

GTI 5G S-Module White Paper

The logo consists of the letters 'GTI' in a bold, white, sans-serif font, centered on a dark blue background. The background features a glowing blue grid pattern that recedes into a bright light source, creating a sense of depth and technology.

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GTI 5G S-Module White Paper



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Document History

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| Oct. 31, 2018 | 23 rd 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-Modules and the typical technology solutions for 5G S-Modules are described. |
| Feb.19, 2019 | 24 th GTI Workshop | V1.1 | Some revisions have been made to Section "8.2.2 Pin Layout" and "8.2.3 Pin Size" of "GTI 5G S-Module Whitepaper (v1.0)" as per the industry R&D progress. Section "8.3.2 Pin Layout" and "8.3.4 Pin Definition" have been updated. Some pins have been clarified as "/Reserved" also. Some misalignments between "8.3.2 Pin Layout" and "8.3.4 Pin Definition" have been fixed. |
| Jun. 21, 2019 | 25 th GTI Workshop | V2.0 | The original "5G S-Module Basic Type 1" and "5G S-Module Basic Type 2" have been merged as "5G S-Module Basic Type-L" as per the latest industry R&D progress. The original "5G S-Module Basic Type 3" has been renamed as "5G S-Module Basic Type-M". Section "5.2.2.1 Modes and Bands" has been updated. Section "6 The Industry Status" has been updated as per the latest progress of the industry. Section "8.4 5G S-Module All-in-one Type-M", Section "8.5 5G S-Module All-in-one Type-L" and Section "11 Typical Application Scenarios for 5G S-Module" have been added. |

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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 for the particular characteristics of specific users. For example, a dense grid network might prioritize low power consumption of massive terminals over connection speed; at the same time, a separate network slice on the same infrastructure could provide high-speed mobile communications for specific application. “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 specific attributes of the 5G S-Module, therefore, we categorize the requirements together and extract a generic requirement for the 5G S-Module. In general, the 5G S-Module will fulfill the requirements 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, benefiting 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)
- [15] GSA, LTE, 5G and 3GPP IoT Chipsets: Status Update, April 2019
- [16] GSA, 5G Device Ecosystem, May 2019

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 required basic functions, 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, Cheerzing
- **Chapter 7 The Basic functions Requirements on 5G S-Module**
Hisense
- **Chapter 8 The Hardware Technical Requirements on 5G S-Module**
SIMCom, Fibocom, Quectel
- **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**
SIMCom, Fibocom, Quectel
- **Annex A 5G RF Component**

- Qorvo, Taiyo Yuden, Murata
Annex B Antenna
- Sunway
Annex C Sensor
- SIMCom, Sprint

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- **Keysight**
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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 improve their performance. For example, Virtual and Augmented Reality, UHD 8K Online 360 Video, 16K VR Head Mounted Display for game 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 GTI 5G device ecosystem develops. 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.

User-centric authentication layer on top of the existing subscription authentication is introduced to share S-Module usage. Once 5G networks are deployed, different users can share limited kinds 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

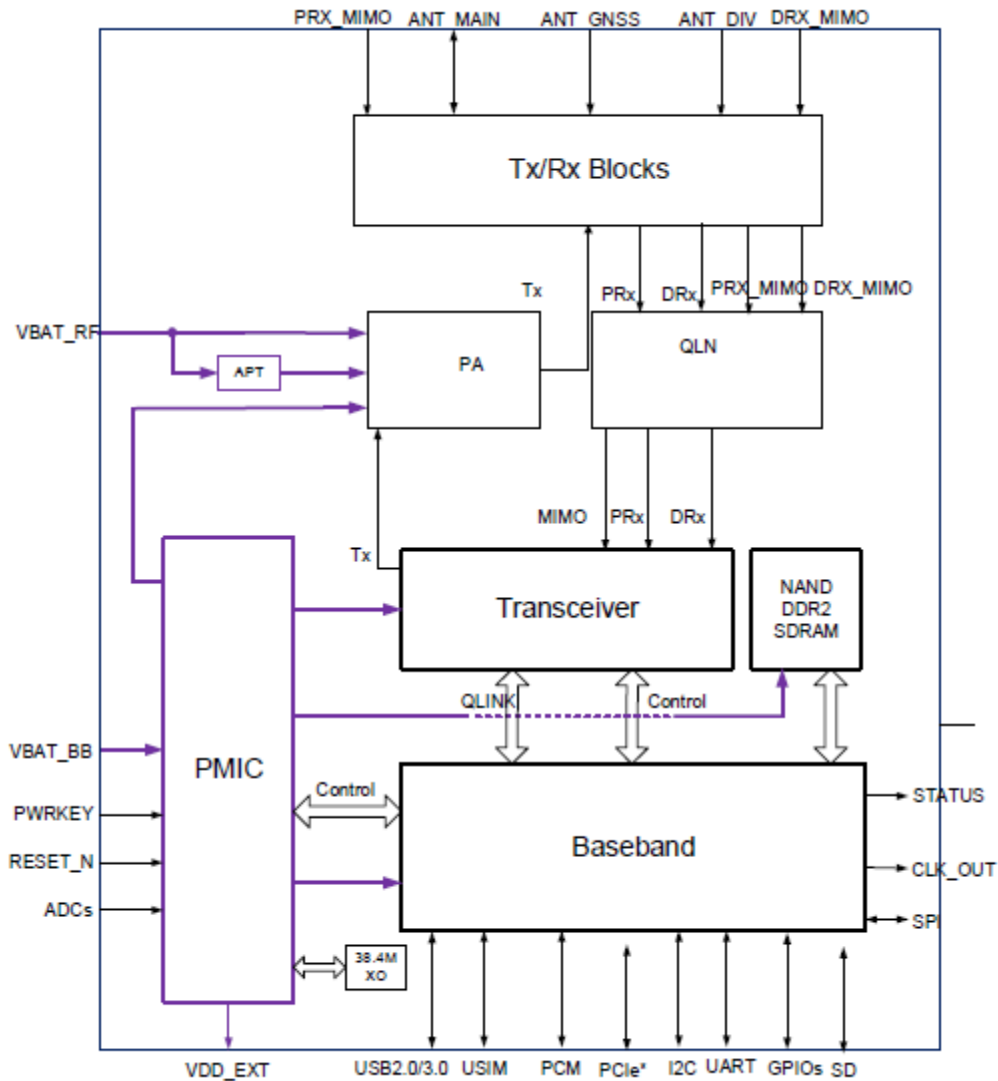


Figure 5-1 Diagram of 5G S-Module

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 two major categories: Basic Type-L and Basic Type-M without high-performance processor, Smart Type with high-performance processor, Basic Type-L with LGA form factor, Basic Type-M 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, n78

Optional: n77

LTE FDD Bands:

Mandatory: B7, B3, B8, B1, B2, B5, B25

Optional: 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: 1.7 Gbps
- 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%.

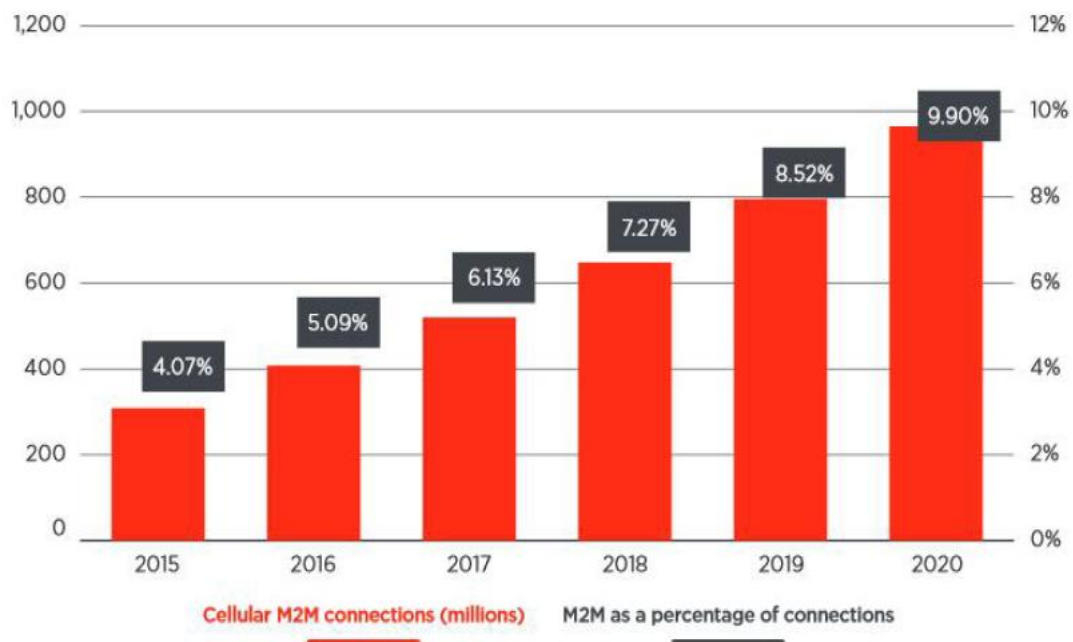


Figure 6-1 Forecast of global cellular M2M connections (From GSMA)

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, automobile, 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, 644 public LTE networks have been deployed and have covered 200 countries/areas. With the evolution of carrier's network, more and more applications are switch to LTE modules from GSM/WCDMA modules.

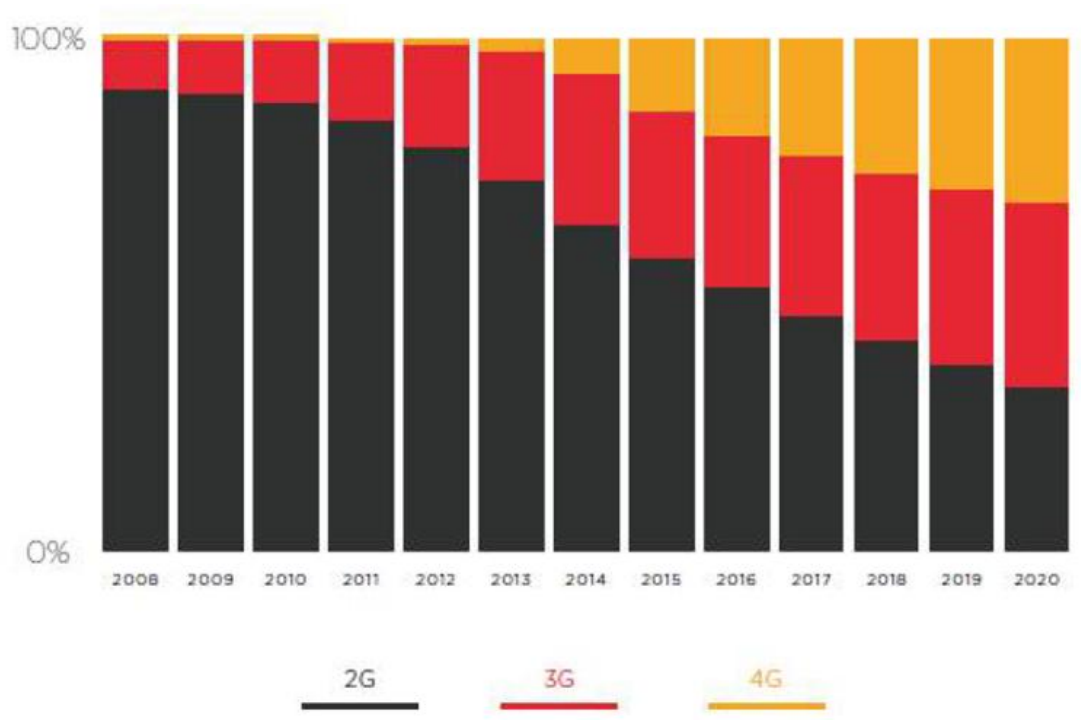


Figure 6-2 Forecast of 2G/3G/4G M2M connections (From Ericsson)

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.

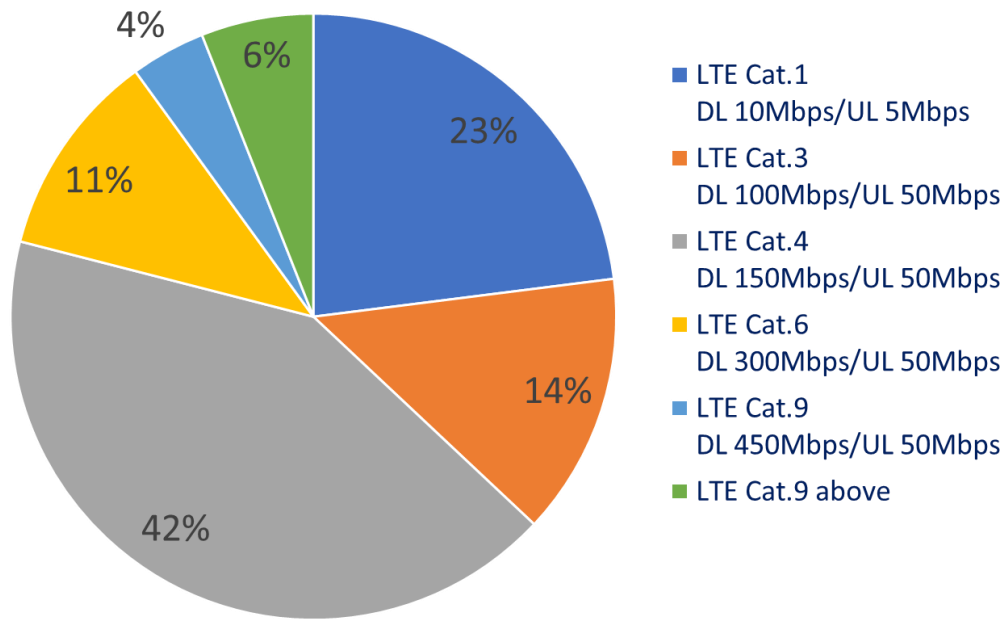


Figure 6-3 Percentage of different LTE category (From CMCC)

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.

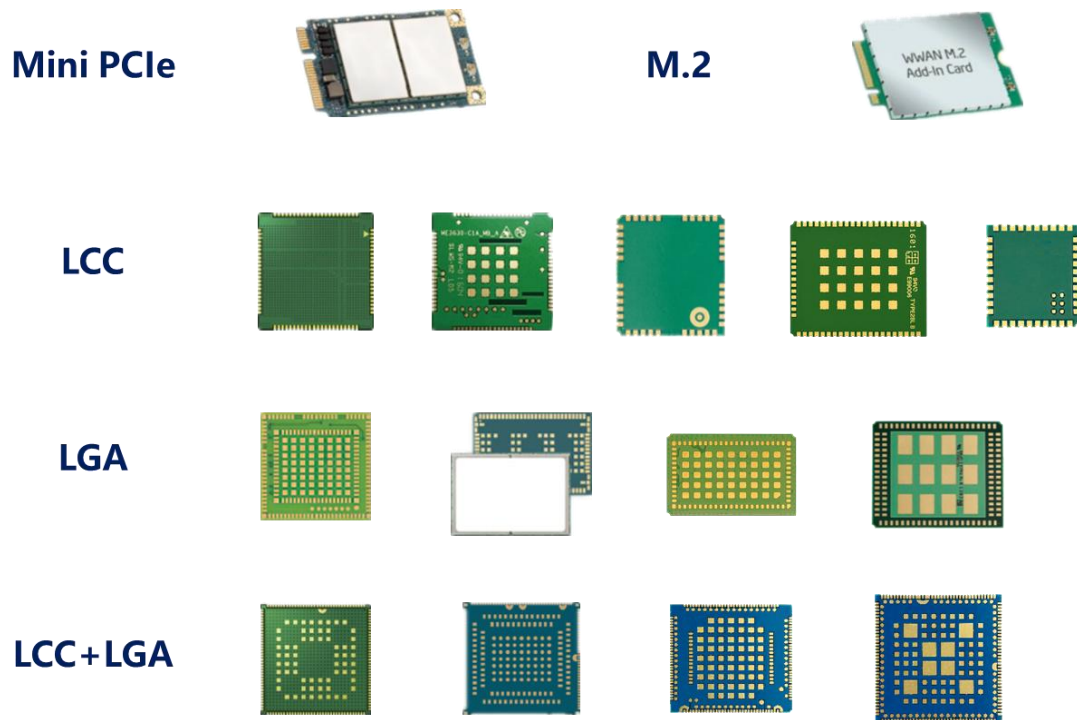


Figure 6-4 Different form factor of LTE module (From public data)

6.2 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.

6.3 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. According to the GSA report and news released by the companies, the announced 5G chipsets are summarized as follows:

- Hi-Silicon (Huawei): the first generation 5G-only Balong 5G01 cellular modem and, the second generation LTE/5G Balong 5000 cellular modem.
- Intel: the XMM8060 and XMM8160 cellular modems. [Note: Intel has announced its withdrawal from the 5G modem market.]

- Mediatek: the Helio M70 modem and the 5G SoC with Helio M70 modem built-in.
- Qualcomm: the Snapdragon 855 mobile platform and the Snapdragon X50 and X55 modems.
- Samsung: the Exynos 5100 (S5T5100) modem.
- UNISOC: the 5G technology platform MAKALU and its first 5G Modem IVY510.

Regarding the performance of pre-commercial/commercial 5G chipsets, the peak downlink speeds for the modems range from 4.7 Gbps to 7 Gbps (expected) and the maximum peak theoretical uplink speeds range from 1.5 Gbps to 3.5 Gbps (from available data). In addition, at least half the commercially available 5G-capable chipsets can support LTE as well as 5G services.

6.4 The Industry Status of 5G Module

The mainstreaming module vendor are starting study the 5G technology and develop 5G modules based on available 5G chipsets. The module develop schedule depends on the 5G baseband chipset schedule. According to the GSA report released in May 2019,

- **16** 5G modules have been announced by **8** vendors.
- **12** 5G modules are developed based on Qualcomm Snapdragon X55 modem, **one** 5G module based on Huawei Balong 5000 modem, **one** to be confirmed, and **2** with no data.
- **8** 5G modules support Sub-6GHz only, **6** 5G modules support both Sub-6GHz and mmWave, and **2** with no data.
- **2** 5G modules are designed for IoV, i.e. Internet of Vehicle.

Most of the 5G modules are in the pre-commercial stage. Some modules are expected to be available for sampling in H2 2019 and commercially available in 2020.

6.5 The Industry Status of 5G Device

Since the beginning of 2019, the number of 5G devices has grown quickly. According to the GSA report, by the end of May 2019,

- **33** vendors have announced available or forthcoming 5G devices.
- **64** 5G devices in **9** form factors have been announced, including 19 indoor/outdoor CPE devices, 17 phones, 16 modules, 6 hotspots, 2 snap-on dongles/adapters, 2 IoT routers, 1 laptop, and 1 USB terminal.

Some of the announced 5G devices have been commercially available, while more devices are in the phase of pre-commercial, sampling, or availability unknown. In addition, several potential 5G devices are not officially announced.

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: $3V\pm 10\%$ or $1.8V\pm 10\%$.

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 | $\leq 41\text{mm} \times 44\text{mm}$ $\leq 30\text{mm} \times 52\text{mm}$ | $\leq 44\text{mm} \times 45\text{mm}$ | $\leq 52\text{mm} \times 93\text{mm}$ $\leq 44\text{mm} \times 70\text{mm}$ |

