM card socket

It is recommended to take electrostatic discharge (ESD) protection measures near the USIM card socket. The USIM socket should be placed near the NGFF interface (<100 mm), because a long circuit may impact signal quality.

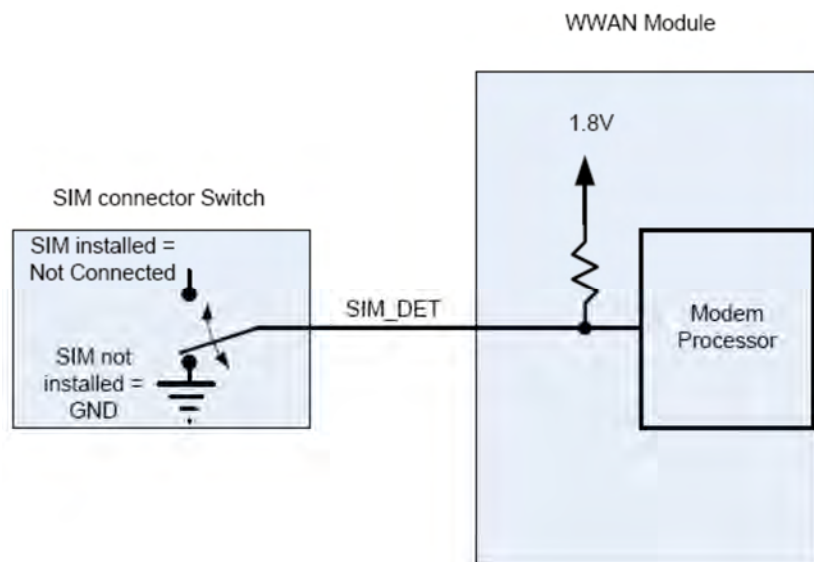
(3) UIM-PWR

UIM_PWR power supply can supply 1.8 V and 2.85 V power to UIM card and auto detects follow SIM card type

(4) SIM Detect

This signal is used to detect the insertion and removal of a SIM device in the SIM socket. With a Normal Short SIM Card connector, PUSH-PUSH type, the detect switch is normally shorted to ground when no SIM card is inserted. When the SIM is inserted, the SIM_DETECT will transition from logic 0 to logic 1 state. The rising edge will indicate insertion of the SIM card. When the SIM is pulled out, the SIM_DETECT will transition from logic1 to logic 0. This falling edge will indicate the pulling out of the SIM card. The M.2 module monitoring this signal will treat the rising/falling edge or the actual logic state as an interrupt, that when triggered, the module will act accordingly.

The UIM_PWR from the PRODUCT shall be turned ON 2 seconds after UIM_DETECT pin is asserted to HIGH. This is to ensure the power is not turned ON earlier before SIM card to be seated well.



(5) eSIM support

Build in eUICC is a product specifically designed for embedded UICC applications. It combines traditional smart card security with a more form factor at close as possible to the chip size, a chip-scale package (CSP), it supports Secure Element with the highest security level (EAL5+ and EMVCo certified hardware) and fully compatible with the ISO/IEC 7816-3

standard (T=0, T=1) and a single-wire protocol (SWP) interface for communication
The detail implementation and requirement needs be engaged and discussed with customer

1.5.10 Antenna Control

(1).T77W968C9 provides GPIO control signals for external antenna tuner application. ANTCTRL (0-3) are provided to allow for the implementation of antenna tuning solutions. The number antenna control lines required will depend on the application and antenna/band requirements. We will provide a tool to fill antenna control table in ODM factory to enable antenna tuner support on specific platforms.

Foxconn general design for WWAN module with two control signals for reference only.

ANTCTL0	ANTCTL1	Frequency (MHz)	Band support
0	0	880 ~ 960	Band8 (WCDMA) + GSM900 + High Bands
0	1	791 ~ 894	Band5 (WCDMA, LTE) + GSM850 + High Bands
1	0	746 ~787	Band13 (LTE) + High Bands
1	1	704 ~746	Band17 (LTE) + High Bands

(2).T77W968C9 also provides MIPI interface (VIO=1.8V) for external antenna tuner application. The function is under development for customization. M.2 pin.56 (MIPI_DATA), 58(MIPI_CLK) M.2 pin.20/24 (antenna tuner Power) are provided to allow for the implementation of antenna tuner solutions with variable capacitors. We will provide a tool to fill MIPI registers in ODM factory to enable antenna tuner support on specific platforms.

Pin No.	I/O	Description	Remark
56	I/O	MIPI Data	For external antenna tuner
58	I/O	MIPI Clock	For external antenna tuner
20	Power	VIO=2.7V	For antenna tuner power
24	Power	VIO=1.8V	For antenna tuner power

1.5.11 Antenna Tuner Mode Switch

T77W968C9 provide two antenna tuner modes configure for Notebook and Tablet scenario through M.2 Pin22 (ANT_TUNER_CONFIG), and get more benefit on antenna performance

Item	Pin 22 State	Tuner Mode	Scenario
1	Low	0	For Notebook
2	High	1	For Tablet

1.5.12 Coexistence

COEX1, COEX2 and COEX3 are provided to allow for the implementation of wireless coexistence solutions between the radio(s) on the M.2 Card and other off-card radio(s). These other radios can be located on another M.2 Card located in the same host platform or as alternate radio implementations (for example, using a PCI Express M.2 CEM or a proprietary form-factor add-in solution).

