Test Plan for Wireless Large-Form-Factor Device Over-the-Air Performance

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Section 1 Introduction

1.1 Purpose

The purpose of this document is to define the CTIA Certification Program test methodology for radiated performance measurements of large-form-factor wireless devices.

1.2 Scope

This test plan defines general requirements for test systems, test conditions, equipment configurations, laboratory techniques, test methodologies, and evaluation criteria that must be met in order to ensure the accurate, repeatable, and uniform over-the-air testing of large-form-factor devices. Large-form-factor devices are defined as devices that exceed the notebook-sized quiet zone size dimensions detailed in CTIA Test Plan for Wireless Device Over-the-Air Performance [5], Section 3.6. The procedures outlined here were adapted from previously published methods for the measurement of mobile handset devices whose physical size is much smaller than the dimensions of the test chamber. This test plan only covers the following cellular protocols: CDMA, CDMA 1xRTT DATA, CDMA 1xEV-DO, GSM, GPRS, EGPRS, UMTS and LTE. The test plan does not cover LTE carrier aggregation and A-GNSS testing at this time. This test plan does not cover the following partial quantities: NHPRP, NHPIS, UHIS, nor PIGS. This test plan does not cover relative sensitivity on intermediate channels at this time. Note that, while the current methodology is based on the use of reverberation chambers, the use of anechoic chambers for TRP/TIS measurement of large form-factor devices is not precluded in future releases.

This test plan provides high-level test procedures and basic test equipment configuration information but does not include detailed test instructions by which to execute certification testing. Such documentation and procedures must be presented by the CTIA Authorized Test Lab (CATL) as part of the CTIA authorization process and subsequently employed and maintained by the CATL to remain authorized to perform certification testing.

1.3 References

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1.4 Glossary

The following specialized terms and acronyms are used throughout this document. Where possible, terms are defined from [8].

Note: Only terms unique to the reverberation chamber should be included in this glossary.

FIGURE 1.6.1-1 GLOSSARY

Acronym/Term	Definition
Coherence Bandwidth	The average bandwidth over which the correlation between frequency components exceeds a specified threshold. For the purposes of this test plan, correlation is defined by use of Equation 2.1.3-1.
Isotropy	A hypothetical, convenient reference reverberation chamber channel characteristic in which radiation intensity is received equally from all directions.
Mode-Stirring Method	A technique that allows a user to obtain samples of the quantity of interest (field strength, power, etc.) either by randomizing the modal structure in the reverberation chamber (e.g., mechanical paddle stirring) or by selecting samples from a given modal structure from different physical locations (e.g., antenna stirring, position stirring) or polarizations (polarization stirring). For the purposes of this test plan, frequency stirring (averaging) is used across the channel bandwidth.
Mode-Stirring Sample	A single measurement sample from within a mode-stirring sequence. For the purposes of this test plan, samples typically correspond to a single acquisition of data from either a vector network analyzer or base-station emulator.
Mode-Stirring Sequence	A collection of mode-stirring samples that form a single, averaged measurement from which a quantity of interested is estimated.
Power Transfer Function	The loss in the reverberation-chamber for a given set-up. Typically measured with a VNA through reference and measurement antennas

Acronym/Term	Definition
	having known efficiencies. The efficiencies of the antennas are corrected for in post processing. The Power Transfer Function is corrected for in post processing to derive power-based metrics such as TRP and TIS.
Reverberation Chamber	An enclosure especially designed to have a long reverberation time and to produce a field (e.g., sound or electric field) as diffuse as possible.
RF Absorber	A material designed to absorb electromagnetic energy. The material may have a flat face or may be formed into pyramids, wedges, or cones [8].

1.5 Reverberation Chamber Test Overview

Cellular-enabled machine-to-machine (M2M) and wireless-internet-of-things (W-IOT) devices can take on many shapes and form factors, from health and fitness monitors worn on the wrist to vending machines and car dashboards. The over-the-air (OTA) performance of larger devices, those having a physical dimension greater than 42 cm, may be evaluated using reverberation chambers. The exact placement of the device within the valid test volume of a reverberation chamber is not critical. This can be an advantage in some cases, for example, for large devices that may be heavy or awkward to position precisely or for devices where the exact location of the radiating element is not known because it is within a much larger chassis. When properly configured, the reverberation chamber provides Total Radiated Power (TRP) and Total Isotropic Sensitivity (TIS) values for SISO wireless devices with uncertainties comparable to anechoic chambers.

The reverberation chamber produces a multipath environment with a decaying time response. In loaded reverberation chambers, instantaneous channels corresponding to individual, stepped, mode-stirring states have a time and spatial dependence (also manifested as a frequency dependence). For most metrics of interest, the ensemble of stepped mode-stirring states is averaged to provide statistically determinable channel characteristics. By carefully loading the chamber, the frequency dependence can be reduced to a level that allows viable wireless communication (e.g. approximating a flat-fading channel) while still maintaining the statistical nature of the measurement result. That is the approach taken in this test plan.

In stepped mode, each measurement is acquired over a static multipath channel that is assumed to be relatively flat in frequency over the coherence bandwidth to be tested. No Doppler component or other time dependent variations are present during each error rate measurement. Note that when the reverberation chamber is continuously stirred, additional time-dependent fading occurs. Consequently, TIS measurements are made using step-wise stirring to eliminate this additional temporal fading during each TIS measurement.

The reverberation chamber configuration(s) necessary to allow accurate SISO testing of large-form-factor devices is thoroughly described in this document. In addition to proper configuration and validation steps, chamber pre-characterization is described. Because the reverberation chamber must typically be loaded with RF absorber for wireless-system tests [1] ([7], [10] [12]) and the RF absorbing properties of large-form-factor equipment under test may affect the performance of the reverberation chamber [1] [2] [3] [10] [14] the chamber's power transfer function characterization steps must be carried out under loaded conditions. Pre-characterization allows the test lab to measure certain parameters in advance of the actual device test in order to save time during actual EUT performance testing.

The testing requirements fall into three categories:

1. Procedures for configuring and pre-characterizing certain parameters of the test system.
2. Pre-characterizing certain parameters of the test system.
3. Estimating the power transfer function (path loss) of the test system for the EUT test and measuring the performance of the wireless device.

The organization of this document is as follows.

First, the methodologies required for characterizing the test system are documented, including chamber configuration for measurement of S parameters (Section 2.1.1), calculation of chamber coherence bandwidth (Section 2.1.2), and determination of the reverberation chamber's power transfer function (Section 2.1.3).

Test procedures for chamber characterization are described next, including cable assembly loss measurement (for TRP measurements, if applicable, Section 2.2.1) and determination of the number of test frequencies required for the VNA set-up (Section 2.2.2). Two pre-characterization steps are next described for determining parameters that are time-consuming to measure during device test: Chamber pre-characterization of the proximity effect (Section 2.2.3) and Chamber pre-characterization of uncertainty due to lack of spatial uniformity.

The EUT measurements are then described, including estimating the reference power transfer function and corresponding uncertainty for an EUT measurement (Section 2.3.1), measurement of total radiated power (Section 2.3.2), and measurement of total isotropic sensitivity (Section 2.3.3).

Finally, the method for calculation of measurement uncertainty is presented (Section 3). Components specific to reverberation chamber measurements are presented in Appendix A.

1.6 Equipment Required for Large-Form-Factor Device Testing in Reverberation Chambers

The equipment required to make radiated performance measurements using a reverberation chamber are specified in the paragraphs below. A typical reverberation chamber measurement setup is shown in Figure 1.6.6-1. A reference antenna, measurement antenna, and RF absorber used to broaden the coherence bandwidth are placed within the chamber. S-parameters are measured by means of the VNA for the chamber power transfer function characterization procedures. The VNA is replaced by a base station emulator for TRP and TIS measurements.

1.6.1. The Reverberation Chamber

The reverberation chambers be large enough to contain the largest EUT to be tested, when the EUT is physically located within the valid test volume. No EUT and supporting equipment (including RF absorber used to load the chamber, RF absorber used in the proximity effect test, and test fixtures) shall occupy more than 8% of the chamber volume [9] The valid test volume is the volume for which uncertainties have been established per Section 2.2.4, and that in other regards is suitable to hold a device under test. Valid test volume boundaries shall be located at least 0.5 λ at the frequency of operation from the walls, mechanical mode-stirrers (if used), and the antennas [6]. The test volume shall encompass both the reference antenna and the EUT. The separation between the reference antenna and the EUT shall exceed the minimum distance determined by the proximity effect evaluation specified in Section 2.2.3. The chamber must support a mode-stirring sequence that shall be chosen such that the measurement uncertainty is below the threshold value specified in Table 7-8 of the CTIA test plan [5].

The EUT shall be placed a minimum distance R with respect to the surfaces of the reverberation chamber, where R corresponds to at least 0.5 λ for the frequency band of interest. Floor-standing devices may be placed closer than 0.5 λ to the floor of the reverberation chamber.

1.6.2. Measurement Antenna(s)

The measurement antenna shall be a monopole-like antenna fixed to a chamber wall or a more directive antenna pointing away from the reference antenna and the EUT antenna(s). If a monopole-like antenna is used, the increased uncertainty created by direct coupling of unstirred energy can be reduced by either cross-polarizing it with respect to the reference and EUT antennas or by use of multiple antennas having various polarizations. Directional measurement antennas shall not be pointed toward the reference antenna or EUT, as this will create large coupling of unstirred energy and thereby increase the uncertainty.

1.6.3. Reference Antenna

To adequately estimate uncertainty of the EUT measurement, it is desirable that the reference antenna have characteristics similar to the EUT antenna in terms of directivity. The radiation efficiency and free-space reflection coefficient of this antenna must be known over the required test frequency points. The efficiency may be provided by manufacturer's specifications or from a direct measurement, such as a three-antenna measurement. In both cases, the uncertainty in the antenna efficiency shall be included in the uncertainty calculation. It is preferred that the reference antenna be mounted on a low-loss dielectric fixture to avoid reflections from the fixture itself.

1.6.4. Vector Network Analyzer

The VNA must cover the frequency bands of interest. In Figure 1.6.6-1, the VNA's calibration reference plane is located where the cables from the VNA connect to the measurement antenna and the reference antenna. Other choices of reference plane may be used with proper de-embedding techniques [14]. The network analyzer is configured to perform a frequency sweep for each mode-stirring sample, and, as such, automated acquisition is highly desirable.

