GTI 5G Sub-6GHz Device Test and Certification White Paper

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1 Executive Summary

With the release of 3GPP 5G NR core specifications in June 2018, global 5G development has steps into the homestretch stage towards 5G commercialization. As the key point impacting the maturity and commercialization of new technologies, terminals, including chipsets, modules, consumer products and industry devices, are not only the bridge connecting end-users and new technologies, but also the carrier on which end-user could experience the advancement of new technologies.

Test and certification are significant methods to guarantee the quality of terminal products. Towards the commercial launch of 5G products in 2019, it's urgent to establish a standardized and effective test and certification solution to give a guideline on how to test the different type of devices and the corresponding certification criteria.

With this in mind, this whitepaper gives an introduction on the 5G terminal products architecture, 5G test methodologies towards 5G terminals and the 5G "3+2" certification solutions.

This whitepaper is co-sourced from Task-T-PM2-PJ1-10 (5G Device Certification), Task-T-PM2-PJ5-3 (5G Terminal OTA) and Task-T-PM2-PJ3-2 (5G S-Module). With sincere gratitude to all the contributors, we are respectfully listing them in alphabetical order under each chapter.

Chapter	Title	Task	Contributors
1	Executive Summary	Task-T-PM2-PJ1-10	CMCC
2	Abbreviations	Task-T-PM2-PJ1-10	CMCC
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6.4	Service Capability Tests	Task-T-PM2-PJ1-10	Datang Linktester
7.1	3+2 Test and Certification Solution	Task-T-PM2-PJ1-10 Task-T-PM2-PJ3-2	CMCC, Quectel
7.2	One-Stop Test Capability	Task-T-PM2-PJ1-10	CMCC
8	Summary	Task-T-PM2-PJ1-10	CMCC

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2 Abbreviations

Abbreviation	Explanation
2/3G	The 2/3rd Generation Telecommunication
3GPP	The 3rd Generation Partnership Project
4G	The 4th Generation Telecommunication
5G	The 5th Generation Telecommunication Technology
AR	Augmented Reality
CPE	Customer Premise Equipment
eMBB	Enhanced Mobile Broadband
ME	Mobile Equipment
MIMO	Multiple-Input Multiple-Output
mmWave	Millimeter Wave
MU-MIMO	Multi-User MIMO
NR	New Radio
NSA	Non-Standalone
OFDM	Orthogonal Frequency Division Multiplexing
PLMN	Public Land Mobile Network
PoC	Proof of Concept
RLC	Radio Link Control
RRC	Radio Resource Control
SA	Standalone
SCG	Secondary Cell Group
SN	Secondary Node
SU-MIMO	Single-User MIMO
UE	User Equipment
UP	User Plane
URLLC	Ultra-Reliable and Low Latency Communications
VR	Virtual Reality
ACPC	Always Connected PC
RFIC	Radio Frequency Integrated Circuit
FEM	Front End Module
SPAC	Single-Probe Anechoic Chamber
MPAC	Multi-Probe Anechoic Chamber
RTS	Radiated Two-Stage

RC	Reverberation chamber
MBIM	Mobile Broadband Interface Model
UAE	Unmanned aerial vehicle
USB	Universal Serial Bus

3 References

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

[1] GTI, “GTI Sub-6GHz 5G Device Whitepaperv3.0”

[2] GTI, “GTI 5G S-Module Whitepaper V1.0”

[3] GTI, “GTI 5G Device OTA Performance White Paper V1.0”

[4] 3GPP, TR 38.901, Study on channel model for frequencies from 0.5 to 100 GHz.

[5] 3GPP TR.37.977, “Verification of radiated multi-antenna reception performance of User Equipment (UE)”

[6] Ya Jing, Xu Zhao, Hongwei Kong, Steve Duffy, and Moray Rumney, “Two-Stage Over-the-Air (OTA) Test Method for LTE MIMO Device Performance Evaluation”, International Journal of Antennas and Propagation, Vol. 2012

[7] 3GPP TR 36.978, “Evolved Universal Terrestrial Radio Access (E-UTRA) User Equipment (UE) antenna test function definition for two-stage Multiple Input Multiple Output (MIMO) Over The Air (OTA) test method”

[8] Moray Rumeny, Hongwei Kong, Ya Jing, etc, ‘Recent advances in the radiated two-stage MIMO OTA test method and its value for antenna design optimization’, Conference: The 10th European Conference on Antennas and Propagation (EuCAP 2016)

[9] M.T. Dao, V.A. Nguyen, Y.T. Im, S.O. Park, and G. Yoon,”3D Polarized Channel Modeling and Performance Comparison of MIMO Antenna Configurations With Different Polarizations,” IEEE Transactions on Antenna and Propagation, VOL. 59, NO. 7, July 2011, pp.2672-2682.

[10] 3GPP R4-157298, Keysight Technologies, General Test Technologies, Analysis of AC methodology results

[11] 3GPP, TS 38.521-1, “NR; User Equipment (UE) conformance specification; Radio transmission and reception; Part 1: Range 1 Standalone”

[12] 3GPP, TS 38.521-2, “NR; User Equipment (UE) conformance specification; Radio transmission and reception; Part 2: Range 2 Standalone”

[13] 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”

[14] 3GPP, TS 38.523-1, “5GS; User Equipment (UE) conformance specification; Part 1: Protocol”

[15] GTI, “5G Sub-6GHz Device Interoperability Test Specification v1.0

[16] GTI, “5G Sub-6GHz Device Field Trial Test Specification- SA mode v1.0”

[17] GTI, “5G Sub-6GHz Device Field Trial Test Specification- NSA mode v1.0”

4 General Description

This whitepaper gives an introduction on the 5G terminal products architecture, 5G test methodologies towards 5G terminal products and the 5G "3+2" certification solutions.
Chapter 5 describes the architecture of 5G terminal products and proposes a new device classification of "Chipset based device" and "Module based device"
Chapter 6 introduces test methodologies towards 5G products from four aspects of Wireless Communication Tests, Software Capability Tests, Hardware Capability Tests and Service Capability Tests
Chapter 7 introduces the certification criteria for 5G chipset, module chipset based device and module based device. The target of One-stop test Capability is also proposed.

5 5G Terminal Product Architecture

The three typical scenarios of 5G Technology, eMBB, mMTC and URLLC, brings a number of enhancements including ultra-high speeds, large quantity of connection, ultra-low latencies, high performance, enhanced reliability and low power consumption. Benefit from these superior features, 5G is expected to be extensively applied to various industries, which leads to the bloom of 5G product types.

From 2G, 3G to 4G, mobile phone is the mainstream terminal product type. Definitely it will still play a significant role in 5G era. Meanwhile, to satisfy the growing requirements of "always online" and "connected to everything", many new terminal types with 5G capabilities have emerged in the field of consumer products, e.g. ACPC, Smart Watch, AR/VR etc.

On the other hand, 5G is expected to bring opportunities for traditional industries to upgrade productivity. Traditional industry devices integrated with 5G capabilities is a hotspot for 5G application in the industry, e.g. CPE, Smart Grid…In the field of new industries such as Robot, automatic drive and drone, these innovative devices equipped with 5G communication units also a potential flashpoint.

Above is the analysis of various types of 5G devices mainly classified as consumer products and industry devices. Considering that some devices are difficult to be classified into these two categories, for example Always Connected PC (ACPC) could be either consumer product or industry device, here we'd like to utilize another classification of "Chipset based Device" or "Module based Device"

From the perspective of implementation, 5G communication capabilities on these devices will be provided either by chipsets or modules, depending on the product design and manufactures' R&D capability. "Chipset based device" means the kind of devices with 5G communication capabilities embedding a 5G chipset. "Module based device" means the kind of devices with 5G communication capabilities embedding a 5G module. Of course the modules are integrated from 5G chipsets.

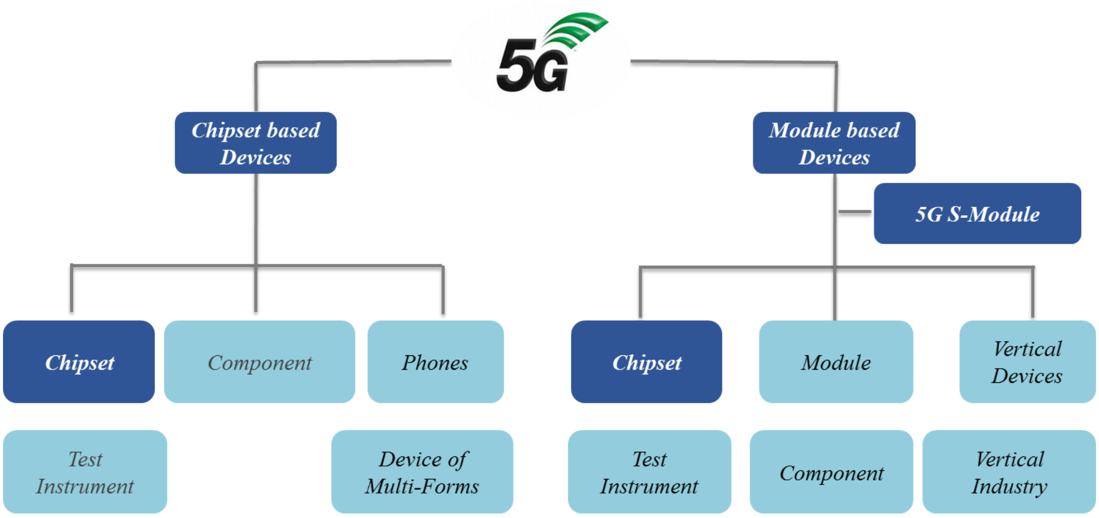

Figure 1 5G Terminal Product Architecture

6 5G Test Methodologies

6.1 Wireless Communication Tests

6.1.1 Conformance Tests

The 5G system communication standard is designed by 3GPP and covers all aspects including network and user equipment behavior and requirements. In addition to defining the technical specifications for the design of the 5G communication standards, 3GPP is also responsible for specifying the test requirements for the network and user equipment. This paper focus on the user equipment in particular. The test specified for user equipment in 3GPP is known as conformance tests. For 5G New Radio (NR), they cover the following areas:-

- Network architecture: Non-StandAlone (NSA) and StandAlone (SA)
- RF Transmitter and Receiver tests including interworking with LTE
- NR Demodulation and CSI Performance
- RF and Radio Resource Management (RRM)
- Protocol test for both the Radio Access Stratum (AS) and Non-Radio Access Stratum (NAS)

These tests are specifically design to ensure the user equipment would communicate with the network in accordance to the design as specified in the technical specifications. Each different part of the tests will have specific test cases defined to test against sections of the technical specifications with the expected test results to match the behavior as described.

