Trends in 5G NR mmWave UE RF Conformance Test Standards

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[Summary] The 3GPP TSG-RAN Working Group 5 (RAN5) is developing Conformance Test specifications for user equipment (UE). NR FR2 (mmWave) adopts the over-the-air (OTA) test method in contrast to the wired tests adopted for LTE and NR FR1, and the active discussions on the test methodology has been taken place. This article explains the 3GPP standardization on 5G NR FR2 UE RF Conformance Test between around 2018 and November 2021. It also describes current issues and future prospects on conformance test. In addition, it outlines Anritsu's standards-compliant RF Conformance Test System ME7873NR.

1 Introduction

The standardization body 3rd Generation Partnership Project (3GPP) is developing the specifications for the 5G New Radio (NR) standard. Within 3GPP, the TSG-RAN Working Group (WG) 5 (RAN5) is developing Conformance Test specifications for user equipment (UE). These RF Conformance Test specifications are divided into three parts: Transmitter/Receiver (TRx)[2], Demodulation)[3, 4], and Radio Resource Management (RRM) tests[5, 6], based on RF requirements developed by TSG-RAN WG4 (RAN4). The Conformance Test specifications are mainly used by the certification organizations such as Global Certification Forum (GCF) and PCS Type Certification Review Board (PTCRB) certification organizations.

The 5G NR standard defines two frequency bands: Frequency Range 1 (FR1), and Frequency Range 2 (FR2)[1]. Unlike the FR1 band (lower than about 6 GHz) used by previous mobile communications technologies, such as Long Term Evolution (LTE), the FR2 band is a new frequency band introduced by 5G NR in the quasi-millimeter and millimeter (mmWave) range above 24.25 GHz. The LTE and FR1 RF requirements are verified by the testing at the UE antenna connector using the Conducted Test over a wired connection. In contrast, the FR2 RF requirements are verified by over-the-air (OTA) testing since there is no antenna connector because the transceiver and antenna sections are integrated in FR2.

Previously, 3GPP has not developed any standard for mmWave OTA tests, resulting in discussions about various issues. Generally, RAN5 starts developing Conformance Test standards after other WG have completed the core specifications for related function, protocol, and requirements. Although the 5G NR Release 15 core standard was already completed[7] in 2018, the Conformance Test specifications for Release 15 were still under discussion as of November 2021. This paper explains the RAN4 and RAN5 standardization process from around 2018 to November 2021 along with the FR2 UE RF Conformance Test specifications, issues, and future prospects. It also outlines Anritsu's RF Conformance Test System ME7873NR, which supports with these standards. In addition to the Conformance Test, 3GPP has also defined an OTA test standard called the SISO/MIMO OTA Test[8, 9]. It measures antenna performance in a more realistic environment using the simulated human body models, which is not supported by the regular RF Conformance Test. The Conformance Test specifications and SISO/MIMO OTA test specifications are differentiated and specified in separated specifications even though they both adopt OTA test method in FR2.

This paper does not cover the SISO/MIMO OTA Test.

2 Current FR2 RF Conformance Test Status

2.1 OTA Test Outline

This section outlines the OTA Test in the RF Conformance Test standard.

2.1.1 Test Methods

The RAN4 WG started studies related to the FR2 OTA test method from 2017 and agreed the following methods in 2018[10].

- Direct Far Field (DFF) method
- Indirect Far Field (IFF) method
- Near Field to Far Field Transform (NFTF) method

Far Field test method represented by DFF and IFF is the method to measure the signals in far-field. On the other hand, the NFTF is a method to measure the signal in Radiative Near Field (Figure 1).

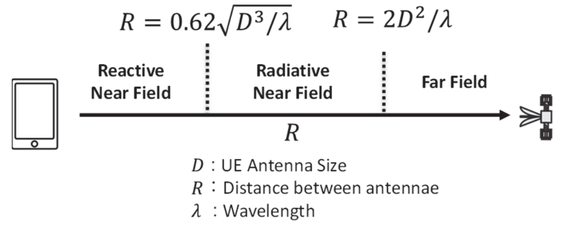


Figure 1 Far Field and Near Field[11)]

RAN5 started development of FR2 Conformance Test specifications from 2018 to determine the measurement uncertainty (MU) and test procedure for each method. For TRx testing, since test system vendors focused on the development of IFF method, now IFF is effectively a single test method that can be used in TRx testing. On the other hand, both the DFF and IFF methods were examined for the demodulation and RRM test standards. Although the NFTF method is currently not used for the Conformance Test, the Near Field method might be adopted again as described in section 3. Figure 2 shows the two far-field methods (DFF and IFF) approved for the Conformance Test. The Quiet Zone in this figure is the volume in the OTA chamber where the phase and amplitude are nearly uniform. The Quality of Quiet Zone (QoQZ) measurement method is specified in Annex O of TS 38.521-2[2)] and is included as one element of the MU. In contrast to the IFF method using a parabolic reflector to form planar waves, the DFF method positions the measurement antenna at some distant position beyond the far field distance so that the radiated waves appear to be planar. DFF requires a large space when the antenna size D is large, and also requires disclosure of information on D by the UE vendor. On the other hand, IFF method requires smaller space even with large antenna size D because the required distance between the UE and measurement antenna does not depend on D. Consequently, the IFF system is called a Compact Antenna Test Range (CATR) method.

2.1.2 Test Approach

Three approaches (Black Box, Gray Box, White Box) were considered depending upon the degree of information disclosure about the UE antenna implementation. Table 1 outlines each approach. The White-Box approach was not adopted for the Conformance Test due to concerns from UE vendors about disclosing design information. The method for disclosing information about the antenna implementation required by the Grey-Box approach is specified in TS 38.508-2[12)].

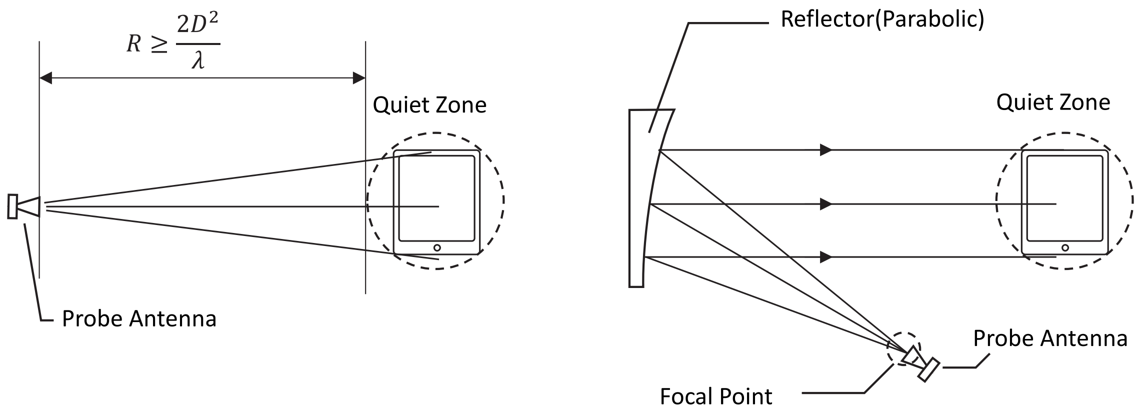


Figure 2 DFF (left) and IFF (right) Methods

Table 1 Test Approach

Approach	Disclosed Data	Adopted	Pros	Cons
White Box	Active antenna position, size	No	Smaller test system Higher accuracy than Black Box	Risk of disclosing UE design data for UE vendor Difficult active antenna switching sometimes
Black Box	None	Yes	Not necessary to disclose UE design data Support active antenna switching	Large measurement system size for large UE size Lower measurement accuracy than White Box
Grey Box	Partial data on active antenna position and size	Yes	Intermediate between White Box and Black Box	

2.1.3 Quiet Zone Size

From the viewpoint of test system standardization, the size of the Quiet Zone is not implementation-dependent but is specified with some specific sizes. The current RF Conformance Test specifies four Quiet Zone sizes of 20, 30, 40, and 55 cm, and the test procedure and MU, etc., are specified for each size.