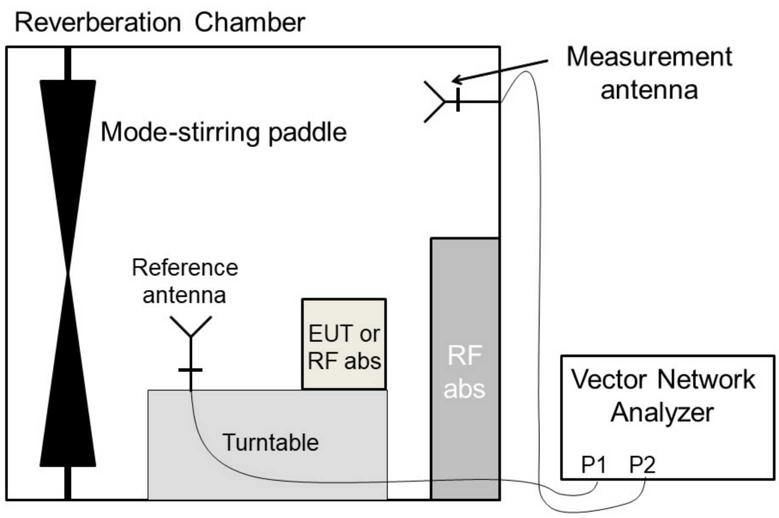
1.6.5. RF Absorber

RF absorbing material may be required to broaden the coherence bandwidth of the chamber, as described in Section 2.1.2. Standard, commercially-available RF absorber covering the appropriate frequency range shall be used. Special "low-loss" formulations shall not be used.

1.6.6. Cables and Adapters

Cables and adapters are utilized as needed, to implement the measurement scenario illustrated in Figure 1.6.6-1.

FIGURE 1.6.6-1 TYPICAL MEASUREMENT SET-UP FOR CHARACTERIZING THE CHAMBER POWER TRANSFER FUNCTION IN A REVERBERATION CHAMBER



The characterization of the chamber power transfer function (chamber loss/gain) is performed with a vector network analyzer (VNA). In Figure 1.6.6-1., RF absorber ("RF abs") has been added to broaden the coherence bandwidth (see Section 2.1.2). The EUT or RF absorber is placed on the EUT fixture. Other set-ups, reference planes, and stirring mechanisms may be used.

Section 2 Transmitter and Receiver Performance Assessment of Large-Form-Factor Devices Using the Reverberation Chamber

2.1 Methodologies Used in Chamber Characterization and EUT Performance Assessment

2.1.1. Methodology – Reverberation Chamber Configuration and Measurement of S-Parameters

This configuration is required to determine the chamber's coherence bandwidth, chamber pre-characterization, and reference power transfer function. The measurement and post-processing steps required for determining the chamber power transfer function are the same for the pre-characterization and reference measurement steps. These steps are described below:

1. The following objects shall be placed into the test volume of the reverberation chamber: the reference antenna, measurement antenna, fixture for the EUT (if utilized), and RF absorber, as described in Sections 2.2.3 (proximity effect test), 2.2.4 (chamber pre-characterization) or 2.3.1 (reference power transfer function measurement) or 2.3.2 and 2.3.3 (EUT measurements). Additional objects may be required, as described in the appropriate subsection. The same antennas shall be used for both the pre-characterization and reference measurement steps. The reference antenna shall be placed in the test volume of the chamber in such a way that it undergoes the same stirring sequence that the EUT antenna will undergo during the TRP or TIS measurements and is a minimum of 0.5 λ from any walls, mode-stirrers, or other metallic objects [6]. Directional reference antennas shall be pointed away from both the EUT and the measurement antennas. This configuration ensures that the loss in the chamber, which determines the power transfer function, is the same during both the reference power transfer function characterization and the EUT measurement.

2. Calibrate the vector network analyzer with a full two-port calibration so that the vector S-parameters between the ports of the measurement antenna and the reference antenna can be measured. See Section 1.6.4.

3. Connect the antennas to the cables and measure the full set of vector two-port S-parameters for N mode-stirring samples. The mode-stirring samples shall be collected in stepped mode. For each mode-stirring sample, the complex S-parameters shall be stored for later calculations.

   The stirring sequence may consist of mechanical stirring, antenna-position stirring, polarization stirring, and other stirring methods. Frequency stirring, (averaging), is used across the channel bandwidth specified in Table 2.4-1.

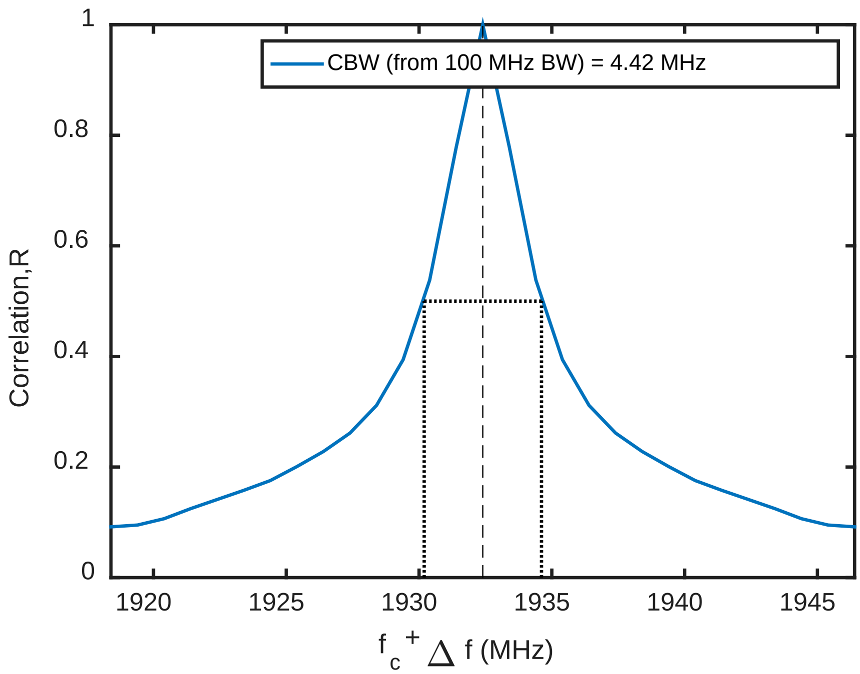
4. The number and type of mode-stirring samples N in the chosen stirring sequence should be selected in such a way that they yield an acceptably low contribution to the total measurement uncertainty. To meet the specified uncertainty, the labs shall use more than 100 independent samples, preferably 200 or 400. As well, position stirring may be more effective in reducing uncertainty than mechanical stirring for large-form-factor devices because of the potential reduction in spatial uniformity caused by the EUT. To reduce the number of samples required, the samples shall meet the correlation requirements defined in Section 2.2.3 (see Equation 2.2.3-1). In this case, the samples are considered "uncorrelated," whereby one sample is not related to another with respect to proximity, frequency step, and/or mechanical stirrer position. The number of uncorrelated samples, which is a subset of all samples, contributes to the random component of the expanded uncertainty. The number of uncorrelated samples depends on the frequency, size of chamber, size and shape of stirrers, the level of loading by absorbing objects, and whether or not frequency stirring is used.

2.1.2. Methodology – Calculation of Chamber Coherence Bandwidth

The coherence bandwidth calculated and averaged over the complete stirring sequence shall be larger than the channel over which the EUT will be measured to prevent test-set-up-induced errors in EUT measurements. Coherence bandwidth is found from S-parameter measurements made over a complete stirring sequence. It is a function of the chamber configuration, including the antennas and loading. The coherence bandwidth for EUT tests shall not be narrower than the values given in Table 2.4-1.

Figure 2.1.2-1 illustrates an example calculation of the normalized correlation function for a reverberation chamber. The expectation in Equation 2.1.2-1 was calculated over several different offsets between 0 and ±100 MHz from the center frequency and the results plotted to generate the correlation curve.

FIGURE 2.1.2-1 ILLUSTRATION OF THE FREQUENCY CORRELATION AVERAGED OVER MULTIPLE MODE-STIRRING SAMPLES. THE COHERENCE BANDWIDTH CORRESPONDING TO A THRESHOLD OF 0.5 IS SHOWN BY THE DOTTED LINE



If the coherence bandwidth must be increased to meet the specifications in Table 2.4-1, the reverberation chamber shall be loaded with RF absorbing material, and Steps 2.1.2-1 through 2.1.2-4 carried out iteratively until the coherence bandwidth meets the specification. Because loading the reverberation chamber also increases measurement uncertainty, it is important to ensure that the uncertainty limit is not exceeded when tuning the chamber to a specific coherence bandwidth.

The methodology for determining the coherence bandwidth for a particular reverberation-chamber set-up is as follows:

1. Using the stirring sequence chosen for device testing, measure the transmission parameter S_{21} for each mode-stirring sample *n* and reference antenna location *t*. A minimum value of *T* = 1 reference antenna locations shall be used. The VNA frequency step for this test shall be at most 100 kHz.
2. Calculate the complex autocorrelation function, R, given by Equation 2.1.2-2 for each mode-stirred sample n_k, at lag, i, [3] [4] [12] over a 100 MHz bandwidth for the center frequency , f_c, of each band to be evaluated.

Equation 2.1.2-3

$$R(i, n_k) = \sum_{j=\max(1,i+1)}^{\min(M,M+i)} S_{21}(f_j, n_k) S_{21}{}^{*}(f_{j-i}, n_k),$$

where $S_{21}(f_j, n_k)$ corresponds to the measured complex S_{21} at frequency step f_j with M frequency points measured within the bandwidth of interest, BW, so that $f_1 = f_c - BW/2$ and $f_M = f_c + BW/2$. The index n_k is the mode-stirring sample (out of N). The index, i, corresponds to one of several frequency step offsets (lags) over the bandwidth of interest (here BW = 100 MHz) where $-(M-1) \leq i \leq (M-1)$. The frequency lag shown in Figure 2.1.2-1 is given by, $\Delta f = i\left(\frac{f_M - f_1}{M-1}\right)$. The asterisk denotes complex conjugation. For $BW = 100$ MHz, the complex autocorrelation function will span 200 MHz. The autocorrelation is implemented in most numerical programs. Assuming the S_{21} data are contained in a matrix called `data_complex` with M rows of frequency steps and N columns of stirring-sequence samples, a routine may be written as

```
    M = number of frequency steps;
    N = number of stir sequence steps;
    R = empty matrix for autocorrelation values with size (2*M-1 rows, N columns);
    for idx = 1 to N
           R_temp = autocorrelation of data_complex over all rows for column idx.
This will be an array 2*M-1 in length;
           R(all 2*M-1 rows,column idx)=R_temp. This fills the column of R;
    end
```

The variable `R` is a matrix of autocorrelation values where the lags are the rows and the columns are still the mode-stirring samples.

