Test Plan for Wireless Device Over-the-Air Performance

CTIA 01.22 Test Methodology, SISO, Millimeter Wave

Version 8.0.0

September 2024

Use Instructions

All testing shall be performed in a CTIA Certification Authorized Test Lab and shall be initiated through one of the following methods:

1. By submitting a PTCRB or IoT Network Certified device certification request at https://certify.ptcrb.com/

2. By submitting an OTA Test Plan use request at https://certify.ctiacertification.org/

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ctiacertification.org/test-plans/

Table of Contents

List of Figures

List of Tables

Section 1   5G Millimeter-Wave Test Overview

1.1   Overview

This test plan presents the individual test procedures organized by type of test (Transmitter, Receiver).

The testing requirements fall into 4 categories:

- Characterizing the basic performance of the test chamber

- Measuring the path loss of the test system,

- Measuring the TX and RX beam peak direction

- Measuring the TX and RX performance of the wireless device

The test methodologies permitted for evaluating the TX and RX performance as part of the CTIA Certification program are introduced in Section 2. The basic performance of the test chamber is covered in *CTIA 01.73* [1]; The site validation method for the amplitude inside the Quiet Zone (QZ) in Section 7 of *CTIA 01.73* [1] is used to determine the uncertainty contribution of the test system; the pass/fail site validation method for the phase inside the QZ is outlined in Section 8 of *CTIA 01.73* [1]. Those quality of quiet zone results shall be supplied as part of the ATL authorization process. Corrections for the path loss of the test system, including range length, measurement antenna, cables, amplifiers, etc. are determined using the range reference measurement described in Section 4 of *CTIA 01.73* [1]. The measurement of the wireless device is covered in Section 3 for radiated power measurements and Section 4 for sensitivity measurements. The respective beam peak search procedures to determine the directions towards which the DUT forms the TX/RX beams are included in Section 3 and Section 4. The overall measurement uncertainty is described in Section 5. Section 6 outlines the measurement grid requirements for the select tests defined in this test plan.

1.2   Acronyms and Definitions

The following specialized terms and acronyms are used throughout this document.

Table 1.2-1 Acronyms and Definitions

Acronym	Definition
AUT	Antenna Under Test
Beam correspondence	The ability of the UE to select a suitable beam for UL transmission based on DL measurements with or without relying on UL beam sweeping
BW	Bandwidth
CATR	Compact Antenna Test Range
ATL	Authorized Testing Laboratory
CCDF	Complementary Cumulative Distribution Function
CDF	Cumulative Distribution Function
CPE	Customer Premises Equipment

Acronym	Definition
C_RNTI	Cell Radio Network Temporary Identity
D	DUT Radiating Aperture
DC	Dual Connectivity
DFT-s-OFDM	Discrete Fourier Transform-spread-OFDM
DUT	Device Under Test
EIRP	Effective Isotropic Radiated Power
EIS	Equivalent Isotropic Sensitivity
EN-DC	E-UTRA/NR DC
DCI	Downlink Control Information
DUT	Device Under Test
FR1	Frequency Range 1
FR2	Frequency Range 2
HARQ	Hybrid Automatic Repeat ReQuest
MOP	Maximum Output Power
MTSU	Maximum Test System Uncertainty
MU	Measurement Uncertainty
NR	New Radio
OFDM	Orthogonal Frequency-Division Multiplexing
OTA	Over The Air
PDCCH	Physical Downlink Control Channel
PDF	Probability Density Function
Pol_{Link}	Polarization, either θ or ϕ, of the DL signal transmitted by the test equipment through the measurement antenna for the DUT to form the TX/RX beam towards it
Pol_{Meas}	Polarization, either θ or ϕ, of the measurement antenna of the test equipment for the measurement being performed
PUSCH	Physical Uplink Shared Channel
REFSENS	Reference Sensitivity
RF	Radio Frequency

Acronym	Definition
RMC	Reference Measurement Channel
RX	Receive
RX beam peak direction	Direction (θ,ϕ) where the best receiver performance is found
SCS	Sub-Carrier Spacing
SS	System Simulator
Test System	The controlled propagation environment used for evaluation of the Device Under Test (DUT). In the context of this version of this test specification, the Compact Antenna Test Range (CATR) is the only valid test system
Test Methodology	The process used to execute tests against the DUT using the Test System(s) specified by this document. In the context of this version of this test specification, the Indirect Far Field methodology based on Compact Antenna Test Range (CATR) is the only permitted test methodology
TRP	Total Radiated Power
TX	Transmit
TX beam peak direction	Direction (θ,ϕ) where the maximum total component of EIRP is found
Quiet Zone	The portion of the useable volume within the test system into which the DUT can be placed and in which the test criteria are met within the applicable uncertainty limits
QoQZ	Quality of Quiet Zone
QZ	Quiet Zone
UBF	UE Beamlock test Function
UE	User Equipment
UL	Uplink
θ	Denotes the zenith angle (in degrees) within the spherical co-ordinate system, as well as measurement antenna polarization along the direction of motion of the zenith axis rotation
ϕ	Denotes the azimuth angle (in degrees) within the spherical co-ordinate system, as well as measurement antenna polarization along the direction of motion of the azimuth axis rotation

1.3 Document References

The following documents are referenced in this test plan:

Document Number, Document Name
[1]   CTIA 01.73, *Supporting Procedures*
[2]   3GPP TS 38.509, *5GS; Special conformance testing functions for User Equipment (UE)*
[3]   CTIA 01.71, *Positioning Guidelines*
[4]   CTIA 01.01, *Test Scope, Requirements, and Applicability*
[5]   CTIA 01.70, *Measurement Uncertainty*
[6]   3GPP TS 38.521-2, *NR; User Equipment (UE) Conformance Specification; Radio Transmission and Reception*
[7]   CTIA 01.50, *Wireless Technology, 3GPP Radio Access Technologies*
[8]   3GPP TS 38.508-1, *5GS; User Equipment (UE) Conformance Specification*
[9]   3GPP TS 38.521-3, *NR; User Equipment (UE) Conformance Specification; Radio Transmission and Reception*
[10] CTIA 01.90, *Informative Reference Material*

Section 2   Introduction to Measurements and Test Methods

This section is outlining the permitted OTA test methods suitable for the UE OTA performance test cases outlined in this test plan.

2.1   Indirect Far-Field (IFF) based on Compact Antenna Test Range (CATR)

2.1.1   Description

The IFF method utilizing a CATR creates a far-field environment in relatively close proximity of the parabolic reflector which serves as collimator transforming spherical waves into plane waves within the desired quiet zone. Figure 2.1.1-1 and Figure 2.1.1-2 demonstrate the reciprocity of the CATR system concept.

For RX testing, as illustrated in Figure 2.1.1-1 the probe/feed antenna placed near the focal point of the reflector radiates a spherical wave towards the reflector which collimates it into a planar wave front received by the DUT. The focal length is approximately the distance between the feed and the reflector. On the other hand, for TX testing, as illustrated in Figure 2.1.1-2 the radiation pattern from the DUT can be described as a series of plane waves propagating in different directions and the probe/ feed antenna receives only the focused beam from the plane wave directed straight at the reflector.

Inside the quiet zone, a planar wave front (uniform amplitude and phase) is achieved. Amplitude uniformity is dependent on the feed pattern, feed alignment, and reflector design while phase planarity is mainly dependent on feed alignment and reflector design. The polarization purity is mainly dependent on the parabolic system geometry considering high polarization purity feeds.
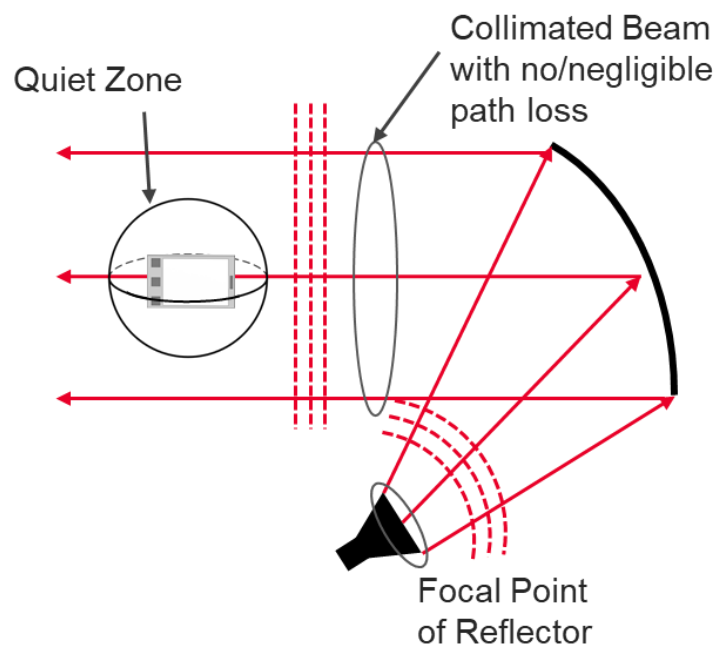
Figure 2.1.1-1 Working Principle for Rx Testing in a CATR
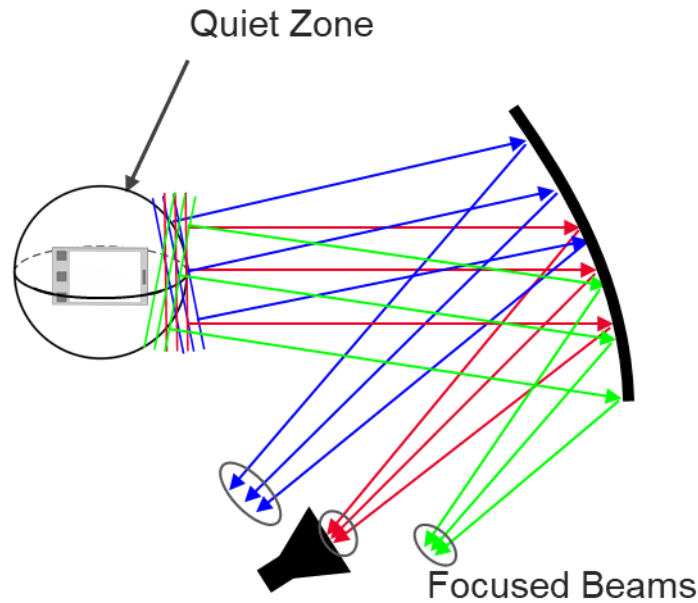
Figure 2.1.1-2 Working Principle for Tx Testing in a CATR

The key aspects of this test method setup are:

- A positioning system such that the angle between the dual-polarized measurement antenna and the DUT has at least two axes of freedom and maintains a polarization reference.

- Before performing the UE Beamlock test Function (UBF) identified in *3GPP TS 38.509* [2] the measurement probe acts as a link antenna maintaining polarization reference with respect to the DUT. Once the beam is locked, the link may be passed to the link antenna which maintains reliable signal level with respect to the DUT.