3GPP is responsible for providing the test specifications. In the case of protocol test, 3GPP would further provide reference test implementation in TTCN and a mechanism to verify the test results against specific test platforms.

The correct implementation of the conformance test cases are checked by certification bodies. GCF is one such body that GTI would work in partnership. The implementation and execution of the conformance test cases from RAN5 in specific test platforms would go through a formal validation process to ensure the test is implemented and executed according to the test specifications. Test case will become approved by GCF once the validation is completed successfully. These approved test case would then become available for GTI operators to use for the conformance part of the overall 5G device tests.

6.1.2 Function and Performance Tests

6.1.2.1 Throughput

Smartphones displays are moving towards ever higher resolutions with HDR quality, with video streaming services such as Netflix following as sufficient devices reach the hands of consumers. Some operator has already committed to stream VR devices over 5G from 2020, which will let users feel like they are actually in the stadium with the athletes. 4K/8K broadcasting and 360-degree drone-enabled live video streaming requires extreme levels of bandwidth only 5G technologies can service, with multi-Gigabit throughput sufficient to make such systems a reality.

As above, throughput would be one of the most important factors affecting user experience of 5G Device. So, the test for 5G Device throughput performance is necessary.

From test technology point of view, following scenarios should be considered during creating test scripts for throughput in order to simulate all kinds of real usage.

- Direction of data transmission: downlink, uplink, bidirectional.
- Transmission channel: static or fading model which defined by 3GPP or other industry specs.
- Physical layer configuration: DL 4x4 MIMO, UL 2x2 MIMO, DL 256QAM, UL 256QAM.
- IP layer configuration: TCP or UDP.

The test scripts should cover all kind of combinations of above.

6.1.2.2 Mobility

5G device should support all kinds of mobility function in order to guarantee the continuity of service. It’s necessary to measure the mobility function of 5G device. Both Intra-system (NR) Mobility and Inter-RAT Mobility should be included.

- ***Intra-system (NR) Mobility***

From test and measurement to 5G device point of view, following scenarios should be considered to emulate multi-cell environment.

- Cell reselection by 5G device among multi-cell
- Intra-system handover. The handover would be under the condition such as: multi-cell with same frequency, multi-cell with different frequency (or even with different band).

During handover, IP layer data transmission should be check to ensure data service continuity.

- If Intra-system handover failure, 5G device should be checked whether Re-establish RRC connection to a prepared cell.

❍ ***Inter-RAT Mobility***

This section will mainly look at LTE and NR interworking scenarios. LTE-NR interworking is important for SA mode of operation, unlike for dual connectivity where there is simultaneous transmission across both RAT's most of the time. Inter-working between LTE and NR is not expected to be significantly different from what is defined in LTE specifications for interworking with other 3G networks. The Inter-RAT mobility is expected to be supported both, in idle mode as well as connected mode.

Of course, test script creating should consider the following scenarios:

- Cell reselection, from NR cell to E-UTRAN cell, or from E-UTRAN cell to NR cell.
- Cell reselection with NSA cell exists, from NR cell to NSA PCell, or from NSA PCell to NR cell.
- Inter-RAT handover, from NR to E-UTRAN cell.
- Inter-RAT Redirection, from NR to E-UTRAN cell, or from E-UTRAN to NR cell.

6.1.2.3 Voice Solution

5G has been introduced to accommodate the high throughput for services like Virtual Conferencing, hologram video transmission, real time video gaming, AR/VR and streaming as well as low latency services like virtual operation theatre from any part of the world. So, with the increase of bandwidth exponentially for the users, Voice and Video call solution will have the near perfect resolution on Virtual Conferencing services. The audio and video codecs should be introduced to support these Real time services. Unlike LTE, in 5G test system should go for testing the Data throughput for these high throughput Video calls.

From function and performance testing point of view, following scenarios should be considered during development of test script for voice solution, to simulate real network user experience:

- VoLTE in case of NSA with splitting of RTP data packets between LTE and NR Cell
- ViLTE in case of NSA with splitting of RTP data packets between LTE and NR Cell (Dedicated bearer for video to be present in NR leg)
- VoNR with Audio and Video calls
- CSFB scenarios
- Audio quality tests for multiple Audio codecs both in static channel and fading channel
- Video quality (PEVQ and other mechanism for MoS) tests for multiple Video codecs both in Static and Fading Channels
- Audio/Video Conferencing and multiparty call services
- Network slicing verification if specific slice is configured for VoNR PDNs
- Guaranteed bit rate and Maximum bit rate verification in case of High Quality Video call services
- Mobility during Call services (moving between different bandwidth cells and change in

codes)

- Emergency calls

6.1.2.4 Roaming

5G Devices should support the roaming capability depending upon the operator agreements. The roaming can be national and international type with designated roaming PLMNs can be provided in SIM parameters itself. The service continuity needs to be verified as different operator may work with different network parameters in roaming conditions. Introduction of Local break out and home routed options in system components of 5G makes verification of this section with multiple options with system components present in VPLMN or HPLMN (in service-based representation of 5G system components). The roaming test cases should include following scenarios:

- PLMN Selection/Cell Selection/Cell Reselection to 5G Roaming cells
- Measurements and mobility on/to 5G Roaming cells
- Access Restriction/Service restriction on 5G Roaming cells
- Service Continuity and data throughput on 5G roaming cells as the parameters differ from Home PLMN cell to VPLMN cell
- Priority Cell Selection/Reselection in case of multiple VPLMN roaming cells

6.1.2.5 High Speed Train

In some countries, the train could move with the speed over 300km/h or higher. With the increase of high speed moving environment, the demand of using mobiles is growing larger. Therefore, it is important to guarantee the user experience under the high speed train scenarios. High speed leads to high Doppler Shift, which may significantly decrease the demodulation performance of UE. For 5G device, the demodulation performance should meet the relevant requirements of 3GPP in the scenarios where the mobility speed is up to 500km/h.

Even more, for the test environment to emulator real case, following condition should be covered besides speed of train:

- Geometry info: antenna info of network side and MIMO configuration should be involved.
- Channel model info: to define kinds of channel mode, such as Plane, Mountain, Tunnel, City or Train Station.

In order to measure the performance of 5G device, it’s suggested to design the criteria of test cases likely to be:

- Successful rate of random access.
- Success rate of cell re-selection
- Success rate of handover
- Data transmission continuity
- Voice Capability
- Throughput capability

6.1.3 Interoperability Tests

6.1.3.1 Lab Tests

The interoperability test in the laboratory is to test the interoperation between 5G chipsets/terminals and network vendors to ensure the good interconnectivity.

Since the network compatibility test focuses on the wireless communication functions of the terminal, which is closely related to the chipset, it is suggested to execute this test on chipsets .In this stage, the requirements of test cases defined in <5G Sub-6GHz Device Interoperability Test Specification> shall be strictly observed, and a variety of targeted test environments shall be built with the real network equipment for case-by-case test and verification.

For the laboratory test phase, it is necessary to include the description of the software and hardware architecture of the test object, the topology diagram of the test environment configuration (which can cover all test cases), the coordination of test equipment, test tools, statistical and analytical methods of key indicators, and test cases.

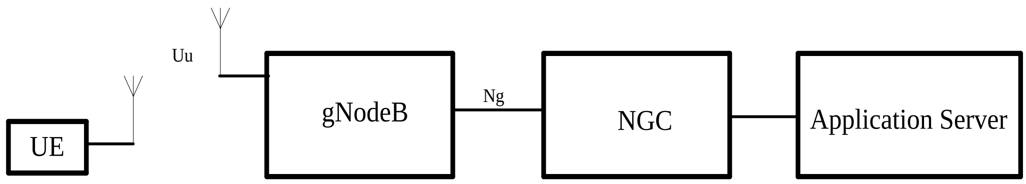

Figure 2 The functional testing environment in Lab

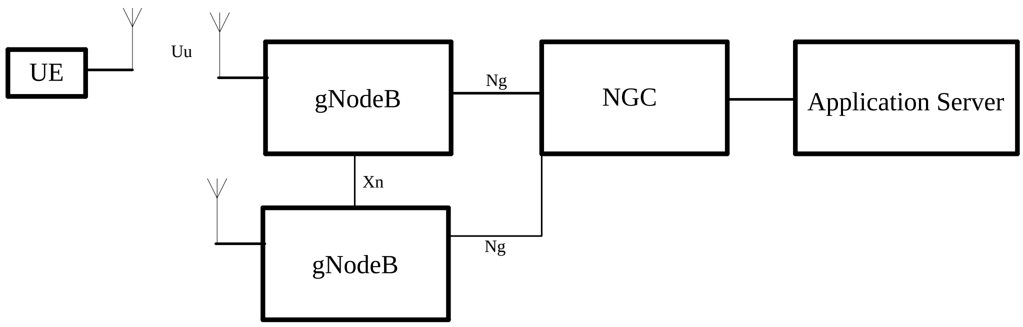

Figure 3 The mobility testing environment in Lab

Test content is divided into function and performance, stability, key technology verification.