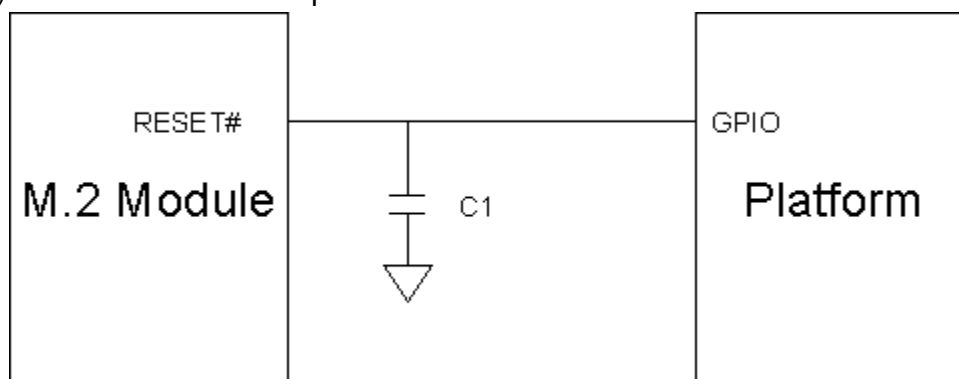
We also dual layout UART Tx/Rx with COEX1 and COEX2 for future extension, please contact with us if need to use these Pins.

Item	Signal name	Description
COEX1	LTE_ACTIVE (COEX_TXD)	TBD
COEX2	LTE_FRAME_SYNC (COEX_RXD)	TBD
COEX3	LTE_WLAN_PRIORITY	TBD

1.5.13 RESET#

Asynchronous RESET# pin, active low. Whenever this pin is active, the modem will immediately be placed in a Power On reset condition. Care should be taken not to activate this pin unless there is a critical failure and all other methods of regaining control and/or communication with the WWAN sub-system have failed.

The Reset# signal is relatively sensitive, it is recommended to install one capacitor (10~100pF) near to the M.2 card pin.



1.5.14 Power off Timing Requirement

When OS enter to S4, S5 state (Windows) or Power off (Linux) by M.2 PIN#6 (FULL_CARD_POWER_OFF#),

(1). For Window 10, need platform to perform M.2 PIN#6 (Full_Card_Power_Off) after sending CID_MBIM_MSHOSTSHUTDOWN to DW5821e and receiving CID_MBIM_MSHOSTSHUTDOWN MBIM_COMMAND_DONE from Module side

(2). For Windows 7 or Linux, Need platform to provide power 2 seconds at least after M.2 PIN#6 (Full_Card_Power_Off)for Win7 and Linux

Refer application note about Power off Timing Requirement and Sequence

2. Hardware features

T77W968C9 consists of the following key engine components, in addition to the required front-end RF and other discrete components.

Modem engine

- Soft Baseband: SDX20-2
- RF: SDR845
- Power: PMX20

Connectivity engine

- PCIe: PCI express (EP and RC modes)
- USIM: located off board
- Antenna: connectors for the off board antennas

2.1 Mobile Data Modem

The SDX20-2 chipset supports high-speed data capabilities over a wide range of air interface standards; the supported RF operating bands are defined by the chipset's RFICs. They are complete system solutions that operate on networks worldwide. The major functions of SDX20-2 used on T77W968C9 are listed below:

□ Processor:

- Manufactured in 10 nm FinFET process
- System uP (1.4 GHz ARM Cortex-A7 application processor with 256 KB L2 cache and 1 GHz Qualcomm® Hexagon™ DSP modem processor)

□ Memory:

- External memory
EBI1: 2Gb LPDDR2, 32-bit LPDDR2 SDRAM at up to 533MHz
- External memory
EBI2: 2Gb NAND flash

□ Air interface:

- WCDMA (R99, HSDPA, HSUPA, HSPA+, DC-HSPA+)
- LTE (R11 Cat9, FDD/TDD)
- GPS/Glonass/Beidou

□ Advance RX operation:

- Mobile receive diversity (WCDMA, LTE)
- 2x2 MIMO (LTE)

□ Connectivity:

- PCI expresses (Supports Endpoint and Root Complex, PCIe Gen 2)

- UART interface
- UIM support (Two dual-voltage (1.8/2.85 V) ports)

2.2 RF transceiver

The SDR845 device is a highly-integrated multimode, multiband RF CMOS transceiver IC that interfaces with the SDX20-2 device through QLink. The SDR845 is the first integrated single-chip RFIC for LTE downlink carrier aggregation (CA) up to 100 MHz BW supporting 5DL CA (two of the carriers must be contiguous). It also supports LTE uplink carrier aggregation up to 20 MHz + 20 MHz for interband and 40 MHz for contiguous intraband.

2.2.1.1 Key features of SDR845

- Qualcomm Technologies, Inc. (QTI) 28 nm RF CMOS device with an integrated modem subsystem in a PSP package (0.35 mm pitch)
- Integrating RF receive, transmit, and the QLink controller
- First QTI single-chip RF device to support three-carrier
- First QTI single-chip RF device to have dedicated MIMO inputs

2.2.1.2 Key benefits of SDR845

- First QTI single-chip RF device to have dedicated MIMO inputs
- QTI RF device that supports high-speed digital interface (QLink) between SDR845 and SDX20-2/SDM845
- QTI RF device supporting external GRFCs that can be used for RF front-end communication and general-purpose functions
- QTI single-chip RF device that supports the integrated envelope tracking (ET) feature for both Tx chains (ETDAC0 and ETDAC1)
- One independent differential low noise amplifier (LNA) port, supporting Tx feedback for all WAN bands (UL)
- Most highly integrated RF transceiver
- Up to 10 receivers running concurrently
- Simplified DC power requirements for this highly integrated RFIC with built-in microprocessor

2.3 Power management IC

T77W968C9 system uses the Qualcomm PMX20. The PMX20 device integrates all the wireless product's power management, general housekeeping, and user interface support functions into a single mixed-signal IC. Its versatile design is suitable for any multimode, multiband product. Since the PMX20 includes so many diverse functions, its operation is more easily

understood by considering major functional blocks individually. Therefore, the PMD9645 document set is organized by the following device functionality:

- Input power management
- Output power management
- General housekeeping
- User interfaces
- IC interfaces
- Configurable pins—either multipurpose pins (MPPs) or general-purpose inputs/outputs (GPIOs)—that can be configured to function within some of the other categories

2.4 Antenna Design

2.4.1 Antenna specification

T77W968C9 also provides connectivity for off board antennas. The antennas and their connection interface for this device satisfy the requirements specified in the PCI Express M.2 Specification Revision Version 1.1 standard. The antenna elements are typically integrated into the notebook/ultrabook /tablet and connected to T77W968C9 module via flexible RF coaxial cables. T77W968C9 provides two RF connectors (MHF type), one for the primary transmitter/receiver port, one for the diversity receiver and GNSS.