- For setups intended for measurements of UE RF characteristics in EN-DC mode with one UL configuration, an LTE link antenna is used to provide the LTE link to the DUT. The LTE link antenna provides a stable LTE signal without precise path loss or polarization control.

- For setups intended for measurements in NR CA mode with FR1 and FR2 inter-band NR CA, test setup provides NR FR1 link to the DUT. The NR FR1 link has a stable and noise-free signal without precise path loss or polarization control.

2.1.2   CATR Coordinate System

The IFF CATR measurement setup for FR2 is shown in Figure 2.1.2-1 The relative orientation of the coordinate system with respect to the reflector and the axes of rotation apply to any CATR measurement setup.
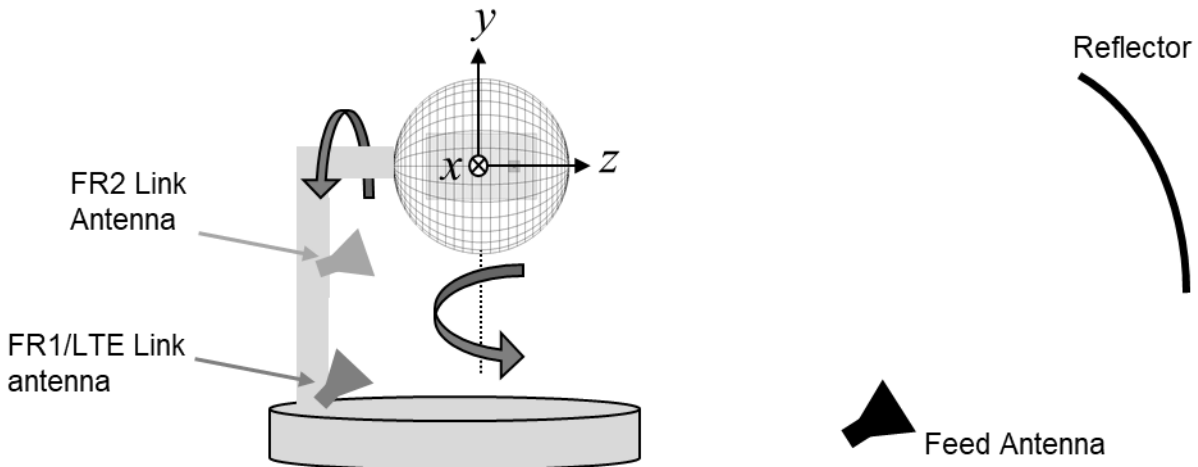
Figure 2.1.2-1 Example of IFF: CATR Measurement Setup

2.1.3 Quiet Zone Dimension

The spherical quiet zone shall have a radius of 150 mm to accommodate smartphone UEs, CPEs, tablets, and small handheld DUTs. To test even larger devices, e.g., larger tablets and laptops, quiet zones with radii of 200 mm and 275 mm are defined. The device types are listed as examples and other device types are not precluded. In either case, the radiating portions of the DUT shall be fully contained in one of the quiet zone sizes defined herein for the entire duration of the test. The device types are listed as examples and other device types are not precluded.

The overview of the two position approaches is outlined in Section 4.1 of *CTIA 01.71* [3], i.e., the black-box approach where the geometrical center of the DUT is aligned with the center of the QZ and the gray-box approach where a declared reference point on the DUT is aligned with the center of the QZ. The corresponding vendor declaration is defined in Section 1.5.2 of *CTIA 01.01* [4].

The amplitude quality of quiet zone procedure for systems supporting multiple quiet zone sizes can be performed for the largest quiet zone radius only and the results can be applied to the smaller quiet zone radii if the same chamber components affecting QoQZ, i.e., reflector, feed probes, etc., are used. Performing separate sets of quality of quiet zone measurements for different radii is not precluded.

Since the phase QoQZ validation procedure for 40 cm QZ includes the test points for the 30 cm QZ the procedure for the larger quiet zone radius can be applied to the results of the smaller QZ radii if the same chamber components affecting QoQZ, i.e., reflector, feed probes, etc., are used.

2.1.4 Quality of the Quiet Zone (QoQZ)

The QoQZ shall be measured for the frequencies defined in *CTIA 01.73* [1] Section 3. The measured QoQZ performance is used in uncertainty calculations for the appropriate QoQZ dimension utilized for the DUT. The amplitude QoQZ is outlined in Section 7 of *CTIA 01.73* [1] is used to determine the uncertainty contribution of the test system; the pass/fail site validation method for the phase inside the QZ is outlined in Section 8 of *CTIA 01.73* [1].

2.1.5 Measurement Distance

The CATR system does not require a measurement distance of $R > 2D^2/\lambda$ to achieve a plane wave as in a conventional anechoic chamber test methodology (direct far-field). Instead, for the CATR system, the far-field distance is seen as the focal length.

The measurement distance for any CATR system implementation shall be adequate to meet the quiet zone dimensions defined in Section 2.1.3.

As the CATR generates a plane wave with no free space path loss inside the quiet zone, the influence of measurement distance on measurement uncertainty can be considered as zero as defined in *CTIA 01.70* [5].

Section 3   Test Procedures - Transmitter

This section outlines the test procedures for the transmitter test cases for this test plan.

For the test environmental conditions described in *3GPP TS 38.521-2* [6], only the normal conditions shall be applied, i.e., normal temperature and normal voltage.

The vendor shall submit to the ATL a declaration of the primary mechanical mode as referenced in this test plan.

The TX procedures in this section shall assume that the DUT autonomously chooses the corresponding TX beam for PUSCH transmission using downlink reference signals to transmit in the direction of the incoming DL signal, which is based on beam correspondence without relying on UL beam sweeping.

3.1   TX Beam Peak Search Procedure

The purpose of this procedure is to determine the TX beam peak direction where the maximum total component of EIRP is found.

The measurement system shall be configured as specified in Section 2. The power radiated by the DUT in the FR2 measurement path shall be measured using a calibrated RF measuring instrument, e.g., a gNB emulator, spectrum analyzer, or power meter capable of averaging across at least one subframe (1ms).

The test conditions are defined in Section 5.2.1.1 of *CTIA 01.50* [7].

The TX beam peak procedure is defined as follows:

1. Select any of the three alignment options (1, 2, or 3) from Table 4.1-1 through Table 4.1-3 in *CTIA 01.71* [3] to mount the DUT inside the QZ.
2. Position the DUT in DUT orientation 1 from Table 4.1-1 through Table 4.1-3 in *CTIA 01.71* [3].
3. Connect the SS (System Simulator) with the DUT through the reference measurement antenna with $Pol_{Link} = \theta$ polarization to form the TX beam towards the measurement antenna. Allow at least BEAM_SELECT_WAIT_TIME (defined in Annex K.1.1 of *3GPP TS 38.521-2* [6]) for the UE TX beam selection to complete. Continuously send power control "up" commands in every uplink scheduling information to the UE; allow at least 200 ms after the first TPC command in this step to ensure that the UE transmits at its maximum output power before continuing.
   a. SS activates the UE Beamlock Function (UBF) by performing the procedure as specified in *3GPP TS 38.508-1* [8], clause 4.9.2 using condition TX only
   b. Measure the mean power $P_{meas}(Pol_{Meas} = \theta, Pol_{Link})$ of the modulated signal arriving at the power measurement equipment
   c. Calculate EIRP $(Pol_{Meas} = \theta, Pol_{Link})$ by adding the composite loss of the entire transmission path for utilized signal path, $L_{EIRP,\theta}$, and frequency to the measured power $P_{meas}(Pol_{Meas} = \theta, Pol_{Link})$.
   d. Measure the mean power $P_{meas}(Pol_{Meas} = \phi, Pol_{Link})$ of the modulated signal arriving at the power measurement equipment.
   e. Calculate EIRP $(Pol_{Meas} = \phi, Pol_{Link})$ by adding the composite loss of the entire transmission path for utilized signal path, $L_{EIRP,\phi}$, and frequency to the measured power $P_{meas}(Pol_{Meas} = \phi, Pol_{Link})$

  f. Calculate total $\mathrm{EIRP}(Pol_{Link} = \theta) = \mathrm{EIRP}(Pol_{Meas} = \theta, Pol_{Link}) + \mathrm{EIRP}(Pol_{Meas} = \phi, Pol_{Link})$.

  g. SS deactivates the UBF by performing the procedure as specified in *3GPP TS 38.508-1* [8], clause 4.9.3.

4. Connect the SS with the DUT through the measurement antenna with $Pol_{Link} = \phi$ polarization to form the TX beam towards the measurement antenna. Allow at least BEAM_SELECT_WAIT_TIME for the UE TX beam selection to complete. Perform steps a-g from Step 3.

5. Advance to the next grid point and repeat steps 3 and 4 until measurements within zenith range $0° \le \theta \le 90°$ have been completed,

6. After the measurements within zenith range $0° \le \theta \le 90°$ have been completed and:

  a. if the re-positioning concept is applied to the TX test cases, position the device in DUT orientation 2 (either options 1 or 2) for the alignment option selected in Step 1. For the TX beam peak search in the second hemisphere, continue steps 3 and 4 for the range of zenith angles $90° < \theta \le 0°$.

  b. If the re-positioning concept is not applied to the TX test cases, continue steps 3 and 4 for the range of zenith angles $90° < \theta \le 180°$

  c. when only a single hemisphere shall be tested (based on a vendor declaration, see Section 1.5.2 of *CTIA 01.01* [4], additional testing in the second hemisphere shall be skipped, i.e., conclude the testing after step 5

The TX beam peak direction is where the maximum total component of $\mathrm{EIRP}(Pol_{Link} = \theta)$ or $\mathrm{EIRP}(Pol_{Link} = \phi)$ is found.

The minimum number of measurement grid points for the TX beam peak search based on testing within the full sphere are outlined in Section 6.2. When testing in just the single hemisphere is requested, based on a vendor declaration, see Section 1.5.2 of *CTIA 01.01* [4], the same grid step size and/or grid density shall be used as for the full spherical testing which correspondingly yields a reduced total number of grid points.

Alternatively, a coarse and fine search grid approach could be used according to the definition in Section 6.2.1.

3.2 Maximum Output Power – EIRP

The intent of this test procedure is to measure the total component of the EIRP in the maximum TX beam peak direction found in Section 3.1.

The EN-DC connections are established as outlined in Section 5.2.1.1 of *CTIA 01.50* [7]. The system simulator and DUT shall be configured per clause 6.2B.1.4.1 of *3GPP TS 38.521-3* [9] for this test case with the exception of the test conditions defined in *CTIA 01.50* [7], Section 5.2.1.1.