8.1 5G S-Module Basic Type-L

8.1.1 Diagram

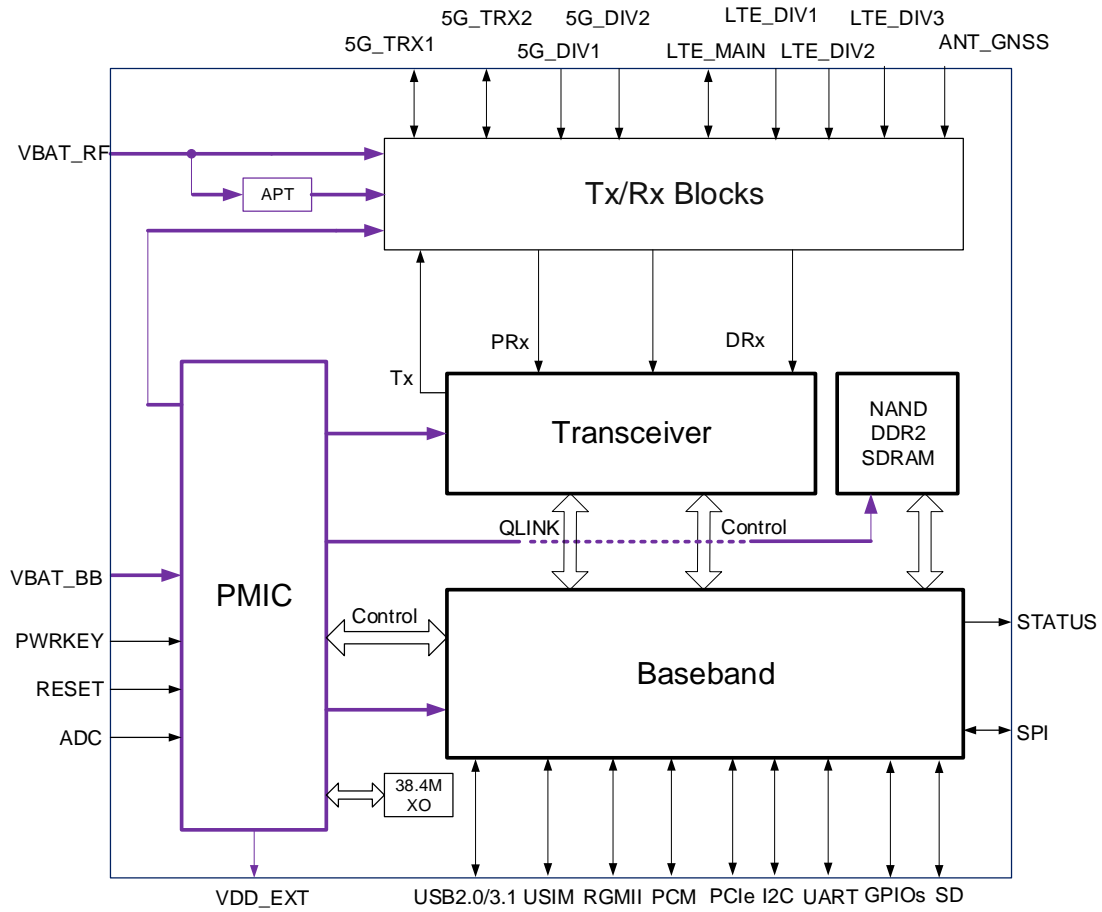


Figure 8-1 5G S-Module Basic Type-L Diagram

8.1.2 Pin Layout

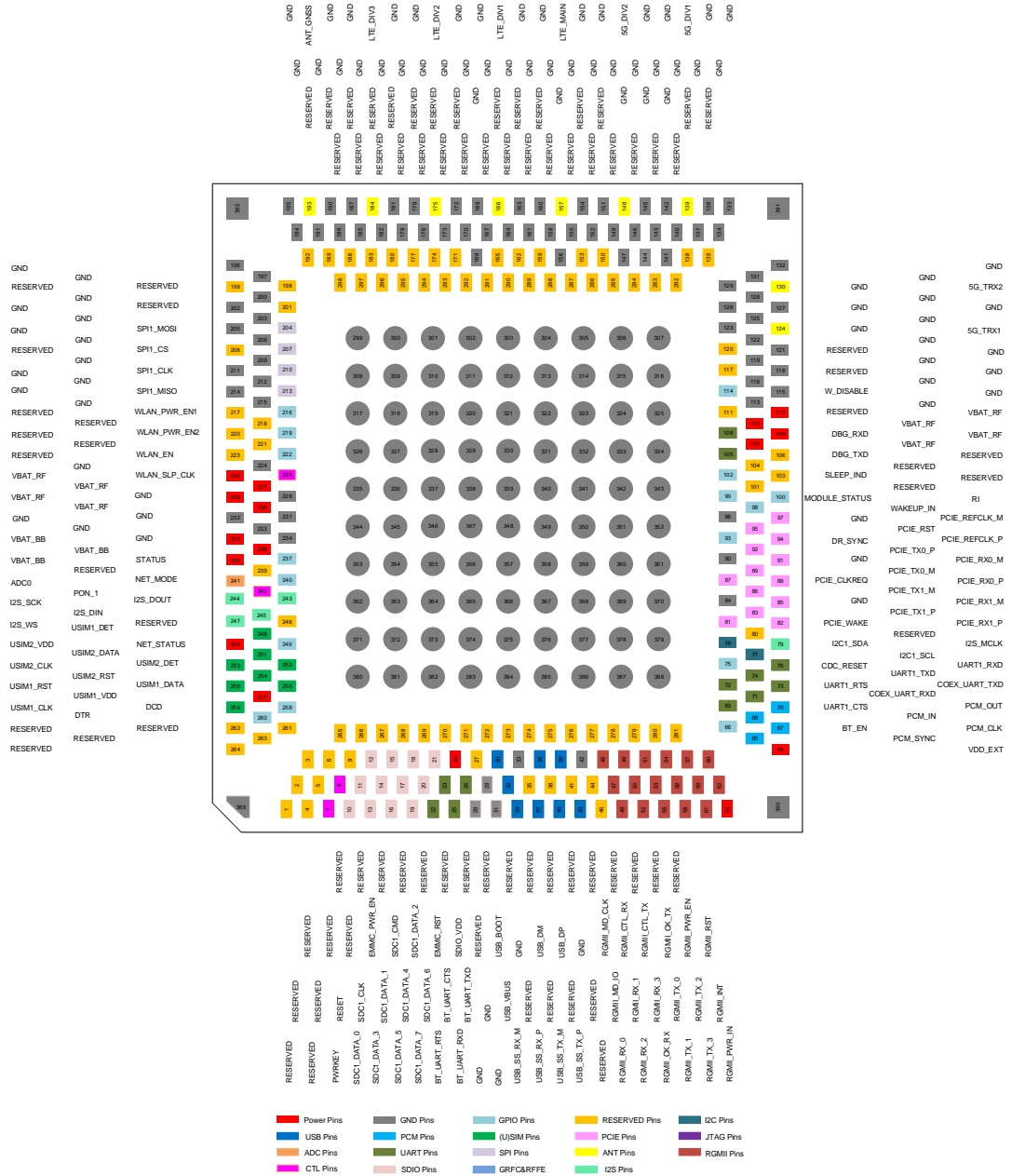


Figure 8-2 5G S-Module Basic Type-L Pin Layout-1

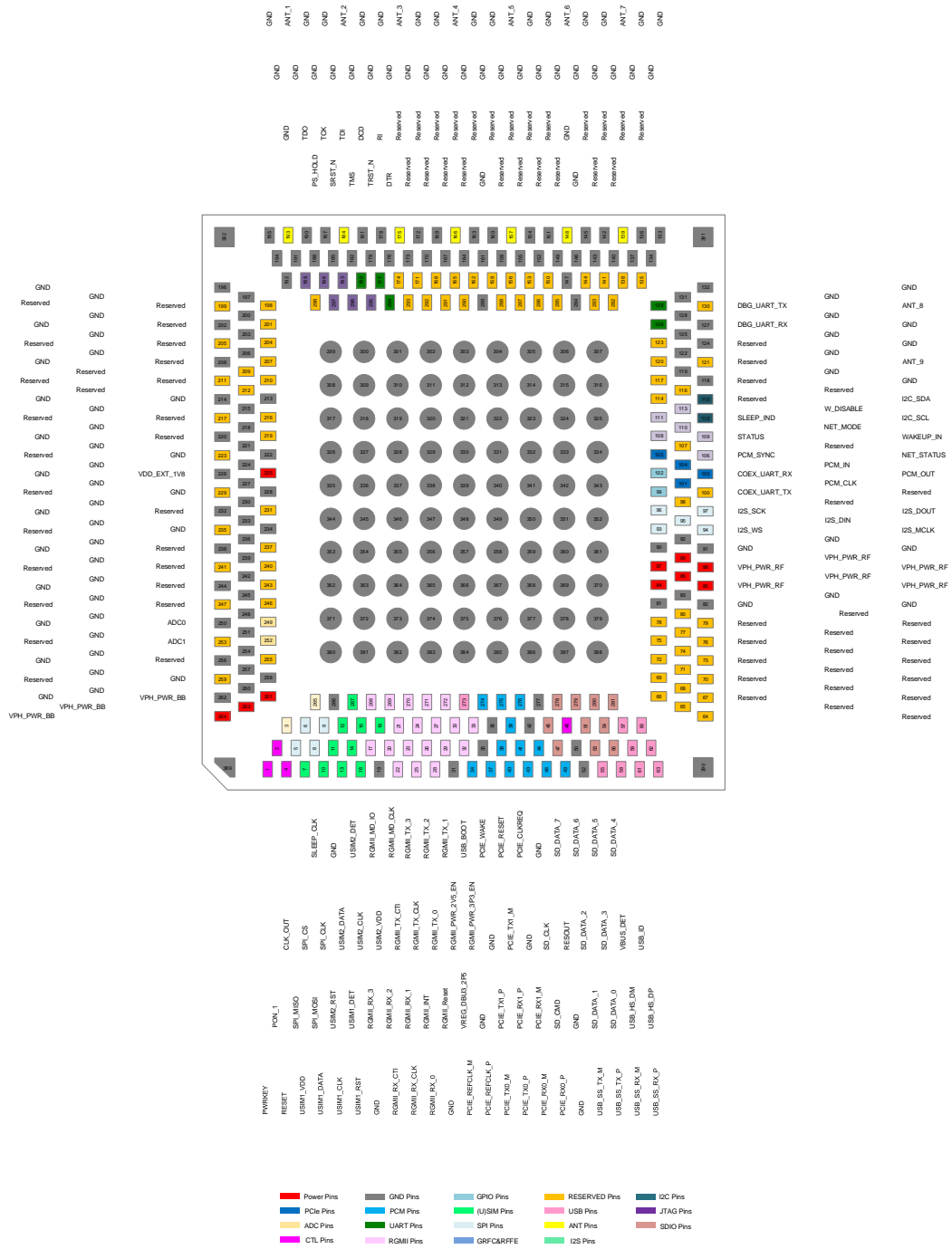
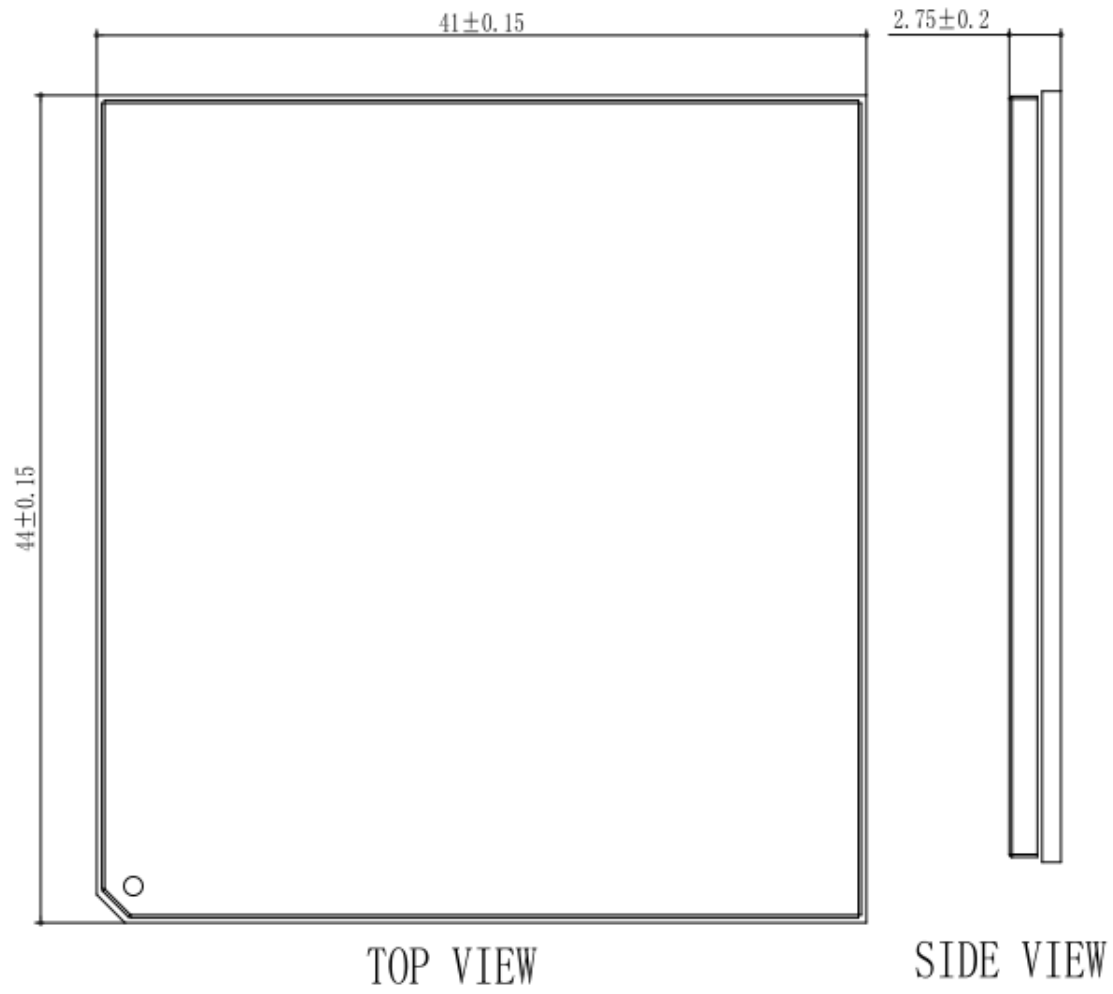


Figure 8-2A 5G S-Module Basic Type-L Pin Layout-2

8.1.3 Pin Size



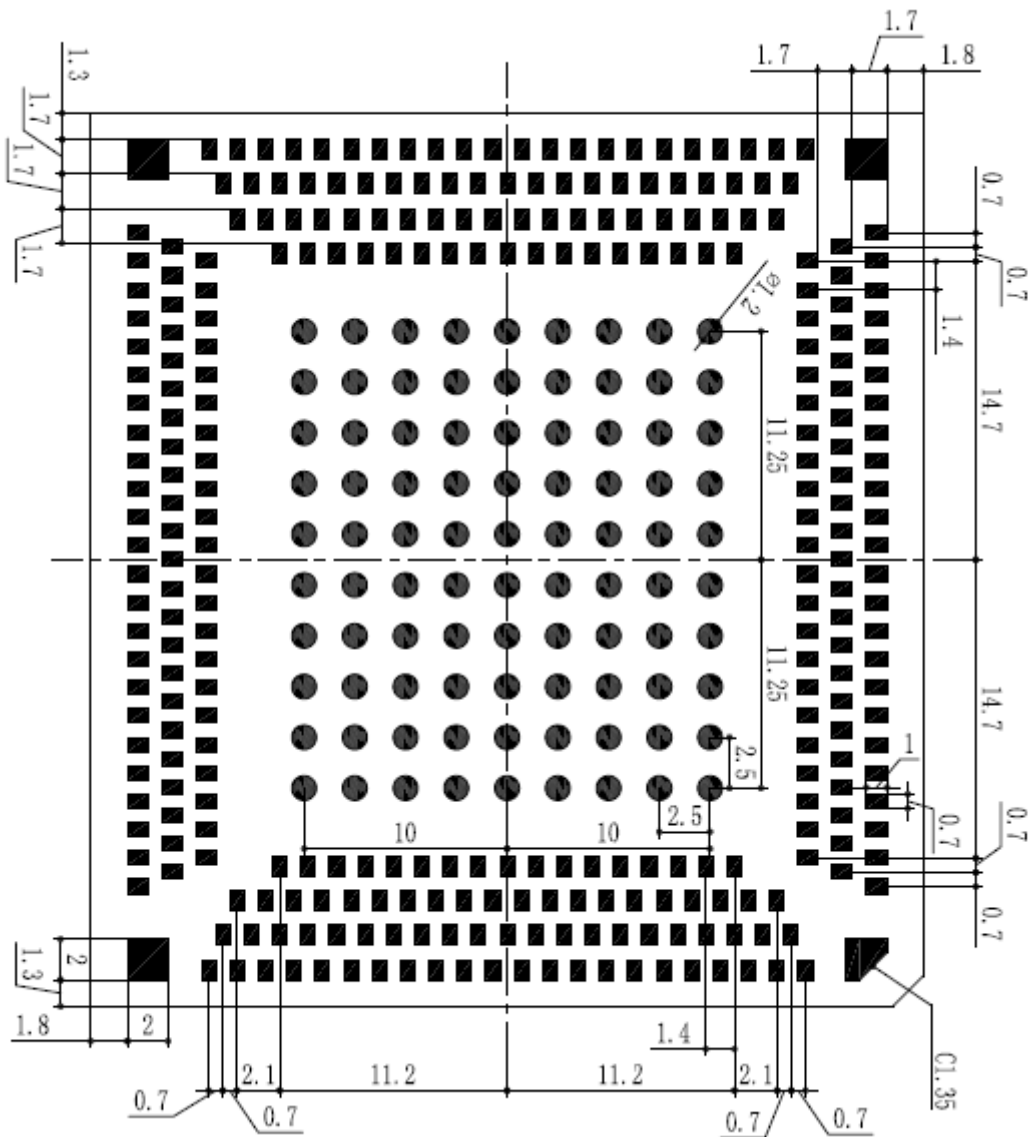


Figure 8-3 5G S-Module Basic Type-L Pin Size

8.1.4 Pin Definition

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

| Pin name | Pin No. | Default status | Description | Comment |
|---------------------|-------------|----------------|------------------------|---|
| Power supply | | | | |
| VBAT_BB | 235,236,238 | PI | Baseband power supply. | Can connect these pins together to the same power source. |
| VBAT_RF | 107,109, | PI | RF power supply. | |

| | | | | |
|-------------------------|--------------------------------------|-----|--|-----------------------------------|
| | 110,112, , 226 227,229,2 30 | | | |
| VDD_EXT | 64 | 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 | 7 | DI | System power on/off control input, active low. | |
| PON_1 | 242 | DI | Pull it to high level will make the module turn on automatically. | |
| RESET | 8 | DI | System reset control input, active low. | |
| Status Indicator | | | | |
| STATUS | 237 | DO | System status output | |
| NET_MODE | 240 | DO | Network Mode output | |
| NET_STATUS | 249 | DO | Network status output | |
| USB interface | | | | |
| USB_VBUS | 32 | AI | USB detection input. | If unused, please keep them open. |
| USB_DP | 39 | AIO | Positive line of the differential, bi-directional USB signal. | |
| USB_DM | 36 | AIO | Negative line of the differential, bi-directional USB signal. | |
| USB_BOOT | 30 | DI | Force the module to boot from USB port | |
| USB_SS_TX_P | 43 | AO | USB Super-Speed transmit – plus | |
| USB_SS_TX_M | 40 | AO | USB Super-Speed transmit – minus | |
| USB_SS_RX_P | 37 | AI | USB Super-Speed receive – plus | |
| USB_SS_RX_M | 34 | AI | USB Super-Speed receive – minus | |
| (U)SIM interface | | | | |

| | | | | |
|----------------------|-----|-----|--|--|
| USIM1_VDD | 257 | PO | Power supply for (U)SIM card1 | 1.8V or 2.85V power domain |
| USIM1_DATA | 255 | DIO | Data signal of (U)SIM card1 | |
| USIM1_CLK | 259 | DO | USIM1 clock output | |
| USIM1_RST | 256 | DO | USIM1 Reset output | |
| USIM1_DET | 248 | DI | USIM1 card detecting input. H: USIM is removed L: USIM is inserted | 1.8V power domain. If unused, keep it open. |
| USIM2_VDD | 250 | PO | Power supply for (U)SIM card2 | 1.8V or 2.85V power domain |
| USIM2_DATA | 251 | DIO | Data signal of (U)SIM card2 | |
| USIM2_CLK | 253 | DO | Clock signal of (U)SIM card2 | |
| USIM2_RST | 254 | DO | Reset signal of (U)SIM card2 | |
| USIM2_DET | 252 | DI | USIM2 card detecting input. H: USIM is removed L: USIM is inserted | 1.8V power domain. If unused, keep it open. |
| SPI interface | | | | |
| SPI1_CS | 207 | DO | SPI chip select | |
| SPI1_CLK | 210 | DO | SPI clock | |

| | | | | |
|--------------------------|-----|----|--------------------------------|-----------------------------------|
| SPI1_MOSI | 204 | DO | Master output slaver input | |
| SPI1_MISO | 213 | DI | Master input slaver output | |
| UART1 interface | | | | |
| RI | 100 | DO | Ring Indicator | If unused, please keep them open. |
| DCD | 258 | DO | Carrier detects | |
| UART1_CTS | 69 | DO | Clear to Send | |
| UART1_RTS | 72 | DI | Request to send | |
| DTR | 260 | DI | Data Terminal Ready | |
| UART1_TXD | 74 | DO | Transmit Data | |
| UART1_RXD | 76 | DI | Receive Data | |
| Debug interface | | | | |
| DBG_RXD | 108 | DI | Debug UART receive Data | If unused, please keep them open. |
| DBG_TXD | 105 | DO | Debug UART transmit Data | |
| BT UART interface | | | | |
| BT_UART_TXD | 26 | DO | BT UART Transmit Data | If unused, please keep them open. |
| BT_UART_RXD | 25 | DI | BT UART Receive Data | |
| BT_UART_RTS | 22 | DI | BT UART Request to send | |
| BT_UART_CTS | 23 | DO | BT UART Clear to Send | |
| ADC interface | | | | |
| ADC0 | 241 | AI | Analog-digital converter input | If unused, please keep them open. |
| PCM interface | | | | |

| | | | | |
|-----------------------|-----|----|----------------------------|---|
| PCM_IN | 68 | DI | PCM data input | If unused, please keep them open. |
| PCM_OUT | 70 | DO | PCM data output | |
| PCM_SYNC | 65 | DO | PCM synchronous signal | |
| PCM_CLK | 67 | DO | PCM clock output | |
| I2S interface | | | | |
| I2S_WS | 247 | IO | I2S word select | 1.8V power domain |
| I2S_SCK | 244 | DO | I2S bit clock | |
| I2S_DIN | 245 | DI | I2S data input | |
| I2S_DOUT | 243 | DO | I2S data output | |
| I2C interface | | | | |
| I2C1_SCL | 77 | OD | I2C clock output | OD gate driver, pull-up resistors of 2.2KR to the VDD_1V8 are needed. If unused, please keep open |
| I2C1_SDA | 78 | OD | I2C data input/output | |
| PCIE interface | | | | |
| PCIE_REFCLK_P | 94 | AO | PCIE reference clock plus | If unused, please keep them open. |
| PCIE_REFCLK_M | 97 | AO | PCIE reference clock minus | |
| PCIE_TX0_M | 89 | AO | PCIE Lane 0 transmit minus | |
| PCIE_TX0_P | 92 | AO | PCIE Lane 0 transmit plus | |
| PCIE_RX0_M | 91 | AI | PCIE Lane 0 receive minus | |
| PCIE_RX0_P | 88 | AI | PCIE Lane 0 receive plus | |

| | | | | |
|-----------------------|-----|-----|----------------------------------|-----------------------------------|
| PCIE_TX1_M | 86 | AO | PCIe Lane 1 transmit minus | |
| PCIE_TX1_P | 83 | AO | PCIe Lane 1 transmit plus | |
| PCIE_RX1_M | 85 | AI | PCIe Lane 1 receive minus | |
| PCIE_RX1_P | 82 | AI | PCIe Lane 1 receive plus | |
| PCIE_CLKREQ | 87 | DI | PCIe clock request | |
| PCIE_RST | 95 | DO | PCIe RC (host) reset | |
| PCIE_WAKE | 81 | DI | PCIe RC (host) wake | |
| WLAN interface | | | | |
| WLAN_PWR_EN1 | 216 | DO | WLAN power enable1 | If unused, please keep them open. |
| WLAN_PWR_EN2 | 219 | DO | WLAN power enable2 | |
| WAKE_SLP_CLK | 225 | DO | WLAN sleep clock | |
| WLAN_EN | 222 | DO | WLAN function enable | |
| COEX_UART_RXD | 71 | DI | Coex UART Receive data | |
| COEX_UART_TXD | 73 | DO | Coex UART Transmit data | |
| SD interface | | | | |
| SDIO_VDD | 24 | PO | Power supply of SDIO data signal | 1.8V or 2.85V power domain |
| SDC1_DATA0 | 10 | DIO | SDIO data 0 | |
| SDC1_DATA1 | 14 | DIO | SDIO data 1 | |
| SDC1_DATA2 | 18 | DIO | SDIO data 2 | |
| SDC1_DATA3 | 13 | DIO | SDIO data 3 | |

| | | | |
|-----------------------|----|-----|-----------------------------|
| SDC1_CMD | 15 | DO | SDIO command output |
| SDC1_CLK | 11 | DO | SDIO clock output |
| SDC1_DATA4 | 17 | DIO | SDIO data 4 |
| SDC1_DATA5 | 16 | DIO | SDIO data 5 |
| SDC1_DATA6 | 20 | DIO | SDIO data 6 |
| SDC1_DATA7 | 19 | DIO | SDIO data 7 |
| EMMC_RST | 21 | DO | Reset signal for eMMC flash |
| EMMC_PWR_EN | 12 | DO | Enable eMMC power supply |
| RGMI interface | | | |
| RGMI_MD_IO | 47 | IO | RGMI MDIO management data |
| RGMI_MD_CLK | 45 | DO | RGMI MDC management clock |
| RGMI_RX_0 | 49 | DI | RGMI receive data bit 0 |
| RGMI_RX_1 | 50 | DI | RGMI receive data bit 1 |
| RGMI_CTL_RX | 48 | DI | RGMI receive control |
| RGMI_RX_2 | 52 | DI | RGMI receive data bit 2 |
| RGMI_RX_3 | 53 | DI | RGMI receive data bit 3 |
| RGMI_CK_RX | 55 | DI | RGMI receive clock |

| | | | | |
|---------------------|-----|-------|--|-------------------|
| RGMII_TX_0 | 56 | DO | RGMII transmit data bit 0 | |
| RGMII_CTL_TX | 51 | DO | RGMII transmit control | |
| RGMII_TX_1 | 58 | DO | RGMII transmit data bit 1 | |
| RGMII_TX_2 | 59 | DO | RGMII transmit data bit 2 | |
| RGMII_CK_TX | 54 | DO | RGMII transmit clock | |
| RGMII_TX_3 | 61 | DO | RGMII transmit data bit 3 | |
| RGMII_PWR_EN | 57 | DO | Used to enable external LDO to supply 2.5V power to RGMII_PWR_IN | 1.8V power domain |
| RGMII_PWR_IN | 63 | PI | Power input for internal RGMII circuit | |
| RGMII_INT | 62 | DI | RGMII PHY interrupt output | 1.8V power domain |
| RGMII_RST | 60 | DO | Reset output for RGMII PHY | |
| RF interface | | | | |
| 5G_TRX1 | 124 | AI/AO | 5G TRX antenna1, support TX and RX | |
| 5G_TRX2 | 130 | AI/AO | 5G TRX antenna2, support TX and RX | |
| 5G_DIV1 | 139 | AI | 5G MIMO antenna interface1 | |
| 5G_DIV2 | 148 | AI | 5G MIMO antenna interface2 | |
| LTE_MAIN | 157 | AI/AO | LTE Main antenna, support TX and RX | |
| LTE_DIV1 | 166 | AI | LTE Receive antenna interface1 | |

| | | | | |
|-----------------|---|----|----------------------------------|--|
| LTE_DIV2 | 175 | AI | LTE Receive antenna interface2 | |
| LTE_DIV3 | 184 | AI | LTE Receive antenna interface3 | |
| ANT_GNSS | 193 | AI | GNSS antenna interface | |
| GPIO | | | | |
| WAKEUP_IN | 98 | DI | Sleep Mode control | |
| W_DISABLE | 114 | DI | Flight Mode control | |
| MODULE_STATUS | 99 | DO | Module status indication signal | |
| SLEEP_IND | 102 | DO | Indicating module sleep status | |
| Others | | | | |
| BT_EN | 66 | DO | BT function enable | |
| CDC_RESET | 75 | DO | Reset of codec | |
| I2S_MCLK | 79 | DO | Clock output | |
| DR_SYNC | 93 | DO | Navigation 1PPS time sync output | |
| GND | | | | |
| GND | 28, 29, 31, 33, 42, 84, 90, 96, 113, 115, 116, 118, 119, 121~123,125~129, 131~134, 136, 137, 140~147, 149, 151, 152, 154~156, 158, 160, 161, 163, 164, 167~170, 172, 173, 176, 178, 179, 181, 182, 185, 187, 188, 190, 191, 194~197, 200, 202, 203, 205, 206, 209, 211, 212, 214, 215, 224, 228, 231~234, 299~392 | | | |
| RESERVED | | | | |
| RESERVED | 1~6, 9,27, 35, 38,41, 44, 46, 80, 101, 103, 104, 106, 111, 117, 120, 135, 138, 150, 153, 159, 162, 165, 171, 174, 177, 180, 183,186, 189, 192, 198, 199, 201, 208, 217, 218, 220, 221, 223, 239, 246, 261~298 | | | |