The 20 and 30-cm sizes were first introduced for handheld devices such as smartphones and tablets. The 40 and 55-cm sizes were newly introduced in 2021 for larger devices such as tablets and laptop PCs. The 40-cm Quiet Zone was standardized on the premise that existing 30-cm test systems will be adapted to support 40 cm size from the perspective of reducing test costs. Moreover, as the cons (Table 1) of the Black-Box approach becomes dominant for a larger Quiet Zone, the declaration of antenna position is newly introduced in addition to the antenna size D (only required for DFF). Specifically, the UE vendor is required to disclose the spherical area (center point coordinates and radius) that contains the antenna, and if the UE can be placed so that the spherical area is contained in the Quiet Zone of the test system, then testing is possible (Figure 3).

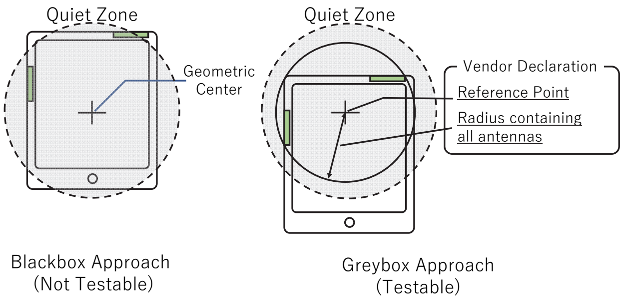


Figure 3 Grey Box Approach

2.1.4 Target Device

There are various types of 5G NR devices such as smartphone, tablet, laptop, mobile router, in-vehicle device if classified by the application. The 3GPP standard uses the power class (PC) to classify devices. Table 2 lists the correspondence between power class and UE type in ITS 38.101-2[1].

Table 2 Power Class and UE type

Power Class	Typical UE type
1	Fixed wireless access (FWA) UE
2	Vehicular UE
3	Handheld UE
4	High-power non-handheld UE
5	Fixed wireless access (FWA) UE

The RF requirements specified by RAN4 are defined in principle for each PC. From the Conformance Test viewpoint, the test method changes with power class due to differences in RF requirements and UE implementation. For example, PC1 UE uses a phased array antenna with more antenna elements than that in PC3 UE, resulting in a smaller half power beam width, which requires finer spatial sampling (measurement grid, see below) to keep measurement error below a certain level. The standardization in RAN5 has progressed from PC3, including smart phones and tablet terminals, and some progress has also been made in PC1. Other power classes are still in progress and will be standardized in the future according to market requirements. It should be noted that there is no standard that associates a power class with a specific UE size.

2.1.5 Definition of Coordinate System

Figure 4 shows the coordinate system for the Conformance Test system. A test system for measuring whole surface of a sphere must have two rotational degrees of freedom. There are two possible implementing depending on how to place the rotational axis: the Combined-axis system and the Distributed-axis system. The latter method locates one axis at a positioner and the other at the probe antenna side while the former method keeps the two axes at the positioner side. Both methods have a spatial zone where sufficient accuracy is not guaranteed due to the positioner support pole. $\theta = 0°$ is defined as the direction towards the probe antenna or reflector and $\theta = 180°$ is defined as the direction towards the positioner support pole.

Guaranteeing accuracy for the hemisphere of $90° < \theta \leq 180°$ depends on the test system implementation. Test system vendor must demonstrate the accuracy by the QoQZ measurement result. If sufficient accuracy cannot be guaranteed, the UE must be measured by flipping the hemisphere to avoid measurement in the hemisphere with the support pole. This is called the Re-positioning Concept.

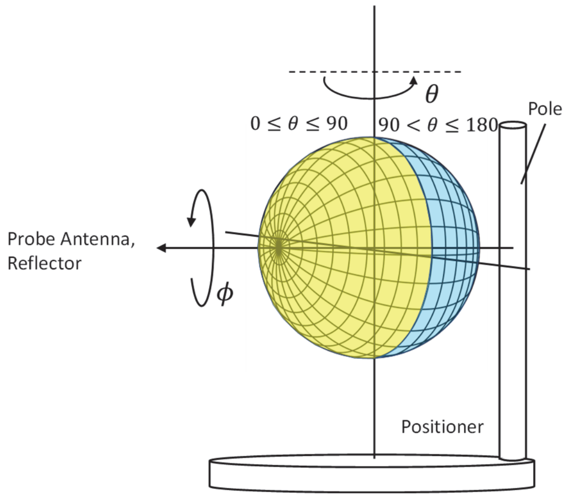


Figure 4 Combined-axis System

2.1.6 Measurement Grid

In actual testing, since it is impossible to measure values continuously over the entire spherical surface, discrete measurement points are put on the sphere. The set of points is called the Measurement Grid. 3GPP defines two types of Measurement Grid: the Constant Step Size Grid and the Constant Density Grid. Figure 5 shows examples of these measurement grids with 266 points and Table 3 lists the features of each grid.

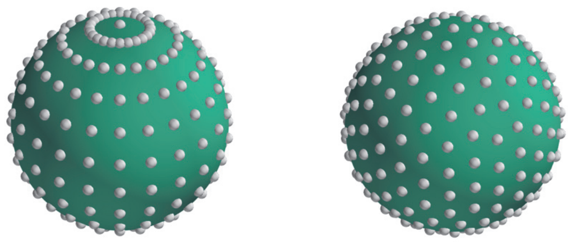


Figure 5 Measurement Grid Examples
Left: Constant Step Size Grid 266 points (15° step)
Right: Constant Density Grid 266 points

Table 3 Features of Two Measurement Grids

	Constant Step Size Grid	Constant Density Grid
Arrange-ment	Equal division on polar coordinate plane	Distributed with nearly equal density
Pros	High-speed scanning due to linear arrangement of each point on θ, ϕ plane	Small error and number of points
Cons	Large inherent error requires large number of points to reduce error	Scanning requires longer time

Annex M in TS 38.521-2[2)] specifies the minimum required number of points for each test. These point numbers are determined so that measurement error is below a certain value for assumed UE beam emission patterns (reference emission pattern). The reference emission pattern assumes either a 2 × 4 or 2 × 8 phased antenna array for PC3 and 12 × 12 for PC1. The tests except for spurious use the beam emission pattern when the element interval is one-half the carrier-frequency wavelength (Figure 6). The spurious test uses the radiation pattern at the second harmonic emitted from the same phased array antenna.

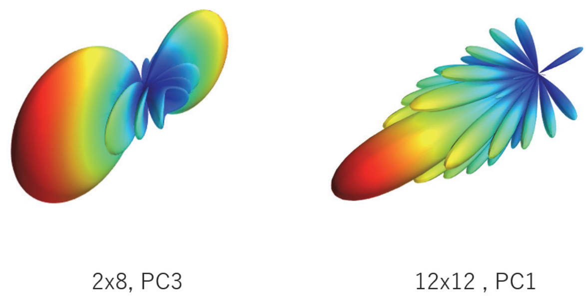


Figure 6 Reference Emission Patterns for PC3 and PC1

2.2 Typical Test Metrics and Measurement Method

The FR2 transmitter (Tx) requirements are defined as the Equivalent Isotropic Radiated Power (EIRP) indicating emitted power in one direction, the Total Radiated Power (TRP), and the EIRP distribution over the entire spherical surface. Similarly, the FR2 receiver (Rx) requirements are specified as the Effective Isotropic Sensitivity (EIS) indicating the receiver sensitivity in one direction, and distribution of EIS over the entire spherical surface. These test metrics have a common measurement procedure irrespective of the test item. This chapter outlines the typical test metrics and its measurement procedure commonly used by the FR2 RF Conformance Test. Annex 1 lists the test metrics for each TRx test case.

2.2.1 Peak Equivalent Isotropic Radiated Power (EIRP)

Peak EIRP is the maximum EIRP over the entire spherical surface. As shown in Annex 1, many carrier-frequency requirements are specified either with Peak EIRP or the quantity at the Tx Beam Peak direction. The Peak EIRP search procedure is described in Annex K.1 of TS 38.521-2[2)] and is summarized below.