The test procedure for maximum output power EIRP at the TX beam peak direction is defined as follows:

1. Select any of the three alignment options (1, 2, or 3) from Table 4.1-1 through Table 4.1-3 in *CTIA 01.71* [3] to mount the DUT inside the QZ.

2. If the re-positioning concept is not applied to the TX test cases, position the device in DUT orientation 1. If the re-positioning concept is applied to the TX test cases,

  a. Position the device in DUT orientation 1 from *CTIA 01.71* [3],Section 4.1, if the maximum beam peak direction is within zenith angular range $0° \le \theta \le 90°$ for the alignment option selected in step 1.

b. Position the device in DUT orientation 2 (either options 1 or 2) from *CTIA 01.71* [3], Section 4.1, if the maximum beam peak direction is within zenith angular range $90° < \theta \le 180°$ for DUT orientation 1 for the alignment option selected in step 1.

3. SS sends uplink scheduling information for each UL HARQ process via PDCCH DCI format [0_1] for C_RNTI to schedule the UL RMC according to Table 6.2.1.1.4.1-1 of *3GPP TS 38.521-2* [6]. Since the UL has no payload and no loopback data to send, the UE sends uplink MAC padding bits on the UL RMC. Messages to configure the appropriate uplink modulation in *3GPP TS 38.508-1* [8], clause 4.6.

4. Set the DUT in the TX beam peak direction found in Section 3.1.

a. Connect the SS with the DUT through the measurement antenna with polarization reference Pol_{Link} that yielded the maximum TX beam peak to form the TX beam towards the TX beam peak direction and respective polarization. Allow at least BEAM_SELECT_WAIT_TIME for the UE TX beam selection to complete.

b. Continuously send uplink power control "up" commands in every uplink scheduling information to the UE; allow at least 200 ms starting from the first TPC command in this step to ensure that the UE transmits at its maximum output power before continuing.

c. SS activates the UBF by performing the procedure as specified in *3GPP TS 38.508-1* [8], clause 4.9.2 using condition TX only.

d. Measure the mean power $P_{meas}(Pol_{Meas} = \theta, Pol_{Link})$ of the modulated signal arriving at the power measurement equipment (such as a spectrum analyzer, power meter, or gNB emulator).

e. Calculate EIRP $(Pol_{Meas} = \theta, Pol_{Link})$ by adding the composite loss of the entire transmission path for utilized signal path, L$_{EIRP,\theta}$, and frequency to the measured power $P_{meas}(Pol_{Meas} = \theta, Pol_{Link})$

f. Measure the mean power $P_{meas}(Pol_{Meas} = \phi, Pol_{Link})$ of the modulated signal arriving at the power measurement equipment.

g. Calculate EIRP $(Pol_{Meas} = \phi, Pol_{Link})$ by adding the composite loss of the entire transmission path for utilized signal path, L$_{EIRP\ \phi}$ and frequency to the measured power $P_{meas}(Pol_{Meas} = \phi, Pol_{Link})$

5. Calculate the resulting total EIRP (Pol_{Link}) for the chosen Pol_{Link} of θ or ϕ as follows:
EIRP (Pol_{Link}) = EIRP $(Pol_{Meas} = \theta, Pol_{Link})$ + EIRP $(Pol_{Meas} = \phi, Pol_{Link})$

3.3   Maximum Output Power – TRP

The intent of this test procedure is to measure total radiated power of the DUT with the UL beam formed in the maximum TX beam peak direction found in Section 3.1.

The minimum number of measurement grid points including allowances to skip measurements near the pole at θ=180° for the TRP measurement are outlined in Section 6.1.

The EN-DC connections are established as outlined in Section 5.2.1.1 of *CTIA 01.50* [7]. The system simulator and DUT shall be configured per clause 6.2B.1.4.1 of *3GPP TS 38.521-3* [9] for this test case with the exception of the test conditions defined in *CTIA 01.50* [7], Section 5.2.1.1.

The test procedure for TRP is as follows:

1. Select any of the three alignment options (1, 2, or 3) from Table 4.1-1 through Table 4.1-3 in *CTIA 01.71* [3] to mount the DUT inside the QZ.

2. If the re-positioning concept is not applied to the TX test cases, position the device in DUT orientation 1. If the re-positioning concept is applied to the TX test cases,

    a. position the device in DUT orientation 1 from *CTIA 01.71* [3], Section 4.1, if the maximum beam peak direction is within zenith angular range $0° \leq \theta \leq 90°$ for the alignment option selected in step 1.

    b. Position the device in DUT orientation 2 (either options 1 or 2) from *CTIA 01.71* [3], Section 4.1, if the maximum beam peak direction is within zenith angular range $90° < \theta \leq 180°$ for DUT orientation 1 for the alignment option selected in step 1.

3. SS sends uplink scheduling information for each UL HARQ process via PDCCH DCI format [0_1] for C_RNTI to schedule the UL RMC according to Table 6.2.1.1.4.1-1 of *3GPP TS 38.521-2* [6]. Since the UL has no payload and no loopback data to send, the UE sends uplink MAC padding bits on the UL RMC. Messages to configure the appropriate uplink modulation are defined in *3GPP TS 38.508-1* [8], clause 4.6.

4. Set the DUT in the TX beam peak direction found in Section 3.1.

    a. Connect the SS with the DUT through the downlink antenna with desired polarization reference Pol_{Link} that yielded the maximum TX beam peak to form the TX beam towards the desired TX beam direction and respective polarization. Allow at least BEAM_SELECT_WAIT_TIME for the UE TX beam selection to complete.

    b. Continuously send uplink power control "up" commands in every uplink scheduling information to the UE; allow at least 200 ms after the first TPC command in this step to ensure that the UE transmits at its maximum output power before continuing.

    c. SS activates the UBF for the entire duration of the test by performing the procedure as specified in *3GPP TS 38.508-1* [8], clause 4.9.2 using condition TX only.

5. For each measurement point, measure $P_{meas} (Pol_{Meas} = \theta, Pol_{Link})$ and $P_{meas} (Pol_{Meas} = \phi, Pol_{Link})$

6. Calculate EIRP $(Pol_{Meas} = \theta, Pol_{Link})$ and EIRP $(Pol_{Meas} = \phi, Pol_{Link})$ by adding the composite loss of the entire transmission path for utilized signal paths, L_{EIRP,θ}, L_{EIRPφ} and frequency to the respective measured powers P_{meas} .

7. The TRP value for the measurement grid is calculated using the TRP integration approaches outlined in *CTIA 01.90* [10] Section 3.

3.4 Maximum Output Power - Spherical Coverage

The intent of this test procedure is to verify that the spatial coverage of the UE in expected directions is acceptable.

The EN-DC connections are established as outlined in Section 5.2.1.1 of *CTIA 01.50* [7]. The system simulator and DUT shall be configured per clause 6.2B.1.4.2 of *3GPP TS 38.521-3* [9] for this test case with the exception of the test conditions defined in *CTIA 01.50* [7], Section 5.2.1.1.

The $EIRP_{target\%-CDF}$ is obtained from the Cumulative Distribution Function (CDF) computed using maximum $(EIRP(Pol_{Link} = \theta), EIRP(Pol_{Link} = \phi))$ for all grid points collected during the TX beam peak search in Section 3.1. Alternatively, the $EIRP_{target\%-CDF}$ can be obtained from the CDF computed using maximum$(EIRP(Pol_{Link} = \theta), EIRP(Pol_{Link} = \phi))$ using the procedure outlined in Section 3.1 but for the minimum number of grid points outlined in Section 6.3. The target percentiles for different UE types are defined in Section 2.2 of *CTIA 01.01* [4].

When using constant step size measurement grids, a theta-dependent correction shall be applied, i.e., the PDF contribution for each measurement point is scaled by the normalized Clenshaw-Curtis weights $W(\theta)/W(\theta = 90°)$ as outlined in *CTIA 01.90* [10] Section 4.1.1.

Section 4　　　Test Procedure – Receiver

This section outlines the test procedures for the receiver test cases for this test plan.

For the test environmental conditions *3GPP TS 38.521-2* [6], only the normal conditions shall be applied, i.e., normal temperature and normal voltage.

4.1　　RX Beam Peak Search Procedure

The purpose of this procedure is to determine the RX beam peak direction where the minimum averaged EIS is found.

The test conditions are defined in Section 5.2.1.2 of *CTIA 01.50* [7].

The RX beam peak procedure is defined as follows:

1. Select any of the three alignment options (1, 2, or 3) from Table 4.1-1 through Table 4.1-3 in *CTIA 01.71* [3] to mount the DUT inside the QZ.
2. Position the DUT in DUT orientation 1 from Table 4.1-1 through Table 4.1-3 in *CTIA 01.71* [3].
3. Connect the SS with the DUT through the measurement antenna with $Pol_{Link} = \theta$ polarization to form the RX beam towards the measurement antenna. Continuously send uplink power control "up" commands in every uplink scheduling information to the UE; allow at least 200 ms for the UE to reach P_{UMAX}. Allow at least BEAM_SELECT_WAIT_TIME (defined in *3GPP TS 38.521-2* [6], annex K.1.1) for the UE RX beam selection to complete.
4. Determine EIS $(Pol_{Meas} = \theta, Pol_{Link} = \theta)$ for θ-polarization, i.e., the power level for the θ-polarization, at which the throughput exceeds the requirements for the specified reference measurement channel. For power steps near the sensitivity level, measure the average throughput for a duration sufficient to achieve statistical significance according to of *3GPP TS 38.521-2* [6], clause H.2.2. The downlink power step size shall be no more than 0.2 dB when the RF power level is near the sensitivity level.
5. Connect the SS with the DUT through the measurement antenna with $Pol_{Link} = \phi$ polarization to form the RX beam towards the measurement antenna. Continuously send uplink power control "up" commands in every uplink scheduling information to the UE; allow at least 200 ms for the UE to reach P$_{UMAX}$. Allow at least BEAM_SELECT_WAIT_TIME for the UE RX beam selection to complete.
6. Determine EIS $(Pol_{Meas} = \phi, Pol_{Link} = \phi)$ for ϕ-polarization, i.e., the power level for the ϕ-polarization, at which the throughput exceeds the requirements for the specified reference measurement channel. For power steps near the sensitivity level, measure the average throughput for a duration sufficient to achieve statistical significance according to of *3GPP TS 38.521-2* [6], clause H.2.2. The downlink power step size shall be no more than 0.2 dB when the RF power level is near the sensitivity level.
7. Advance to the next grid point and repeat steps 3 through 6 until measurements within the zenith range of $0° \leq \theta \leq 90°$ have been completed
8. After the measurements within zenith range $0° \leq \theta \leq 90°$ have been completed and
   a. If the re-positioning concept is applied to the RX test cases, position the device in DUT orientation 2 (either options 1 or 2) from Table 4.1-1 through Table 4.1-3 in *CTIA 01.71* [3] for the alignment option selected in Step 1. For the RX beam peak

search in the second hemisphere, perform steps 3 through 6 for the range of zenith angles $90° < \theta \le 0°$.

b. If the re-positioning concept is not applied to the RX test cases, continue steps 3 through 6 for the range of zenith angles $90° < \theta \le 180°$

c. when only a single hemisphere shall be tested (based on a vendor declaration, see Section 1.5.2 of *CTIA 01.01* [4], additional testing in the second hemisphere shall be skipped, i.e., conclude the testing after step 7

9. Calculate the resulting averaged EIS for each grid point as:

$$EIS_{avg} = 2^* [1/\text{EIS} \ (Pol_{Meas} = \theta, Pol_{Link} = \theta) + 1/\text{EIS} \ (Pol_{Meas} = \phi, Pol_{Link} = \phi)]^{-1}$$

The RX beam peak direction is where the minimum EIS_{avg} is found.