8.2 5G S-Module Basic Type-M

8.2.1 Diagram

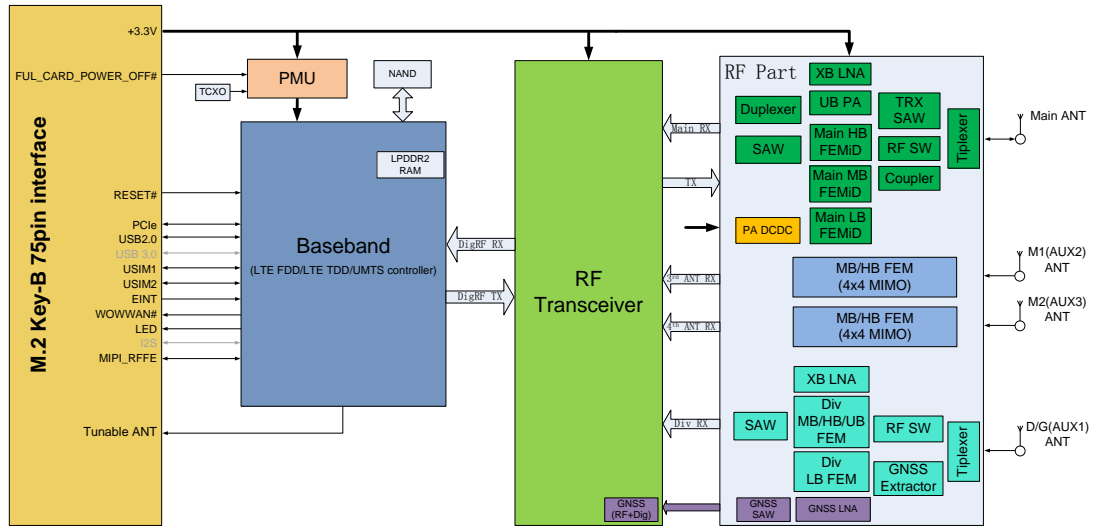


Figure 8-4 5G S-Module Basic Type-M Diagram

8.2.2 Pin Layout

| | | | |
|----|-------------------|---------------|----|
| 74 | +3.3V | CONFIG_2 | 75 |
| | | GND | 73 |
| 72 | +3.3V | GND | 71 |
| 70 | +3.3V | CONFIG_1 | 69 |
| 68 | ANT_CONFIG(1.8V) | 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+/Reserved | 37 |
| 36 | UIM1_PWR | | |
| | | USB3.0-Rx-/Reserved | 35 |
| 34 | UIM1_DATA | | |
| | | GND | 33 |
| 32 | UIM1_CLK | | |
| | | USB3.0-Tx+/Reserved | 31 |
| 30 | UIM1_RESET | | |
| | | USB3.0-Tx-/Reserved | 29 |
| 28 | I2S_WA(1.8V)/Reserved | | |
| | | GND | 27 |
| 26 | W_DISABLE2#(3.3/1.8V) | | |
| | | DPR(3.3/1.8V) | 25 |
| 24 | I2S_TX(1.8V)/Reserved | | |
| | | WOWWAN#(1.8V) | 23 |
| 22 | I2S_RX/Reserved | | |
| | | CONFIG_0 | 21 |
| 20 | I2S_CLK/Reserved | | |
| | | Notch | |
| | Notch | | |
| | | Notch | |
| | Notch | | |
| | | Notch | |

| | | | |
|----|-------------------------------|-----------------|----|
| | Notch | | |
| | Notch | | |
| 10 | LED1#(3.3V OD) | GND | 11 |
| 8 | W_DISABLE1#(3.3/1.8V) | USB D-/Reserved | 9 |
| 6 | FUL_CARD_POWER_OFF#(3.3/1.8V) | USB D+/Reserved | 7 |
| 4 | +3.3V | GND | 5 |
| 2 | +3.3V | GND | 3 |
| | | CONFIG_3 | 1 |

Figure 8-5 5G S-Module Type-M Pin Layout

8.2.3 Pin Size

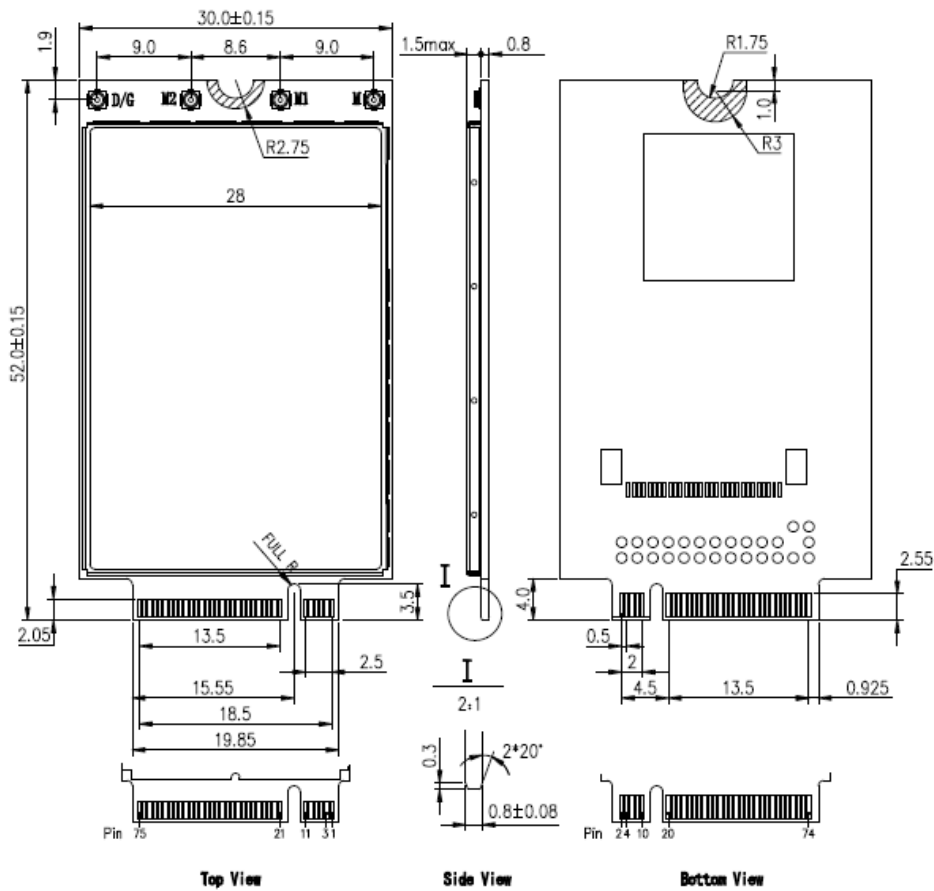


Figure 8-6 5G S-Module Type-M Pin Size

8.2.4 Pin Definition

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

| Pin | Pin Name | I/O | Reset Value | Pin Description | Type |
|-----|----------------------|-----|-------------|---|---------------|
| 1 | CONFIG_3 | O | NC | NC, 5G 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 |
| 7 | USB D+ | I/O | | USB Data Plus, Reserved | 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, Reserved | 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, 5G 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 |

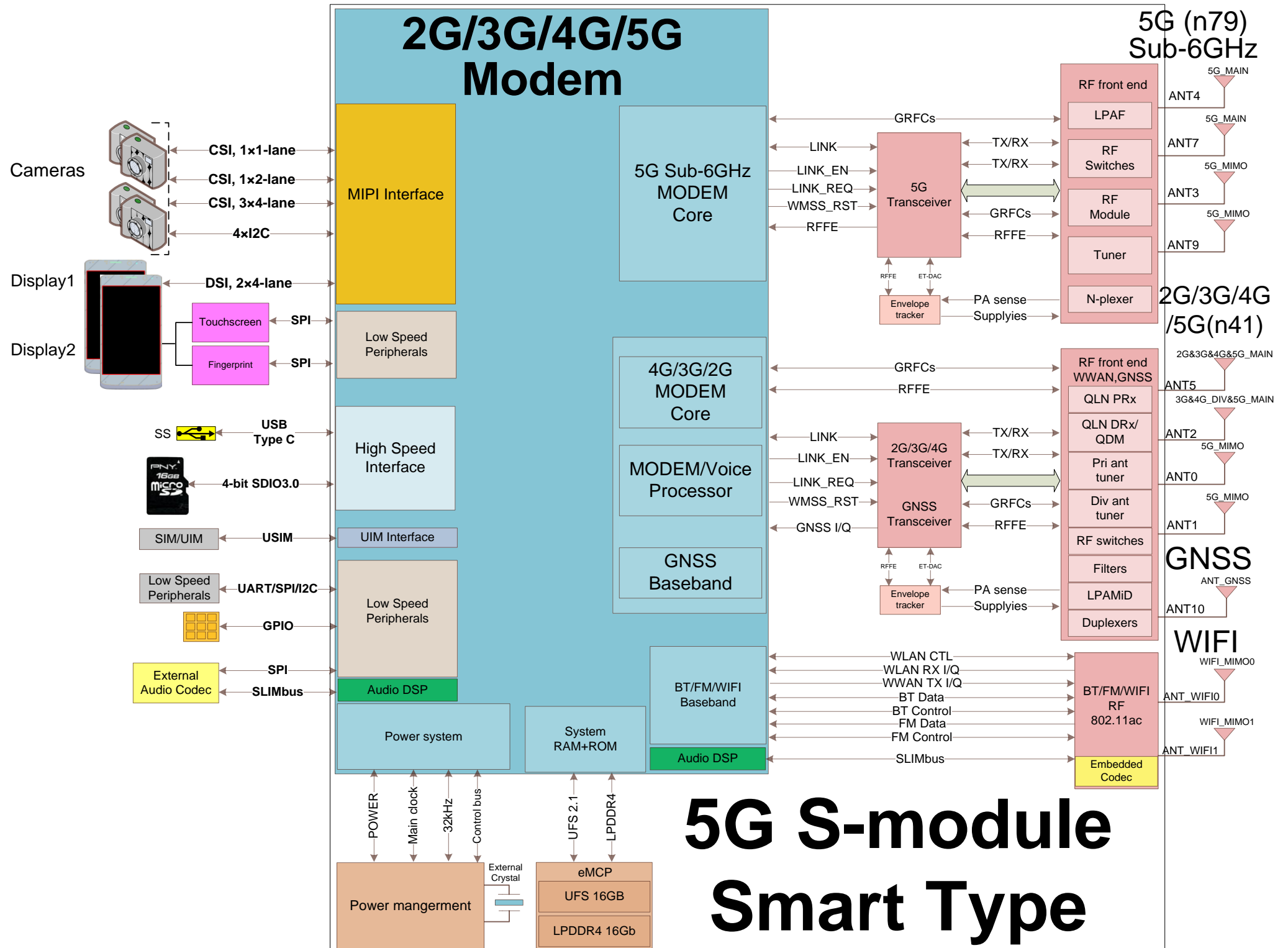
| Pin | Pin Name | I/O | Reset Value | Pin Description | Type |
|-----|-------------|-----|-------------|--|---------------|
| 24 | I2S_TX | O | PD | I2S Serial transmit data, Reserved | CMOS 1.8V |
| 25 | DPR | I | PD | Body SAR Detect, active low | CMOS 3.3/1.8V |
| 26 | W_DISABLE2# | I | PD | GNSS 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 |
| 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(390K Ω), 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 | CMOS 3.3V |

| Pin | Pin Name | I/O | Reset Value | Pin Description | Type |
|-----|------------|-----|-------------|---|--------------|
| | | | | will reset whole module, not only PCIe interface. Active low, internal pull up(10KΩ) | |
| 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 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 Wi-Fi/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 Wi-Fi/BT modules, based on BT-SIG coexistence protocol. UART receive | CMOS 1.8V |

| Pin | Pin Name | I/O | Reset Value | Pin Description | Type |
|-----|-------------|-----|-------------|--|--------------|
| | | | | signal(WWAN module side), Reserved | |
| 63 | ANTCTL2 | O | PD | Tunable ANT CTRL2 | CMOS 1.8V |
| 64 | COEX_TXD | O | T | Wireless Coexistence between WWAN and Wi-Fi/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(390K Ω), active high | CMOS 1.8V |
| 67 | RESET# | I | PU | WWAN reset input, internal pull up(10K Ω), active low | CMOS 1.8V |
| 68 | ANT_CONFIG | I | PD | Host antenna configuration detect, internal pull up(100K Ω), Reserved | CMOS 1.8V |
| 69 | CONFIG_1 | O | GND | GND, 5G 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, 5GM.2 module is configured as the WWAN – PCIe, USB3.0 interface type | |

8.3 5G S-Module Smart Type

8.3.1 Diagram



5G S-module Smart Type

Figure 8-7 5G S-Module Smart Type Diagram

8.3.2 Pin Layout

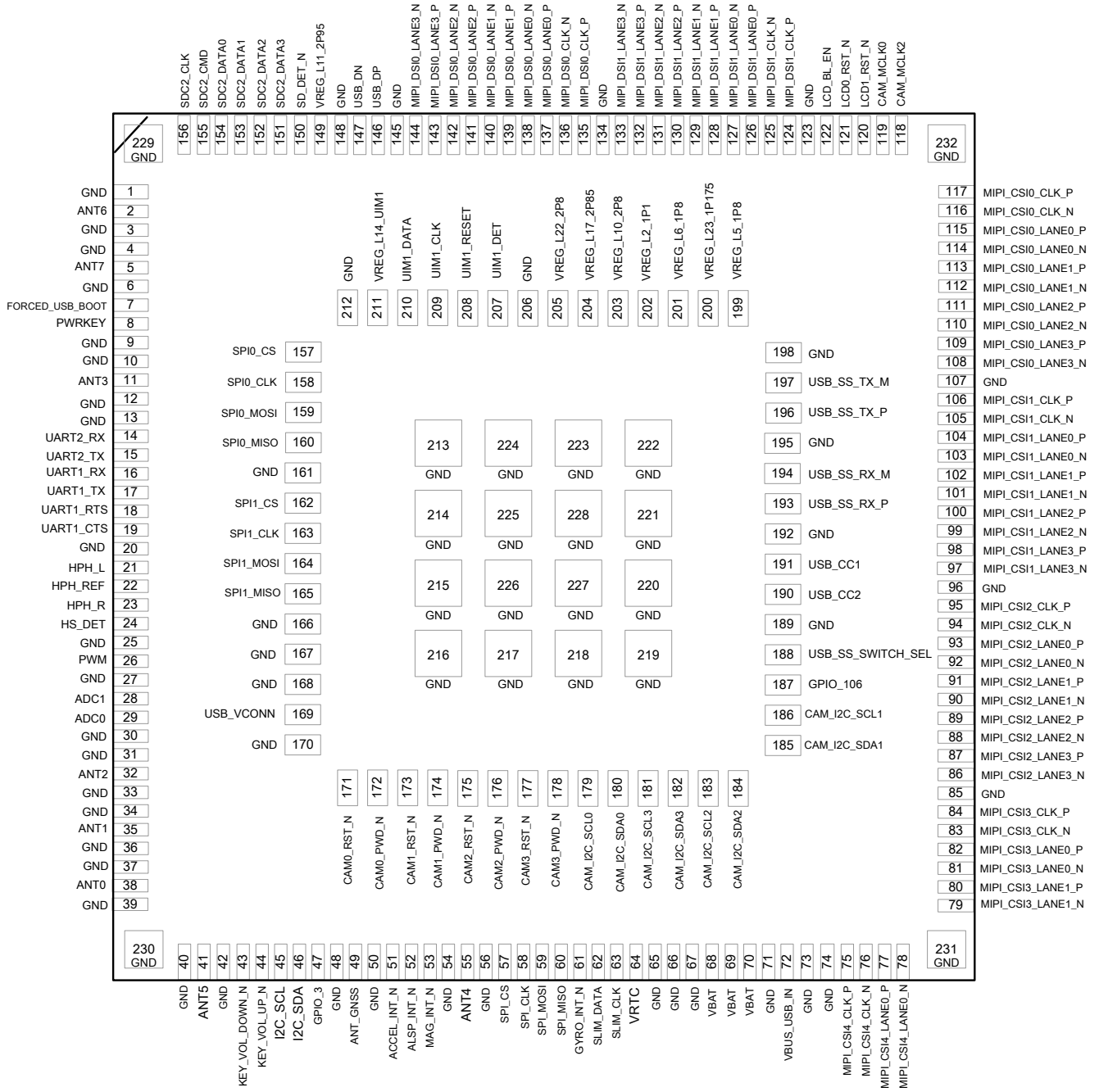


Figure 8-8 5G S-Module Smart Type Pin Layout

8.3.3 Pin Size

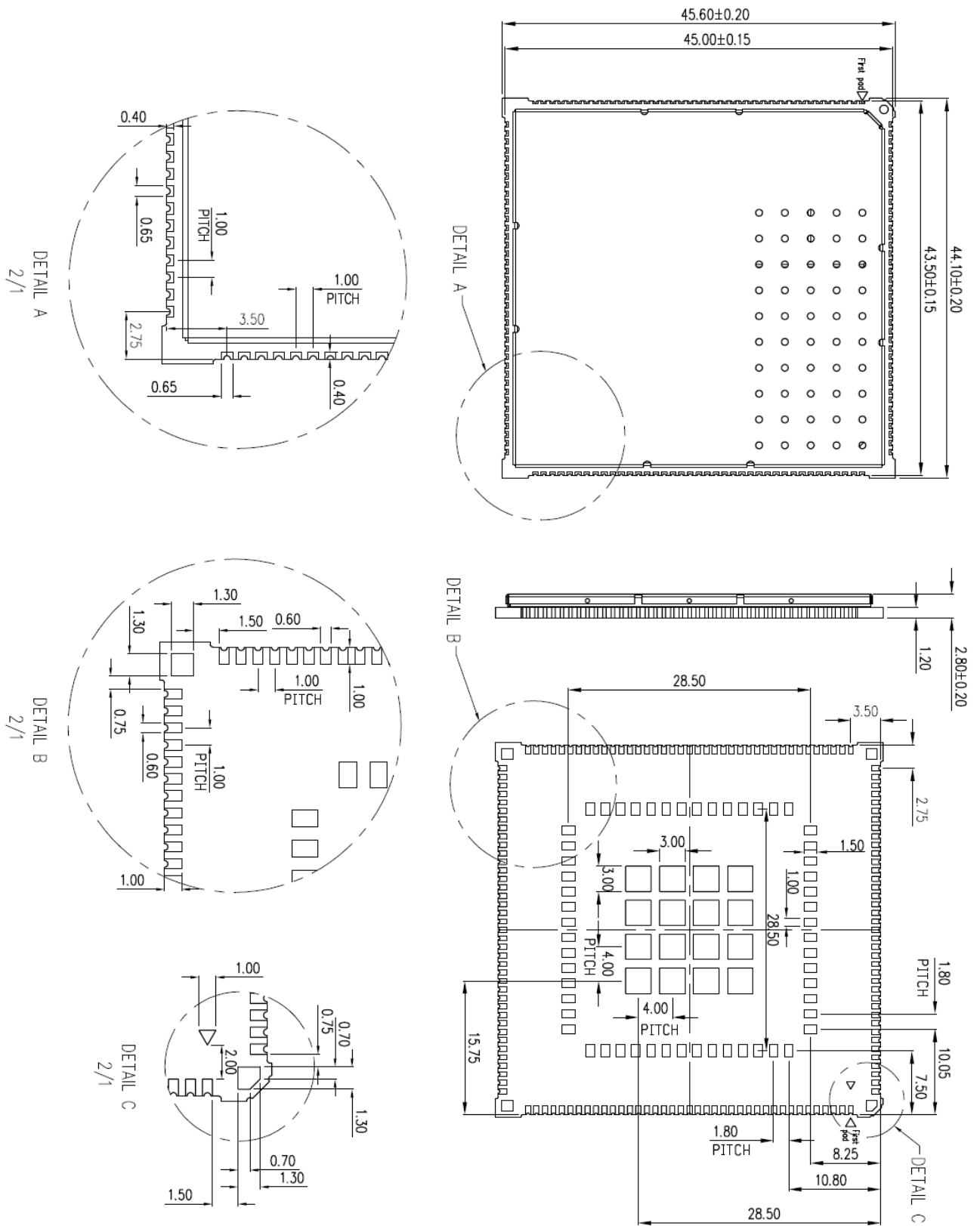


Figure 8-9 5G S-Module Smart Type Pin Size

8.3.4 Pin Definition

Table 8-3 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 | |
| SPIO_MOSI | 159 | DOL | Master output slaver input 0 | |
| SPIO_MISO | 160 | DI,PD | Master input slaver output 0 | |
| SPIO_CS | 157 | DOH | SPI chip select 0 | |
| SPIO_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_CSIO_LANE3_N | 108 | I | Camera0 MIPI interface | |
| MIPI_CSIO_LANE3_P | 109 | I | | |
| MIPI_CSIO_LANE2_N | 110 | I | | |
| MIPI_CSIO_LANE2_P | 111 | I | | |
| MIPI_CSIO_LANE1_N | 112 | I | | |

| | | | | |
|-------------------|-----|---|--------------------------------|--|
| MIPI_CSIO_LANE1_P | 113 | I | | |
| MIPI_CSIO_LANE0_N | 114 | I | | |
| MIPI_CSIO_LANE0_P | 115 | I | | |
| MIPI_CSIO_CLK_N | 116 | I | | |
| MIPI_CSIO_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_WI-FI0 | 2 | AI/O | WI-FI MIMO antenna 0 |
| ANT_WI-FI1 | 5 | AI/O | WI-FI MIMO antenna 1 |

| ANT_WI-FI02AI/OWI-FI MIMO antenna 0ANT_WI-FI15AI/OWI-FI MIMO antenna 1UART 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 | |

8.4 5G S-Module All-in-one Type-M

8.4.1 Diagram

The 5G S-Module All-in-one block diagram is shown as following:

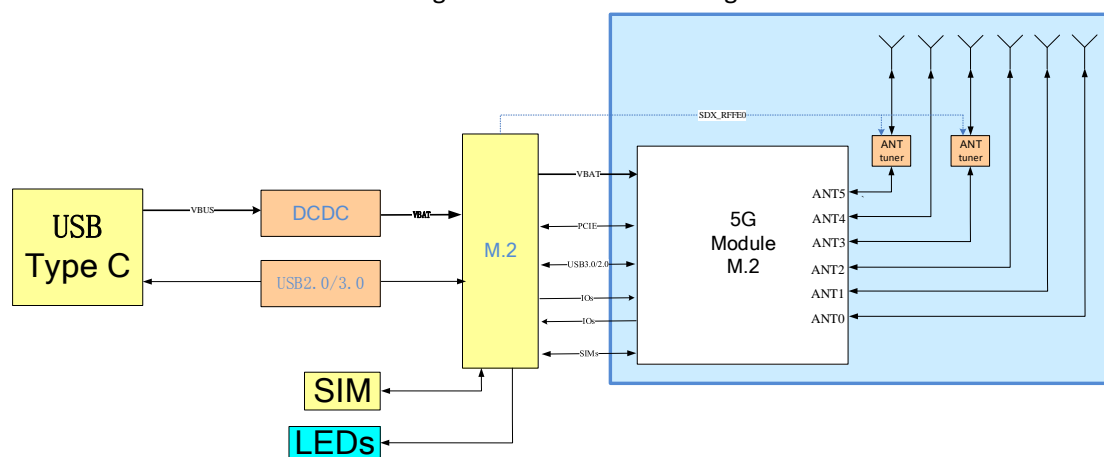


Figure 8-10 5G S-Module All-in-one Type-M Diagram

The All-in-one module Type-M provides terminal the access to cellular network though USB 3.1, which can simplify the design significantly.

The function includes:

- ✓ USB 3.1 data and power supply
- ✓ 5G connectivity

- ✓ SIM socket
- ✓ GNSS Integrated
- ✓ Status indicator
- ✓ External Antenna sockets

8.4.2 PCB Layout

The 5G S-Module All-in-one pcb layout top view.

