DEMC Korea 2025

REVERBERATION & ISO STANDARDS: A COMPREHENSIVE UPDATE

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Make ideas real

AGENDA

- Annex D Tuned mode and stirred mode
- 4. Test condition
- 5. Test location
- 8. Test procedure
  - 8.1 General
  - 8.3 Stirring configurations
  - 8.4 Working volume and reverb reference points
  - 8.5 Test methods

REVERBERATION CHAMBER METHOD
D.4 COMPARISON

Method	Pros	Cons
Tuned mode	- CW test possible - Same consideration of dwell time and DUT response time applicable as in ISO 11452-2 testing	- Significantly longer calibration and test time; much lower efficiency - Higher test level uncertainty
Stirred mode	- Calibration and test time are significantly reduced; much higher efficiency - Higher test level accuracy	- CW test not possible - Uncertainty due to DUT response time

Table D.1 – Comparison tuned mode and stirred mode

REVERBERATION CHAMBER METHOD

- 4. Test condition
  - The applicable frequency range of the test method is from LUF to 18GHz.
  - The applicable frequency range is 0.01MHz to LUF for the TLS method (see Annex E), 30MHz, for example, to LUF for the cavity mode method (see Annex F), and LUF to 18GHz for the other reverb methods (see Annex G, Annex H and Annex I).
  - The user shall specify the test severity level(s) over the frequency range. Suggested test levels are included in Annex A.
  - Standard test conditions shall be according to ISO 11452-1 for the following:
    - Test temperature;
    - Supply voltage;
    - Modulation;
    - Dwell time;
    - Frequency step size;
    - Definition of test severity levels; and
    - Test signal quality

REVERBERATION CHAMBER METHOD

- 5. Test location
  - The test shall be performed in a reverberation chamber.
  - The aim of using a reverberation chamber is to create statistically homogeneous and isotropic electromagnetic fields within the working volume.
  - A reverberation chamber for component testing consists of a shielded enclosure, one or several field generating devices, and some mechanical apparatus to change the boundary conditions for the electromagnetic fields.
  - This mechanical apparatus may, for example, contain one or several rotating tuners or moving walls, or may even be realized by using conductive fabrics as shielded enclosure (e.g. a VIRC).
  - The size, shape, and construction of the reverberation chamber can vary considerably.

REVERBERATION CHAMBER METHOD

- 8. Test procedure
  - 8.1 General
    - After initial construction, the reverberation chamber shall be characterized in accordance with the chosen test methods (see tables 1 & 2) and Annex C.
    - The LUF of the reverberation chamber is determined during this initial characterization., A new chamber characterization shall be carried out following any major modifications (e.g. changes to the tuners).
    - Further guidance is provided in Annex M about the steps to be followed from initial characterization of the reverberating chamber to DUT test.

REVERBERATION CHAMBER METHOD

- 8. Test procedure
  - 8.3 Stirring configurations
    - Several stirring methods exist and may be used separately or in combination.
    - They can provide a continuous stirring or a discrete stepped or tuned stirring. Consequently, the mathematical operations included in the formulas to calculate the test level, the number of independent stirring configurations, and the field uniformity have to be modified for each stirring method or each combination.
    - With the mean value (or the maximum value) over all stirring configurations (totality of methods or combination of methods chosen by the user shall be applied for calibration and testing), a proper calculation over all relevant stirring methods is meant, denoted as $\langle\cdot\rangle_{sc}\left(or\ as\ \underset{sc}{Max}(\cdot)\right)$.