The minimum number of measurement grid points for the RX beam peak search based on testing within the full sphere are outlined in Section 6.2. When testing in just the single hemisphere is requested, based on a vendor declaration, see Section 1.5.2 of *CTIA 01.01* [4], the same grid step size and/or grid density shall be used as for the full spherical testing which correspondingly yields a reduced total number of grid points.

Alternatively, a coarse and fine search grid approach could be used according to the definition in Section 6.2.1.

4.2   REFSENS – EIS

The intent of this test procedure is to measure the averaged EIS in the RX beam peak direction found in Section 4.1. The EN-DC connections are established as outlined in Section 5.2.1.2 of *CTIA 01.50* [7]. The system simulator and DUT shall be configured per clause 7.3B.2.4 of *3GPP TS 38.521-3* [9] for this test case with the exception of the test conditions defined in *CTIA 01.50* [7], Section 5.2.1.2.

The test procedure for is defined as follows:

1. Select any of the three alignment options (1, 2, or 3) from Table 4.1-1 through Table 4.1-3 in *CTIA 01.71* [3] to mount the DUT inside the QZ.

2. If the re-positioning concept is not applied to the RX test cases, position the device in DUT orientation 1. If the re-positioning concept is applied to the RX test cases:

   a. position the device in DUT orientation 1 from *CTIA 01.71* [3], Section 4.1, if the maximum beam peak direction is within zenith angular range $0° \le \theta \le 90°$ for the alignment option selected in step 1,

   b. position the device in DUT orientation 2 (either options 1 or 2) from *CTIA 01.71* [3], Section 4.1, the maximum beam peak direction is within zenith angular range $90° < \theta \le 180°$ for DUT orientation 1 for the alignment option selected in step 1.

3. Connect the SS with the DUT through the measurement antenna with $Pol_{Link} = \theta$ polarization to form the RX beam towards the RX beam peak direction. Send continuously uplink power control "up" commands in every uplink scheduling information to the UE; allow at least 200 ms for the UE to reach P$_{UMAX}$. Allow at least BEAM_SELECT_WAIT_TIME (defined in *3GPP TS 38.521-2* [6], clause K.1.1, for the UE RX beam selection to complete.

4. Determine $\text{EIS}(Pol_{Meas} = \theta, Pol_{Link} = \theta)$ for θ-polarization, i.e., the power level for the θ-polarization at which the throughput exceeds the requirements for the specified reference measurement channel. For power steps near the sensitivity level, measure the average throughput for a duration sufficient to achieve statistical significance according to of *3GPP*

TS 38.521-2 [6], clause H.2.2. The downlink power step size shall be no more than 0.2 dB when the RF power level is near the sensitivity level.

5. Connect the SS with the DUT through the measurement antenna with $Pol_{Link} = \phi$ polarization to form the RX beam towards the RX beam peak direction. Continuously send uplink power control "up" commands in every uplink scheduling information to the UE; allow at least 200 ms for the UE to reach P_{UMAX}. Allow at least BEAM_SELECT_WAIT_TIME for the UE RX beam selection to complete.

6. Determine $\text{EIS}(Pol_{Meas} = \phi, Pol_{Link} = \phi)$ for ϕ-polarization, i.e., the power level for the ϕ-polarization at which the throughput exceeds the requirements for the specified reference measurement channel. For power steps near the sensitivity level, measure the average throughput for a duration sufficient to achieve statistical significance according to *3GPP TS 38.521-2* [6], clause H.2.2. The downlink power step size shall be no more than 0.2 dB when the RF power level is near the sensitivity level.

7. Calculate the resulting averaged EIS in the RX beam peak direction as:

$$EIS_{avg} = 2^*[1/\text{EIS}\ (Pol_{Meas} = \theta, Pol_{Link} = \theta) + 1/\text{EIS}\ (Pol_{Meas} = \phi, Pol_{Link} = \phi)]^{-1}$$

4.3   REFSENS – Spherical Coverage

The intent of this test procedure is to verify that the spatial coverage of the UE in the expected directions is acceptable.

The EN-DC connections are established as outlined in Section 5.2.1.2 of *CTIA 01.50* [7]. The system simulator and DUT shall be configured per clause 7.3B.4 of *3GPP TS 38.521-3* [9] this test case with the exception of the test conditions defined in *CTIA 01.50* [7], Section 5.2.1.2.

The $\text{EIS}_{target\%-\text{CCDF}}$ is obtained from the Complementary Cumulative Distribution Function (CCDF) computed from the EIS$_{avg}$ measurements for all grid points collected during the RX beam peak search in Section 4.1. Alternatively, the $\text{EIS}_{target\%-\text{CCDF}}$ can be obtained from the CCDF computed from the EIS$_{avg}$ measurements using the procedure outlined in Section 4.1 but for the minimum number of grid points outlined in Section 6.3. The target percentiles for different UE types are defined in Section 2.2 of *CTIA 01.01* [4].

When using constant step size measurement grids, a theta-dependent correction shall be applied, i.e., the PDF contribution for each measurement point is scaled by the normalized Clenshaw-Curtis weights $W(\theta)/W(\theta = 90°)$ as outlined in *CTIA 01.90* [10], Section 4.1.1.

Section 5 Measurement Uncertainty

5.1 EIRP Tests

The Effective Isotropic Radiated Power (EIRP) test method determines the unknown performance of the DUT by correcting the absolute power measurements at the input port of the test instrumentation using a relative correction value determined using the range reference measurement described in Section 4 of *CTIA 01.73* [1]. This correction value offsets each power measurement back to the equivalent power that would have been radiated by a theoretical isotropic radiator in order to produce the same measured level. This corrected value is known as the EIRP.

In Table 5.1-1 uncertainties are identified that belong to either the DUT measurement, the range reference measurement stage or both for the EIRP test case.

Table 5.1-1 Uncertainty Contributions for EIRP Measurements

UID	Description Of Uncertainty Contributions	Reference
Stage 2: DUT Measurement		
1	Positioning Misalignment	See Section 2.14 of *CTIA 01.70* [5]
2	Measurement Distance	See Section 2.41 of *CTIA 01.70* [5]
3	Quality of Quiet Zone	See Section 2.11.1 of *CTIA 01.70* [5]
4	Mismatch	See Section 2.1 of *CTIA 01.70* [5]
5	Chamber Standing Wave	See Section 2.14 of *CTIA 01.70* [5]
6	RF Power Measurement Equipment	See Section 2.4 of *CTIA 01.70* [5]
7	Phase Curvature	See Section 2.33 of *CTIA 01.70* [5]
8	Amplifiers	See Section 2.7 of *CTIA 01.70* [5]
9	Random Uncertainty	See Section 2.22 of *CTIA 01.70* [5]
10	Influence of the XPD	See Section 2.34 of *CTIA 01.70* [5]
11	Multiple Measurement Antennas	See Section 2.35 of *CTIA 01.70* [5]
12	DUT Repositioning	See Section 2.18 of *CTIA 01.70* [5]
Stage 1: Range Reference Measurement		
13	Mismatch	See Section 2.1 of *CTIA 01.70* [5]
14	Amplifiers	See Section 2.7 of *CTIA 01.70* [5]
15	Misalignment of Positioning System	See Section 2.15 of *CTIA 01.70* [5]
16	Network Analyzer	See Section 2.6 of *CTIA 01.70* [5]
17	Absolute Gain of the Calibration Antenna	See Section 2.8.1 of *CTIA 01.70* [5]
18	Positioning and Pointing Misalignment between the Reference Antenna and the Measurement Antenna	See Section 2.16 of *CTIA 01.70* [5]
19	Phase Center Offset of Calibration Antenna	See Section 2.36 of *CTIA 01.70* [5]
20	Quality of Quiet Zone for Calibration Process	See Section 2.11.2 of *CTIA 01.70* [5]
21	Influence of the Calibration Antenna Feed Path	See Section 2.37 of *CTIA 01.70* [5]
22	Standing Wave between Reference Calibration Antenna and Measurement Antenna	See Section 2.32 of *CTIA 01.70* [5]
23	Insertion Loss Variation	See Section 2.3 of *CTIA 01.70* [5]
Systematic Uncertainties		
24	Influence of Noise	See Section 2.38 of *CTIA 01.70* [5]
25	Systematic Error related to Beam Peak Search	See Section 2.39 of *CTIA 01.70* [5]

5.2 TRP Tests

The Total Radiated Power (TRP) test method is based on the EIRP approach outlined in Section 5.1 but requires the integration of EIRPs across the total spherical surface to determine the TRP.

In Table 5.2-1, uncertainties are identified that belong to either the DUT measurement, the range reference measurement stage or both for the TRP test case.