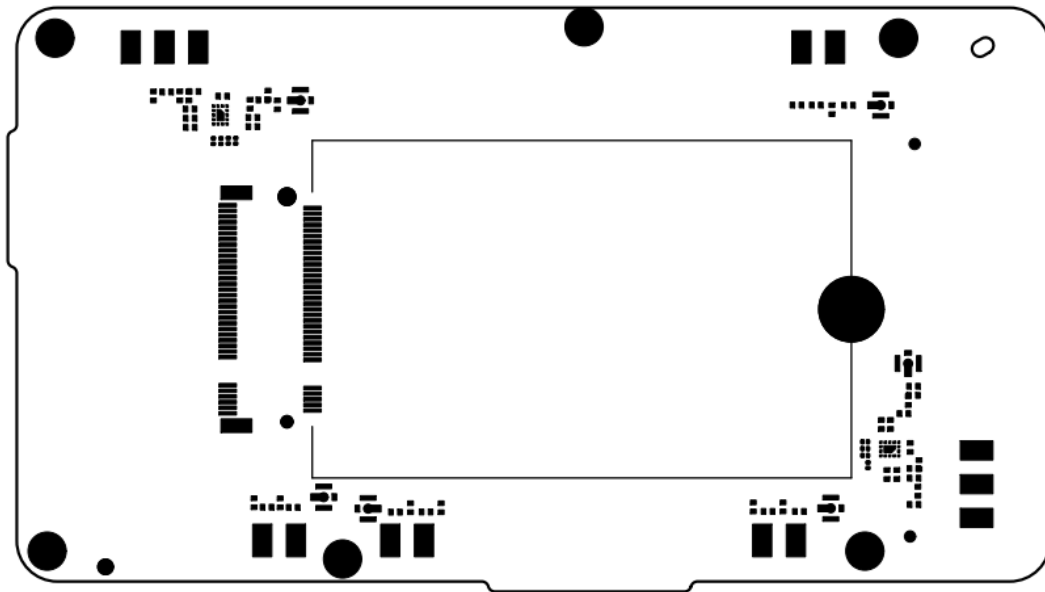


Figure 8-11 5G S-Module All-in-one Type-M Pin Layout top view

The 5G S-Module All-in-one pcb layout BOT view.

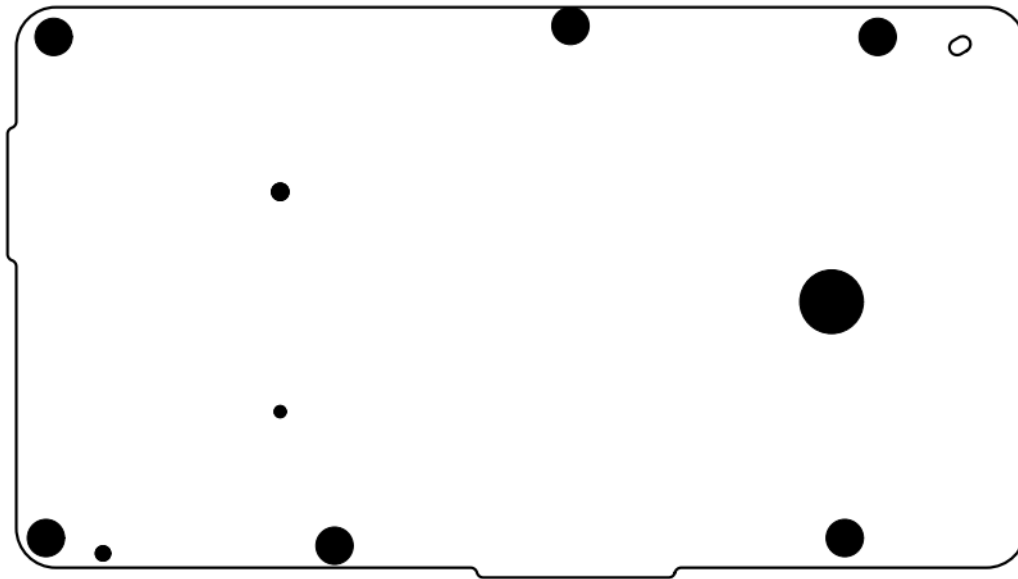


Figure 8-12 5G S-Module All-in-one Type-M Pin Layout BOT view

8.4.3 PCB Size

The 5G S-Module All-in-one pcb size view.

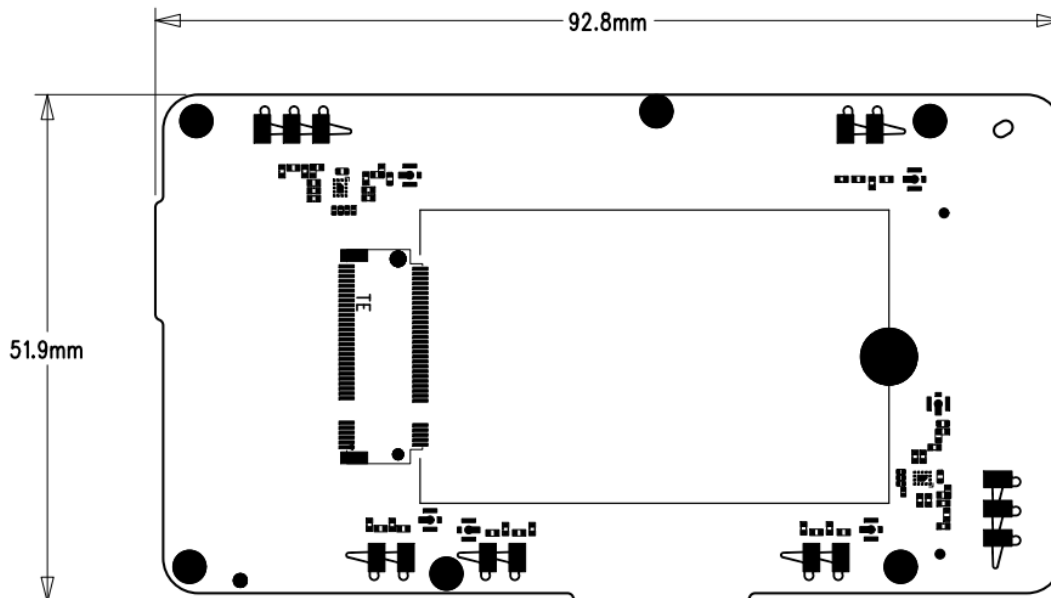


Figure 8-13 5G S-Module All-in-one Type-M PCB Size

8.4.4 Pin Definition

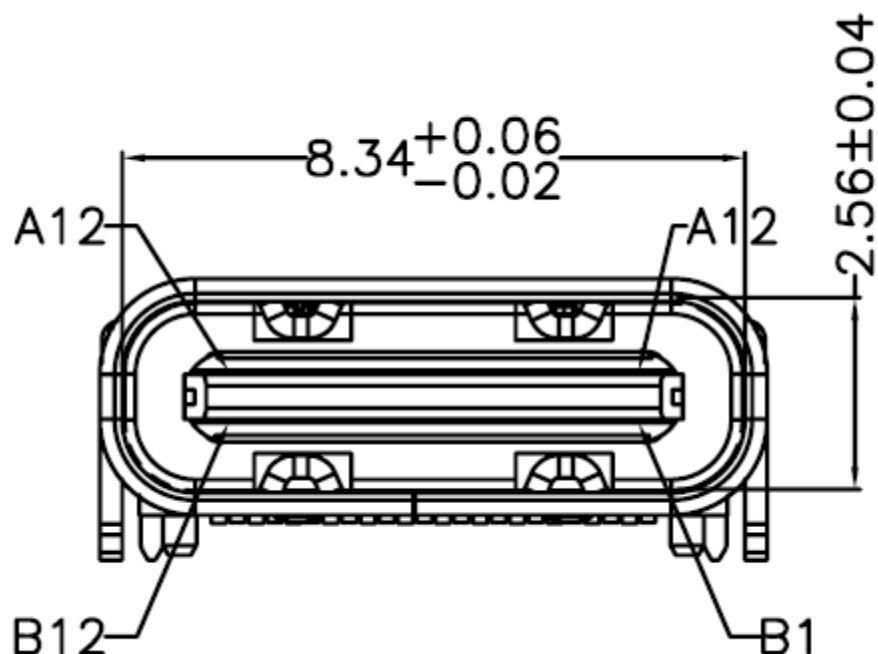


Figure 8-14 5G S-Module All-in-one Type-M USB Type-C Size

USB Type-C Receptacle Interface (Front View).

| A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 | A10 | A11 | A12 |
|-----|------|------|------|------|----|----|------|------|------|------|-----|
| GND | TX1+ | TX1- | VBUS | CC1 | D+ | D- | SBU1 | VBUS | RX2- | RX2+ | GND |
| GND | RX1+ | RX1- | VBUS | SBU2 | D- | D+ | CC2 | VBUS | TX2- | TX2+ | GND |
| B12 | B11 | B10 | B9 | B8 | B7 | B6 | B5 | B4 | B3 | B2 | B1 |

USB Full-Featured Type-C Plug Interface (Front View)

| A12 | A11 | A10 | A9 | A8 | A7 | A6 | A5 | A4 | A3 | A2 | A1 |
|-----|------|------|------|-------|----|----|------|------|------|------|-----|
| GND | RX2+ | RX2- | VBUS | SBU1 | D- | D+ | CC | VBUS | TX1- | TX1+ | GND |
| GND | TX2+ | TX2- | VBUS | VCONN | | | SBU2 | VBUS | RX1- | RX1+ | GND |
| B1 | B2 | B3 | B4 | B5 | B6 | B7 | B8 | B9 | B10 | B11 | B12 |

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

8.5.1 Diagram

5G S-Module All-in-one Type-L Block Diagram is shown as bellowing:

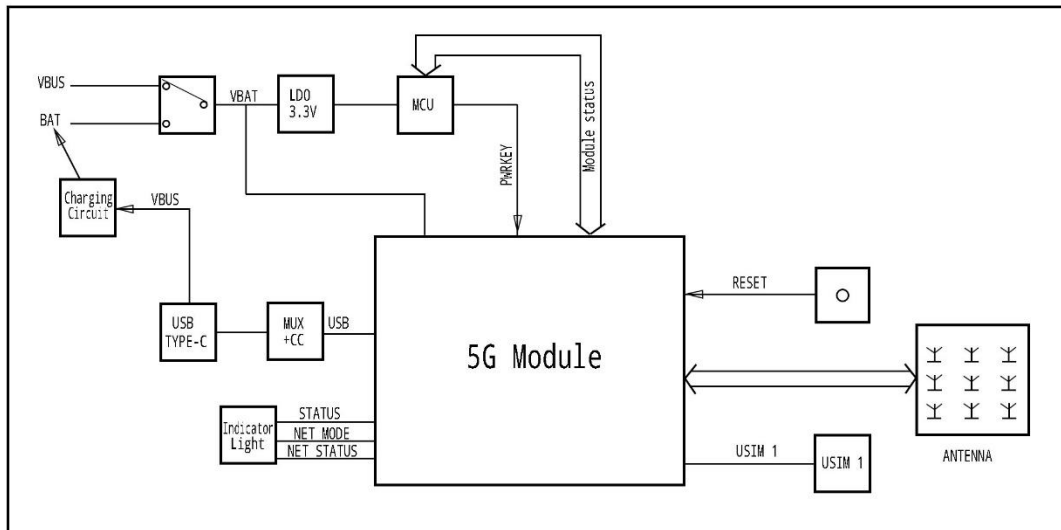


Figure 8-15 5G S-Module All-in-one Type-L Diagram

The All-in-one module Type-L provides terminal the access to cellular network though USB 3.1, which can simplify the design significantly.

The function includes:

- ✓ USB 3.1 data and power supply
- ✓ 5G connectivity
- ✓ SIM socket
- ✓ GNSS Integrated
- ✓ Status indicator
- ✓ External Antenna sockets

8.5.2 PCB Layout

5G S-Module All-in-one Type-L PCB Layout Top View.

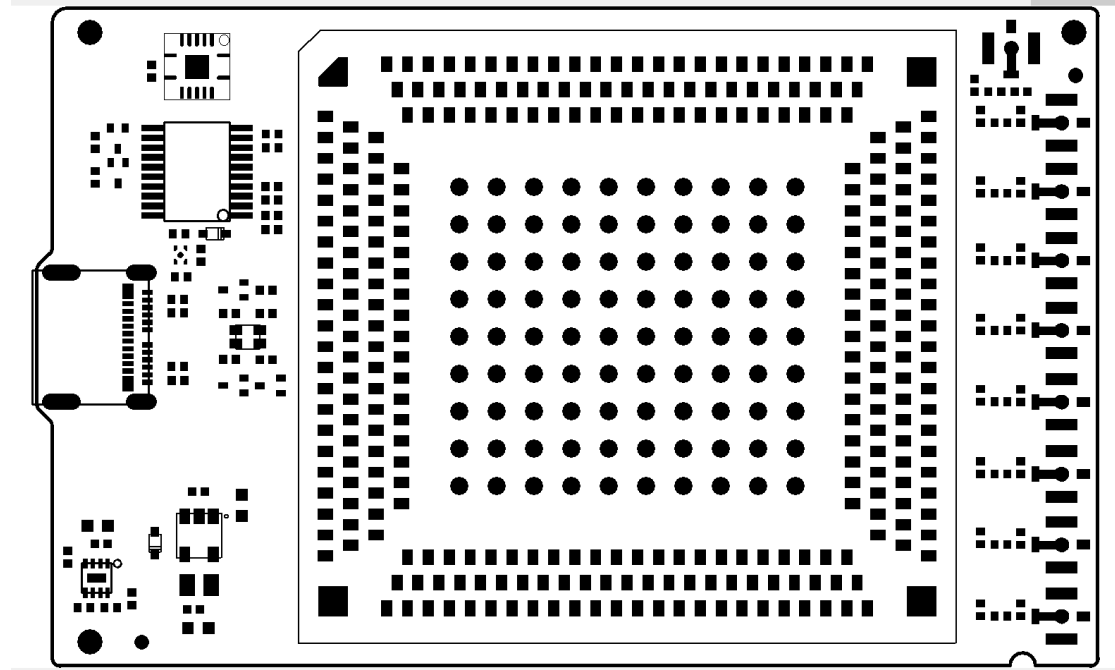


Figure 8-16 5G S-Module All-in-one Type-L Pin Layout top view

5G S-Module All-in-one Type-L PCB Layout Bottom View.

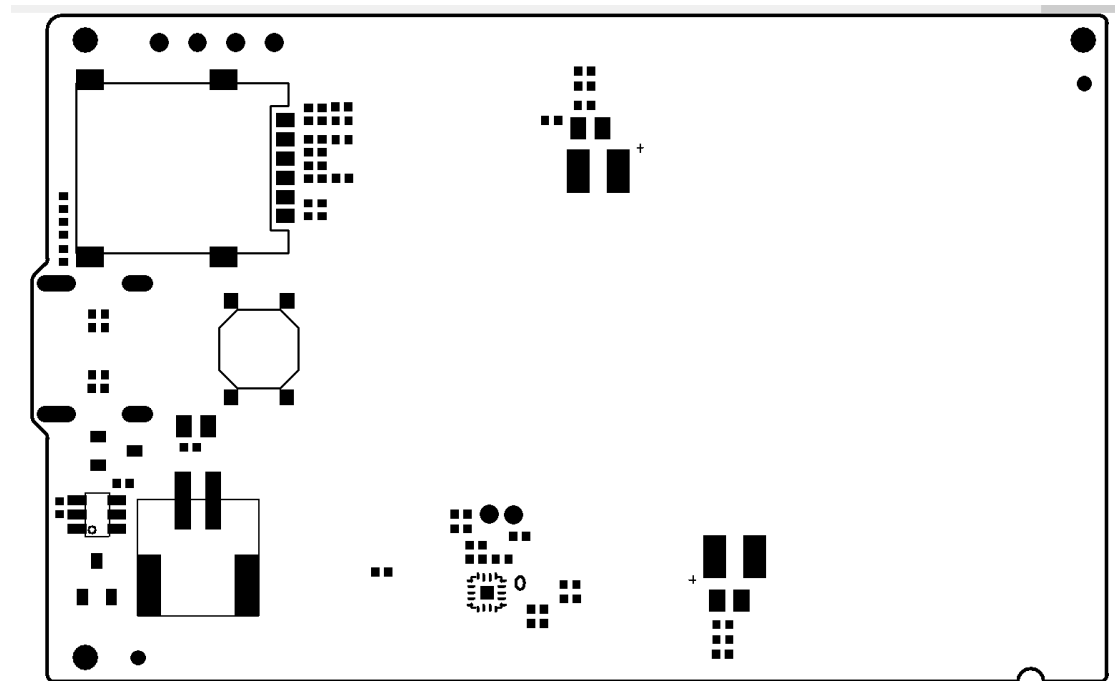


Figure 8-17 5G S-Module All-in-one Type-L Pin Layout BOT view

8.5.3 PCB Size

5G S-Module All-in-one Type-L PCB Size View.

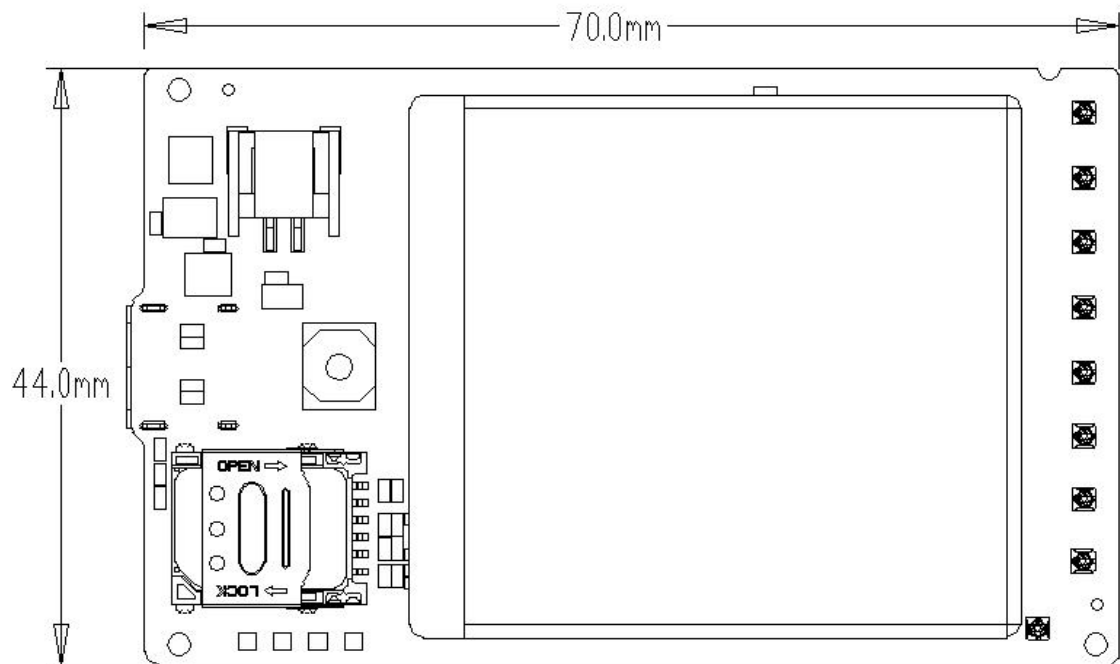


Figure 8-18 5G S-Module All-in-one Type-L PCB Size

8.5.4 Pin Definition

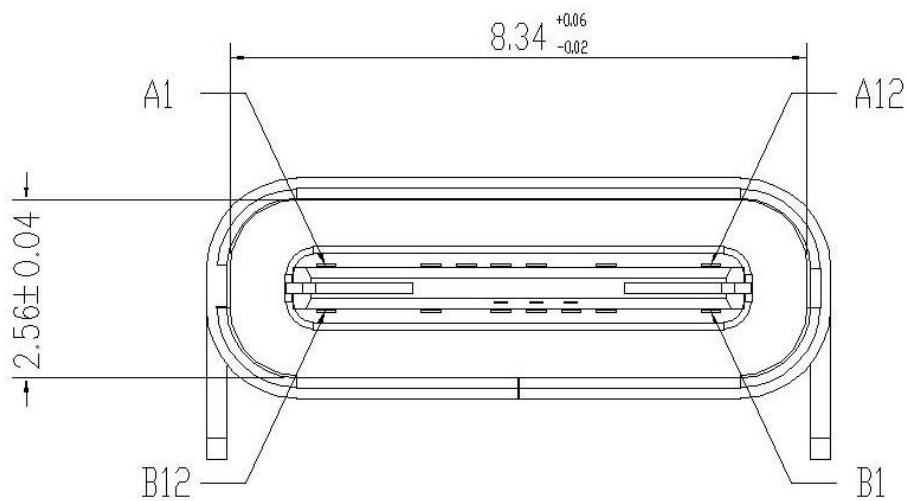


Figure 8-19 5G S-Module All-in-one Type-L USB Type-C Size

USB Type-C Receptacle Interface (Front View)

| | | | | | | | | | | | |
|-----|------|------|------|------|----|----|------|------|------|------|-----|
| A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 | A10 | A11 | A12 |
| GND | TX1+ | TX1- | VBUS | CC1 | D+ | D- | SBU1 | VBUS | RX2- | RX2+ | GND |
| | | | | | | | | | | | |
| GND | RX1+ | RX1- | VBUS | SBU2 | D- | D+ | CC2 | VBUS | TX2- | TX2+ | GND |
| B12 | B11 | B10 | B9 | B8 | B7 | B6 | B5 | B4 | B3 | B2 | B1 |

USB Full-Featured Type-C Plug Interface (Front View)

| | | | | | | | | | | | |
|-----|------|------|------|-------|----|----|------|------|------|------|-----|
| A12 | A11 | A10 | A9 | A8 | A7 | A6 | A5 | A4 | A3 | A2 | A1 |
| GND | RX2+ | RX2- | VBUS | SBU1 | D- | D+ | CC | VBUS | TX1- | TX1+ | GND |
| | | | | | | | | | | | |
| GND | TX2+ | TX2- | VBUS | VCONN | | | SBU2 | VBUS | RX1- | RX1+ | GND |
| B1 | B2 | B3 | B4 | B5 | B6 | B7 | B8 | B9 | B10 | B11 | B12 |

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 power to RF and baseband circuits.

For VBAT pads the peak 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 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.

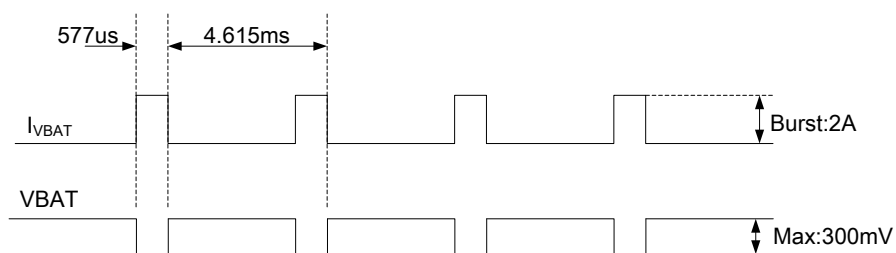


Figure 9-1 VBAT Voltage Drop during Burst Emission (GSM/GPRS)

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 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 use 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.

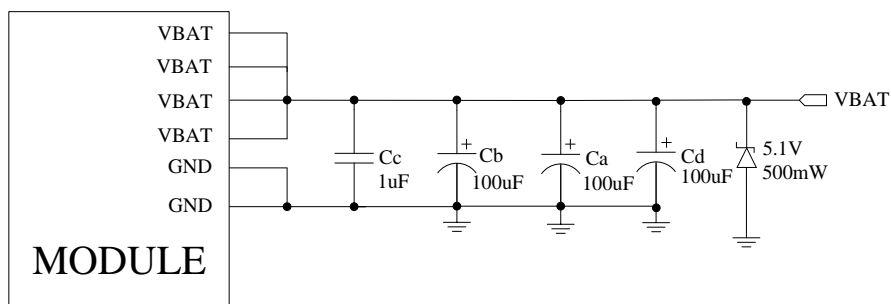


Figure 9-2 Power Supply Application Circuit

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

In addition, in order to implement 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.