To ensure stable RF performance, customer must assemble adequate antenna according to the antenna specification.

Table 2-1 Main antenna specifications

Parameter	Min.	Typ.	Max.	Units	Notes
Cable loss	/	/	0.5	dB	Maximum loss to antenna
Impedance	/	50	/	Ohm	Antenna load impedance
VSWR	/	/	3:1	/	Maximum allowed VSWR of antenna

Note:

1. Main antenna peak gain limit as 2.5dBi for frequency <1.5GHz and 4dBi for frequency >1.5GHz of module level certification
2. For Japan regional peak gain should be limited as 2.5dBi for frequency <1.5GHz and 3dBi for frequency >1.5GHz
3. For Band 30 peak gain limit as 3dBi (Meet FCC requirement)

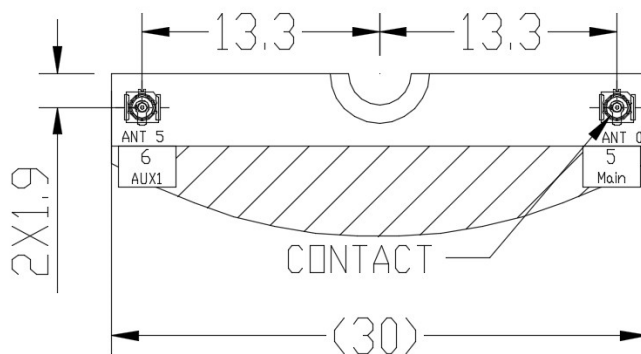
Table 2-2 Aux antenna specifications

Parameter	
Gain	Maximum gain and uniform converge in high angle elevation and zenith. Gain in the azimuth is not desired.
Average 3D gain	>-5dBi
VSWR	Typical value <3:1
Isolation(diversity to Main)	>15dB in all related bands
Polarization	Any

2.4.2 Antenna location and mechanical design.

To ensure customer has a clear knowledge of the two antennas, check below product picture.

Figure 2-1 Antenna connector location and type



Antenna	Interface
0	WWAN Main
1	TBD
2	TBD
3	TBD
4	TBD
5	WWAN Aux/GPS

Figure 2-2 RF connectors

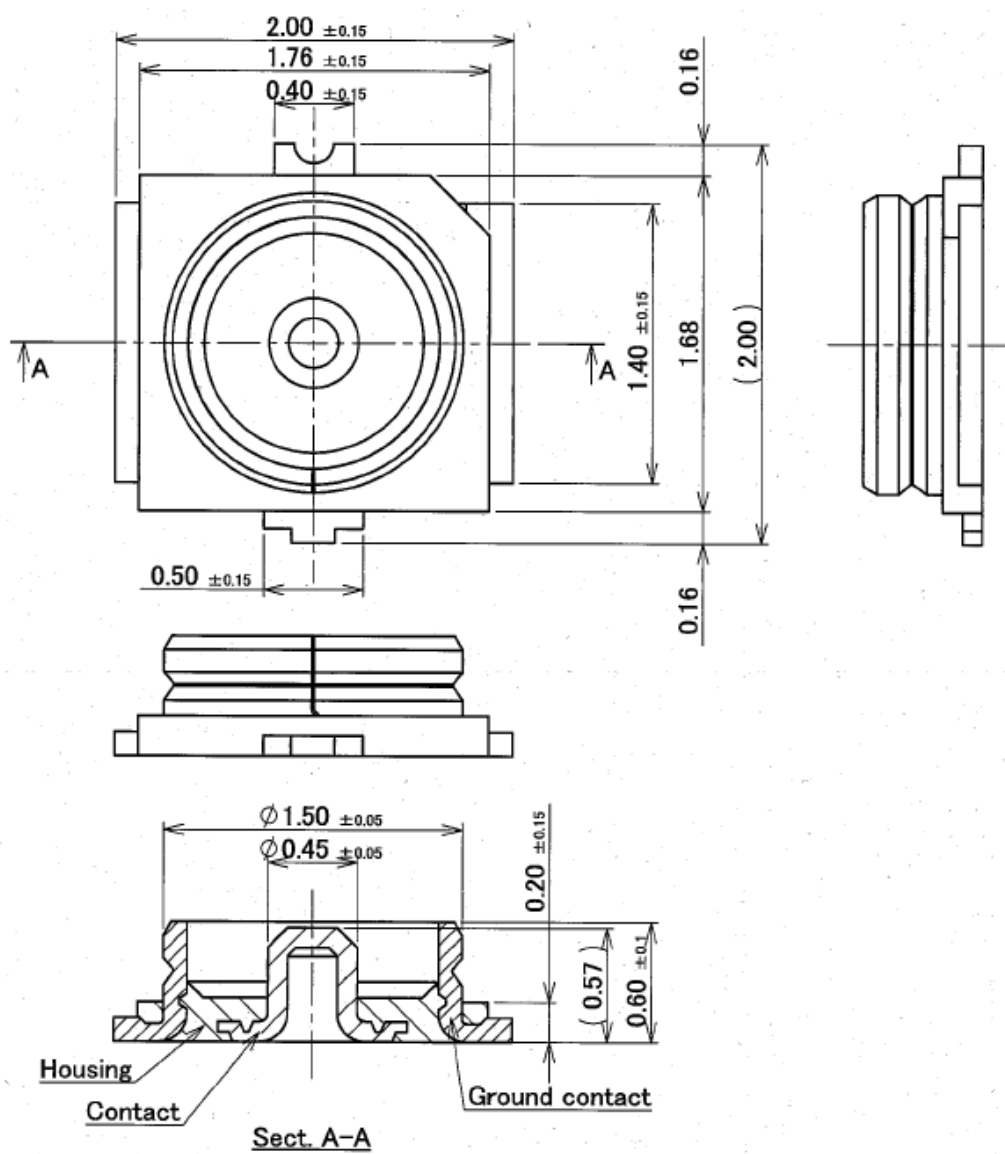
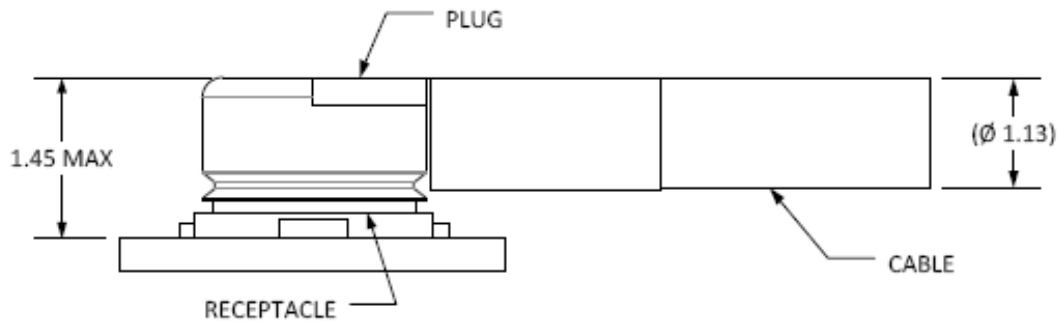
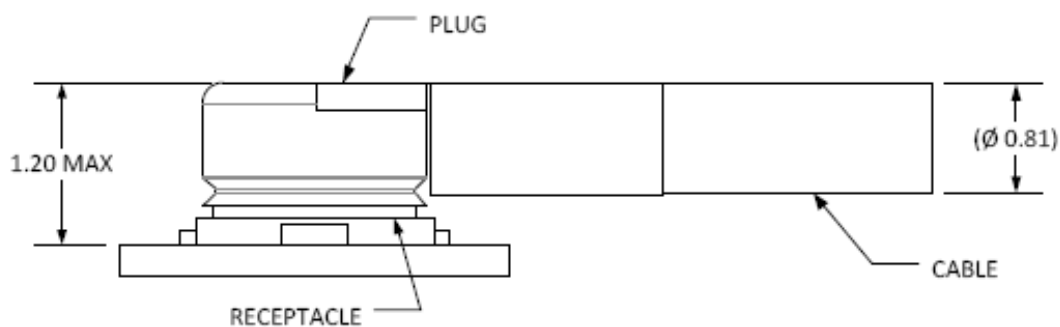