Functional test includes: Physical Layer, L2, L3 subsystem configuration, physical channel, logical channel, resource scheduling, data conversion and compression, interface process, link adaptation, security, mobility management, interoperation between systems, business and network, operation and maintenance and other key processes.

Performance test includes: using test instrument, comparing service rate test, delay test and success rate test of ideal channel and fading channel under different motion speed conditions.

Stability testing focuses on maintaining or repeating the same test behavior for a long time. By observing the performance of the business and signaling process and combining with the test log information, the abnormal state in the test process is analyzed to find hidden hardware and software problems of the equipment.

Key technologies verification of terminal is to test some specific scenarios or test cases that solve exclusive problems or optimize their properties. In a laboratory controlled test environment, the technical solution can be verified and a conclusion can be drawn, which is conducive to the subsequent promotion and application.

In the laboratory, through the targeted design of the test environment, to verify certain functions or performance, to promote the network and terminal protocol understanding and implementation of the purpose of consistency. The adjustable link attenuation is used to simulate various signal coverage scenarios, and the program control mechanism is used to automate the execution of part of the test content, improve the test efficiency and reduce the interference of human factors, and enhance the reliability of test results.

6.1.3.2 Field Trial Tests

Field Trial testing emphatically focus on the verification for the terminal performance in the real network environment. The test will be impacted by the complicated wireless environment and geographical environment in field trial. The presence of line-of-sight channel and non line-of-sight channel will also influence on the result of the test. The suggestions is that strictly abide by the requirements defined in < 5G Sub-6GHz Device Field Trial Test Specification- SA mode> and <5G Sub-6GHz Device Field Trial Test Specification- NSA mode> ensure the comparability of the test result.

The field test content including: throughput, measurement accuracy and range (RSRP, SINR), the duration of cell-searching cell, success rate of cell access at fixed position and with different movement speed, intensity of network coverage of the control plane delay and delay, dragnet in the cut over the success rate, success rate of different system interoperability, outdoor voice quality.

The choice of test location in the field is differentiated according to the different test concerns of the use case. The test location is determined by the signal strength measured by the terminal and the SINR. Meanwhile, the results of the CDF pull network need to be referred to.

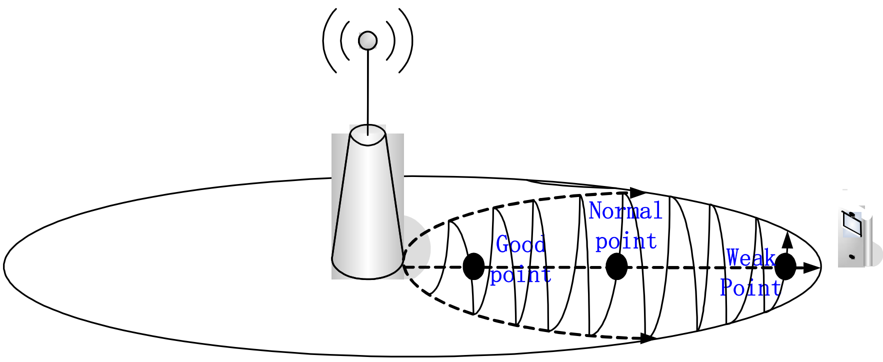

Figure 4 The performance testing environment in field

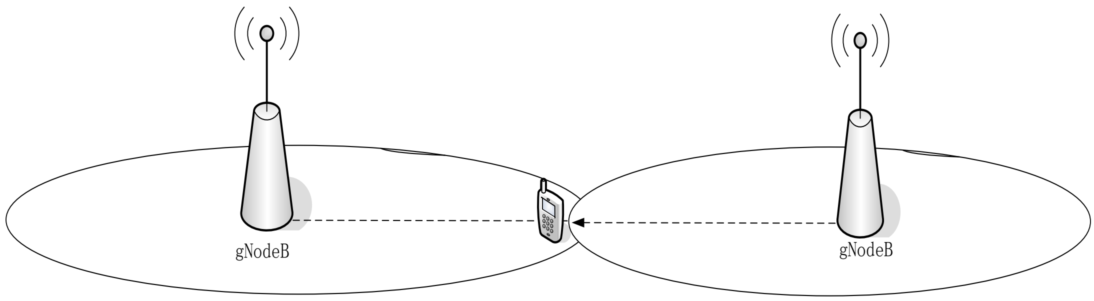

Figure 5 The mobility testing environment in field

As far as possible, the test route should include the main traffic roads that can be driven within its coverage, traversing the entire coverage of the cell as far as possible, and experiencing the switching scenes within and between base stations. Before each test, align the PC and system side of the test terminal. Mobility test requires repeated tests along the test route, with appropriate changes in motion speed to simulate different motion scenes.

The test terminal can connect with the computer to record and display the signaling sequence sent and received by the terminal, and can count the throughput, measurement, physical layer, application layer and other related information. The location and moving speed information of the test terminal can be recorded by the roadside equipment. If the test terminal can also realize relevant functions, the test will be more efficient.

6.2 Software Tests

Generally, 5G module has better software capability than LTE Module. The SW test cases are listed in the following section.

6.2.1 Management Function

- ***Device management (DM) Function***

Device management (DM) is a tool or software to distribute application, data and configuration to mobile communication device (here is the wireless module), and to monitor device activity. Device management is aiming to optimize the function and security of mobile wireless network, and maximally reduce the cost and module down time. It will monitor and control module and device access to the network, ensure device and data security, enforce module configuration. With the device management software, the manager could easily monitor the modules and devices.

An ideal device management system must be:

Be compatible with module operating system and application software, could be run by multiple service provider, could be executed over the air, could efficiently deploy the next generation hardware, operating system and application software, could add or remove device in the system if necessary, to guarantee the best network efficiency and security.:

Another Device Management function is FOTA - remote upgrade FW over the air, which will be introduced in the Software Upgrade section.

DM could be developed under the OMA DM protocol or LwM2M, is designed to provide individuals, families and enterprises with centralized management, protection and configuration of diverse mobile devices on various operating systems as well as mobile data and applications on these devices.

- ***Device Management Testing***

Any deliveries of Device Management software should be fully tested. The usual testing processes and methods are described below.

Before any device can be tested against the Operator's Lab or Production instances of the OMA servers, it must first complete Interoperability Testing against the given platform and the results of this testing must be supplied to the Operator. Also, together with Interoperability Testing, there is a Conformance Testing which aims to test device management protocols.

Therefore, the test cases are split in two categories, conformance and interoperability test cases.

The conformance test cases are aimed to verify the adherence to normative requirements described in the technical specifications. Generally, for instance, Conformance Testing is to test protocol commands: Get, Replace, Add, Delete, Exec, Copy.

The interoperability test cases are aimed to verify that implementations of the specifications work satisfactory. Generally, third party DM client/server production should be used to test against the targeted DM server/client production.

So far, Interoperability Testing is the main test method to test DM production. SCTS test tool is also used to test DM protocols.

For DM test, following functions need to be tested, first we need to register a module to the server, then report company/customer name, it needs to know IOT server build, device/module name and number, device type, DM client vendor, operating system with version, IOT start/complete date, factory bootstrap, OMA DM or LwM2M version supported, firmware update capability, engineering TAC for IOT testing, authentication method supported, WLAN MAC address supported in DDF Device detail, network initiated updates supported, user initiated updates supported, devices initiated updates supported, periodic device initiated schedule, background installation supported, generic alert format for user initiated updates, generic alert format for device initiated updates, Programmable code to expose the factory bootstrap account parameters, Programmable code to expose the transport node setting value, Programmable code to expose the Scheduled Events, Initial Activation Date Stamp supported in Device Detail MO inside DDF, Operating System Details supported in Device Detail MO inside DDF, HTTPS used for download of update package, AGPS supported, AGPS version, Server used to host the update packages

6.2.2 SIM Functions

For SIM function testing, many software function need to be tested, such as network registration, network selection, phone calls, SMS, data transfer etc. To test SIM function, SIM card need to be inserted into the module SIM slot, and a series of software test cases will be executed. The SIM function test could be tested under live network as well.

Following software testing are related to SIM functions and need to be tested:

1, For Network related testing, there are following items to be tested, such as Network registration, Operator selection, Facility lock, change password, Unstructured supplementary service data, supplementary service notifications, Preferred operator list, Read operator names, Preferred mode selection, Preferred band selection, Acquisitions order preference, Inquiring UE system information, Show network system mode, network registration status, Automatic time and time zone update, Time and time zone reporting, etc.

2, For Call Control, we need to test Voice hang up control, Hang up call, Select bearer service type, Radio link protocol, Service reporting control, Cellular result codes, List current calls, Extended error report, Call waiting, Call related supplementary services, Call forwarding number and conditions, Calling line identification presentation, Calling line identification restriction, Connected line identification presentation, DTMF and tone generation, Tone duration, Select type of address, Call mode, Speaker mute control, Microphone mute control, Enable or disable report MO ring URC, Switch voice channel device, Loudspeaker volume level, Set side tone, Change default ACDB filename, USB audio control, inhibit far-end echo, Inhibit echo during doubletalk, Inhibit echo in the high band, Enable or disable VOICE_MOD_ENABLE, Adjust echo canceller, Control codec by Host device or Module

3, For SMS tests, the following need to be tested: Select message service, Preferred message storage, Select SMS message format, SMS service centre address, Select cell broadcast message indication, Set text mode parameters, Show text mode parameters, New message acknowledgement to ME/TA, New message indications to TE, Select service for MO SMS messages, List SMS messages from preferred store, Read message, Send message, Send message from storage, Write message to memory, Delete message, Change message status, Set message valid period, Read and delete message, Send multi messages from storage, etc.

4, The related Phonebook function will be tested, such as Select phonebook memory storage, Read phonebook entries, Find phonebook entries, Write phonebook entry, subscriber numbers.

5, SIM Application Toolkit (STK) could be tested for following contents, SAT Indication, Get SAT information, SAT respond, STK switch, Set STK pdu format, Original STK PDU Envelope Command.