3. Average the autocorrelation functions from Equation 2.1.2-1 over all N mode-stirring samples at each frequency point giving the expectation of the N channels. Normalize the expectation values to a maximum of 1. A routine for this step may be written as

```
    R_ave_comp = mean across columns of R;
    R_ave_norm = R_ave_comp/(maximum of R_ave_comp);
    R_ave_mag = absolute value of R_ave_norm
```

where `R` was defined in step 2, `R_ave_comp` is a vector comprised of the mean of the autocorrelation values over mode-stirring sample, `R_ave_norm` is `R_ave_comp` with each element divide by the maximum complex value in `R_ave_comp`, and `R_ave_mag` is the normalized magnitude of the mean autocorrelation function.

4. Determine the coherence bandwidth for the current loading condition from the frequency band that exceeds the threshold value. The threshold value shall be 0.5. An example routine may be,

```
    Deltafreq = vector of frequency steps that is 2*M-1 in length with 0 as its
    center midpoint;
    midpoint = index of the midpoint of Deltafreq
    threshold = 0.5;
    pnt1 = interpolate R_ave_mag versus Deltafreq at threshold for     points with
    index 1 to midpoint;
    pnt2 = interpolate R_ave_mag versus Deltafreq at threshold for     points with
    index midpoint to 2*M-1;
    CBW = pnt2-pnt1;
```

where `Deltafreq` is a vector of lags for the autocorrelation calculation, the interpolation is used to determine the location of the intercept with the `threshold` at 0.5, and `CBW` is the coherence bandwidth.

2.1.3. Methodology – Determination of the Reverberation Chamber's Power Transfer Function

The power transfer function G_{ref} for a given reverberation chamber configuration is estimated from T sets of the proposed stirring sequence, where each of the T sets is conducted at spatially uncorrelated reference antenna positions (see Equation 2.2.3-1, [10]) as specified in Section 2.2.4, step 1. At each location, one sample of the chamber's power transfer function is determined from the mean of the measured transmission parameter S_{21}, where the mean is calculated over all frequencies F and mode-stirring samples N. The power transfer function is then calculated from the mean of the samples that were measured at the multiple locations. The standard deviation of these samples is also used to find the component of uncertainty due to lack of spatial uniformity in Section 2.2.4.

For example, if a proposed stirring sequence consists of N=200 mode-stirring samples, the measurement of G_{ref} is carried out for T different, unique sets of this 200-sample stirring sequence at T uncorrelated reference antenna positions. Correlation is defined in Equation 2.2.3-1. For large-form-factor devices, it may be necessary to increase Tcal to ensure that the uncertainty in a measurement that uses a given stirring sequence does not exceed the level specified in Table 7-8 of the CTIA Test Plan for Over the Air Performance [5]. Uncertainty may also be reduced by increasing the number of mode-stirring samples that define a stirring sequence or modifying the stirring sequence.

For each channel to be tested, the estimate of the power transfer function G_{ref} of the reverberation chamber shall be calculated by the following equation, see [1][10] [14].

EQUATION 2.1.3-1

$$, G_{\text{ref},t} = \frac{\frac{1}{NF}\sum_{n=1}^{N}\sum_{f=1}^{F}\left|S_{21}(f,n)\right|^2}{e_{\text{mismatch,meas}}\, e_{\text{mismatch,ref}}\, \eta_{\text{meas}}\, \eta_{\text{ref}}}$$

where $e_{mismatch}$ is the mismatch of the measurement antenna, $e_{mismatch,ref}$ is the mismatch of the reference antenna, and η_{ref} is the radiation efficiency of the reference antenna. Note that value of the mismatch and radiation efficiency of the measurement antenna is not required, because it will be the same during both the reference and EUT measurements and, therefore, will not affect the final results. These values are included for consistency with published literature. The term $e_{mismatch}$ can be found from $1-|\langle\langle S_{11}\rangle_F\rangle_N|^2$ of the antenna in question, where <.> represents the averages over N mode-stirring samples and F frequencies across the channel bandwidth to be tested given in Table 2.4-1.$G_{ref,t}$ represents the tth power transfer function (obtained from NF samples) of a particular reverberation chamber configuration, corrected for mismatch of both the measurement antenna and the reference antenna, as well as the radiation efficiency of the reference antenna. Note that the radiation efficiency of the measurement antenna is not corrected for, because it will be the same during both the reference and EUT measurements and, therefore, will not affect the final results.

The power transfer function is then given by:

EQUATION 2.1.3-2

$$G_{\text{ref}} = \frac{1}{T_{\text{val}}} \sum_{t=1}^{T_{\text{val}}} G_{\text{ref,t}}$$

where $T_{val} = T_{prox}$-(Section 2.2.3), T_{pre} (Section 2.2.4), or T_{cal} (Section 2.3.1).

1. Measure S-parameters over a full stirring sequence, as specified in Section 2.1.1
2. Calculate the power transfer function for the *t*th reference antenna location, $G_{ref,t}$ from Equation 2.1.3-1 The power transfer function G_{ref} is the mean of these *T* estimates given in Equation 2.1.3-2. The standard deviation of the T_{pre} power transfer functions found in Section 2.2.4 for the loading condition used in the EUT measurement is used to estimate the uncertainty due to the lack of spatial uniformity, as given in Section 2.2.4.

2.2 Test Procedures Used in Chamber Pre-Characterization

These tests shall be conducted prior to use of the chamber and repeated annually or whenever the chamber configuration changes, with the exception of changes in loading within the limits specified in Section 2.2.4.

2.2.1. Test Procedure – Cable Assembly Loss Measurement (for TRP measurements, if applicable)

This measurement step will calibrate the power loss of the cable(s) needed to connect the instrument used to measure the received power from the measurement antenna during TRP measurements, and to generate the power radiated by the measurement antenna during TIS measurements. This instrument is normally a base station emulator, but can also consist of a base station emulator connected to power meter or spectrum analyzer through a power splitter. To measure the loss in this cable (and splitter, if used), proceed with the following steps:

1. Connect the cable assembly (which may include a power splitter whose third port is terminated in 50 Ω) between the two ports of the network analyzer. The VNA must be calibrated at its two input ports, rather than at the ends of the cables that connect to the measurement and calibration antennas. Alternatively, the cable assembly may be connected between the two reference planes shown in Figure 1.6.6-1 and the VNA calibration from the reference measurement may be used.
2. Measure the transmission S-parameter (S_{21} or S_{12}) of the cable assembly.
3. Save the power transfer values $G_{cable} = |S_{21}|^2$ for the test frequencies where the measurements will be conducted.

2.2.2. Test Procedure – Determination of Number of Test Frequencies

The number of frequency points needed for the G_{ref} measurement depends on the chamber configuration. This test ensures that the frequency step is small enough to measure the power transfer function.

1. Configure the chamber to measure S parameters and calibrate the VNA as described in Section 2.1.1. Start with a frequency step that yields F_1=41 points within each channel to be measured (refer to Table 2.4-1. The chamber shall be loaded for the minimum loading case to be used.
2. Measure the transmission S-parameter S_{21} between the measurement and reference antennas over a complete stirring sequence. Do this for a single reference antenna location.
3. Calculate $P_i = \langle |S_{21}(f,n)|^2 \rangle_N$ for all *N* stirring states for each measured frequency for the channel of interest.
4. Average these values over frequency within a single channel in the highest frequency band to be tested.

5. Repeat steps 2 through 4 above with a subset of the measured frequencies corresponding to F_2=21, F_3=11, F_4=5, and F_5=3 frequency points.

6. Calculate the difference between P_i and P_{i+1}. The maximum frequency step is found from the smallest value of P in which the difference between P_i and P_{i+1} is less than 0.05 dB (1% change). A larger frequency step may be used, but the difference between P_i and P_{i+1} shall be included as an uncertainty term "frequency flatness" in Table 3.3-2.

2.2.3. Test Procedure – Chamber Pre-Characterization of Proximity Effect

The proximity effect [1] refers to the loss of power that occurs when radiation from the reference or EUT antenna is absorbed in a lossy material without undergoing any reflections in the chamber. The proximity effect test ensures that this loss does not exceed the variance due to the lack of spatial uniformity in the chamber for a given loading condition.

1. RF absorbers whose surface area represents the largest EUT to be tested are placed in the chamber at the locations that will be used during the EUT measurements. For chambers with turntables, this is typically on the turntable, directly across from the reference antenna. For chambers without turntables, the location is not critical, but should be within the test volume.

2. Place the reference antenna at the location intended for EUT measurements, as shown in Figure 2.2.3-1(a) by the distance "Aux1". This is Position 1 for the test. Orient the reference antenna in one of three orthogonal orientations and at one of three heights corresponding to z=0, z=Z_{max}, and z=Z_{max}/2 (T_{prox}= 9). Directional antennas shall be oriented away from the absorber.

3. The power transfer function G_{ref} (see Section 2.1.3) and the standard uncertainty due to lack of spatial uniformity $u_{G_{\mathrm{ref}}}$ (see Section 2.2.4) for this chamber set-up are estimated from a minimum set of T = 9 uncorrelated power transfer function measurement samples. The interval $G_{\mathrm{ref}} \pm 2.31\, u_{G_{\mathrm{ref}}}$ is calculated. A single 10 MHz band located at the center frequency in each technology band to be measured shall be tested for the Proximity Effect. The frequency step shall correspond to that determined in Section 2.2.2 The total loading shall provide a coherence bandwidth equal to or greater than that specified in Table 2.4-1.

4. The reference antenna is then positioned closer to and, if a directional antenna is being used, aimed toward the lossy object (absorber and/or EUT), as shown in Figure 2.2.3-1(b). This is Position 2 for the test. The reference antenna is moved toward the lossy object and far enough from the last set of power transfer function measurements that all samples from the two sets shall be uncorrelated. This is verified by use of Pearson's cross correlation function calculated over stirring sequences made at Position 1 and Position 2 for each of the T = 9 power transfer function measurement samples [10].