Figure 2-3 RF receptacles



Mated Plug for Ø 1.13 mm Coax Cable



Mated Plug for Ø 0.81 mm Coax Cable

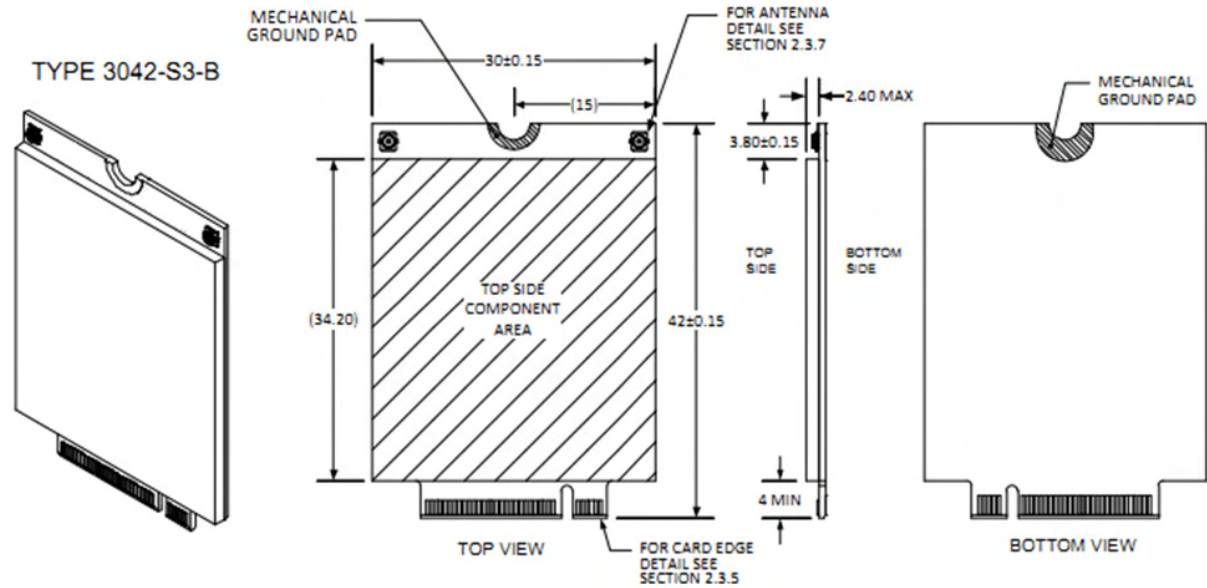
3. Mechanical Specifications

3.1 Overview

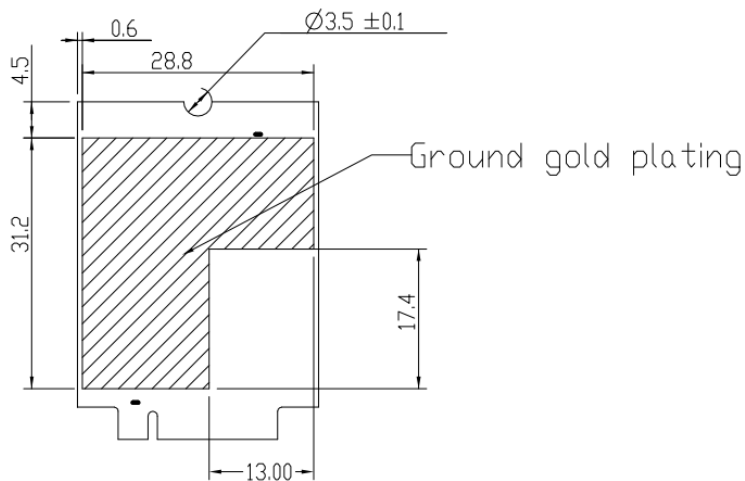
T77W968C9 is compatible with the PCI Express M.2 Specification 3042 Key.B type 75-pin card edge-type connector. Refer to Electromechanical Specification Revision 0.7a, Version 1.0 with Input Power and Voltage Tolerance ECN for more details.