1. Measure EIRP at each point i of the Beam Peak Search Grid. EIRP is measured at each point for each downlink (DL) signal polarization θ and ϕ. Write them $EIRP_{link=\theta}(\theta_i, \phi_i)$ and $EIRP_{link=\phi}(\theta_i, \phi_i)$, respectively.
2. The maximum value among $EIRP_{link=\theta}$, $EIRP_{link=\phi}$ over whole points is selected as the Peak EIRP, and the position of the point and the DL polarization direction are defined as Tx Beam Peak direction.

When applying the Re-positioning Concept, step 1 is performed for each hemisphere by flipping the UE.

More than 800 points are specified for the Beam Peak Search PC3 Constant Density Grid, requiring a long search time in step 1. Hence, the use of the Coarse Scan method described in TS 38.521-2[2)] Annex M.2.2 is also allowed. In the Coarse Scan, measurement is performed firstly on a rough measurement grid, and then the true peak is searched for by measuring with finer grid over the vicinity of the point where the high EIRP values are obtained with a rough measurement grid. Details of the Coarse Scan procedure are left to the test-system implementation.

2.2.2 TRP

TRP is the sum of the power radiated from the UE. The requirement of the unwanted emissions such as Spurious and Spectrum Emission Mask (SEM) tests are defined with TRP. It is equivalent to the mean of the EIRP over the entire sphere and is approximated by the following equations depending to the measurement grid type.

Constant Step Grid:

$$TRP \approx \frac{\pi}{2NM}\sum_{i=1}^{N}\sum_{j=1}^{M} EIRP(\theta_i,\phi_j)\,W(\theta_i) \qquad (1)$$

$W(\theta_i)$ is a weighting factor for correcting the non-uniformity of the measurement grid. It is either $W(\theta_i) = \sin(\theta_i)$ or the Clenshaw-Curtis Weight defined in TS 38.521-2[2)] Annex M.4.2.1.

Constant Density Grid:

$$TRP \approx \frac{1}{N}\sum_{i=1}^{N} EIRP(\theta_i,\phi_j) \qquad (2)$$

The TRP measurement procedure is described in TS 38.521-2[2)] Annex K.1.7 and is summarized below.

1. When applying the re-positioning concept, position the UE so that Tx Beam Peak directs within 0°≤θ≤90° (opposite side to support pole).
2. Set the DL polarization to the one obtained from Peak EIRP Search and rotate the UE towards Tx Beam Peak direction.
3. Lock the Tx Beam using UE Beamlock Function (UBF).
4. Measure EIRP at each point i of the Measurement grid and calculate TRP.

The UBF in step 3 above is an instruction to the UE to fix the current beam which is formed autonomously by the UE based on the estimated DL direction results. This kind of special functions used for testing purpose are called Test Functions and are specified in TS 38.509[13)]. Also, for test cases other than spurious tests, unlike the case of Peak EIRP Search, it is not necessary to flip the UE for measuring $90° < \theta \leq 180°$ even when applying the Re-positioning Concept. This is due to that most of the radiated power is assumed to be concentrated on the opposite side of the support pole since the UBF in step 3 directs the peak direction at the other side of the support pole. Since this assumption cannot be made for the Spurious Test, it is necessary to flip the UE between each hemisphere when applying the Re-positioning Concept.

2.2.3 Peak EIS

Peak EIS is the maximum EIS over the entire spherical surface. 3GPP defines the DL signal level at 95% of the maximum throughput as the EIS (excluding Blocking Test described later). The EIS for each polarization is obtained for the polarization θ and ϕ of the DL signal of the test system. The EIS used as the measured value is the harmonic mean of them derived from the following equation.

$$EIS(\theta_i,\phi_i) = 2\left(\frac{1}{EIS_{link=\theta}(\theta_i,\phi_i)} + \frac{1}{EIS_{link=\phi}(\theta_i,\phi_i)}\right)^{-1} \qquad (3)$$

The peak search method is the same as the EIRP method; the $EIS(\theta_i,\phi_i)$ is measured at each point i of the EIS Beam Peak Search Grid and the value at the best point is used as the Peak EIS with that direction defined as the Rx Beam Peak Direction. The concept of Re-positioning and Coarse Scan is the same as Peak EIRP.

2.2.4 Spherical Coverage (EIRP, EIS)

The EIRP Spherical Coverage requirement is defined as the X percentile of the EIRP cumulative distribution function (CDF) measured over the entire sphere. The EIS Spherical Coverage requirement is defined as the X percentile of the EIS complementary cumulative distribution function (CCDF) measured over the entire sphere. The value of X changes according to the PC. For example, it is 50 for PC3 and 80 for PC1. The test system calculates the probability density function (PDF) of the EIRP and EIS sampled in the Spherical Coverage Grid and the accumulated CDF or CCDF to obtain the X percentile value. When calculating the PDF, since the Measured Grid density is not constant for the Constant Step Size Grid, it is necessary to apply weighting as with TRP using either sin (θ_i) or the Clenshaw–Curtis Weight. The concept of the Re-positioning is the same as the Peak EIRP/EIS Search.

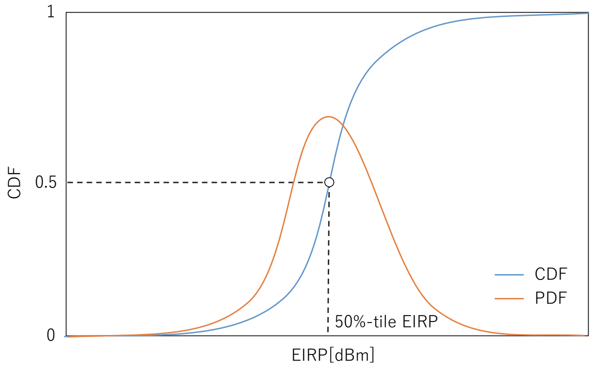


Figure 7 Spherical Coverage

2.3 Extreme Condition Tests

The RF requirements are specified for Normal Condition and Extreme Condition with respect to temperature and voltage condition. Table 4 lists the temperature and voltage conditions defined in TS 38.101-2[1] Annex E. The case where the temperature and voltage conditions are set to the Extreme Condition are called the Extreme Temperature Condition (ETC) test and Extreme Voltage Condition (EVC) test, respectively.

Table 4 Environmental Conditions

	Normal	Extreme
Temperature	+25° ±10°C	−10° ±55°C
Voltage	1.0 × Nominal or 1.1 × Nominal	0.85 × Nominal − 1.3 × Nominal
	* Applied condition depends on power supply (e.g., commercial AC, battery)	

Some RF requirements are the same for both the Normal Condition and Extreme Condition, some are different and some are defined only for the Normal Condition.

The Extreme Condition test for the LTE and FR1 was conducted by putting only the UE inside the temperature chamber. The test system is wired to the UE antenna connector and remains outside the chamber along with the external power supply. With this form of environment, there is no impact to the MU. On the other hand, measurement result using the OTA test environment can be affected by the thermal insulation box in the chamber as well as by power supply cables, so the handling of such effects was a main topic of the discussion.

For ETC test, the impact from condensation and the thermal insulation box to the test results and the feasibility of rotating the DUT have been discussed. Test-system vendors agreed that the addition of an insulation box in the chamber and the 2-axis rotational degrees of freedom as in the Normal Condition could be achieved with an extra 0.29 dB increase in the MU. Figure 8 shows an example of the ETC test environment. This example implements a two-axis positioner in a thermal-insulation enclosure inside the chamber connected to an external air conditioner.

The FR2 RF Conformance Test does not cover the EVC test[14] because it is impossible to establish a quantitative procedure for evaluating the impact of power leakage from cables used to control the power supply and from power control equipment.