EQUATION 2.2.3-1

$$\rho_{c,t}(f) = \left| \frac{\sum_{n=1}^{N}\left[\left(S_{21,1} - \langle S_{21,1}\rangle_N\right)\left(S_{21,2} - \langle S_{21,2}\rangle_N\right)^*\right]}{\sqrt{\sum_{n=1}^{N}\left[\left|S_{21,1} - \langle S_{21,1}\rangle_N\right|^2\right]}\sqrt{\sum_{n=1}^{N}\left[\left|S_{21,2} - \langle S_{21,2}\rangle_N\right|^2\right]}} \right|,$$

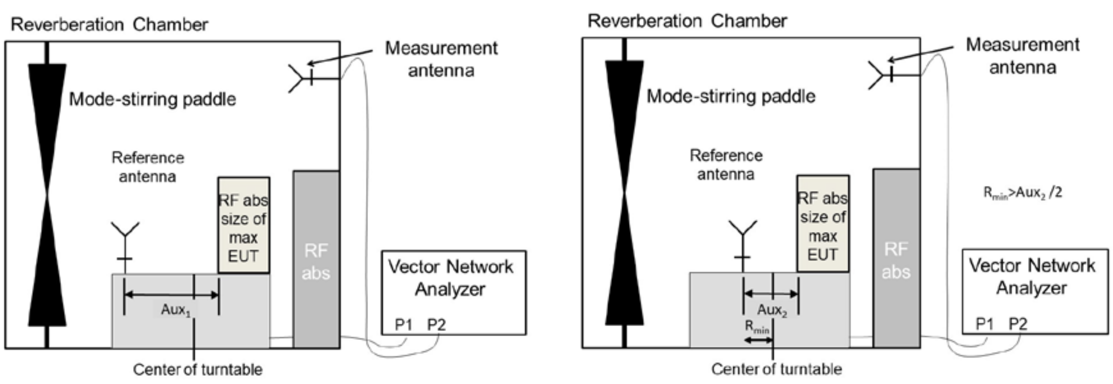
where $\rho_c(f)$ is averaged over the F measured frequencies in the channel. A threshold value of 0.3 shall not be exceeded for this average value. If any of the T = 9 positions are correlated, then a new auxiliary Position 2 shall be selected that is farther from Position 1.

5. A minimum set of T = 9 auxiliary power transfer function measurement samples shall be acquired. A new transfer function $G_{\mathrm{ref,aux}}$ is calculated from the auxiliary measurements by use of Equation 2.1.3-1 and Equation 2.1.3-2..

6. The standard uncertainty is calculated and the interval corresponding to $G_{\mathrm{ref,aux}} \pm 2.31 u_{G_{\mathrm{ref,aux}}}$ is calculated. If this interval overlaps with the interval $G_{\mathrm{ref}} \pm 2.31 u_{G_{\mathrm{ref}}}$, the proposed antenna placement in step 2 is deemed acceptable. If these intervals do not overlap, the reference antenna must be placed farther from the lossy object or objects at a new Position 1. The procedure is then repeated until an acceptable antenna placement is found for Position 1 and Position 2. The distance corresponding to the minimum acceptable reference antenna placement shall also be maintained between the reference antenna and any absorber used to load the chamber.

7. For chambers with turntables, the minimum radius for the test volume, R_{min}, shall be determined as the distance from the reference antenna location in the Aux_2 measurement, shown in Figure 2.2.3-1(b), to the center of the turntable. See Section 1.6.1 for further definition of the test volume. For chambers without turntables, the minimum distance for the valid, R_{min}, shall be the distance Aux_2

FIGURE 2.2.3-1 SIDE VIEW OF THE REVERBERATION CHAMBER SET-UP TO MEASURE THE PROXIMITY EFFECT FOR A GIVEN CHAMBER SET-UP



(a) (b)

Description of Figure 2.2.3-1: The EUT is represented by RF absorbers whose surface area represents the largest EUT to be tested. It shall be placed in the location of the EUT. In (a), the omnidirectional reference (transmit) antenna (used as an example) is placed a nominal distance (Aux_1) from the simulated large-form-factor EUT. In (b), to test for the proximity effect, the reference antenna is moved closer to the simulated EUT equidistant from the center of the turntable (distance of Aux_2). If the reference antenna is directional, it is oriented toward the EUT. Note that only stepped-mode-stirring is supported in this test plan.

2.2.4. Test Procedure – Chamber Pre-Characterization of Uncertainty due to Lack of Spatial Uniformity

In a theoretically ideal reverberation chamber, the average transmission between two antenna ports is the same regardless of the location or orientation of the antennas inside the valid test volume. The uncertainty due to lack of spatial uniformity serves to quantify how much the actual environment deviates from this ideal. Because this uncertainty may require a large work effort to determine, estimation is allowed based on a pre-characterization test campaign separate from the EUT measurement.

A major driver of this uncertainty is the loading condition of the chamber. In a pre-characterization measurement, the chamber shall be configured with RF absorbers and antennas in the positions where they will be located during a EUT TIS/TRP measurement. In place of an actual EUT, RF absorber having dimensions equal to or exceeding those of the maximum-size EUT to be tested shall be placed in the location of the EUT. The amount and position of all RF absorber shall be specified/documented so that it can be faithfully replicated in a EUT test. Pre-characterization measurements are made for several such loading conditions representing the expected range of loading under use conditions.

The pre-characterization procedure consists of measuring the power transfer function under various loading conditions. The corresponding chamber loss, coherence bandwidth, and uncertainty due to lack of chamber spatial uniformity are determined for each loading condition. Measure all loading conditions for each reference antenna position and/or orientation before moving the reference antenna to the next position. This ensures that the reference antenna position is exactly the same for every loading condition. These data shall be tabulated for future use of the reverberation chamber.

1. Place the reference antenna at one of four locations and one of three orthogonal orientations at each location (T_{pre}= 12). For chambers with turntables, the reference antenna shall be placed at r = R_{min} (see Section 2.2.3) and r = R_{max}, and at two heights corresponding to the z=0 and z=Z_{max} of the test volume. For

chambers without turntables, the reference antenna shall be placed at the two opposite corners of a cube at z=0 of the test volume and then at the other two corners at z=Z_{max} of the test volume.

2. Configure the chamber to measure S parameters and calibrate the VNA as described in Section 2.1.1
3. Determine the maximum chamber loading, that is, the loading that is required to create a coherence bandwidth that exceeds the channel to be measured. This is typically done iteratively by loading the chamber with increasing amounts of RF absorber, measuring S parameters over a mode-stirring sequence and then calculating the coherence bandwidth from Section 2.1.2.

   Note that if a user encounters an EUT that presents more loss to the chamber than the one simulated during this pre-characterization step, the user will need to determine the additional uncertainty due to lack of spatial uniformity with the steps outlined below.
4. Perform S-parameter measurements over a complete stirring sequence in each frequency band of interest for a set of loading cases. The loading cases correspond to numbers of blocks of RF absorber (or the exposed surface area of the RF absorber) ranging from zero (or a small amount of) RF absorber to the maximum RF absorber in approximately equal increments. The finer the loading increment tested, the more accurately the uncertainty can be estimated.
5. For each loading condition *i*, calculate the coherence bandwidth as specified in Section 2.1.2.
6. For each loading condition *i*, calculate the reference power transfer function, G^i_{ref}, as specified in Section 2.1.3 Equation 2.1.3-1 with a minimum of T_{pre} = 12 reference measurement samples as specified in step 1. This calculation shall be carried out at the center frequency for each channel to be tested, averaging the F measured frequencies over the channel bandwidth specified in Table 2.4-1. for each airlink technology to be supported by the chamber.
7. For each loading condition *i* and for each transmission standard to be tested, calculate the standard deviation $\sigma_{G^i_{ref}}$ with Equation 2.2.4-1 using the channel bandwidths defined in Table 2.4-1 for all the available frequencies across each band.

   EQUATION 2.2.4-1

   $$\sigma_{G^i_{ref}} = \sqrt{\frac{1}{(T_{pre}-1)}\sum_{t=1}^{T_{pre}}\left(G^i_{ref,t} - G^i_{ref}\right)^2}.$$

   For each band, the highest value of $\sigma_{G^i_{ref}}$ shall be entered into the pre-characterization table.
8. Create a table, where the first column corresponds to the operating band, the second column corresponds to the loading condition *i* (blocks of RF absorber or surface area of RF absorber), the third column corresponds to the coherence bandwidth, the fourth column corresponds to $\sigma_{G^i_{ref}}$, Columns two, three and four should be repeated for each loading configuration. This table will be used by future users of the chamber to estimate the coherence bandwidth and uncertainty due to lack of spatial uniformity under various loading conditions. An example of such a table is given in Table 2.2-1.

TABLE 2.2-1 EXAMPLE PRE-CHARACTERIZATION TABLE SHOWING THE BAND, LOADING USED, COHERENCE BANDWIDTH, CHANNEL BANDWIDTH, AND THE CORRESPONDING UNCERTAINTY DUE TO LACK OF SPATIAL UNIFORMITY

Band	# of Absorbers	Coherence BW (MHz)	Channel BW (MHz)	σGref	# of Absorbers	Coherence BW (MHz)	Channel BW (MHz)	σGref	# of Absorbers	Coherence BW (MHz)	Channel BW (MHz)	σGref	# of Absorbers	Coherence BW (MHz)	Channel BW (MHz)	σGref
Cellular (818-894 MHz)	0		0.20		2		0.20		4		0.20		6		0.20	
			1.20				1.20				1.20				1.20	
			2.40				2.40				2.40				2.40	
			3.80				3.80				3.80				3.80	
			10.00				10.00				10.00				10.00	
			20.00				20.00				20.00				20.00	

Note that the coherence bandwidth is calculated over a 100 MHz bandwidth at the center of each operating band, while σ_{Gref} is calculated over the channel bandwidth defined in Table 2.4-1, for all the available frequencies in each band. The worst case for σ_{Gref} for each operating band is entered into the table for each loading condition.

2.3 Test Procedures Used in EUT Performance Assessment

The tests in Section 2.3.1 are performed once for each EUT configuration (i.e., mechanical mode, usage mode, etc.). The tests in Sections 2.3.2 and 2.3.3 are performed for each configuration, operating band, cellular radio mode, applicable procedures and settings as given in the CTIA Test Plan for Over the Air Performance [5] Sections 5 and 6.

2.3.1. Test Procedure - Estimating the Reference Power Transfer Function and Corresponding Uncertainty for an EUT Measurement

During the pre-characterization step of Section 2.2.4, the chamber's power transfer function is estimated from VNA measurements made over multiple sets of a proposed mode-stirring sequence. These multiple sets are made at spatially uncorrelated locations within the chamber. At each stirring state in the sequence a sweep of S-parameters over frequency is collected and stored. From the collected S parameter data the power transfer function is computed per Section 2.1.3.

For the EUT measurement, the user performs a minimum of T_{cal} =1 calibration measurements (over a mode-stirring sequence) to estimate the reference power transfer function for each chamber set-up. As defined here, the "set-up" includes the same antennas as were used in the pre-characterization step, the EUT, and the number and location of RF absorbers that will be used during testing of the EUT. The reference power transfer function is estimated from the T_{cal}, samples and the user estimates the uncertainty due to lack of spatial uniformity from the pre-characterization data derived in Section 2.2.4. Note that the use of T_{cal} >1 calibration measurements typically results in lower uncertainties.

