GTI 5G S-Module White Paper

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Document History

Date	Meeting #	Version #	Revision Contents
31-10-2018	23rd GTI Workshop	V1.0	The first version of GTI 5G S-Module Whitepaper. The standardization status of 5G universal modules, the industry status of 5G S-Modulesand the typical technology solutions for 5G S-Modules are described.

Table of Contents

1 Executive Summary

This white paper provides a technical overview of the **5G Superior Universal Module**, which is known as “**5G S-Module**”. It covers the industry status, the requirement, and the technology for 5G S-Module.

5G Technology has three typical scenarios: eMBB, mMTC, and URLLC, which bring a number of enhancements including ultra-high speeds, large quantity of connection, ultra-low latencies, high performance, enhanced reliability and low power consumption. eMBB brings high throughput for the 5G devices, which increases the network efficiency and performance. Our 5G S- Module will start with the application for the eMBB scenario.

In 5G network, there is a “network slicing” characteristic. It creates the possibility of tailoring mobile data services to the particular characteristics of specific users. For example, a dense grid network might prioritize low power consumption of terminals over connection speed; at the same time, a separate network slice on the same infrastructure could deliver high-speed mobile broadband. “Network slicing” will help 5G S-Module to use the network resources efficiently.

Network slicing ability for different services on the same physical networks raises the possibility of services targeted at different industrial verticals. Here we also analyze the status of the vertical market, the different requirement of the different verticals. For a particular industry, it may need certain attributes of the 5G S-Module, so we categorize the requirements together and have a generic requirement for the 5G S-Module. In general, the 5G S-Module will fulfill the requirement of different industry verticals.

The 5G S-Module solution helps the industry to finish their 5G capable device development easily, and makes it possible for a “turnkey” solution for different applications. The industries with embedded modules are always quite segmented. With 5G S-Module, it could meet the most industry requirements and operates at high-performance, yet benefits from the 5G NR technology.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

[1] http://resources.mipi.org/mipi-i3c-v1-download

[2] 3GPP, TS 38.101-1, NR; User Equipment (UE) radio transmission and reception; Part 1: Range 1 Standalone.

[3] 3GPP, TS 38.101-2, NR; User Equipment (UE) radio transmission and reception; Part 2: Range 2 Standalone.

[4] 3GPP, TS 38.101-3, NR; User Equipment (UE) radio transmission and reception; Part 3: Range 1 and Range 2 Interworking operation with other radios.

[5] 3GPP, TS 38.101-4, NR; User Equipment (UE) radio transmission and reception; Part 4: Performance requirements.

[6] 3GPP, TS 38.521-1, NR; User Equipment (UE) conformance specification; Radio transmission and reception; Part 1: Range 1 Standalone.

[7] 3GPP, TS 38.521-2, NR; User Equipment (UE) conformance specification; Radio transmission and reception; Part 2: Range 2 Standalone.

[8] 3GPP, TS 38.521-3, NR; User Equipment (UE) conformance specification; Radio transmission and reception; Part 3: Range 1 and Range 2 Interworking operation with other radios.

[9] 3GPP, TS 38.521-4, NR; User Equipment (UE) conformance specification; Radio transmission and reception; Part 4: Performance.

[10] 3GPP, TS 38.523-1, 5GS; UE conformance specification; Part 1: Protocol.

[11] 3GPP, TS 38.523-2, 5GS; UE conformance specification; Part 2: Applicability of protocol test cases.

[12] 3GPP, TS 38.523-3, 5GS; User Equipment (UE) conformance specification; Part 3: Protocol Test Suites.

[13] 3GPP, TS 38.533, NR; User Equipment (UE) conformance specification; Radio Resource Management (RRM)

[14] GTI, GTI Sub-6GHz 5G Device Whitepaper (v3.0)

3 Abbreviations

Abbreviation	**Explanation**
3GPP	3rd Generation Partnership Project
ACPC	Always Connected Personal Computer
ADC	Analog-to-Digital Converter
APN	Access Point Name
APT	Average Power Tracking
AR/VR	Augmented Reality / Virtual Reality
BT	Blue Tooth
CMCC	China Mobile Communications Corporation
eMBB	Enhanced Mobile Broadband
eMBMS	Evolved Multimedia Broadcast Multicast Services
eMMC	Embedded Multi-Media Card
ET	Envelop Tracking
eUICC	Embedded Universal Integrated Circuit Card
ESD	Electro-Static Discharge
ETSI	The European Telecommunication Standards Institute
FBAR	thin Film Bulk Acoustic Resonator
FCC	Federal Communications Commission
FEM	Front-End Module
FOTA	Firmware Over-The-Air
GCF	Global Certification Forum
GLONASS	GLObal NAvigation Satellite System
GNSS	Global Navigation Satellite System
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile communications
GSMA	Global System for Mobile communications Alliance
GTI	Global TD-LTE Initiative
HPUE	High Power User Equipment
I2C	Inter-Integrated Circuit
I2S	Integrated Interchip Sound
IMEI	International Mobile Equipment Identity
IMSI	International Mobile Subscriber Identity
IMT	International Mobile Telecommunication
IoT	Internet of Things
ITU	International Telecommunication Union

ITU-R	International Telecommunication Union - Radio
LGA	Land Grid Array
LNA	Low Noise Amplifier
LTCC	Low Temperature Co-Fired Ceramic
LTE	Long Term Evolution
M2M	Machine to Machine
MCU	Micro-Controller Unit
MIMO	Multi-input Multi-output
MLCC	Multi-Layer Ceramic Chip
MNO	Mobile Network Operator
MWC	Mobile World Congress
NR	New Radio
OAM	Operation, Administration and Maintenance
ODU	Outdoor Unit
OEM	Original Equipment Manufacturer
ODM	Original Design Manufacturer
PCIe	Peripheral Component Interconnect express
PCM	Pulse-Code Modulation
PTCRB	PCS Type Certification Review Board
QoS	Quality of Service
RAN	Radio Access Network
RED	Radio Equipment Directive
RRM	Radio Resource Management
SAW	Surface Acoustic Wave
SIM	Subscriber Identification Module
SMD	Surface Mount Technology
SPI	Serial Peripheral Interface
TD-LTE	Time Division Long Term Evolution
TDD	Time Division Duplex
TIS	Total Isotropic Sensitivity
TRP	Total Radiated Power
UART	Universal Asynchronous Receiver/Transmitter
UE	User Equipment
UHD	Ultra High Definition
USB	Universal Serial Bus
USIM	UMTS Subscriber Identity Module
WCDMA	Wideband Code Division Multiple Access

4 Introduction

This whitepaper mainly focuses on the 5G S-Module and has been carried out in several sections in turn. Combined with the standardization status and the industry status of 5G S-Module, the whitepaper analyses the basic functions requirements, the hardware technical requirements, the electrical interface technical requirements, test & certification and the typical technical solutions for 5G S-Module. For the communication capability, please refer to the "GTI Sub-6GHz 5G Device Whitepaper". This GTI 5G S-Module Whitepaper is expected to help people to develop 5G S-Modules and to promote 5G industrial development especially in verticals. This whitepaper may also help people to know more about the standardization status and industrial status of 5G S-Module. Meanwhile, it may also help readers interested in 5G S-Modules and vertical devices to gain from the further thinking.

Sincere thanks to all the contributors and the supporters for their hard work in writing this whitepaper, so we are respectfully listing them in alphabetical order under every chapter.

- **Chapter 1 Executive Summary**
  CMCC, SIMCom
- **Chapter 2 Reference**
- **Chapter 3 Abbreviations**
  CMCC
- **Chapter 4 Introduction**
  CMCC
- **Chapter 5 The Standardization Status**
  CMCC, Quectel, Sprint
- **Chapter 6 The Industry Status**
  Fibocom
- **Chapter 7 The Basic functions Requirements on 5G S-Module**
  Hisense
- **Chapter 8 The Hardware Technical Requirements on 5G S-Module**
  SIMCom, Fibocom
- **Chapter 9 The Electrical Interface Technical Requirements on 5G S-Module**
  SIMCom
- **Chapter 10 The Test and Certification of 5G S-Module**
  Anritsu, CMCC, Keysight, R&S, SIMCom, Sprint
- **Chapter 11 Typical Technical Solutions for 5G S-Module**
  Fibocom
- **Annex A 5G RF Component**

Qorvo, Taiyo Yuden, Murata

- **Annex B Antenna**

  Sunway

- **Annex C Sensor**

  SIMCom, Sprint

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  Dr. Dan Song, Mr. Xiaofeng Peng, Mr. Shuai Ma, Mr. Shanpeng Xiao and Dr. Guangyi Liu

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- **SIMCom**

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- **Fibocom**

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- **Quectel**

  Mr. Albert Deng

- **Hisense**

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- **Taiyo Yuden**

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- **Murata**

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- **Sunway**

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- **Rohde & Schwarz**

  Mr. Tim Wang

This whitepaper will be continuously updated according to the research and development progress.

5 The Standardization Status

5.1 Motivation

5G network provides the enhanced bandwidth and helps many applications improving their performance. For example, Virtual and Augmented Reality, UHD 8K Online 360 Video, 16K VR Head Mounted Display for gaming and training, Connected Drones, Connected Automotive, Wireless e-Health – Remote Surgery, Wireless home entertainment – smart home gateway, Live Radio/Video Broadcasting, Smart helmet, Always- connected PC/Tablet/2-in-1 PC, Real-time UHD Video Surveillance and Robots (See more in "GTI Report on Vertical Requirements for 5G S-Modules and Devices"). Thus, 5G devices could serve the users in a much better and efficient way. The key motivations are as follows:

- The available bandwidth for the applications will be substantial
- Data throughput will be increased along with enhanced connectivity, higher user mobility and higher accuracy positioning
- The 5G devices could use 5G S-Module and work out their solution efficiently

5G networks can support a large number of high bandwidth devices. 5G is power efficient. It delivers a long mobile battery life because it has been engineered and optimized to operate over an extended period. 5G NR network with eMBB provides high bandwidth for the 5G multi-mode multi-band modules and modem end-devices, thus it will be beneficial for the 5G device vendors. For example, ACPC vendors could use 5G S-Module in their device product and solution directly. Economies of scale arise because the capacity of S-Module suppliers is essentially shared around the GTI markets and at the 5G industry level. The quicker we bridge 5G chipsets to S-Module, the better it is for GTI 5G device ecosystem. Currently every module vendor designs their own wireless modules, with different size, form factor and pin definition. This is an industry wide bottleneck and we intend to improve the situation.

Introduce user-centric authentication layer on top of the existing subscription authentication to share S-Module usage. Once 5G networks are deployed, different users can share one kind of 5G S-Module. To improve the user experience, it would be beneficial to automatically change settings of operator deployed services according to the users' settings. This requires the user to be identified in addition to the existing identification of subscription based off S-Module SIM. Network settings can be adapted and services offered to users according to their user identities, independent of the subscription that is used to establish the connection [TR22.904]. Using network resource slicing technology, application aware user experience could be delivered to all user identities shared the same S-Module gateway simultaneously [TR 23.727].

5.2 Standardization of 5G S-Module

5.2.1 The Diagram of 5G S-Module

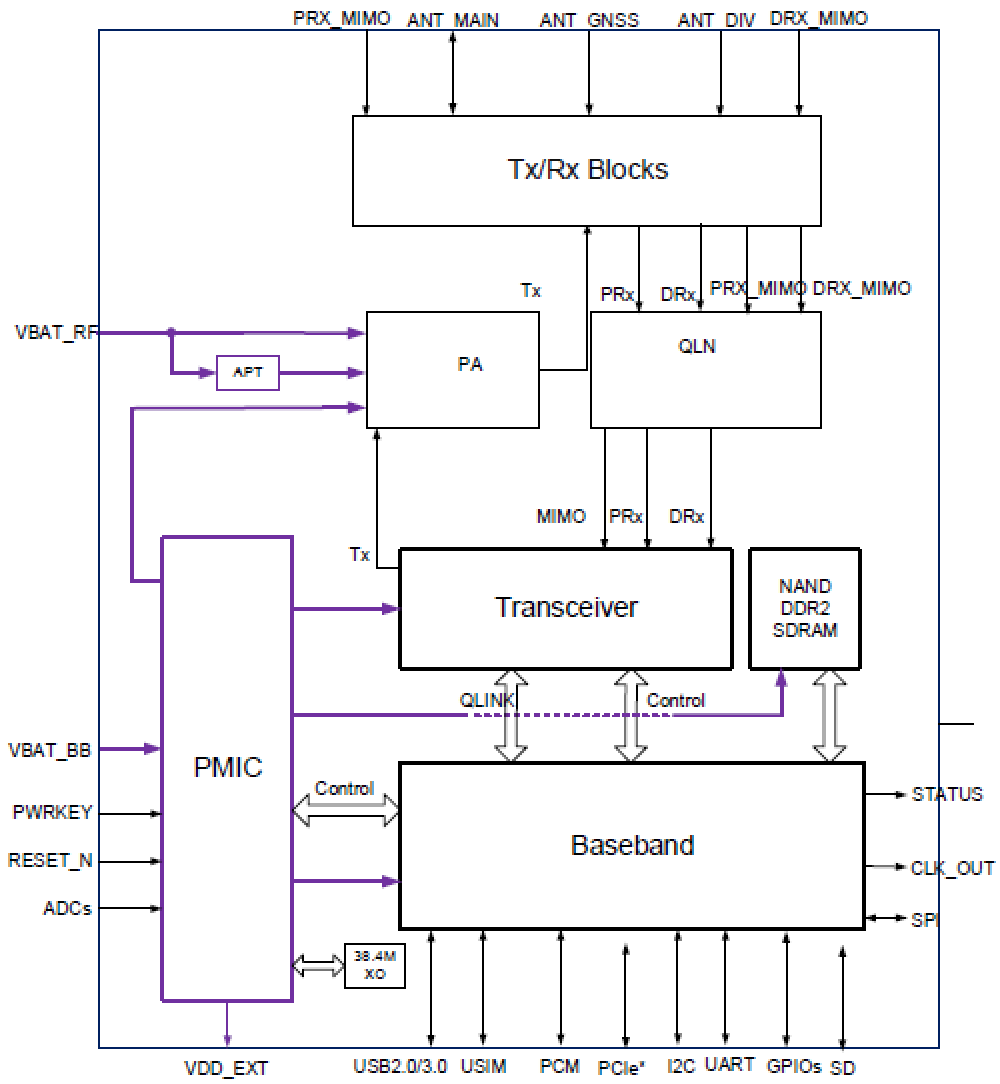


Figure 5-1 Diagram of 5G S-Module

5.2.2 The Key Points to classify 5G S-Module

To facilitate 5G device developments, we define modes, bands, data rate, size, form factor, weight, interface, AP/MCU, and Antenna of the 5G S-Module. Considering requirements from different applications, 5G S-Modules have been divided into three major categories: Basic Type 1, 2&3 without high-performance processor, Smart Type with high-performance processor, Basic Type 1&2 with LGA form factor, Basic Type 3 with M.2 form factor, and All-in-one Type with built-in antennas.

5.2.2.1 Modes and Bands

The 5G S-Module may be a series of modules, depending on how many modes and how many bands it supports. The modes and bands specification are as follows:

5G NR Bands:
    Mandatory: n41, n79

LTE FDD Bands:
    Mandatory: B7, B3, B8, B25
    Optional: B1, B4, B12, B17, B20

TD-LTE Bands:
    Mandatory: B34, B39, B40, B41

5.2.2.2 Data Rate

Date rate requested for 5G NR Sub 6GHz Module:
SA Mode:

1) DL peak rate: 1.7Gbps

2) UL peak rate: 190 Mbps

Note: 5G NR bandwidth 100MHz

5.2.2.3 Size and Form Factor

The 5G S-Module may be a series of modules, depending on different size.

1) Package Dimension (LGA):

   LGA form factor module can be applied to most of the eMBB and IoT applications, such as CPE, STB, Laptop, Tablet, and Telematics. It is also the most widely used form factor in current 4G module industry.

2) Package Dimension (LGA+LCC)

   LGA+LCC form factor module can be applied to almost all the applications for its flexibility, and sometimes it can greatly simplify the design of module and external applications.

3) Package Dimension (M.2):

   M.2 form factor follows the definition of PCI Express M.2 Specification. It provides plug-in module solution for the end-device manufacturers.

5.2.2.4 Weight

Weight: less than 10g.

The consumer application such as AR/VR always prefer low weigh components. According to the weight of PCB, chips and other components in the module, the total weight of the 5G S-Module should be less than 10g.

5.2.2.5 Interface

- (U)SIM interface:

The (U)SIM interface circuitry meets ETSI and IMT-2000 requirements. Either 1.8V or 3.0V (U)SIM cards are supported.

- USB 3.1(Optional)/3.0/2.0 interface:

5G S-Module provides one integrated Universal Serial Bus (USB) interface which complies with the USB 3.1/3.0/2.0 specifications. It supports SuperSpeed+ (10Gbps) on USB 3.1 Gen 2 (Optional), SuperSpeed (5Gbps) on USB 3.0, High Speed (480 Mbps) and Full Speed (12 Mbps) modes on USB 2.0. The USB interface is used for AT command communication, data transmission, GNSS NMEA output, software debugging, firmware upgrade and so on.

- PCIe interface:

5G S-Module includes a PCIe interface, which is compliant with PCI Express Specification Revision 3.0.

- UART interface:

The module provides 3 UART interfaces: the main UART interface, the debug UART interface, and the BT UART interface.

- PCM and I2C interface:

5G S-Module supports audio communication via Pulse Code Modulation (PCM) digital interface and I2C interface. We recommend to support I3C interface in the future revision of this whitepaper.

5.2.2.6 AP/MCU

The 5G S-Module may be a series of modules, depending on different computing capabilities.

1) Applications such as artificial intelligence demand that S-Module should provide high performance computing capability. Hence, the 5G S-Module used in these fields should include a processor running at 1.3GHz or higher, more than 4GB of RAM and 8GB of ROM.

2) Applications such as router and gateway do not require that S-Module provide high performance computing capability. Hence, the 5G S-Module used in these fields should include a processor running at 800 MHz or higher, more than 2GB of RAM and 4GB of ROM.

5.2.2.7 Antenna

The plug and play devices such as USB Dongle Wireless Modem Stick demand built-in antennas, which should be included in the 5G S-Modules.

6 The Industry Status

This section studies the global cellular module industry status, market share, growth opportunity, key players and challenges.

6.1 The Industry Status of 4G Module

According to GSMA estimates, the number of cellular M2M connections in the world will reach 1 billion in 2020, with an average annual growth rate of 26.8%.

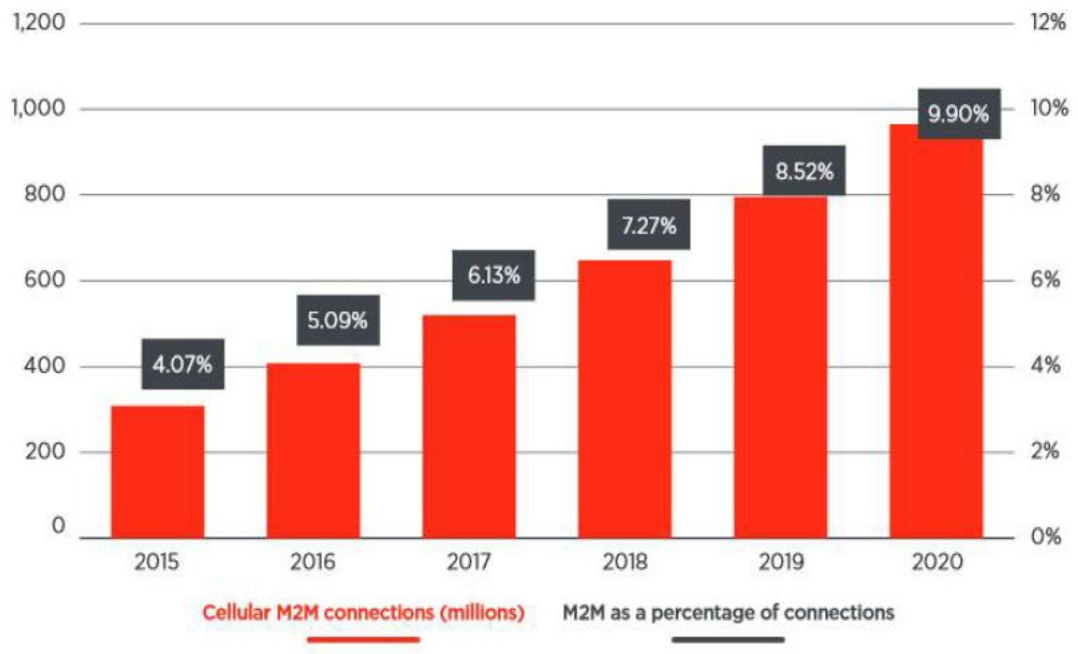


Figure 6-1 Forecast of global cellular M2M connections (From GSMA)

Cellular IoT modules are devices that allow for machine to machine (M2M) connectivity across a variety of communication networks. The module is widely used in wireless POS, automotive, smart metering, connect laptop, CCTV, vehicle monitoring, remote control, telemetry, gateway, digital signage, vending machine, robot control, smart agriculture etc.

Industry application of cellular module is closely related to the construction of carriers' network. The commonly communication technologies are 2G,3G and 4G, some carries are also being deployed Cat.NB1 and Cat.M1 technologies. At the end of 2017, there are 644 public LTE networks been deployed that covered 200 countries and areas. With the evolution of carrier's network, more and more applications are switch to LTE modules from GSM/WCDMA modules.

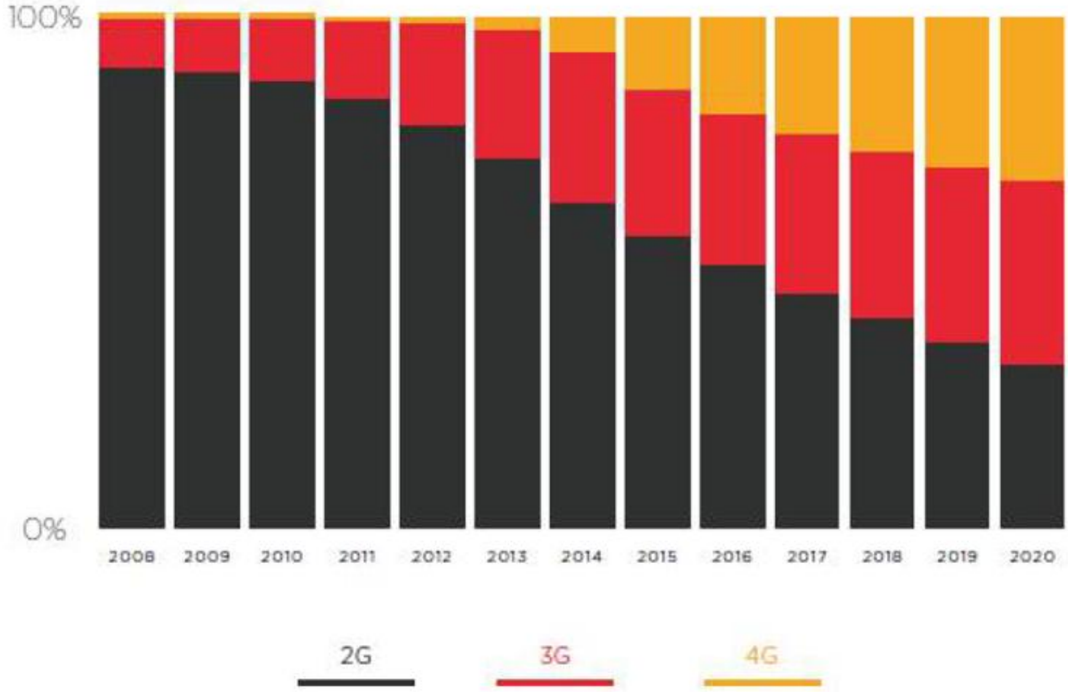


Figure 6-2 Forecast of 2G/3G/4G M2M connections (From Ericsson)

The major module suppliers include Simcom, Fibocom, Quectel, Telit, Sierra wireless, Gemalto, U-Blox, ZTE Welink, Neoway etc.

Multiple application brings a fragmented LTE category application. Some use LTE Cat1 or Cat3 for replacing 3G technology because of carrier network upgrade, some use LTE Cat4 for better network coverage in these five years like china national grid, some use LTE Cat6 or Cat9 for better downlink data throughput, and some use Cat16 or above for both downlink and uplink, also for pre-5G research.

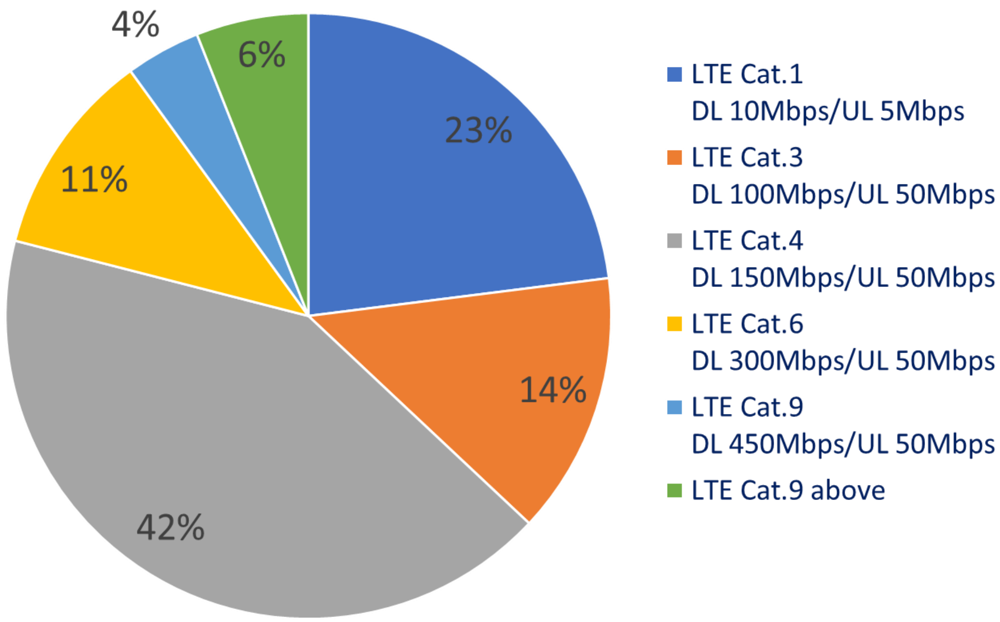


Figure 6-3 Percentage of different LTE category (From CMCC)

That also brings different kinds of module dimension in the market. There are standard interfaces like mini-PCIe and M.2, and other private definition interfaces. There are the different form factors like LCC, LGA, LCC+LGA. Even the same form factor module has different dimension and different pin definition between different module vendors.

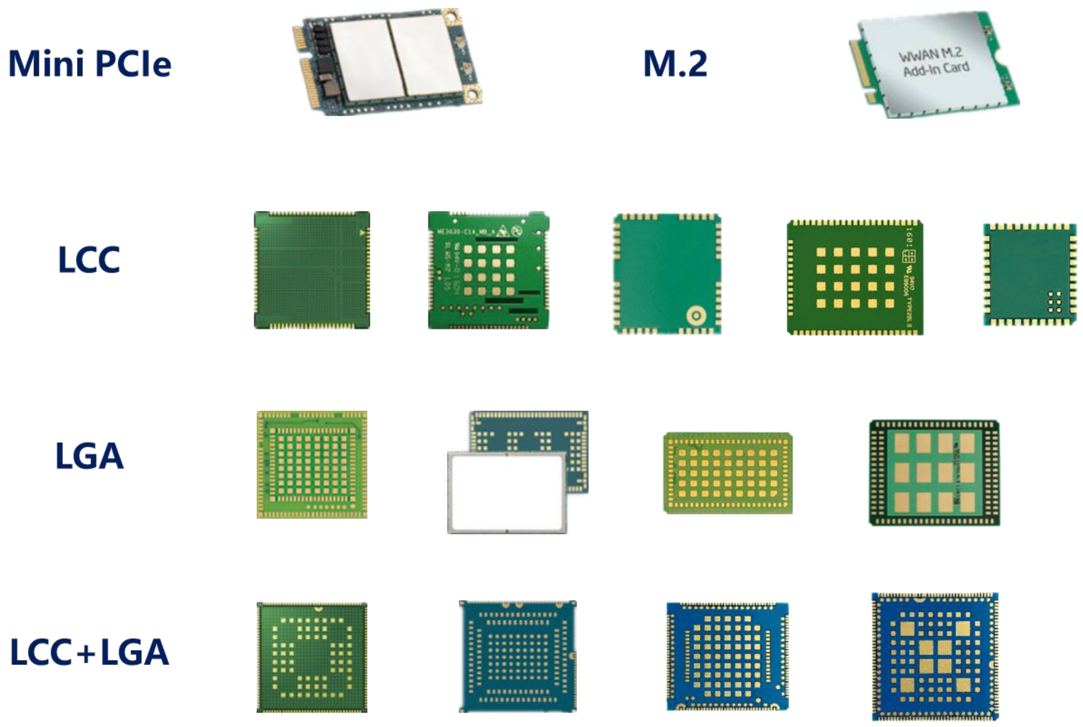


Figure 6-4 Different form factor of LTE module (From public data)

6.1.1 How to make 5G S-Module?

The upstream of the cellular module is vendors of the standardized baseband chip, and the downstream is the application of industry.