Table 5.2-1 Uncertainty Contributions for TRP Measurements

UID	Description of Uncertainty Contributions	Reference
Stage 2: DUT Measurement		
1	Positioning Misalignment	See Section 2.14 of *CTIA 01.70* [5]
2	Measurement Distance	See Section 2.41 of *CTIA 01.70* [5]
3	Quality of Quiet Zone	See Section 2.11.1 of *CTIA 01.70* [5]
4	Mismatch	See Section 2.1 of *CTIA 01.70* [5]
5	Chamber Standing Wave	See Section 2.31 of *CTIA 01.70* [5]
6	RF Power Measurement Equipment	See Section 2.4 of *CTIA 01.70* [5]
7	Phase Curvature	See Section 2.33 of *CTIA 01.70* [5]
8	Amplifiers	See Section 2.7 of *CTIA 01.70* [5]
9	Random Uncertainty	See Section 2.22 of *CTIA 01.70* [5]
10	Influence of the XPD	See Section 2.34 of *CTIA 01.70* [5]
11	Influence of TRP Measurement Grid	See Section 2.21.3 of *CTIA 01.70* [5]
12	Multiple Measurement Antennas	See Section 2.35 of *CTIA 01.70* [5]
13	DUT Repositioning	See Section 2.18 of *CTIA 01.70* [5]
Stage 1: Range Reference Measurement		
14	Mismatch	See Section 2.1 of *CTIA 01.70* [5]
15	Amplifiers	See Section 2.7 of *CTIA 01.70* [5]
16	Misalignment of Positioning System	See Section 2.15 of *CTIA 01.70* [5]
17	Network Analyzer	See Section 2.6 of *CTIA 01.70* [5]
18	Absolute Gain of the Calibration Antenna	See Section 2.8.1 of *CTIA 01.70* [5]
19	Positioning and Pointing Misalignment between the Reference Antenna and the Measurement Antenna	See Section 2.16 of *CTIA 01.70* [5]
20	Phase Center Offset of Calibration Antenna	See Section 2.36 of *CTIA 01.70* [5]
21	Quality of Quiet Zone for Calibration Process	See Section 2.11.2 of *CTIA 01.70* [5]
22	Influence of the Calibration Antenna Feed Path	See Section 2.37 of *CTIA 01.70* [5]
23	Standing Wave between Reference Calibration Antenna and Measurement Antenna	See Section 2.32 of *CTIA 01.70* [5]
24	Insertion Loss Variation	See Section 2.3 of *CTIA 01.70* [5]
Systematic Uncertainties		
25	Influence of Noise	See Section 2.38 of *CTIA 01.70* [5]

5.3   EIRP Spherical Coverage

The EIRP Spherical Coverage test method is based on the EIRP approach outlined in Section 5.1 but requires the computation of the CDF of EIRPs measured on each grid point of the spherical surface.

In Table 5.3-1, uncertainties are identified that belong to either the DUT measurement, the range reference measurement stage or both for the EIRP spherical coverage test case.

Table 5.3-1 Uncertainty Contributions for EIRP Spherical Coverage Measurements

UID	Description of Uncertainty Contributions	Reference
Stage 2: DUT Measurement		
1	Positioning Misalignment	See Section 2.14 of *CTIA 01.70* [5]
2	Measurement Distance	See Section 2.41 of *CTIA 01.70* [5]
3	Quality of Quiet Zone	See Section 2.11.1 of *CTIA 01.70* [5]
4	Mismatch	See Section 2.1 of *CTIA 01.70* [5]
5	Chamber Standing Wave	See Section 2.31 of *CTIA 01.70* [5]
6	RF Power Measurement Equipment	See Section 2.4 of *CTIA 01.70* [5]
7	Phase Curvature	See Section 2.33 of *CTIA 01.70* [5]
8	Amplifiers	See Section 2.7 of *CTIA 01.70* [5]
9	Random Uncertainty	See Section 2.22 of *CTIA 01.70* [5]
10	Influence of the XPD	See Section 2.34 of *CTIA 01.70* [5]
11	Multiple Measurement Antennas	See Section 2.35 of *CTIA 01.70* [5]
12	DUT Repositioning	See Section 2.18 of *CTIA 01.70* [5]
13	Influence of Spherical Coverage Grid	See Section 2.21.4 of *CTIA 01.70* [5]
Stage 1: Range Reference Measurement		
14	Mismatch	See Section 2.1 of *CTIA 01.70* [5]
15	Amplifiers	See Section 2.7 of *CTIA 01.70* [5]
16	Misalignment of Positioning System	See Section 2.15 of *CTIA 01.70* [5]
17	Network Analyzer	See Section 2.6 of *CTIA 01.70* [5]
18	Absolute Gain of the Calibration Antenna	See Section 2.8.1 of *CTIA 01.70* [5]
19	Positioning and Pointing Misalignment between the Reference Antenna and the Measurement Antenna	See Section 2.16 of *CTIA 01.70* [5]
20	Phase Center Offset of Calibration Antenna	See Section 2.36 of *CTIA 01.70* [5]
21	Quality of Quiet Zone for Calibration Process	See Section 2.11.2 of *CTIA 01.70* [5]
22	Influence of the Calibration Antenna Feed Path	See Section 2.37 of *CTIA 01.70* [5]
23	Standing Wave between Reference Calibration Antenna and Measurement Antenna	See Section 2.32 of *CTIA 01.70* [5]
24	Insertion Loss Variation	See Section 2.3 of *CTIA 01.70* [5]
Systematic Uncertainties		
25	Influence of Noise	See Section 2.38 of *CTIA 01.70* [5]

5.4   EIS Tests

The Effective Isotropic Sensitivity (EIS) test method is similar to the EIRP method above, in that the range reference measurement outlined in Section 4 of *CTIA 01.73* [1] is used to correct the unknown performance of the DUT back to values relative to that of a theoretical isotropic receiver. In this case, the correction value offsets each sensitivity level measurement back to the equivalent sensitivity level of a theoretical isotropic receiver exposed to an incoming isotropic wave with the same magnitude. This corrected value is known as the EIS.

In Table 5.4-1, uncertainties are identified that belong to either the DUT measurement, the range reference measurement stage or both for the EIS test case.

Table 5.4-1 Uncertainty Contributions for EIS Measurements

UID	Description of Uncertainty Contributions	Reference
Stage 2: DUT Measurement		
1	Positioning Misalignment	See Section 2.14 of *CTIA 01.70* [5]
2	Measurement Distance	See Section 2.41 of *CTIA 01.70* [5]
3	Quality of Quiet Zone	See Section 2.11.1 of *CTIA 01.70* [5]
4	Mismatch	See Section 2.1 of *CTIA 01.70* [5]
5	Chamber Standing Wave	See Section 2.31 of *CTIA 01.70* [5]
6	gNB Emulator	See Section 2.4 of *CTIA 01.70* [5]
7	Phase Curvature	See Section 2.33 of *CTIA 01.70* [5]
8	Amplifiers	See Section 2.7 of *CTIA 01.70* [5]
9	Random Uncertainty	See Section 2.22 of *CTIA 01.70* [5]
10	Influence of the XPD	See Section 2.34 of *CTIA 01.70* [5]
11	Multiple Measurement Antennas	See Section 2.35 of *CTIA 01.70* [5]
12	DUT Repositioning	See Section 2.18 of *CTIA 01.70* [5]
Stage 1: Range Reference Measurement		
13	Mismatch	See Section 2.1 of *CTIA 01.70* [5]
14	Amplifiers	See Section 2.7 of *CTIA 01.70* [5]
15	Misalignment of Positioning System	See Section 2.15 of *CTIA 01.70* [5]
16	Network Analyzer	See Section 2.6 of *CTIA 01.70* [5]
17	Absolute Gain of the Calibration Antenna	See Section 2.8.1 of *CTIA 01.70* [5]
18	Positioning and Pointing Misalignment between the Reference Antenna and the Measurement Antenna	See Section 2.16 of *CTIA 01.70* [5]
19	Phase Center Offset of Calibration Antenna	See Section 2.36 of *CTIA 01.70* [5]
20	Quality of Quiet Zone for Calibration Process	See Section 2.11.2 of *CTIA 01.70* [5]
21	Influence of the Calibration Antenna Feed Path	See Section 2.37 of *CTIA 01.70* [5]
22	Standing Wave between Reference Calibration Antenna and Measurement Antenna	See Section 2.32 of *CTIA 01.70* [5]
23	Insertion Loss Variation	See Section 2.3 of *CTIA 01.70* [5]
Systematic Uncertainties		
24	Systematic Error related to Beam Peak Search	See Section 2.39 of *CTIA 01.70* [5]

5.5   EIS Spherical Coverage

The EIS spherical coverage test method is based on the EIS approach outlined in Section 5.4 but requires the computation of the CCDF of EISs measured on each grid point of the spherical surface.

In Table 5.5-1, uncertainties are identified that belong to either the DUT measurement, the range reference measurement stage or both for the EIS spherical coverage test case.

Table 5.5-1 Uncertainty Contributions for EIS Spherical Coverage Measurements

UID	Description of Uncertainty Contributions	Reference
Stage 2: DUT Measurement		
1	Positioning Misalignment	See Section 2.14 of *CTIA 01.70* [5]
2	Measurement Distance	See Section 2.41 of *CTIA 01.70* [5]
3	Quality of Quiet Zone	See Section 2.11.1 of *CTIA 01.70* [5]
4	Mismatch	See Section 2.1 of *CTIA 01.70* [5]
5	Chamber Standing Wave	See Section 2.31 of *CTIA 01.70* [5]
6	gNB Emulator	See Section 2.4 of *CTIA 01.70* [5]
7	Phase Curvature	See Section 2.33 of *CTIA 01.70* [5]
8	Amplifiers	See Section 2.7 of *CTIA 01.70* [5]
9	Random Uncertainty	See Section 2.22 of *CTIA 01.70* [5]
10	Influence of the XPD	See Section 2.34 of *CTIA 01.70* [5]
11	Multiple Measurement Antennas	See Section 2.35 of *CTIA 01.70* [5]
12	DUT Repositioning	See Section 2.18 of *CTIA 01.70* [5]
13	Influence of Spherical Coverage Grid	See Section 2.21.4 of *CTIA 01.70* [5]
Stage 1: Range Reference Measurement		
14	Mismatch	See Section 2.1 of *CTIA 01.70* [5]
15	Amplifiers	See Section 2.7 of *CTIA 01.70* [5]
16	Misalignment of Positioning System	See Section 2.15 of *CTIA 01.70* [5]
17	Network Analyzer	See Section 2.6 of *CTIA 01.70* [5]
18	Absolute Gain of the Calibration Antenna	See Section 2.8.1 of *CTIA 01.70* [5]
19	Positioning and Pointing Misalignment between the Reference Antenna and the Measurement Antenna	See Section 2.16 of *CTIA 01.70* [5]
20	Phase Center Offset of Calibration Antenna	See Section 2.36 of *CTIA 01.70* [5]
21	Quality of Quiet Zone for Calibration Process	See Section 2.11.2 of *CTIA 01.70* [5]
22	Influence of the Calibration Antenna Feed Path	See Section 2.37 of *CTIA 01.70* [5]
23	Standing Wave between Reference Calibration Antenna and Measurement Antenna	See Section 2.32 of *CTIA 01.70* [5]
24	Insertion Loss Variation	See Section 2.3 of *CTIA 01.70* [5]
Systematic Uncertainties		
25	Systematic error related to EIS spherical coverage	See Section 2.40 of *CTIA 01.70* [5]

5.6   Criteria – Maximum Test System Uncertainty

The results of the calculations for expanded uncertainty for all test cases measurements shall be reported, along with full documentation to support the resulting values. The test performance requirements shall not be adjusted by the measurement uncertainty when determining compliance of the DUTs.

The expanded uncertainties must not exceed the maximum test system uncertainty (MTSU) values in Table 5.6-1 for a maximum DUT size of 30 cm, in Table 5.6-2 for a maximum DUT size of 40 cm, and in Table 5.6-3 for a maximum DUT size of 55 cm at a confidence level, of approximately 95% (k=2) per *CTIA 01.70* [5].