1. Configure the chamber to measure S parameters and calibrate the VNA as described in Section 2.1.1. Place into the reverberation chamber the EUT, additional loading, reference antenna, and measurement antenna(s) that will be used during the reference, TRP and TIS measurements.
2. Place the reference antenna at a location within the test volume of the chamber representative of where an EUT may be placed, as shown in Figure 1.6.6-1. If multiple reference measurements are made for the

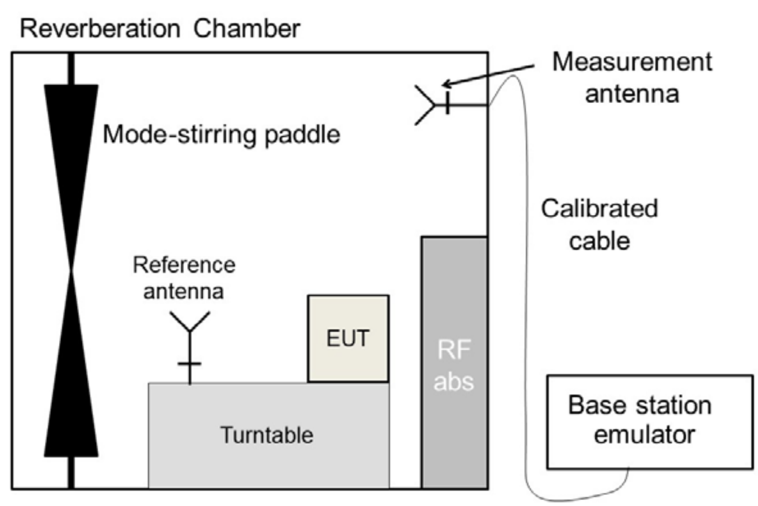
EUT measurement, antennas shall be placed at uncorrelated positions (correlation less than 0.3) within the test volume, where correlation between positions is determined by use of Equation 2.2.3-1. These positions may correspond to those used in pre-characterization Section 2.2.4, or they may be other uncorrelated positions. The reference antenna shall be placed in the test volume of the chamber in such a way that it undergoes the same stirring sequence as the EUT antenna during the TRP or TIS measurements and is a minimum of 0.5 λ from any walls, mode-stirrers, or other metallic objects [6]. Directional reference antennas shall be pointed away from both the EUT and the measurement antennas.

3. Determine the loading needed for a given coherence bandwidth, using the pre-characterization table described in Section 2.2.4.
4. Perform S-parameter measurements over a complete stirring sequence for each channel of interest.
5. Calculate the reference power transfer function, $G_{ref,EUT}$, with a minimum of T_{cal} = 1 from Section 2.1.3
6. Subtract $G_{ref,EUT}$, from the pre-characterized unloaded reference power transfer function $G_{ref,0}$. This provides the chamber loss relative to the unloaded condition, $\Delta G_{ref,EUT}$.
7. Find the values of ΔG^{i}_{ref} and ΔG^{i+1}_{ref} that bound $\Delta G_{ref,EUT}$ from the pre-characterization table formed in Section 2.2.4 where ΔG^{i+1}_{ref} is greater than $\Delta G_{ref,EUT}$.
8. Use $G_{ref,EUT}$ as G_{ref} in Equation 2.3.2-1 (TRP) or Equation 2.3.3-1 (TIS). Use $\sigma_{G^{i+1}_{ref}}$ in Equation A-2 to find the value of uncertainty due to lack of spatial uniformity in the uncertainty budget for the TRP or TIS measurement, as described in Section 3.

2.3.2. Test Procedure – Total Radiated Power

The TRP measurement configuration is similar to that of the reference power transfer function characterization measurements described above, with the network analyzer replaced by a base station emulator and power meter or spectrum analyzer. The base station emulator is used to establish and maintain an airlink connection to the device under test and control its traffic channel and output power. The power meter or spectrum analyzer is used to sample the transmitted power. A base station emulator with an integrated power meter may also be used. Figure 2.3.2-1 shows the configuration for TRP measurements with a base station emulator used for the power sampling.

FIGURE 2.3.2-1 EXAMPLE SETUP FOR TOTAL RADIATED POWER AND TOTAL ISOTROPIC SENSITIVITY MEASUREMENTS IN A REVERBERATION CHAMBER. RF ABSORBER ("RF ABS") HAS BEEN INCLUDED TO BROADEN THE COHERENCE BANDWIDTH



The TRP measurement is performed as follows:

1. Conduct the reference power transfer function characterization procedure described in the previous sections, including the determination of the antenna mismatch, reference power transfer function, and cable-assembly loss measurement, if applicable. The antenna used during the reference power transfer function characterization step shall be terminated in a 50 Ω load and remain located within the chamber. The EUT shall be positioned within the test volume of the chamber so that the chamber loading is the same for the reference power transfer function characterization and EUT measurement steps and so that it undergoes the same stirring sequence as the reference antenna during the calibration and characterization tests.
2. With the base station emulator, establish an airlink connection to the EUT and control it to radiate at its maximum output power on the traffic channel to be measured.
3. With the power meter, spectrum analyzer, or base station emulator, measure the power in each mode-stirring sample using the same mode-stirring sequence determined in the reference power transfer function characterization step.
4. Calculate the TRP value by taking an average of all power samples and applying the reference power transfer function as (see [1][9][10][14]).

EQUATION 2.3.2-1

$$P_{\mathrm{TRP}} = \frac{1}{N}\frac{\sum_{n=1}^{N} P_n}{G_{\mathrm{ref}}\, e_{\mathrm{mismatch,meas}}\, \eta_{\mathrm{meas}}\, G_{\mathrm{cable}}},$$

where P_n is measured for mode-stirring sample n, N is the total number of mode-stirring samples, G_{cable} is the loss in the cable assembly (which may include a cable and power splitter, as discussed above), G_{ref} = $G_{\text{ref},EUT}$ (Section 2.3.1), and e_{mismatch} is the measurement antenna mismatch factor as found from the reference power transfer function measurements. The uncertainty in P_{TRP} must not exceed the uncertainty specified in Table 7-8 of the CTIA Test Plan for Over the Air Performance [5]. Note that the summation is performed using linear power values, even though the results are normally presented in dBm.

2.3.3. Test Procedure – Receiver Performance

This section describes how to perform measurements of (TIS) in a reverberation chamber [11] for large-form-factor devices. The chamber reference power transfer function characterization procedure for these measurements is the same as for the (TRP) measurements, and is found in Section 2.3.2 above.

The TIS procedure is based on searching for the lowest base station emulator output power in each mode-stirring sample that gives a performance metric (e.g., BER, BLER, throughput) that is lower than the specified target error rate, or above the target throughput, as given in the CTIA Test Plan for Over the Air Performance [5], Section 6. The TIS procedure is executed with the following steps:

1. Perform the reference power transfer function characterization procedure described in Section 2.3.1 including the calculations of mismatch and chamber reference power transfer function, and measurement of transmission loss of the cable connecting the base station emulator to the measurement antenna. The EUT and reference antenna shall remain located within the chamber. The EUT shall be positioned so that the chamber loading is the same for the characterization and measurement steps and so that it undergoes the same stirring sequence as the reference antenna during the characterization tests and is a minimum of 0.5 λ from any walls, mode-stirrers, or other object. The reference antenna shall be terminated in a 50 Ω load.
2. Page the EUT, direct it to the traffic channel of interest and place it in loopback mode to enable a digital error rate or throughput measurement, as applicable to the airlink technology under test.
3. Set the base station emulator to a specific output power and perform a digital error rate or throughput measurement.
4. Increase or decrease the base station output power as needed, and repeat step 2.3.3.3 until the lowest output power (power step size shall be no more than 0.5 dB when the RF power level is near the final

declared sensitivity level) is found that gives a digital error rate lower than the specified target BER or a throughput above the target, as applicable.

5. Repeat steps 2.3.3.2 to 2.3.3.4 for each of the mode-stirring samples in the measurement sequence.
6. Calculate the TIS value from the following equation [11].

EQUATION 2.3.3-1

$$P_{\text{TIS}} = G_{\text{ref}} e_{\text{mismatch,meas}} \eta_{\text{meas}} G_{\text{cable}} \left(\frac{1}{N} \sum_{n=1}^{N} \frac{1}{P_{\text{BSS}}(n)} \right)^{-1}$$

where $P_{BSS}(n)$ is the output power from the base station emulator when it is adjusted to give the specified digital error rate or throughput from the EUT for mode-stirring sample n, N is the total number of mode-stirring positions, G_{cable} is the loss in the cable assembly connecting the base station emulator to the measurement antenna, and $G_{ref} = G_{ref,EUT}$, and $e_{mismatch}$ are the reference power transfer function and measurement antenna mismatch factor as found in the characterization steps. The uncertainty in P_{TIS} must not exceed the uncertainty specified in Table 7-8 of the CTIA Test Plan for Over the Air Performance [5]. Note that the summation is performed using linear power values, even though the results are normally presented in dBm.

2.4 Large-Form-Factor SISO Device OTA Test Requirements for Reverberation Chambers

2.4.1. Test Frequencies

The frequency range of the network analyzer (for chamber reference measurements) or base station emulator (for EUT measurements) shall cover the communication bands for which the chamber is going to be used. The frequency step in each channel shall be small enough such that the variation in a measurement of <|S21|^2> as a function of frequency step is negligible for a low loading case, as defined in Section 2.2.2. If the intention of the measurement is to compute coherence bandwidth or power delay profile in the time domain, the frequency step shall be selected to give valid results, i.e. significantly smaller than a coherence bandwidth.

Table 2.4-1 provides the minimum coherence bandwidth requirement for each transmission standard. The required maximum VNA frequency steps shall be determined using the method specified in Section 2.2.2. Frequency averaging is typically carried out over the channel bandwidth.

TABLE 2.4-1 TRANSMISSION STANDARD, CHANNEL BANDWIDTH (MHZ), AND COHERENCE BANDWIDTH (MHZ)

Transmission standard	Channel Bandwidth (MHz)	Coherence Bandwidth (MHz)
GSM\GRPS\EGPRS	0.2	0.2
CDMA\1xEVDO\1xRTT	1.23	1.3
UMTS (WCDMA)	3.84	4.0
LTE	No. resource blocks x 180 kHz	4.0[1]
Note 1: The CBW for LTE is based on the upper limit for loading (WCDMA) as opposed to actual channel bandwidth.		