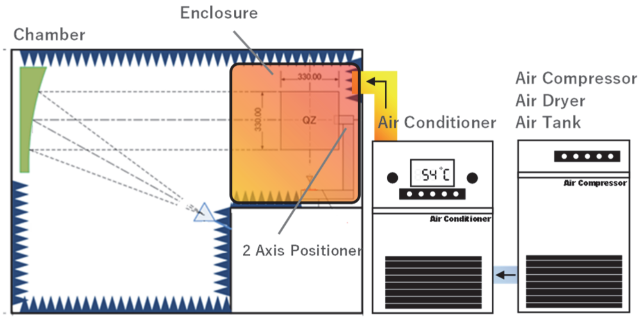


Figure 8 Example of ETC Test Setup

2.4 TRx Test

TRx tests include various radio performance tests at carrier frequencies, as well as unwanted emission tests such as spurious tests and blocking tests to determine interference immunity. In particular, many of the unwanted emissions requirements are specified based on national and regional regulations. This section outlines the notable TRx Test methods.

2.4.1 Spurious Test

The Spurious Test is one of the most challenging tests because the spurious requirement covers an extremely wide frequency from 30 MHz to twice the carrier frequency. Additionally, measurement requires a very long time because the spurious requirements are defined by the TRP. The Spurious Test standard was developed taking the test system's technical difficulty, complexity, cost and test time into account, and followings are agreed:

- Frequency range to test: from 6 GHz to twice the carrier frequency
- Permit use of offset antenna up to offset angle of 10° when using multiple measurement antennas
- Introduce Coarse Scan to cut measurement times. Use coarser Measurement Grid than original grid with

strengthened requirements corresponding to additional MU. If result is not PASS, measure again using original Measurement Grid.

Figure 9 shows an example of the Spurious Test setup using an offset antenna. When an offset antenna is used, QoQZ deteriorates due to the shift in focal-point, but it has been confirmed that an offset of a few degrees does not have a significant effect as long as the irradiation angle to the reflector is carefully adjusted.

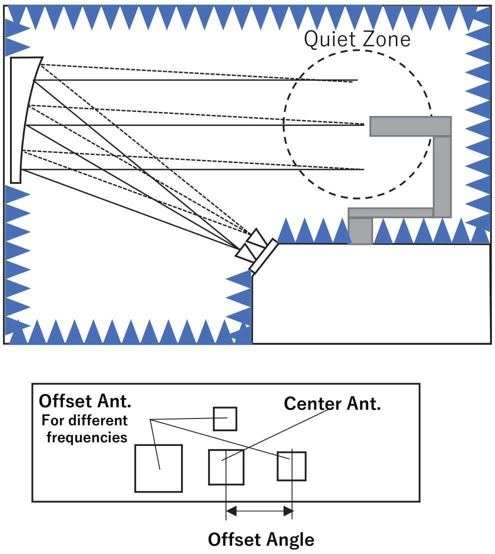


Figure 9 Offset Antenna Usage at Spurious Test

2.4.2 Blocking Test

The in-band blocking and Adjacent Channel Selectivity RF performance are regulated by the FR2 Blocking Test which tests the EIS requirement when subjected to high-level interference adjacent to the carrier frequency. Although the wanted signal and interference arrive in a combination of directions in an real-world environment, the RF performance requirement is defined on the assumption that both arrive from the Rx Beam Peak direction of the wanted signal.

Normally, a test system uses different equipment to generate the wanted and interference waveforms. Consequently, these signals must be combined before output from the probe antenna, so both are output from the same direction. When the frequencies are separated by more than the bandwidth supported by the single RF Frontend (up-converter and amplifier), the signals must be combined after conversion to the mmWave frequency. As described in section 3.2, FR2 has measurement limit issues related to Low PSD/High Power tests, so a few dB loss due to signal combining can be a problem. As a result, implementations using an offset antenna (Figure 10) for the interference signal are permitted. However, since the UE antenna gain drops towards the offset antenna direction, it is necessary to compensate it by giving higher interferer signal power corresponding to the difference of UE antenna gain of center and offset direction.

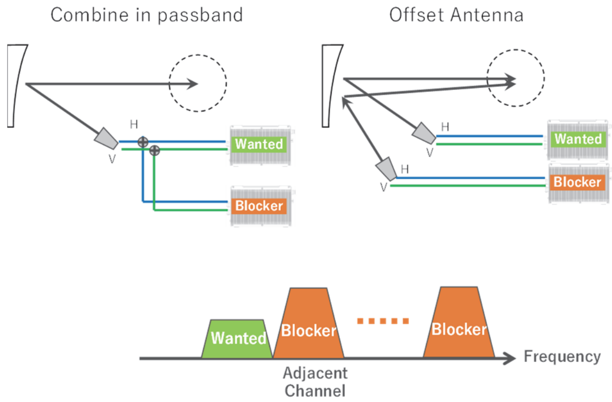


Figure 10 Blocking Test Setup

2.4.3 Beam Correspondence Test

Beam Correspondence (BC) is defined in TS 38.101-2[1)] as the ability of the UE to select a suitable beam for UL transmission based on DL measurements. There are two types of UE.

(1) UE supporting BC without relying on UL Beam Sweeping

(2) UE supporting BC relying on UL Beam Sweeping

Here, UL Beam Sweeping means the process where the base station (BTS) selects the best beam and notifies the UE about the selection after UE send beams in multiple directions. More specifically, Beam Sweeping is executed using a Sounding Reference Signal (SRS).

In case (1) above, the BC requirement is considered to be satisfied if the UE-autonomously selected UL beam meets the Minimum Peak EIRP and EIRP Spherical Coverage requirements. Therefore, in this circumstance there is no special BC test case, and the test is included in the Maximum Output Power Test. In case (2) above, the Minimum Peak EIRP and EIRP Spherical Coverage requirements of the Maximum Output Power Test must be satisfied using UL Beam Sweeping. Moreover, the CDF of the difference of the EIRP with and without UL Beam Sweeping must satisfy the requirements. In this case, the EIRP is measured over the Spherical Coverage Grid with and without UL Beam Sweeping ($EIRP_2$, $EIRP_1$, respectively), and the X percentile of $\Delta EIRP_{BC} = EIRP_2 - EIRP_1$ calculated over the points exceeding the N percentile of $EIRP_2$ is compared with the test requirements. The value of N = 50, and X = 85 for PC3.

2.5 Demodulation Test

The Demodulation test verifies the UE demodulation performance and the accuracy of CSI Report. In defining the demodulation requirements for FR2 in RAN4, there have been discussions on whether it should be an end-to-end test including antenna performance or a test to confirm baseband performance. RAN4 decided to adopt a Baseband Test in the UE Conformance Test[15] with the end-to-end test to be handled by the FR2 MIMO OTA Test[16].

The Baseband Test executed by the FR2 Demodulation Test introduces a concept called the Wireless Cable Mode (WCM) outlined in Figure 11. The WCM concept applies the previous Conducted Test to a OTA environment. The FR2 test system and a typical UE both have a dual-polarized antenna with orthogonal polarization each other. Therefore, by aligning their polarization planes each other, they are considered to be connected by a virtual cable. This is the basic WCM concept. However, rather than requiring direct contact between the polarization-wave faces, the proviso is to establish an independent channel with a guaranteed isolation of better than 12 dB between the two TRx branches of the test system and UE. An isolation of better than 12 dB can be confirmed using the Reference Signal Received Power per Branch (SS-RSRPB) defined in TS 38.215[17]. The actual method for securing the isolation of better than 12 dB depends on the test-system implementation and is undefined.

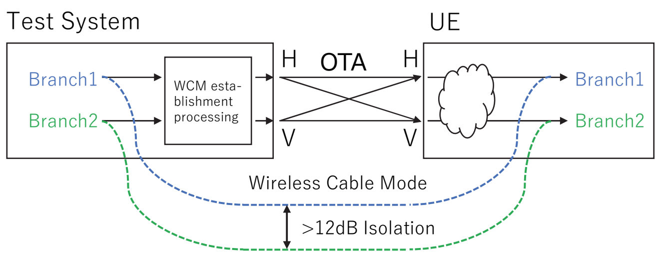


Figure 11 Wireless Cable Mode for FR2 Demodulation Tests

2.6 RRM Test

The targets of the RRM Test are the essential functions for facilitating mobility, such as measuring the quality of cells and handover based on measurement results.