The requirement of 5G S-Module will focus on the eMBB application.

The R&D of cellular module need to have strong communication technology, signal processing technology, information processing technology and other professional development capabilities, and need to have a strong protocol knowledge, OS drivers, embedded software development capabilities.

6.1.2 The Industry Status of 5G S-Module

The mainstreaming module vendor are starting study the 5G technology, the module develop schedule still depend on 5G baseband chipset schedule.

6.1.3 The Industry Status of 5G Chipset

Due to the prospect of 5G, the main manufacturers are constantly pushing forward the development process of chip products.

Qualcomm has released snapdragon X50 series on 28GHz millimeter waves technology. And 5G mobile phone, which is equipped with Qualcomm communication technology, is expected to be released in 2019.

Intel released the first chip supporting both sub 6 and millimeter wave technology in 2017. And Intel will release the commercial baseband chip at the end of 2018.

Hisilicon will release the commercial baseband chip in 2019. Spectrum and MediaTek will release their 5G chipset in 2020.

6.1.4 The Industry Status of 5G Device

There is unprecedented buzz around 5G, because it can create a world boasting services and products like "Mobile Beyond Giga", "Real-Time World", and "All-Online Everywhere". Mobile networks have emerged as fundamental to productivity, enabling digital transformation throughout all industries.

Mobile networks are designed to create a super connected world, in which the generated data is contextualized, constructed and processed over the cloud, continuously creating value. Connected cars, always connect PC, VR/AR, online 4K/8K video, and other applications are some of the first, most promising areas for IoT to focus on. These applications are poised to rapidly develop in the 5G eMBB era.

7 The Basic functions Requirements on 5G S-Module

7.1 Management Functions

7.1.1 Identity Management

5G S-Module should have module identity. The module identity could be IMEI or IMSI on user card.

7.1.2 Status Management

5G S-Module should have capability of status management. It could be achieved by interface to indicate module working status.

7.1.3 Parameter Preset Management

5G S-Module should be preset for cellular network bearer access parameters, including but not limited to APN, SMS center number, IP(or URL) and port number.

7.2 SIM Functions

5G S-Module should support one or more of pluggable SIM/USIM/CSIM interface, SMD type SIM/USIM/CSIM（eUICC）and other SIM form. The following table shows the pins of pluggable SIM/USIM/CSIM. One of two voltage levels should be supported: 3V±10% or 1.8V±10%.

Table 7-1 (U)SIM Interface

Interface Type	Interface Name	Interface Description	Interface Characteristics
SIM interface	USIM_DETECT	USIM DETECT Signal	I
	USIM_RESET	USIM RESET Signal	O
	USIM_CLK	USIM CLK Signal	O
	USIM_DATA	USIM DATA Signal	I/O
	USIM_VCC	USIM Power Output	O

7.3 Debug Functions

The 5G S-Module needs to support developing debug log, opening and closing debug log and outputting debug log via UART or USB or SPI interface.

7.4 Firmware Upgrade Functions

The 5G S-Module should support secured firmware upgrade. The firmware of 5G S-Module could be upgraded by FOTA. The implementation of firmware upgrade depends on device implementation.

The update workflow includes FOTA initializing, downloading update package segment, getting FOTA update result, getting package name, getting package version and firmware upgrading.

8 The Hardware Technical Requirements on 5G S-Module

Basing on variety of characteristics, form factor, sizes, etc, the 5G S-Module could be classified into 3 types shown below: Basic Type, Smart Type and All-in-one Type.

Type	**Basic Type**	**Smart Type**	**All-in-one Type**
Characteristics	Only communication capability	High performance Application Processor	Built-in antennas
Form Factor	LGA and M.2	LCC+LGA	Dongle
Size	36mm*42mm 38mm*40mm 30mm*52mm	44mm*45mm	**TBD**

8.1 5G S-Module Basic Type 1

8.1.1 Diagram

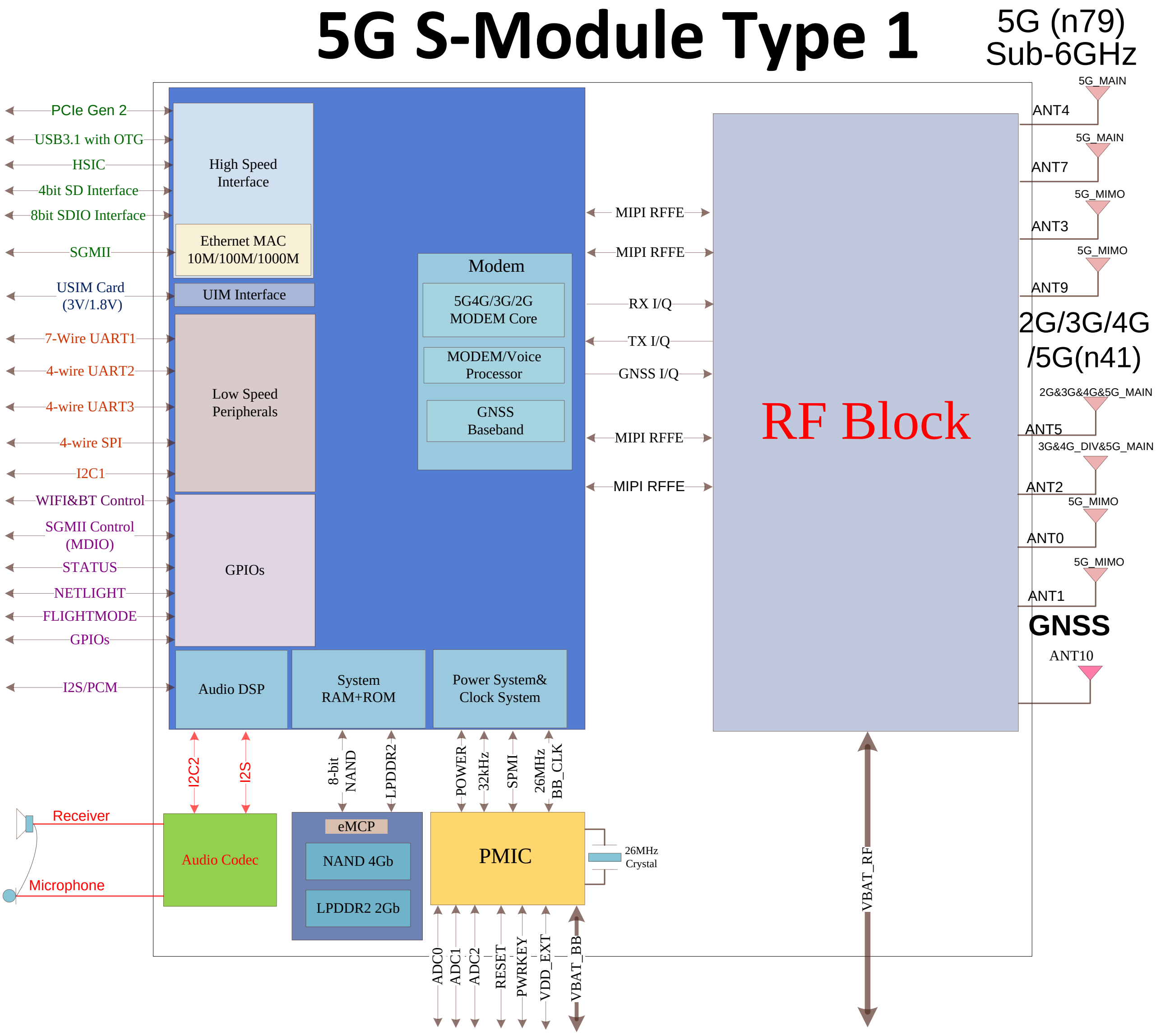


Figure 8-1 5G S-Module Basic Type 1 Diagram

8.1.2 Pin Layout

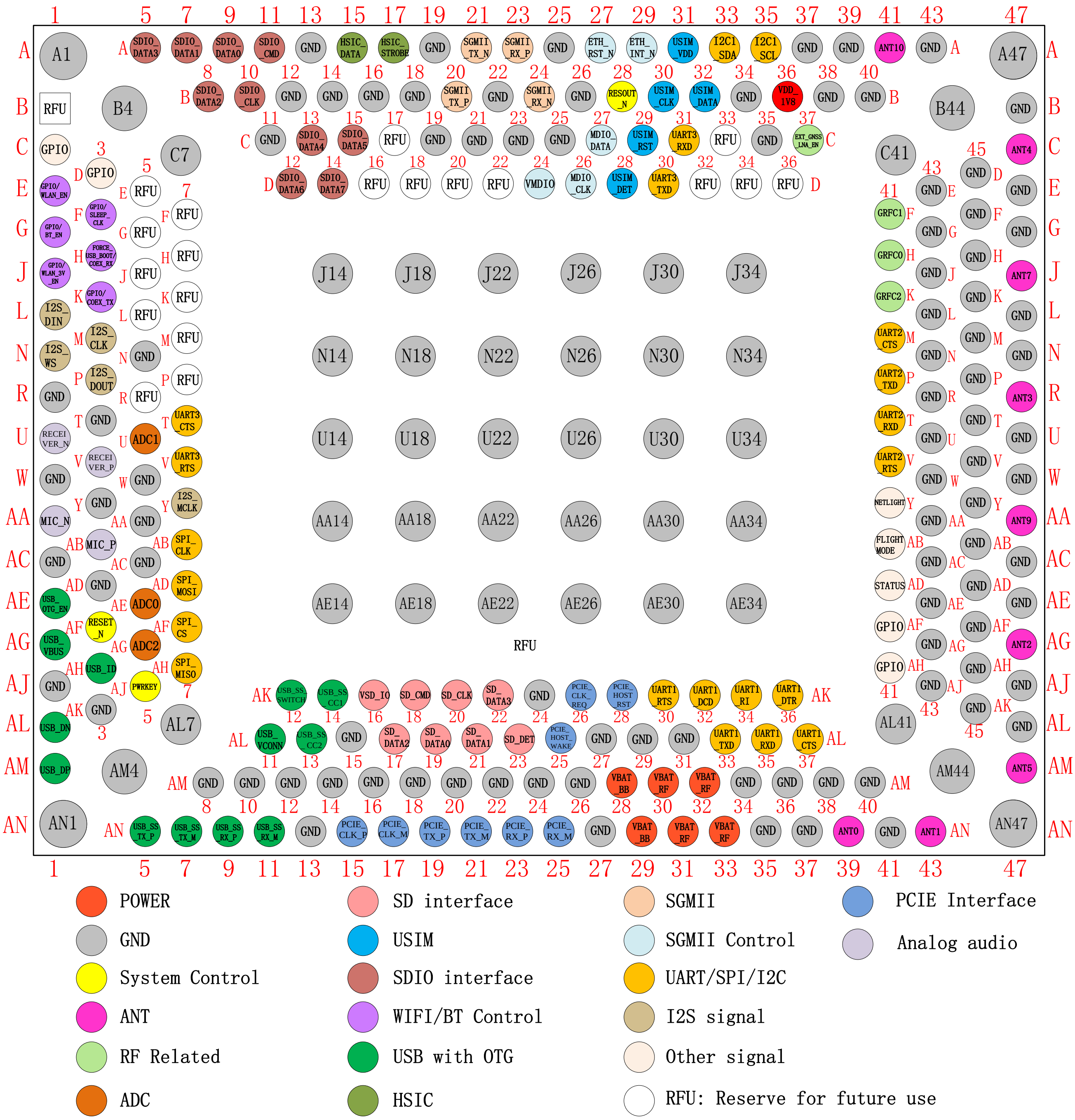


Figure 8-2 5G S-Module Basic Type 1 Pin Layout

8.1.3 Pin Size

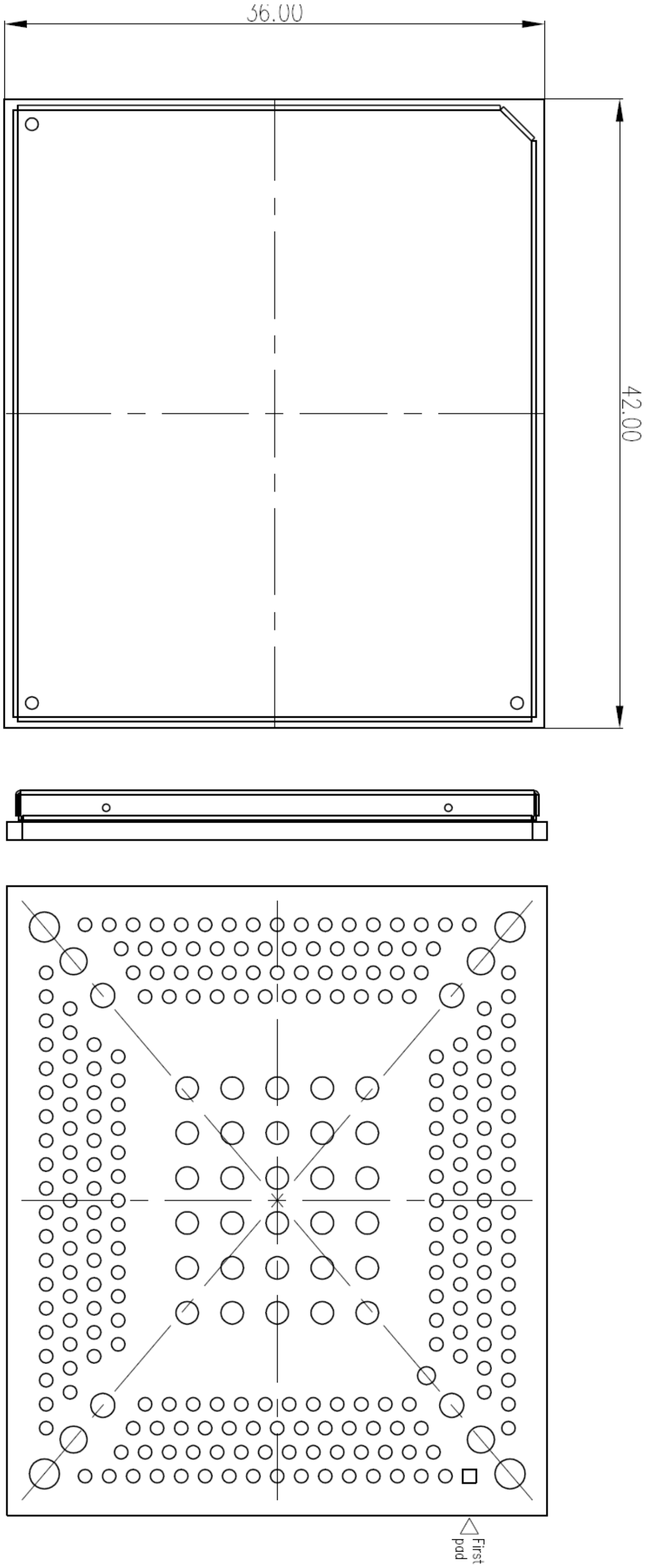


Figure 8-3 5G S-Module Basic Type 1 Pin Size

8.1.4 Pin Definition

Table 8-1 5G S-Module Basic Type 1 Pin Definition

Pin name	Pin No.	Default status	Description	Comment
Power supply				
VBAT_BB	AM28,AN29	PI	Baseband power supply.	User can connect these pins together to the same source.
VBAT_RF	AN31,AN33,AM30,AM32	PI	RF power supply.	
VDD_1V8	B36	PO	1.8 output with Max 50mA current output for external circuit, such as level shift circuit.	If unused, please keep it open.
System Control				
PWRKEY	AJ5	DI,PU	System power on/off control input, active low.	
RESET_N	AF3	DI, PU	System reset control input, active low.	
RESOUT_N	B28	DO	System reset control output, active low.	If unused, please keep it open.
USB 3.1 interface				
USB_VBUS	AG1	DI,PD	Valid USB detection input.	If unused, please keep them open.
USB_DN	AL1	AIO	Negative line of the differential, bi-directional USB signal.	
USB_DP	AM1	AIO	Positive line of the differential, bi-directional USB signal.	
USB_ID	AH3	DI,PU	USB ID input	
USB_OTG_EN	AE1	DO	External boost DCDC enable, if the USB_ID pin has been pulled low, this pin will drive high level.	
USB_SS_TX_P+	AN5	AO	USB Super-Speed+(10Gbps) transmit – plus	
USB_SS_TX_M+	AN7	AO	USB Super-Speed+(10Gbps) transmit – minus	

USB_SS_RX_P+	AN9	AI	USB Super-Speed+(10Gbps) receive – plus	
USB_SS_RX_M+	AN11	AI	USB Super-Speed+(10Gbps) receive – minus	
USB_VCONN	AL11	AI	Power input pin to drive active cables during the DFP	
USB_SS_SWITCH	AK12	DO	USB type-C switch control signal.	
USB_SS_CC1	AK14	AIO	USB type-C connector configuration channel 1	
USB_SS_CC2	AL13	AIO	USB type-C connector configuration channel 2	
HSIC interface				
HSIC_STROBE	A17	DIO	HSIC strobe	Slave mode by default. If unused, please keep them open.
HSIC_DATA	A15	DIO	HSIC data	
SD interface				
SD_DATA0	AL19	DIO	SD data 0	VSD_IO is used to pull up the SD_DATA through resistor as the poor drive strength of some SD card, do not use it to power the SD card. When connected to the eMMC card, the RESOUT_N signal should be connected to the reset signal of the eMMC card. If unused, please keep them open.
SD_DATA1	AL21	DIO	SD data 1	
SD_DATA2	AL17	DIO	SD data 2	
SD_DATA3	AK22	DIO	SD data 3	
SD_CLK	AK20	DO	SD clock output	
SD_CMD	AK18	DO	SD command output	
VSD_IO	AL16	PO	Voltage of data signal of the SD card	
SD_DET	AL23	DI,PU	SD card insertion detect H: SD card is removed L: SD card is inserted	
SDIO interface				
SDIO_DATA0	A9	DIO	SDIO data0	For WLAN solution by default. Could also be connected to the eMMC card. If unused, please keep them open.
SDIO_DATA1	A7	DIO	SDIO data1	
SDIO_DATA2	B8	DIO	SDIO data2	
SDIO_DATA3	A5	DIO	SDIO data3	
SDIO_CMD	A11	DIO	SDIO command	
SDIO_CLK	B10	DO	SDIO clock	
SDIO_DATA4	C13	DIO	SDIO data4	
SDIO_DATA5	C15	DIO	SDIO data5	
SDIO_DATA6	D12	DIO	SDIO data6	
SDIO_DATA7	D14	DIO	SDIO data7	
WLAN assistant interface				

GPIO/COEX_TX	K3	DIO/DO	GPIO/ LTE&WLAN coexistence data transmit	Module will be forced into USB download mode by connect H3pin to VDD_1V8 during power up. If unused, please keep them open.
FORCE_USB_BOOT/COEX_RX	H3	DI/DI	Force USB BOOT/ LTE&WLAN coexistence data receive	
GPIO/WLAN_EN	E1	DI/DO	GPIO/ WLAN function enable	
GPIO/SLEEP_CLK	F3	DIO/DO	GPIO/ Sleep clock output	
GPIO/BT_EN	G1	DIO/DO	GPIO/ Bluetooth function enable	
GPIO/WLAN_3V_EN	J1	DIO/DO	GPIO/ WLAN power enable	
SGMII interface				
SGMII_TX_P	B20	AO	SGMII transmit– positive	If unused, please keep them open.
SGMII_TX_N	A21	AO	SGMII transmit - negative	
SGMII_RX_P	A23	AI	SGMII receive – positive	
SGMII_RX_N	B24	AI	SGMII receive - negative	
SGMII control interface				
ETH_INT_N	A29	DI,PU	Ethernet PHY interrupt	External 1.5K pull-up resistor from VSDIO to MDIO_DATA and 10K pull-up resistor from VDD_1V8 to ETH_INT_N are needed if be used. If unused, please keep them open.
ETH_RST_N	A27	DO	Ethernet PHY reset	
MDIO_DATA	C27	DIO	Management data input/output-data	
MDIO_CLK	D26	DO	Management data input/output-clock	
VMDIO	D24	PO	Power domain of the MDIO interface	
USIM interface				

USIM_VDD	A31	PO	Power output for USIM card, the voltage depends on the USIM card type. Its output current is up to 50mA.	All lines of USIM interface should be protected against ESD.
USIM_DATA	B32	DIO	USIM Card data I/O, which has been pulled up via a 10KR resistor to USIM_VDD internally. Do not pull it up or down externally.	
USIM_CLK	B30	DO	USIM clock output	
USIM_RST	C29	DO	USIM Reset output	
USIM_DET	D28	DI	USIM card detecting input. H: USIM is removed L: USIM is inserted	
UART1 interface				
UART1_TXD	AL33	DOH	Transmit Data 1	If unused, please keep them open.
UART1_RXD	AL35	DI,PU	Receive Data 1	
UART1_CTS	AL37	DI,PU	Clear to Send 1	
UART1_RTS	AK30	DOH	Request to send 1	
WAKEUP_OUT	AK34	DOH	Ring Indicator	
UART1_DCD	AK32	DOH	Carrier detects 1	
WAKEUP_IN	AK36	DI,PU	DTE get ready	
UART2 interface				
UART2_TXD	P41	DOH	Transmit Data 2	If unused, please keep them open.
UART2_RXD	T41	DI,PU	Receive Data 2	
UART2_CTS	M41	DI,PU	Clear to Send 2	
UART2_RTS	V41	DOH	Request to send 2	
UART3 interface				
UART3_TXD	D30	DOH	Debug transmit Data 3	If unused, please keep them open.
UART3_RXD	C31	DI,PU	Debug receive Data 3	

UART3_CTS	T7	DI,PU	Clear to Send 3	
UART3_RTS	V7	DOH	Request to send 3	
SPI interface				
SPI_MOSI	AD7	DOL	Master output slaver input	If unused, please keep them open.
SPI_MISO	AH7	DI,PU	Master input slaver output	
SPI_CS	AF7	DOL	SPI chip select	
SPI_CLK	AB7	DOL	SPI clock	
Analog audio				
MIC_P	AB3	AI	Differential audio input	If unused, please keep them open.
MIC_N	AA1	AI		
RECEIVER_P	V3	AO	Differential audio output	
RECEIVER_N	U1	AO		
I2C interface				
I2C1_SCL	A35	OD	I2C clock output 1	OD gate driver, pull-up resistors of 2.2KR to the VDD_1V8 are needed. If unused, please keep open
I2C1_SDA	A33	OD	I2C data input/output 1	
I2S interface				
I2S_DIN/ PCM_DIN	L1	DI	I2S data input/PCM data input	If unused, please keep them open.
I2S_DOUT/ PCM_DOUT	P3	DO	I2S data output/PCM data output	
I2S_CLK/ PCM_CLK	M3	DO	I2S clock output/PCM clock output	
I2S_WS/PCM_SYNC	N1	DO	I2S word select/PCM synchronous signal	
I2S_MCLK	Y7	DO	I2S system main clock.	
GPIO				
NETLIGHT	Y41	DO	LED control output as network status indication.	If unused, keep them open.
FLIGHTMODE	AB41	DI,PU	Flight Mode control input. High level(or open): Normal Mode Low level: Flight Mode	
STATUS	AD41	DO	Operating status output. High level: Power on and firmware ready Low level: Power off	

GPIO	C1	DIO	General purpose input /output	
GPIO	D3	DIO	General purpose input /output	
GPIO	E1	DIO	General purpose input /output	
GPIO	AH41	DIO	General purpose input /output	
RF interface				
ANT4	C47	AIO	5G NR(n79) main antenna	
ANT7	J47	AIO	5G NR(n79) main antenna	
ANT3	R47	AI	5G NR(n79) MIMO antenna	
ANT9	AA47	AI	5G NR(n79) MIMO antenna	
ANT5	AM47	AIO	5G NR(n41)&4G LTE main antenna	
ANT2	AG47	AIO	5G NR(n41) main antenna,4G LTE diversity antenna	
ANT0	AN39	AI	5G NR(n41) MIMO antenna	
ANT1	AN43	AI	5G NR(n41) MIMO antenna	
ANT10	A41	AI	GNSS antenna	
RF relative interface				
GRFC0	H41	DO	General RF control 0	If unused, please keep them open.
GRFC1	F41	DO	General RF control 1	
GRFC2	K41	DO	General RF control 2	
EXT_GNSS_LNA_EN	C37	DO	External GNSS LNA enable	
Other interface				
ADC0	AE5	AI	Analog-digital converter input 0	If unused, please keep them open.
ADC1	U5	AI	Analog-digital converter input 1	
ADC2	AG5	AI	Analog-digital converter input 2	
PCIE				
PCIE_CLK_REQ	AK26	DO	PCIe clock request	If unused, please keep them open.
PCIE_HOST_RST	AK28	DO	PCIe RC (host) reset	
PCIE_HOST_WAKE	AL25	DI	PCIe RC (host) wake	

PCIE_CLK_P	AN15	AO	PCIe reference clock plus	
PCIE_CLK_M	AN17	AO	PCIe reference clock minus	
PCIE_TX_P	AN19	AO	PCIe transmit plus	
PCIE_TX_M	AN21	AO	PCIe transmit minus	
PCIE_RX_P	AN23	AI	PCIe receive plus	
PCIE_RX_M	AN25	AI	PCIe receive minus	
GND				
GND	R1,W1,AC1,AJ1,T3,Y3,AD3,AK3,N5,W5,AA5,AC5,AK24,AL31,AL29,AL27,AL15,AM40,AM38,AM36,AM34,AM26,AM24,AM22,AM20,AM18,AM16,AM14,AM12,AM10,AM8,AN41,AN37,AN35,AN27,AN13,B47,E47,G47,L47,N47,U47,W47,AC47,AE47,AJ47,AL47,AK45,AH45,AF45,AD45,AB45,Y45,V45,T45,P45,M45,K45,H45,F45,D45,E43,G43,J43,L43,N43,R43,U43,W43,AA43,AC43,AE43,AG43,AJ43,C35,C25,C23,C21,C19,C11,B40,B38,B34,B26,B22,B18,B16,B14,B12,A43,A39,A37,A25,A19,A13			
RFU				
RFU	C17		Reserved for future use	
RFU	D16		Reserved for future use	
RFU	D18		Reserved for future use	
RFU	D20		Reserved for future use	
RFU	D22		Reserved for future use	
RFU	C33		Reserved for future use	
RFU	D32		Reserved for future use	
RFU	D34		Reserved for future use	
RFU	D36		Reserved for future use	
RFU	B1		Reserved for future use	
RFU	E5		Reserved for future use	
RFU	G5		Reserved for future use	
RFU	J5		Reserved for future use	
RFU	L5		Reserved for future use	
RFU	F7		Reserved for future use	
RFU	H7		Reserved for future use	
RFU	K7		Reserved for future use	
RFU	M7		Reserved for future use	
RFU	R5		Reserved for future use	
RFU	P7		Reserved for future use	
RFU	AD41		Reserved for future use	
RFU	AF41		Reserved for future use	
RFU	AH41		Reserved for future use	