Section 3 Measurement Uncertainty in Reverberation-Chamber Measurements of Large-Form-Factor Devices

This section treats the calculation of measurement uncertainty for the tests described in this test plan. Where applicable, references are made to the over-the-air (OTA) tests made with anechoic-chamber measurement setups. For the reverberation-chamber measurement setups described in this section, many, but not all, of the error contributions are identical to those described for the anechoic chamber setup. Therefore, this section describes those contributions that apply to reverberation-chamber measurements of large-form-factor devices by referencing the existing uncertainty elements and providing additional uncertainty elements in Appendix A.

3.1 General Considerations

Sections 7.1 and 7.2 of the CTIA Test Plan for Wireless Device Over-the-Air Performance [5]. give general guidelines for how the measurement uncertainty contributions shall be calculated for TRP and TIS tests, respectively, and also the practical steps involved in the determination and compilation of a complete uncertainty budget. The same general guidelines shall be applied to tests performed in reverberation-chamber measurement setups where applicable, as described below.

In Sections 3.2 and 3.3, this calculation process is fully described for the TRP and TIS tests of this test procedure, respectively.

3.2 TRP Tests

The TRP test method determines the unknown performance of the EUT by correcting the absolute power measurements at the input port of the test instrumentation using a relative correction value determined using the Reference Measurement described Section 2.1.3 (Methodology – Calculation of the reference power transfer function). The test procedure for TRP is described in Section 2.3.2 "Total Radiated Power." To reduce the overall measurement uncertainty, the same cable configuration and equipment used during the reference measurement should be used during the EUT measurement. In this way, a number of the individual uncertainty contributions will cancel. Examples include the uncertainty in the insertion loss of the cable(s) between the Measurement Antenna and the spectrum analyzer/measurement receiver, the uncertainty in the efficiency of the Measurement Antenna, etc.

3.2.1. EUT Measurement

The EUT and other RF-absorbing material including RF absorbers that load the chamber to increase the coherence bandwidth (Section 2.1.2) and support structures, if any, shall be placed within the chamber during the chamber characterization, reference, and EUT measurements, as described in Section 2.1.1 (Reverberation Chamber Configuration to and Measurement of S-Parameters). At the receiving end, the spectrum analyzer, measurement receiver or base station emulator shall be connected via a cable and/or attenuator to the measurement antenna through a chamber bulkhead adapter.

The identified uncertainties in this part are listed in Table 3.2-1. Where 0.00 dB values are entered in Table 3.2-1, this means that the uncertainty contribution appears in the reference measurement also and therefore cancels. The uncertainty contributions that can be assumed to cancel are those contributions associated with system components that are the same as those utilized in the reference measurement. If the configuration changes between the EUT measurement and the reference measurement, an estimation of the uncertainty contributions shall be made to replace the 0.00 dB values. Since components such as the measurement antenna and associated cables are measured in the reference measurement, there is one lump uncertainty associated with that measurement, rather than the individual uncertainties of each component.

TABLE 3.2-1 TRP STANDARD UNCERTAINTIES FOR THE CONTRIBUTIONS IN THE EUT MEASUREMENT PART

Description of uncertainty contributions	Standard Uncertainty, dB
Mismatch: receiving part (i.e. between receiving device & Measurement Antenna)	See Appendix G.1 of [5]
Cable factor: Measurement Antenna	See Appendix G.2 of [5]
Insertion loss: Measurement Antenna cable	0.00
Insertion loss: Measurement Antenna attenuator (if present)	0.00
Receiving device: absolute level	See Appendix G.4 of [5]
EUT: influence of the ambient temperature on the ERP of the carrier	See Appendix G.9 of [5]
Miscellaneous uncertainty (measurement system repeatability)	See Appendix G.13 of [5]
Frequency resolution for TRP measurement	0.00 See Appendix G.22 of [5] and Section 2.2.2 regarding frequency stirring, which accounts for frequency flatness of the test set-up for TRP measurements.
Chamber lack of spatial uniformity (based on standard deviation of multiple pre-characterized reference measurements and single user EUT measurement)	See Appendix A.1
Unknown K factor	For future study

Once all the relevant standard uncertainty values in Table 3.2-1 have been calculated, they shall be combined (by RSS) to give the combined standard uncertainty $u_{c\ contribution\ from\ the\ EUT\ measurement}$ for this part of the test.

3.2.2. Reference Measurement

This is the reference power transfer function of the chamber G_{ref} in terms of power loss, as given in Section 2.1.3 (Methodology – Calculation of the reference power transfer function). The uncertainty of the reference measurement is a significant factor in the accuracy of the measured TRP value. Any error in the determination of G_{ref} (e.g., error in the determination of the efficiency of the Reference Antenna) will result in an error in the TRP value.

The EUT and other RF-absorbing material including RF absorbers that load the chamber to increase the coherence bandwidth (Section 2.1.2) and support structures, if any, shall be placed within the chamber during both the Reference measurement, as described in Section 2.1.1 (Reverberation Chamber Configuration and Measurement of S-Parameters). At the receiving end, the vector network analyzer shall be connected via a cable and/or attenuator to the Measurement Antenna through a chamber bulkhead adapter.

The contributors to the overall uncertainty of this part of the measurement are given in Table 3.2-2. Again, the contributors that appear in both parts of the measurement are set equal to 0.00 dB because they have the same effect in both parts, provided the relevant components of the test set-up have not been changed. If the configuration changes during the individual reference measurement steps, an estimation of the uncertainty contributions shall be made to replace the 0.00 dB values.

TABLE 3.2-2 TRP STANDARD UNCERTAINTIES FOR THE CONTRIBUTIONS IN THE REFERENCE MEASUREMENT PART

Description of uncertainty contributions	Standard Uncertainty, dB
Mismatch: transmitting part (between vector network analyzer excitation port and Reference Antenna)	See Appendix G.1 of [5]
Mismatch: receiving part (between vector network analyzer receiving port and Measurement Antenna)	See Appendix G.1 of [5]
Vector network analyzer: absolute level	See Appendix G.5 of [5]
Vector network analyzer: level stability	See Appendix G.5 of [5]
Insertion loss: calibrated Reference Antenna cable	See Appendix G.3 of [5]
Insertion loss: Measurement Antenna cable	0.00
Insertion loss: Calibrated Reference Antenna attenuator (if present)	See Appendix G.3 of [5]
Insertion loss: Measurement Antenna attenuator (if present)	0.00
Chamber lack of spatial uniformity (based on standard deviation of multiple pre-characterized reference measurements and single user reference measurement)	See Appendix A.1
Antenna: radiation efficiency of the calibrated Reference antenna	See Appendix A.2

Once all the standard uncertainty values have been derived, they shall be combined (by RSS) to give the following combined standard uncertainty $u_{c\ \textit{contribution from the reference measurement}}$ for this part of the test.

3.2.3. Calculation of the Combined and Expanded Uncertainties for the Overall TRP Measurement

Having calculated the combined standard uncertainties from the two parts of the measurement, they shall be combined as follows to derive the overall combined standard uncertainty:

$$u_c = \sqrt{u^2_{c\ \textit{contribution from the EUT measurement}} + u^2_{c\ \textit{contribution from the reference measurement}}}$$

From this, the expanded uncertainty, *U*, is calculated with a coverage factor of 2. This is the resulting value of the TRP expanded uncertainty and shall be stated in the test report, See Appendix B.

3.3 TIS Tests

The TIS test method is similar to the TRP method above, in that the Reference measurement is used to correct the unknown performance of the EUT back to values relative to that of a theoretical isotropic receiver. The test procedure for TIS is described in Section 2.3.2 (Receiver Performance). EUT measurements are corrected for the chamber reference by use of techniques described Section 2.1.3 (Methodology – Calculation of the reference power transfer function). To reduce the overall measurement uncertainty, the same cable configuration and equipment used during the reference measurement should also be used during the EUT measurement, rather than measuring individual components and applying the corrections separately. In this way, a number of the individual uncertainty contributions will cancel because they contribute the same uncertainty to both the reference measurement and the EUT measurement. Examples include the uncertainty in the insertion loss of the cable(s) between the measurement antenna and the base station emulator, the uncertainty in the gain of the measurement antenna, etc.

3.3.1. EUT Measurement

The EUT and other RF-absorbing material including RF absorbers that load the chamber to increase the coherence bandwidth (Section 2.1.2) and support structures, if any, shall be placed within the chamber during the chamber characterization and EUT measurements, as described in Section 2.1.1 (Reverberation Chamber Configuration and Measurement of S-Parameters). At the receiving end, the base station emulator shall be connected via a cable and/or attenuator to the Measurement Antenna through a chamber bulkhead adapter. If the configuration changes between the EUT measurement and the reference measurement, an estimation of the uncertainty contributions shall be made to replace the 0.00 dB values.

The identified uncertainties in this part are listed in Table 3.3-1.

TABLE 3.3-1 TIS STANDARD UNCERTAINTIES FOR THE CONTRIBUTIONS IN THE EUT MEASUREMENT PART

Description of uncertainty contributions	Standard Uncertainty, dB
Mismatch: transmitting part (i.e. between Base Station Simulator and Measurement Antenna)	See Appendix G.1 of [5]
Base station simulator: absolute output level	See Appendix G.5 of [5]
Base station simulator: output level stability	See Appendix G.5 of [5]
Cable factor: Measurement Antenna	0.00
Insertion loss: Measurement Antenna cable	0.00
Insertion loss: Measurement Antenna attenuator (if present)	0.00
Sensitivity search step size	See Appendix G.11 of [5]
EUT influence of ambient temperature on the EIS	See Appendix G.9 of [5]
Miscellaneous uncertainty (measurement system repeatability)	See Appendix G.13 of [5]
Chamber lack of spatial uniformity (based on standard deviation of multiple pre-characterized reference measurements and single user EUT measurement)	See Appendix A.1
Unknown K factor	For future study
Frequency resolution for TIS measurement	See Appendix A.3

The standard uncertainties from Table 3.3-1 should be combined by RSS to give the combined standard uncertainty $u_{c\ \text{contribution from the EUT measurement}}$ for this part of the test.

3.3.2. Reference Measurement

The same analysis as described in Section 3.2.2 (Reference Measurement in the TRP case) applies here. If the configuration changes during the individual reference measurement steps, an estimation of the uncertainty contributions shall be made to replace the 0.00 dB values. The same contributions as stated in Table 3.3-2 shall be used to calculate the combined standard uncertainty $u_{c\ \text{contribution from the reference measurement}}$ for the reference part of the measurement.