The FR2 RRM Test specifies various test scenarios related to the Angle of Arrival (AoA). Table 5 lists the AoA setups specified by the Conformance Test.

Table 5 FR2 RRM Test AoA Setup

Setup	AoA Count	Test Direction
Setup 1	1	Rx beam peak direction
Setup 2	1	Non-Rx beam peak direction
Setup 3	2	Non-Rx beam peak directions
Setup 4	2	Rx beam peak & non-Rx beam peak directions

For the case of Non-Rx beam peak direction, test is executed in any direction meeting the EIS Spherical Coverage requirements.

It should be noted here that there are 2AoA test setups (Setup 3 and Setup 4) requiring simulation of two different AoA. The 2AoA tests for PC3 require the test system to simulate relative AoA of 30°, 60°, 90°, 120°, and 150°. As shown in Figure 12, there are three methods for implementing the 2AoA setup: DFF only, IFF only (with multiple reflectors), and a combination of DFF and IFF (hybrid method). Each has pros and cons. In particular, the DFF method has the cons that TRx testing cannot be performed and the IFF method has the cons of increased cost due to the use of multiple reflectors. In contrast, the Hybrid method, optimized based on the Quiet Zone size and D size required by the PC3 UE, can realize TRx and 2AoA RRM tests at low cost and space saving.

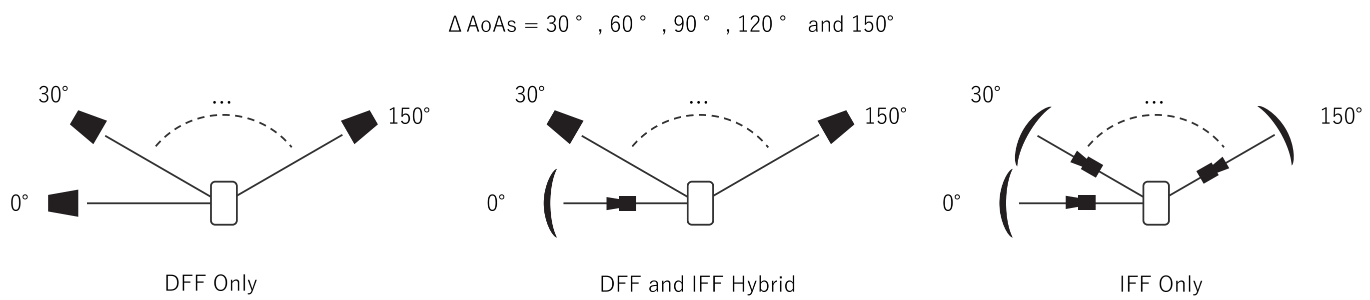


Figure 12 FR2 RRM 2AoA Setup Example

2.7 Measurement Uncertainty and Test Tolerance

One key task of RAN5 is defining the Maximum Test System Uncertainty (MTSU) and Test Tolerance (TT). Since the FR2 OTA Test MU is larger in comparison to LTE and FR1, discussions were held with many interested companies.

The MU of the Conformance Test is defined as Expanded Uncertainty at the 95% confidence level and has been discussed primarily by the test system vendors for each test case. The MTSU is described in TS 38.521-2[2] Annex F and the calculation bases for each test case are outlined in TR 38.903[18].

TT is a relaxation to a requirement to reduce the risk that a conformant UE will be judged as nonconformant due to the MU. This concept is called the Shared Risk Principle[19]. The original requirements are called the Core Requirement while the requirements relaxed by the TT are called the Test Requirement. Figure 13 outlines the Shared Risk Principle.

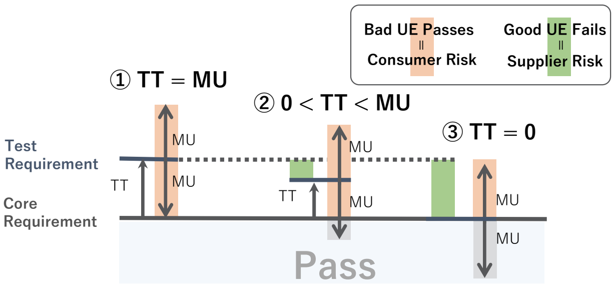


Figure 13 Shared Risk Principle

Table 6 lists the MTSU and TT for typical tests. Other tests are described in TS 38.521-2[2] Annex F. While MTSU is calculated based on a technical basis, TT is determined depending on the risk tolerance of UE vendors and operators. In LTE, TT=MTSU or TT=0 was generally used, but in FR2, many of them are specified with intermediate values (0<TT<MTSU) because the total amount of risk taken by UE vendors and carriers has increased due to the increased MU. TT = 0 is still used for some regulatory requirements.

Table 6 Example of MTSU and TT (23.45 to 32.125 GHz)

	MTSU	TT
MOP (Minimum Peak EIRP)	±4.89 dB	2.87 dB
MOP (Maximum Peak EIRP)	±4.89 dB	0 dB
MOP (TRP)	±4.42 dB	2.65 dB
REFSENS (Peak EIS)	±5.19 dB	2.34 dB

3 FR2 RF Conformance Test Issues & Prospects

This section describes some issues and prospects related to the FR2 RF Conformance Test standard.

3.1 Improving MU

As described in section 2.7, MU is larger for FR2 than for LTE/FR1, which increases the total risk for UE vendors and operators. Consequently, UE vendors must manufacture their products to meet stricter conditions than the Core Requirement while operators and service providers bear the risk of e.g. reduced effective use of frequency resources by adopting the relaxation (TT) for UE performance requirements. On the other hand, reducing MU presents risks of technical difficulties and increased production costs for test-system vendors. RAN5 accepted proposals from UE vendors and operators and agreed[20, 21, 22] to start MU reduction study (called MU Evolution) when there is a certain prospect to complete development of Release 15 test cases. Currently (November 2021), the MU Evolution study is expected to start in summer 2022. Active discussions by UE vendors, carriers and test-system vendors are expected.

3.2 Improving Low-PSD/High-Power Test Measurement Limits

The FR2 OTA test has limits on the measurable UL level and feasible DL level due to the high mmWave free-space attenuation and many tests have a Testability Issue. The Tx Transmit OFF Power test is the typical example. The core requirement is defined with −35 dBm/chBW. Considering free-space attenuation (at about 1 m) and other attenuation factors, the requirement level −35dBm/chBW corresponds to approximately −90 dBm/chBW at the test system input connector. For a 400 MHz BW, this is a lower level than the thermal noise (−174 dBm/Hz) and measurement is not feasible (Figure 14). Additionally, a high output power is required at the test-system side to compensate for the high free-space attenuation even for the Rx Test. One example is the Maximum Input Level Test of the Rx Test which is not measurable because current test systems cannot provide sufficient power. Other non-TRx tests, such as Demodulation Tests using high-order-modulation face similar challenges.

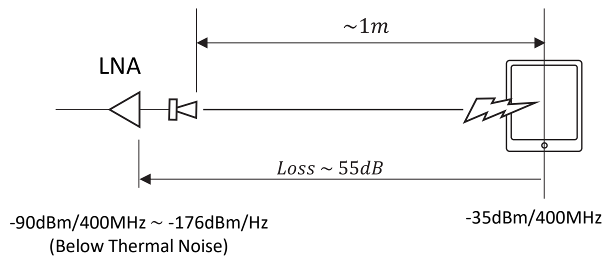


Figure 14 Low-PSD Testability Issue at Tx OFF Power

These challenges have been discussed at length by RAN4/RAN5. The problem of such measurement limits also exists for tests derived from regulations, such as the aforementioned Transmit OFF Power and Receiver Spurious Emission tests, and the inability to test conformance to the regulatory requirements set by each country and region is a major problem. As a result, there was a Liaison between 3GPP and national/regional regulatory organizations[23), 24), 25)].