REVERBERATION CHAMBER METHOD

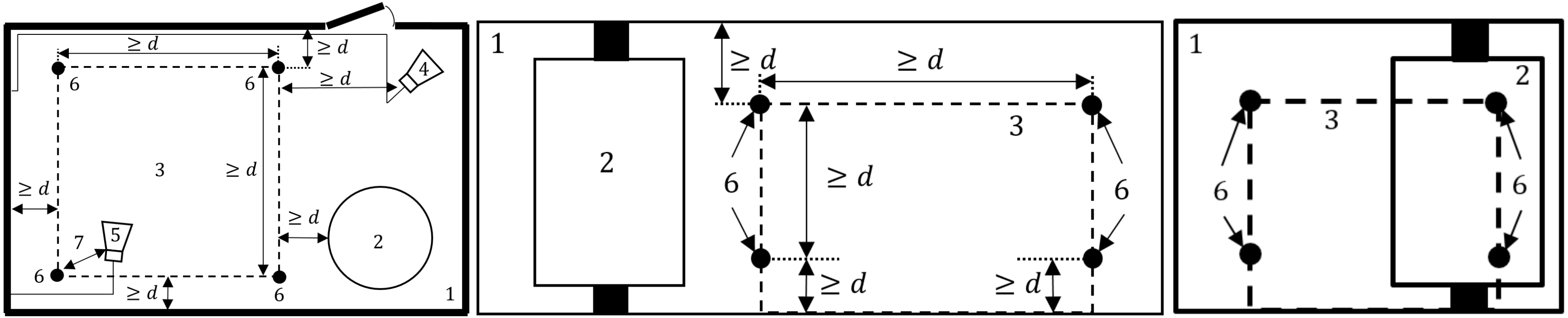
- 8. Test procedure
  - 8.4 Working volume and reverb reference points
    - This working volume typically has a cuboid shape, but this is not a requirement.
    - The minimum distance between the working volume and the walls and ceiling of the shielded enclosure or any tuner or any transmitting antenna shall be at least λ /4 at the lowest used frequency of the reverb mode.
    - For TLS method (see Annex E), and cavity mode method (see Annex F), the λ /4 minimum distance requirement does not apply.

    ex) LUF 80MHz, λ=$\frac{c}{frequency}$; $\frac{1}{4} * \frac{3*10^8}{8*10^7} \cong 0.9375m$

    - The reverb reference points are eight points on the four vertical corner edges of the cuboid working volume.
    - The lower four points shall be at least λ /4 (at LUF) above the shielding enclosure floor, the upper four points shall be at least as high as the highest DUT intended to be tested and at least λ /4 (at LUF) above the lower four points.

REVERBERATION CHAMBER METHOD

- 8. Test procedure
  - 8.4 Working volume and reverb reference points

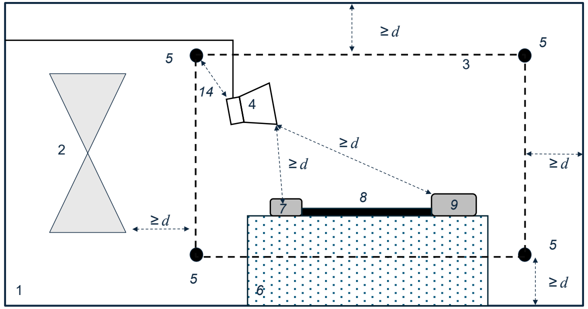


a) Top view b) Front view c) side view

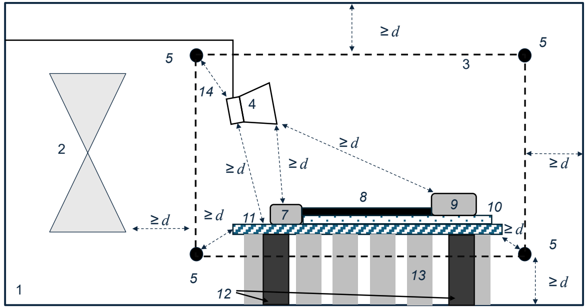
1	Reverberation chamber / VIRC	5	Receiving antenna, if used (only shown in top view)
2	Tuner	6	Reverb reference points (8 points)
3	Working volume	7	Minimum distance between receiving antenna and any field probe shall be at least $d = \lambda_{\mathrm{LUF}}/4$
4	Transmitting antenna (only shown in top view)	d	Minimum distance $d = \lambda_{\mathrm{LUF}}/4$

REVERBERATION CHAMBER METHOD

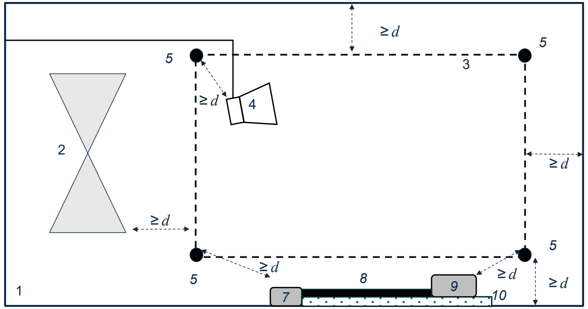
- 8. Test procedure
  - 8.4 Working volume and reverb reference points



a) Test setup without ground plane



b) Test setup with ground plane



c) Specific tests setup on the ground floor

1	reverberation chamber / VIRC	8	test harness
2	tuner, if used	9	DUT (grounded locally if required in test plan)
3	chamber working volume	10	low relative permittivity support ($\varepsilon_r \leq 1{,}4$)
4	receiving antenna, if used	11	elevated ground plane
5	reference points (8 points)	12	ground plane support / stand
6	non-metallic test bench	13	ground straps
7	support equipment	14	when receiving antenna and measuring field probe placed at the reference point are used at the same time, the minimum distance $d = \lambda_{\mathrm{LUF}}/4$
d	minimum distance $d = \lambda_{\mathrm{LUF}}/4$		