6.2.3 Debug Functions

The 5G module debugging function will be available on each different chipset platform.

For example, if we use a Qualcomm chipset, then we use QXDM to catch logs, and also the system logs need to be caught at the test instrument. SW engineers will analyze the logs and change software and configuration accordingly.

Usually 5G modules have debug functions and it needs the joint effort of SW engineers to resolve all the issues during the test process.

6.2.4 Firmware Upgrade Functions

All the 5G modules will have FW upgrade tool, it could be provided by the chipset vendor or the module vendor. For example, QPST is a Qualcomm Tool which could upgrade module FW, or the module vendors could use their own SW upgrade tool as well.

FOTA is another important FW upgrade feature; it allows the user to upgrade the module FW remotely over the air. The module vendors could use OMA-DM, LWM2M, or their own FOTA mechanism to implement FOTA. The Carrier could provide FOTA server, or the module vendor could provide FOTA server by themselves. The FOTA client will be implemented in the modules.

6.3 Hardware Tests

6.3.1 Power Consumption

Battery performance or power consumption testing is important for understanding the device power usage for the services like High Data Throughput and Call services enacted by the smartphones/wireless devices. The output current and input voltage are two measurements used by the power consumption tester when a wireless device is coupled with Base station simulator for signalling or performance cases. Dummy batteries can be used in case of smartphones kept under testing. Device in RRC idle mode and RRC inactive will use less power compare to when in RRC connected mode of signalling. The measurements will go high in RRC connected mode when devices start using the services like data throughput or streaming. In cell centre scenarios, devices will use less power compare to cell edge scenarios where UE receiver must apply more transmission power. As explained in below Figure, the power consumption tester output is connected to the device to set the input voltage and the power consumption tester measures the current used by device. The interface connected between power consumption tester to Base Station simulator should provide the measured current used by the device.

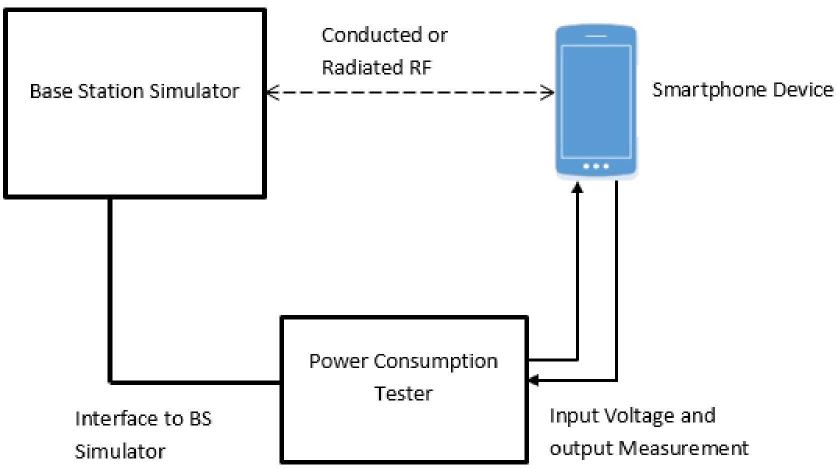

Figure 6 Test diagram

Typical power consumption test starts with simulating signalling scenario using a Base Station simulator. Then power consumption test step to be started with collecting the minimum, maximum and average current used by the device at the designated test point. These measurements are measured in mA unit. Depending upon the measurements, Base Station Simulator system should provide the necessary verdicts as defined in the test specifications.

6.3.2 Antenna Performance Tests

6.3.2.1 Test Metrics

6.3.2.1.1 Single Antenna Performance

- ***Parameters to be tested***

Good radiated performance is critical to the effective operation of a wireless device in today's networks. The total radiated power (TRP) test is required to characterize the radiated performance of the device. The TRP requires the spherical effective isotropic radiated power (EIRP) to be measured.

For a complete sphere measured with N theta intervals and M phi intervals, both with even angular spacing, the Total Radiated Power is calculated as follows.

$$TRP \cong \frac{\pi}{2NM} \sum_{i=1}^{N-1} \sum_{j=0}^{M-1} \left[EiRP_\theta(\theta_i, \phi_j) + EiRP_\phi(\theta_i, \phi_j) \right] \sin(\theta_i)$$

Receiver performance, or EIS (Effective Isotropic Sensitivity) is as important to the overall system performance as radiated transmitter performance. This test requires average spherical effective radiated receiver sensitivity (termed Total Isotropic Sensitivity, TIS) to be measured.

For a complete sphere measured with N theta intervals and M phi intervals, both with even angular spacing, the Total Isotropic Sensitivity is calculated as follows.

$$TIS \cong \frac{2NM}{\pi \sum_{i=1}^{N-1} \sum_{j=0}^{M-1} \left[\frac{1}{EIS_\theta(\theta_i, \phi_j)} + \frac{1}{EIS_\phi(\theta_i, \phi_j)} \right] \sin(\theta_i)}$$

where EIS is the radiated effective isotropic sensitivity measured at each direction and polarization.

- ***Test process***

Typical system schematics for both TRP and TIS measurements are shown in Figure 1 and Figure 2 respectively. The shown configurations are only representative examples of common measurement systems and do not represent an exhaustive list of allowable configurations.

Figure 7 and Figure 8 also include illustrations showing conducted power and conducted sensitivity measurement setups.

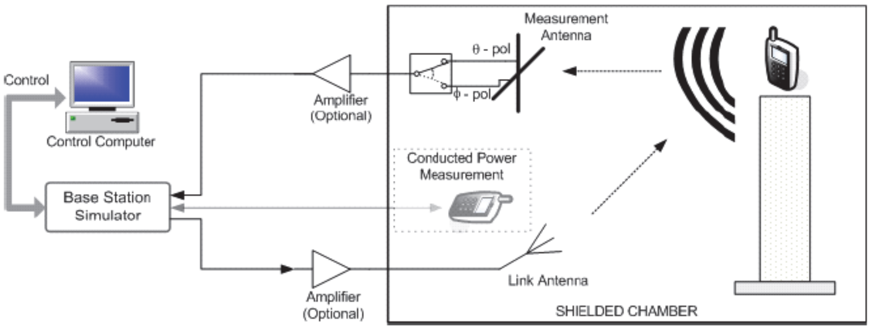

Figure 7 Simplified block diagram showing for a common configuration for the use of a base station simulator for TRP measurements

In figure 6, the forward link communication is transmitted through the communication link antenna and the reverse link is received through the measurement antenna. This configuration supports amplification of both signal paths if necessary.

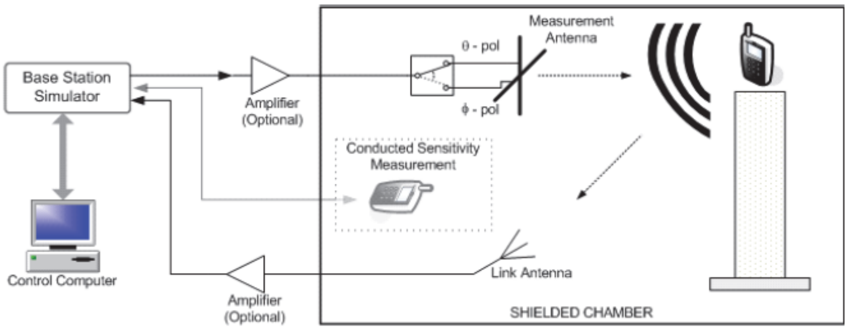

Figure 8 Simplified block diagram showing for a common configuration for TIS measurements

In figure 7, the forward link communication is transmitted through the measurement antenna and the reverse link is received through the communication link antenna. This configuration supports amplification of both signal paths if necessary.

6.3.2.1.2 Multi-antenna Performance

MIMO OTA mainly evaluate the average throughput performance of devices with multi antennas. Total Radiated Multi-antenna Sensitivity (TRMS) and the MIMO Average Radiated SIR Sensitivity (MARSS) are two most widely used metrics in MIMO OTA test. The above two metrics reflect devices' multi-antenna performance from different perspective.

In 3GPP, the MIMO OTA metric is Total Radiated Multi-antenna Sensitivity (TRMS) where the UE must meet or exceed data throughput levels defined as a percentage of the maximum throughput of the reference measurement channel (RMC). The cell power decreased step by step and no extra noise is added in the test environment. With this method, the throughput is mainly sensitive to 3 metrics, namely, ECC, power imbalance and the antenna efficiency.

In CTIA, the metric used for MIMO OTA is MIMO Average Radiated SIR Sensitivity (MARSS) where SIR is the signal to interference ratio. With this method, the influence of antenna efficiency can be neglected due to the added noise is much higher than the noise floor device. The throughput performance is only sensitive to the antenna correlation

MIMO OTA requires the minimum RS-EPRE/SINR at which the DUT can get 95% and 70% of the maximum throughput. Take the online video as an example, 95% throughput means the film is not so fluency and 70% represent the experience is not acceptable.

Except for the above end-to-end sensitivity test metrics, MIMO antenna property under specified channel model also can be evaluated by metrics of MIMO antenna gain, power imbalance and correlation. Given the information of Tx antenna pattern, channel model and the Rx antenna pattern, MIMO channel co-variance matrix can be derived according to MIMO channel fading coefficients generation equation. Then it is possible to compute a wide variety of signal characteristics from MIMO channel co-variance matrix, for example MIMO antenna gain, power imbalance and correlation, which can help predict and explain the variation in DUT performance. With these statistical characteristics MIMO channel capacity also can be calculated.

6.3.2.2 Test Methods

6.3.2.2.1 SPAC

Two acceptable methods of scanning the EUT are proposed. The “great circle” cut method, whereby the Measurement Antenna remains fixed and the EUT is rotated about two axes in sequential order. The “conical” cut method, whereby the EUT rotates on its long axis and the measurement antenna is moved to several locations both above and below the level of the EUT for each rotation.