8.2 5G S-Module Baisc Type 2

8.2.1 Diagram

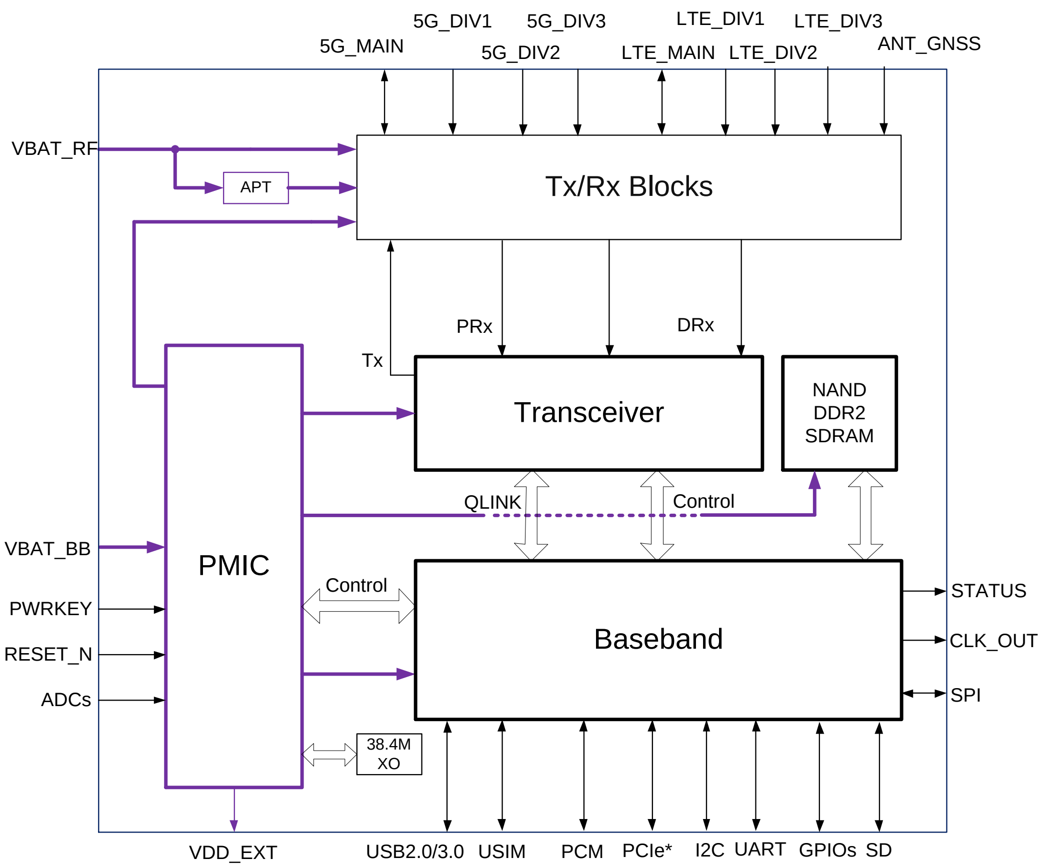


Figure 8-4 5G S-Module Basic Type 2 Diagram

8.2.2 Pin Layout

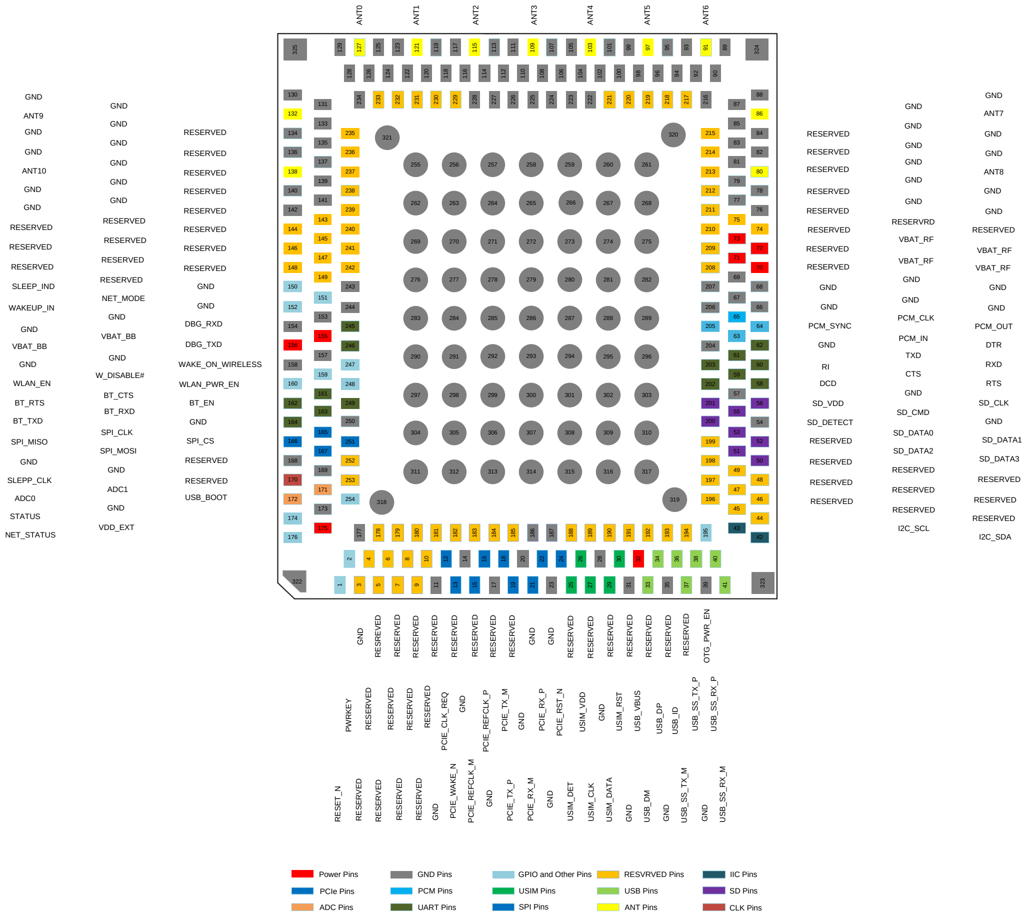


Figure 8-5 5G S-Module Basic Type 2 Pin Layout

8.2.3 Pin Size

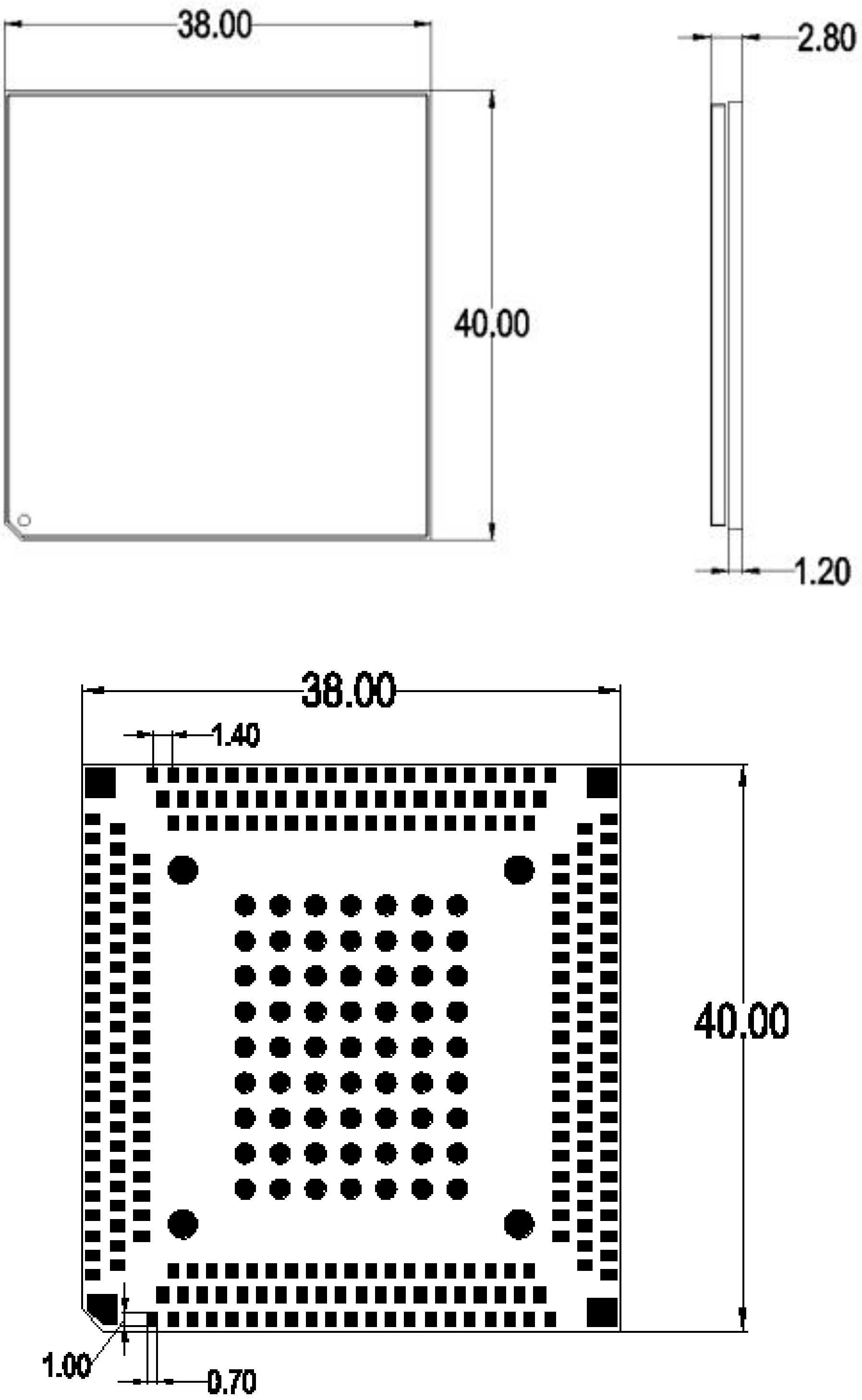


Figure 8-6 5G S-Module Basic Type 2 Pin Size

8.2.4 Pin Definition

Table 8-2 5G S-Module Basic Type 2 Pin Definition

Pin name	Pin No.	Default status	Description	Comment
Power supply				
VBAT_BB	155, 156	PI	Baseband power supply.	User can connect these pins together to the same source.
VBAT_RF	70,71 72,73	PI	RF power supply.	
VDD_EXT	175	PO	1.8 output with Max 50mA current output for external circuit, such as level shift circuit.	If unused, please keep it open.
System Control				
PWRKEY	2	DI,PU	System power on/off control input, active low.	
RESET_N	1	DI, PU	System reset control input, active low.	
Status Indicator				
STATUS	174	DO	System status output	
NET_MODE	151	DO	Network Mode output	
NET_STATUS	176	DO	Network status output	
USB interface				
USB_VBUS	32	DI,PD	Valid USB detection input.	If unused, please keep them open.
USB_DP	34	AIO	Negative line of the differential, bi-directional USB signal.	
USB_DM	33	AIO	Positive line of the differential, bi-directional USB signal.	
USB_ID	36	DI,PU	USB ID input	
USB_SS_ TX_P	38	AO	USB Super-Speed transmit – plus	
USB_SS_ TX_M	37	AO	USB Super-Speed transmit – minus	

USB_SS_ RX_P	40	AI	USB Super-Speed receive – plus	
USB_SS_ RX_M	41	AI	USB Super-Speed receive – minus	
(U)SIM interface				
USIM_VDD	26	PO	Power output for USIM card, the voltage depends on the USIM card type. Its output current is up to 50mA.	All lines of USIM interface should be protected against ESD.
USIM_DATA	29	DIO	USIM Card data I/O, which has been pulled up via a 10KR resistor to USIM_VDD internally. Do not pull it up or down externally.	
USIM_CLK	27	DO	USIM clock output	
USIM_RST	30	DO	USIM Reset output	
USIM_DET	25	DI	USIM card detecting input. H: USIM is removed L: USIM is inserted	
SPI interface				
SPI_CS	251	DO	SPI chip select	
SPI_CLK	165	DO	SPI clock	
SPI_MOSI	167	DIO	Master output slaver input	
SPI_MISO	166	DIO	Master input slaver output	
UART1 interface				
RI	203	DO	Ring Indicator	If unused, please keep them open.
DCD	202	DO	Carrier detects	
CTS	59	DO	Clear to Send	

RTS	58	DI	Request to send		
DTR	62	DI	Data Terminal Ready		
TXD	61	DO	Transmit Data		
RXD	60	DI	Receive Data		
BT interface					
BT_TXD	164	DO	Transmit Data	If unused, please keep them open.	
BT_RXD	163	DI	Receive Data		
BT_RTS	162	DI	Request to send		
BT_CTS	161	DO	Data Terminal Ready		
Debug interface					
DBG_RXD	245	DI	Debug transmit Data	If unused, please keep them open.	
DBG_TXD	246	DO	Debug receive Data		
ADC interface					
ADC0	172	AI	Analog-digital converter input 0	If unused, please keep them open.	
ADC1	171	AI	Analog-digital converter input 1		
PCM interface					
PCM_IN	63	DI	PCM data input	If unused, please keep them open.	可选
PCM_OUT	64	DO	PCM data output		可选
PCM_SYNC	205	DIO	PCM synchronous signal		可选
PCM_CLK	65	DO	PCM clock output		可选
I2C interface					

I2C_SCL	43	OD,O	I2C clock output	OD gate driver, pull-up resistors of 2.2KR to the VDD_1V8 are needed. If unused, please keep open
I2C_SDA	42	OD, I/O	I2C data input/output	
PCIE interface				
PCIE_REF CLK_P	16	AO	PCIe reference clock plus	
PCIE_REF CLK_M	15	AO	PCIe reference clock minus	
PCIE_TX_M	18	AO	PCIe transmit plus	
PCIE_TX_P	19	AO	PCIe transmit minus	
PCIE_RX_M	21	AI	PCIe receive plus	
PCIE_RX_P	22	AI	PCIe receive minus	
PCIE_CLK_ REQ	12	DO	PCIe clock request	If unused, please keep them open.
PCIE_RST_N	24	DO	PCIe RC (host) reset	
PCIE_WAKE_N	13	DI	PCIe RC (host) wake	
WLAN interface				
WLAN_PWR_ EN	248	DO	WLAN power enable	If unused, please keep them open.
WAKE_ON_ WIRELESS	247	DO	Host wakeup	
WLAN_EN	160	DO	WLAN function enable	
SD interface				
SD_VDD	201	PO	Voltage of data signal of the SD card	SD_VDD is used to pull up the SD_DATA through resistor as the poor drive strength of some SD card, do not use it to power the SD card. When connected to the eMMC card, the RESOUT_N signal should be connected to the reset signal of the eMMC card. If unused, please keep them open.
SD_DATA0	53	DIO	SD data 0	
SD_DATA1	52	DIO	SD data 1	
SD_DATA2	51	DIO	SD data 2	
SD_DATA3	50	DIO	SD data 3	

SD_CMD	55	DO	SD command output	
SD_CLK	56	DO	SD clock output	
SD_ DETECT	200	DI， PU	SD card insertion detect H: SD card is removed L: SD card is inserted	
RF interface				
ANT5	97	AIO	5G NR(n41)&4G LTE main antenna	
ANT2	115	AIO	5G NR(n41) main antenna &4G LTE diversity antenna	
ANT0~1	121,127	AI	5G NR(n41) MIMO antenna	
ANT10	138	AI	GNSS antenna	
ANT7,4	86,103	AIO	5G NR(n79) main antenna	
ANT3,9	109,132	AI	5G NR(n79) MIMO antenna	
ANT6,8	91,80	AIO	Reserved	
GPIO				
WAKEUP_IN	152	DI	Sleep Mode control	
W_DISABLE#	159	DI	Flight Mode control	
Others				
USB_BOOT	254	DI	Module will be forced into USB download mode by connect this pin.	
BT_EN	249	DO	BT function enable	
SLEEP_IND	150	DI	Sleep Mode control	
OTG_PWR_EN	195	DO	OTG power enable	
GND				

GND	11, 14, 17, 20, 23, 28, 31, 35, 39, 54, 57, 66, 67, 68, 69, 76,77,78, 79, 81~85, 87~ 90, 92~96, 98~102, 104~108,110~114,116~120,122~126,128~131, 133~137, 139~142, 153, 154, 157,158, 168, 169, 173, 177, 186, 187, 204, 206, 207, 216, 222~228, 234, 243, 244, 250, 255~325	

8.3 5G S-Module Basic Type 3

8.3.1 Diagram

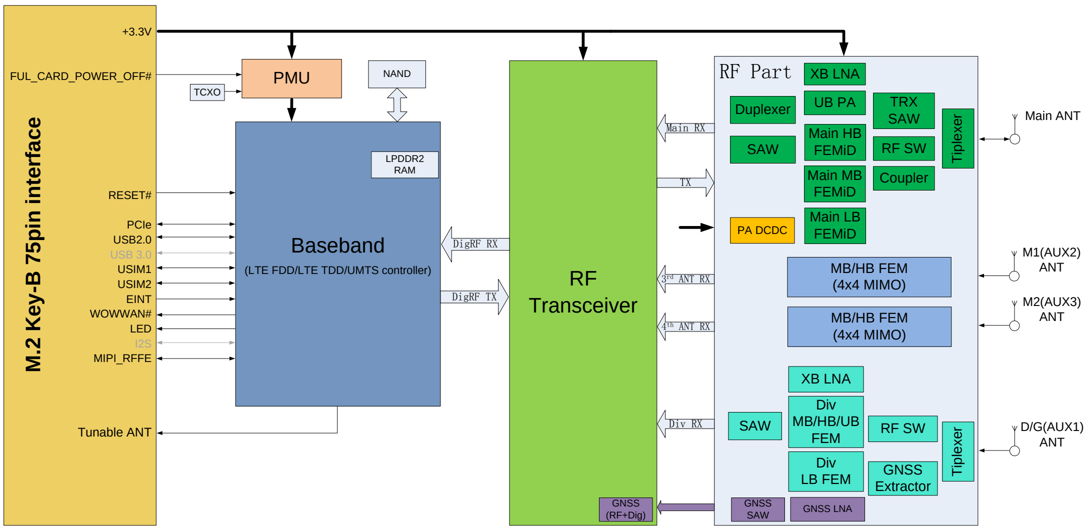


Figure 8-7 5G S-Module Basic Type 3 Diagram

8.3.2 Pin Layout

		CONFIG_2	75
74	+3.3V	GND	73
72	+3.3V	GND	71
70	+3.3V	CONFIG_1	69
68	NC	RESET#(1.8V)	67
66	SIM1_DETECT(1.8V)	ANTCTL3(1.8V)	65

64	COEX1(1.8V)	ANTCTL2(1.8V)	63
62	COEX2(1.8V)	ANTCTL1(1.8V)	61
60	COEX3(1.8V)	ANTCTL0(1.8V)	59
58	RFE_RFFE_SDATA	GND	57
56	RFE_RFFE_SCLK	REFCLKP	55
54	PEWAKE# (3.3V)	REFCLKN	53
52	CLKREQ# (3.3V)	GND	51
50	PERST# (3.3V)	PERp0	49
48	UIM2_PWR	PERn0	47
46	UIM2_RESET	GND	45
44	UIM2_CLK	PETp0	43
42	UIM2_DATA	PETn0	41
40	SIM2_DETECT(1.8V)	GND	39
38	NC	USB3.0-Rx+	37
36	UIM1_PWR	USB3.0-Rx -	35
34	UIM1_DATA	GND	33
32	UIM1_CLK	USB3.0-Tx+	31
30	UIM1_RESET	USB3.0-Tx -	29
28	I2S_WA(1.8V)	GND	27
26	W_DISABLE2#(3.3/1.8V)	DPR(3.3/1.8V)	25
24	I2S_TX(1.8V)	WOWWAN#(1.8V)	23

22	RFE_RFFE_VIO		
20	I2S_CLK	CONFIG_0	21
	Notch	Notch	
	Notch	Notch	
	Notch	Notch	
	Notch	Notch	
10	LED1#(3.3V OD)	GND	11
8	W_DISABLE1#(3.3/1.8V)	USB D-	9
6	FUL_CARD_POWER_OFF#(3.3/1.8V)	USB D+	7
4	+3.3V	GND	5
2	+3.3V	GND	3
		CONFIG_3	1

Figure 8-8 5G S-Module Type3 Pin Layout

8.3.3 Pin Size

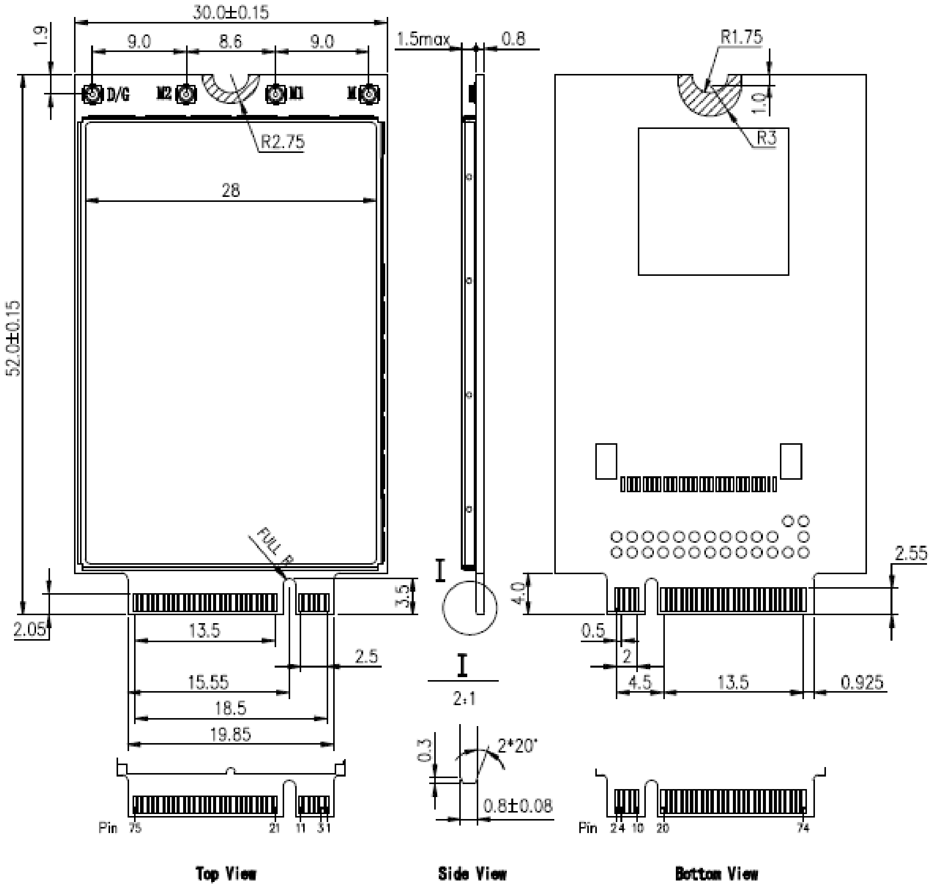


Figure 8-9 5G S-Module Type3 Pin Size

8.3.4 Pin Definition

Table 8-3 5G S-Module Type3 Pin Definition

Pin	Pin Name	I/O	Reset Value	Pin Description	Type
1	CONFIG_3	O	NC	NC, L860 M.2 module is configured as the WWAN – PCIe, USB3.0 interface type	
2	+3.3V	PI	-	Power input	Power Supply
3	GND	-	-	GND	Power Supply
4	+3.3V	PI	-	Power input	Power Supply
5	GND	-	-	GND	Power Supply
6	FULL_CARD_ POWER_OFF#	I	PU	Power enable, Module power on input, internal pull up	CMOS 3.3/1.8V

Pin	Pin Name	I/O	Reset Value	Pin Description	Type
7	USB D+	I/O		USB Data Plus	0.3---3V
8	W_DISABLE1#	I	PD	WWAN Disable, active low	CMOS 3.3/1.8V
9	USB D-	I/O		USB Data Minus	0.3---3V
10	LED1#	OD	T	System status LED, Output open drain, CMOS 3.3V	CMOS 3.3V
11	GND	-	-	GND	Power Supply
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	I2S_CLK	O	PD	I2S Serial clock, Reserved	CMOS 1.8V
21	CONFIG_0		NC	NC, L860 M.2 module is configured as the WWAN – PCIe, USB3.0 interface type	
22	I2S_RX	I	PD	I2S Serial receive data, Reserved	CMOS 1.8V
23	WOWWAN#	O	PD	Wake up host, Reserved	CMOS 1.8V
24	I2S_TX	O	PD	I2S Serial transmit data, Reserved	CMOS 1.8V
25	DPR	I	PD	Body SAR Detect, active low	CMOS 3.3/1.8V
26	W_DISABLE2#	I	PD	GNSS disable, active low, Reserved	CMOS 3.3/1.8V
27	GND	-	-	GND	Power Supply
28	I2S_WA	O	PD	I2S Word alignment/select, Reserved	CMOS 1.8V
29	USB3.0_TX-	O		USB3.0 Transmit data minus, Reserved	
30	UIM_RESET	O	L	SIM reset signal	1.8V/3V
31	USB3.0_TX+	O		USB3.0 Transmit data plus, Reserved	
32	UIM_CLK	O	L	SIM clock Signal	1.8V/3V
33	GND	-	-	GND	Power Supply

Pin	Pin Name	I/O	Reset Value	Pin Description	Type
34	UIM_DATA	I/O	L	SIM data input/output	1.8V/3V
35	USB3.0_RX-	I		USB3.0 receive data minus, Reserved	
36	UIM_PWR	O		SIM power supply, 3V/1.8V	1.8V/3V
37	USB3.0_RX+	I		USB3.0 receive data plus, Reserved	
38	NC			NC	
39	GND	-	-	GND	Power Supply
40	SIM2_DETECT	I	PD	SIM2 Detect, internal pull up(390KΩ), active high	CMOS 1.8V
41	PETn0	O		PCIe TX Differential signals Negative	
42	UIM2_DATA	I/O	L	SIM2 data input/output	1.8V/3V
43	PETp0	O		PCIe TX Differential signals Positive	
44	UIM2_CLK	O	L	SIM2 clock Signal	1.8V/3V
45	GND	-	-	GND	Power Supply
46	UIM2_RESET	O	L	SIM2 reset signal	1.8V/3V
47	PERn0	I		PCIe RX Differential signals Negative	
48	UIM2_PWR	O		SIM2 power supply, 3V/1.8V	1.8V/3V
49	PERp0	I		PCIe RX Differential signals Positive	
50	PERST#	I	PU	Asserted to reset module PCIe interface default. If module went into core dump, it will reset whole module, not only PCIe interface. Active low, internal pull up(10KΩ)	CMOS 3.3V
51	GND	-	-	GND	Power Supply
52	CLKREQ#	O	PU	Asserted by device to request a PCIe reference clock be available (active clock state) in order to transmit data. It also used by L1 PM Sub states mechanism, asserted by either host or device to initiate an L1 exit. Active low, internal pull up(10KΩ)	CMOS 3.3V
53	REFCLKN	I		PCIe Reference Clock signal	

Pin	Pin Name	I/O	Reset Value	Pin Description	Type
				Negative	
54	PEWAKE#	O	L	Asserted to wake up system and reactivate PCIe link from L2 to L0, it depends on system whether supports wake up functionality. Active low, open drain output and should add external pull up on platform	CMOS 3.3V
55	REFCLKP	I		PCIe Reference Clock signal Positive	
56	RFFE_SCLK	O	PD	MIPI Interface Tunable ANT, RFFE clock	CMOS 1.8V
57	GND			GND	Power Supply
58	RFFE_SDATA	I/O	PD	MIPI Interface Tunable ANT, RFFE data	CMOS 1.8V
59	ANTCTL0	O	L	Tunable ANT CTRL0	CMOS 1.8V
60	COEX3	I/O	PD	Wireless Coexistence between WWAN and WiFi/BT modules, based on BT-SIG coexistence protocol. COEX_EXT_FTA, Reserved	CMOS 1.8V
61	ANTCTL1	O	PD	Tunable ANT CTRL1	CMOS 1.8V
62	COEX_RXD	I	T	Wireless Coexistence between WWAN and WiFi/BT modules, based on BT-SIG coexistence protocol. UART receive signal(WWAN module side), Reserved	CMOS 1.8V
63	ANTCTL2	O	PD	Tunable ANT CTRL2	CMOS 1.8V
64	COEX_TXD	O	T	Wireless Coexistence between WWAN and WiFi/BT modules, based on BT-SIG coexistence protocol. UART transmit signal(WWAN module side), Reserved	CMOS 1.8V
65	ANTCTL3	O	PD	Tunable ANT CTRL3	CMOS 1.8V
66	SIM1_DETECT	I	PD	SIM1 Detect, internal pull up(390KΩ), active high	CMOS 1.8V
67	RESET#	I	PU	WWAN reset input, internal pull up(10KΩ), active low	CMOS 1.8V

Pin	Pin Name	I/O	Reset Value	Pin Description	Type
68	ANT_CONFIG	I	PD	Host antenna configuration detect, internal pull up(100KΩ), Reserved	CMOS 1.8V
69	CONFIG_1	O	GND	GND, L860 M.2 module is configured as the WWAN – PCIe, USB3.0 interface type	
70	+3.3V	PI	-	Power input	Power Supply
71	GND	-	-	GND	Power Supply
72	+3.3V	PI	-	Power input	Power Supply
73	GND	-	-	GND	Power Supply
74	+3.3V	PI	-	Power input	Power Supply
75	CONFIG_2	O	NC	NC, L860 M.2 module is configured as the WWAN – PCIe, USB3.0 interface type	