TABLE 3.3-2 TIS STANDARD UNCERTAINTIES FOR THE CONTRIBUTIONS IN THE REFERENCE MEASUREMENT PART

Description of uncertainty contributions	Standard Uncertainty, dB
Mismatch: transmitting part (between vector network analyzer excitation port and Reference Antenna)	See Appendix G.1 of [5]
Mismatch: receiving part (between vector network analyzer receiving port and Measurement Antenna)	See Appendix G.1 of [5]
Vector network analyzer: absolute level	See Appendix G.5 of [5]
Vector network analyzer: level stability	See Appendix G.5 of [5]
Insertion loss: calibrated Reference Antenna cable (if used)	See Appendix G.3 of [5]
Insertion loss: Measurement Antenna cable	0.00
Insertion loss: Calibrated Reference Antenna attenuator (if present)	See Appendix G.3 of [5]
Insertion loss: Measurement Antenna attenuator (if present)	0.00
Chamber lack of spatial uniformity (based on standard deviation of multiple pre-characterized reference measurements and single user reference measurement)	See Appendix A.1
Antenna: radiation efficiency of the calibrated Reference antenna	See Appendix A.2

The standard uncertainties from Table 3.3-2 should be combined by RSS to give the combined standard uncertainty $u_{c\ contribution\ from\ the\ reference\ measurement\ for\ this\ part\ of\ the\ test}$.

3.3.3. Calculation of the Combined and Expanded Uncertainties for the Overall TIS Measurement

Having calculated the combined standard uncertainties from the two parts of the measurement, they shall be combined as follows to derive the overall combined standard uncertainty:

$$u_c = \sqrt{u^2_{c\ contribution\ from\ the\ EUT\ measurement} + u^2_{c\ contribution\ from\ the\ reference\ measurement}}$$

From this, the expanded uncertainty, *U*, is calculated with a coverage factor of 2. This is the resulting value of the TIS expanded uncertainty and shall be stated in the test report, see Appendix B.

3.4 Criteria—Measurement Uncertainty

The results of the calculations for expanded uncertainty for both TRP and TIS measurements shall meet the requirements and shall be reported, along with full documentation to support the resulting values as specified in Section 7.5 of [5].

Appendix A Instructions for Calculating Standard Uncertainty Values for Reverberation Chamber (Normative)

Note: This appendix contains specifications of uncertainty values specific to tests performed with reverberation-chamber-based techniques. For specifications of general error contributions, see Appendix G of the CTIA Test Plan for Over the Air Performance [5].

The uncertainty in a reverberation-chamber measurement will depend on chamber size, frequency of operation, type of stirring in the sequence, stirrer types and shapes, polarization stirring (if any), frequency averaging bandwidth, and the degree of loading of the chamber. All of these factors must remain the same for the reference power transfer function characterization and DUT measurement procedures.

The additional components of uncertainty due to the use of the reverberation chamber are detailed below. If the total expanded uncertainty exceeds the required level of uncertainty, the stirring sequence may be altered, typically by adding additional mode-stirring samples. For measurement of large-form-factor devices, these additional positions often utilize antenna-location stirring.

A.1 Uncertainty Due to Implementation of Mode-Stirring Sequence and Chamber Lack of Spatial Uniformity

This component embodies the non-ideal effects of, for example, loading by the DUT or other components, a nonzero K factor [7] [10] and the limited number of modes within the chamber. This component reflects the uncertainty in positioning of the EUT and the reference antenna.

This component of uncertainty is determined by repeated reference measurements performed during a pre-characterization step, as described in Section 2.1.3 “Methodology – Calculation of the reference power transfer function” and Section 2.2.4 “Test Procedure – Chamber Pre-Characterization of Uncertainty due to Lack of Spatial Uniformity.” This uncertainty contribution is a composite value consisting of most of the specific reverberation chamber contributions, such as lack of spatial uniformity due to loading with RF absorber, limited number of modes, K-factor, and mode-stirring methods.

Note that both the number of mode-stirring samples and the variation in the estimate of G_{ref} due to lack of spatial uniformity will affect the value of $\sigma_{G_{\mathrm{ref}}}$. Based on a significance test [14], it was determined that the variation due to lack of spatial uniformity was typically the dominant component of uncertainty in an estimate of G_{ref} because of the large number of mode-stirring samples that are generally used.

The standard uncertainty $u_{G_{ref}}$ for the reference and EUT measurement is:

EQUATION A-1

$$u_{G_{\mathrm{ref}}} = \frac{\sigma_{G_{\mathrm{ref}}^{i+1}}}{\sqrt{T_{\mathrm{cal}}}}$$

where $\sigma_{G_{ref}^{i+1}}$ shall be found from for the loading condition used in the EUT measurement from the table compiled in Section 2.2.4.

To compute the combined uncertainty as described in Section 3, a coverage factor of 2 will be applied. Because the uncertainty due to lack of spatial uniformity is computed from a limited number of samples (T_{pre} = 12), the coverage factor should be higher than 2 for this component of uncertainty. K_p is used to ensure that the expanded uncertainty covers the expected 95% confidence. For this case, (11 degrees of freedom), the 95% coverage factor would be 2.201. Thus, the value of K_p = 1.10 is used to account for the limited number of samples for this element, resulting in the following expression for uncertainty:

EQUATION A-2

$$u_{95,G_{\mathrm{ref}}} = \frac{\sigma_{G_{\mathrm{ref}}^{i+1}}}{\sqrt{T_{\mathrm{cal}}}} \times K_p$$

Note that T_{cal} may be different for the reference and EUT measurements. For the reference measurements the value of T_{cal} is the number of positions/orientations used for the reverberation chamber calibration ($T_{cal} \geq 1$), and for the EUT measurement $T_{cal} = 1$.

The standard measurement uncertainty estimate shall be obtained for each channel bandwidth case as defined in Table 2.4-1 by selecting the worst case for all available frequencies across each band. The value used for T_{cal} shall be reported in the MU budget and in the test report, see Appendix B. Use separate MU templates for each channel bandwidth if necessary.

A.2 Radiation Efficiency of Calibrated Reference Antenna

The measured average transmission level in the reference measurement is directly related to the stated radiation efficiency of the calibrated reference antenna. Therefore, the uncertainty of the radiation efficiency value is directly transferred to the uncertainty calculation of the reference measurement.

This component of uncertainty shall be taken as the uncertainty stated by the laboratory that calibrates the reference antenna.

A.3 Frequency Flatness for TIS Reference Measurements

Section 2.2.2 Test Procedure – Determination of Number of Test Frequencies ensures that the frequency step used for the reference measurement is small enough to characterize the chamber's reference to within 0.05 dB across the frequency band of interest. If a user wishes to utilize a larger frequency step, an additional component of uncertainty is included.

The procedure for determining this uncertainty is given in Section 2.2.2.

Appendix B Reporting of Test Results (Normative)

B.1 Test Report Tables

The following content shall be included in the test report. The tables are provided as examples for information.

Table B.1-5 to Table B.1-8 shall be used for CDMA, CDMA 1xEV-DO DATA, CDMA 1xRTT DATA, GSM, and UMTS.

Table B.1-9 to Table B.1-12 shall be used for GPRS and EGPRS.

Table B.1-13 to Table B.1-16 shall be used for LTE.

B.1.1 EUT Information Table

TABLE B.1-1 EQUIPMENT UNDER TEST (EUT) INFORMATION

Manufacturer	
Model	
Serial Number(s)/ESN(s)/IMEI(s)	
FCC ID Number	
Hardware Version	
Software Version	
Configuration of Primary Mechanical Mode	

TABLE B.1-2 BANDS AND PROTOCOLS SUPPORTED BY EACH ANTENNA

Antenna Label	Bands and Protocols for Which the Antenna Is Connected to the Transmitter	Bands and Protocols for Which the Antenna Is Connected to the Primary Receiver and Is Always Active	Bands and Protocols for Which the Antenna Is Connected to the Primary Receiver and Is Dynamically Active	Bands and Protocols for Which the Antenna Is Connected to the Secondary Receiver and Is Always Active	Bands and Protocols for Which the Antenna Is Connected to the Secondary Receiver and Is Dynamically Active
A	WCDMA 2,5, LTE 2, 5	WCDMA 2,5, LTE 2, 5			
B				LTE 2, 5	WCDMA 2, 5
C	LTE 7	LTE 7			
D				LTE 7	

Note that sample data has been entered into the table.

TABLE B.1-3 EUTS USED FOR EACH TEST

Serial Number/ ESN/IMEI	CATL and Chamber used	Cellular Radio Mode(s)	Band(s)	Test Type(s)	Test Condition(s)

TABLE B.1-4 CELLULAR RADIO MODE OTA SUMMATION TEST REPORT

Band	Channel	Frequency (MHz)	Conducted Power / Conducted Sensitivity (dBm)	Antenna Label	TRP / TIS (dBm)[1]
					FS
Note 1: Values that do not pass shall be marked in red font.					

TABLE B.1-5 MINIMUM TRP LEVEL REQUIREMENTS FOR THE PRIMARY MECHANICAL MODE[1]

Minimum TRP Level Requirements for the Primary Mechanical Mode[1]						
Cellular Technology/Band						
				FS		
Antenna Type	Device Power Class	Channel	TX Frequency (MHz)	Limit (dBm)[2]	Test Results (dBm)	Pass / Fail / Info
				TBD		

Note 1: Primary Mechanical Mode refers to device configured in preferred mode per manufacturer instructions (typically means antenna extended, but depends on form factor).

Note 2: The appropriate limits shall be populated in this column.

TABLE B.1-6 MINIMUM TRP LEVEL REQUIREMENTS FOR THE PRIMARY MECHANICAL MODE FOR THE PRIMARY AND SECONDARY ANTENNAS[1]

Minimum TRP Level Requirements for the Primary Mechanical Mode for the Primary and Secondary Antennas[1]												
Cellular Technology/Band												
Antenna Type	Device Power Class	Test Position	Channel	TX Frequency (MHz)	Primary Antenna Label	Primary TRP (dBm)	Primary TRP Limit (dBm)[2]	Pass / Fail / Info	Secondary Antenna Label	Secondary TRP (dBm)	Secondary TRP Limit (dB)[2]	Pass / Fail / Info
		FS					TBD				TBD	

Note 1: Primary Mechanical Mode refers to device configured in preferred mode per manufacturer instructions (typically means antenna extended, but depends on form factor).

Note 2: The appropriate limits shall be populated in this column.

TABLE B.1-7 MAXIMUM TIS LEVEL REQUIREMENTS FOR THE PRIMARY MECHANICAL MODE[1]

Maximum TIS Level Requirements for the Primary Mechanical Mode[1]						
Cellular Technology/Band						
Antenna Type	Device Power Class	Channel	RX Frequency (MHz)	FS		
				Limit (dBm)[2]	Test Results (dBm)	Pass / Fail / Info
All				TBD		

Note 1: Primary Mechanical Mode refers to device configured in preferred mode per manufacturer instructions (typically means antenna extended, but depends on form factor).