Figure below shows the typical setup using a combined-axes system (the great circle cut method). In addition to the pictured theta-axis rotation, the EUT will have to be rotated about the Z-axis (phi rotation) in order to perform the full spherical scans.

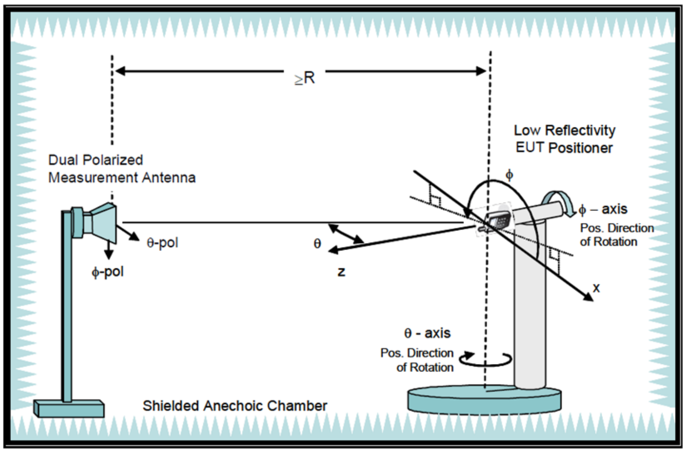

Figure 9 Typical setup for a combined-axes system

Figure below shows the typical setup using the distributed-axes system (the conical cut method). In this configuration, the phi and theta angles are traversed separately by the distributed positioners in the chamber.

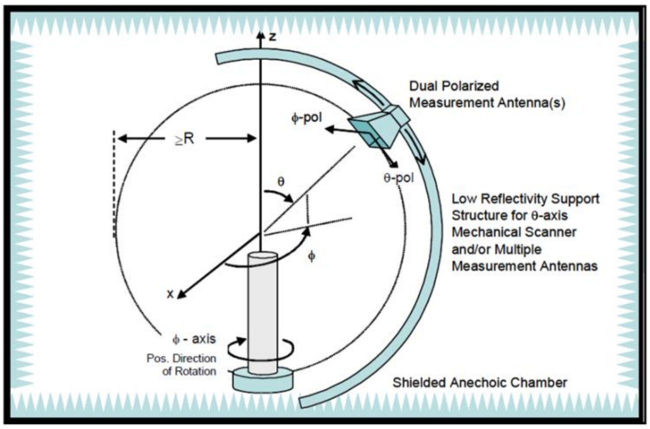

Figure 10 Typical setup for a distributed-axes system

6.3.2.2.2 MPAC

The basic concept for MPAC method is to generate the signal from different directions in the chamber using multiple probe antennas directly as shown in Figure 6-X. This figure shows a typical wireless propagation environment, signal transmitted from the BS propagates in the wireless environment and arrives to the phone from different directions with different delays. For each cluster the signal has the fading, doppler character. The fading and doppler characters will be emulated in channel emulator prior to injecting all the directional signals into the chamber. The character of different angle of arrival is emulated by the probe antennas located in different directions to send the signal to device directly from different directions. The resulting field distribution in the test volume is then integrated by the DUT antennas and processed by the receivers just as it does in real world multipath environment.

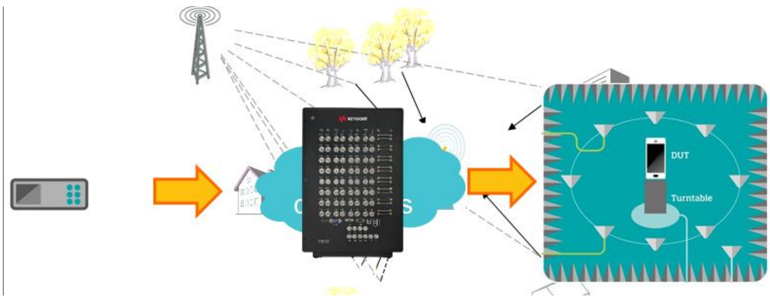

Figure 11 Concept of MPAC

Figure 10 shows the structure of MPAC which can be used for both UL and DL MIMO OTA test. The multi-cluster spatial channel models used to evaluate the DUT, a boundary array distributed as an azimuthal ring about the DUT is considered sufficient to adequately reproduce the target channel models. The transmit link should be established separately for the UL and DL MIMO test, such as the circulators and PAs which should be used to have a sufficiently large dynamic range for downlink and uplink signals

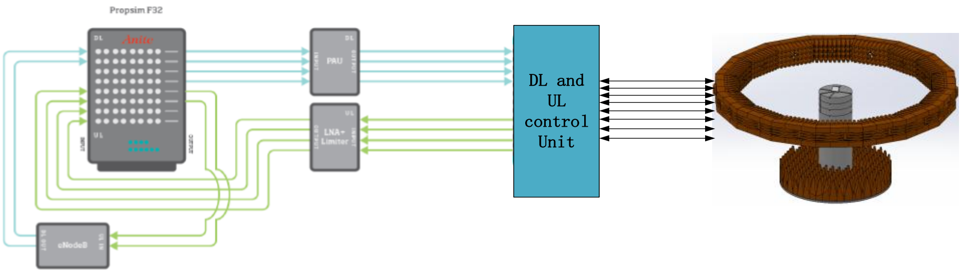

Figure 12 System configuration

6.3.2.2.3 RTS

The basic concept of RTS is shown as Figure 6-X, it divides the MIMO OTA test into two stages: 1) In the first stage the device antenna pattern is measured. 2) In the second stage a channel emulator is used to convolve the measured antenna pattern with the desired channel model to provide the stimulus radiated throughput test on the DUT. This process generates the signals at the DUT receiver that would have been received by the DUT been placed in the same 2D or 3D spatial field and feeds the signals to DUT RF ports by using the wireless cable. The wireless cable effect is generated by measuring the transmission matrix between probe antenna and DUT RF ports and applying the inverse matrix in the channel emulator to cancel the cross coupling. To accurately measure the antenna patterns of the device, it is necessary for the DUT to support amplitude and relative phase measurements of the antennas.

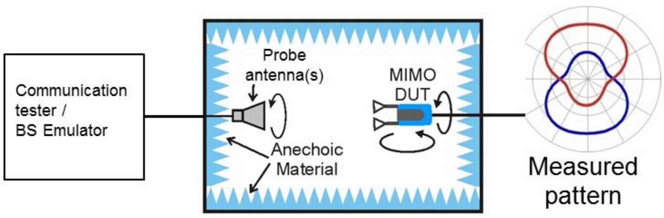

Figure 13 First stage: DUT antenna pattern measurement in an anechoic chamber

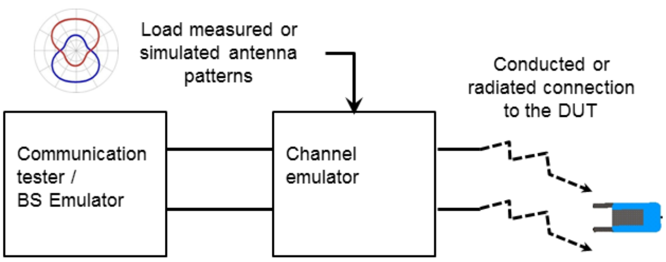

Figure 14 Second stage: DUT throughput measurement using a radiated connection in an anechoic chamber

In the RTS method multipath fading, the angular spread for transmit and receive sides and the XPR are all generated in the channel emulator enabling a simple anechoic chamber to emulate arbitrarily complex 2D or 3D channels. The 2 by 2 RTS MIMO test setup is shown in below figure 6-X. If MIMO performance with more than 2 Rx is measured, multiple probe antennas are required to be installed in the chamber. The number of probe antenna should be at least equal or larger than Rx RF channel number.

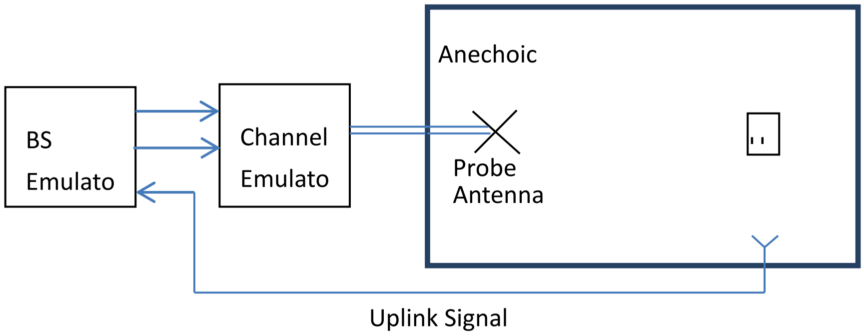

Figure 15 RTS MIMO OTA Test Setup

6.3.2.2.4 RC

The RC (Reverberation Chamber) test system consists of a reverberation chamber (with a turntable and a stirring sequence), and a radio communication tester, channel emulator is also needed sometimes.

OTA test in RC used a stirring sequence make the DUT experiences plane waves from an even distribution of angles on the sphere. This method evaluates the isotropic performance of DUT. RC can't output the antenna pattern of DUTs and the exact test results with RC is usually different from those with MPAC and RTS, but the performance rank of all the methods is usually consistent. Owning to that RC has advantages in measurement time and measurement cost, it is widely used by

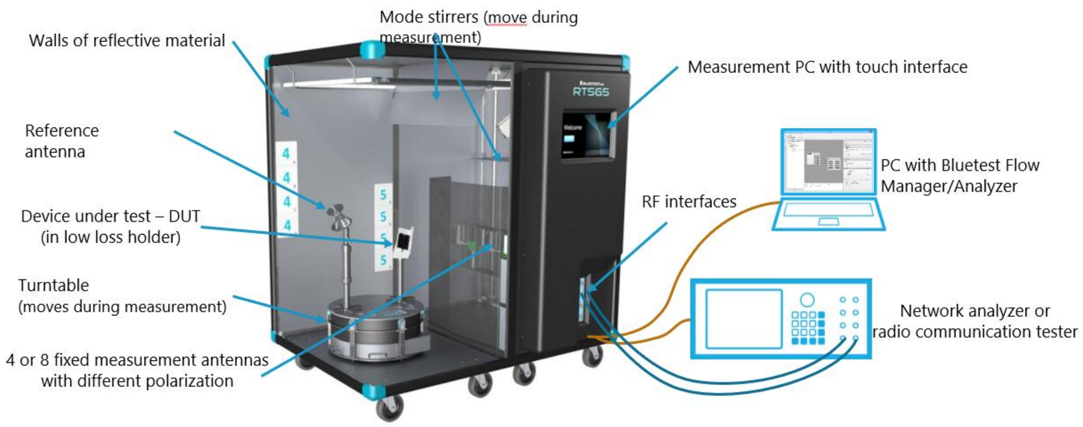

Figure 16 Measurement setup for MIMO TPUT measurements, utilizing a standalone reverberation chamber.