8.4 5G S-Module Smart Type

8.4.1 Diagram

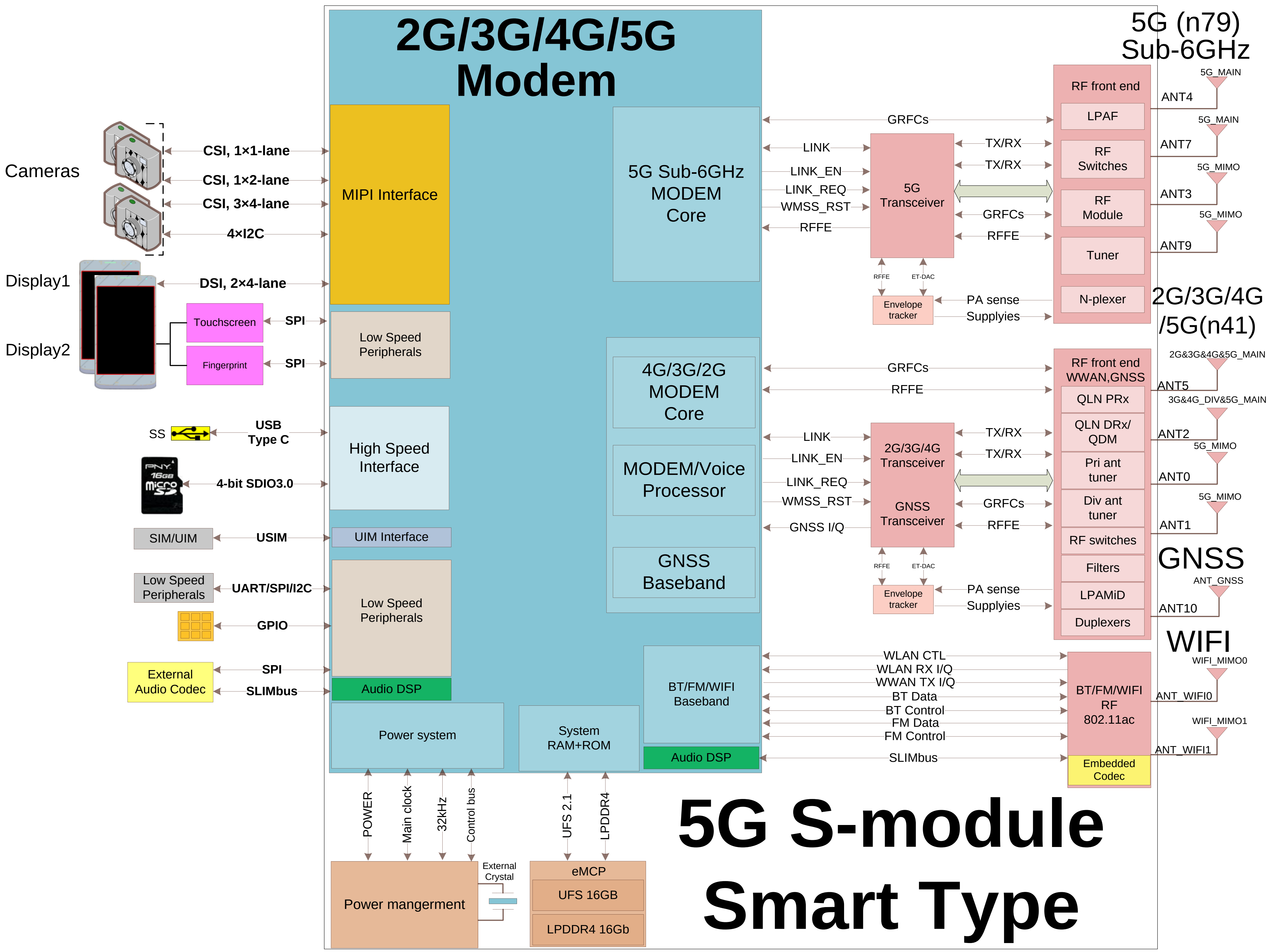


Figure 8-10 5G S-Module Smart Type Diagram

8.4.2 Pin Layout

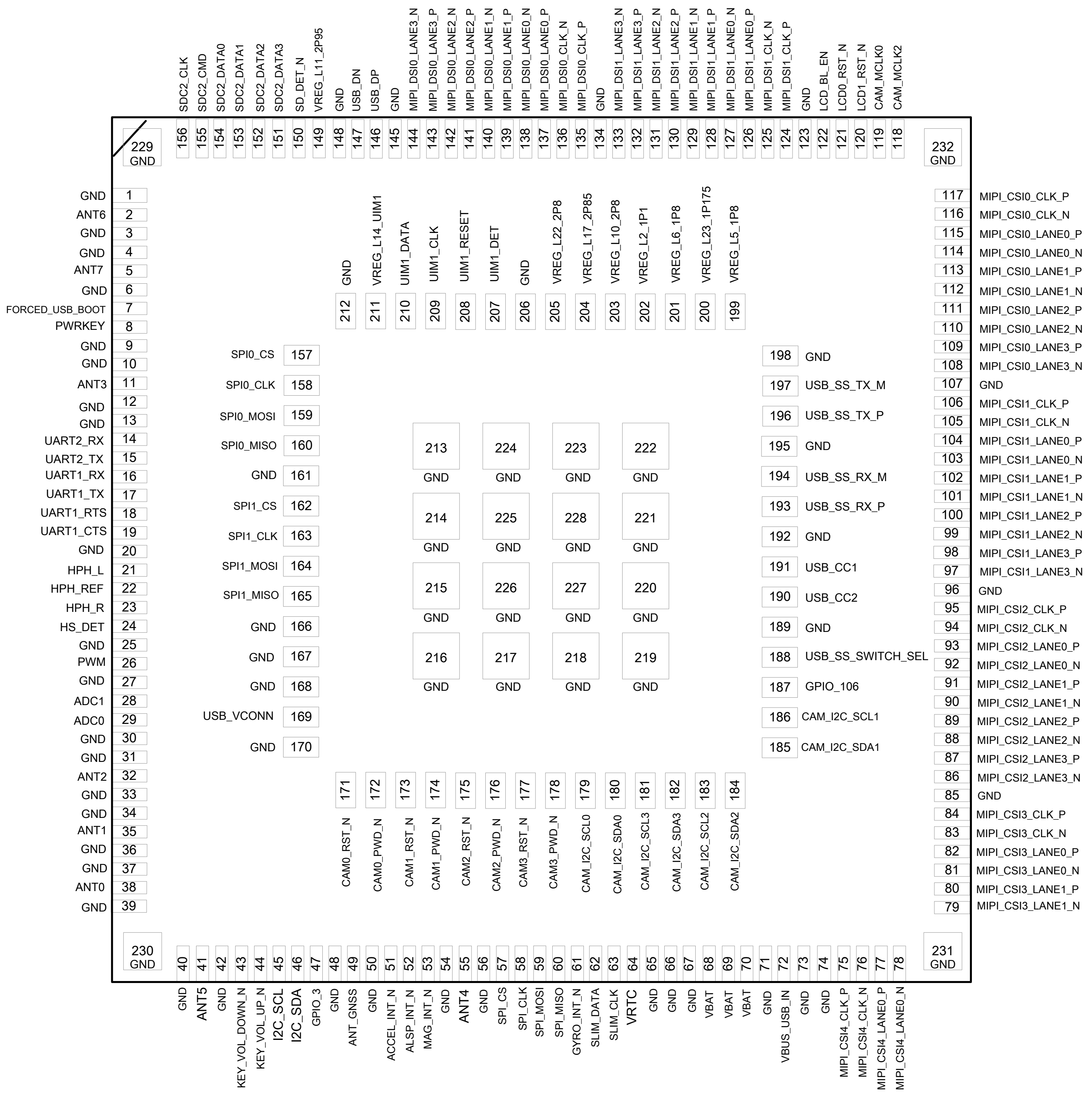


Figure 8-11 5G S-Module Smart Type Pin Layout

8.4.3 Pin Size

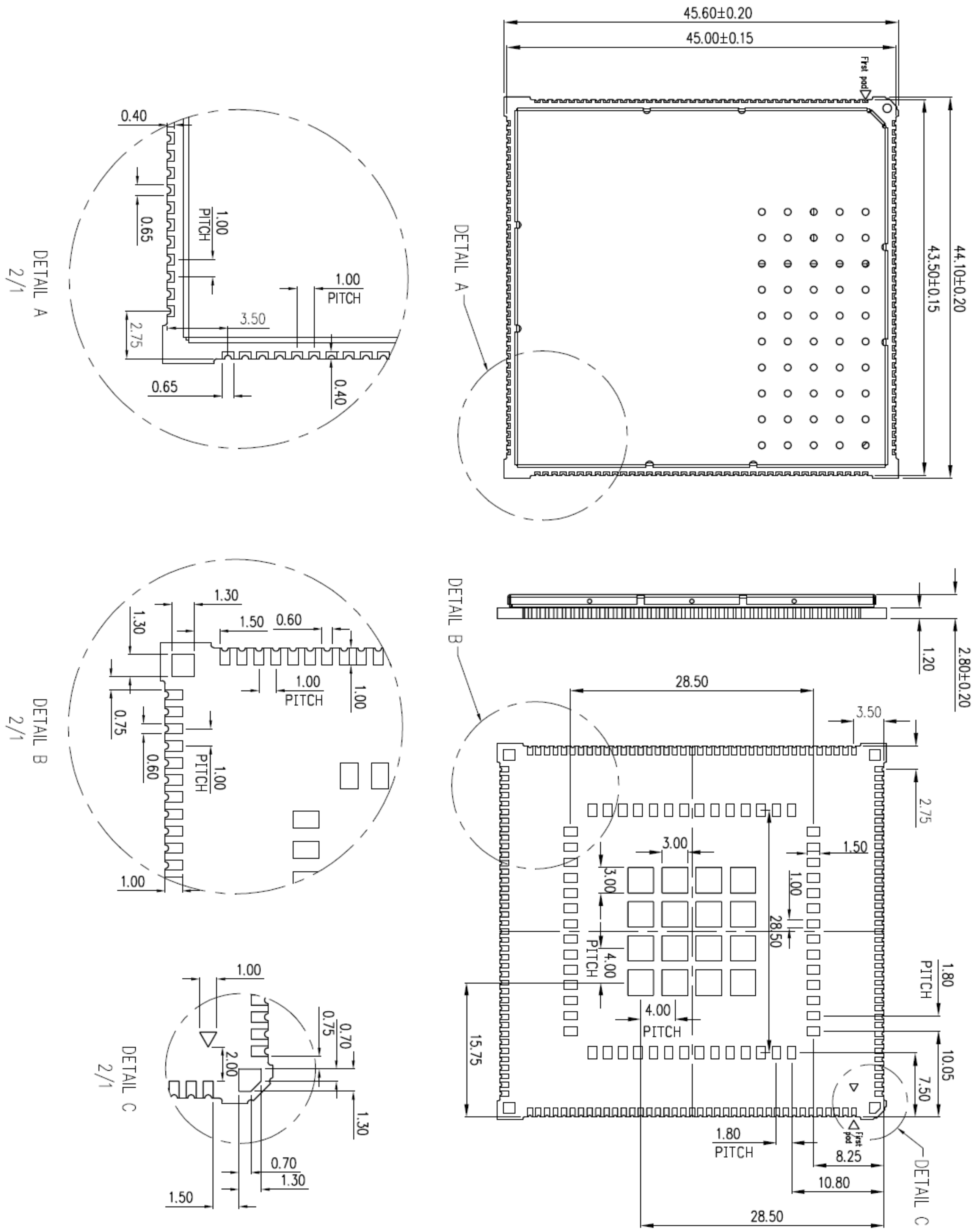


Figure 8-12 5G S-Module Smart Type Pin Size

8.4.4 Pin Definition

Table 8-4 5G S-Module Smart Type Pin Definition

Pin name	Pin No.	Default status	Description	Comment
Power supply				
VBAT	73,74,75	PI	Main power supply, voltage range: 3.4～4.2V.	
VREG_L22_2P8	4	PO	AVDD power for main/auxiliary cameras	
VREG_L17_2P85	5	PO	Analog power for LCD and cameras	
VREG_L10_2P8	6	PO	Main power for touch-panel and sensors	
VREG_L2_1P1	8	PO	Digital power for main camera	
VREG_L6_1P8	10	PO	Digital 1.8V for external sensor, which would be turned off when the module has been in the sleep mode.	
VREG_L23_1P175	11	PO	Digital power for the auxiliary camera	
VREG_L5_1P8	12	PO	Digital power for the GPIO, always active even in the sleep mode	
VRTC	63	PI/O	Coin cell battery or backup battery	
GND				
GND	1,3,4,6,9,10,12,13,16,17,19,20,25,27,28,30,31,33,34,36,37,39,40,42,48,50,54,56,61,70,71,72,76,85,96,107,123,134,145,148,169,181,189,192,195,198,206,212,213,214,215,216,217,218,219,220,221,222,223,224,225,226,227,228,229,230,231,232	P	Ground	
USB TYPE-C interface				
VBUS_USB_IN	77,78	P	Valid USB detection input	
USB_DN	147	I/O	Negative line of the differential, bi-directional USB signal.	
USB_DP	146	I/O	Positive line of the differential, bi-directional USB signal.	
USB_VCONN	170	AI	Power input for type C connection in the DFP mode.	
USB_SS_SWITCH_SEL	188	DO	USB Type C switch selection	

USB_CC2	190	AI/AO	USB Type C configuration 2	
USB_CC1	191	AI/AO	USB Type C configuration 1	
USB_SS_RX_P+	193	AI	USB super-speed+ (10Gbps) receive-plus	
USB_SS_RX_M+	194	AI	USB super-speed+ (10Gbps) receive-minus	
USB_SS_TX_P+	196	AO	USB super-speed+ (10Gbps) transmit-plus	
USB_SS_TX_M+	197	AO	USB super-speed+ (10Gbps) transmit-minus	
UIM card interface				
UIM1_DETECT	207	I	USIM card detecting input.	
UIM1_RESET	208	O	USIM Reset output	
UIM1_CLK	209	O	USIM clock output	
UIM1_DATA	210	I/O	USIM Card data I/O	
VREG_L14_UIM1	211	P	Power output for USIM card, the voltage depends on the USIM card. Its output current is up to 50mA.	
SDIO/SD interface				
VREG_L11_2P95	149	P	Voltage of data signal of the SD card	
SDC2_CLK	156	O	SD clock output	
SDC2_CMD	155	I/O	SD command output	
SDC2_DATA0	154	I/O	SD data 0	
SDC2_DATA1	153	I/O	SD data 1	
SDC2_DATA2	152	I/O	SD data 2	
SDC2_DATA3	151	I/O	SD data 3	
SD_DET_N	150	I	SD card insertion detect H: SD card is removed L: SD card is inserted	
SPI interface-				
SPI_CS	57	DOH	SPI chip select	
SPI_CLK	58	DOL	SPI clock	
SPI_MOSI	59	DOL	Master output slaver input	
SPI_MISO	60	DI,PD	Master input slaver output	
SPI0_MOSI	159	DOL	Master output slaver input 0	
SPI0_MISO	160	DI,PD	Master input slaver output 0	
SPI0_CS	157	DOH	SPI chip select 0	
SPI0_CLK	158	DOL	SPI clock 0	
SPI1_MOSI	165	DOL	Master output slaver input 1	
SPI1_MISO	166	DI,PD	Master input slaver output 1	

SPI1_CS	163	DOH	SPI chip select 1	
SPI1_CLK	164	DOL	SPI clock 1	
Display interface				
MIPI_DSI0_CLK_P	135	O	LCD0 MIPI interface	
MIPI_DSI0_CLK_N	136	O		
MIPI_DSI0_LANE0_P	137	O		
MIPI_DSI0_LANE0_N	138	O		
MIPI_DSI0_LANE1_P	139	O		
MIPI_DSI0_LANE1_N	140	O		
MIPI_DSI0_LANE2_P	141	O		
MIPI_DSI0_LANE2_N	142	O		
MIPI_DSI0_LANE3_P	143	O		
MIPI_DSI0_LANE3_N	144	O		
MIPI_DSI1_CLK_P	124	O	LCD1 MIPI interface	
MIPI_DSI1_CLK_N	125	O		
MIPI_DSI1_LANE0_P	126	O		
MIPI_DSI1_LANE0_N	127	O		
MIPI_DSI1_LANE1_P	128	O		
MIPI_DSI1_LANE1_N	129	O		
MIPI_DSI1_LANE2_P	130	O		
MIPI_DSI1_LANE2_N	131	O		
MIPI_DSI1_LANE3_P	132	O		
MIPI_DSI1_LANE3_N	133	O		
LCD1_RST_N	120	O	LCD1 reset output	
LCD0_RST_N	121	O	LCD0 reset output	
LCD0_BL_EN	122	O	LCD0 backlight enable	
LCD1_BL_EN	119	O	LCD1 backlight enable	
TS0_INT	161	I	Touch screen0 interrupt input	
TS0_RST	162	O	Touch screen0 reset output	
TS1_INT/FP_INT	167	I	Touch screen1 interrupt input/ Finger print interrupt 1	
TS1_RST/FP_RST	168	O	Touch screen1 reset output/ Finger print reset output	
Camera interface				
MIPI_CSI0_LANE3_N	108	I	Camera0 MIPI interface	
MIPI_CSI0_LANE3_P	109	I		
MIPI_CSI0_LANE2_N	110	I		
MIPI_CSI0_LANE2_P	111	I		
MIPI_CSI0_LANE1_N	112	I		

MIPI_CSI0_LANE1_P	113	I		
MIPI_CSI0_LANE0_N	114	I		
MIPI_CSI0_LANE0_P	115	I		
MIPI_CSI0_CLK_N	116	I		
MIPI_CSI0_CLK_P	117	I		
MIPI_CSI1_LANE3_N	97	I	Camera1 MIPI interface	
MIPI_CSI1_LANE3_P	98	I		
MIPI_CSI1_LANE2_N	99	I		
MIPI_CSI1_LANE2_P	100	I		
MIPI_CSI1_LANE1_N	101	I		
MIPI_CSI1_LANE1_P	102	I		
MIPI_CSI1_LANE0_N	103	I		
MIPI_CSI1_LANE0_P	104	I		
MIPI_CSI1_CLK_N	105	I		
MIPI_CSI1_CLK_P	106	I		
MIPI_CSI2_LANE3_N	86	I	Camera2 MIPI interface	
MIPI_CSI2_LANE3_P	87	I		
MIPI_CSI2_LANE2_N	88	I		
MIPI_CSI2_LANE2_P	89	I		
MIPI_CSI2_LANE1_N	90	I		
MIPI_CSI2_LANE1_P	91	I		
MIPI_CSI2_LANE0_N	92	I		
MIPI_CSI2_LANE0_P	93	I		
MIPI_CSI2_CLK_N	94	I		
MIPI_CSI2_CLK_P	95	I		
MIPI_CSI3_LANE1_N	79	I	Camera3 MIPI interface	
MIPI_CSI3_LANE1_P	80	I		
MIPI_CSI3_LANE0_N	81	I		
MIPI_CSI3_LANE0_P	82	I		
MIPI_CSI3_CLK_N	83	I		
MIPI_CSI3_CLK_P	84	I		
CAM0_RST_N	171	O	Reset signal for camera 0	
CAM0_PWD_N	172	O	Power down signal for camera 0	
CAM1_RST_N	173	O	Reset signal for camera 1	
CAM1_PWD_N	174	O	Power down signal for camera 1	
CAM2_RST_N	175	O	Reset signal for camera 2	
CAM2_PWD_N	176	O	Power down signal for camera 2	
CAM3_RST_N	177	O	Reset signal for camera 3	

CAM3_PWD_N	178	O	Power down signal for camera 3	
CAM_I2C_SDA0	180	I/O	camera I2C data 0	
CAM_I2C_SCL0	179	O	camera I2C clock 0	
CAM_I2C_SDA1	186	I/O	camera I2C data 1	
CAM_I2C_SCL11	185	O	camera I2C clock 1	
CAM_MCLK0	118	O	Clock for camera0	
CAM_MCLK1	182	O	Clock for camera1	
CAM_MCLK2	183	O	Clock for camera2	
CAM_MCLK3	184	O	Clock for camera3	
Key interface				
KEY_VOL_UP	43	I	Volume up	
KEY_VOL_DOWN	44	I	Volume down	
PWRKEY	8	I	System power on/off control input, active low.	
Sensor interface				
I2C_SCL	45	O	I2C clock	
I2C_SDA	46	I/O	I2C data	
ACCEL_INT_N	51	I	Accelerate sensor interrupt input	
ALSP_INT_N	52	I	Ambient light sensor interrupt	
MAG_INT_N	53	I	Magnetic sensor interrupt input	
GYRO_INT_N	62	I	Gyrocompass sensor interrupt input	
Audio interface				
HPH_L	21	O	Earphone left tunnel input	
HPH_REF	22	I	Earphone reference ground	
HPH_R	23	O	Earphone right tunnel input	
HS_DET	24	I	Earphone insert detection	
RF interface				
ANT4	11	AIO	5G NR(n79) main antenna	
ANT7	18	AIO	5G NR(n79) main antenna	
ANT3	29	AI	5G NR(n79) MIMO antenna	
ANT9	32	AI	5G NR(n79) MIMO antenna	
ANT5	41	AIO	5G NR(n41)&4G LTE main antenna	
ANT2	49	AIO	5G NR(n41) main antenna&4G LTE diversity antenna	
ANT0	38	AI	5G NR(n41) MIMO antenna	
ANT1	35	AI	5G NR(n41) MIMO antenna	
ANT10	55	AI	GNSS antenna	
ANT_WIFI0	2	AI/O	WIFI MIMO antenna 0	
ANT_WIFI1	5	AI/O	WIFI MIMO antenna 1	

ANT_WIFI02AI/OWIFI MIMO antenna 0ANT_WIFI15AI/OWIFI MIMO antenna 1**UART interface**				
UART1_RX	64	I	Receive Data 1	
UART1_TX	65	O	Transmit Data 1	
UART1_RTS	66	O	Request to send 1	
UART1_CTS	67	I	Clear to Send 1	
UART2_RX	14	O	Receive Data 2	
UART2_TX	15	I	Transmit Data 2	
GPIO				
GPIO	47	I/O	GPIO	
GPIO	187	I/O	GPIO	
Other interface				
FORCED_USB_BOOT	7	I	Module will be forced into USB download mode by connect this pin to VREG_L5_1P8 during power up.	
PWM	26	O	Backlight PWM control signal	
ADC0	68	I	Analog-digital converter input 0	
ADC1	69	I	Analog-digital converter input 1	

8.5 5G S-Module All-in-one Type

Editor's note: To summarize the Diagram, Pin Layout, Pin Size and Pin Definition of 5G S-Module All-in-on Type. This Section will be updated according to the R&D progress of 5G S-Module All-in-on Type.

9 The Electrical Interface Technical Requirements on 5G S-Module

This chapter introduces the main electrical interface (pin definition) of the 5G S-Module, which includes the power interface, control and status interface, RF interface, SIM interface, DATA IO interface, analog interface and audio interface, etc.

9.1 Power Supply Interface

9.1.1 Power Supply

The power pins supply the power to RF and baseband circuits.

For VBAT pads the ripple current could rises to 2A in some condition and may cause voltage drop, which due to GSM/GPRS emission burst (every 4.615ms). Therefore, the power supply for these pads must be able to provide sufficient current up to more than 3A in order to avoid the voltage drop to be more than 300mV.

The following figure shows the VBAT voltage ripple wave at the maximum power transmit phase.

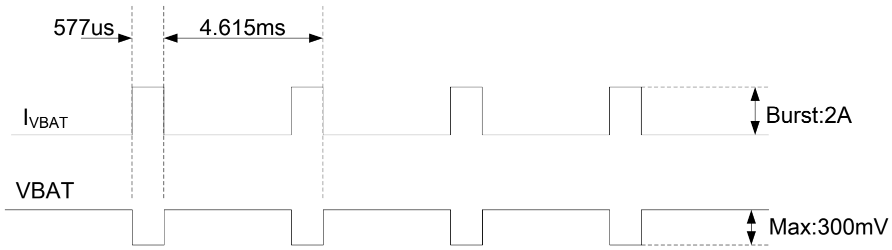


Figure 9-1 VBAT Voltage Drop during Burst Emission (GSM/GPRS)

Table 9-1 VBAT pins electronic characteristic

Symbol	Description	Min.	Typ.	Max.	Unit
VBAT	Module power voltage	3.3	3.8	4.3	V
$I_{VBAT(peak)}$	Module power peak current in normal mode.	-	3	-	A
$I_{VBAT(power-off)}$	Module power current in power off mode.	-	-	50	uA

9.1.2 Power Supply Design Guide

Make sure that the voltage on the VBAT pins will never drop below 3.4V, even during a transmit burst, when current consumption may rise up to 3A. If the voltage drops below 3.4V, the RF performance may be affected.

Note: If the power supply for VBAT pins can support more than 3A, using a total of more than 300uF capacitors is recommended, or else users must using a total of 1000uF capacitors typically, in order to avoid the voltage drop to be more than 300mV.

Some multi-layer ceramic chip (MLCC) capacitors (0.1/1uF) with low ESR in high frequency band can be used for EMC.

These capacitors should be put as close as possible to VBAT pads. Also, users should keep VBAT trace on circuit board wider than 3 mm to minimize PCB trace impedance. The following figure shows the recommended circuit.

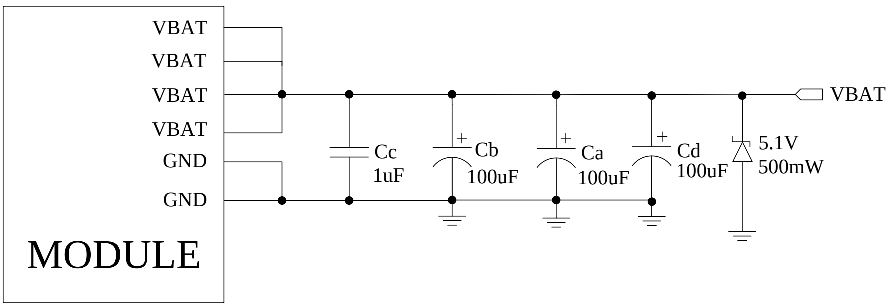


Figure 9-2 Power Supply Application Circuit

Note: The test condition: The voltage of power supply for VBAT is 3.9V, Ca, Cb and Cd were 100 μF tantalum capacitors (ESR=0.7Ω).

In addition, in order to guard for over voltage protection, it is suggested to use a zener diode with 5.1V reverse voltage and more than 500mW power dissipation.

Table 9-2 Recommended Zener Diode List

No.	Manufacturer	Part Number	Power dissipation	Package
1	On semi	MMSZ5231BT1G	500mW	SOD123
2	Prisemi	PZ3D4V2H	500mW	SOD323
3	Vishay	MMSZ4689-V	500mW	SOD123
4	Crownpo	CDZ55C5V1SM	500mW	0805

9.1.3 Recommended Power Supply Circuit

It is recommended that a switching mode power supply or a linear regulator power supply is used. It is important to make sure that all the components used in the power supply circuit can resist the current, which could be more than 3A.

The following figure shows the linear regulator reference circuit with 5V input and 3.8V output.

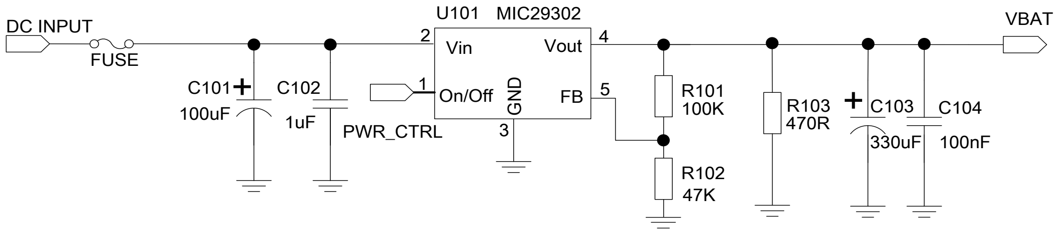


Figure 9-3 Linear Regulator Reference Circuit

If there is a high dropout between input and VBAT, or the efficiency is extremely important, then a switching mode power supply will be preferable. The following figure shows the switching mode power supply reference circuit with 12V input and 3.8V output.

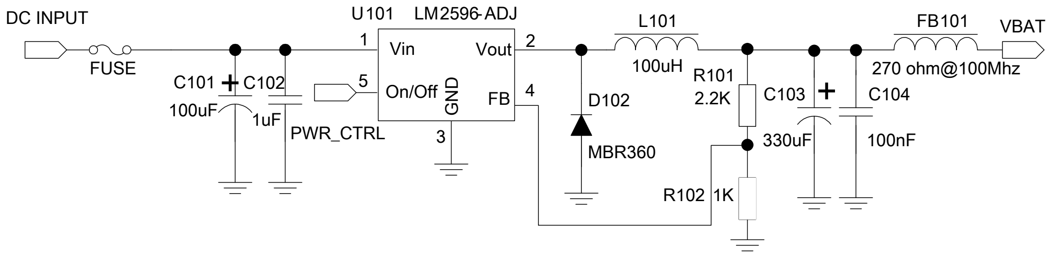


Figure 9-4 Switching Mode Power Supply Reference Circuit

Note: The Switching Mode power supply solution for VBAT must be chosen carefully against Electro Magnetic Interference and ripple current from depraving RF performance.

9.2 Module Control and Status Interface

9.2.1 Power On

Module can be powered on by pulling the PWRKEY pin down to ground.

The PWRKEY pin has been pulled up with a diode to 1.8V internally, so it does not need to be pulled up externally. It is strongly recommended to put a100nF capacitor, an ESD protection diode, close to the PWRKEY pin as it would strongly enhance the ESD performance of PWRKEY pin. Please refer to the following figure for the recommended reference circuit.

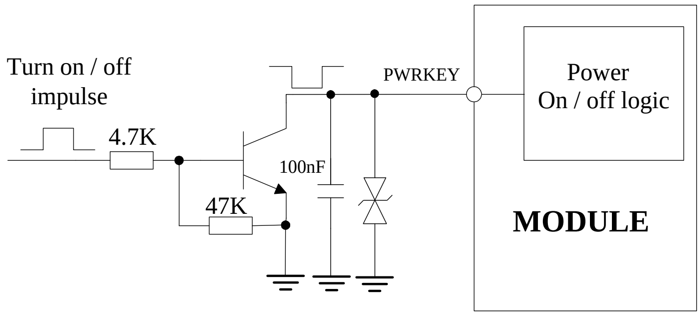


Figure 9-5 Reference Power On/Off Circuit

Note: Module could be automatically power on by connecting PWRKEY pin to ground via 0R resistor directly.