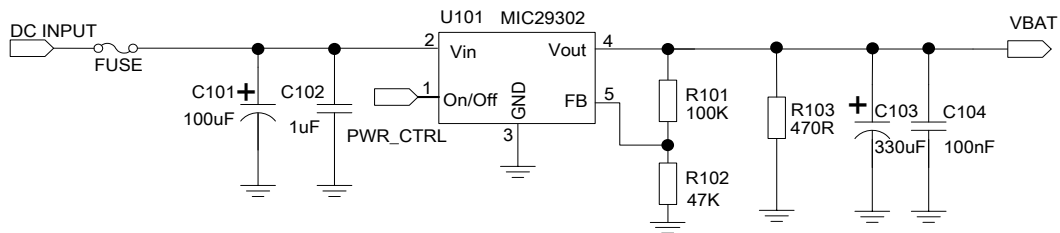


Figure 9-3 Linear Regulator Reference Circuit

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.

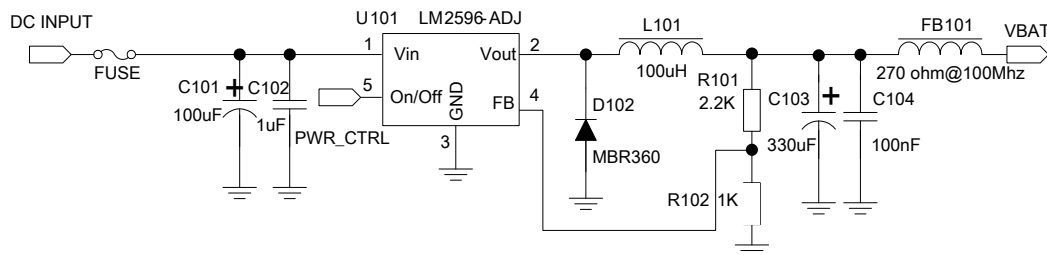


Figure 9-4 Switching Mode Power Supply Reference Circuit

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 a 100nF 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.

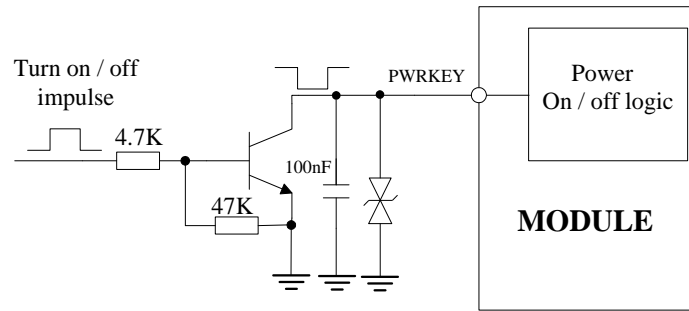


Figure 9-5 Reference Power On/Off Circuit

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

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

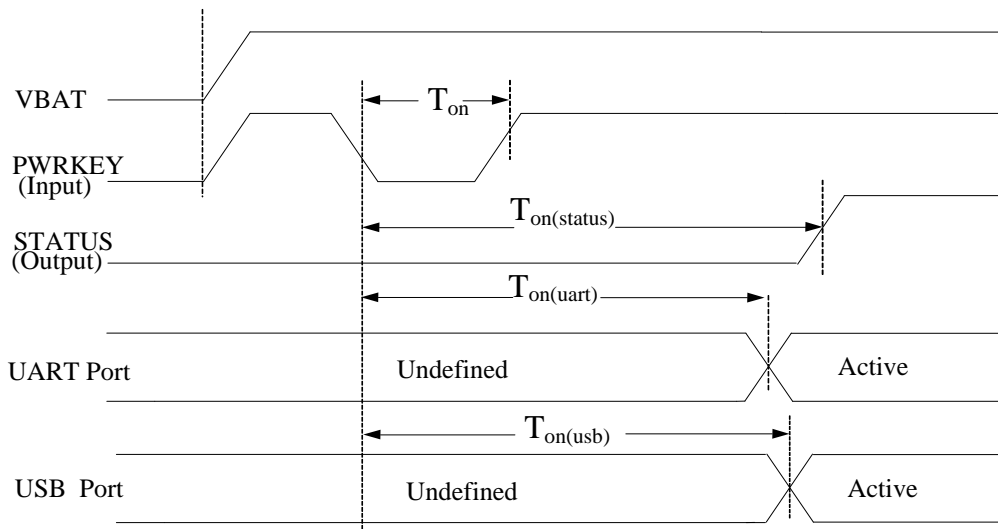


Figure 9-6 Power On Timing Sequence

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.

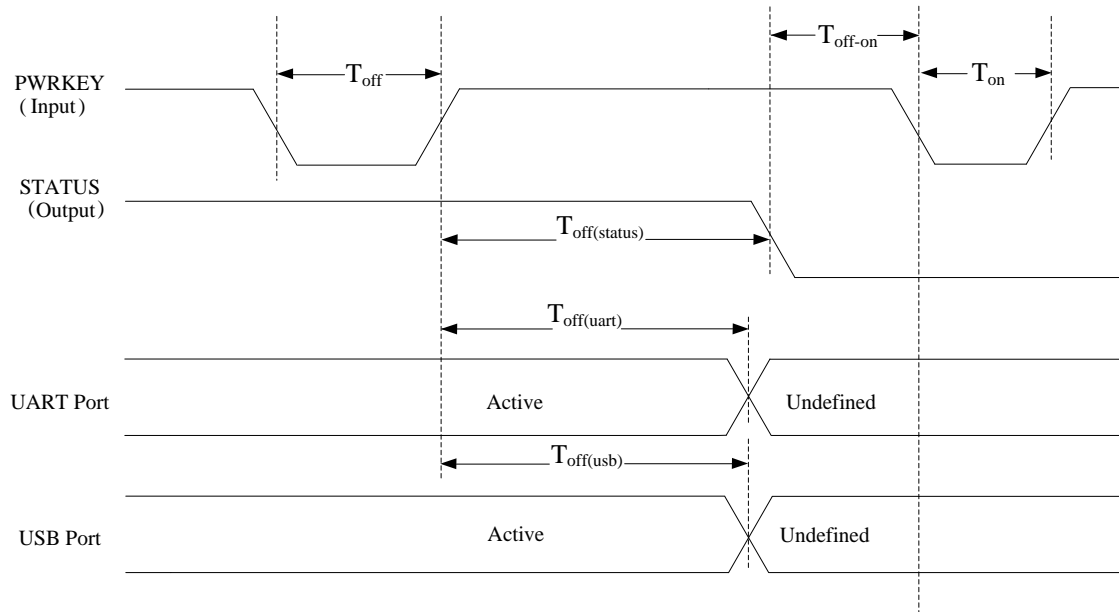


Figure 9-7 Power off timing sequence

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 a 100pF capacitor and an ESD protection diode close to the RESET_N pin. Please refer to the following figure for the recommended reference circuit.

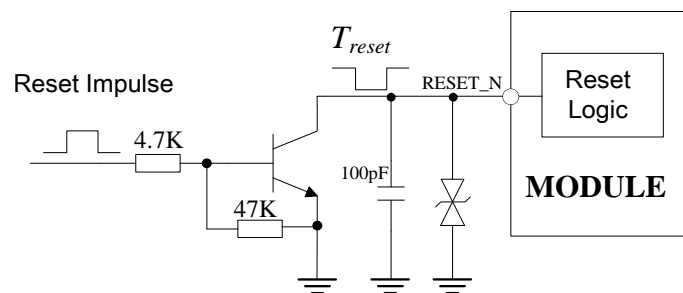


Figure 9-8 Reference Reset Circuit

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 WI-FI 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 WI-FI 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.

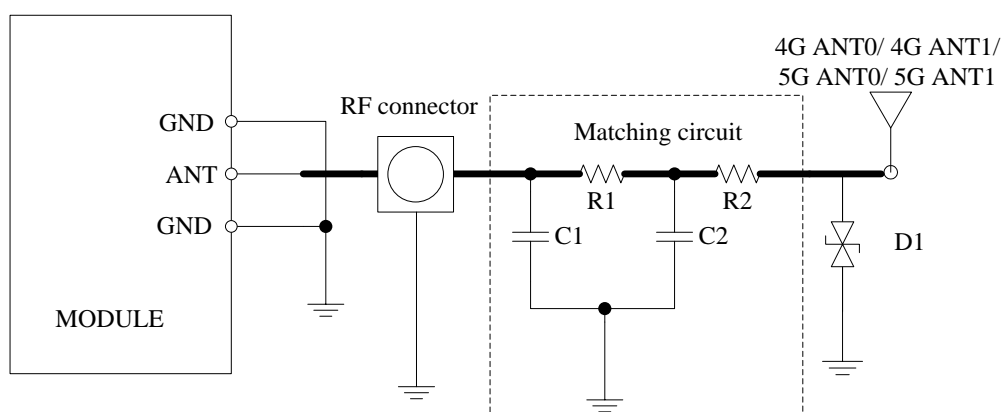


Figure 9-9 Antenna Matching Circuit (ANT_MAIN)

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 place 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 Figure 9-10 is the reference circuit.

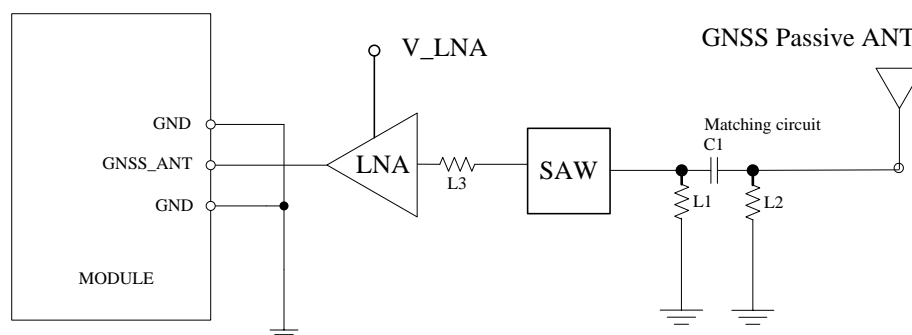


Figure 9-10 Passive Antenna Circuit (Default)

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

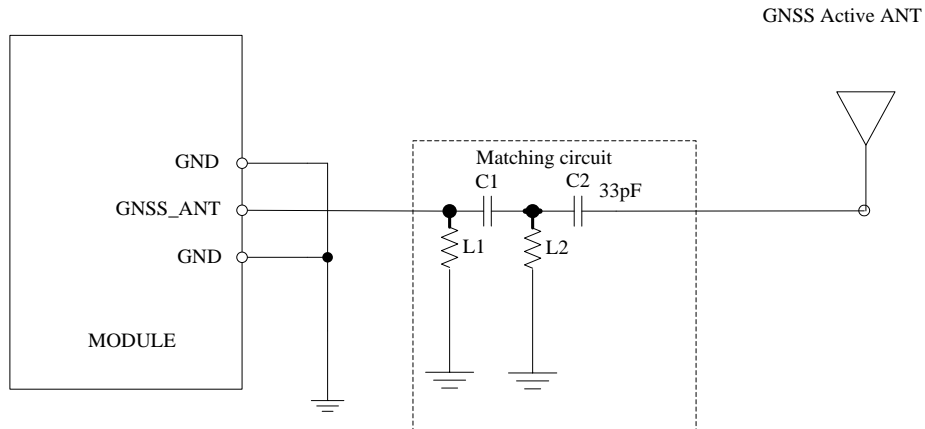


Figure 9-11 Active antenna circuit

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 power supplies which can be supplied by MODULE. LDO/DCDC is recommended to get lower current consuming by shutting down active antennas and LNA when GNSS is not working.

9.3.3 Wi-Fi/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.

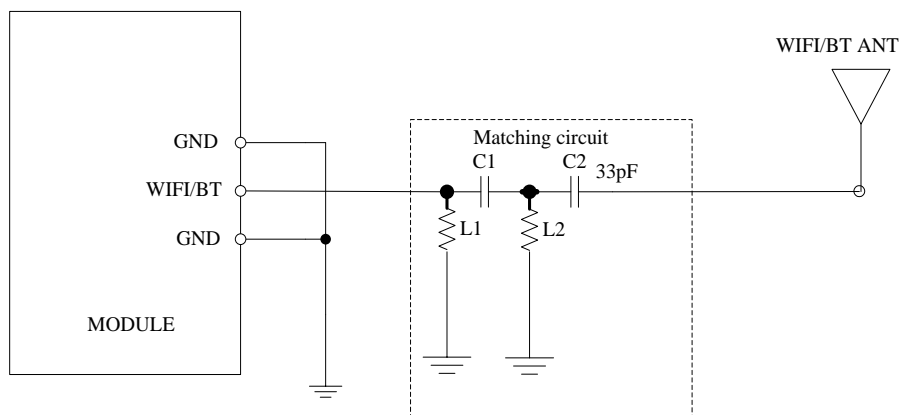


Figure 9-12 Active Antenna Circuit

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 ESDA6V1-5W6 produced 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.

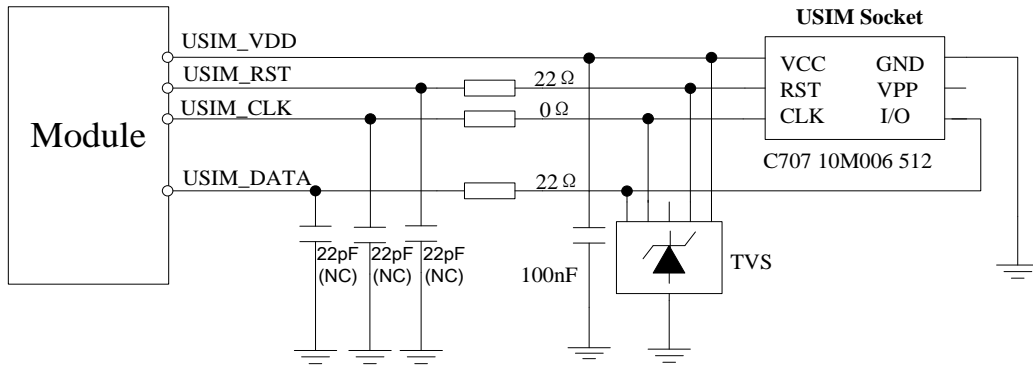


Figure 9-13 USIM Interface Reference Circuit

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.

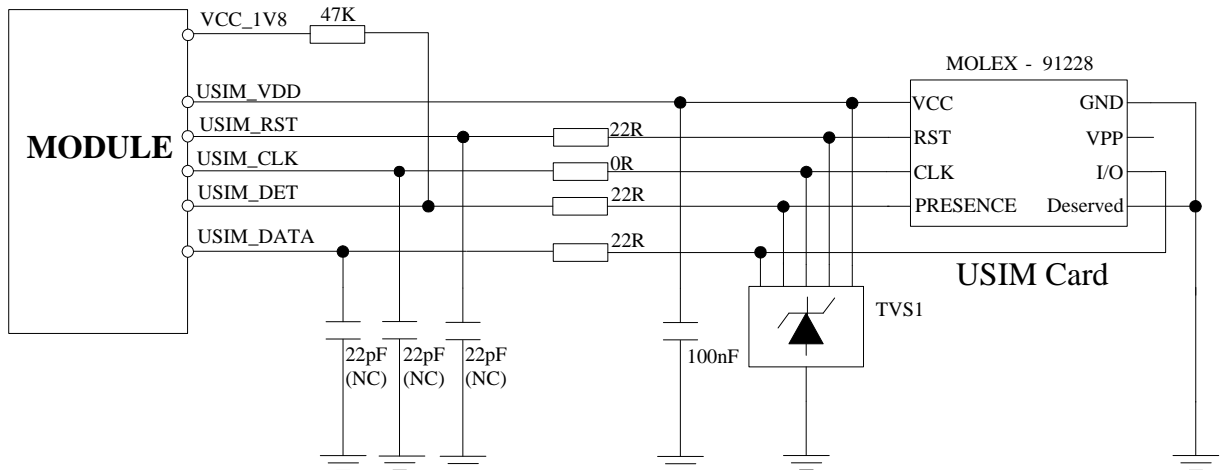


Figure 9-14 USIM Interface Reference Circuit with USIM_DET

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 in PCB layout.
- SIM traces should keep away from RF transmission lines, VBAT and high-speed signal transmission lines.
- The traces should be as short as possible.
- Keep SIM holder's GND connect to main ground directly.
- Shield 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 diodes, 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.

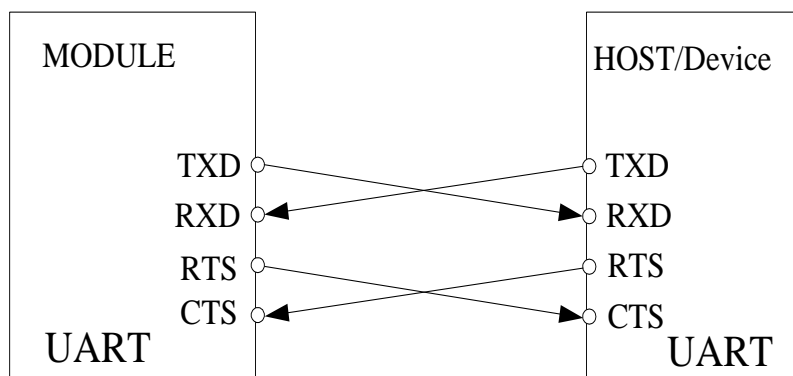


Figure 9-15 UART Reference Schematic

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.

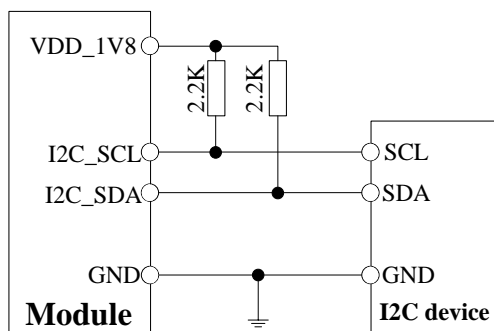


Figure 9-16 I2C Reference Circuit

Note: SDA and SCL have no pull-up resistors in MODULE. Therefore, 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 [1].

9.7.1.1 I2S timing

MODULE supports 48 KHz I2S sampling rate and 32 bit coding signal (16 bit word length), the timing diagram is showed as following:

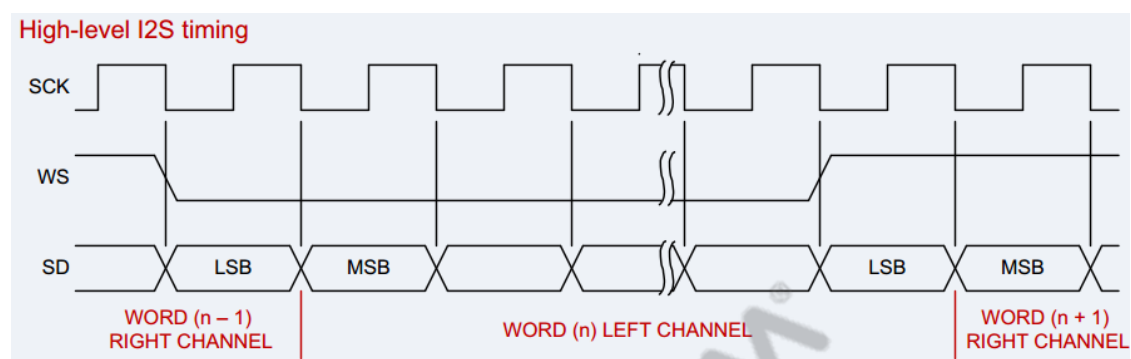


Figure 9-17 I2S Timing

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 9-18 shows the external codec reference circuit.

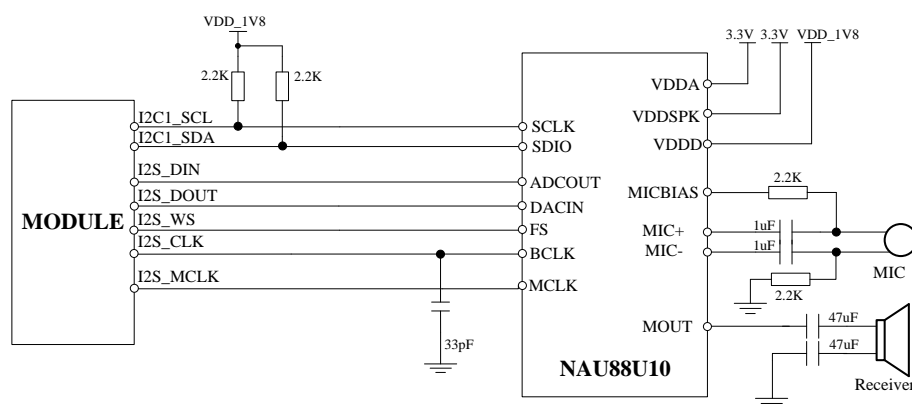


Figure 9-18 Audio codec reference circuit

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 Figure 9-19 to Figure 9-22. Amplifier circuit for audio could be used, for example, National Semiconductor Company's LM4890.

9.7.2 Speaker Interface Configuration

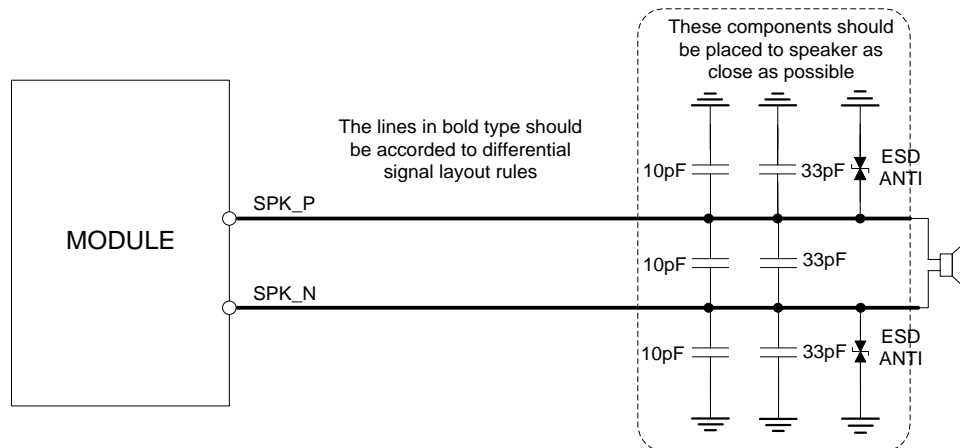


Figure 9-19 Speaker Reference Circuit

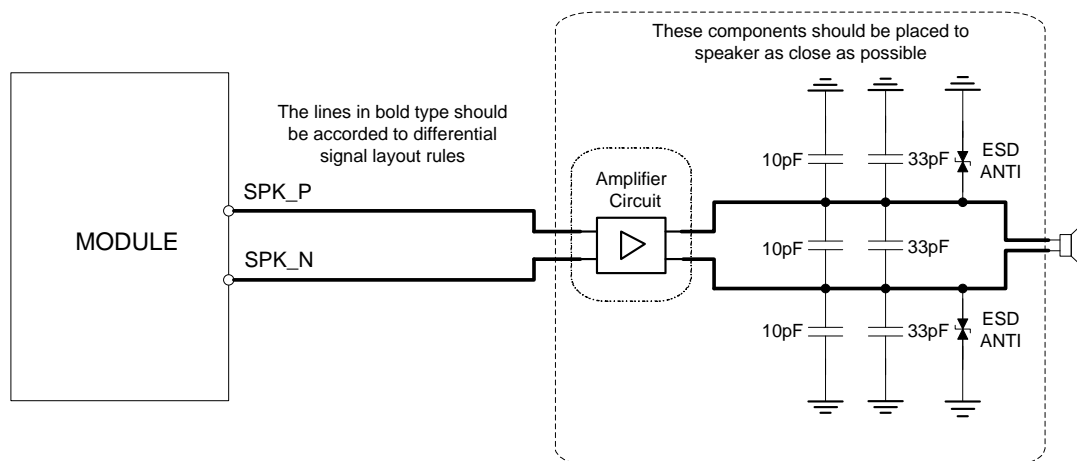


Figure 9-20: Speaker with Amplifier Reference Circuit

9.7.3 Microphone Interfaces Configuration

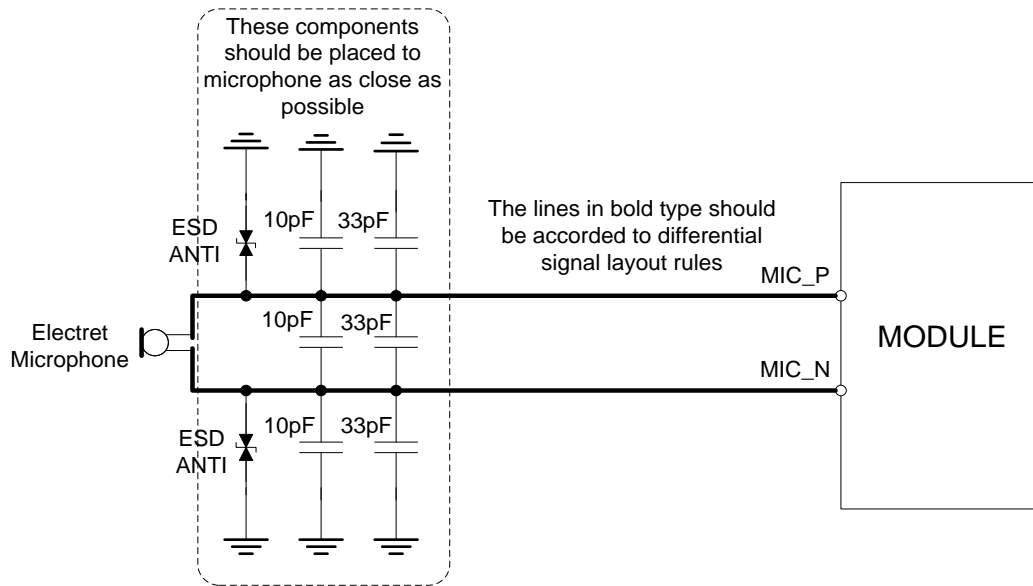


Figure 9-21 Microphone Reference Circuit

9.7.4 Earphone Interface Configuration

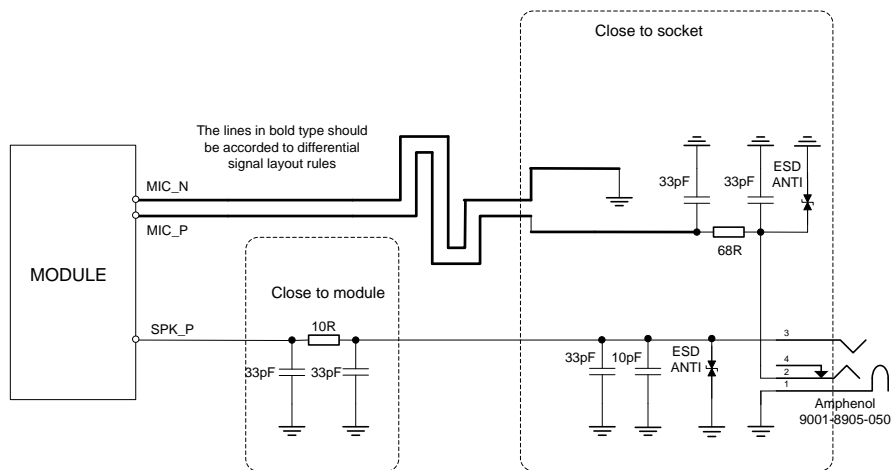


Figure 9-22 Earphone Reference Circuit

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 goes to the market. First we need do lab test and field test, then we will do industry test and regulatory test, and 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 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 | <i>um-WithLongSN</i> |
| 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:-