Upgrading test-system performance can be one solution to this problem but will be difficult as test systems become increasingly complex to meet future requirements for higher frequencies, wider bandwidths and longer range length for testing larger UE. In these circumstances, introduction of Combined Far Field and Near Field (CFFNF) and Combined Far Field and Direct Near Field (CFFDNF) based on the near-field method is being reconsidered. These methods combine both Far Field and Near Field methods to secure measurement accuracy and improve attenuation by jointly using a Far Field (IFF, DFF) antenna/reflector with a Near Field antenna in the chamber (Figure 15).

Figure 15 CFFNF and CFFDNF Chamber (extract from TR 38.884[26)])

3.3 Improving Measurement Time

The issue of the FR2 RF Conformance Test time was discussed right from the start. This is because the OTA test adds a measurement dimension in the spatial domain and takes longer time than the LTE/FR1 conducted corresponding to the measurement points (e.g., more than 135 times longer for a PC3 TRP) by simple calculation. The following solutions have already been adopted.

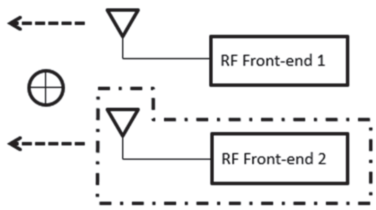
- Introduction of Coarse Scan specification: Beam Peak Search, Spurious Emission, etc.
- Reduction of Measurement Grid points: Use measurement grid with fewer point if UE vendors declare the use of an antenna array of not more than 2 × 4
- Introduction of rules related to re-use of Beam Peak data: Permit re-use of specific Beam Peak data (frequency, bandwidth, modulation method, etc.) for other conditions depending on UE vendor declaration

Introduction of the following methods is also being examined.

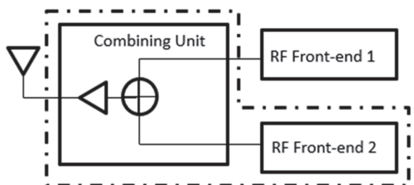
- Spherical Coverage Early Decision: Judge PASS when measuring subset of the grid points
- Rx Beam Peak Search using RSRPB report
- Single link polarization measurement: Use only one DL polarization for EIRP measurement
- Non-Uniform TRP Measurement Grids: Use fine Measurement Grid near Tx Beam Peak and coarse grid elsewhere

3.4 Widening Bandwidth

Widening the channel bandwidth is a typical solution for increasing mmWave band communications capacity. In comparison to the maximum channel bandwidth of 20 MHz per component carrier (1CC) used so far by LTE, Release 16 specifies channel bandwidths up to 400 MHz per 1CC for the FR2 frequency region (≤52.6 GHz) to achieve a maximum bandwidth of 1.6 GHz using Carrier Aggregation (CA). Moreover, the maximum bandwidth is 2.4 GHz including the gap for Intra-band non-contiguous CA, requiring a BS with extremely wideband signal processing. The issues surrounding a Conformance Test standard for test systems with these wider channel bandwidths are the flatness of the Rx sensitivity and the output signal level more than the processable bandwidth. As described in section 3.2, the expected issues with the Low PSD/High Power Test are increasing MU and progressively worse measurement limits due to bandwidth widening. Figure 16 shows some methods using combinations of multiple TRx equipment and signal layouts for implementing test systems with a wider channel bandwidth to solve these issues. Table 7 lists the features of each method shown in Figure 16.



Method 1 Combination in Free Space



Method 2 Combination Near TRx Antenna

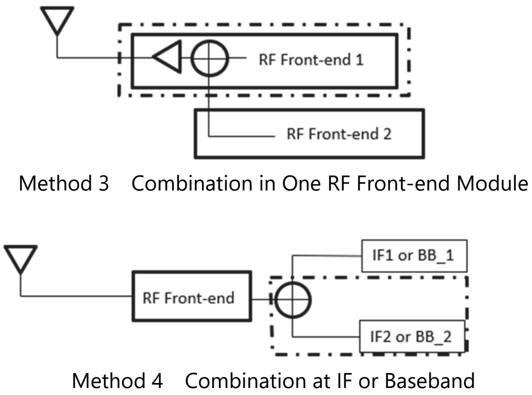


Figure 16 Quad-Signal Combining Method

Moreover, implementation of a test system using (an) offset antenna(s) has already been investigated in the RAN4 Study Item and the applicability of this test system to UE with the Independent Beam Management (IBM) function is currently under examination. The results are published in TR 38.884[26].

3.5 Extending Frequency

Current work on Release 17 has extended the bands defined for the FR2 frequency range between 24.25 and 52.6 GHz from n257 to n262 and the same Release 17 Work Item is also discussing the use of frequency bands beyond 52.6 GHz. These activities started at the ITU World Radiocommunication Conference 2019 (WRC-19) with the identification of the IMT band from 66 to 71 GHz[27]. Currently, ITU concluded to identify this range based on the fact that ranges around 57 to 71 GHz are already allocated as unlicensed bands in various countries for data communications, and 3GPP is continuing activities to define the band by June 2022. Table 8 lists the unlicensed- band allocations from 52.6 to 71 GHz in each country.

Table 8 Status of Regional Unlicensed Bands above 52.6 GHz (extract from TR38.807[28])

<table>
<tr><th rowspan="2">Region</th><th rowspan="2">Country/Region</th><th colspan="11">Frequency (GHz)</th></tr>
<tr><th>52.6-54.25</th><th>54.25-55.78</th><th>55.78-56.9</th><th>56.9-57</th><th>57-58.2</th><th>58.2-59</th><th>59-59.3</th><th>59.3-64</th><th>64-65</th><th>65-66</th><th>66-71</th></tr>
<tr><td rowspan="3">ITU Region 1</td><td>Europe/CEPT</td><td></td><td></td><td></td><td></td><td colspan="7">U (Mobile)</td></tr>
<tr><td>Israel</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>South Africa</td><td></td><td></td><td></td><td></td><td colspan="6">U (Mobile)</td><td></td></tr>
<tr><td rowspan="4">ITU Region 2</td><td>USA</td><td></td><td></td><td></td><td></td><td colspan="7">U (Mobile)</td></tr>
<tr><td>Canada</td><td></td><td></td><td></td><td></td><td colspan="7">U (Mobile)</td></tr>
<tr><td>Brazil</td><td></td><td></td><td></td><td></td><td colspan="4">U (Mobile)</td><td></td><td></td><td></td></tr>
<tr><td>Mexico</td><td></td><td></td><td></td><td></td><td colspan="4">U (Mobile)</td><td></td><td></td><td></td></tr>
<tr><td rowspan="8">ITU Region 3</td><td>China</td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2">U (Mobile)</td><td></td><td></td><td></td></tr>
<tr><td>Japan</td><td></td><td></td><td></td><td></td><td colspan="6">U (Mobile)</td><td></td></tr>
<tr><td>Korea</td><td></td><td></td><td></td><td></td><td colspan="6">U (Mobile)</td><td></td></tr>
<tr><td>India</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Taiwan</td><td></td><td></td><td></td><td></td><td colspan="6">U (Mobile)</td><td></td></tr>
<tr><td>Singapore</td><td></td><td></td><td></td><td></td><td colspan="6">U (Mobile)</td><td></td></tr>
<tr><td>Australia</td><td></td><td></td><td></td><td></td><td colspan="7">U (Mobile)</td></tr>
</table>

The impact to the conformance tests by adding bands in ranges above and below 52.6 GHz is being considered. The n262 band (47.2 to 48.2 GHz) newly added in Release 17 is in the first assumed FR2 frequency range and could be described as expanding the design investigated from the 5G NR start, including chambers and reflectors, and each test-equipment vendor can reuse part of existing design assets. However, testing higher frequency bands than currently specified makes the previously mentioned issues of measurement limits and MU more remarkable. Moreover, adding bands higher than 52.6 GHz has a larger impact on test systems and causes various issue. First, the design of each vendor's current FR2 test system including the chamber and reflector(s) assumes a measurement limit of 100 GHz including the spurious region. Conversely, offering test systems for both the 66 to 71-GHz band and the anticipated 5G-Advanced (called Release 18 hereafter)/6G standard, requires designing chambers, reflectors, antennas, etc., taking into consideration of supporting the second harmonic signals of 140 to 200 GHz. Moreover, integrating future test systems for frequency bands up to 52.6 GHz with test systems for bands above 52.6 GHz also increases problems. The RAN4

Table 7 Comparison of Signal Combining Methods 1 to 4

Signal Combining Method	Combining point	Pros	Cons
1 (Multiple Antenna Output)	Free Space	• Supports wideband CA without affecting MU for existing single-carrier tests • Scalable system	• Restrictions on antenna location and degraded QoQZ. Requires design and calibration to minimize effects such as measurement at position offset from UE beam peak direction, gradient in Quiet Zone field strength distribution, antenna coupling, etc.
2, 3, 4 (One Antenna Output)	Upstream of Antenna	• Supports signal output from one measurement antenna • Eliminates additional MU due to beam arrival drift for as in Method 1 at CA	• Requires amplifier circuit to compensate for increased path loss due to signal combiner. More technical challenges for Low PSD/High Power Test measurement limits. • Changes in measurement path losses of existing TRx test systems require investigation of MU revision not only for CA but also for current MU.