Table 5.6-1 Maximum Test System Uncertainty for Different Test Cases

	Expanded Uncertainty [dB]			
Test Case	FR2_1 (24.25GHZ- 32GHZ)	FR2_2 (32 GHZ - 40 GHZ)	FR2_3 (40 GHZ - 48 GHZ)	FR2_4 (48 GHZ - 52.6GHZ)
Maximum Output Power – EIRP	4.87	5.07	TBD	TBD
Maximum Output Power – TRP	4.40	4.60	TBD	TBD
Maximum Output Power – Spherical Coverage	4.58	5.18	TBD	TBD
REFSENS – EIS	5.19	5.19	TBD	TBD
REFSENS – Spherical Coverage	4.90	4.90	TBD	TBD

Table 5.6-2 Maximum Test System Uncertainty for Different Test Cases for a Maximum DUT Size of 40cm in Diameter

	Expanded Uncertainty [dB]			
Test Case	FR2_1 (24.25GHZ- 32GHZ)	FR2_2 (32 GHZ - 40 GHZ)	FR2_3 (40 GHZ - 48 GHZ)	FR2_4 (48 GHZ - 52.6GHZ)
Maximum Output Power – EIRP	5.04	5.24	TBD	TBD
Maximum Output Power – TRP	4.57	4.77	TBD	TBD
Maximum Output Power – Spherical Coverage	4.74	5.34	TBD	TBD
REFSENS – EIS	5.34	5.34	TBD	TBD
REFSENS – Spherical Coverage	5.05	5.05	TBD	TBD

Table 5.6-3 Maximum Test System Uncertainty for Different Test Cases for a Maximum DUT size of 55cm In Diameter

Test Case	Expanded Uncertainty [dB]			
	FR2_1 (24.25GHZ- 32GHZ)	FR2_2 (32 GHZ - 40 GHZ)	FR2_3 (40 GHZ - 48 GHZ)	FR2_4 (48 GHZ - 52.6GHZ)
Maximum Output Power – EIRP	FFS	FFS	TBD	TBD
Maximum Output Power – TRP	FFS	FFS	TBD	TBD
Maximum Output Power – Spherical Coverage	FFS	FFS	TBD	TBD
REFSENS – EIS	FFS	FFS	TBD	TBD
REFSENS – Spherical Coverage	FFS	FFS	TBD	TBD

The applicability mapping between minimum QZ size, maximum device size and maximum test system uncertainty (MTSU) is outlined in. The underlying assumptions for the proposed mapping are as follows:

- The maximum device size ranges/limits follow the defined QZ sizes, i.e., 30cm, 40cm, and 55cm
- The applicable MTSU follows the max device size, e.g., a max device size of 30cm to 40cm yields an MTSU of $MTSU_{40cm}$.
- The applicable MTSU is the same regardless of whether a gray-box or black-box approach, outlined in Section 4.1 of *CTIA 01.71* [3], is selected to simplify the mapping.
- A maximum device size exceeding 55cm does not have an applicable MTSU given the lack of a larger QZ.

Table 5.6-4 Proposed Mapping Between Minimum QZ size, Maximum Device Size, and Applicable MTSU

Minimum QZ Required To Contain All Active Antennas Within The Quiet Zone (Vendor Declaration)	Max Device Size	Applicable MTSU	Note
30cm	≤30cm	$MTSU_{30cm}$	A system supporting a {30cm, 40cm, 55cm} QZ can be used as long as the assessed MU with a {30cm, 40cm, 55cm} QoQZ validation is ≤ $MTSU_{30cm}$
30cm	>30cm and ≤40cm	$MTSU_{40cm}$	A system supporting a {30cm, 40cm, 55cm} QZ can be used as long as the assessed MU with a {30cm, 40cm, 55cm} QoQZ validation is ≤ $MTSU_{40cm}$
30cm	>40cm and ≤55cm	$MTSU_{55cm}$	A system supporting a {30cm, 40cm, 55cm} QZ can be used as long as the assessed MU with a {30cm, 40cm, 55cm} QoQZ validation is ≤ $MTSU_{55cm}$
30cm	>55cm	Not applicable until larger QZ is defined	Pending larger QZ (exceeding 55cm) definition

Minimum QZ Required To Contain All Active Antennas Within The Quiet Zone (Vendor Declaration)	Max Device Size	Applicable MTSU	Note
40cm	≤40cm	$MTSU_{40cm}$	A system supporting a {40cm, 55cm} QZ can be used as long as the assessed MU with a {40cm, 55cm} QoQZ validation is ≤ $MTSU_{40cm}$
40cm	>40cm and ≤55cm	$MTSU_{55cm}$	A system supporting a {40cm, 55cm} QZ can be used as long as the assessed MU with a {40cm, 55cm} QoQZ validation is ≤ $MTSU_{55cm}$
40cm	>55cm	Not applicable until larger QZ is defined	Pending larger QZ (exceeding 55cm) definition
55cm	>40cm and ≤55cm	$MTSU_{55cm}$	
55cm	>55cm	Not applicable until larger QZ is defined	Pending larger QZ (exceeding 55cm) definition
>55cm	>55cm	Not applicable until larger QZ is defined	Note: QZs exceeding 55cm cannot be declared due to lack of larger QZ definition

Section 6   Measurement Grids

This test plan is currently applicable only to UE antennas with radiating aperture less than or equal to $5\,\mathrm{cm}$. Measurement grids and measurement uncertainties for DUTs with antenna apertures greater than $5\,\mathrm{cm}$ have not been defined yet and can therefore not be certified using this test plan.

This section outlines important aspects of measurement grids including minimum number of grid points for constant step-size and constant density and the corresponding MU values. The PC3 analyses were based on an 8x2 antenna array. Alternate measurement grids can be applied based on a vendor declaration outlined in Section 1.5.2 of *CTIA 01.01* [4].

6.1   TRP Measurement Grids

The TRP grid is used to determine the Total Radiated Power emitted by the DUT.

For Power Class 3 devices with radiating apertures of less than or equal to 5 cm, i.e., non-sparse antenna arrays, either of the following measurement grids and implementations were found to be the best trade-off between measurement uncertainties, measurement grid points, and test time. Either of the choices shall be used for this test plan:

If the re-positioning concept is not applied to TRP test cases:

- 135 measurement grid points for constant density grid – Charged Particle implementation, with standard deviation of 0.23 dB

- At least 192 unique measurement grid points ($\Delta\theta = 16.36°$, $\Delta\phi = 18.95°$) for constant step size grid using the Clenshaw Curtis weights integration approach, with standard deviation of 0.20 dB with the allowance to skip and interpolate measurements at the pole at $\theta = 180°$.

If the re-positioning concept is applied to TRP test cases:

- 135 measurement grid points for constant density grid – Charged Particle implementation, with standard deviation of 0.23 dB with the allowance to skip and interpolate measurements for
$$\theta \geq 165°$$

- 150 measurement grid points for constant density grid – Charged Particle implementation, with standard deviation of 0.25 dB with the allowance to skip and interpolate measurements for
$$\theta \geq 150°$$

- At least 192 unique measurement grid points ($\Delta\theta = 16.36°$, $\Delta\phi = 18.95°$) for constant step size grid using the Clenshaw Curtis weights integration approach, with standard deviation of 0.20 dB with the allowance to skip and interpolate measurements the at pole at $\theta = 180°$.

- At least 266 unique measurement grid points ($\Delta\theta = 15°$, $\Delta\phi = 15°$) for constant step size grid using the Clenshaw Curtis weights integration approach, with standard deviation of 0.15 dB with the allowance to skip and interpolate measurements for $\theta \geq 165°$

Based on an optional vendor declaration outlined in Section 1.5.2 of *CTIA 01.01* [4], PC3 devices with an $M \, x \, N \, (M \geq N)$ configuration with $M \leq 4$ and $N \leq 2$ can utilize either of the following minimum number of grid points for TRP procedures

- without the repositioning approach applied to TRP test cases:

  - 50 measurement grid points for constant density grid – Charged Particle implementation, with standard deviation of 0.14 dB

- 80 measurement grid points for constant density grid – Charged Particle implementation, with standard deviation of 0.23 dB with the allowance to skip and interpolate measurements for $\theta \geq 165°$

- At least 86 unique measurement grid points ($\Delta\theta = \Delta\phi = 25.71°$) for constant step size grid – Clenshaw Curtis weights integration approach, with standard deviation of 0.20 dB with the allowance to skip and interpolate measurements at the pole at $\theta = 180°$.

- with the re-positioning applied to TRP test cases:

  - 50 measurement grid points for constant density grid – Charged Particle implementation, with standard deviation of 0.14 dB with the allowance to skip and interpolate measurements for
    $$\theta \geq 150°$$

  - At least 62 unique number of grid points ($\Delta\theta = \Delta\phi = 30°$) for constant step size grid – Clenshaw Curtis weights integration approach, with standard deviation of 0.20 dB with the allowance to skip and interpolate measurements the at pole at $\theta = 180°$.

  - At least 86 unique number of grid points ($\Delta\theta = \Delta\phi = 25.71°$) for constant step size grid – Clenshaw Curtis weights integration approach, with standard deviation of 0.09 dB with the allowance to skip and interpolate measurements for $\theta \geq 128.58°$

Based on an optional vendor declaration outlined in Section 1.5.2 of *CTIA 01.01* [4], PC3 devices with an $M \times N$ ($M \geq N$) configuration with $4 < M \leq 6$ and $N \leq 2$ can utilize either of the following minimum number of grid points for TRP procedures

- without the repositioning approach applied to TRP test cases:

  - 100 measurement grid points for constant density grid – Charged Particle implementation, with standard deviation of 0.13 dB

  - At least 130 unique measurement grid points ($\Delta\theta = 20°, \Delta\phi = 22.5°$) for constant step size grid – Clenshaw Curtis weights integration approach, with standard deviation of 0.23 dB with the allowance to skip and interpolate measurements at the pole at $\theta = 180°$.

- with the re-positioning applied to TRP test cases:

  - 90 measurement grid points for constant density grid – Charged Particle implementation, with standard deviation of 0.21 dB with the allowance to skip and interpolate measurements for $\theta \geq 150°$

  At least 130 unique number of grid points ($\Delta\theta = 20°, \Delta\phi = 22.5°$) for constant step size grid – Clenshaw Curtis weights integration approach, with standard deviation of 0.18 dB with the allowance to skip and interpolate measurements the at pole at $\theta \geq 140°$.

6.2   Beam Peak Search Measurement Grids

The beam peak search grid is used to determine the beam peak of the TX and RX beams.