› Overview: Time line - RAN5 5G NR targets

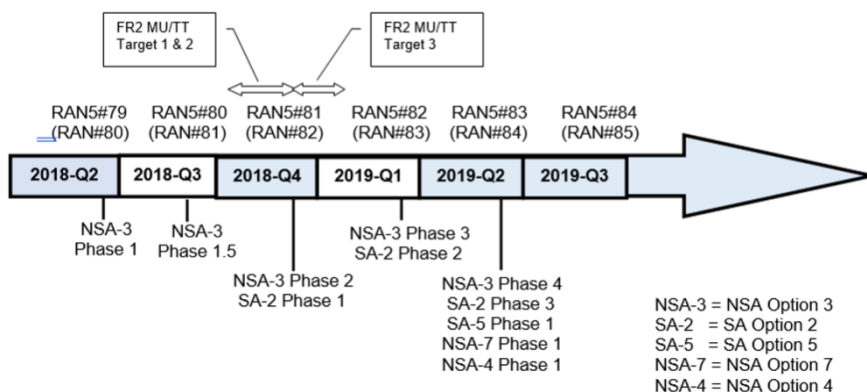


Figure 10-1 The plan to develop the NSA and SA test cases

An additional delivery point has been added to Feb-2019 for SA phase 2 and NSA phase 3. This is 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- <i>nx</i> WI-500_EUTRA-5GC- <i>x</i> WI-500_EN-DC_ <i>x_ny</i> WI-500_NGEN-DC_ <i>x_ny</i> | 3GPP TS 38.521-1 3GPP TS 38.521-2 3GPP TS 38.521-3 |
| WI-501: 5G RRM | WI-501_NR- <i>nx</i> WI-501_EUTRA-5GC- <i>x</i> WI-501_EN-DC_ <i>x_ny</i> WI-501_NGEN-DC_ <i>x_ny</i> | 3GPP TS 38.533 |
| WI-502: 5G De-Mod/CSI | WI-502_NR- <i>nx</i> WI-502_EUTRA-5GC- <i>x</i> WI-502_EN-DC_ <i>x_ny</i> WI-502_NGEN-DC_ <i>x_ny</i> | 3GPP TS 38.521-4 |
| WI-503: 5G AS Protocol | WI-503_NR- <i>nx</i> | 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 | <i>N/A – band independent</i> | 3GPP TS 34.229-1 |
| WI-506: 5G Positioning | <i>N/A – band independent</i> | 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- <i>{band}</i> | WI-503- <i>{band}</i> | WI-504- <i>{band}</i> |
| 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.

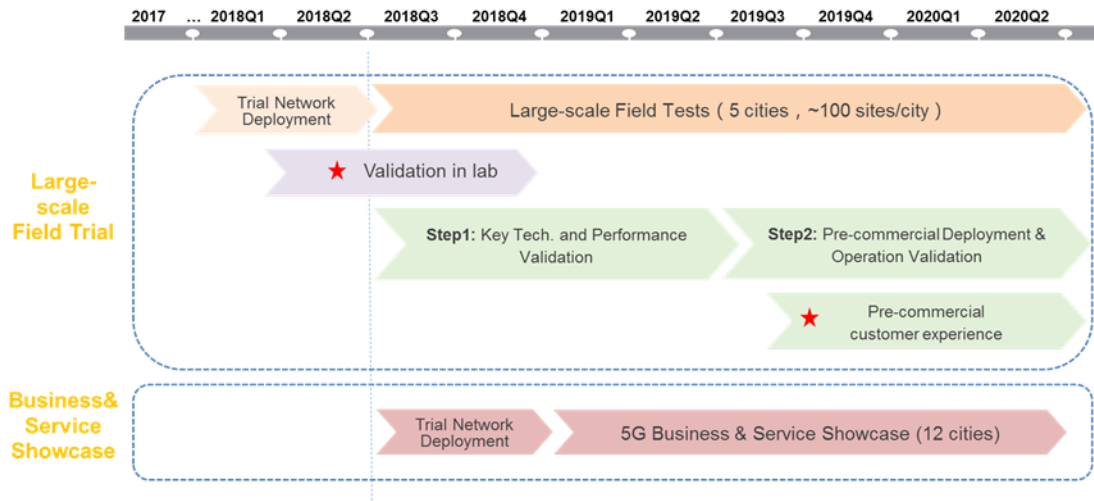


Figure 10-3 The Roadmap of China Mobile’s Large-scale Field Trial and B&S Showcase

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.

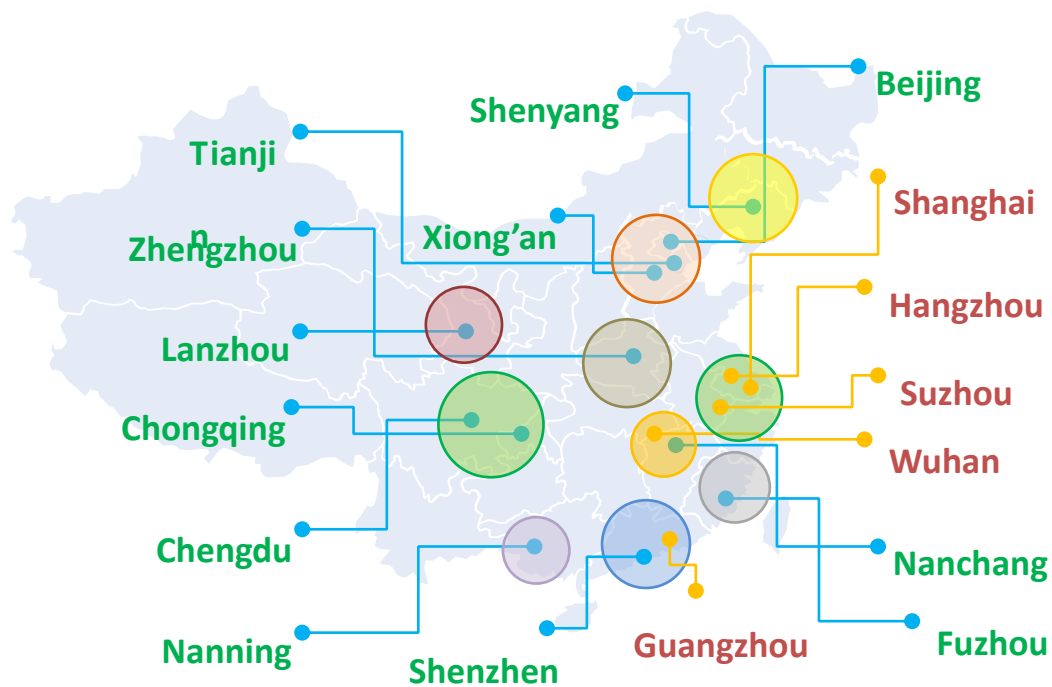


Figure 10-4 The cities for the large-scale Field Trial and B&S Showcase

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.

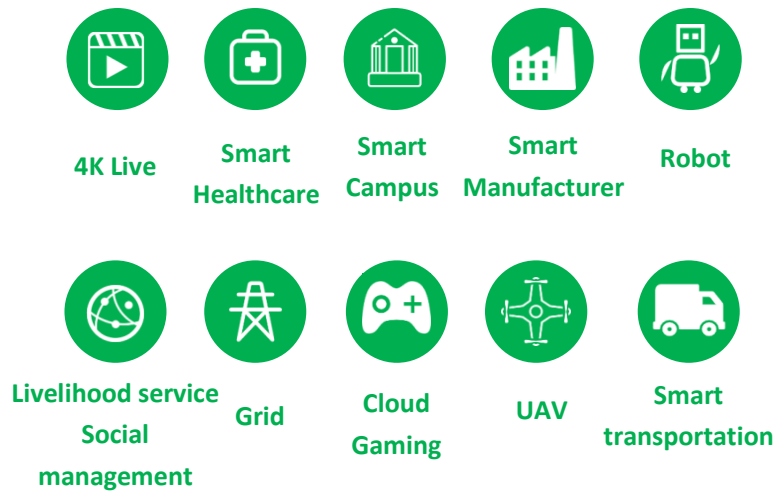


Figure 10-5 The typical application showcases

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 Regulatory 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](http://eur-lex.europa.eu).

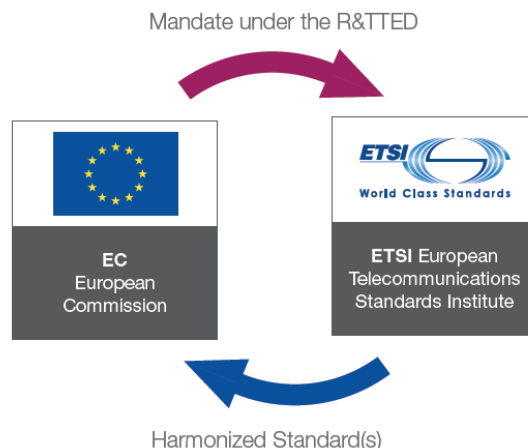


Figure 10-7 R&TTED test regulation

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 when 5G S-Modules are integrated 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 $-10^{\circ}\text{C}\sim+40^{\circ}\text{C}$), we should make sure that the 5G S-Modules could work normally with a wide working temperature range, such as $-40^{\circ}\text{C}\sim+85^{\circ}\text{C}$. 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 Application Scenarios for 5G S-Module

The 5G S-Module will use the most cutting-edge technology and give device vendor a chance to develop their application easily, therefore, we summarize the different typical application scenarios for 5G S-Module to meet the customer's requirements are as below.

11.1 5G S-Module Basic Type-L

11.1.1 Smart Factory – Robot

Mobile robots and mobile platforms have numerous applications in industrial and internal logistics environments and will play an increasingly important role in future factories. Mobile robot systems are characterized by maximum mobility relative to the environment, with a certain degree of autonomy and perceptive ability, that is, they can perceive and respond to their environment, and controlled by central system.

Mobile robot systems can operate in indoor and outdoor areas. These environmental conditions have an impact on the requirements of the communications system to ensure the required cycle time, and the main use of the interior is the transport of semi-finished products of light cargo, possibly in different plants. The outdoor application can be the transport of the port's container of unit-load vehicles, or for the large farms. Indoor and outdoor refers to the combination of factory buildings and open areas, such as traction vehicles, cows/animal-feeding robots on farms, etc.

Mobile robots have the following potential requirements for network performance: the requirements for delay, availability of communications services, and certainty are stringent. Communication service availability is 99.9999% with ms-grade delay requirements. For example, for precision collaborative robot motion control, the delay will be 1ms, while for remote control for video operation, it will be 10ms to 100ms. The data transmission rate of each mobile robot will be bigger than 10 Mbps. The ground speed of user equipment up to 50 km/h, and it should support interfaces for reliability monitoring.

5G S-Module Type-L could meet this requirement and it will be reliable and efficient. Currently, for a factory or farm, 5G S-Module Type-L could be put into each robot system and communicate with control center.



Figure 11-1 Mobile robots

11.1.2 Connected Energy – Industrial Routers

There is a large demand of industrial routers with strong and stable performance. It should support wireless standard of 650MHZ, with large capacity DDR2 RAM and high speed S PI Flash, with 300Mbps 2.4g wireless network. It will provide at least five 10/100M self-adapted Ethernet interface, with USB3.0 or above router interface, and it will provide rich industrial communication interfaces, such as RS232, 485, 5G dialing, electrical relay control, IO output interfaces with or without latch function, to satisfy various industrial application requirement with high performance. The wireless requirement of industrial routers should conform to IEEE802.11n/g/b wireless network protocol, and adopt 4x4 MIMO (Multiple Input Multiple output) architecture. The wireless transfer rate should be over 300Mbps, with two 2.4G antennas and four 5G antennas. The wireless signal coverage should be bigger than 50 meters and with the theoretical capacity of 30 connected devices.

5G S-Module could easily replace the 4G modules in the industrial routers and with much higher performance. It will have higher data ratio, with less delay, and work for connecting more devices. It will be a new direction to improve the industrial routers' quality and provide more functions.



Figure 11-2 Industrial Routers

11.1.3 UHD 8K Online Video & living broadcast

The typical scenarios Basic Type-L could be applied in UHD 8K Online Video or living broadcast. In 2018, enterprises launched display systems supporting 8K Super High Definition (SHD). Currently, where mobile phone screens have become the "first screen" for individuals, SHD online video supported by 5G technology will add mobile features for 8K technology. In addition, video sharing on mobile social networks, especially popular live broadcast platforms, will greatly benefit from the online live broadcast capacity using 5G technology. Now, 5G S-Module Basic Type-L can be integrated into 5G Terminals to fully meet these requirements.

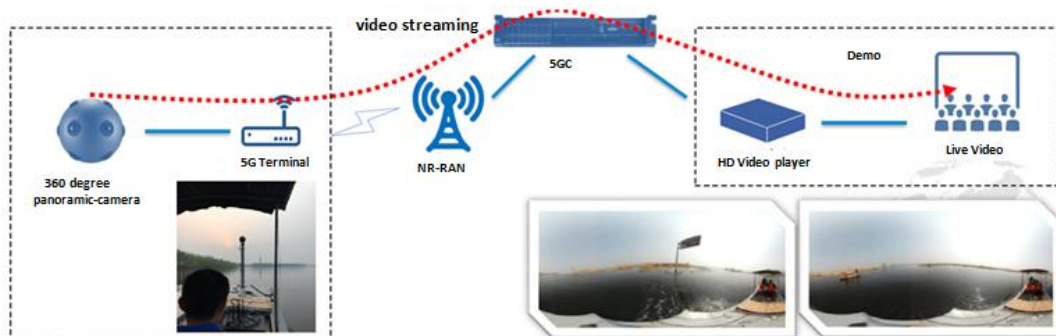


Figure 11-3 UHD 8K Online Video & living broadcast

11.1.4 Wireless eHealth

Remote diagnostics plays a more and more important role in modern life. With the growth of aging population the increase of sufferers of chronic diseases and the shortage of medical resources emerge. Also, with the rapid pace of modern life, it is time consuming for the young people to go to the hospital and wait in the long line. Therefore, the service model of health care will be changed. The development of the Internet of Things has provided essential conditions for smart medical care. The introduction of mobile devices using M2M communication modules plays a substantial role in the prevention, diagnosis, treatment, and monitoring fields. Remote diagnosis can be used to diagnose the patient's condition. This new Mobile Healthcare (mHealth) medical model not only reduces labor and material costs, but also combines various types of mobile devices, such as smart phones and tablet PCs. With the applications are available on the mobile devices, it is now possible to keep track of the health status and improve the reliability of medical care.

5G S-Module Basic Type-L can be used in the diagnostic devices with high performance, which

will enable the devices for remote video. Thus, doctors can use these devices to monitor patients' health conditions. With high data rate and low latency, it could bring a revolution for remote diagnostics.



Figure 11-4 Wireless eHealth

11.1.5 FWA

FWA (Fixed Wireless Access) is a concept for providing broadband service to homes and small and medium-sized enterprises (SMEs) that is particularly attractive in cases where there is no infrastructure in place to deliver wired broadband via copper, fiber or hybrid solutions. It can also be used when the existing infrastructure is not able to provide sufficient service. With 5G which can provide 10 to 100 times more capacity than 4G, it has the potential to enable cost-efficient FWA solutions on a massive scale. The 5G S-Module Basic Type-L can be easily integrated into CPE devices used for FWA.

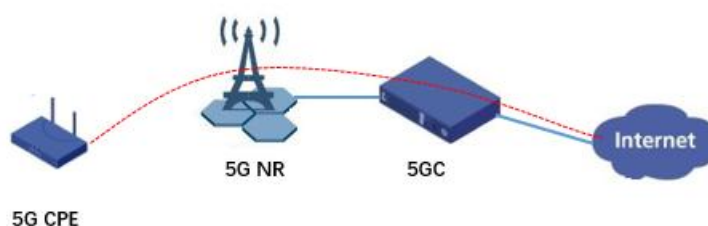


Figure 11-5 Fixed Wireless Access

11.1.6 Video Surveillance

With 4G wireless network transmission, surveillance devices can perform video surveillance in the mobile environment, such as police patrol car surveillance, traffic police surveillance, and personnel mobile command. 5G technology will further expand the applicability of SHD video surveillance in emergency response scenarios including urban security, urban emergency management, and major accident live broadcasting. For example, the current technology

implements 4M video surveillance for trains and subways, which is poor in timeliness and clarity. 5G eMBB scenario, featuring high data rate, will provide new technical support for scenarios like this. According to calculations, video surveillance at 6M, 8M pixels or even 4K resolution requires bandwidth above 50MHz, while real-time HD images at 8K 60fps require transmission bandwidth above 120MHz. 5G S-Module Basic Type-L can fully fulfill the requirements and be easily integrated into surveillance devices such SHD camera.

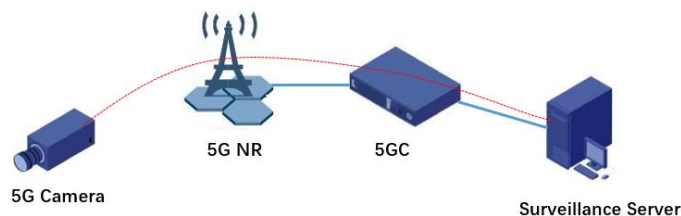


Figure 11-6 SHD video surveillance through 5G Network

11.1.7 AR/VR

According to Gartner, the use of VR and AR is one of six top technology workplace trends that will drive the digital workplace and “are ready for mainstream businesses”. At present, the huge amount of computation and storage AR/VR requirements restrict low cost of terminal devices and fast growth of related applications. The integration of 5G and cloud computing provides an evolution for VR/AR. Real-time content downloading, real-time modeling and rendering will provide the ultimate experience for mixed reality applications. Moving computing and storage to the cloud will greatly reduce the cost of the terminal devices. Meanwhile, 5G ultra-high-bandwidth and ultra-low-latency networks are responsible for transmitting the large amounts of data. 5G S-Module Basic Type-L can be used in VR/AR devices to meet the needs of devices requiring ultra-high bandwidth and significant data transmission.

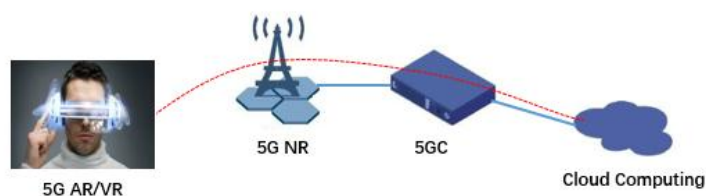


Figure 11-7.8 Cloud AR/VR

11.2 5G S-Module Basic Type-M

11.2.1 Laptop industry and sky office application

Basic Type-M could be applied in Laptop industry, which is one of the typical scenarios, and in 2018 PC already integrated Cat 16 LTE module. In the next generation Laptop need module to support higher data rate for downlink and uplink.

The features of 5G type-M module such as high data rate, low latency, and safety will bring an opportunity for innovation of office. At the same time, 5G makes it possible to work anytime, anywhere, such as keeping online on the high-speed train with the 350-500km/h speed. Laptops with 5G modules will synchronize with cloud, and achieve some user cases such as file management in cloud, cloud coordination, remote HD meetings, upgrading normal PC + high end display to work station and so on. The application scenarios are shown in Figure 11-8. Also, unlimited data plan from the operators will become the main trend to stimulate the usage of 5G laptop.



Figure 11-8 the Application Scenario of 5G S-Module Basic Type-M

The 5G S-Module Basic Type-M need meet PCIe M.2 Electro-Mechanical Card specification, revision 1.1 and RF part meet release 15 NSA and release 16 SA. It had better be a single hardware SKU with support for worldwide coverage and certification on networks. It also shall support external 4x4 MIMO antennas for 5G MR-DC (Multi Rats dual connectivity). For software the 5G S-Module Basic Type-M shall support Operator Name String (EONS), PAP/CHAP, USSD, PCSC SIM authentication OMA-DM, OTA-DM, static IP SIM, diagnostic, activation, Multi-IMSI SIM, Roaming Broker, and shared network, SPN (Service Provider Name) display etc. With these features, 5G S-module could easily replace the 4G modules in the laptop and with much higher performance.

11.3 5G S-Module Smart Type

11.3.1 Smart POS

Smart hardware is represented by unmanned retail, smart POS and unmanned containers. These aspects require a lot of man-machine interaction and M2M work, including advertisement, identification of user behavior and payment security. Smart POS (Smart Point of sales, also called micro POS) is a new concept versus the traditional POS. Its main functions include the traditional POS functions such as scanning bar code, swiping the card. It can also scan two-dimensional bar code, member cards verification and customer management via CRM system and big data analysis. Its main task is electrical payment, which will replace the cash payment.

Smart POS are mainly divided into two categories: desktop smart POS and portable smart POS according to their size. They are also categorized as keypad type and touch screen type. Smart POS generally are customized on Android system. Portable smart POS starts a new era of mobile payment system, which will improve customer satisfaction. The 5G S-Module Smart Type can meet Smart POS requirements. POS manufacturers need only add a colored screen in order to make a Smart POS.



Figure 11-9 Smart POS

Firstly, 5G S-Module Smart Type could lower the cost for Total BOM, because the cost of Smart Modules will be less than “AP + standard Modem”. Secondly, 5G S-Module Smart Type has abundant functions with Modem/Wi-Fi/BT/GNSS/FM/LCD/Camera/Video/Audio/USB and so on., which are greater than “AP +standard Modem”. Finally, 5G S-Module Smart Type has flexible usage: it will simplify hardware design for complex systems, and Internet companies could develop and run Android APP by 5G S-Module Smart Type.