Study Item discussions hoped to offer test systems including all these frequencies[29] but a common system increases the complexity and impacts conventional systems up to 52.6 GHz. As a result, as described earlier, RAN5 started investigating MU Evolution but agreed that these improvements were difficult and would risk delaying time to market (TTM) release[30]. The same Study Item is examining the pros and cons of combining test systems but as described above, there is a tradeoff between increasing MU and TTM. As infrastructure supporting expansion to higher frequency bands is deployed to the market, perhaps there is a need of a consensus among communities on the necessity to separate test systems according to the merits/demerits of increased MU.

On the other hand, the result of examination on defining bands in the frequency bands between FR2 and FR1 (7 to 24 GHz), introduced in WRC-19 on use of the 10 to 10.5-GHz is described in TR 38.921[31]. The structure of the UE antenna for this band is like that for FR1 and the UE measurement method is assumed to be the same Conducted method used for FR1.

3.6 More Test Scenarios

While the LTE technology has various V2X, NB-IoT, and Category M use cases, 5G NR has already widened the application range even further and technology targets are diversifying. First, as described above, in addition to conventional mobile phones, there are increasing numbers of targets using built-in communications, such as laptops, tablets, fixed wireless access (FWA)/consumer premises equipment (CPE), automobiles, railroads, drones, aerospace, satellites, and more. Furthermore, TRx/RRM/Demodulation specifications are diverging along with maintaining coverage areas while suppressing power consumption as much as possible, or as the result of increasing the number of power class definitions. This section explains several of these measurement scenarios and their specific challenges.

High-Speed Train

Release 17 includes discussions about FR2 standards for high-speed train (HST). A specific HST feature is the either unidirectional or bidirectional signal AoA at the CPE according to the Remote Radio Head (RRH) deployment scenario, and, unlike current tests, there are no preconditions about a fixed CPE location. As a result, simultaneous bidirectional measurement is required when the beam switches while the train is moving at high speed. Although the Release 17 TRx specifications were agreed assuming unidirectionality only, discussions covered both unidirectional and bidirectional scenarios for the RRM/Demodulation Test and there were concerns that this would increase the test system complexity. Figure 17 shows the unidirectional RRH deployment scenario.

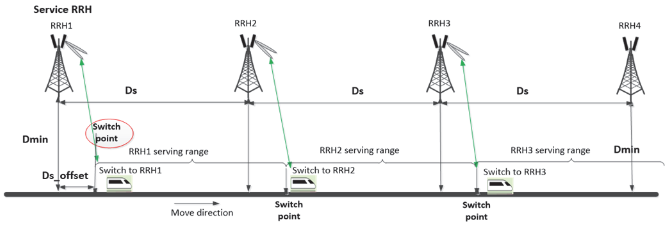


Figure 17 FR2 HST Uni-directional RRH Deployment Scenario (extract from R4-2114024[32])

Multi-TRxP (Transmission and Reception Point)

Excluding some RRM tests, the test methods investigated so far have assumed a unidirectional BS connection even for multiple simultaneously active antenna panels. Release 16 and later have targeted investigation of Multi-TRxP infrastructure assuming use of multiple beams and antenna-panel control[33), 34]. Figure 18 shows the concept of simultaneous communications using bidirectional gNB (TRxP). RAN4 is now investigating the Multi-TRxP/fixed multi-panel requirements for TRx, Demodulation, and RRM tests. Depending on the results, it may be necessary to add a new 2AoA test to the TRx and Demodulation tests. Although the WCM FR2 Demodulation Test assumes a 1AoA connection between the UE and test system, adding the 2AoA feature is expected to require a multi-antenna WCM connection.

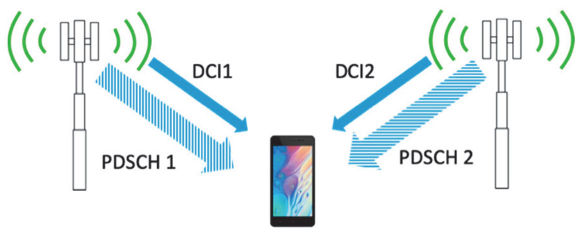


Figure 18 Multi-TRxP (extract from RP-192406[35])

Non-PC3 UE Test Scenarios

As described previously, UE PC1 to 5 are defined for the current FR2 range and RAN4 defined different requirements for Maximum Output Power (TRP, EIRP), Rx sensitivity (EIS), EIRP/EIS Spherical Coverage, and Percentile, depending on these PC. At first glance, although the differences seem to be just these values, since the FR2 UE RF Conformance Test assumes OTA testing including antenna characteristics at the finished product stage, it is impossible to sever the relationship between DUT size and each test system. Comparing with the PC3 UE until now, considering a case that the 5G NR communication module is built in various products, it is expected that OTA tests of finished products become difficult. Since there are likely to be problems with Conformance Tests of large objects such as automobiles and drones, 3GPP must soon publish guidelines on Conformance Test implementation methods. It will be one of the important objectives for 5G NR products to create an environment to become widely used from now, for example by creating a rule to separate stages to carry out the conformance test with a standalone communication module, and another stage that only tests emissions and Rx characteristics with the finished products.

4 RF Conformance Test System ME7873NR

UE conformance must be certified using test cases defined by the GCF and PTCRB certification organizations. To obtain certification, the test equipment used by GCF or PTCRB must also be certified.

Anritsu's New Radio Conformance Test System ME7873NR is fully compliant with the 3GPP Conformance Test standards and is a GCF and PTCRB-approved test platform.

Figure 19 ME7873NR FR1 System

Figure 20 ME7873NR FR2 System

The ME7873NR platform uses Anritsu's MT8000A as a 5G NR base station simulator for 3GPP-compliant tests of UE TRx, Demodulation and RRM performance. In addition, it supports carrier acceptance tests (North-American CAT) with quarterly updates to 3GPP standards. Supported items are listed below.