The power-on scenarios are illustrated in the following figure.

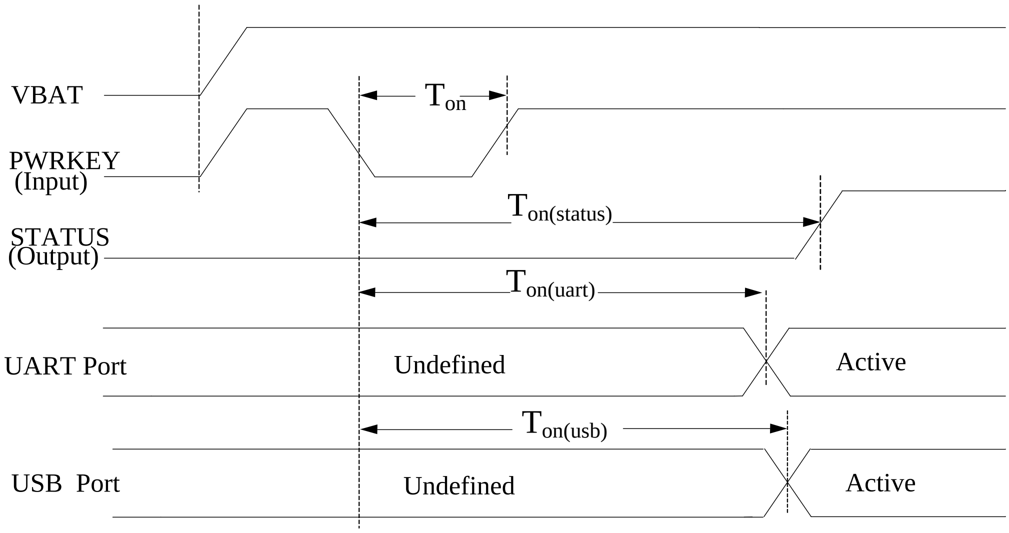


Figure 9-6 Power On Timing Sequence

9.2.2 Power Off

Users could use the PWRKEY to power off MODULE.

These procedures will make MODULE disconnect from the network and allow the software to enter a safe state, and save data before MODULE be powered off completely.

The power off scenario by pulling down the PWRKEY pin is illustrated in the following figure.

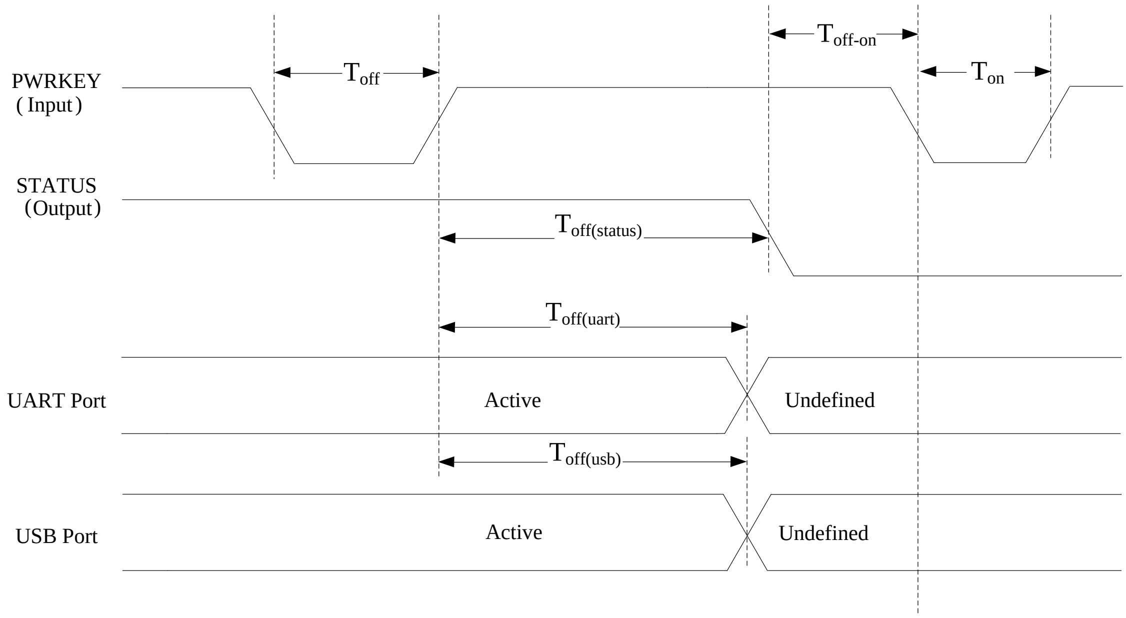


Figure 9-7 Power off timing sequence

9.2.3 Reset Function

Module can be reset by pulling the RESET_N pin down to ground.

Note: This function is only used as an emergency reset.

The RESET_N pin has been pulled up internally, so it does not need to be pulled up externally. It is strongly recommended to put a100pF capacitor and an ESD protection diode close to the RESET_N pin. Please refer to the following figure for the recommended reference circuit.

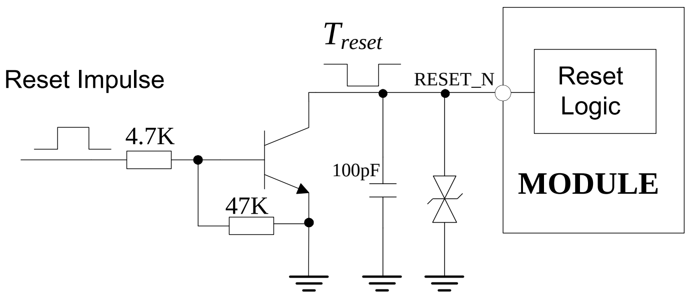


Figure 9-8 Reference Reset Circuit

9.3 RF Interface

9.3.1 GSM /UMTS/LTE/5G sub-6GHz Antenna Design Guide

Users should connect antennas to MODULE's antenna pads through micro-strip line or other types of RF trace and the trace impedance must be controlled in 50Ω. We recommend that the total insertion loss between the antenna pads and antennas should meet the following requirements:

Table 9-3 Traceloss

Frequency	Loss
700MHz-960MHz	<0.5dB
1710MHz-2170MHz	<0.9dB
2300MHz-2650MHz	<1.2dB
3300MHz-5000MHz	<2dB

For there are many antennas in the system, the isolation from any antenna should be noticed, the minimum requirement is showing below:

1. The isolation from 4G main antenna to the 4G DRX antenna should be more than 20db which has same band.
2. The isolation from 5G NR main antenna to the 5G NR DRX antenna should be more than 20db which has same band.
3. The isolation from 4G main antenna to the 5G NR main antenna should be more than 10db which has different band.
4. The isolation from 4G main antenna to the 5G NR DRX antenna should be more than 10db.
5. The isolation from 4G main antenna to the GPS antenna should be more than 40db which has BAND13 AND 30db if not..
6. The isolation from WIFI antenna to the 4G DRX and main antenna should be more than 30db which has band7/40 and 20db if not.
7. The isolation from WIFI antenna to the 5G NR DRX and main antenna should be more than 20db

To facilitate the antenna tuning and certification test, a RF connector and an antenna matching circuit should be added. The following figure is the recommended circuit.

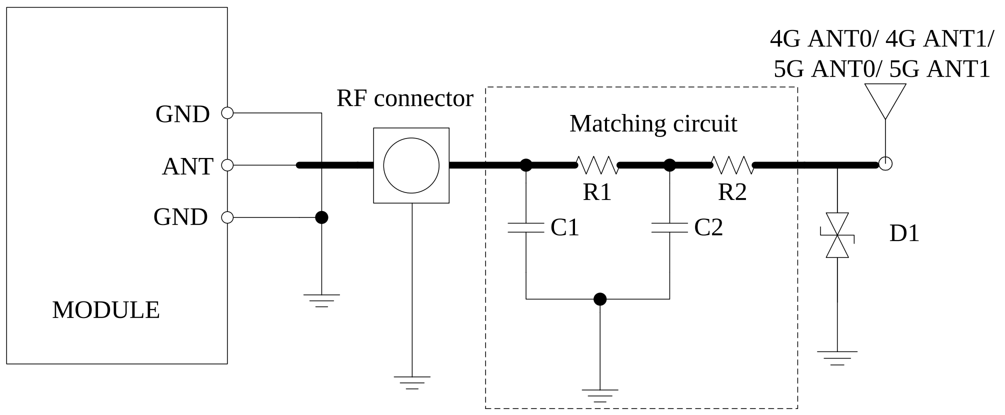


Figure 9-9 Antenna Matching Circuit (ANT_MAIN)

In above figure, the components R1,C1,C2 and R2 are used for antenna matching, the values of components can only be achieved after the antenna tuning and usually provided by antenna vendor. By default, the R1, R2 are 0Ω resistors, and the C1, C2 are reserved for tuning. The component D1 is a TVS for ESD protection, and it is optional for users according to application environment.

The RF test connector is used for the conducted RF performance test, and should be placed as close as to the MODULE's ANT_MAIN pin. The traces impedance between MODULE and antenna must be controlled in 50Ω.

Table 9-4 Recommended TVS

Package	Part Number	Vender
0201	LXES03AAA1-154	Murata
0402	LXES15AAA1-153	Murata

9.3.2 GNSS Application Guide

MODULE merges GNSS(GPS/GLONASS/BD) satellite and network information to provide a high-availability solution that offers industry-leading accuracy and performance. This solution performs well, even in very challenging environmental conditions where conventional GNSS receivers fail, and provides a platform to enable wireless operators to address both location-based services and emergency mandates.

Users can adopt an active antenna or a passive antenna to MODULE.

If using a passive antenna, an external LNA is necessary to get better performance. The following figures are the reference circuits;

If using an active antenna, then external VDD power need not to be supplied to antenna, because it can be given from module.

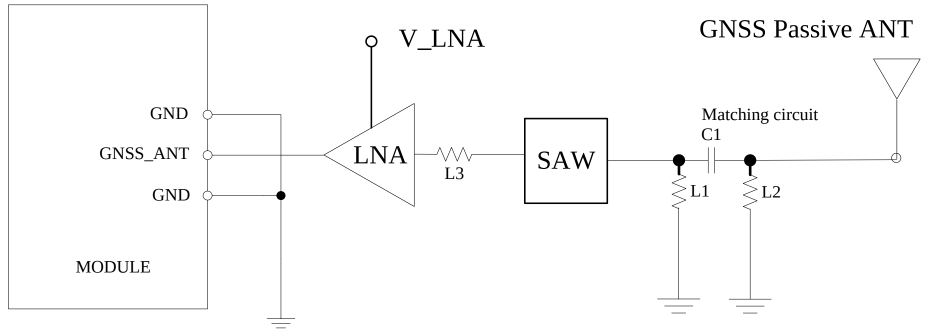


Figure 9-10 Passive Antenna Circuit (Default)

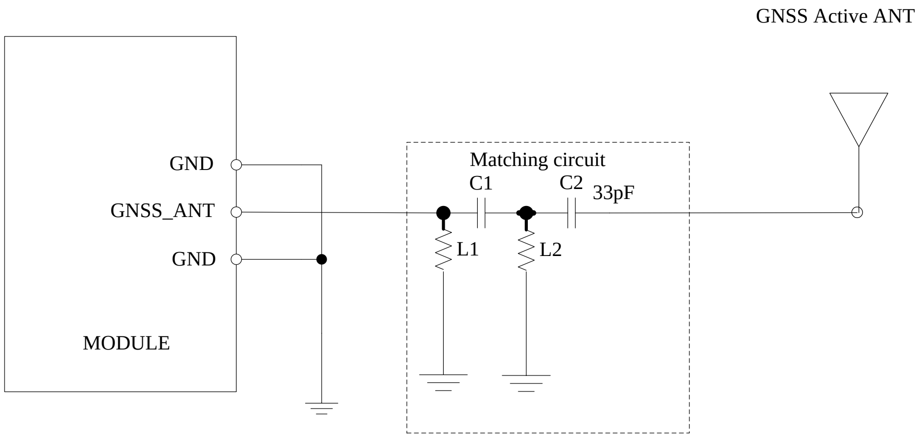


Figure 9-11 Active antenna circuit

In above figures, the components C1, L1 and L2 are used for antenna matching. Usually, the values of the components can only be achieved after antenna tuning and usually provided by antenna vendor.C2 is used for DC blocking. L3 is the matching component of the external LNA, and the value of L3 is determined by the LNA characteristic and PCB layout.

Both VDD of active antenna and V_LNA need external power supplies which should be considered according to active antenna and LNA characteristic. LDO/DCDC is recommended to get lower current consuming by shutting down active antennas and LNA when GNSS is not working.

9.3.3 WIFI/BT Application Guide

Users should connect antennas to MODULE's antenna pads through micro-strip line or other types of RF trace and the trace impedance must be controlled in 50Ω.

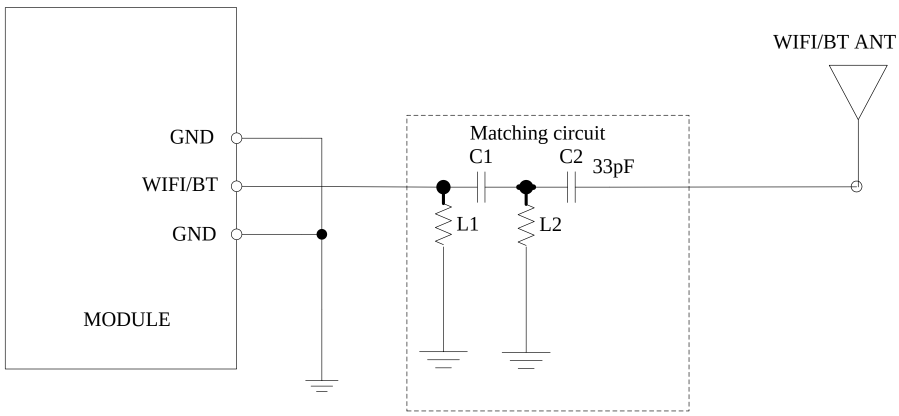


Figure 9-12 Active Antenna Circuit

In above figures, the components C1, L1 and L2 are used for antenna matching. Usually, the values of the components can only be achieved after antenna tuning and usually provided by antenna vendor.C2 is used for DC blocking.

9.4 SIM Interface

MODULE supports both 1.8V and 3.0V USIM Cards.

Table 9-5 USIM Electronic Characteristic in 1.8V Mode (USIM_VDD=1.8V)

Symbol	Parameter	Min.	Typ.	Max.	Unit
USIM_VDD	LDO power output voltage	1.75	1.8	1.95	V
V_{IH}	High-level input voltage	0.65*USIM_VDD	-	USIM_VDD +0.3	V
V_{IL}	Low-level input voltage	-0.3	0	0.35*USIM_VDD	V
V_{OH}	High-level output voltage	USIM_VDD -0.45	-	USIM_VDD	V
V_{OL}	Low-level output voltage	0	0	0.45	V

Table 9-6 USIM electronic characteristic 3.0V mode (USIM_VDD=2.95V)

Symbol	Parameter	Min.	Typ.	Max.	Unit
USIM_VDD	LDO power output voltage	2.75	2.95	3.05	V
V_{IH}	High-level input voltage	0.65*USIM_VDD	-	USIM_VDD +0.3	V
V_{IL}	Low-level input voltage	-0.3	0	0.25*USIM_VDD	V
V_{OH}	High-level output voltage	USIM_VDD -0.45	-	USIM_VDD	V
V_{OL}	Low-level output voltage	0	0	0.45	V

9.4.1 USIM Application Guide

It is recommended to use an ESD protection component such as ESDA6V1-5W6produced by ST or SMF12C produced by ON SEMI. Note that the USIM peripheral circuit should be close to the USIM card socket. The following figure shows the 6-pin SIM card holder reference circuit.

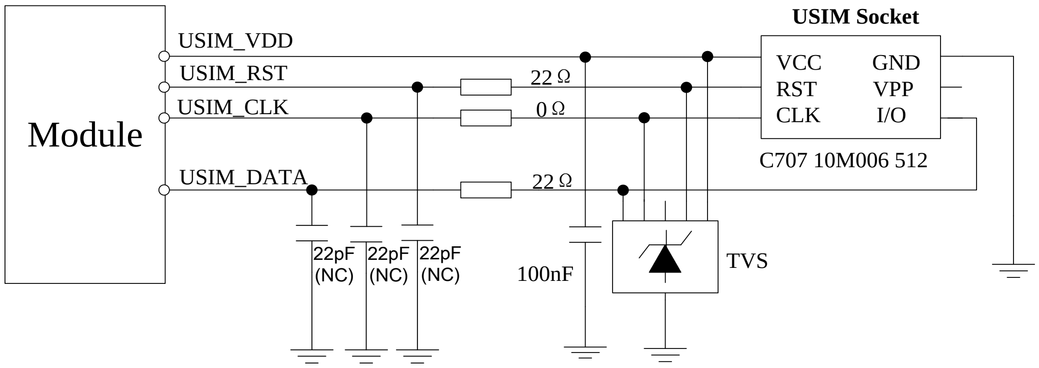


Figure 9-13 USIM Interface Reference Circuit

The USIM_DET pin is used for detection of the USIM card hot plug in. User can select the 8-pin USIM card holder to implement USIM card detection function.

The following figure shows the 8-pin SIM card holder reference circuit.

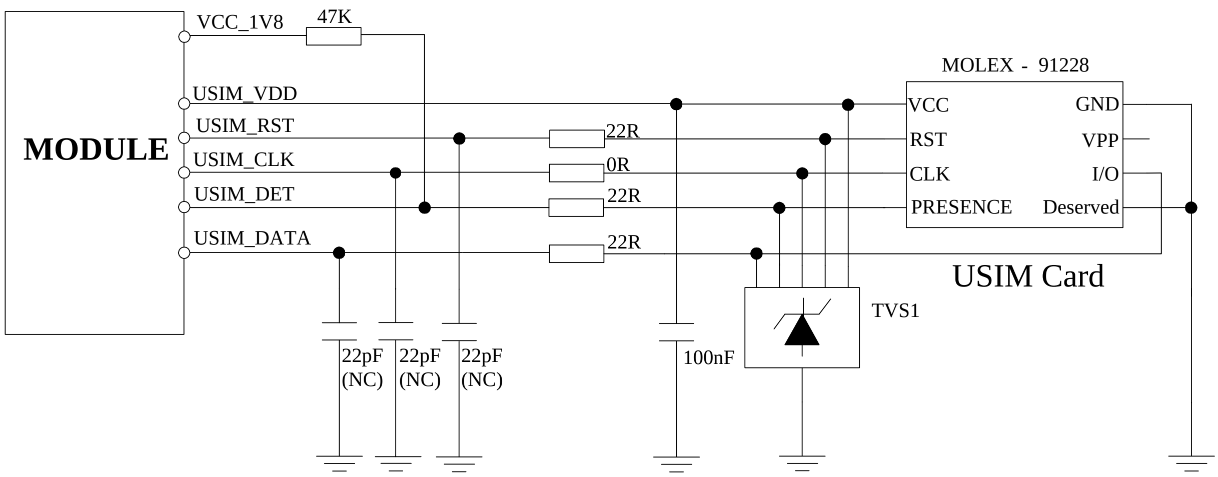


Figure 9-14 USIM Interface Reference Circuit with USIM_DET

If the USIM card detection function is not used, user can keep the USIM_DET pin open.

SIM card circuit is susceptible, and the interference may cause the SIM card failures or some other situations, so it is strongly recommended to follow these guidelines while designing:

- Make sure that the SIM card holder should be far away from the antenna while in PCB layout.
- SIM traces should keep away from RF lines, VBAT and high-speed signal lines.
- The traces should be as short as possible.
- Keep SIM holder’s GND connect to main ground directly.
- Shielding the SIM card signal by ground.

- Recommended to place a 0.1~1uF capacitor on USIM_VDD line and keep close to the holder.
- The rise/fall time of USIM_CLK should not be more than 40ns.
- Add some TVS, and the parasitic capacitance should not exceed 60pF.

9.5 Data I/O Interface

9.5.1 4-wire UART

MODULE provides 4-wire UART interface. AT commands and data transmission can be performed through UART interface.

The following figures show the reference design.

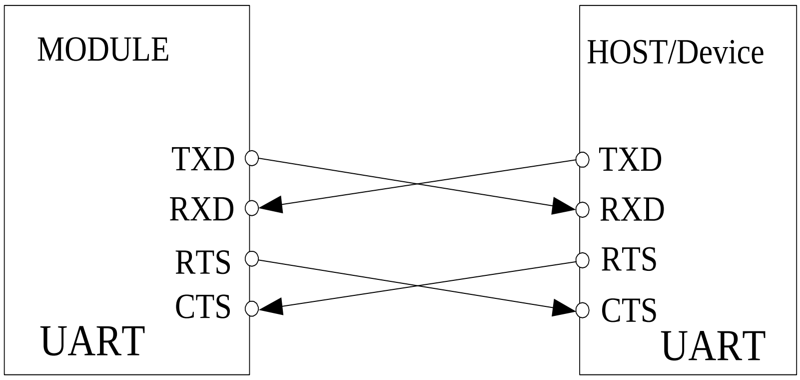


Figure 9-15 UART Reference Schematic

Note: MODULE supports the following baud rates: 300, 600, 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200, 230400, 460800, 921600, 3200000, 3686400. The default band rate is 115200bps.

9.5.2 I2C Interface

MODULE provides I2C interface to control the external device. Its operation voltage is 1.8V.

The following figure shows the I2C bus reference design.

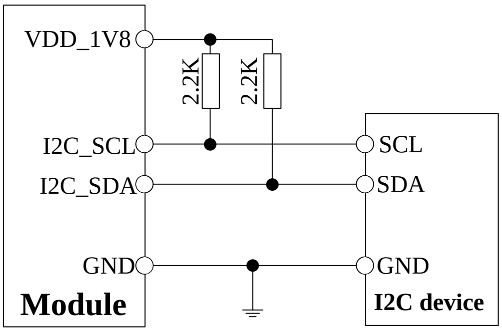


Figure 9-16 I2C Reference Circuit

Note：SDA and SCL have no pull-up resistors in MODULE. So, 2 external pull up resistors are necessary in application circuit.
The I3C protocol will be supported in the future.

9.5.3 SPI Interface

Module provides the SPI interface as master only. It provides a duplex, synchronous, serial communication link with peripheral devices. Its operation voltage is 1.8V, with clock rates up to 50 MHz

The SPI interface could also be configured as UART, I2C or GPIOs, which could refer to the Table 10 below.

Table 9-7 SPI Configuration

Default mode	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5
SPI_MOSI	TXD	TXD	TXD	GPIO	GPIO
SPI_MISO	RXD	RXD	RXD	GPIO	GPIO
SPI_CS	CTS	I2C_SDA	GPIO	I2C_SDA	GPIO
SPI_CLK	RTS	I2C_SCL	GPIO	I2C_SCL	GPIO

9.6 Analog Interface

9.6.1 ADC

MODULE has 3 dedicated ADC pins named ADC0, ADC1 and ADC2.They are available for digitizing analog signals such as battery voltage and so on. These electronic specifications are shown in the following table.

Table 9-8 ADC0, ADC1 and ADC2 Electronic Characteristics

Characteristics	Min.	Typ.	Max.	Unit
Resolution	–	15	–	Bits
Conversion time	–	442	–	us
Input Range	0.1		1.7	V
Input serial resistance	1	–	–	MΩ

9.7 Audio Interface

9.7.1 I2S Interface

MODULE provides an I2S interface for external codec, which comply with the requirements in the Phillips I2S Bus Specifications.

Table 9-9 I2S Format

Characteristics	Specification
LineInterfaceFormat	Linear(Fixed)
Datalength	16bits(Fixed)
I2S Clock/SyncSource	Master Mode(Fixed)
I2S ClockRate	1.536 MHz (Default)
I2S MCLK rate	12.288MHz (Default)
DataOrdering	MSB

Note: For more details about I2S AT commands, please refer to document [1].

9.7.1.1 I2S timing

MODULE supports 48 KHz I2Ssampling rate and 32 bit coding signal (16 bit word length), the timing diagram is showed as following:

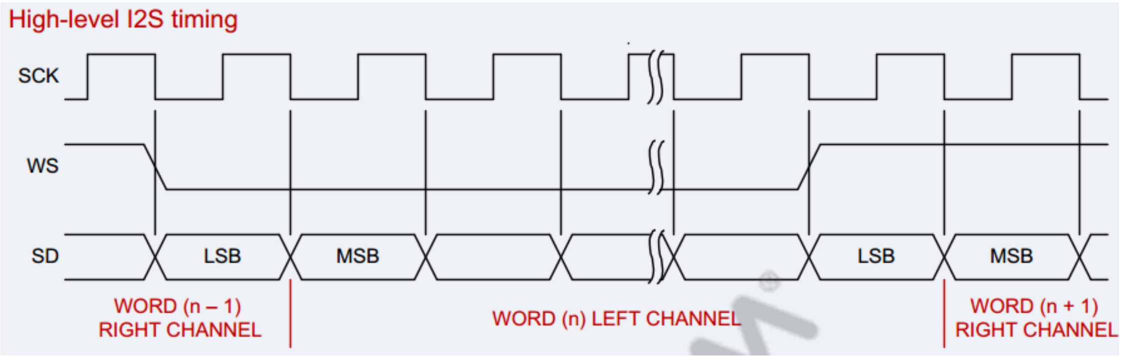


Figure 9-17 I2S Timing

Table 9-10 I2S Timing Parameters

Signal	Parameter	Description	Min.	Typ.	Max.	Unit
I2S_MCLK	Frequency	Frequency	–	12.288	12.288	MHz
	T	Clock period	81.380	81.380	–	ns
	t(HC)	Clock high	0.45T	–	0.55T	ns
	t(LC)	Clock low	0.45T	–	0.55T	ns
I2S_CLK	Frequency	Frequency	8	48	48	KHz
	T	Clock period	20.83	20.83	125	us
	t(HC)	Clock high	0.45T	–	0.55T	ns
	t(LC)	Clock low	0.45T	–	0.55T	ns
I2S_WS	t(sr)	DIN/DOUT and WS input setup time	16.276	–	–	ns
	t(hr)	DIN/DOUT and WS input hold time	0	–	–	ns
	t(dtr)	DIN/DOUT and WS output delay	–	–	65.10	ns
	t(htr)	DIN/DOUT and WS output hold time	0	–	–	ns

9.7.1.2 I2S reference circuit

The following figure shows the external codec reference design.

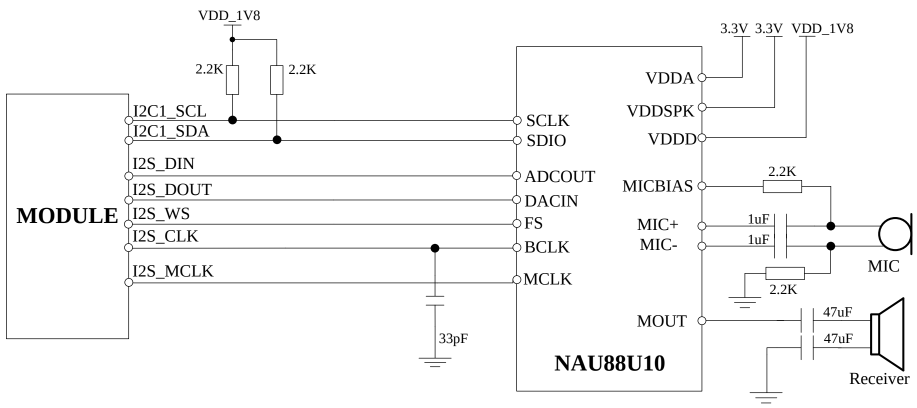


Figure 9-18 Audio codec reference circuit

Module provides one analog input, which could be used for electric microphone. The module also provides one analog output. The output can directly drive 32Ω receiver.

In order to improve audio performance, the following reference circuits are recommended. The audio signals have to be layout according to differential signal layout rules as shown in following figures. If user needs to use an amplifier circuit for audio, National Semiconductor Company's LM4890 is recommended.