For Power Class 3 devices with radiating apertures of less than or equal to $5\,cm$, i.e., non-sparse antenna arrays, either of the following measurement grids and implementations were found to be the best trade-off between measurement uncertainties, measurement grid points, and test time. Either of the two choices shall be used for this test plan based on testing within the full sphere:

- At least 800 measurement grid points for the constant density grid using the charged particle implementation
- At least 1106 measurement grid points (angular step size of 7.5°) for the constant step size grid

Based on the vendor declaration outlined in Section 1.5.2 of *CTIA 01.01* [4], PC3 devices with an $M \ x \ N \ (M \ \geq \ N)$ configuration with $M \ \leq \ 4$ and $N \ \leq \ 2$ can utilize either of the following minimum number of grid points for beam peak search procedures:

- At least 310 measurement grid points for the constant density grid using the charged particle implementation

- At least 422 measurement grid points (angular step size of ($\Delta\theta = \Delta\phi = 12.0°$) for the constant step size grid

Based on the vendor declaration outlined in Section 1.5.2 of *CTIA 01.01* [4], PC3 devices with an $M \ x \ N \ (M \ \geq \ N)$ configuration with $4 < \ M \ \leq \ 6$ and $N \ \leq \ 2$ can utilize either of the following minimum number of grid points for beam peak search procedures:

- At least 575 measurement grid points for the constant density grid using the charged particle implementation

- At least 762 measurement grid points with angular step size of $\Delta\theta = \Delta\phi = 9.0°$ for the constant step size grid

When testing in just the single hemisphere is requested, based on a vendor declaration, see Section 1.5.2 of *CTIA 01.01* [4], the same grid step size and/or grid density shall be used as for the full spherical testing which correspondingly yields a reduced total number of grid points.

The corresponding systematic error related to Beam Peak Search is 0.5 dB for the above choices.

6.2.1   Coarse and Fine Search Measurement Grids

The baseline beam peak search is based on a single and fine beam peak search grid to determine the TX/RX beam peak of the DUT in any given direction. This means that even in sectors where poor EIRP/EIS performance is observed, a very fine grid is used to search for the TX/RX beam peak.

An optimized approach based on an initial coarse search followed by a subsequent fine search could reduce the number of beam peak search grid points significantly. The basis for this approach is to use a coarse grid with fewer number of points than the ones described in Section 6.2 in the first stage to identify candidate regions that contain the global beam peak and search for the global beam peak with the fine grid in the second stage with a minimum number of points described in Section 6.2.

As an example, Figure 6.2.1-1 illustrates the coarse and fine measurement grid approach applied to TX beam search; while this illustration is for EIRP, it can easily be extended to RX beam peak search using EIS metric. For simplification purposes, 2D coarse and fine searches are illustrated but the concept can be extended to 3D easily. The UE is assumed to form a total of six beams in the 2D plane as illustrated on the left of Figure 6.2.1-1. In the center of Figure 6.2.1-1, the 36 coarse beam peak search grid points in the 2D plane are illustrated. On the right, the grey circles on the respective antenna patterns illustrate the measured EIRP values towards each coarse grid point direction based on the respective beam steering directions. This illustration shows that the EIRP beam peak of the coarse search, $EIRP_{CSBP}$, is found to be the peak of the orange beam while the global TX beam peak (red beam) was not identified due to the coarse sampling of the grid points.
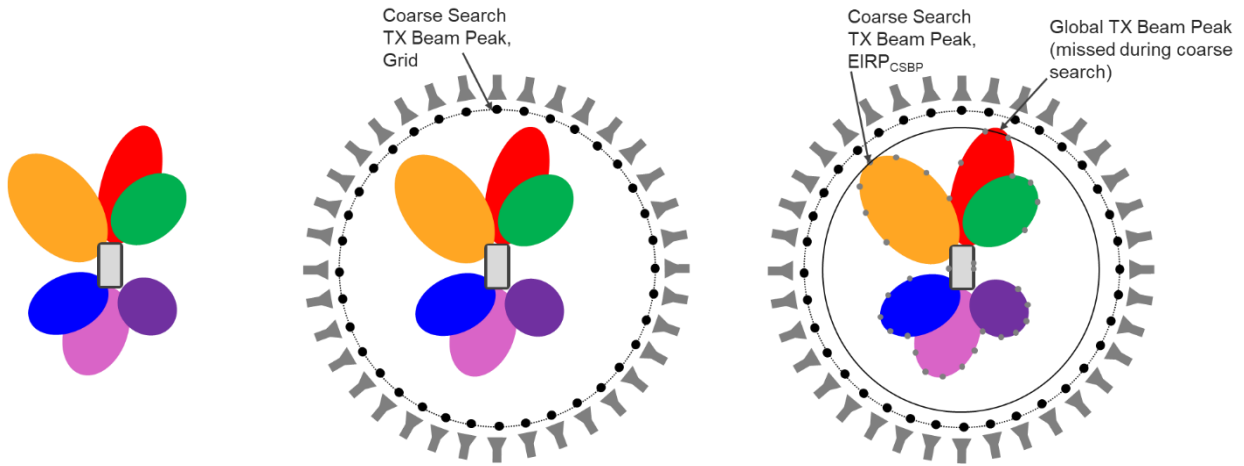
Figure 6.2.1-1 Illustration of the Coarse Search Approach for TX Beam Peak Search. Left: Antenna Pattern Assumptions in 2D, Centre: Coarse Beam Peak Search Grid Points/Discrete Antenna Measurement Positions, Right: TX Beam EIRP Measurements Per Grid Point

The proposed fine search approach is illustrated further in Figure 6.2.1-2. A fine search region starting from the beam peak identified in the coarse search, $EIRP_{CSBP}$, over a range of Δ_{FS} is used to identify the regions that need to be investigated more closely with the fine search algorithm. The fine search range Δ_{FS} is a function of the angular spacing of the coarse beam peak search grid as well as the beam width of the reference antenna pattern considered for smartphone UEs.
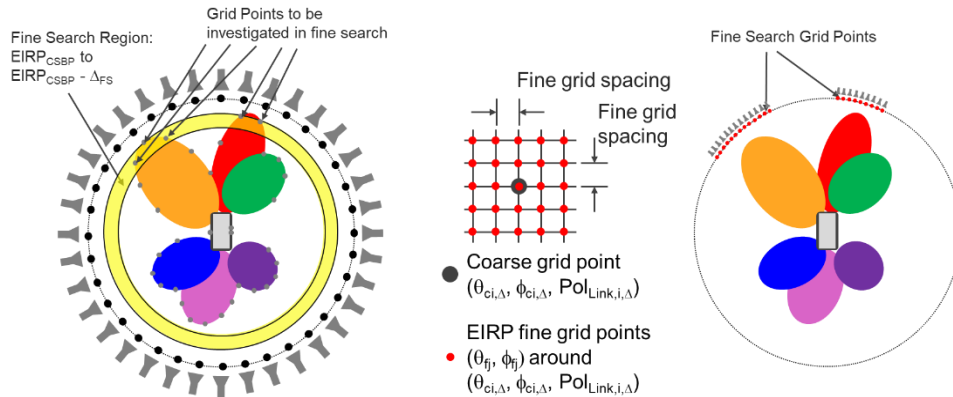

Figure 6.2.1-2 Illustration of the Fine Beam Peak Search Grid. Left: Identify the Measurement Grid Points that Yielded EIRP Values Within The Fine Search Region, Right: Placement of Fine Beam Peak Search Grid Points

Figure 6.2.1-3 illustrates coarse and fine grids for constant step size measurement grids; the applicability of coarse and fine measurement grids for constant density grids will be addressed in a future release of the test plan.
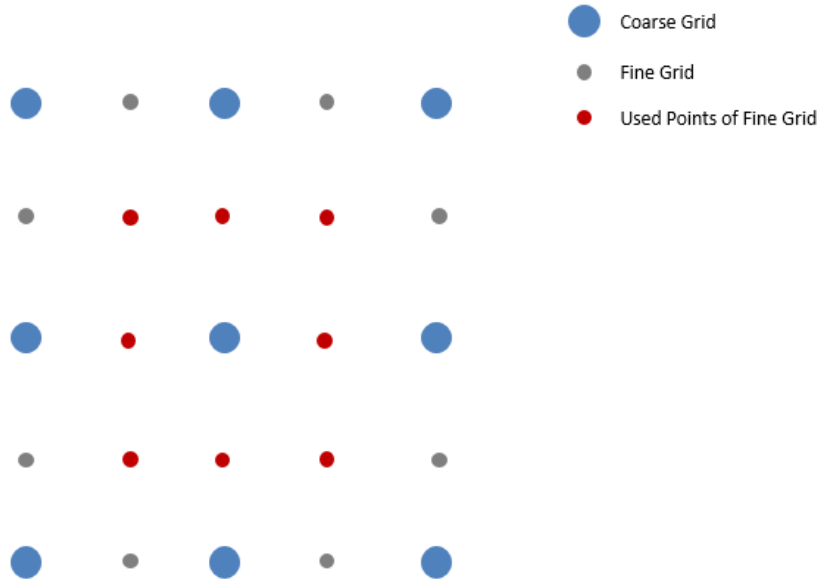
Figure 6.2.1-3 Illustration: Coarse & Fine Constant Step Size Grids

The Δ_{FS} parameter, i.e., the range of the fine search region from the coarse grid beam peak, is tabulated in Table 6.2.1-1. For the time being, only coarse and fine searches with measurement grids using $\theta\Delta = \Delta\phi = 15°$ for the coarse grid and $\theta\Delta = \Delta\phi = 7.5°$ for the fine grid shall be utilized.

Table 6.2.1-1 Measurement Grid Parameters for the Constant Step-Size Coarse and Fine Beam Peak Search Measurement Grids for PC3 UEs with a Coarse Grid of $\Delta\theta = \Delta\phi = 15°$ (Spherical Coverage Grid)

Antenna Configuration / Grid Parameters	8X2	6X2	4X2
Δ_{FS} [dB] with fine grid $\theta\Delta = \Delta\phi = 7.5°$ (Note 1)	4.5	2.5	1.5
Coarse grid with $\theta\Delta = \Delta\phi = [°]$	15	15	15
Note 1: Local searches in the "fine search region" are performed on the 8 fine grid points surrounding each coarse grid point within the Δ_{FS} region (Figure 6.2.1-3).			

The metric using a coarse and fine grid approach for the TX beam peak search is EIRP for both grids. For RX beam peak search, the metric is EIS for coarse grids and for fine grids.

6.3   Spherical Coverage Measurement Grids

The spherical coverage measurement grid is used to determine the CDF (CCDF) curve for EIRPs (EISs) measured on each grid point. For constant step size measurement grid types, the PDF contribution for each measurement point is scaled by the normalized Clenshaw-Curtis weights $W(\theta)/W(\theta = 90°)$ as outlined in *CTIA 01.90* [10], Section 4.4.1, to account for the denser grid point distribution near the poles. When just a single measurement at the poles is performed, the PDF probability contributions need to be scaled by $M^* W(\theta)/W(\theta = 90°)$ to account for the M longitudes at those two grid points. When using constant density grids, these corrections are not needed.