REVERBERATION CHAMBER METHOD

- 8. Test procedure
  - 8.5 Test methods
    - 8.5.1 Test method selection
      - This document defines several test methods described in the main body and in Annex E to Annex I. Table 1and Table 2 summarize the main properties of each test method. Table 1 and Table 2 are intended to serve as a guide for selecting a test method that best fits the needs. Unless otherwise specified, methods described in 8.5.2.2 or 8.5.2.3 are the methods to be used. Methods described in Annex E to Annex I are alternative ones.

REVERBERATION CHAMBER METHOD

Test method	Subclause	Features
Reverb method with substitution method power control + Loading factor method	8.5.2.2	Frequency range: f_{LUF} to 18 000MHz Same method as defined in IEC 61000-4-21. Tuned mode and stirred mode are possible. Requires a spectrum analyser or power meter and a receiving antenna for loading determination. Field uniformity check only for maximum loading. As long as actual loading is smaller, validity of field uniformity is assumed. If only one measurement with receiving antenna is used for determining CLF, this method is less accurate than the two other calibration methods for substitution method. The accuracy may be improved by taking measurements with different receiving antenna positions, but this will take more time. Since power control loop typically is faster than field control loop, settling time of test level is faster than with closed-loop method.
Reverb method with substitution method power control + Field calibration with the DUT present	8.5.2.3	Frequency range: f_{LUF} to 18 000MHz Tuned mode and stirred mode are possible. Needs field probes for the calibration for each new DUT(class) available. For each DUT(class) the field uniformity is actually measured and allows therefore a direct comparison with the field homogeneity requirements. Thus, a too high loading can be directly determined and the (iterative) experimental determination of the maximum permissible loading is not needed. Unless multi-probe setups are used, this method needs the longest loading determination time. Since power control loop typically is faster than field control loop, settling time of test level is faster than with closed-loop method.

[Table 1- Test methods in the main body]

REVERBERATION CHAMBER METHOD

Test method	Subclause	Features
TLS method	Annex E	Frequency range: 10kHz to f_{LUF} Only test method below 30MHz. Alternative method to cavity mode method in frequency range 30MHz to f_{LUF} Only stirred mode possible.
Cavity mode	Annex F	Frequency range: 30MHz to f_{LUF} Mainly intended for tuned mode, but stirred mode possible. Requires tune able monopoles, but other antennas may be used.
Reverb method with closed-loop power control	Annex G	Frequency range: f_{LUF} to 18 000MHz Only stirred mode possible. Fast stirring (e.g. VIRC) necessary so that statistics can be reasonably measured in a short time. No calibration needed. No need for determining loading effects prior to testing. Always provides the field uniformity with the actual DUT. Needs fast field probes and a multi-probe setup.
Reverb method with substitution method power control + Chamber time constant method	Annex H	Frequency range: f_{LUF} to 18 000MHz Tuned mode and stirred mode possible. Needs a vector network analyser or spectrum analyser and a signal generator with pulse modulation (both synchronized) for measuring the chamber time constant.
VNA method	Annex I	Frequency range: f_{LUF} to 18 000MHz Tuned mode and stirred mode possible. Needs a vector network analyser for calibration. No need for field probes and considerations of isotropy of field probes necessary.

[Table 2- Alternative test methods in Annexes]

REVERBERATION CHAMBER METHOD

- 8.5.2.2 Substitution method with empty chamber calibration
  - 8.5.2.2.1General
    - This section describes a field calibration procedure that is based on the field calibration of the empty chamber and uses a power compensation of the DUT loading.
    - This method uses the mean of the normalized received power to quantify the loading effect. This procedure is the same as defined in IEC 61000-4-21.