3.2 Mechanical constraints

Figure 3-1 shows the mechanical constraints of T77W968C9(3042-S3-B)



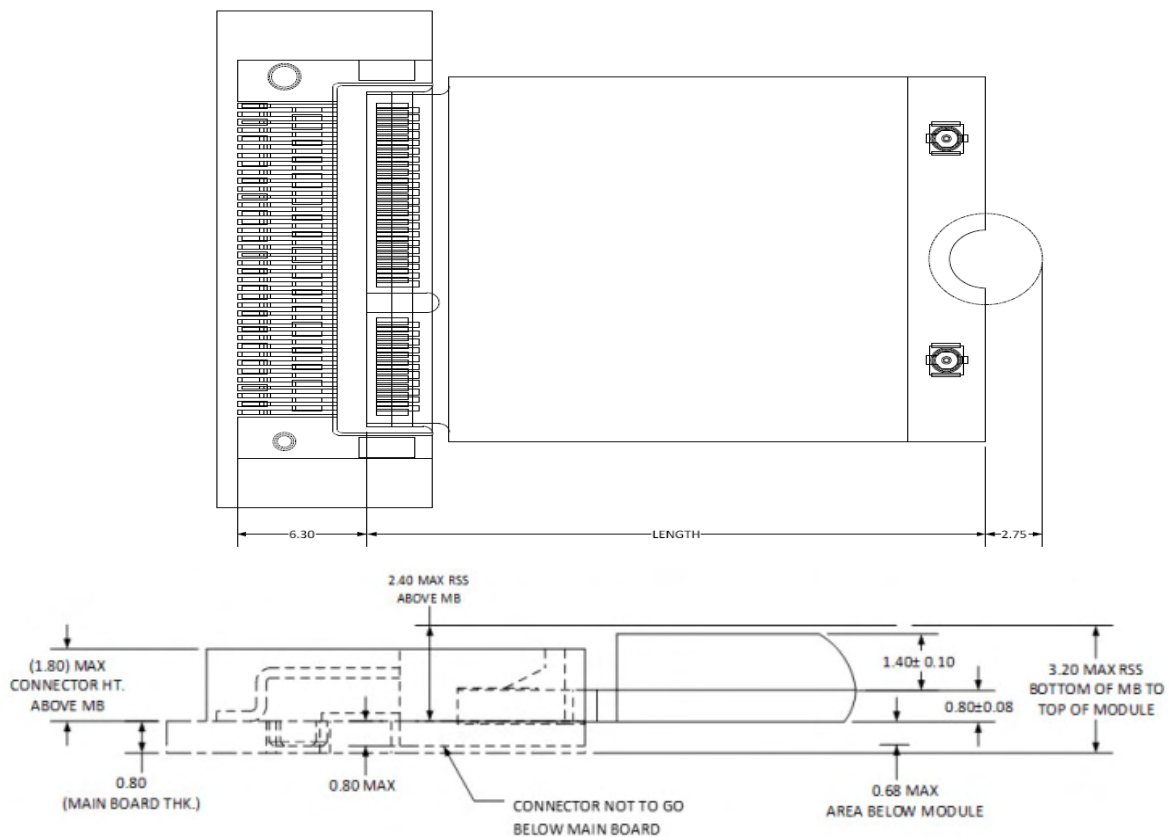
Ground area (with gold plating) on bottom side



3.3 M.2 card assembly

3.3.1 Mid-mount Connection with Single Sided Module

Figure 3-2 shows Stack-up Mid-Line (In-line) Single Sided Module for 1.5 Maximum Component Height, refer to section 2.4.8.3.1 of PCIe M.2_Rev 1.1 standard.

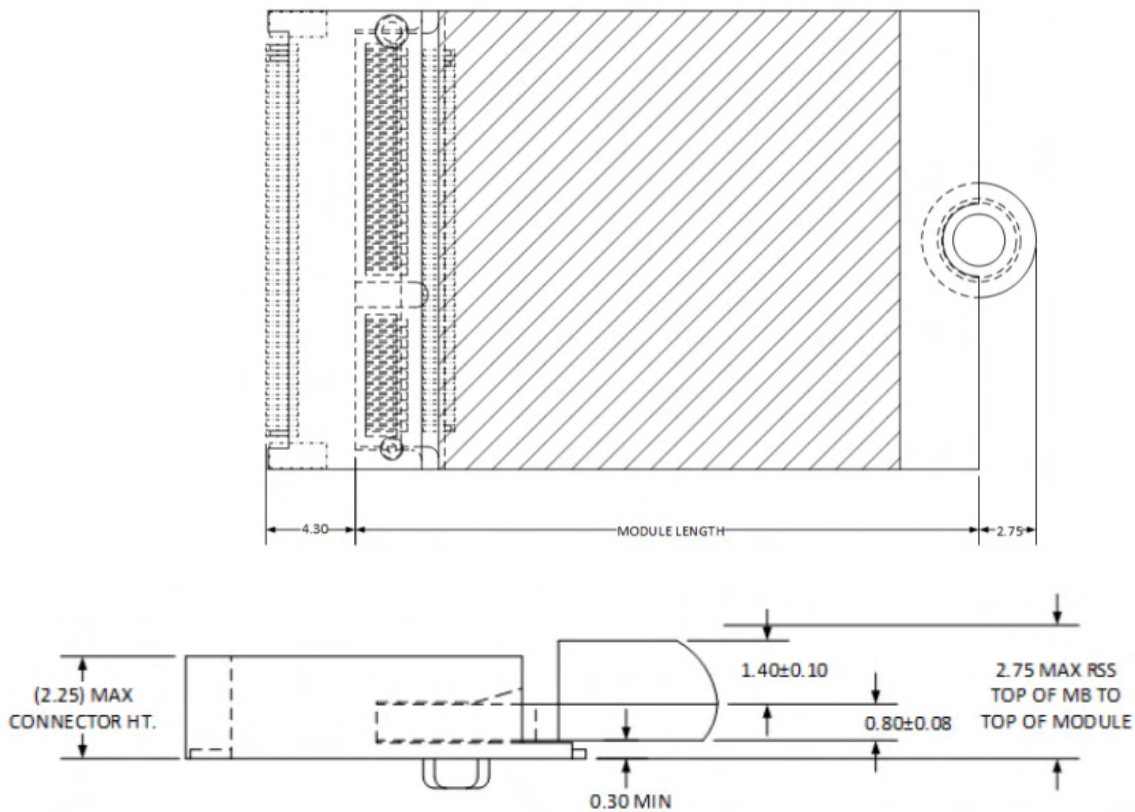


Remark:

- 2.4mm maximum above mother board
- Cut area of main board under M.2 module
- Need to add thermal pad between M.2 modules with mechanical component (like material shielding) for thermal dissipation.

3.3.2 Top-mount Connection with Single Sided Module

Figure 3-4 shows Top Mount Single-sided Module for 1.5 Maximum Component Height; refer to section 2.4.7.3.1 of PCIe M.2_Rev 1.1 standard.

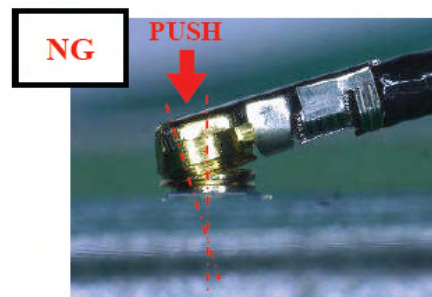
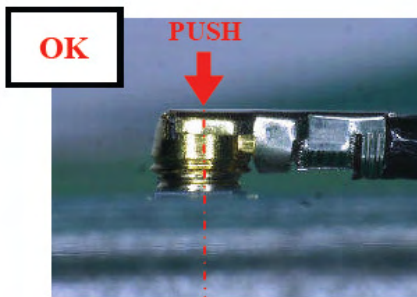


Remark:

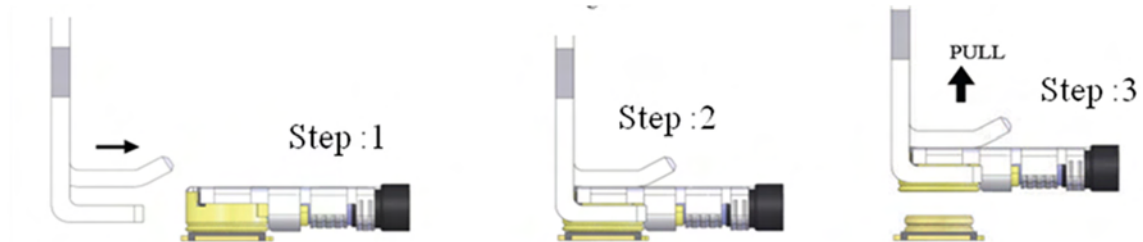
- 2.75mm maximum above mother board
- Full Keep out area 30x42mm" below module which means platform do not place any components and routings below M.2 module
- Need to add thermal pad between M.2 modules with mother board for thermal dissipation

3.4 Connector assembly

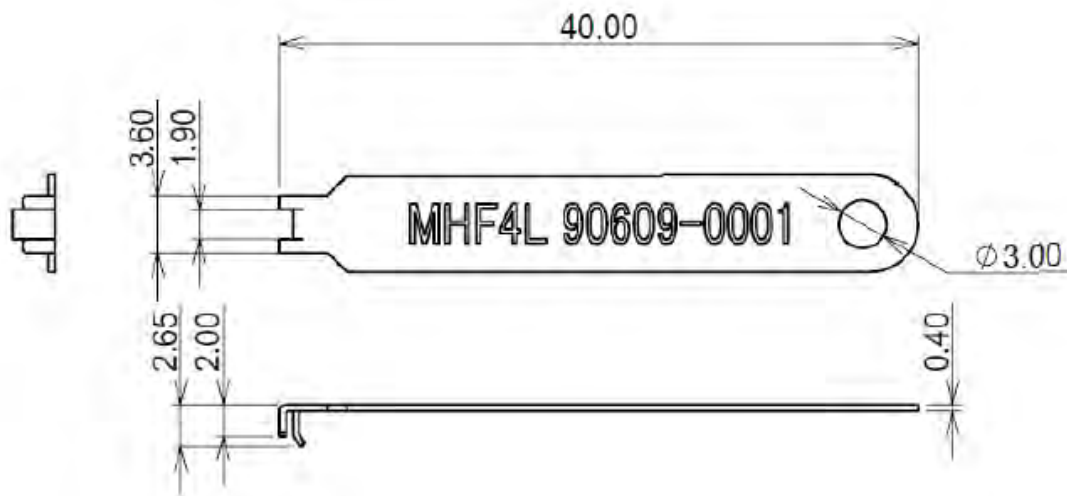
- Mate the connector vertically as much as possible. Adjusting the mating axis of plug and receptacle. Do not slant mate.



b. Unmating: In case of unmating by pulling tool. Use the pulling tool as the following drawing, and pull plug to vertical direction as directly as possible



c. Pulling tool(Unit: mm)



4. Electrical Specifications

4.1 Recommended operating conditions

Table 4-1 Recommended operating conditions

Parameter	Min	Type	Max	Units
Storage temperature	-30	+25	+85	°C
Recommend operating temperature (3GPP compliant) (*1)	-30	+25	+70	°C
Extendable (with limited performance) Temperature measure on T77W968C9 module(*2)	-40		+85	
Operating voltage	3.135	3.3	4.4	Vdc

Note: The operating temperature reference point is board temperature on module bottom side (Ground Golding plating area)

(1)Refer application note about thermal mitigation plan

(2).Extendable operation allows normal mode data transmission for limited time until automatic thermal shutdown takes effect. Within the extendable temperature range (outside the operating temperature range) the specified electrical characteristics may be degraded.