6.3.3 Interface

The 5G module interface test is mainly to verify the data transmission and communication between the module and AP host, 5G module interfaces include PCIe, USB3.0 and USB3.1, as shown in following figures

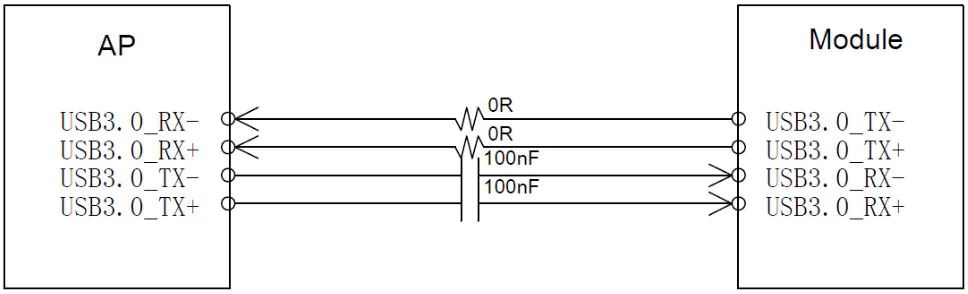

Figure 17 USB3.0 interface

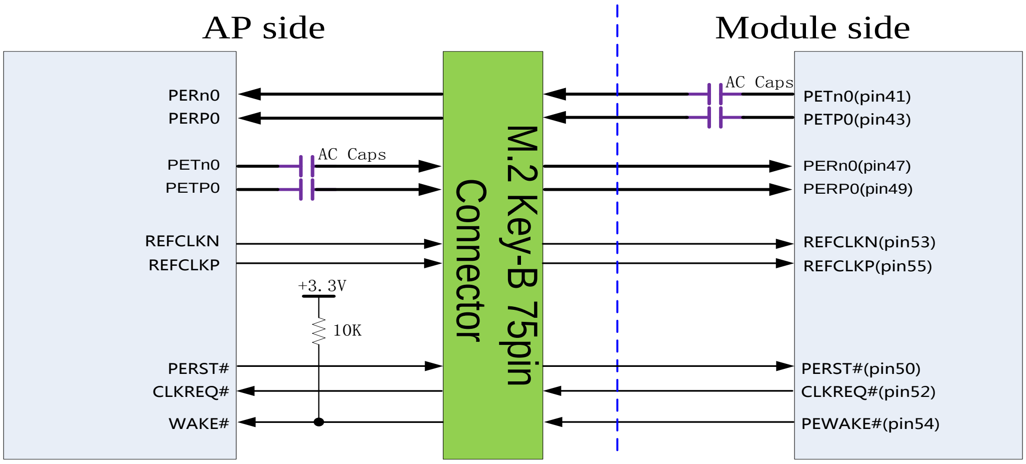

Figure 18 PCIe interface

USB3.1/USB3.1 Interface performance test includes: transmission speed rate, UI-Unit Interval, Rj-Tx random jitter-Dual Dirac, Mask Hits, TSSC-Freq-Dev-Max, TSSC-Freq-Dev-Min, TSSC-Mod-Rate - SSC Modulation rate, DJ-Tx deterministic Jitter-Dual Dirac, TJ-Tx total jitter-Dual Dirac at 1E-12 BER, Eye Height - Transmitter Eye Mask, Eye Width @ 1E-12 BER, LFPS Duty Cycle, LFPS Fall Time, LFPS TPeriod, LFPS Vcm-AC, LFPS Vtx-DIFF-PP, LFPS TBurst, LFPS TRepeat,

PCIe interface performance test includes: Total Jitter at BER, Minimum eye width, Deterministic Jitter Delta-Delta, Random Jitter (RMS),Minimum Transition Eye Voltage,Maximum Transition Eye Voltage, Minimum Non Transition Eye Voltage, Maxi um Non Transition Eye Voltage,Composit Bye Relght,CoIlposit Bye LocatloD ,Data Rate (Gb/s)

Regarding the test equipment, 5G module interface test equipments include MSO71604C, Keysight MSOV164A Oscilloscope and so on.

6.3.4 Size

GTI 5G S-Module defines module type including LGA, M.2, LCC and LGA+LCC. In each type the module size includes LGA 36mm*42mm, 42mm*46mm, M.2 30mm*52mm for Basic Type, LGA+LCC 44mm*45mm for Smart Type

The 5G sub-6Ghz module size test mainly to verify the module size is consistent with GTI S-module definition or module suppliers specification

In Design and Certification Test, vernier caliper tool is used to test module length, width and height

In Production line, size is tested using the module fixture by the way of putting the module in the fixture with standard size

Production line test size can use Quadratic meta-test, High magnification optical magnification imaging of the measured object is carried out by optical microscope. After the magnified object image is sent to the computer by CCD camera system, the contour and surface shape, size, angle and position of various complex work pieces can be detected efficiently, especially the microscopic detection and quality control of precision parts. Measuring data can be directly input into AUTOCAD to form a complete engineering drawing. Graphics can generate DXF documents, and can also be input into WORD, EXCEL, SP reports for statistical analysis. Simple Xbar can be delineated.

Figure 19 Vernier Caliper

Figure 20 Test tool in Production line

6.3.5 Reliability

The 5G Sub-6Ghz module reliability testing mainly examines the working state of communication module in various harsh environments, including High and Low Temperature Environment, transport, Long-term continuous work, working in Vibration Environment. At the end of reliability test, it must be verified that the module performance doesn't decrease and module can be work normal.

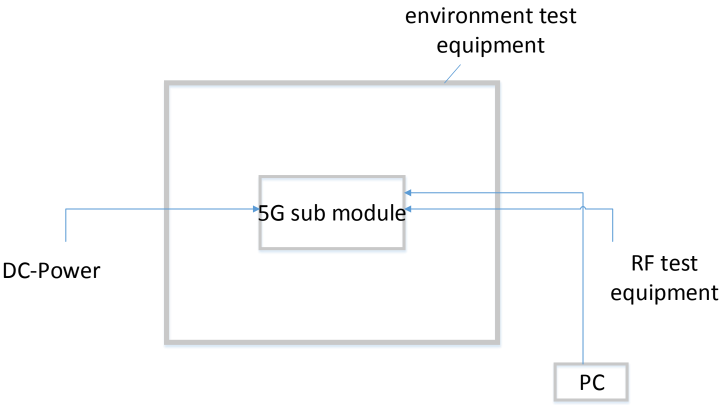

Figure 21 Test Diagram

5G Sub-6GHZ module reliability test includes : High Temp Start ,Low Temp start, High Temp Operating Life Test, Temp cycle, High Temp/ High Humidity, Damp Cycle, Thermal Shock, Vibration Operating: (Sinusoidal),Vibration Operating: (Random),Vibration (Non Operatin), Shock Test (operating),Shock (Shipping).

Table 1 Reliability Test Items and Test Specifications

Test Items		Test Specifications
High Temperature Transmit Performance		3GPP-38.521
Low Temperature Transmit Performance		3GPP-38.521
Function	Power ON/OFF	Function realizable
	Register and Connect	
	Handover	
	Max Throughput	
	Slow clock	
High Temperature Storage		IEC 60068-2-2
Low Temperature Storage		IEC 60068-2-1
Humidity		IEC 60068-2-3
Moist Heat Cycling		IEC 60068-2-30
Temperature Cycling		IEC 60068-2-14
Thermal Shock		IEC 60068-2-14
Tumbling		IEC 60068-2-32
Micro-drop		IEC 60068-2-32
ESD		CEI/IEC 61000-4-2

The reliability test equipment includes network simulator and environment test equipment including Vibration Tester , Drop Tester, Therml Chamber, Thermal Shock Chamber, Programmable Temperature / Humidity Chamber

6.4 Service Tests

6.4.1 Service Functional Tests

5G will promote a new upgrade of human interaction, providing users with more extreme service experiences such as ultra-high-definition live video, VR/AR (virtual reality / augmented reality) immersion games.

5G integration with industrial, medical, automotive, education, tourism and other industries will profoundly change the way of life, bring Internet Unmanned aerial vehicle, telemedicine, car networking, cloud desktop and other new applications for people to live, work, leisure, Provision of convenience for transport, etc.

Service capability test is a guarantee of these service experiences. Service functional test is the foundation of service capability tests. A good test system should include all key test metric, such as service interoperation, platform control, Cooperative service processing, data capture and report,etc. The test content varies depending on the service implemented by the device. Following takes live video, Unmanned aerial vehicle, sky office and AR as examples to introduce test contents.

- ***Ultra-high-definition live video***

Interoperability test could ensure the interconnection of units in the system,

Figure 22 live video

Typical system schematics for Ultra-high-definition live video service functional tests in Figure 22.

The UE has installed live video APP. When UE is in RRC Connected State after Registering in NR cell, start live Video APP, select one video to play. Check whether the UE could connect the live video APP and whether the UE could select and play live video.