9.7.2 Speaker Interface Configuration

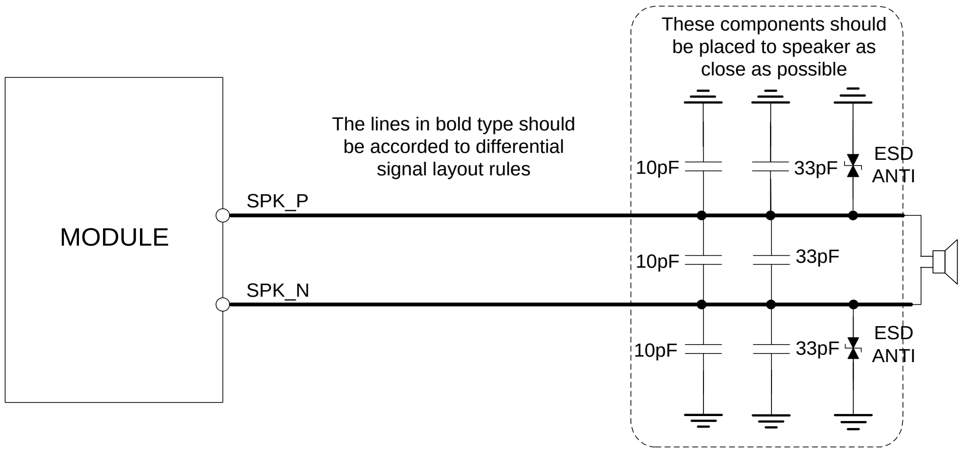


Figure 9-19 Speaker Reference Circuit

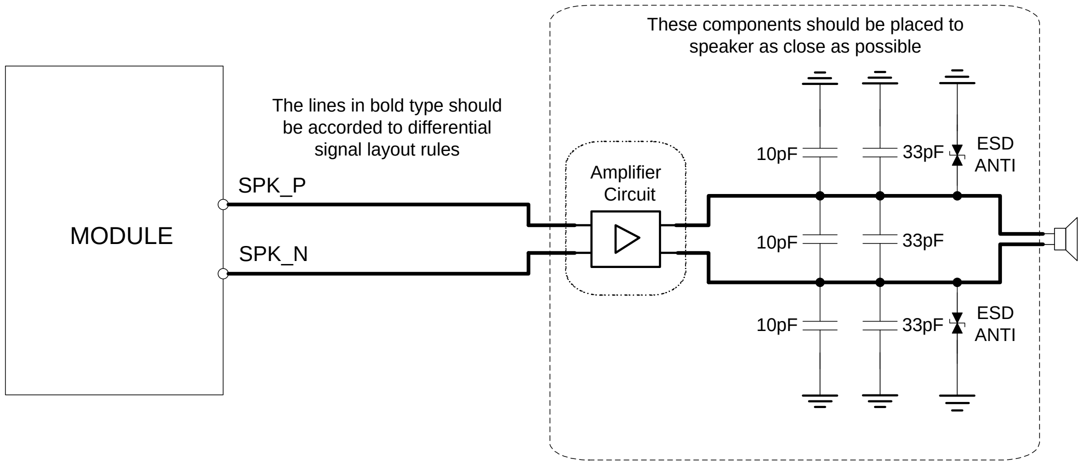


Figure 9-20: Speaker with Amplifier Reference Circuit

9.7.3 Microphone Interfaces Configuration

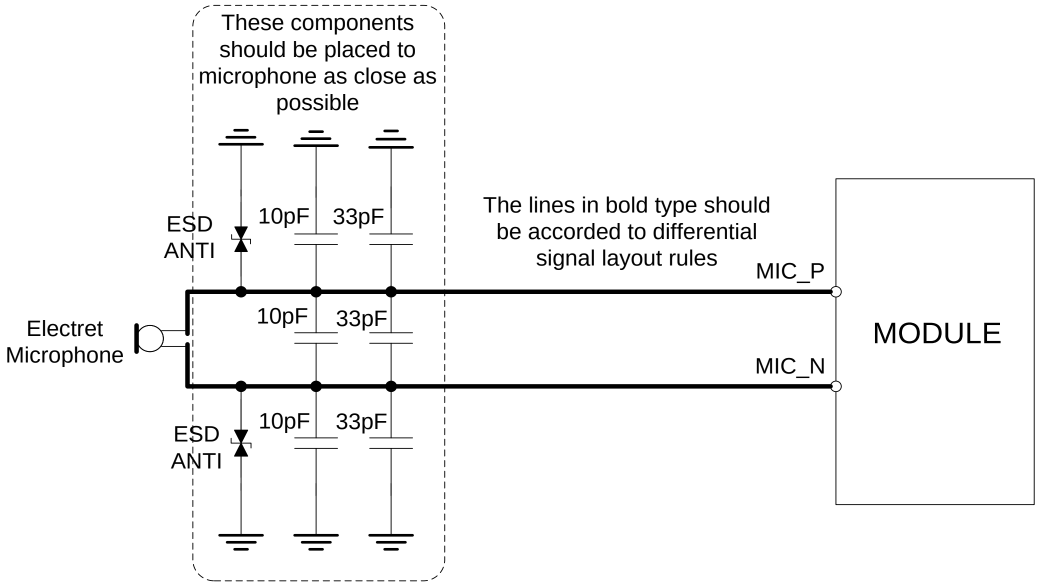


Figure 9-21 Microphone Reference Circuit

9.7.4 Earphone Interface Configuration

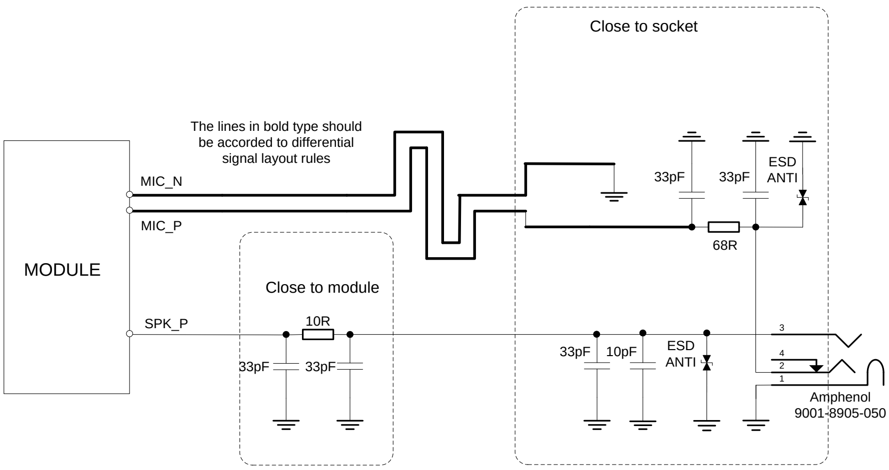


Figure 9-22 Earphone Reference Circuit

10 The Test and Certification of 5G S-Module

When the 5G S-Module is developed, it will undergo certain test and certification before it is going to the market. First we need do lab test and field test, then we will do industry test and regulatory test, the last step will be the carrier acceptance test.

As for the electrical interface test, further studies will be needed.

10.1 Lab Conformance Test

Lab RF/RRM/SIG conformance test should be done to test the 5G S-Module functions and performance. We should generate the first batch of test cases needed for 5G S-Module.

3GPP Status: RF test case is defined in TS 38.521-1[6], TS 38.521-2[7], TS 38.521-3[8], Performance test is defined in TS 38.521-4[9]. RRM is defined in TS 38.533[13]. Protocol test cases are defined in TS 38.523-1[10], TS 38.523-2[11] with the test module and TTCN implementation in TS 38.523-3[12].

3GPP TS 38.101-1[2], TS 38.101-2[3], TS 38.101-3[4], TS 38.101-4[5] defined sub6G, mmWave, LTE-NR/FR1-FR2 inter-working and performance test requirements. After test method and test procedure implemented, TS38.521 will publish for real test.

An estimate of 37 test cases for RX / TX test will be published in Dec 2018 for TS 38.521 -1/-2, Performance test cases for TS 38.521-4 will be published in summer 2019. RRM test cases will publish in summer 2019.

The lab test cases that should be run against the 5G S-Module are defined in the following 3GPP test specifications.

Table 10-1 3GPP RAN5 5GS Conformance Test Specifications

Test Specification	Description
3GPP TS 38.521-1	5G NR RF conformance test cases, FR1 (sub 6GHz), Standalone
3GPP TS 38.521-2	5G NR RF conformance test cases, FR2 (mmWave), Standalone
3GPP TS 38.521-3	5G NR RF conformance test cases, FR1 + FR2 interworking, Inter-RAT and Non-standalone
3GPP TS 38.521-4	5G NR RF conformance test cases, Performance
3GPP TS 38.523-1	5G NR Protocol conformance test cases
3GPP TS 38.533	5G NR RRM conformance test cases
3GPP TS 34.229-1	5G NR IMS conformance test cases
3GPP TS 37.571-1	5G NR Positioning conformance test cases, RF
3GPP TS 37.571-2	5G NR Positioning conformance test cases, Protocol

Lab testing is usually performed as part of the GCF device certification process, but may also be performed during the R&D phase to ensure that the device is ready to undergo formal GCF testing at an independent test laboratory. The test equipment and test cases used are the same as those that are validated at GCF.

After the lab test and field test are finished, we could start the industry regulatory test such as FCC/PTCRB/IC/GCF/GTI, etc.

GCF Status:

In RAN# 80 Meeting held in June 2018, NSA Option3 EN-DC phase 1 test case was defined. A list of EN-DC golden protocol test cases were selected for initial TTCN implementation and is a shown below and they have been released by ETSI.

Table 10-2 List of Protocol Conformance Golden Test Cases

SIG TC# (38.523-1 [1])	SIG test case (TC) title	RAN5#79 pCR#(s)	UE capability dependency (38.306 [2])
MAC			
7.1.1.2.1	Correct Handling of DL MAC PDU / Assignment / HARQ process	R5-182940, R5-183143	
RLC			
7.1.2.2.4	UM RLC / 12-bit SN / Correct use of sequence numbering	R5-183144, R5-183149	***um-WIthLongSN***
7.1.2.3.4	AM RLC / 18-bit SN / Correct use of sequence numbering	R5-183144, R5-183150, R5-182966	
PDCP			
7.1.3.1.2	Maintenance of PDCP sequence numbers / User plane / 18 bit SN	R5-183145, R5-182945	
RRC			
8.2.2.4.1	PSCell addition, modification and release / SCG DRB / EN-DC	R5-183230	
8.2.2.5.1	PSCell addition, modification and release / Split DRB / EN-DC	R5-183135	
8.2.2.9.1	Bearer Modification / Uplink data path / Split DRB Reconfiguration / EN-DC	R5-183115	
8.2.3.1.1	Measurement configuration control and reporting / Inter-RAT measurements / Event B1 / Measurement of NR cells / EN-DC	R5-183117	
8.2.3.4.1	Measurement configuration control and reporting / Event A1 / Measurement of NR PSCell / EN-DC	R5-183134	
NAS			
10.2.1.2	Dedicated EPS bearer context activation	none	

The next target for TTCN implementation is to have 80% of NSA Option 3 test cases implemented by end of October.

The first delivery of TTCN test cases for SA Option 2 is planned for early December.

In a recent RAN5 NR AH#3 meeting, the plan to develop the NSA and SA test cases in the test specifications have been revised in R5-185691 and is shown below:-

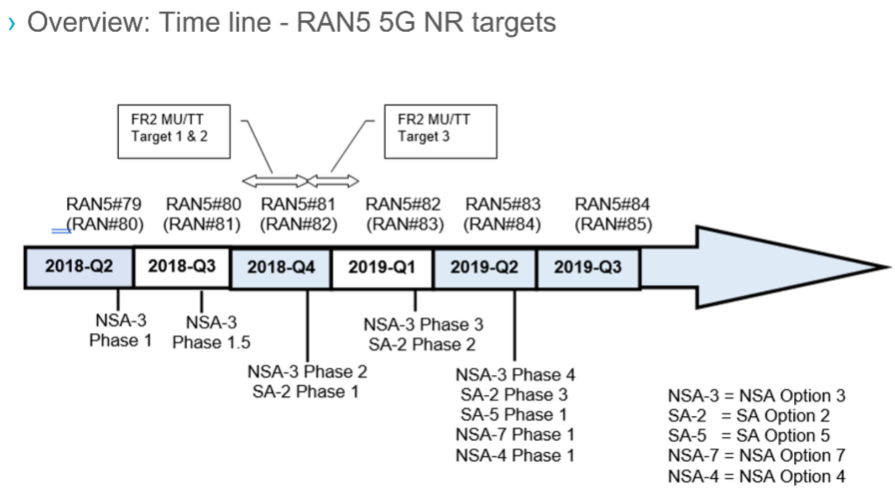


Figure 10-1 The plan to develop the NSA and SA test cases

An additional delivery point has been added to Feb-2019 for SA phase 2 and NSA phase 3. This is an aimed as accelerating the SA test case development.

10.1.1 GCF Testing

The Global Certification Forum (GCF) is responsible for administering a certification program for devices that support 3GPP mobile communication technologies. Many major mobile network operators around the world require devices to be certified according to the current GCF certification requirements.

GCF device certification must be performed by a GCF Recognized Test Organization, using test equipment and test cases that have been validated by an independent test laboratory. The GCF certification requirements are grouped into work items, with the following 5G work item structure being agreed at the CAG#54bis meeting in May 2018:

Table 10-3 GCF New Work Items for 5G Conformance Tests

Umbrella Work Item	Sub Work Items	3GPP Test Specifications
WI-500: 5G RF	WI-500_NR-*nx* WI-500_EUTRA-5GC-*x* WI-500_EN-DC_*x*_*ny* WI-500_NGEN-DC_*x*_*ny*	3GPP TS 38.521-1 3GPP TS 38.521-2 3GPP TS 38.521-3
WI-501: 5G RRM	WI-501_NR-*nx* WI-501_EUTRA-5GC-*x* WI-501_EN-DC_*x*_*ny* WI-501_NGEN-DC_*x*_*ny*	3GPP TS 38.533
WI-502: 5G De-Mod/CSI	WI-502_NR-*nx* WI-502_EUTRA-*5GC-x* WI-502_EN-DC_*x*_*ny* WI-502_NGEN-DC_*x*_*ny*	3GPP TS 38.521-4
WI-503: 5G AS Protocol	WI-503_NR-*nx*	3GPP TS 38.523-1

Umbrella Work Item	Sub Work Items	3GPP Test Specifications
	WI-503_EUTRA-*5GC-x* WI-503_EN-DC_*x_ny* WI-503_NGEN-DC_*x_ny*	
WI-504: 5G NAS Protocol	WI-504_NR-*nx* WI-504_EUTRA-5GC-*x* WI-504_EN-DC_*x_ny* WI-504_NGEN-DC_*x_ny*	3GPP TS 38.523-1
WI-505: IMS Protocol	*N/A – band independent*	3GPP TS 34.229-1
WI-506: 5G Positioning	*N/A – band independent*	3GPP TS 37.579-1

At the CAG#55 meeting in July 2018, sub-work items for WI-500, WI-503 and WI-504 were created for the following bands / band combinations, with further bands due to be added at future CAG meetings:

Table 10-4 List of NR-LTE Band Combinations for 5G Conformance Tests

Band	Number of test cases in sub-work item		
	WI-500-*{band}*	WI-503-*{band}*	WI-504-*{band}*
EN-DC_(n)41A		88	
EN-DC_19A_n77A	21		
EN-DC_19A_n78A	21		
EN-DC_1A_n77A	21		
EN-DC_1A_n78A	21	88	3
EN-DC_25A_n41A		88	
EN-DC_39A_n78A	21	88	3
EN-DC_39A_n79A	21	88	3
EN-DC_3A_n77A	21	88	3
EN-DC_3A_n78A	21	88	3
EN-DC_3A_n79A	21	88	3
EN-DC_41A_n41A		88	
EN-DC_41A_n78A	21	88	3
EN-DC_41A_n79A	21	88	3
EN-DC_5A_n78A	21	88	3
EN-DC_7A_n78A	21	88	3
EN-DC_8A_n78A	21	88	3
EN-DC_8A_n79A	21	88	3
n78	40		
n79	40		

Validation of the above test cases against 5G test platforms is estimated as follows:

- CAG#57 (January 2019) = NSA Opt3 (EN-DC) FR1 (sub-6GHz bands)
- CAG#57 (January 2019) = NSA Opt3 (EN-DC) FR2 (mmWave bands)
- CAG#58 (April 2019) = SA Opt2 (NR) FR1 (sub 6GHz bands)

Full details of the current GCF certification requirements can be found in the GCF Device

Certification Criteria (DCC) database, which is accessible to GCF member companies at https://www.globalcertificationforum.org.

10.1.2 PTCRB Testing

PTCRB have defined their 5G RFT structure as follows:

RFT	Description	Test Cases
501-1	5G RF NR	TBD
501-2	5G RF EUTRA-5GC	TBD
501-3	5G RF EN-DC	5
501-4	5G RF NGEN-DC	TBD
502-1	5G RRM NR	TBD
502-2	5G RRM EUTRA-5GC	TBD
502-3	5G RRM EN-DC	TBD
502-4	5G RRM NGEN-DC	TBD
503-1	5G De-Mod/CSI NR	TBD
503-2	5G De-Mod/CSI EUTRA-5GC	TBD
503-3	5G De-Mod/CSI EN-DC	TBD
503-4	5G De-Mod/CSI NGEN-DC	TBD
504-1	5G RAN Protocol NR	TBD
504-2	5G RAN Protocol EUTRA-5GC	TBD
504-3	5G RAN Protocol EN-DC	75
504-4	5G RAN Protocol NGEN-DC	TBD
505-1	5G NAS Protocol NR	TBD
505-2	5G NAS Protocol EUTRA-5GC	TBD
505-3	5G NAS Protocol EN-DC	3
505-4	5G NAS Protocol NGEN-DC	TBD
506-1	5G IMS Protocol	TBD
507-1	5G Positioning	TBD

Source: outcome from PVG#82 meeting

Following list of bands has been added:

- FR1:
  - n71, n78A
- FR2:
  - n257A, n260?, n261A
- DC:
  - DC_5A_n78A, DC_7A_n78A, DC_5A-7A_n78A, DC_7A-7A_n78A, DC_7C_n78A, DC_2A_n257A, DC_5A_n257A, DC_7A_n257A, DC_2A-5A_n257A, DC_2A-66A_n257A, DC_5A-66A_n257A, DC_5A-7A_n257A, DC_7A-7A_n257A, DC_66A-66A_n257A, DC_5A-7A-7A_n257A
  - DC_2A-66A_n261A-n261A, DC_2A-66A_n261A, DC_66A_n261A-n261A, DC_2A_n261A-n261A, DC_2A_n261A,DC_66A_n261A
  - DC_2A-66A_n260A-n260A, DC_2A-66A_n260A, DC_66A_n260A-n260A, DC_2A_n260A-n260A, DC_2A_n260A, DC_66A_n260A
  - DC_2A-66A_(n)71B, DC_2A-66A_n71A, DC_2A_(n)71B, DC_66A_(n)71B, DC_(n)71B, DC_66A_n71A,DC_2A_n71A

Figure 10-2 The 5G RFT Structure of PTCRB

There should be further detail defined in the upcoming PVG meetings.

10.2 Field Test

Field test could only be performed in certain test area where the real network is already deployed. Operators will provide a road map and locations for the field test in certain cities and certain areas.

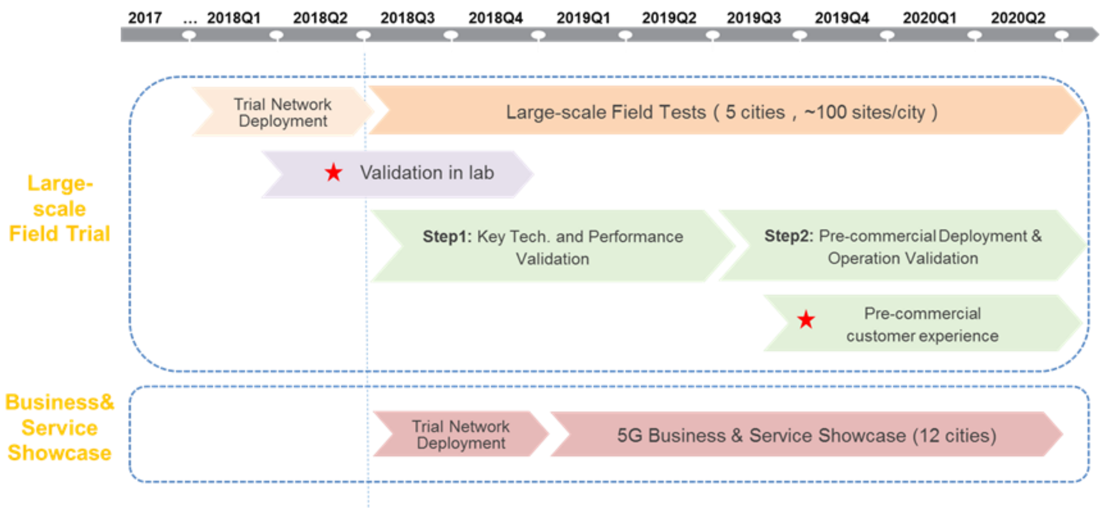


Figure 10-3 The Roadmap of China Mobile's Large-scale Field Trial and B&S Showcase

China Mobile will perform the large-scale trial in 5 cities (Shanghai, Hangzhou, Suzhou, Guangzhou and Wuhan) and the 5G typical application showcase in another 12 cities to facilitate the 5G commercialization.

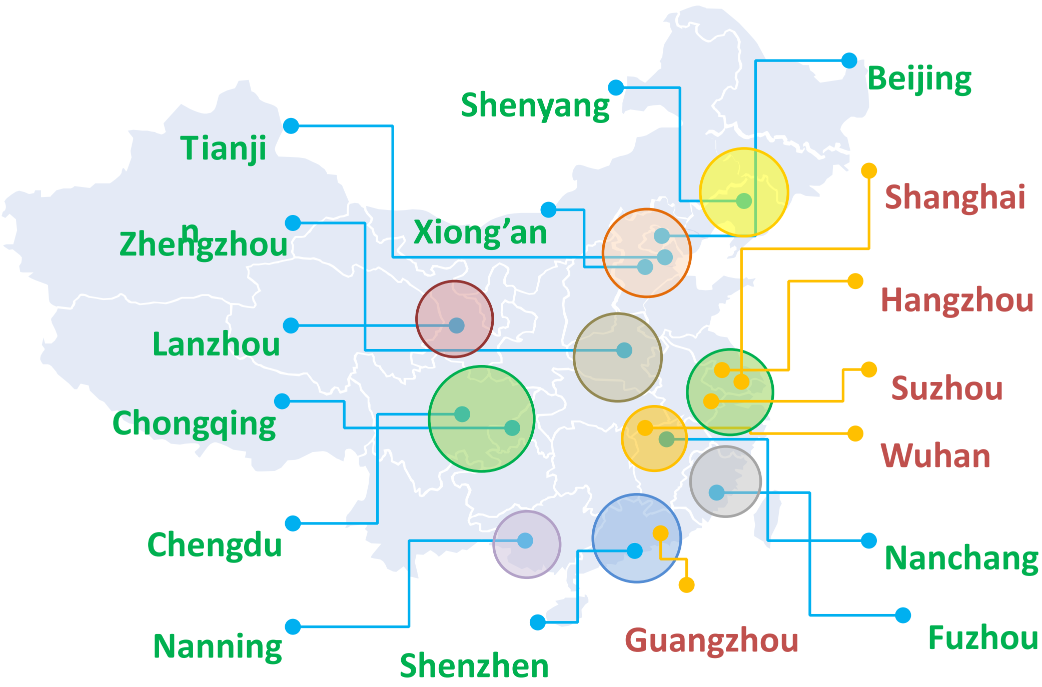


Figure 10-4 The cities for the large-scale Field Trial and B&S Showcase

The figure above shows the 5 cities for the large-scale trial and another 12 cities for the typical application showcase, including 4K Live, Smart healthcare, smart campus, smart manufacturer, robot, livelihood service social management, grid, could gaming, UAV, smart transportation and etc.

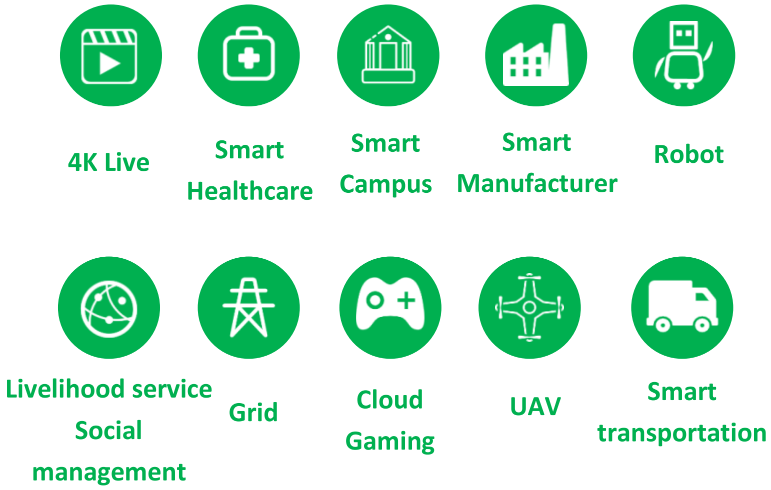


Figure 10-5 The typical application showcases

10.3 Industry Regulatory Test

10.3.1 Regulatory Testing

ETSI is responsible for the development of Harmonized Standards under the Radio Equipment Directive 2014/53/EU (RED) in response to the European Commission (EC) mandates.

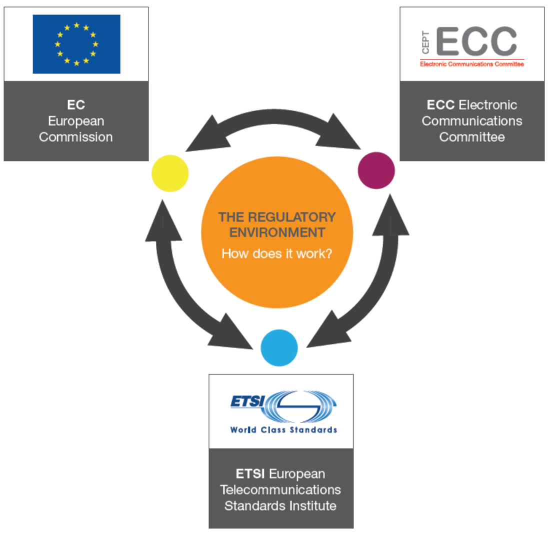


Figure 10-6 European Regulaotry Test Bodies

Harmonized Standards take effect when they are cited in the Official Journal of the European Union. This is available from the EUR-Lex website.

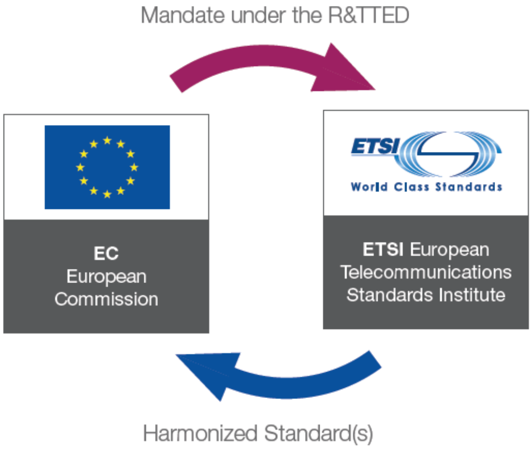


Figure 10-7 R&TTED test regulation

EU regulatory testing

Standard	EU
Radiofrequency (RF)	EN 301 908-1/-13
Electromagnetic Compatibility (EMC)	EN 301 489-1/-24
Electrical Safety (ES)	EN 60950-1
Specific Absorption Rate (SAR)	EN 50360 & EN 62311

Figure 10-8 Regulatory test specifications

ETSI EN 301 908-13: "IMT cellular networks; Harmonized Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU; Part 13: Evolved Universal Terrestrial Radio Access (E-UTRA) User Equipment (UE)."

EN 301 908-13 covers the essential requirements of article 3.2 of the Radio Equipment Directive (RED) for E-UTRA UE in addition to those common ones of Part 1.

The Radio Equipment Directive (RED) has replaced the existing Radio & Telecommunications Terminal Equipment Directive (R&TTED) (1999/5/EC), so EU Member States have to adapt their National laws to this new Radio Equipment Directive (RED). Manufacturers who were compliant with the existing legislation (RTTED or LVD/EMCD) had until 13 June 2017 to comply with the new requirements.

EN 301 908-13 currently covers LTE requirements and leverages the contents of the 3GPP TS 36.521-1, with variations in the test requirements. When published, it is expected that the version covering 5G NR will also leverage the contents of the 3GPP TS 38.521-1/2/3 test specifications.

Other countries and regions have their own regulatory requirements that are applicable to mobile devices.

10.4 Carrier Acceptance Test

Finally, certain carrier acceptance tests need to be finished for 5G S-Module. For example, CMCC test in the China area, Sprint certification for North America, Vodafone, Orange, TIM certification for European market.

Besides the traditional carrier acceptance tests for smart phones, such as RF/RRM/SIG test, for 5G S-Modules, carrier acceptance tests will also include the demodulation performance test and power consumption test. For some vertical applications, there will also be voice quality test, service test and even AI test by integrating the 5G S-Modules into the vertical devices.

Some reliability and application tests will also be included, which are very different from the traditional carrier acceptance test and are not so familiar to the traditional communication industry but will be important and necessary to the vertical applications. For example, for the drones, the vibration test, rain test and irradiance test should be necessary to the reliable use. For the Always Connected PC, the high temperature test and the drop test may also be necessary. For some outdoor vertical applications, the working temperature range will be much wider than the consumer electronics (usually -10℃~+40℃), we should make sure that the 5G S-Modules could work normally with a wide working temperature range, such as -40℃~+85℃. So the high temperature test and low temperature test should be necessary.