11.3.2 Connected Automotive

Connected automotive is a vertical service based on high-speed wide-area network, which is closely related to the development of 5G network. For example, autonomous driving requires a delay of less than 1ms, which falls within the requirement for 5G standards. The introduction of C-V2X technology provides the most important technical guarantee for the application of 5G in the automotive industry.

Automatic driving technology needs a large quantity of surrounding environmental data and information to make real-time decision. Sensors and the V2V and V2I communications are two main data resources. For guaranteeing the safe driving for automatic vehicles, it has higher requirement for the data transfer rate and stability. 5G network could provide more powerful networking capability, with the advantage of low latency, higher reliability and high bandwidth. The transfer rate will be over 2GB per second, so it is the technology and network base of guaranteeing automatic driving. 5G S-Module could be used for different devices in the automatic vehicles, such as video recorder, real time map, smart driving cockpit. The automotive grade 5G S-Module Smart Type can be applied using vehicle-mounted communication tools.

11.3.3 Connected Drones

A variety of practical applications of drones have been developed since drones were used for live broadcasting at the G20 summit in Hangzhou, China. The current application mainly focuses on the exploration and monitoring of public buildings and their surrounding environments. The application of 5G can significantly increase data transmission rate, enabling drones to detect and transmit more parameters of different types with less delay.

There are some required functions of the connected drones. It should be compatible with 4G and 5G network, and can switch seamlessly between 4G and 5G. It will have the relay function, and can relay Wi-Fi signals. It can have smooth handover between different base stations and can reconnect automatically when it drops from the network. It should have anti-interrupt function, and have strong signal stability. It will have high environment adaptability, and extreme environmental condition such as high temperature, low temperature and vibration will have no obvious impact on it. This raises very high requirement for the 5G S-Module Smart Type, which can be used in this application.

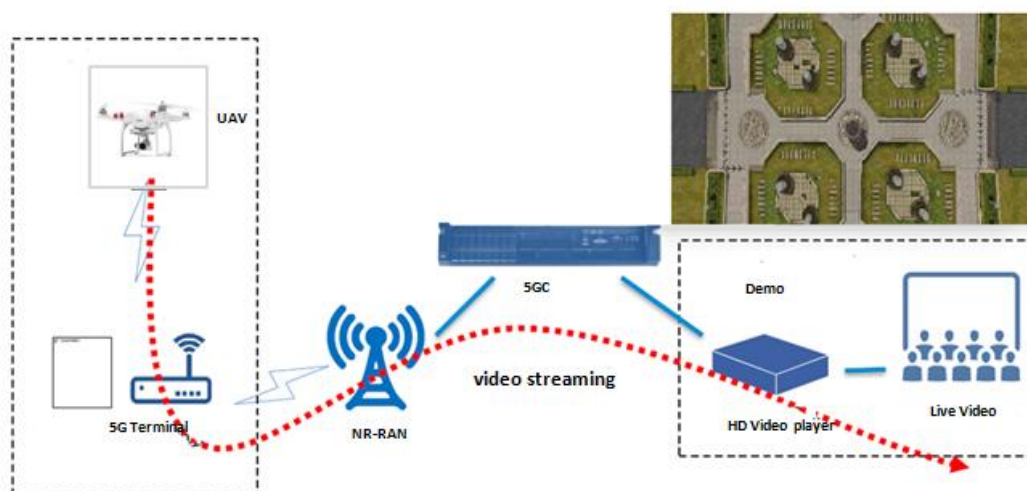


Figure 11-10 UAV Real time video live broadcasting

11.4 5G S-Module All-in-one Type-M and Type-L

11.4.1 USB Dongle

USB Dongle is a small device that plugs into a USB port on a host computer or host device to provide a connection to the cellular network. By attaching the dongle to the computer's USB port, Users could use USB dongle at home or at office without the guarantee of fixed internet access. Users can have a persistent internet connection to all workstations, because USB dongle allows for higher rates of utilization of the software.

USB dongles can be also used in the car system, which can be used seamlessly with user device, OS, and the car dash board, and can be used with Google map or other applications. When the car is equipped with USB dongle, it will be able to connect to the smart phone and other devices, and use the car built-in display screen and control key, and interact with the smart phone or other terminal. Users could make phone calls easily and safely, listen to the music, send and receive text message, use navigation, and much more.

USB dongle can also be used in remote medical systems. Since 5G guarantees the high data rate and low latency, the 5G USB dongle will be suitable to be applied in the medical systems for remote diagnosis and help the doctors to cure the patients remotely.

By using 5G S-Module All-in-one Type, 5G USB Dongle is expected to reduce system complexity and get to market faster.



Figure 11-11 USB dongle

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

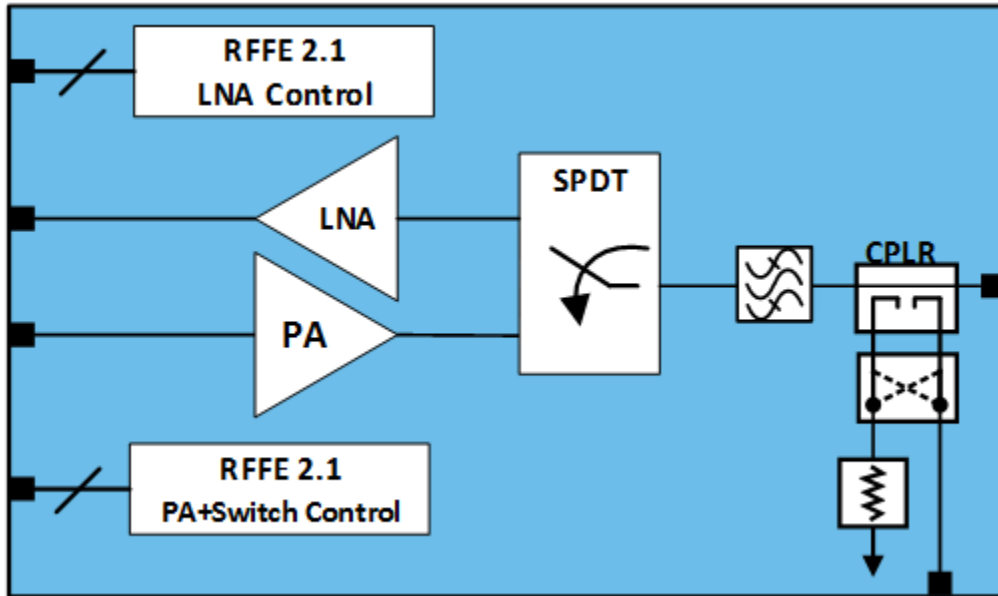


Figure A-1 Diagram

Annex A.1.2 Pin Layout

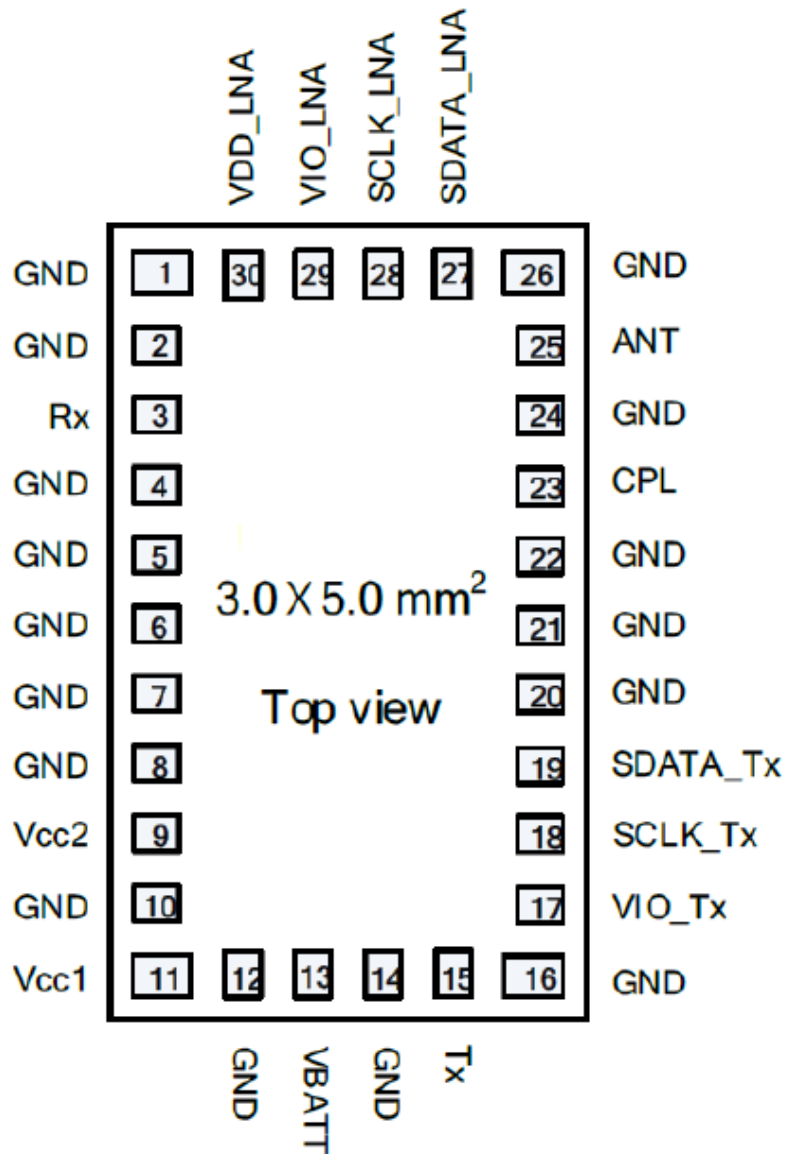


Figure A-2 Pin Layout

Annex A.1.3 Pin Size

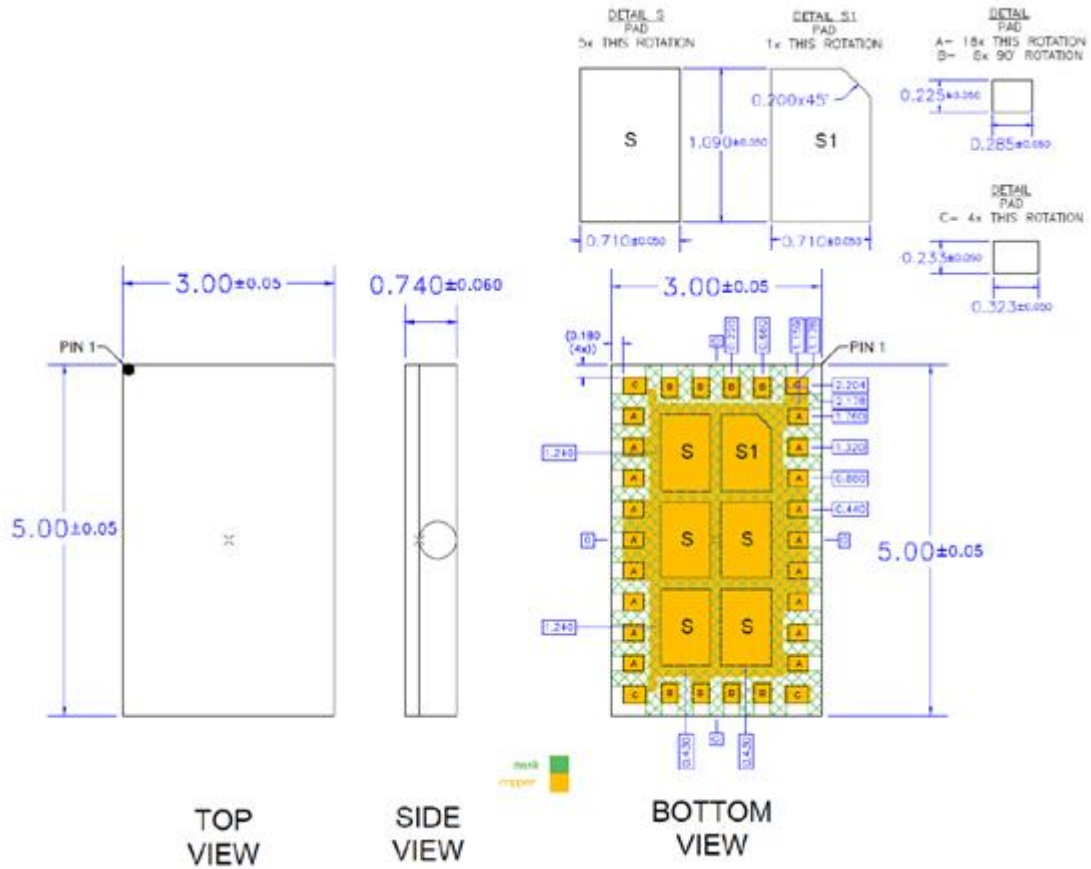


Figure A-3 Pin Size

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

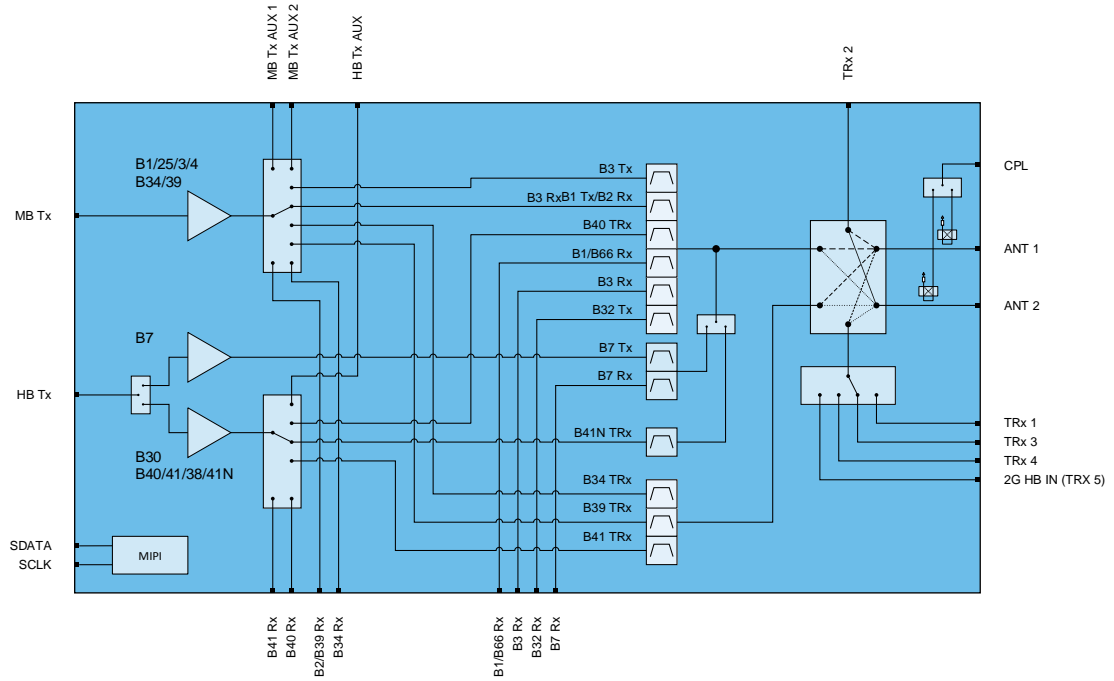


Figure A-4 Diagram

Annex A.2.2 Pin Layout

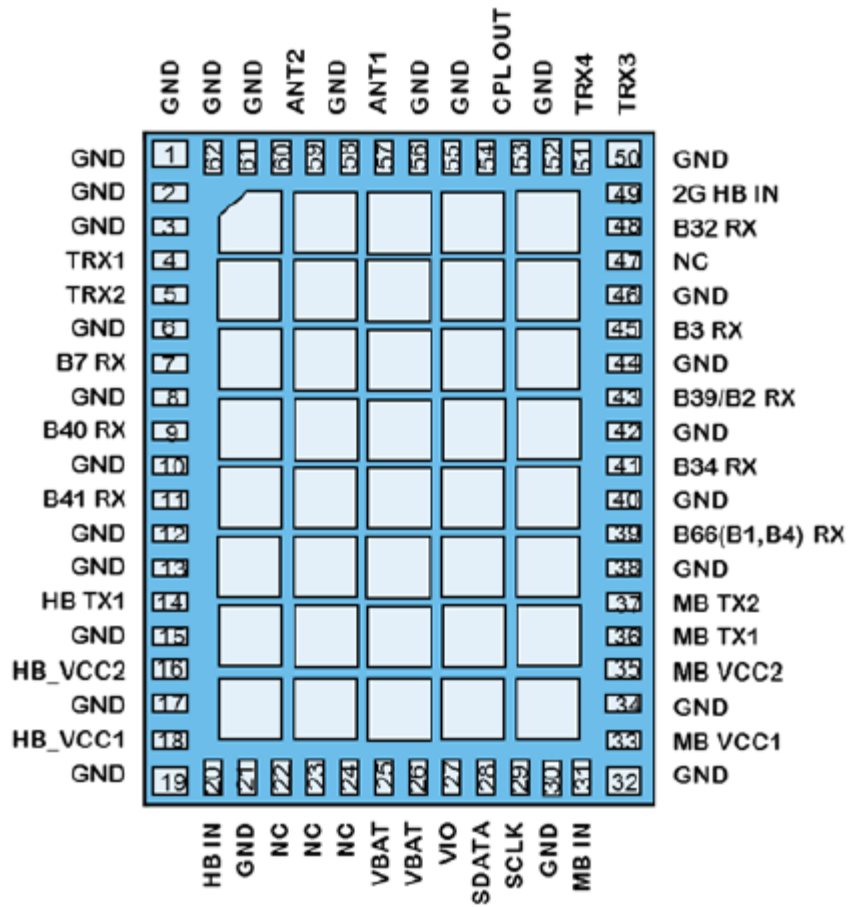


Figure A-5 Pin Layout

Annex A.2.3 Pin Size

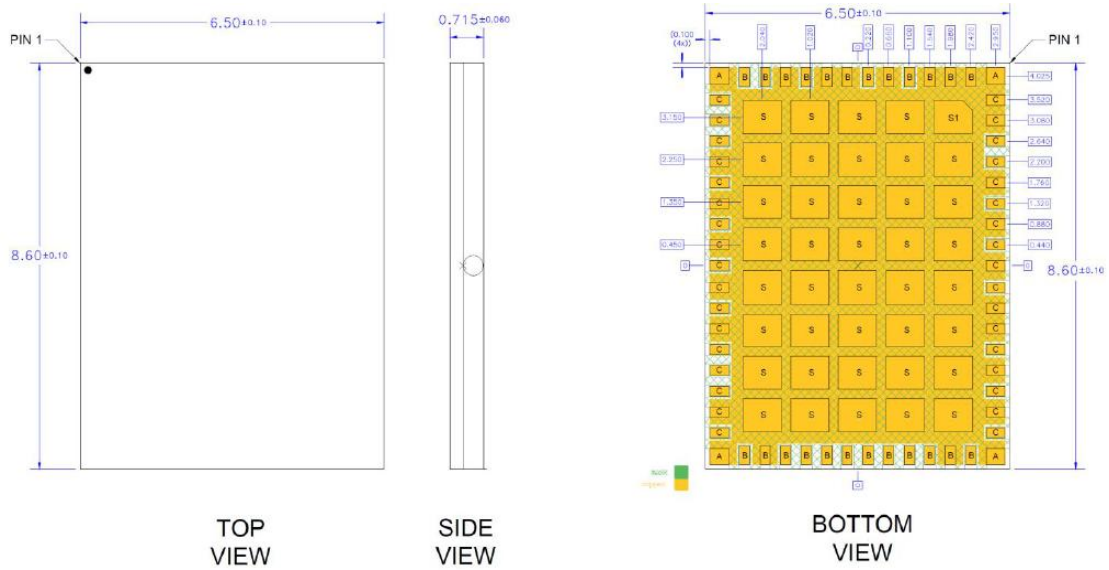


Figure A-6 Pin Size

Note: Above RF Module information and data in Clause A.4 are 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. As shown in 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.

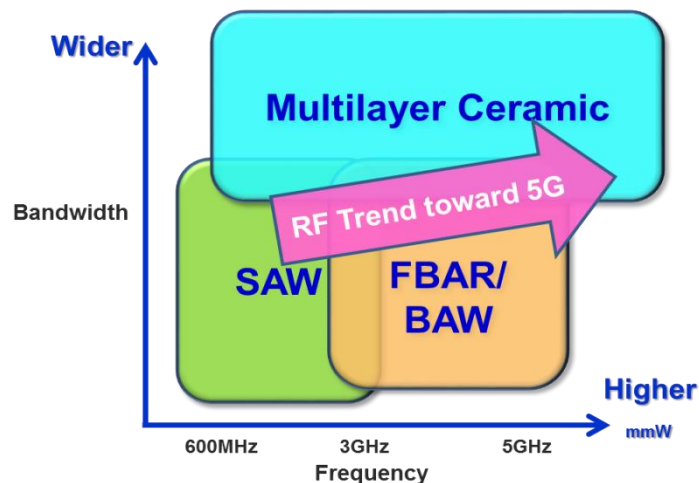


Figure A-7 Common Filter Technologies from Taiyo Yuden

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

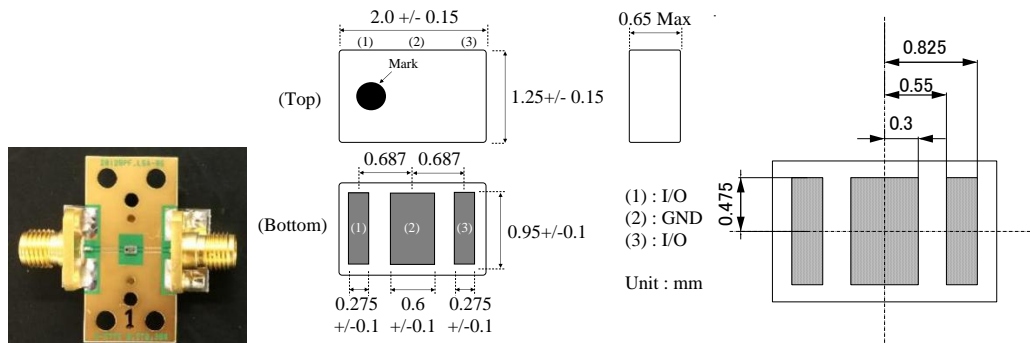


Figure A-8 Multilayer Ceramic Filter with its evaluation board (example photo), Dimension and footprint

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)

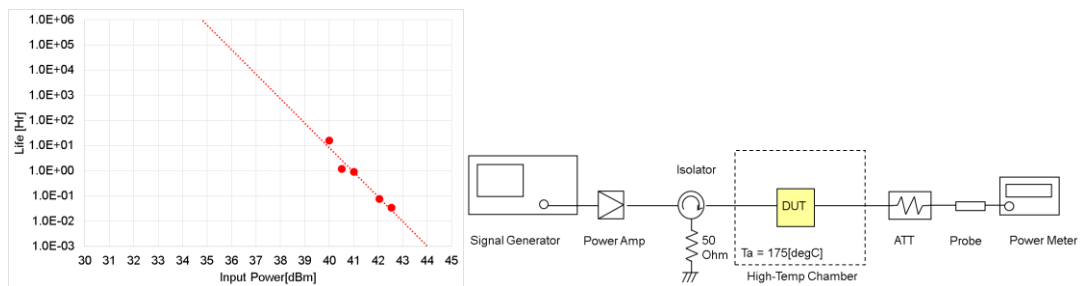


Figure A-9 Test result example of DUT: 2012 (EIA: 0805) size 3.5GHz BPF

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.