- ***Unmanned Aerial Vehicle***

Unmanned aerial vehicle (UAV) is widely used in the field of infrastructure inspection because of its advantages of low cost, high flexibility, high security, less impact on natural environment and terrain, and better viewing angle. the Unmanned aerial vehicle inspection can not only avoid the safety risk of climbing tower operation, but also can view the details of equipment from 360 ° perspective.

Improve the quality of inspection. From the aspects of operation safety, operation efficiency, operation quality and so on, unmanned aerial vehicle (UAV) is gradually replacing manual patrol, which is the inevitable choice for electric power industry to solve the old and difficult problems and to carry out intelligent inspection technology.

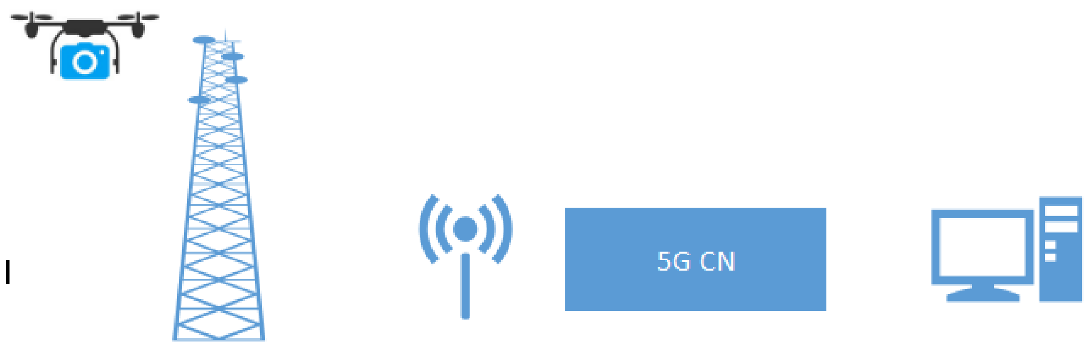

Figure 23 Unmanned Aerial Vehicle

Typical system schematics for Internet Unmanned aerial vehicle service functional tests in Figure 23.

With a zoom camera mounted, a networked UAV can perform tasks such as loose screws, tags, video capture and reporting according to the tasks specified by the control platform, and can also complete the calculation of antenna hanging height and inclination angle combined with image recognition. And generate inspection records and inspection report.

- ***Sky office***

Sky office achieves maximum lightweight, users can just open a web browser to easily run powerful cloud office applications instead of only installing bloated client software. Secondly, using SaaS mode, customers can use cloud office application in the form of on-demand payment, so as to reduce the cost of office.

Sky office applications have powerful collaborative characteristics, and their powerful cloud storage ability not only makes data documents everywhere, but also combines new concepts such as cloud communication to communicate and discuss documents intuitively, or to carry out multi-person collaborative editing. Therefore, the efficiency and quality of the team cooperation project can be greatly improved.

Collaborative is the key KPI of 5G cloud office,Upload and download documents, multiple co-editing, approval platform, attendance platform and other platforms, video conferencing.

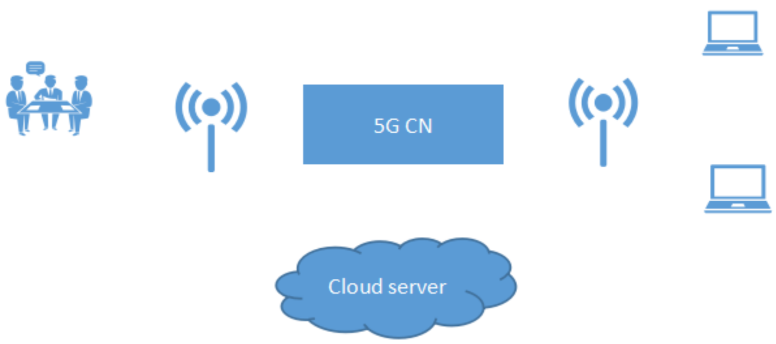

Figure 24 Sky office

- ***AR***

AR is a new generation of information technology, such as near-eye reality, perceptive interaction, rendering processing, network transmission and content production, to build new business type across the end of the cloud to meet the needs of users in the field of experience.

The combination of AR and 5G can not only give full play to 5G low delay, large bandwidth and other technical characteristics, but also further expand the interactive and immersive experience of AR. It will be widely used in various industries. People can use AR for auxiliary maintenance equipment. The interworking between AR headset and cloud server is the key of server function tests.

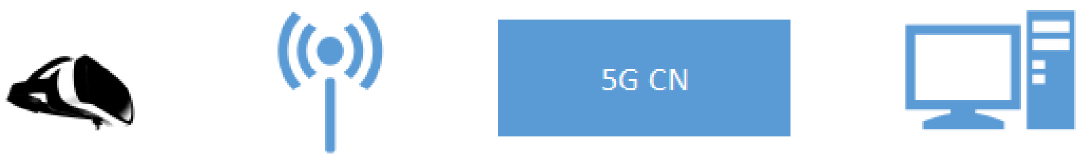

Figure 25 AR

6.4.2 Service Performance Tests

5G provides at least 10 times the peak rate of 4G, millisecond transmission delay and hundreds of billions of levels of connectivity to achieve a new leap in network performance with a new mobile communication system architecture.

Service functional test ensures that the system can be used, service performance test is related to the user experience, Upload and download speed, time delay, power consumption, voice / image quality are key test metrics of service performance test.

The test content varies depending on the service implemented by the device. Following takes live video, unmanned aerial vehicle, sky office and AR as examples to introduce test contents.

- ***Ultra-high-definition live video***

For the Ultra-high-definition live video, these KPIs are important: Video frame rate performance, audio-video sync performance, video freeze metrics, video impairment metrics,composite smoothness scores, PEVQ video MOS,POLQA audio MOS.

One of the significant performances is power consumption. User need long battery life to enjoy Ultra-high-definition live video. The service power consumption test should not only record the power consumed by communication module but also the energy consumed by display screen, application process and other related component.

With the increase of ultra-high data performance, the CPU and GPU computing speed of the mobile phone also increases, so fever test is also an important parameter for Ultra-high-definition live video. Use infrared thermometer to record the working temperature of the UE.

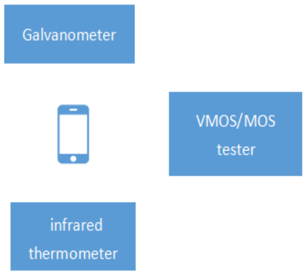

Figure 26 System schematics for service performance tests

Typical system schematics for service performance tests is shown in Figure 26. When UE is in RRC Connected State after Registering in NR cell, start 4K Online Video, measure the power consumption, working temperature，VMOS （video quality measurement）value under different channel conditions.

The test results include VMOS value from VMOS /MOS tester, power consumption from Galvanometer, working temperature from infrared thermometer and battery life of the device.

- ***Unmanned aerial vehicle***

Different from the requirement of download rate for live video, UAV requires higher uplink rate. Internet Unmanned aerial vehicle patrol scene network index is below.

Table 2 Performance requirement for UAE

Service attribute	UL rate	DL rate	Server time delay	Control time delay	Positional	Cover height
4K video	UL 25Mbps	DL	<200ms	<20ms	<0.5m	100m

return		300Kbps				

The network simulator sends commands to theinternet UAV, check the return video quality,UL rate, time delay.

- ***Sky office***

The high speed of 5G makes it possible to upload and download documents anytime and anywhere. The upload and download rate, time delay and image quality of video conference are all the key performance indicators of 5G sky officet.

- ***AR***

The enhancement of immersion depends on the resolution of image quality, the processing speed of rendering and interaction, and the overall improvement of transmission speed, among which the role of network transmission is becoming more and more important. From AR as a whole

In different stages of development, the demand for bandwidth and delay increases gradually. The bandwidth is gradually increased from 25Mbps to nearly 3.5 Gbps, and the delay is reduced from 30ms to less than 5ms.

Power Consumption is also important for AR, the battery need to cover the entire overhaul process.

7 5G Test and Certification Solution

Based on the test methodologies in Chapter 6, this Chapter introduces the certification criteria for 5G chipset, module chipset based device and module based device. The target of One-stop test Capability is also proposed.

7.1 “3+2” Test and Certification Solution

Corresponding to the 5G device classification of “Chipset based Device” and “Module based Device” in Chapter 5, here we propose the concept of “3+2” test and certification solution. “3” means the three layer certification scheme including chipset, module and device towards “Module based Device”. “2” means the dual-layer certification scheme including chipset and device towards “Chipset based Device”.

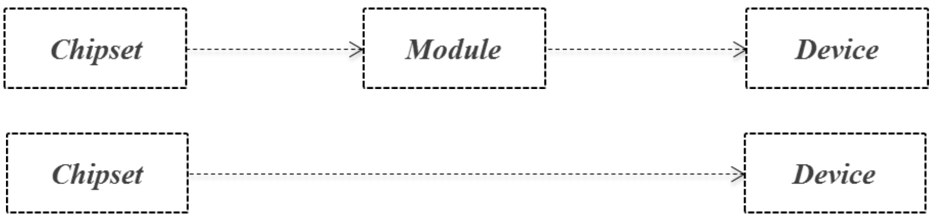

Figure 27: “3+2” test and certification solution

“3+2” test and certification solution is aiming to decompose the test contents into different objects including devices, embedded modules and embedded chipsets in a reasonable way. The target is to avoid the overlapped test contents, improve test efficiency and reduce test cost.

Based on the test methodologies in chapter 6, this section gives an introduction on "3+2" test and certification solution, and also describes the test requirement on each layer including chipset, module, chipset based device and module based device. Following figures XXX and XXX are overview of the certification scheme for 5G products.