(3).Due to temperature measurement uncertainly, a tolerance on the stated shutdown thresholds may occur. The possible deviation is in the range of +/- 2 °C at the over-temperature and under-temperature limit.

(4). Need implement thermal solution on Platform (Example add thermal pad to heat dissipated from LTE module to Platform PCB) would get more thermal margin and benefit then extend the operating temperature

Operating T77W968C9 device under conditions beyond its absolute maximum ratings (Table 4-1) may damage the device. Absolute maximum ratings are limiting values to be considered individually when all other parameters are within their specified operating ranges. Functional operation and specification compliance under any absolute maximum condition, or after exposure to any of these conditions, is not guaranteed or implied. Exposure may affect device reliability

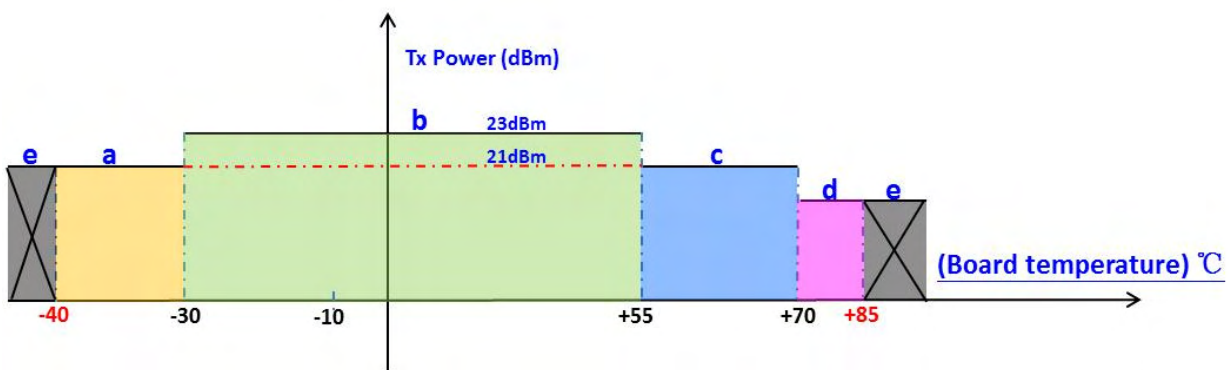
4.2 Power consumption

Table 4-2 Radio system power consumption

Test condition	Estimated Power Range (Typical)	Estimated Power Range (Max.)
WCDMA in Suspend Mode	<3 mA	
WCDMA (Tx=24dBm)	<800 mA	<1500 mA
LTE in Suspend Mode	<3 mA	
LTE (Tx=23.5 dBm)	<950 mA	<1200 mA
LTE 3CA mode 2x 2, Tx=23.5dBm	<1200 mA	<2200 mA
GPS/GNSS Tracking	<150 mA	<300 mA
Connected Standby	<3 mA	
Radio Off	<3 mA	

4.3 Thermal dissipation proposal

4.3.1 Transmit Power policy



- a. From -40 to -30°C, degrade max Tx power to 21±2dBm (Limited Performance)
- b. From -30 to +55°C, normal max Tx power with 23±2dBm (3GPP compliance)
- c. From +55 to +70°C, degrade max Tx power to 21±2dBm (3GPP compliance)
- d. From +70 to +85°C, depend on Platform thermal solution (Limited Performance)
- e. Out of range from -40 to +85°C, RF disables

4.3.2 Software policy

Support RF part thermal mitigation mechanism based on PA Sensor,

Level 1 – Uplink Data Throttling

Level 2 – Tx power Back off

Level 3 – Emergency Shutdown

4.3.3 Implement thermal solution on Platform side to get more thermal margin and benefit then extend the Module operating temperature

- Add thermal pad on Module bottom side to heat dissipated to Platform PCB or chassis
- Add thermal pad and heat sink on Module top shield to thermal dissipation

Refer application note about Thermal Mitigation Proposal

4.3.4 Shield temperature requirement

- Transmission mode < 75°C
- Idle mode < 85°C

5. RF performance specifications

Radio performance for T77W968C9 is given in the following sections, including RF receiver, RF transmitter.

5.1 RF maximum TX power specifications

Table 5-1 Conductive Maximum transmits power (LTE BW: 10MHz)

Notes: The below test result is for reference only, we will update the final Spec. base on 1st 10k MP build CPK

Band	3GPP Standard (dBm)	Design Spec.(dBm)		
		Max.	Typ.	Min.
1	23 +/-2	24.5	23.5	22.0
2	23 +/-2	24.5	23.5	22.0
3	23 +/-2	24.5	23.5	22.0
4	23 +/-2	24.5	23.5	22.0
5	23 +/-2	24.5	23.5	22.0
7	23 +/-2	24.5	23.5	22.0
8	23 +/-2	24.5	23.5	22.0
12	23 +/-2	24.5	23.5	22.0
13	23 +/-2	24.5	23.5	22.0
14	23 +/-2	24.5	23.5	22.0
17	23 +/-2	24.5	23.5	22.0
18	23 +/-2	24.5	23.5	22.0
19	23 +/-2	24.5	23.5	22.0
20	23 +/-2	24.5	23.5	22.0
25	23 +/-2	24.5	23.5	22.0
26	23 +/-2	24.5	23.5	22.0
28	23 +/-2	24.5	23.5	22.0
30	23 +/-2	23.0	22.0	21.0
38	23 +/-2	24.5	23.5	22.0
39	23 +/-2	24.5	23.5	22.0
40	23 +/-2	24.5	23.5	22.0
41	23 +/-2	24.5	23.5	22.0
66	23 +/-2	24.5	23.5	22.0
WCDMA	3GPP Standard (dBm)	Design Spec.(dBm)		
		Max.	Typ.	Min.
1	24+1.7/-3.7	24.5	23.5	22.5
2	24+1.7/-3.7	24.5	23.5	22.5

4	24+1.7/-3.7	24.5	23.5	22.5
5(6/19)	24+1.7/-3.7	24.5	23.5	22.5
8	24+1.7/-3.7	24.5	23.5	22.5
9	24+1.7/-3.7	24.5	23.5	22.5