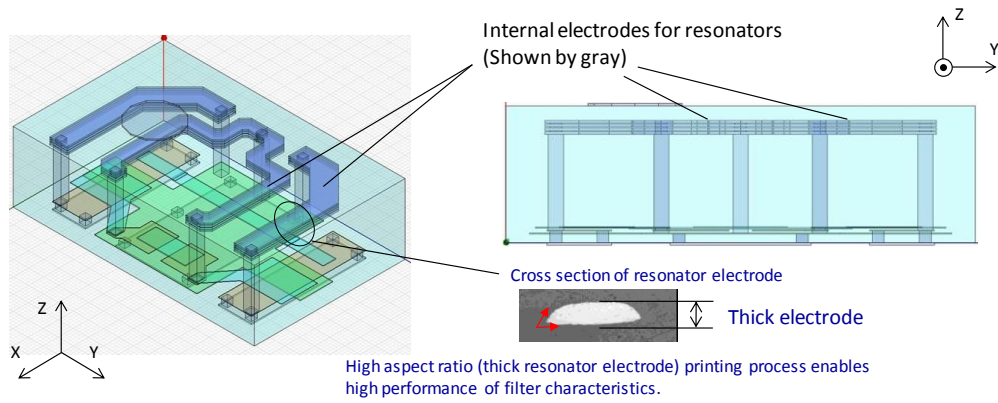


Figure A-10 Perspective View and side view of Distributed Element Filter

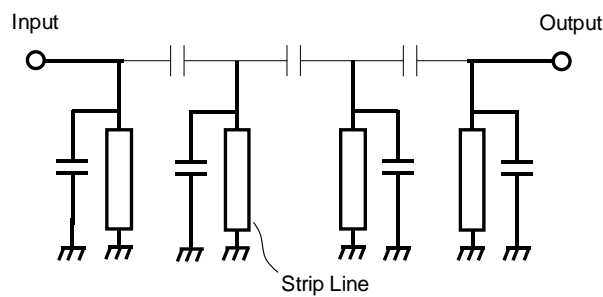


Figure A-11 Equivalent circuit of Distributed Element Filter

Annex A.3.5 SAW/FBAR Filter for Band n41

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

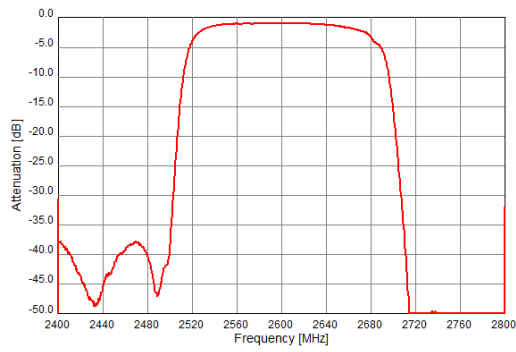
(These products had been originally developed for TD-LTE. Assuming these products can also be used for n41 while new conditions and/or requirements are under investigation.)

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)

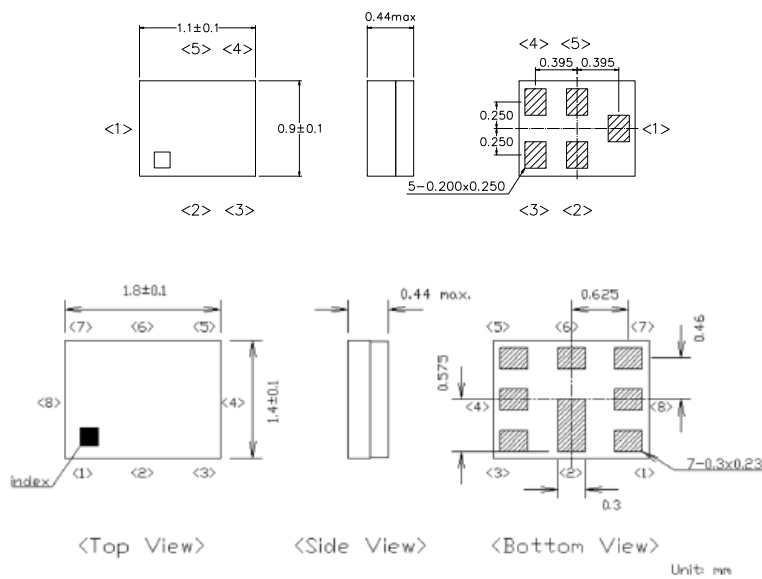
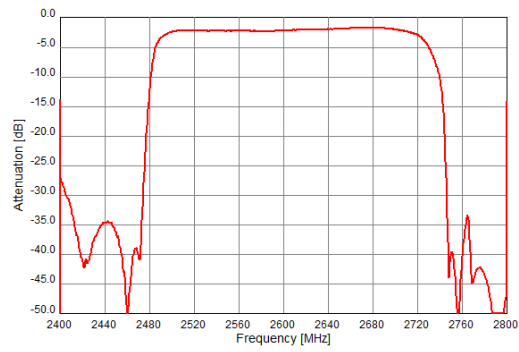


Figure A-12 Dimension for 1109 size and 1814 size SAW / FBAR Filters

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

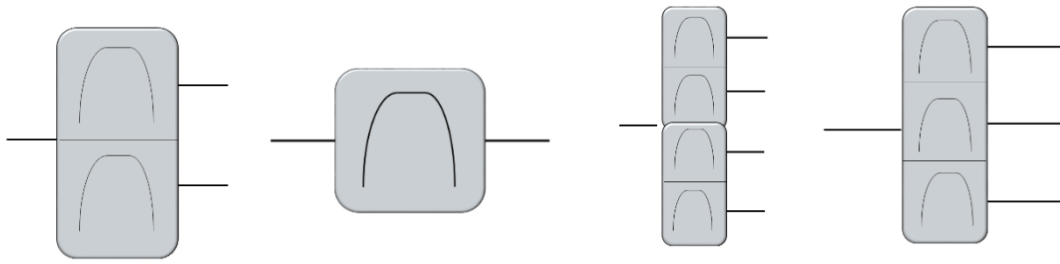


Figure A-13 Block Diagram of SAW Duplexer, SAW Filter, SAW QPX and SAW Tri-Filter

Annex A.4.2 Pin Layout

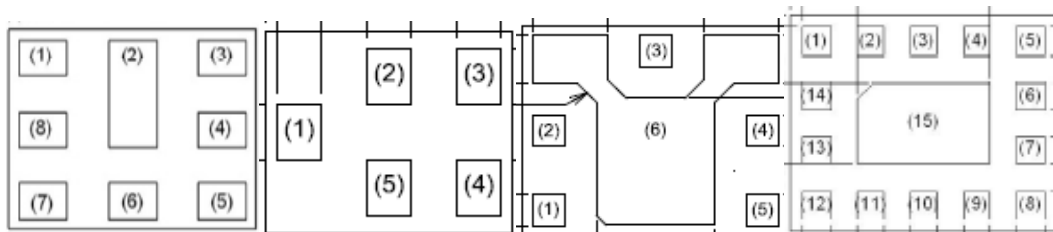


Figure A-14 Pin Layout of SAW Duplexer, SAW Filter, SAW QPX and SAW Tri-Filter

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.

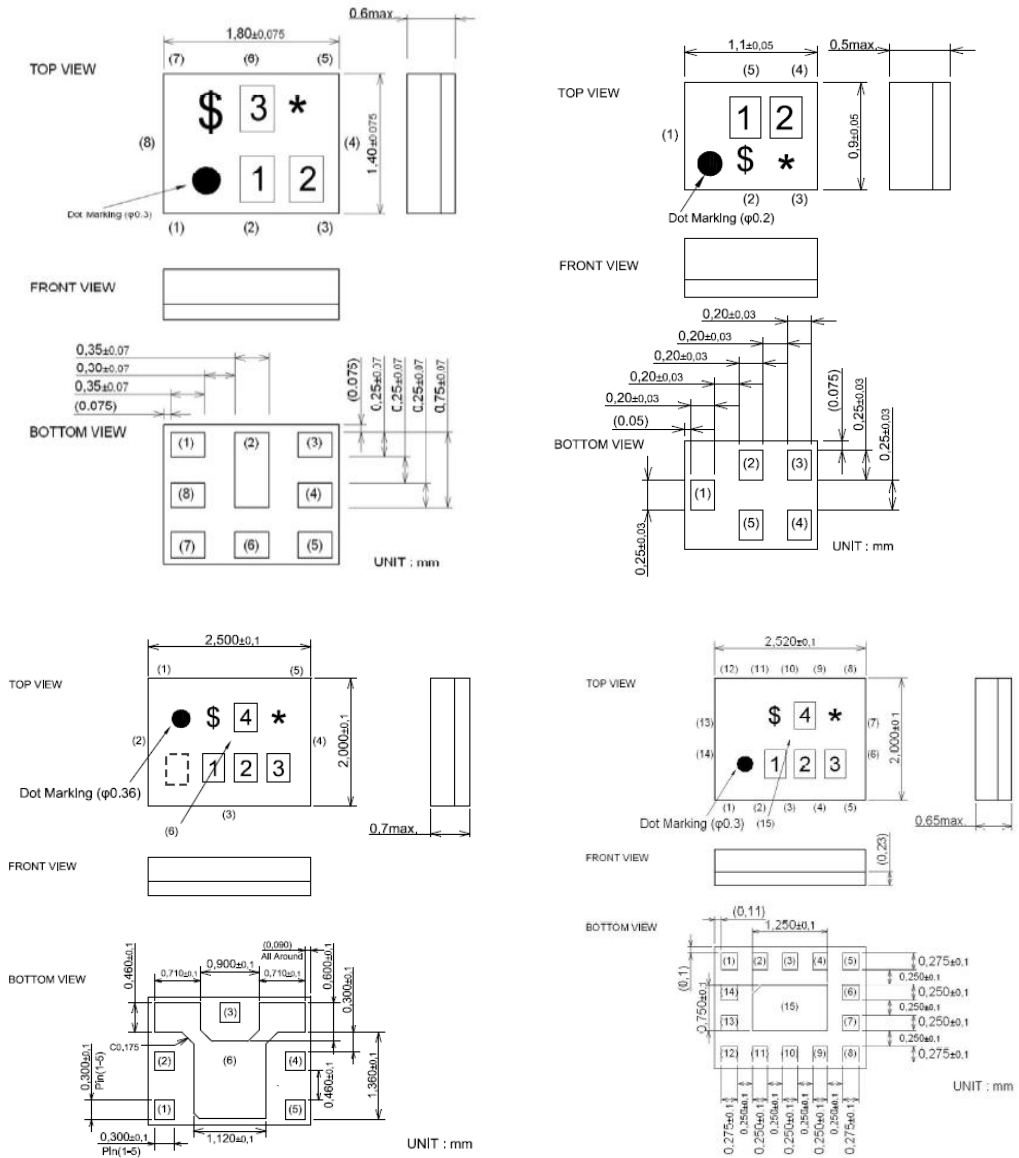
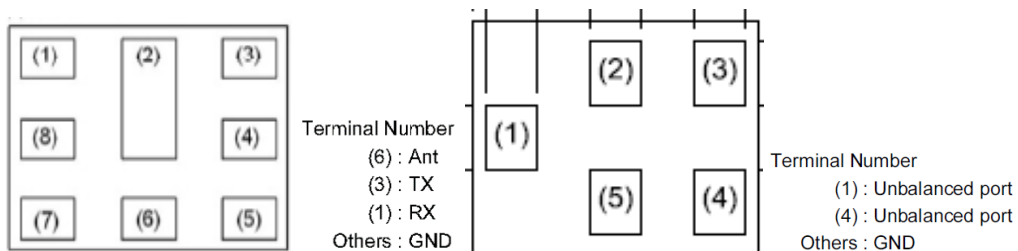


Figure A-15 Pin Size of 1814 SAW Duplexer, 1109 SAW Filter, 2520 SAW QPX and 2520 SAW Tri-Filter

Annex A.4.4 Pin Definition



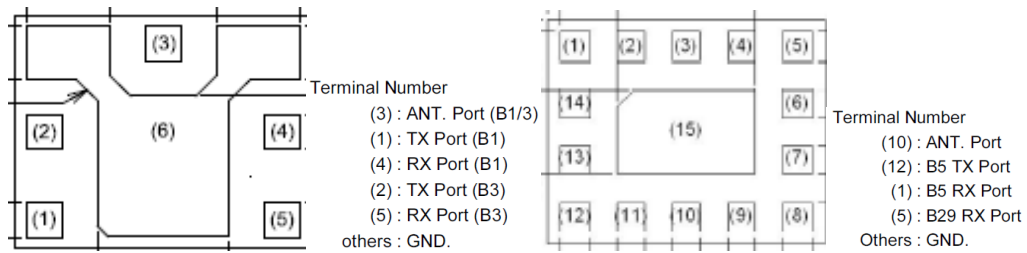


Figure A-16 Pin Definition of 1814 SAW Duplexer, 1109 SAW Filter, 2520 SAW QPX and 2520 SAW Tri-Filter

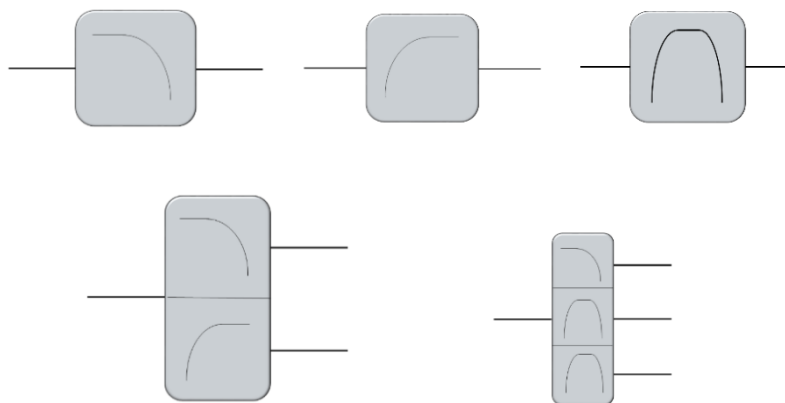
Note: Above RF Module information and data in Clause A.6 are provided by Murata.

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



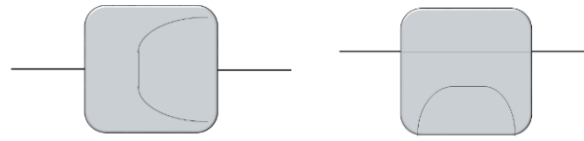


Figure A-17 Block Diagram of LPF, HPF, BPF, Diplexer, Triplexer, Balun and Coupler

Annex A.5.2 Pin Layout

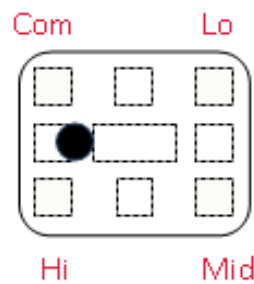


Figure A-18 Layout Illustration of LTCC Components

Annex A.5.3 Pin Size

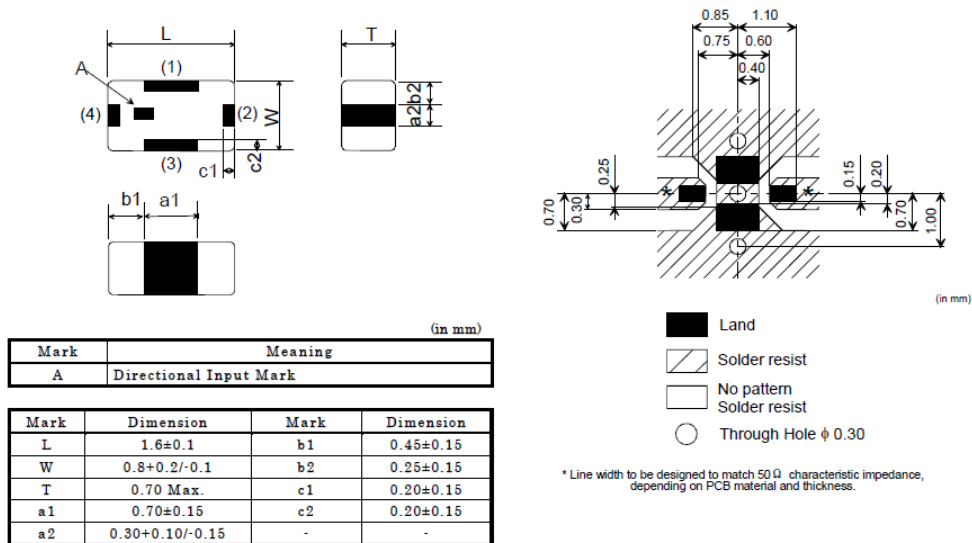


Figure A-19 Pin Size Illustration of LTCC Components

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 Basic Type

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.

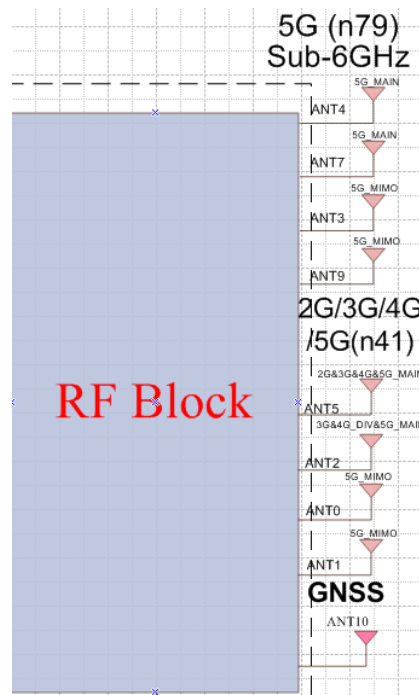


Figure B-1 Antenna Diagram

Annex B.1.2 Antennas connected to the module

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

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

Table B-1 Antennas for S-Module Basic Type

| Antenna | Bands | Antennas | Feature of Antennas | Description |
|---------|-------|----------|---------------------|-------------|
|---------|-------|----------|---------------------|-------------|

| Type | | to Module | | |
|----------------|---|-----------|--|---|
| 4G/5G Antennas | 5G NR Bands: Mandatory:n41 | AM47 | 5G NR(n41)&4G LTE main antenna | To get high data throughput for the products, 4 MIMO antenna design needs to use for 5G S-Module. For the compatibility of the network, 4G LTE antennas are still required. |
| | FDD-LTE Bands: Mandatory: B7, B3, B8, B25 | AG47 | 5G NR(n41) main antenna&4G LTE diversity antenna | |
| | Optional: B1, B4, B12, B17, B20 | AN39 | 5G NR(n41) MIMO antenna | |
| | TDD-LTE Bands: Mandatory: B34, B39, B40, B41 | AN43 | 5G NR(n41) MIMO antenna | |
| 5G Antennas | 5G NR Bands: Mandatory: n79 | ANT4 | 5G NR(n79)main antenna | To get high data throughput for the products, 4 MIMO antenna design needs to use for 5G S-Module. |
| | | ANT7 | 5G NR(n79) main antenna | |
| | | ANT3 | 5G NR(n79) MIMO antenna | |
| | | ANT9 | 5G NR(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 be customized. 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

TTF (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.

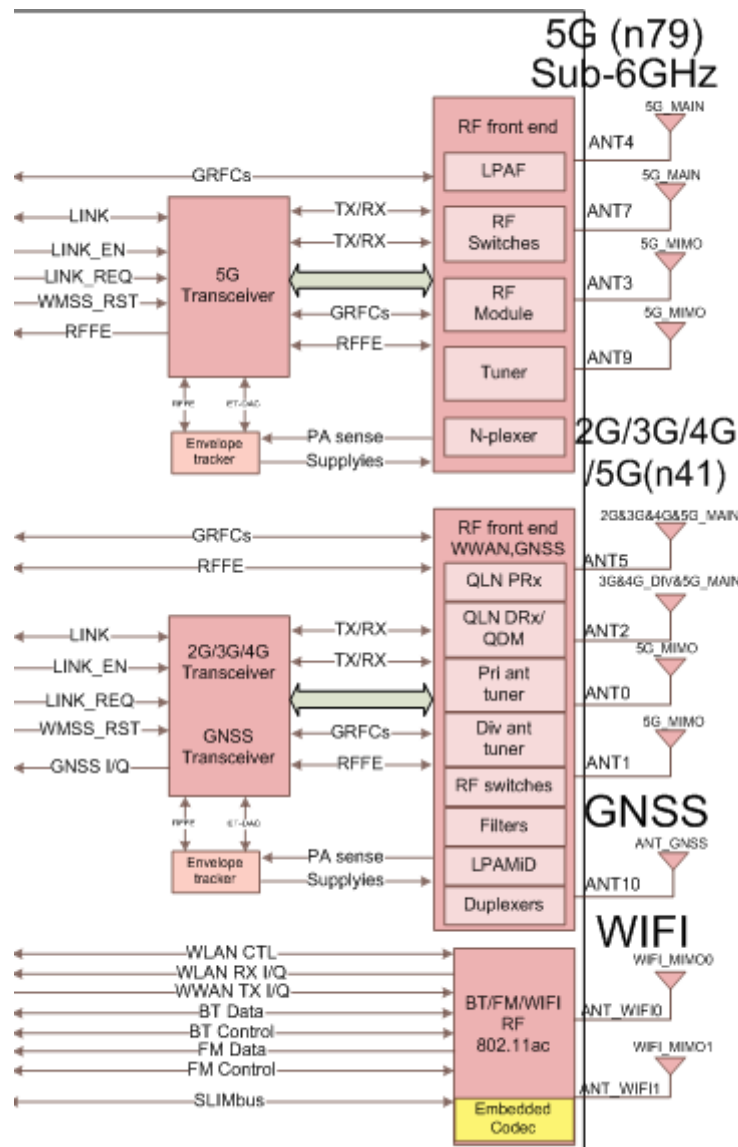


Figure B-2 Antenna Diagram

Annex B.2.2 Antennas connected to the module

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

The information of antennas that are applied for the S-Module is 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 | AM47 | 5G NR(n41)&4G LTE main antenna | To get high data throughput for the products, 4 MIMO antenna design needs to use for 5G S-Module. For the compatibility of the network, 4G LTE antennas are still required. |
| | FDD-LTE Bands: Mandatory: B7, B3, B8, B25 Optional: B1, B4, B12, B17, B20 | AG47 | 5G NR(n41) main antenna&4G LTE diversity antenna | |
| | TDD-LTE Bands: Mandatory: B34, B39, B40, B41 | AN39 | 5G NR(n41) MIMO antenna | |
| | | AN43 | 5G NR(n41) MIMO antenna | |
| 5G Antennas | 5G NR Bands: Mandatory: n79 | ANT4 | 5G NR(n79)main antenna | To get high data throughput for the products, 4 MIMO antenna design needs to use for 5G S-Module. |
| | | ANT7 | 5G NR(n79) main antenna | |
| | | ANT3 | 5G NR(n79) MIMO antenna | |
| | | ANT9 | 5G NR(n79) MIMO antenna | |
| GNSS Antenna | GPS, BeiDou, GLONASS, or Galileo | ANT10 | GNSS antenna | To meet the demand of precision positioning, GNSS antenna is applied |
| Wi-Fi Antenna | 2.4G, 5G | ANT_WI-FI0 | Wi-Fi main antenna | 2x2 Wi-Fi MIMO are applied |
| | 2.4G, 5G | ANT_WI-FI1 | Wi-Fi MIMO antenna | |

To achieve the designed performance of the module, the antennas of the products need to be customized. 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

TTF (Time to first fix): Max time < 18s

Wi-Fi Antennas

Antenna Band: 2.402 – 2.483 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 feature 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 easy to 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 challenges 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 with 5G S-Module for wide applications.

Annex C.2 Cutting-edge Sensor Application

Sensors have applications in many fields and have increased requirement in different areas. Here we introduce some cutting-edge development which may combine 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 360° sensor which could provide orientation with 0.2°, 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 a 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 of 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, and allow 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 depends 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.

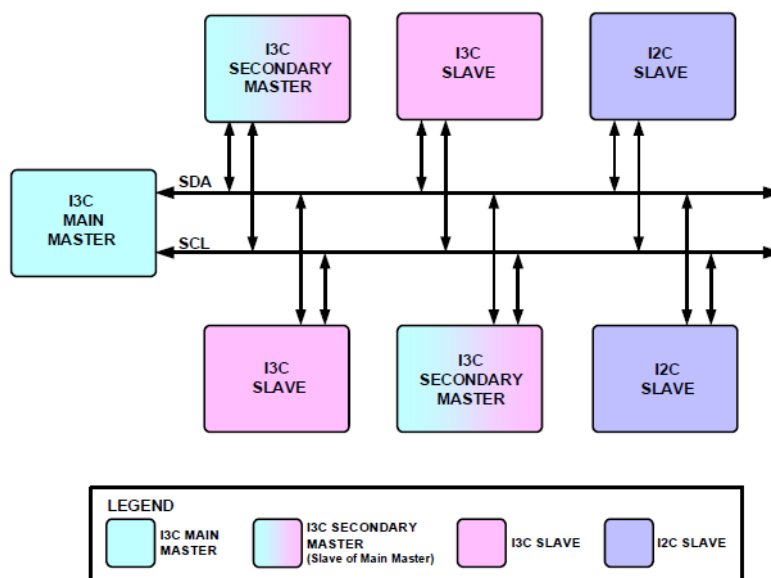


Figure C-1 I3C Bus with I2C Devices and I3C Devices (Source: MIPI)

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