For Power Class 3 devices with radiating apertures of less than or equal to 5 cm, i.e., non-sparse antenna arrays, either of the following measurement grids and implementations were found to be the best trade-off between measurement uncertainties, measurement grid points, and test time. Either of the two choices shall be used for this test plan based on testing within the full sphere:

- At least 200 measurement points for the constant density grid using the charged particle implementation with a standard deviation of 0.11 dB
- At least 266 unique measurement grid points (angular step size of 15°) constant step size grid with a standard deviation of 0.12 dB

Based on the vendor declaration outlined in Section 1.5.2 of *CTIA 01.01* [4], devices with an $M \, x \, N$ ($M \geq N$) configuration with $M \leq 4$ and $N \leq 2$ can utilize either of the following minimum number of grid points for spherical coverage procedures:

- At least 180 measurement points for the constant density grid using the charged particle implementation with a standard deviation of 0.12dB.

- At least 266 unique measurement grid points (angular step size of 15°) constant step size grid with a standard deviation of 0.11dB.

Based on the vendor declaration outlined in Section 1.5.2 of *CTIA 01.01* [4], devices with an $M \, x \, N$ ($M \geq N$) configuration with $4 < M \leq 6$ and $N \leq 2$ can utilize either of the following minimum number of grid points for spherical coverage procedures:

- At least 200 measurement points for the constant density grid using the charged particle implementation with a standard deviation of 0.14dB.

- At least 266 unique measurement grid points (angular step size of 15°) constant step size grid with a standard deviation of 0.15dB.

When testing in just the single hemisphere is requested, based on a vendor declaration, see Section 1.5.2 of *CTIA 01.01* [4], the same grid step size and/or grid density shall be used as for the full spherical testing which correspondingly yields a reduced total number of grid points.

For EIS spherical coverage, an additional systematic error needs to be included in the measurement uncertainty budget that matches the DL power step size for the final EIS search.

The spherical coverage measurements can be performed without having to have the beam peak placed on a grid point, i.e., the beam peak does not need to be known prior to performing the spherical coverage test cases.

6.3.1   Clarification of Min EIRP/Max EIS at Target CDF/CCDF Value

When CDF/CCDF curves are generated based on spherical coverage measurement grids instead of beam peak search measurements grids, the number of non-zero PDF values could be very limited which causes the CDF curve to appear staggered. One sample, simulated CDF curve is shown in Figure 6.3.1-1 for a coarse measurement grid.
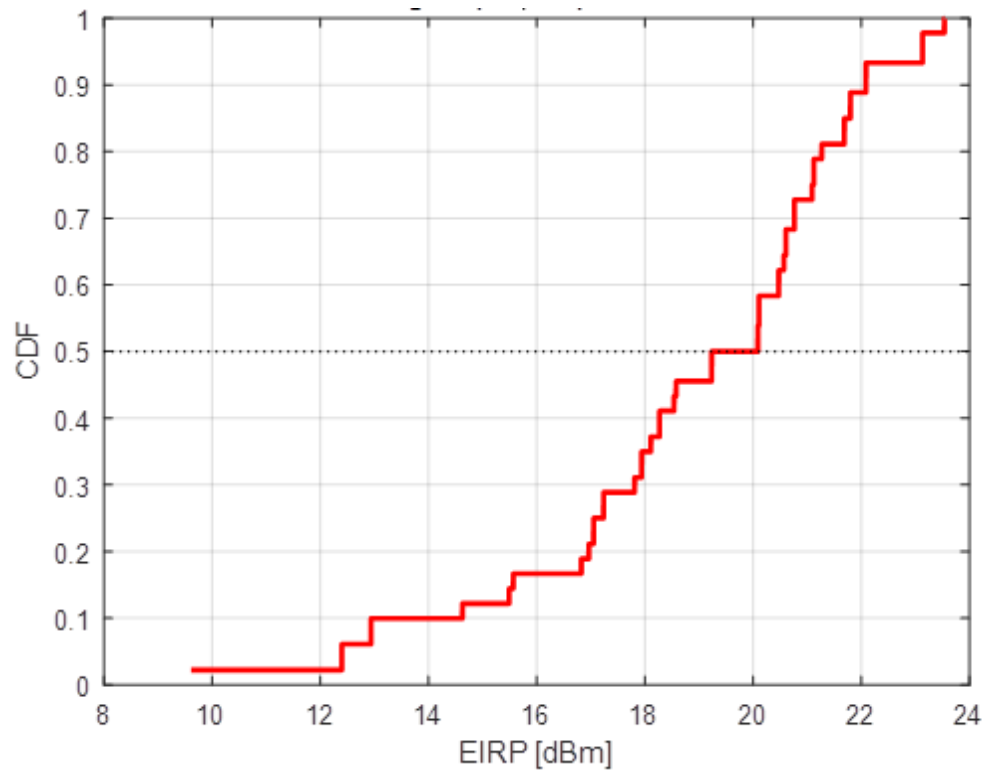
Figure 6.3.1-1 Sample CDF Curve for a Coarse Measurement Grid

While for very fine measurement grids, the definition of the min EIRP (max EIS) at the target % CDF (CCDF), $EIRP_{target\%-CDF}$ ($EIS_{target\%-CCDF}$)is pretty clear since the CDF (CCDF) curve is smooth, the definition of the EIRP (EIS) value at the respective CDF (CCDF) target should be clarified for coarse grids with staggered CDF (CCDF) curves. Two scenarios are outlined in Figure 6.3.1-2 for EIRP; the concept can easily be applied to EIS. Figure 6.3.1-2a shows the case where the CDF is not met with any EIRP value while in Figure 6.3.1-2 b, the target CDF is met with one (or more, as illustrated) EIRP values.

For the case shown in Figure 6.3.1-2 , min. EIRP at the target CDF shall be determined based on an interpolation of the CDF curve between the top of raising edges located right above the CDF target (blue circle) and right below the target (green circle).

For the case where the target CDF is met with one or more EIRP value(s), as illustrated in Figure 6.3.1-2 , min EIRP at the target CDF shall be determined as the min EIRP value that meets the CDF target.
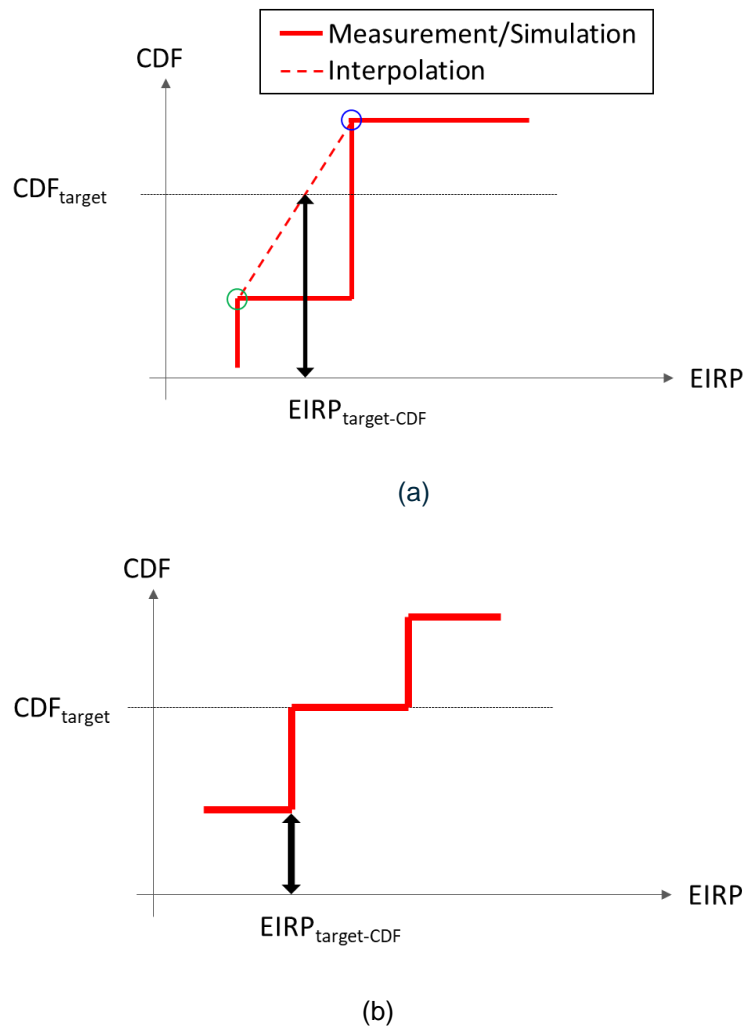
(a)

(b)

Figure 6.3.1-2 Illustration of CDF Scenarios, a) CDF Target is Not Met with any EIRP Value, b) CDF Target Is Met with One or More EIRP Values

It can be concluded that, for the case when the target CDF (CCDF) is not met with any EIRP (EIS) values, the min EIRP (max EIS) at the target CDF (CCDF) is determined based on an interpolation of the CDF (CCDF) curve between the raising edges located right above the CDF (CCDF) target and right below the target. For the case where the target CDF (CCDF) is met with one more or EIRP (EIS) values, define the min EIRP (max EIS) at the target CDF (CCDF) as the min EIRP (max EIS) value that meets the CDF (CCDF) target.

The target percentiles for different UE types are defined in Section 2.2 of *CTIA 01.01* [4] .

Appendix A   Revision History

Date	Version	Description
February 2022	4.0.0	Initial release. Changes compared to Version 1.0.2 **Section 5:** Revised test sequence order for TX test cases **Section 6:** Clarification of Clenshaw-Curtis weight usage at the poles
November 2022	4.0.1	**Section 6:** Corrected figure numbers to 6.3.1.1 and 6.3.1.2.
December 2022	5.0.0	**No changes in this release.**
March 2023	6.0.0	**Section 2:** Additional QZ sizes were added **Section 3&4:** • Added testing with just a single hemisphere based on vendor declaration • Generalized target percentile of CDF/CCDF **Section 5:** • Added MTSU tables for additional max DUT sizes • Added mapping between minimum QZ size, maximum device size, and applicable MTSU **Section 6:** • Clarified TRP measurement grids with respect to repositioning concept • Clarified testing with just a single hemisphere based on vendor declaration • Generalized target percentile of CDF/CCDF
April 2024	7.0.0	**Section 6:** • Added measurement grids for Beam Peak Search, MOP-TRP, and Spherical Coverage based on 4x2 antenna configuration which can be applied based on a vendor declaration.
September 2024	8.0.0	**Section 6:** • Added measurement grids for Beam Peak Search, MOP-TRP, and Spherical Coverage based on 6x2 antenna configuration which can be applied based on a vendor declaration. • Added Section 6.2.1 to introduce coarse & fine search measurement grids for constant step size grids.

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