5.2 RF min. Rx sensitivity specifications

Table 5-2 Conductive Minimum Sensitivity (LTE BW: 10MHz)

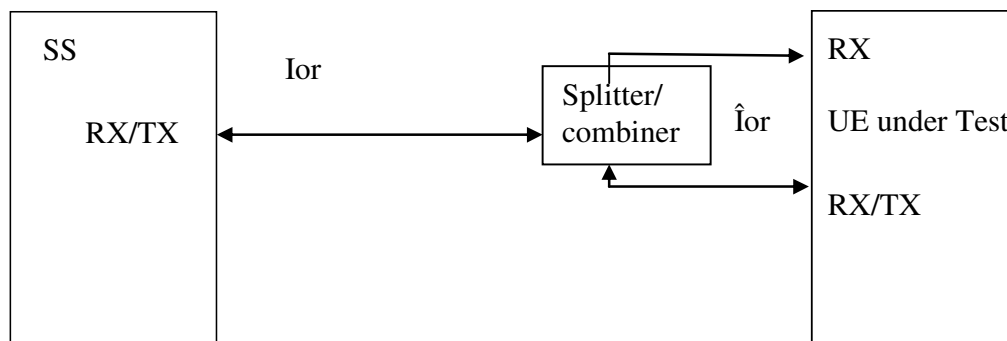
Notes: The below test result is for reference only,

Band	3GPP MIMO Combined (dBm)	Design Spec.(dBm)		
		PRx	DRx	MIMO Combined
1	-95	-98	-98	NA
2	-95	-98	-98	NA
3	-94	-98	-98	NA
4	-97	-98	-98	NA
5	-95	-99	-99	-102
7	-95	-97.5	-97.5	NA
8	-94	-99	-99	-102
12	-94	-99	-99	-102
13	-94	-99	-99	-102
14	-94	-99	-99	-102
17	-94	-99	-99	-102
18	-97	-99	-99	-102
19	-97	-99	-99	-102
20	-94	-99	-99	-102
25	-93.5	-98	-98	NA
26	-94.5	-99	-99	-102
28	-95.5	-99	-99	-102
29	-94	-99	-99	-102
30	-97	-97.5	-97.5	NA
32	-97	-99	-99	-102
38	-97	-97.5	-97.5	NA
39	-97	-98.5	-98.5	-101
40	-97	-97.5	-97.5	NA
41	-96	-97.5	-97.5	NA
66	-96.5	-98	-98	-101
WCDMA	3GPP MIMO Combined (dBm)			
		PRx	DRx	MIMO Combined
1	-106.7	-109	-109	-112
2	-104.7	-109	-109	-112
4	-106.7	-109	-109	-112
5(6/19)	-104.7	-110	-110	-113
8	-103.7	-110	-110	-113
9	-105.7	-110	-110	-113

GNSS Spec.		Design target (dBm)	Spec (dBm)	
GNSS tracking sensitivity (Stand Alone)	GPS	-160	-158±2	
	GLONASS	-160	-158±2	
	BEIDOU	NA	NA	
	GALILEO	NA	NA	
AGPS tracking sensitivity		-157	-156±1	

Remark:

- It has 3dB margin at least refer to 3GPP standard.
- The typical value of LTE was measured as combine Rx sensitivity which was follow test setup of 3GPP standard (TS36.521 charter 7.2 and charter 7.3.5), the test setup is follow TS36.508 Annex A Figure A.3.
- Above table is for general application, please inform us if you have any specific requirement.



Federal Communication Commission Interference Statement

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

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

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

FCC Caution: Any changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate this equipment.

This transmitter must not be co-located or operating in conjunction with any other antenna or transmitter.

This device is intended only for OEM integrators under the following conditions:

The antenna must be installed such that 20 cm is maintained between the antenna and users, and

The transmitter module may not be co-located with any other transmitter or antenna.

As long as **2** conditions above are met, further transmitter test will not be required.

However, the OEM integrator is still responsible for testing their end-product for any additional compliance requirements required with this module installed

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

End Product Labeling

This transmitter module is authorized only for use in device where the antenna may be installed such that 20 cm may be maintained between the antenna and users. The final end product must be labeled in a visible area with the following: "Contains FCC ID:MCLT77W968C9". The grantee's FCC ID can be used only when all FCC compliance requirements are met.

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.

Radiation Exposure Statement:

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

Industry Canada statement:

This device complies with ISSED's licence-exempt RSSs. 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.

Le présent appareil est conforme aux CNR d' ISSED applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) le dispositif ne doit pas produire de brouillage préjudiciable, et (2) ce dispositif doit accepter tout brouillage reçu, y compris un brouillage susceptible de provoquer un

fonctionnement indésirable.

Radiation Exposure Statement:

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

Déclaration d'exposition aux radiations:

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

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

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

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

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

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

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

IMPORTANT NOTE:

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

NOTE IMPORTANTE:

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

End Product Labeling

This transmitter module is authorized only for use in device where the antenna may be installed such that 20 cm may be maintained between the antenna and users. The final end product must be labeled in a visible area with the following: "Contains IC: 2878D-T77W968C9".

Plaque signalétique du produit final

Ce module émetteur est autorisé uniquement pour une utilisation dans un dispositif où l'antenne peut être installée de telle sorte qu'une distance de 20cm peut être maintenue entre l'antenne et les utilisateurs. Le produit final doit être étiqueté dans un endroit visible avec l'inscription suivante: "Contient des IC: 2878D-T77W968C9".

Manual Information To the End User

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

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

Manuel d'information à l'utilisateur final

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

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

低功率電波輻射性電機管理辦法

本模組於取得認證後將依規定於模組本體標示審驗合格標籤。

2. 系統廠商應於平台上標示「本產品內含射頻模組：「XXXyyyLPDzzzz-x」字樣。

電磁波警語標示：「減少電磁波影響，請妥適使用」。

標示方式：必須標示於設備本體適當位置及設備外包裝及使用說明書上。

「電