In a word, carrier acceptance test will have some reliability and application tests for the 5G S-Modules applied in the verticals. For the test cases could not be implemented by the carriers, the certification results of the third-party laboratory could also be considered.

11 Typical Technical Solutions for 5G S-Module

Editor's note: To summarize the key points of this clause. This Section will be updated according to Clause 7 before Nov. 2019.

The 5G S-Module will use the most cutting-edge technology and give device vendor a chance to develop their application easily, below we summarize the differentarchitecture/design/deployment to meet the customer's requirements.

11.1 5G S-Module: Type 1

Editor's note: To introduce 5G S-Module Type 1, including the diagram, applicability, capability, key parameters, etc.

11.2 5G S-Module: Type 2

Editor's note: To introduce 5G S-Module Type 2, including the diagram, applicability, capability, key parameters, etc.

11.3 5G S-Module: Type 3

Editor's note: To introduce 5G S-Module Type 3, including the diagram, applicability, capability, key parameters, etc.

Annex A 5G RF Component

Annex A.1 5G RF FEM Type1 (Separated n41 and n79)

Annex A.1.1 Diagram

- Separated n41 and n79 pin to pin 3x5mm modules
- Enables simultaneous 2 DL 2 UL supports in n41-n79
- Provides worldwide and regional coverage for initial 5G NR deployments
- Integrated high performance filter addressing co-existence requirements
- 4.5V ET/APT optimized
- PC2 for n41 and PC2 for n79
- Small solution size: 3x5 mm

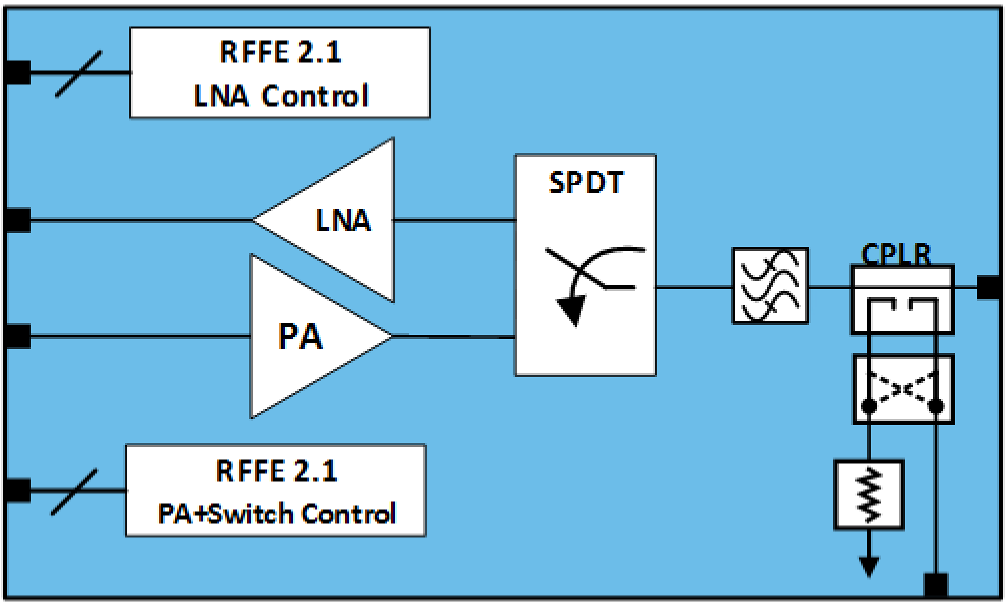


Figure A-1 Diagram

Annex A.1.2 Pin Layout

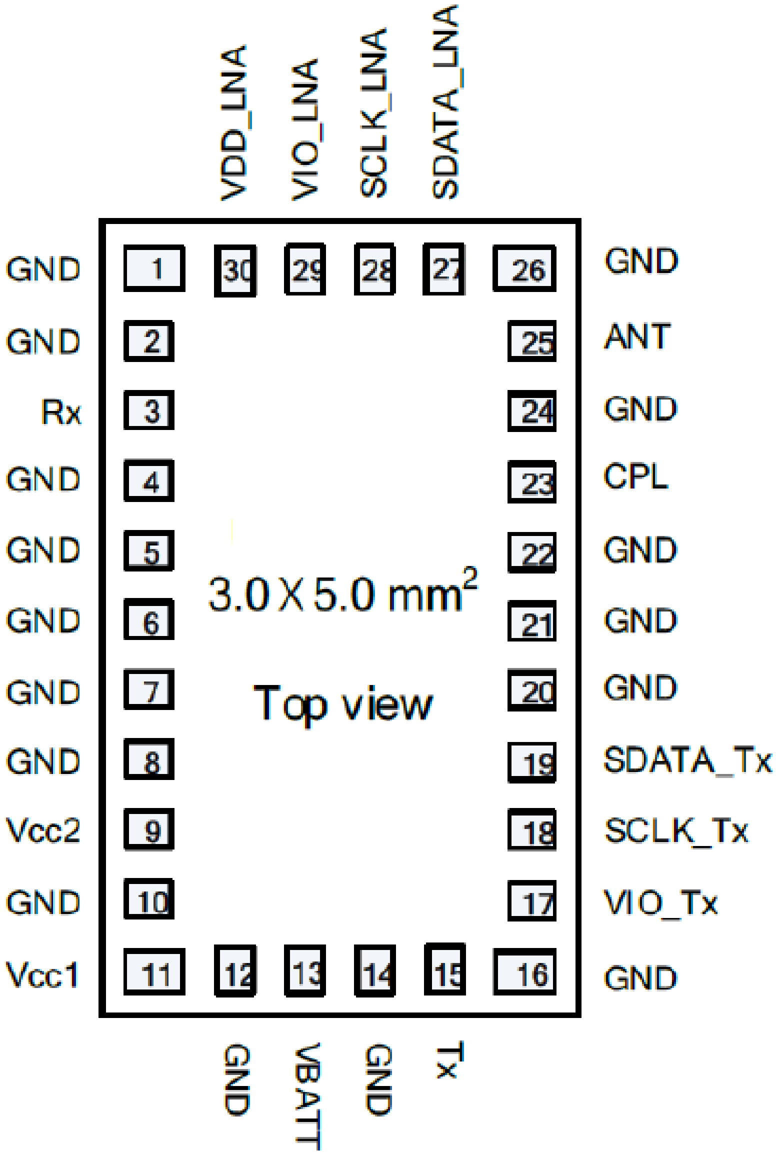


Figure A-2 Pin Layout

Annex A.1.3 Pin Size

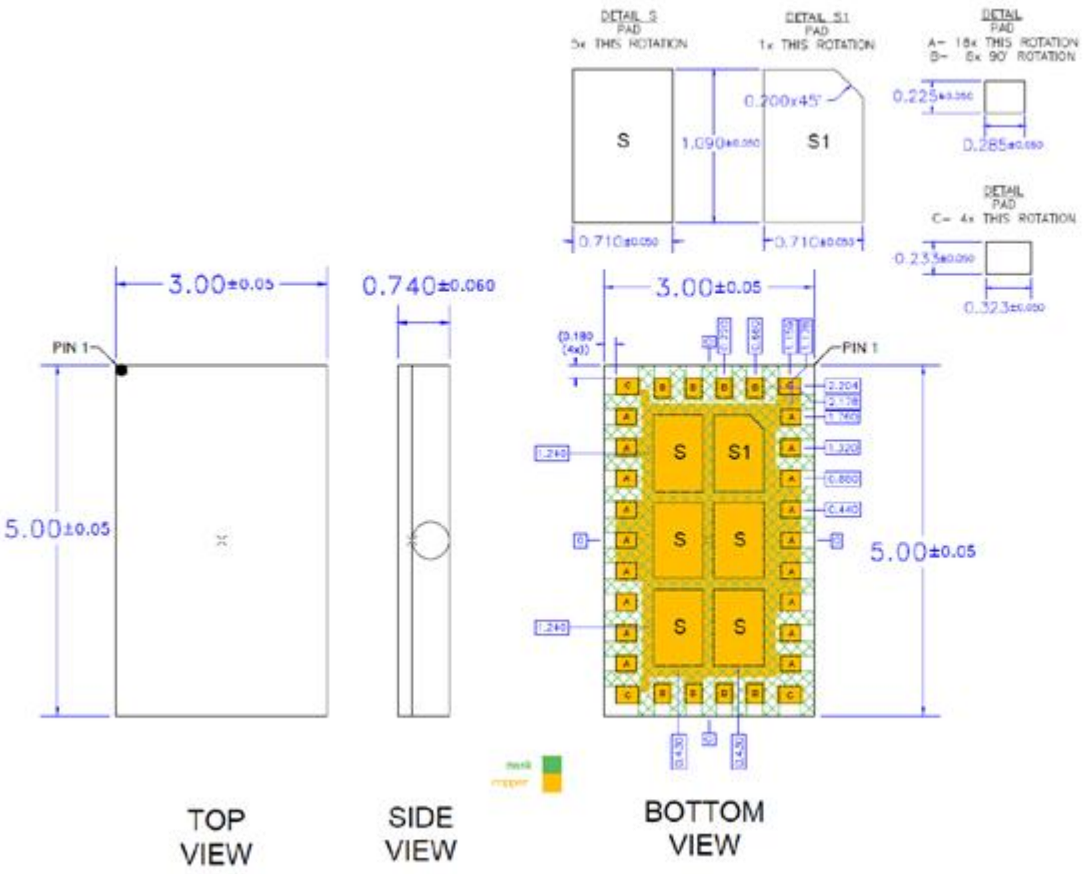


Figure A-3 Pin Size

Note: Above RF Module information and data in Clause A.1 are provided by Qorvo.

Annex A.2 5G RF FEM Type2 (n41)

Annex A.2.1 Diagram

- ET optimized, APT compatible PA's
- FDD Bands 1, 3, 4, 7, 66RX, 32SDL
- TDD Bands 34, 38, 39, 40, 41
- Small solution size: 6.5x8.6 mm

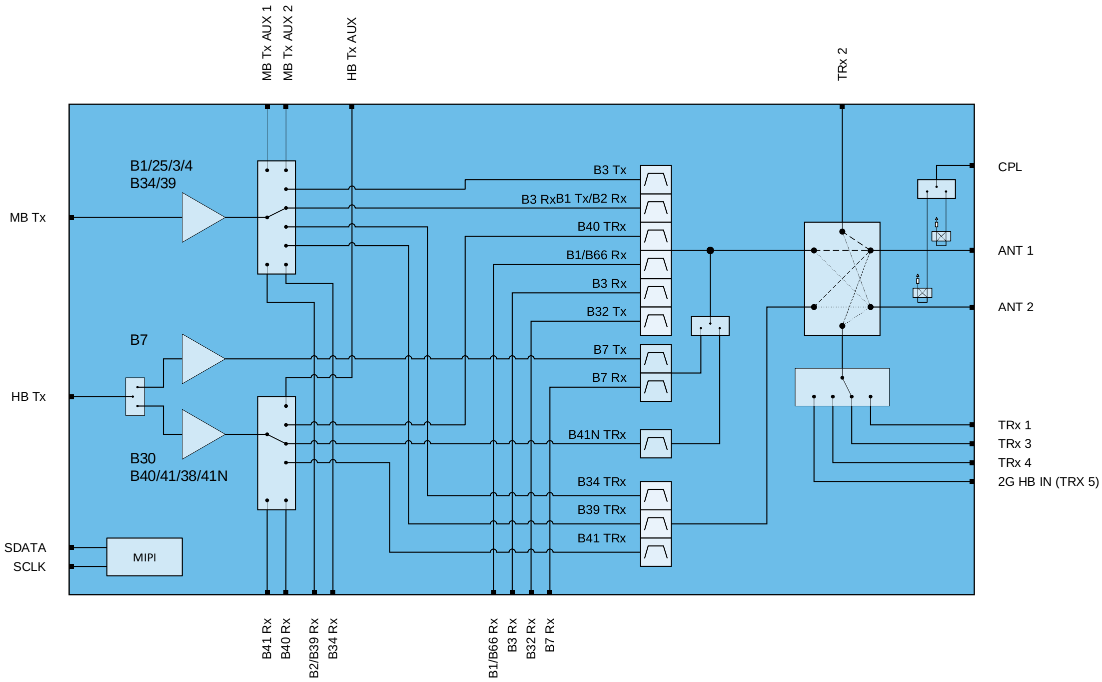


Figure A-4 Diagram

Annex A.2.2 Pin Layout

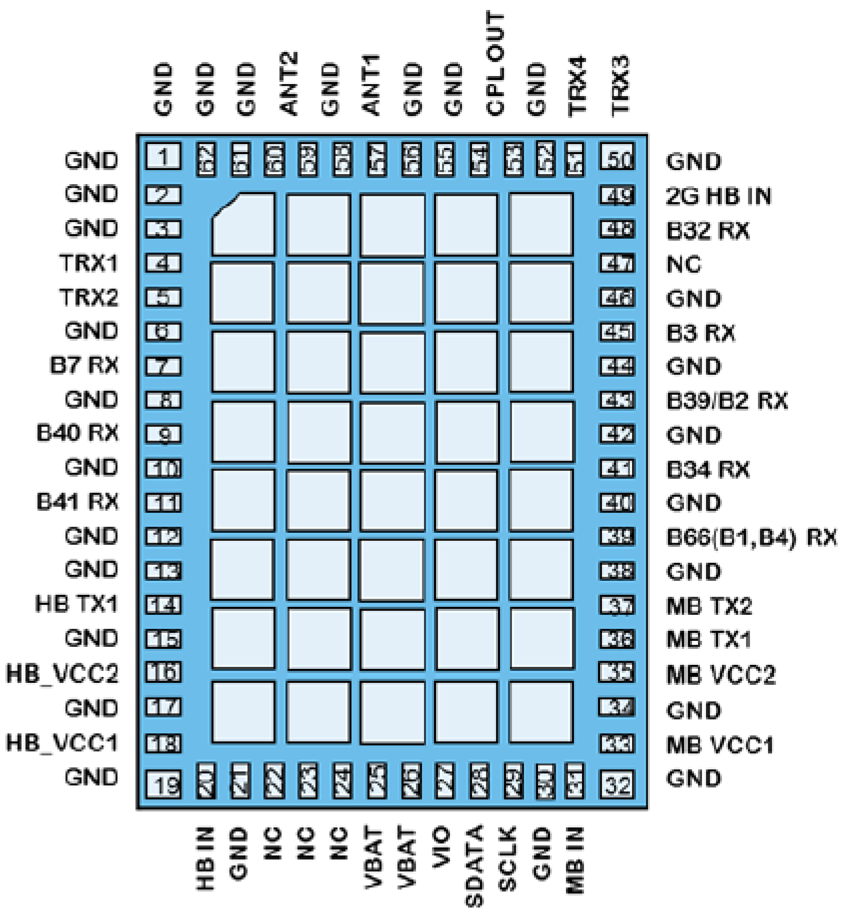


Figure A-5 Pin Layout

Annex A.2.3 Pin Size

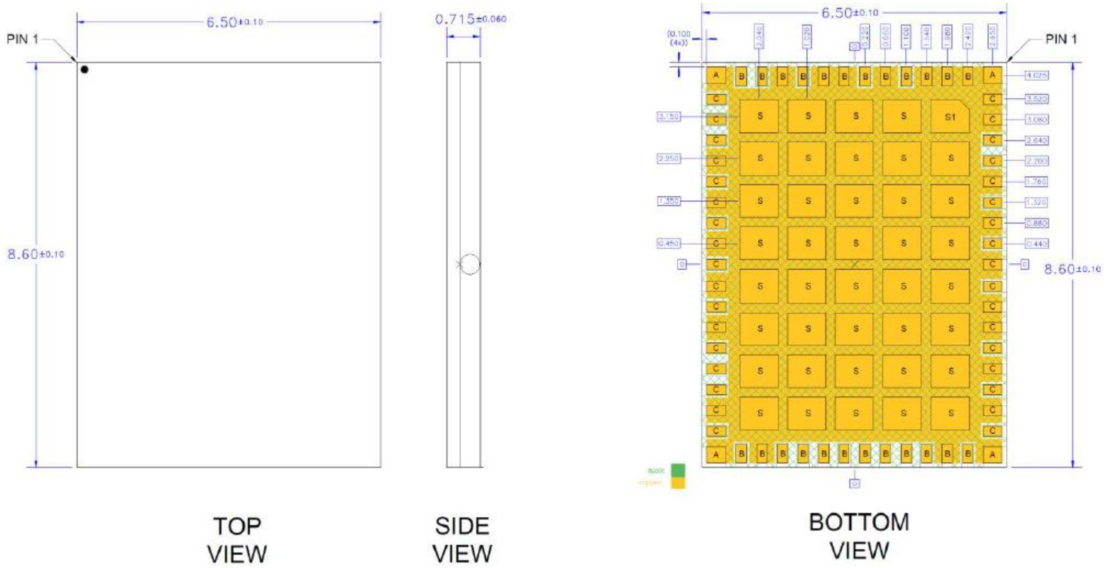


Figure A-6 Pin Size

Note: Above RF Module information and data in Clause A.4are provided by Qorvo.

Annex A.3 5G LTCC/SAW/FBAR Filters

As the detailed filter requirement and the background was discussed in another GTI report "GTI 5G Device RF Component Research Report", 5G filtering components would be required to cover much higher relative bandwidth ratio as opposed to current 4G requirement. Unlike the requirement for smartphones, the standard filter should be adopted for S-Module design as it has sufficient flexibility of adopting standardized filtering component. Per the following chart, at the present the technology of filters has been divided into 3 series: ONE is SAW technology, TWO is FBAR/BAW technology, THREE is LTCC or Multilayer Ceramic filter technology. It is capable of satisfying wider frequency bandwidth and higher frequency requirement. And this technology would be the choice for filtering components to be adopted for the S-Module design.

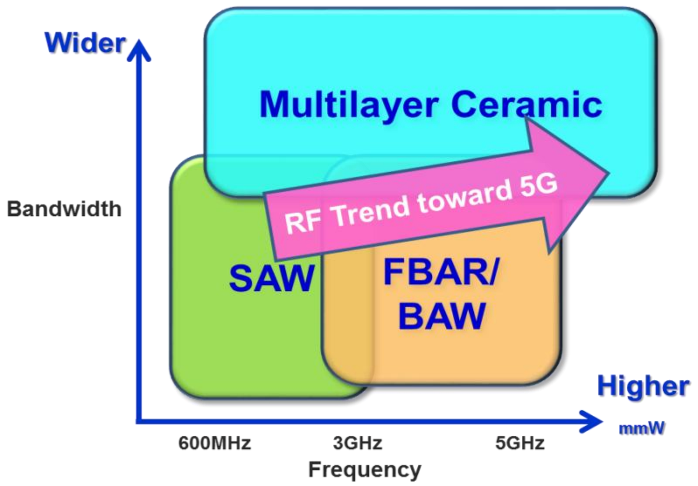


Figure A-7 Common Filter Technologies from Taiyo Yuden

With the utilization of multilayer ceramic technologies, it can provide extremely low insertion loss for Sub-6GHz while covering entire required bandwidth. The relative bandwidth that can be covered with multilayer ceramic filters is approximately from 5 to 50%. It also contributes to the downsizing and lower profile requirements with significantly stable performance and relatively low cost. This technology also provides rather higher power handling capabilities in comparison with SAW/BAW/FBAR technologies and this should be another advantage as HPUE has been required by 5G Sub-6GHz standard.

At the present, there are already solutions available supporting the HPUE compatible device incorporating Band n77, Band n78 and Band n79. Example of main performance of Band n79 filter is shown below.

Annex A.3.1 Diagram

Table A-1 Multilayer Ceramic Band Pass Filter for 5G NR Sub-6GHz Band n79 HPUE

Pass band Frequency	4.4GHz – 5.0GHz	
Insertion Loss (Typ)	0.55dB	
Attenuation (Typ)	2400-2500MHz	50.6dB
	2500-2690MHz	39.9dB
	8800-10000MHz	22.1dB
	13200-15000MHz	31.7dB
Power Capability	+33dBm at pass band frequency，10000Hr	
Size	2.0mm x 1.25mm x 0.65mm MAX，LGA Package	

Annex A.3.2 Pin Layout, Pin Size, Pin Definition

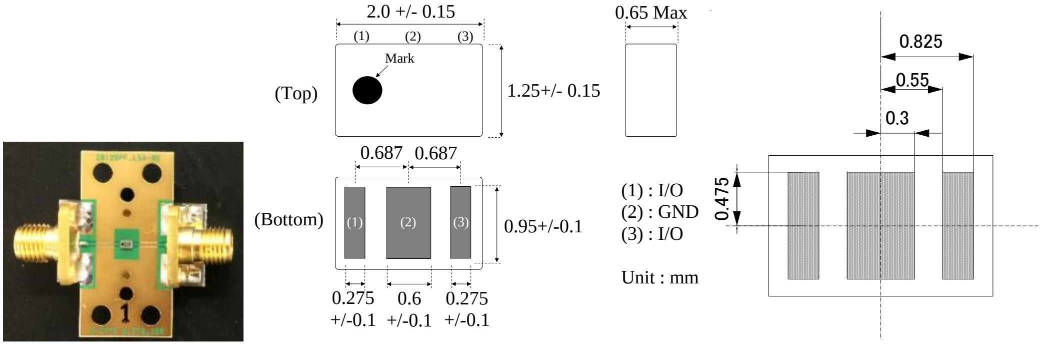


Figure A-8 Multilayer Ceramic Filter with its evaluation board (example photo), Dimension and footprint

Annex A.3.3 High power handling

Multilayer Ceramic Filter can survive +33dBm with over 10,000 hours due to the utilization of high quality inner electrode (including fine material and structure) which contributes to higher power durability while heat generation is minimized. (see reference test result)

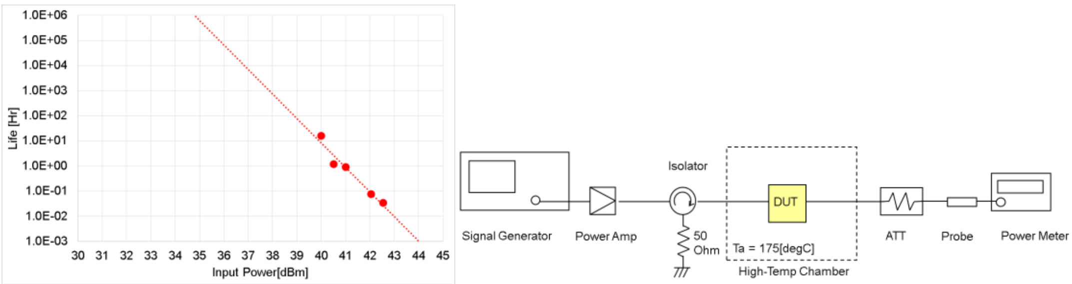


Figure A-9 Test result example of DUT: 2012 (EIA: 0805) size 3.5GHz BPF

Annex A.3.4 Structure and equivalent circuit

Utilization of distributed element filter:

Some resonators are structured in the filter. By increasing the number of resonators, wider bandwidth and steep cut-off can be realized. Distribution element system is mainly used for band pass filter including upcoming 5G NR Sub-6GHz requirement.

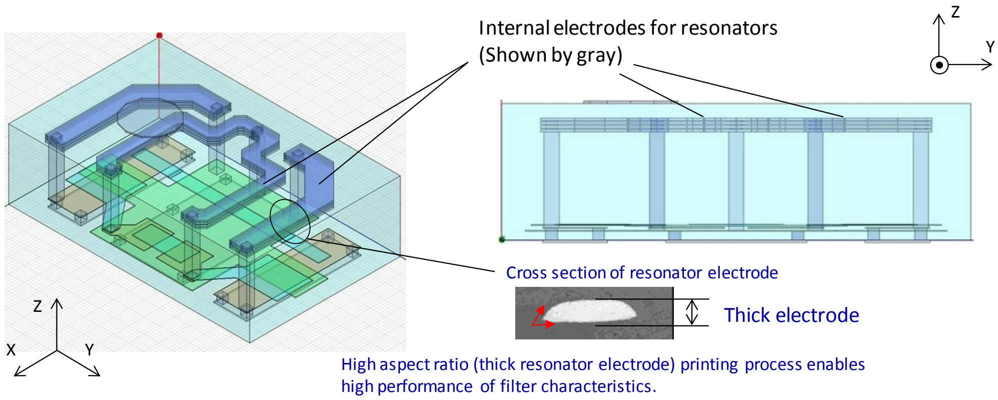


Figure A-10 Perspective View and side view of Distributed Element Filter

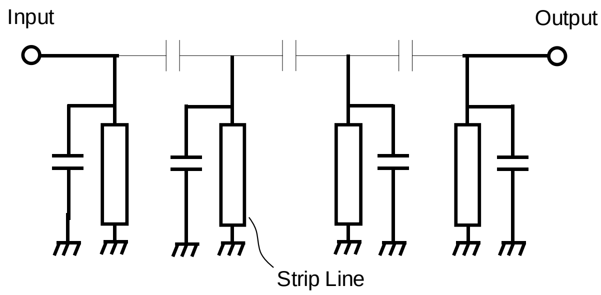


Figure A-11 Equivalent circuit of Distributed Element Filter

Annex A.3.5 SAW/FBAR Filter for Band n41

SAW/FBAR Filter Line-up for Band n41 in below table.

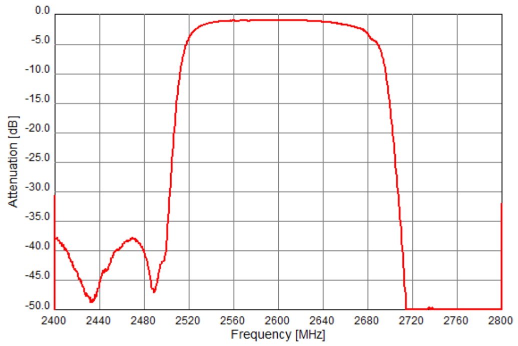
(These products had been originally developed for TD-LTE. Assuming these products can also be used for n41 while new conditions and/or requirements are under investigation.)

Table A-2 SAW/FBAR Filter for 5G NR n41 HPUE

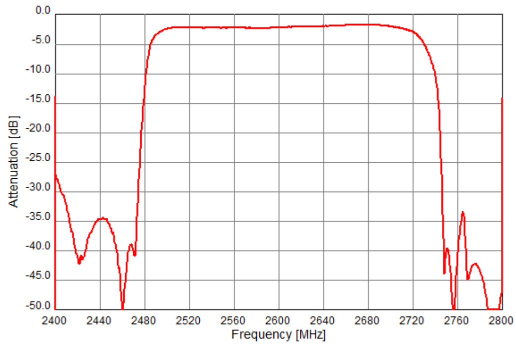
Status	Size	Frequency	Power Capability (TD-LTE)*
MP	1109	2535-2655MHz (BW: 120MHz)	+31dBm (2535-2655MHz) +32dBm (2575-2635MHz)
MP	1814	2496-2690MHz (BW : 194MHz)	+32dBm (2496-2690MHz)

*The power handling test condition for 5G NR (CBW: 100MHz) is under investigation.

2535-2655MHz (size: 1109)



2496-2690MHz (size: 1814)



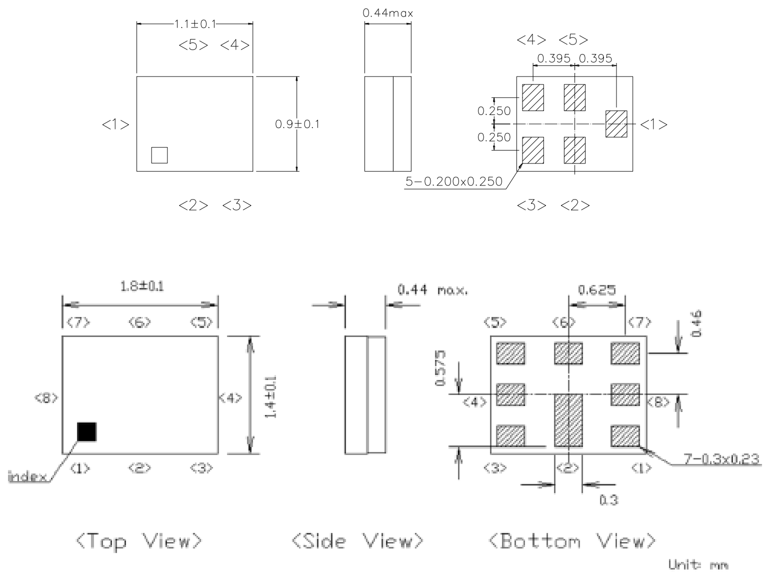


Figure A-12 Dimension for 1109 size and 1814 size SAW / FBAR Filters

Note: Above RF Filter information and data in Clause A.5 are provided by Taiyo Yuden.

Annex A.4 5G SAW Filters

Basically in the 5G era we can still use some of the SAW filters, including DPX, DRX, QPX, Tri-SAW filters, as we are using them now, such as n41(which should have the same frequency allocation with B41).