Note 2: The appropriate limits shall be populated in this column.

TABLE B.1-8 MAXIMUM TIS AND BPD LEVEL REQUIREMENTS FOR THE PRIMARY MECHANICAL MODE[1]

Maximum TIS and BPD Level Requirements for the Primary Mechanical Mode[1]												
Cellular Technology/Band												
Device Power Class	Test Position	Channel	RX Frequency (MHz)	Primary Antenna Label	Primary TIS (dBm)	Primary TIS Limit (dBm)[2]	Pass / Fail / Info	Secondary Antenna Label	Secondary TIS (dBm)	BPD (dB)	BPD Limit (dB)[2]	Pass / Fail / Info
	FS					TBD					TBD	
Note 1: Primary Mechanical Mode refers to device configured in preferred mode per manufacturer instructions (typically means antenna extended, but depends on form factor).												
Note 2: The appropriate limits shall be populated in this column.												

TABLE B.1-9 MINIMUM TRP LEVEL REQUIREMENTS FOR THE PRIMARY MECHANICAL MODE[1,2]

Minimum TRP Level Requirements for the Primary Mechanical Mode[1,2]						
Cellular Technology/Band						
Multi-slot Class	Device Power Class	Channel	TX Frequency (MHz)	FS		
				Limit (dBm)[3]	Test Results (dBm)	Pass / Fail / Info
				TBD		
Note 1: Primary Mechanical Mode refers to device configured in preferred mode per manufacturer instructions (typically means antenna extended, but depends on form factor).						
Note 2. The associated TRP value is based on measurements made with one uplink slot. Devices tested using two uplink time slots are allowed a TRP reduction of 3 dB, devices tested using three uplink slots are allowed a TRP reduction of up to 4.8 dB and devices tested using four uplink slots are allowed a TRP reduction of up to 6 dB. These allowances for uplink slot counts greater than one are based on a DUT capable of meeting the minimum TRP performance in single slot operation. This allowance is in alignment with 3GPP TS 45.005, Section 4.1.1, Table 4.1-5.						
Note 3: The appropriate limits shall be populated in this column.						

TABLE B.1-10 MINIMUM TRP LEVEL REQUIREMENTS FOR THE PRIMARY MECHANICAL MODE FOR THE PRIMARY AND SECONDARY ANTENNAS[1 2]

Minimum TRP Level Requirements for the Primary Mechanical Mode for the Primary and Secondary Antennas[1 2]												
Cellular Technology/Band												
Multi-slot Class	Device Power Class	Test Position	Channel	TX Frequency (MHz)	Primary Antenna Label	Primary TRP (dBm)	Primary TRP Limit (dBm)[3]	Pass / Fail / Info	Secondary Antenna Label	Secondary TRP (dBm)	Secondary TRP Limit (dBm)[3]	Pass / Fail / Info
							TBD				TBD	

Note 1: Primary Mechanical Mode refers to device configured in preferred mode per manufacturer instructions (typically means antenna extended, but depends on form factor).

Note 2. The associated TRP value is based on measurements made with one uplink slot. Devices tested using two uplink time slots are allowed a TRP reduction of 3 dB, devices tested using three uplink slots are allowed a TRP reduction of up to 4.8 dB and devices tested using four uplink slots are allowed a TRP reduction of up to 6 dB. These allowances for uplink slot counts greater than one are based on a DUT capable of meeting the minimum TRP performance in single slot operation. This allowance is in alignment with 3GPP TS 45.005, Section 4.1.1, Table 4.1-5.

Note 3: The appropriate limits shall be populated in this column.

TABLE B.1-11 MAXIMUM TIS LEVEL REQUIREMENTS FOR THE PRIMARY MECHANICAL MODE[1 2]

Maximum TIS Level Requirements for the Primary Mechanical Mode[1 2]						
Cellular Technology/Band						
				FS		
Multi-slot Class	Device Power Class	Channel	TX Frequency (MHz)	Limit (dBm)[2]	Test Results (dBm)	Pass / Fail / Info
				TBD		

Note 1: Primary Mechanical Mode refers to device configured in preferred mode per manufacturer instructions (typically means antenna extended, but depends on form factor).

Note 2: The appropriate limits shall be populated in this column.

TABLE B.1-12 MAXIMUM TIS LEVEL REQUIREMENTS FOR THE PRIMARY MECHANICAL MODE FOR THE PRIMARY AND SECONDARY ANTENNAS[1]

Maximum TIS Level Requirements for the Primary Mechanical Mode for the Primary and Secondary Antennas[1]												
Cellular Technology/Band												
Multi-slot Class	Device Power Class	Test Position	Channel	RX Frequency (MHz)	Primary Antenna Label	Primary TIS (dBm)	Primary TIS Limit (dBm)[2]	Pass / Fail / Info	Secondary Antenna Label	Secondary TIS (dBm)	Secondary TIS Limit (dBm)[2]	Pass / Fail / Info
							TBD				TBD	

Note 1: Primary Mechanical Mode refers to device configured in preferred mode per manufacturer instructions (typically means antenna extended, but depends on form factor).

Note 2: The appropriate limits shall be populated in this column.

TABLE B.1-13 MINIMUM TRP LEVEL REQUIREMENTS FOR THE PRIMARY MECHANICAL MODE[1]

Minimum TRP Level Requirements for the Primary Mechanical Mode[1]					
Cellular Technology/Band					
Channel	UL RB Allocation	TX Frequency (MHz) [center of UL RB allocation]	FS		
			Limit (dBm)[2]	Test Results (dBm)	Pass / Fail / Info
			TBD		

Note 1: Primary Mechanical Mode refers to device configured in preferred mode per manufacturer instructions (typically means antenna extended, but depends on form factor).

Note 2: The appropriate limits shall be populated in this column

TABLE B.1-14 MINIMUM TRP LEVEL REQUIREMENTS FOR THE PRIMARY MECHANICAL MODE FOR THE PRIMARY AND SECONDARY ANTENNAS[1]

Minimum TRP Level Requirements for the Primary Mechanical Mode for the Primary and Secondary Antennas[1]											
Cellular Technology/Band											
Test Position	Channel	UL RB Allocation	TX Frequency (MHz) [center of UL RB allocation]	Primary Antenna Label	Primary TRP (dBm)	Primary TRP Limit (dBm)[2]	Pass / Fail / Info	Secondary Antenna Label	Secondary TRP (dBm)	Secondary TRP Limit (dBm)[2]	Pass / Fail / Info
FS						TBD				TBD	

Note 1: Primary Mechanical Mode refers to device configured in preferred mode per manufacturer instructions (typically means antenna extended, but depends on form factor).

Note 2: The appropriate limits shall be populated in this column.

TABLE B.1-15 MAXIMUM TIS LEVEL REQUIREMENTS FOR THE PRIMARY MECHANICAL MODE[1]

Maximum TIS Level Requirements for the Primary Mechanical Mode[1]					
Cellular Technology/Band					
			FS		
Channel	DL RB Allocation	TX Frequency (MHz)	Limit (dBm)[2]	Test Results (dBm)	Pass / Fail / Info
			TBD		

Note 1: Primary Mechanical Mode refers to device configured in preferred mode per manufacturer instructions (typically means antenna extended, but depends on form factor).

Note 2: The appropriate limits shall be populated in this column

TABLE B.1-16 MAXIMUM TIS AND BPD LEVEL REQUIREMENTS FOR THE PRIMARY MECHANICAL MODE[1]

Maximum TIS and BPD Level Requirements for the Primary Mechanical Mode[1]														
Cellular Technology/Band														
Test Position	Channel	DL RB Allocation	RX Frequency (MHz)	Primary Antenna Label	Primary Antenna TIS (dBm)	Primary Antenna TIS Limit (dBm)[2]	Pass / Fail / Info	Secondary Antenna Label	Secondary Antenna TIS (dBm)	Secondary Antenna TIS Limit (dBm)[2]	Pass / Fail / Info	BPD (dB)	BPD Limit (dBm)[2]	Pass / Fail / Info
FS						TBD				TBD			TBD	

Note 1: Primary Mechanical Mode refers to device configured in preferred mode per manufacturer instructions.

Note 2: The appropriate limits shall be populated in this column.

Appendix C Version History

Date	Version	Description
September 2016	1.0	• Initial release of document
October 2016	1.0.1	-Updated date and revision number updated in footer -List of Tables added Text added in Section 1.5, paragraph 3 “In stepped mode, each measurement is acquired over a static multipath channel that is assumed to be relatively flat in frequency over the channel bandwidth to be tested. No Doppler component or other time dependent variations are present during each error rate measurement. The resulting ensemble of the individual power samples acquired from each mode-stirring sample for an adequately stirred reverberation chamber should be Rayleigh distributed.” -Text added in Section 2.2.3, step 2 “Directional antennas shall be oriented away from the absorber.” -Text deleted underneath Figure 2.2.3-1: “The RF absorber shall have absorption in excess of that likely to be presented by the EUT.” -Text added underneath Figure 2.2.3-1: “Description of Figure 2.2.3-1” -Added link to Equation A-1 -Deleted subscript “meas” from “e_mismatch,meas” in paragraph following Equation 2.3.3-1 -Inserted text at end of paragraph following Equation 2.3.3-1 “The uncertainty in PTIS must not exceed the uncertainty specified in Table 7-8 of the CTIA Test Plan for Over the Air Performance [5]. Note that the summation is performed using linear power values, even though the results are normally presented in dBm.” -Changed “Section 1.6” to “Section 2.2.2” in first paragraph of Section 2.4.1 -Changed title of Table 2.4-1 to “TRANSMISSION STANDARD, CHANNEL BANDWIDTH (MHZ), AND COHERENCE BANDWIDTH (MHZ)” -Added text after Table 3.3-2 “The standard uncertainties from Table 3.3 2 should be combined by RSS to give the combined standard uncertainty uc_contribution from the reference measurement for this part of the test.”

Date	Version	Description
October 2016	1.0.1	Deleted duplicate sigma term in Equation A-1 -Replaced “is” with “shall be” after Equation A-1 -Replaced “is” with “shall be” in last paragraph of Section A-1 -Added links to all tables specified in Section B.1 - Renumbered tables to from Section “3.4” to Appendix “B.1”
July 2017	1.1	Added the following contributions to the 1.0.1 released document: CPWG170313-1R1, CPWG170313-2R1, CPWG170425-2, CPWG170426-3, CPWG170426-5, CPWG170426-4.
June 2018	1.1.1	Added the following contributions: OTAWIOT170915-2R1, OTAWIOT170927-1R1, OTAWIOT171121-1R3, OTAWIOT180129_1R3