Table 3 Certification scheme for module based device

Test Items		Chipset	Module	Module based Device
Wireless Communication Tests	RF	Y	Y	
	PCT	Y		
	RRM	Y	Y	
	Throughput	Y	Y	
	Mobility	Y		
	Voice Solution			Y*
	Roaming			Y**
	High Speed Train	Y		
	Lab Interoperability Tests	Y		
	Field Trail Tests	Y		
Software Tests	Management		Y	
Hardware Tests	Power Consumption	Y	Y	
	Antenna Performance Tests			Y
	Interface		Y	
	Size		Y	
	Reliability		Y	
Service Tests	Service Functional Tests			Y
	Service Performance Tests			Y
*: Only required for the devices with voice capability **: Not required if the device is static				

Table 4 Certification scheme for chipset based device

Test Items		Chipset	Chipset based Device
Wireless Communication Tests	RF	Y	Y
	PCT	Y	
	RRM	Y	Y
	Throughput	Y	Y
	Mobility	Y	
	Voice Solution		Y*
	Roaming		Y**

	High Speed Train	Y	
	Lab Interoperability Tests	Y	
	Field Trail Tests	Y	
Software Tests	Management		
Hardware Tests	Power Consumption	Y	Y
	Antenna Performance Tests		Y
	Interface		
	Size		
	Reliability		
Service Tests	Service Functional Tests		Y
	Service Performance Tests		Y

*: Only required for the devices with voice capability
**: Not required if the device is static

7.1.1 Chipset

Chipset embedded in 5G modules or devices is expected to provide 5G wireless communication capability, thus the test and certification toward chipsets should mainly focus on the Wireless Communication Tests. Besides this, power consumption test also needs to be considered.

- ***Wireless communication tests***

Conformance tests including RF, Protocol and RRM are recommended to be fully executed on chipsets to verify that the implementation of 5G chipsets keep complete consistent with 3GPP core specification. Protocol and RRM conformance tests could guarantee the quality of baseband chipset while RF tests mainly verify the performance of RFIC and FEM.

Conformance tests are fundamental and general test methods but couldn't reflect the difference of network deployments between different operators. Thus most operators will also design their own test scenarios based on test platform to simulate the real network deployment, for example mobility tests, voice solution tests, roaming and HST tests. Considering that the mobility and HST performance are mainly determined by baseband chipsets, it is recommended to test these two features on chipsets. Roaming and voice solution should be test on devices as they will also be impacted by the hardware design and roaming policy on devices.

In 5G era, benefited from enhanced mobile broadband, there will be a bloom of high data rate services such as VR, 4K/8K videos and live video streaming.. Then the throughput will become one of the key factors impacting user experience. Of course we could test the high data rate services on end devices directly, but the throughput performance on chipset is the foundation. Thus it is recommended to test throughput performance on chipsets.

It is strong recommended to execute the full interoperability tests including lab tests and filed trial tests on chipsets. This is the test scenarios closest the DUT behaviors under real network.

- ***Hardware capability tests***

Power consumption is one of the significant measurement criteria when evaluating the performance of 5G chipsets. The wider bandwidth, higher TX power and faster processing capability make power consumption a major challenge for 5G chipsets and devices. The power consumption optimizations not only reply on the software algorithm but also impacted by hardware design. The power consumption optimizations on wireless communication layer are mainly implemented by chipsets. Thus it is necessary to test power consumption on the level of chipsets.

- ***Overview of the tests items for chipsets***

Table 5 Certification scheme for chipsets

Test Items		Chipset
Wireless Communication Tests	RF	Y
	PCT	Y
	RRM	Y
	Throughput	Y
	Mobility	Y
	High Speed Train	Y
	Lab Interoperability Tests	Y
	Field Trail Tests	Y
Hardware Capability Tests	Power Consumption	Y

7.1.2 Module

The module itself is an intermediate link between the upstream standardized chipset and the downstream terminal communication product, which needs to meet the specific requirements for different customers and different application scenarios.

Table 6 Certification scheme for module

Test Items		Module
Wireless Communication Tests	RF	Y
	RRM	Y
	Throughput	Y
Software Tests	Management	Y
Hardware Tests	Power Consumption	Y
	Interface	Y
	Size	Y
	Reliability	Y

- ***Wireless Communication Tests***

Module is developed on chipset basis and the RF design is also independent. Therefore, the items listed in the table have been tested in Chipset should also be mandatory items on the Module side.

RF performance is a critical verification for 5G module. It is used to measure the modulation and demodulation performance of the module. According to 3GPP, the test content includes transmitter characteristics and receiver characteristics. According to the actual application, some additional test contents are added.

Table 7 Wireless Communication test scheme for Module

Test Items	Test Conditions	Standard	Module
Transmit Performance	According to 3GPP	3GPP-38.521	Y
Receiver Performance	According to 3GPP	3GPP-38.521	Y
Throughput	User defined	User-defined	Y

- ***Software Capability Test***

To guarantee the quality of 5G terminal products and satisfy the market requirements, the software test and certification items defined in section 6.2 should be performed for module, especially the following items

- AT Command that Conformed to 3GPP Specification Test
- Firmware Upgrade Functions Test
- Power ON/OFF Test
- USB tethering

- ***Hardware Capability Tests***

Power consumption is an important index of product. When using battery power, the battery life is the service life of the module. Therefore, it is necessary to test the power consumption as a reference to calculate the service life. The power consumption test needs to include the power consumption in various working modes including working state, power off state, sleep state, idle state and active state.

In terms of interfaces, the module should support the following interface at least.

- Support one Universal Serial Bus Specification USB 2.0 high speed/3.1 super speed interface.
- Support PCIe standards, Gen 3.
- Support two dual voltage USIM interface

Reliability testing is used to judge the application scenarios of modules. As defined in section 6.3.5, the reliability of the module is tested by changing environmental variables such as temperature, humidity, vibration and static electricity. Set different environment variables according to different application scenarios.

7.1.3 Chipset Based Device

For chipset based device, the 5G communication capability is mainly provided by chipsets. Theoretically there is no significant difference between the device and embedded chipsets on the aspect of wireless communication protocol stack. If the functional tests, such as protocol conformance test, mobility test, HST test and etc.., have fully tested on the embedded chipsets, they could be exempted on “chipset based device”. Of course the voice solution should be tested on device if the device has voice capability because it’s tightly bound to the device implementation. So does the roaming test for mobile devices – it means for static device there is no need to test roaming scenario.

Regarding the performance test including RF performance, throughput and power consumption, it’s necessary to test on devices as the RF design in devices maybe varies from chipsets.

One of the significant differences between chipset and chipset based device is that device should integrate antennas. For 5G device, because of the multiple transmit and multiple receiving, the number of antennas has reached a new level which leads to the challenge of antenna design. Thus antenna performance is a mandatory test for 5G devices.

Following table takes smart phone as an example to list the certification solution for chipset based device.

Table 8 Certification scheme for Chipset based Device

Test Items		Chipset based Device
Wireless Communication Tests	RF	Y
	RRM	Y
	Throughput	Y
	Voice Solution	Y
	Roaming	Y
Hardware Tests	Power Consumption	Y
	Antenna Performance Tests	Y
Service Tests	Service Functional Tests	Y
	Service Performance Tests	Y

7.1.4 Module Based Device

Device types vary in 5G era. As a key equipment of realizing connection of everything, modules play an essential role in 5G device. The major application contexts for 5G wireless communication modules in industries cover: the realization of standardized production monitoring in smart agriculture, environmental monitoring(including hydrological data and pollution data), industrial sensing monitoring, power transmission and distribution equipment monitoring, remote metering(including electricity meter, water meter and gas meter), smart health care, smart city, smart furniture, security control , smart logistics, smart transportation and smart wearing. Following the further promotion and development of IoT applications, more scenarios would spring out and an explosive rise can be foresaw in the demand for cellular wireless communication modules. Therefore, the technical and electrical specification of standardized modules is in need in the market as well as in the technology field. Typical devices for application modules include:

- Consumer type: ACPC, AR/VR, home CPE

- Industrial type: drone, robot, monitoring camera, smart POS, gateway, metering, ect.

The test method of 5G S-Module has been briefly described in 7.2.2, based on which we would further discuss the test method for the devices integrated 5G modules.

To guarantee the quality of 5G terminal products and satisfy the market requirements, following three types of test and certification for module based devices are proposed:

- Compulsory certification test
- Industrial regulatory test
- Customized test

Compulsory certification test includes 3C certification test, SRRC test, entrance testing of government, etc...Industrial regulatory test includes GCF/PTCRB/CTIA test, GTI test, TAF test, etc.. Customized test includes operator acceptance test, etc...

Besides the above tests, module based device still need extra performance test such as OTA test, etc. In the following section, we would take CPE for example to support the analysis. As shown in Table 7.2.1, based on the already-taken RF conformance test, power consumption test and throughput test on embedded module, the Module based Device would still need antenna performance test, roaming tests and service tests to guarantee its capability in practical use scenario.

Table 9 Test and Certification for CPE

Test Items		Module	Module based Device
Wireless Communication Tests	RF	Y	
	PCT		
	RRM	Y	
	Throughput	Y	
	Mobility		
	Voice Solution		
	Roaming		Y
	High Speed Train		
	Lab Interoperability Tests		
	Field Trail Tests		
Software Tests	Management	Y	
Hardware Capability Tests	Power Consumption	Y	
	Antenna Performance Tests		Y
	Interface	Y	
	Size	Y	
	Reliability	Y	
Service Tests	Service Functional Tests		Y
	Service Performance Tests		Y

7.2 One-Stop Test Capability

From M-IoT to 5G, the vision of GTI certification is to provide global partners with credible product quality assessment. With this in mind, GTI is committing to construct One-Stop Test Capability based on the collaboration with test laboratory partners. By aggregating the laboratories with specific test capability together, GTI is expected to be a full-scale and high-efficient test and certification platform for 5G products.

8 Summary

This whitepaper defines the test and certification solution for 5G terminal products based on the characteristics of 5G technology. This test and certification solution is expected to provide certification criteria for operators and industry partners, provide standard test methods for 5G manufactures and test vendors, provide guideline on test capability construction for test laboratory, and finally facilitate the maturity of 5G devices.