- 3GPP TS 38.521-1 NR User Equipment (UE) conformance specification Radio transmission and reception Part 1: Range 1 Standalone
- 3GPP TS 38.521-2 NR User Equipment (UE) conformance specification Radio transmission and reception Part 2: Range 2 Standalone
- 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
- 3GPP TS 38.521-4 NR User Equipment (UE) conformance specification Radio transmission and reception Part 4: Performance requirements
- 3GPP TS 38.533 NR User Equipment (UE) conformance specification Radio Resource Management (RRM)

Table 9 ME7873NR FR1 Specification

Downlink Output Frequency	450 MHz to 3.8 GHz (LTE) 450 MHz to 6 GHz (NR)
Uplink Measured Frequency	450 MHz to 3.8 GHz (LTE) 450 MHz to 6 GHz (NR)
Interference Frequency	450 MHz to 6 GHz (modulated) 1 MHz to 12.75 GHz (CW)
Spurious Measured Frequency	9 kHz to 26 GHz
Others	• Power supply control using DC supply (for EVC Test) • Environmental temperature control using temperature chamber (for ETC Test)

Table 10 ME7873NR FR2 Specification

Downlink Output Frequency	450 MHz to 6 GHz (LTE) 24.25 to 29.5 GHz, 37 to 43.5 GHz (NR)
Uplink Measured Frequency	24.25 to 29.5 GHz, 37 to 43.5 GHz (NR)
Spurious Measured Frequency	6.0 to 87.0 GHz
Quiet Zone	330 mm
Others	• Power supply control using DC supply (for EVC Test) • Environmental temperature control using temperature chamber (for ETC Test)

5 Conclusions

This article explains trends in the UE RF Conformance Test for 5G NR FR2 (mmWave). Standardization of the FR2 Conformance Test has nearly been completed in November 2021 for the limited cases such as Release 15, PC3 and frequency ≤ 40 GHz. However, there are still some remaining problems such as the measurement limits in Low PSD/High Power test as well as improvement challenges of MU. Expansion to higher frequencies and wider bandwidths, testing for devices other than mobile terminals, and test methods for new scenarios to be introduced after Release 15 are also being discussed and will continue to be actively discussed along with existing issues. As a test system vendor, Anritsu will continue to contribute to the development and growth of 5G NR by participating deeply in the development of conformance test standards and the resolution of issues, and by continuously providing test solutions compliant with the standards.

References

1) 3GPP, TS 38.101-2 v17.4.0 (2021-12), "User Equipment (UE) radio transmission and reception; Part 2: Range 2 Standalone"
2) 3GPP, TS 38.521-2 v16.10.0 (2021-12), "User Equipment (UE) radio transmission and reception; Part 2: Range 2 Standalone"
3) 3GPP, TS 38.101-4 v17.3.0 (2021-12), "NR; User Equipment (UE) radio transmission and reception; Part 4: Performance requirements"
4) 3GPP, TS 38.521-4 v16.10.0 (2021-12), "NR; User Equipment (UE) conformance specification; Radio transmission and reception; Part 4: Performance"
5) 3GPP, TS 38.133 v17.4.0 (2021-12), "NR; Requirements for support of radio resource management"
6) 3GPP, TS 38.533 v17.1.0 (2021-12), "NR; User Equipment (UE) conformance specification; Radio Resource Management (RRM)"
7) 3GPP, News Release, https://www.3gpp.org/news-events/1965-rel-15_news, June 2018
8) 3GPP, TS 38.151 v0.6.0 (2021-11), "NR; User Equipment (UE) Multiple Input Multiple Output (MIMO) Over-the-Air (OTA) performance requirements"
9) 3GPP, TS 38.161 v0.0.1 (2020-11), "NR; User Equipment (UE) TRP (Total Radiated Power) and TRS (Total Radiated Sensitivity) requirements; Range 1 Standalone and Range 1 Interworking operation with other radios"
10) 3GPP, TR 38.810 v16.6.1 (2020-09), "NR; Study on test methods"
11) C.A. Balanis, "Antenna Theory: Analysis and Design", 4th ed., John Wiley & Sons, Inc., 1997.
12) 3GPP, TS 38.508-2 v17.3.0 (2021-12), "5GS; User Equipment (UE) conformance specification; Part 2: Common Implementation Conformance Statement (ICS) proforma"
13) 3GPP, TS 38.509 v16.3.0 (2021-12), "5GS; Special conformance testing functions for User Equipment (UE)"
14) Anritsu, R5-185525, "Treatment of power supply cable for FR2 UE tests", RAN5#80, Aug. 2018
15) Intel, Qualcomm, R4-1801288, "WF on performance testing for FR2", RAN4 NR AdHoc 1801, Jan. 2018
16) RP-181402, "Study on radiated metrics and test methodology for the verification of multi-antenna reception performance of NR UEs", Study Item Proposal, RAN#80, June 2018
17) 3GPP, TS 38.215 v16.4.0 (2020-12), "Physical layer measurements"
18) 3GPP, TR 38.903 v16.10.0 (2021-12), "Derivation of test tolerances and measurement uncertainty for User Equipment (UE) conformance test cases"
19) Recommendation ITU-R M.1545, "Measurement uncertainty as it applies to test limits for the terrestrial component of International Mobile Telecommunications-2000"
20) R5-190793, "WF of test tolerances and measurement uncertainty for User Equipment (UE) conformance test", RAN5 AdHoc NR#4
21) R5-192820, "WF on Maximum Test System Uncertainty Evolution for FR2", RAN5#82
22) R5-195410, "WF on Test System Uncertainty Evolution for FR2", RAN5#83
23) TSG-RAN, RP-191603, "5G-NR FR2 Transmitter & Receiver Testability Issues", RAN#84
24) ARIB, R5-196960, "Reply LS on 5G-NR FR2 Transmitter & Receiver Testability Issues", RAN5#84

25) MSG TFES, R5-200018, "Reply LS on 5G-NR FR2 Transmitter & Receiver Testability Issues", RAN5#86-e
26) 3GPP, TR 38.884 v1.1.0 (2021-08), "Study on enhanced test methods for FR2 NR UEs (Release 17)"
27) WRC-19 Final acts, Article 5/ Resolution 241
28) 3GPP, TR 38.807 v16.1.0 (2021-03), "Study on requirements for NR beyond 52.6 GHz"
29) Moderator (Intel), R4-2115804, "Email discussion summary for [100-e][335] FR2_enhTestMethods_Part2", RAN4#100e
30) Keysight, R4-2114386, "On 52.6-71GHz Testability", RAN4#100e
31) 3GPP, TR 38.921 v17.0.0 (2021-03), "Study on International Mobile Telecommunications (IMT) parameters for 6.425-7.025GHz, 7.025-7.125GHz and 10.0-10.5GHz"
32) Nokia, R4-2114024, "TR for FR2 HST", RAN4#100e
33) Samsung, RP-200474, "Revised WID: Enhancements on MIMO for NR", RAN#87e
34) Samsung, RP-202024, "Revised WID: Further Enhancements on MIMO for NR", RAN#89e
35) NTT Docomo, RP-192406, "Summary of email discussion on inter-gNB coordination for multi-carrier/TRP operations for NR", RAN#86

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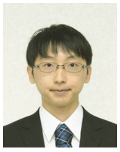

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Annex Table 1 TRx Test

Test Case		Test Metric
Transmitter (Tx) Characteristics	UE Maximum Output Power	Peak EIRP (Min., Max.), TRP (Max.), Spherical Coverage (EIRP)
	UE Maximum Output Power Reduction	Peak EIRP
	Minimum Output Power	Peak EIRP
	Transmit OFF Power	TRP
	Transmit ON/OFF Time Mask	Peak EIRP
	Absolute Power Tolerance	Tx Beam Peak
	Relative Power Tolerance	Tx Beam Peak
	Aggregated Power Tolerance	Tx Beam Peak
	Frequency Error	Tx Beam Peak
	Error Vector Magnitude (EVM)	Tx Beam Peak
	Carrier Leakage	Tx Beam Peak
	In-band Emission	Tx Beam Peak
	EVM Equalizer Spectrum Flatness	Tx Beam Peak
	Occupied Bandwidth (OBW)	Tx Beam Peak
	Spectrum Emission Mask (SEM)	TRP
	Adjacent Channel Leakage Ratio (ACLR)	Core Requirement: TRP Test Requirement: Peak EIRP (Changed due to low PSD testability issue)
	Transmitter Spurious Emission	TRP (Section 2.4.1)
	Beam Correspondence	Difference of EIRP With/Without UL Beam Sweeping (Section 2.4.3)
Receiver (Rx) Characteris-	Reference Sensitivity	Peak EIS, Spherical Coverage (EIS)
	Maximum Input Level	Peak EIS
	Adjacent Channel Selectivity	Peak EIS (in presence of interferer) (Section 2.4.2)
	In-band Blocking	Peak EIS (in presence of interferer) (Section 2.4.2)
	Receiver Spurious Emission	TRP (Section 2.4.1)