Annex A.4.1 Diagram

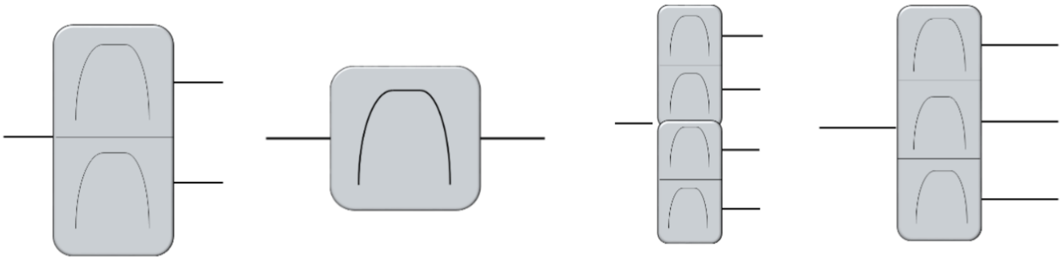


Figure A-13 Block Diagram of SAW Duplexer, SAW Filter, SAW QPX and SAW Tri-Filter

Annex A.4.2 Pin Layout

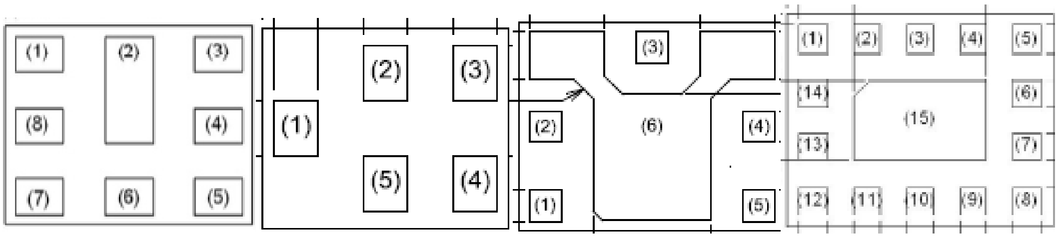


Figure A-14 Pin Layout of SAW Duplexer, SAW Filter, SAW QPX and SAW Tri-Filter

Please refer to the above figure of the pin layout of SAW Filters.

Annex A.4.3 Pin Size

The following illustration shows that under current situation 1814 sized SAW Duplexers have been designed with this kind of pin size. And this design may not be changed without any critical performance issues. Basically, the 1814 sized SAW Duplexers are designed with seven pins with the same size of 0.35mm×0.25mm and one bigger sized pin of 0.35mm×0.75mm.

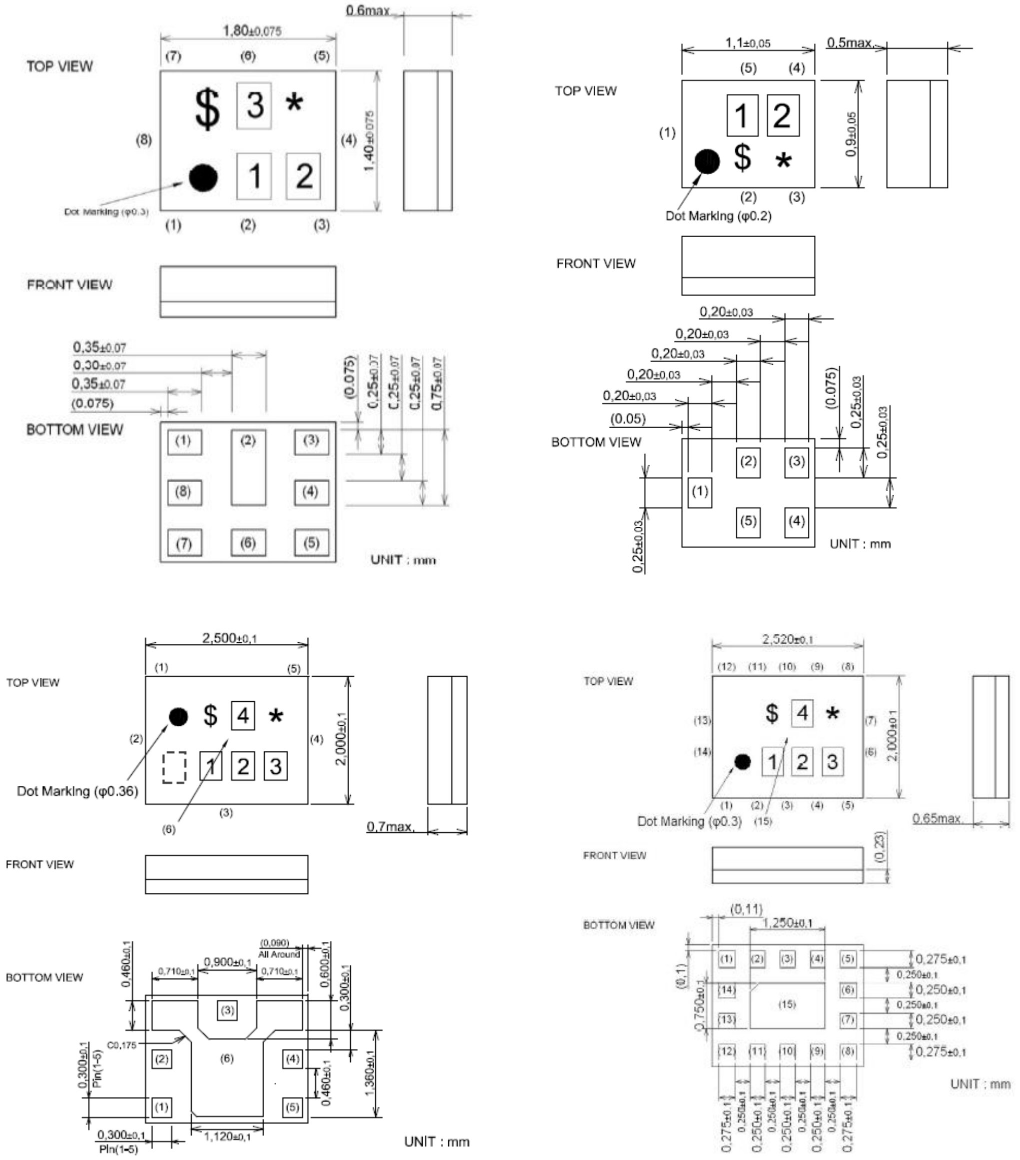
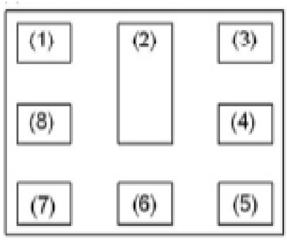
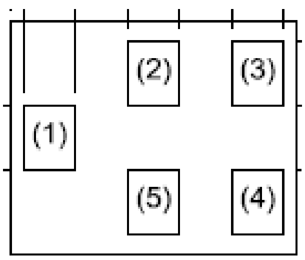


Figure A-15 Pin Size of 1814 SAW Duplexer, 1109 SAW Filter, 2520 SAW QPX and 2520 SAW Tri-Filter

Annex A.4.4 Pin Definition



Terminal Number
(6) : Ant
(3) : TX
(1) : RX
Others : GND



Terminal Number
(1) : Unbalanced port
(4) : Unbalanced port
Others : GND

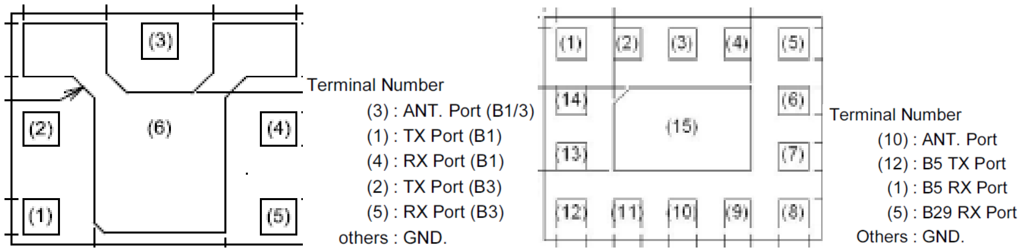


Figure A-16 Pin Definition of 1814 SAW Duplexer, 1109 SAW Filter, 2520 SAW QPX and 2520 SAW Tri-Filter

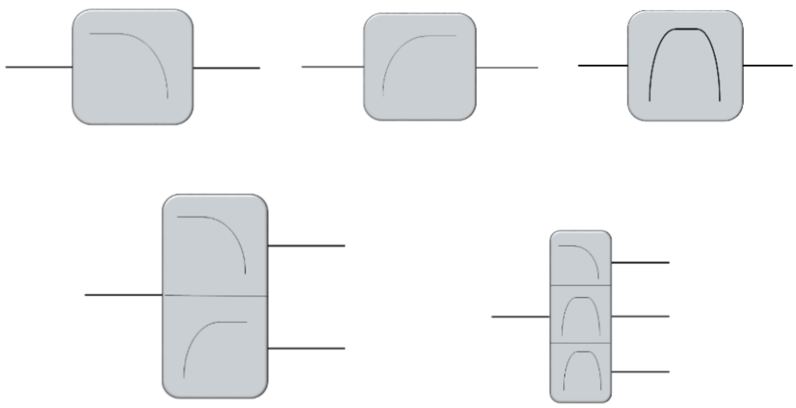
Note: Above RF Module information and data in Clause A.6 are provided by Murata.

Annex A.5 5G LTCC Components

Basically, in the 5G era we can still use some of the LTCC filters, including LPFs, HPFs, BPFs, Multiplexers, Baluns, and Couplers, as we are using them now. Based on the LTCC techniques, there will be various combinations of the LTCC components. Therefore, the below illustrations are just samples to let people know briefly about LTCC components.

As everyone knows that there will be various types of the LTCC components so that the pin layout of different LTCC components may be different as well, the following illustration is only a sample to show one of the possible layout structures of the LTCC components. To those who may concern about the applications of LTCC products, it should be noticed that the layout design, pin size, and pin definition of LTCC components should be including but not limited to the following design.

Annex A.5.1 Diagram



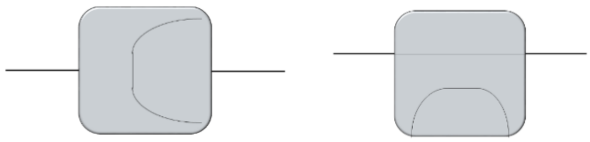


Figure A-17 Block Diagram of LPF, HPF, BPF, Diplexer, Triplexer, Balun and Coupler

Annex A.5.2 Pin Layout

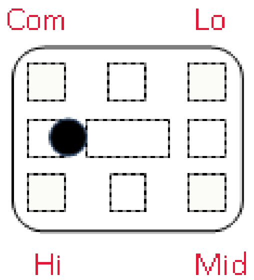
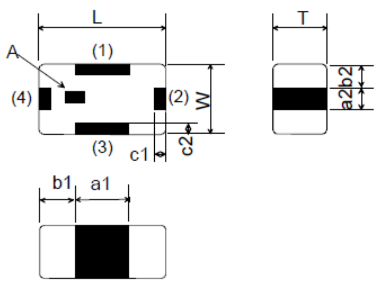


Figure A-18 Layout Illustration of LTCC Components

Annex A.5.3 Pin Size



(in mm)

Mark	Meaning
A	Directional Input Mark

Mark	Dimension	Mark	Dimension
L	1.6±0.1	b1	0.45±0.15
W	0.8+0.2/-0.1	b2	0.25±0.15
T	0.70 Max.	c1	0.20±0.15
a1	0.70±0.15	c2	0.20±0.15
a2	0.30+0.10/-0.15	-	-

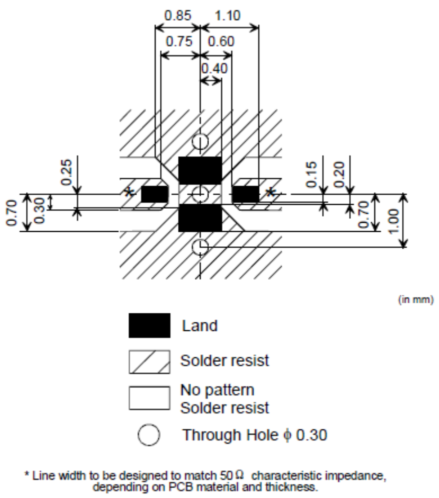


Figure A-19 Pin Size Illustration of LTCC Components

Annex A.5.4 Pin Definition

TERMINAL CONFIGURATION

Terminal No.	Terminal Name	Terminal No.	Terminal Name
(1)	GND	(3)	GND
(2)	OUT	(4)	IN

Figure A-20 Pin Definition Illustration of LTCC Components

Note: Above RF Module information and data in Clause A.6 are provided by Murata.

Annex B Antenna for 5G S-Module

Annex B.1 Antennas for S-Module Type 1

Annex B.1.1 Diagram

The module doesn’t embed antennas itself. External antennas are required to apply in the products. The external antennas diagram is shown below.

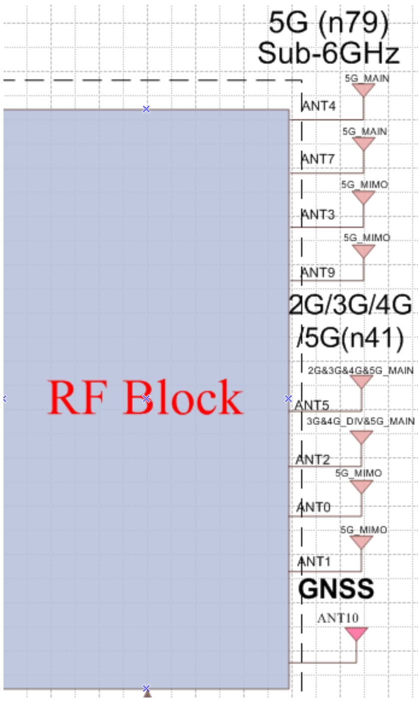


Figure B-1 Antenna Diagram

Annex B.1.2 Antennas connected to the module

Connections of antennas: IPEX connectors are built in the module，that are used to connect external antennas and module.

The information of antennas that are applied for the S-Module are shown in table B-1.

Table B-1 Antennas for S-Module type 1

Antenna	Bands	Antennas	Feature of Antennas	Description

Type		to Module		
4G/5G Antennas	5G NR Bands: Mandatory:n41 FDD-LTE Bands: Mandatory: B7, B3, B8, B25 Optional: B1, B4, B12, B17, B20 TDD-LTE Bands: Mandatory: B34, B39, B40, B41	AM47	5GNR(n41)&4G LTE main antenna	To get high data throughput for the products, 4 MIMO antenna design need to use for 5G S-Module. For the compatibility of the network, 4G LTE antennas are still required.
		AG47	5GNR(n41) main antenna&4G LTE diversity antenna	
		AN39	5GNR(n41) MIMO antenna	
		AN43	5GNR(n41) MIMO antenna	
5G Antennas	5G NR Bands: Mandatory: n79	ANT4	5GNR(n79)main antenna	To get high data throughput for the products, 4 MIMO antenna design need to use for 5G S-Module.
		ANT7	5GNR(n79) main antenna	
		ANT3	5GNR(n79) MIMO antenna	
		ANT9	5GNR(n79) MIMO antenna	
GNSS Antenna	GPS, BeiDou, GLONASS, or Galileo	ANT10	GNSS antenna	To meet the demand of precision positioning, GNSS antenna is applied

To achieve the designed performance of the module, the antennas of the products need to customize. Suggested antenna performance will be shown in next section.

Annex B.1.3 Suggested antenna performance requirement

5G antennas

5G NR Bands:

Mandatory: n41, n79

The new radio (NR) equipment radio transmission and reception performance requirement should follow 3GPP specification TS 38.101-4 [5].

4G antennas

The test method shall be performed as defined by 3GPP TR36.978

FDD-LTE Bands:
Mandatory: B7, B3, B8, B25
Optional: B1, B4, B12, B17, B20

TDD-LTE Bands:
Mandatory: B34, B39, B40, B41

Equipment radio transmission and reception performance requirement should follow 3GPP specification #36.101

GNSS antenna

Antenna bandwidth: Return loss > 6dB (50 ohm) within working band (GPS, BeiDou, GLONASS, or Galileo)
Total efficiency: Total efficiency > -6 dB within Antenna Bandwidth
GNSS antenna radiated sensitivity (TIS): -145 dB
TTFF (Time to first fix): Max time < 18s

Annex B.2 Antenna for S-Module Smart Type

Annex B.2.1 Diagram

The module doesn't embed antennas itself. External antennas are required to apply in the products. The external antennas diagram is shown below.

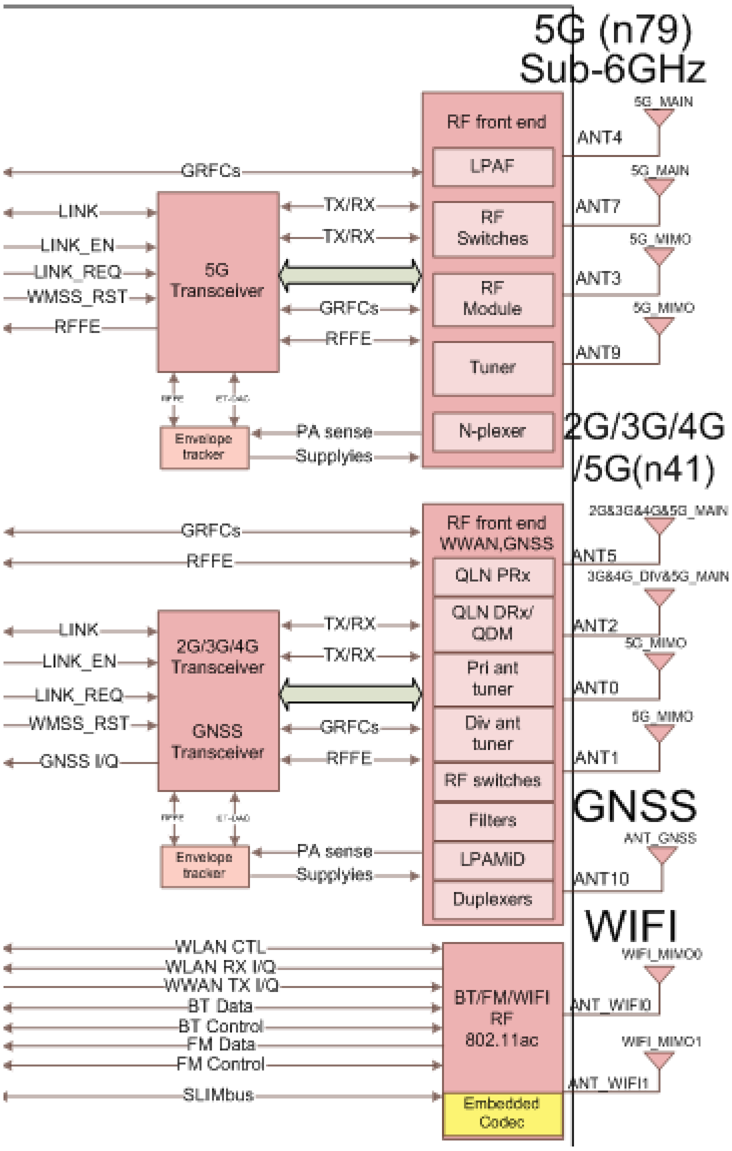


Figure B-2 Antenna Diagram

Annex B.2.2 Antennas connected to the module

Comparing the antenna configuration of S-Module type 1, There are 2 more WiFi antennas for S-Module Smart type .

Connections of antennas: IPEX connectors are built in the module，that are used to connect external antennas and module.

The information of antennas that are applied for the S-Module are shown in table B-2

Table B-2 Antennas for S-Module Smart type

Antenna Type	Bands	Antennas to Module	Feature of Antennas	Description
4G/5G Antennas	5G NR Bands: Mandatory:n41 FDD-LTE Bands: Mandatory: B7, B3, B8, B25 Optional: B1, B4, B12, B17, B20 TDD-LTE Bands: Mandatory: B34, B39, B40, B41	AM47	5GNR(n41)&4G LTE main antenna	To get high data throughput for the products, 4 MIMO antenna design need to use for 5G S-Module. For the compatibility of the network, 4G LTE antennas are still required.S-Module
		AG47	5GNR(n41) main antenna&4G LTE diversity antenna	
		AN39	5GNR(n41) MIMO antenna	
		AN43	5GNR(n41) MIMO antenna	
5G Antennas	5G NR Bands: Mandatory: n79	ANT4	5GNR(n79)main antenna	To get high data throughput for the products, 4 MIMO antenna design need to use for 5G S-Module.
		ANT7	5GNR(n79) main antenna	
		ANT3	5GNR(n79) MIMO antenna	
		ANT9	5GNR(n79) MIMO antenna	
GNSS Antenna	GPS, BeiDou, GLONASS, or Galileo	ANT10	GNSS antenna	To meet the demand of precision positioning, GNSS antenna is applied
Wifi Antenna	2.4G，5G	ANT_WIFI0	Wifi main antenna	2x2 Wifi MIMO are applied
	2.4G，5G	ANT_WIFI1	Wifi MIMO antenna	

To achieve the designed performance of the module, the antennas of the products need to customize. Suggested antenna performance will be shown in next section

Annex B.2.3 Suggested antenna performance requirement

5G antennas

5G NR Bands:
Mandatory: n41, n79

The new radio (NR) equipment radio transmission and reception performance requirement should follow 3GPP specification #38.101-4

4G antennas

The test method shall be performed as defined by 3GPP TR36.978

FDD-LTE Bands:
Mandatory: B7, B3, B8, B25
Optional: B1, B4, B12, B17, B20

TDD-LTE Bands:
Mandatory: B34, B39, B40, B41

equipment radio transmission and reception performance requirement should follow 3GPP specification #36.101

GNSS antenna

Antenna bandwidth: Return loss > 6dB (50 ohm) within working band (GPS, BeiDou, GLONASS, or Galileo)
Total efficiency: Total efficiency > -6 dB within Antenna Bandwidth
GNSS antenna radiated sensitivity (TIS): -145 dB
TTFF (Time to first fix): Max time < 18s

WiFi Antennas

Antenna Band: 2.402 – 2483 GHz, & 4.910 – 5.835 GHz
Total efficiency: Total efficiency > -6 dB within Antenna Bandwidth

Annex C Sensor

Annex C.1 Sensor Technology

Sensor technology, computer technology and communication are three pillars of information technology. From the view of IoT, sensor technology measures the degree of information. Sensor technology is to get information from the nature, then use physical effect, chemical effect, and biological effect, and transfer the physical quantity, chemical quantity, and biological quantity into the quantity of electricity. Sensor uses numerous latest technologies from modern science and it is adopted by many industries.

The compositions of sensors are sensing element, transduction element, measurement, and conversion circuit.

There are three generations of sensor technology. The first-generation is structure type sensors, such as resistive sensor. The second-generation sensor is solid sensor, such as Thermocouple sensor, Hall sensor, etc. The third-generation sensor is smart sensor.

All sensors require accuracy, reliability, sensibility, and stability. They need to be small size, fast response, easy to use and easy to adapt. And they should have low cost and low power consumption.

The smart sensors use smart sensing technology to process signal. They should be self-calibrated, self-learning, self-adaptive and combine with other AI technology.

The current study and development trend for the sensors are:

- Improve the sensors in automatic apparatus and robots;
- Develop new type sensors, such as non-contact temperature sensor for the PCB board, and ultrasonic sensor;
- Develop Micro-assembly sensor system;
- Put more emphasis on data assembly, merge AI technology;
- Develop new effects, new materials, and new functions;
- The sensors will be more integrated, multi-functional and miniaturized;
- For the smart sensors, they will be digital, intelligent, and networked;
- There are challenge in the undeveloped field, such as Bio-sensors.

Sensors are a kind of functional sub-modules, which can transfer external signals to electrical signals. They could be used inside or along with5G S-Module for wide applications.

Annex C.2 Cutting-edge Sensor Application

Sensors have applications in many fields and have increased requirement indifferent areas. Here we introduce some cutting-edge development which may be used with the 5G S-Modules.

In the digital medical field, there are use cases like combined sensor for babies, continuous biosensor for the elderly, and the test sensors inside human body for testing medicines. Such micro sensor has a tiny volume (1mmx1mmx0.45mm), and is implanted into the normal medicine. It is made of mini-silicon and tiny amount of Mg and Cu. When it is swallowed, it will create tiny voltage by gastric acid. Then there is a respondent apparatus outside human body and near the stomach. This apparatus gets the voltage signal and sensor transfers the data to the doctor's mobile phone. Thus, the doctor could monitor the patients on medicine, heart rate and body temperature.

STMicroelectronics developed an MEMS microphone, which could monitor the ultrasonic frequency spectrum in deep-layer, to detect pipeline leakage and other fault. This sensor is less than $1 and it can transfer the data stream to the microcontroller unit (MCU).

TDK's new magnetic sensor (TMR sensor) is a 360º sensor which could provide orientation with 0.2º, and is also less than $1. The new TAD2140 sensor could be used in the car steering wheel and windshield wiper and motor. It also could be used in the mobile handset for shockproof.

There is plastic sensor for amputation patients. The British company PST sensor has newest development on sensors which are integrated to soft plastic board. This innovation is for artificial limb. The sensor could report the temperature and moisture in the limb using Bluetooth. This sensor will be tested in the National Health Service in UK in Fall of 2018.

There are sensors in IMU market. The French company Thales Group uses its newest NavChip2 to develop new market for its six axis IMU sensor. This sensor has 16G and velocity of 2,000 degree/second. It provides less than 5 degree/hour positioning drift, which is quite accurate. It could be used in cars, drones, and robots.

There is sensor with low power. Rohm develops a micro contactless current sensor, which uses magnetic bias measurement to detect PCB current. This module is also less than $1. It has lowered the power consumption and heat dramatically.

Microchip Technology develops an enhanced capacitor contact sensor, which could be embedded into its new 32-bit MCU. This chipset is the first MCU which supports ARM TrustZone hardware safety technology. The contact sensor could get 4 signals in parallel and has better anti-noise and anti-moisture capability.

Japanese company Alps Electric developed different kinds of sensors. They can accurately detect changes in temperature, humidity, location, acceleration, light, and force. Alps will provide end-to-end IOT solutions with the sensors.

Annex C.3 The Universal Interfaces of Sensors

If we have to deploy 5G S-Module today with built-in sensor or connection to the sensor network, we may have to go with the UART, I2C and/or SPI interfaces since the available market-ready sensors do not support better designed I3C sensor interface. However, 5G S-Module is target for late 2019 deployment. That gives us some time to work with sensor component ecosystem to adopt the MIPI I3C interface.

The I3C combines features from I2C and SPI to provide a standard and scalable interface to connect multiple sensors with a low pin count and at low power. It is backward compatible with I2C, allowing I2C slave devices to exist on the same interface as other I3C devices. It provides in-band interrupts within the same I2C 2-wire interface.

The data rate supported on an I3C bus depend on the bus mode and device type. It can be from 8.8 to 26.7Mbit/s on a pure I3C bus. If the bus connects a mix of I2C and I3C devices, the I3C master can communicate to the I2C slaves at up to 400Kbit/s or 1 Mbit/s and to I3C slaves at up to 20.5Mbit/s.

A pure I3C bus supports sleep mode and connects a dozen devices.

An example block diagram of I3C interconnections is shown in Figure 8-9. There are devices with Master role, devices with an I3C Slave role, and devices with an I2C Slave role. Note that I3C Secondary Master Devices are capable of both Master and Slave roles at different times.

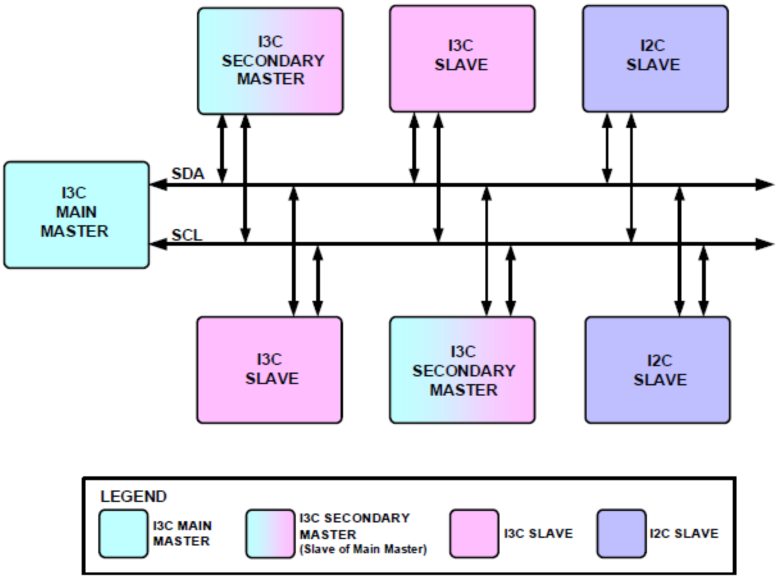


Figure C-1 I3C Bus with I2C Devices and I3C Devices (Source: MIPI)

To meet the requirement of different vertical industry application, it is best to have S-Module with dual-role (master and slave) I3C capability built-in.