    The method is performed in four phases:
    - field calibration of the empty chamber (see 8.5.2.2.2);
    - determination of the maximum loading factor (see 8.5.2.2.3);
    - determination of the chamber loading factor (see 8.5.2.2.4);
    - DUT test (see 8.5.2.2.5)

REVERBERATION CHAMBER METHOD

- 8.5.2.2 Substitution method with empty chamber calibration
  - 8.5.2.2.2 Field calibration of the empty chamber
    - Calibration is performed within a cleared working volume, if needed.
    - The specific test level (field) shall be calibrated periodically by recording the forward power required to produce a specific test level (calculated from field probe measurements in the eight reverb reference points)for each test frequency.
    - This calibration shall be performed with an unmodulated sinusoidal wave.
    - When requested, the values of forward and reverse power recorded in the calibration file and a precise description of the associated position of the field probe shall be included in the test report.
    - Place the field generating device(s) at the intended location(s).
    - A receiving antenna placed within the working volume is used to measure received power.

REVERBERATION CHAMBER METHOD

- 8.5.2.2 Substitution method with empty chamber calibration
  - 8.5.2.2.2 Field calibration of the empty chamber
    - In place of the receiving antenna, a calibrated isotropic field probe may be used. In this case, the received power P_{rcv} is calculated from the measured electric field strength component E_i with Formula (1):

$$P_{rvc} = \frac{\lambda^2 E_i^2}{320\pi^2}$$

    - P_{rcv} is the received power for a single stirring configuration in W;
    - λ is the wavelength at the test frequency in m;
    - E_i is the measured component of the electric field strength in any direction x, y or z in V/m.

REVERBERATION CHAMBER METHOD

- 8.5.2.2 Substitution method with empty chamber calibration
  - 8.5.2.2.2 Field calibration of the empty chamber
    - For all eight reverb reference points, do the following:
      - the reached test level E_{RC}in V/m according to Formula (B.1),
        - Formula (B.1) $E_{RC} = \frac{1}{24}\sum_{p=1}^{8}\left(Max\left(E_{x,p}\right) + Max\left(E_{y,p}\right) + Max\left(E_{z,p}\right)\right)$
    - For the forward power and reverse power calculate the mean values all eight measurements using Formula (2);

$$\langle P_f \rangle_{sc} = \frac{1}{8}\sum_{p=1}^{8} \langle P_{f,p} \rangle_{sc}$$

    - For each test frequency, calculate the chamber gain $G_{RC,empty}$ of the empty chamber using Formula (3);

$$G_{RC,empty} = \frac{E_{RC}}{\sqrt{\langle P_f \rangle_{sc}}}$$

    - For each test frequency, check that the field uniformity requirements given in Table C.2 are met .
    - Determine the lowest test frequency f_c that fulfils the field uniformity requirement.

REVERBERATION CHAMBER METHOD
C.5 FIELD UNIFORMITY

Average of maxima of E-field:

$$\langle e_x \rangle = \frac{1}{N}\sum_{n=1}^{N} e_{x,n}$$

$$\langle e_y \rangle = \frac{1}{N}\sum_{n=1}^{N} e_{y,n}$$

$$\langle e_z \rangle = \frac{1}{N}\sum_{n=1}^{N} e_{z,n}$$

$$\langle e \rangle = \frac{1}{3N}\sum_{n=1}^{N} \left(e_{x,n} + e_{y,n} + e_{z,n}\right)$$

Standard deviation:

$$\sigma_x = \sqrt{\frac{1}{N-1}\sum_{n=1}^{N}\left(e_{x,n} - \langle e_x \rangle\right)^2}$$

$$\sigma_y = \sqrt{\frac{1}{N-1}\sum_{n=1}^{N}\left(e_{y,n} - \langle e_y \rangle\right)^2}$$

$$\sigma_z = \sqrt{\frac{1}{N-1}\sum_{n=1}^{N}\left(e_{z,n} - \langle e_z \rangle\right)^2}$$

$$\sigma = \sqrt{\frac{1}{3N-1}\sum_{n=1}^{N}\left(\left(e_{x,n} - \langle e_x \rangle\right)^2 + \left(e_{y,n} - \langle e_y \rangle\right)^2 + \left(e_{z,n} - \langle e_z \rangle\right)^2\right)}$$

Standard deviation(dB):

$$\sigma_{x,dB} = 20log_{10}\left(\frac{\sigma_x + \langle e_x \rangle}{\langle e_x \rangle}\right)$$

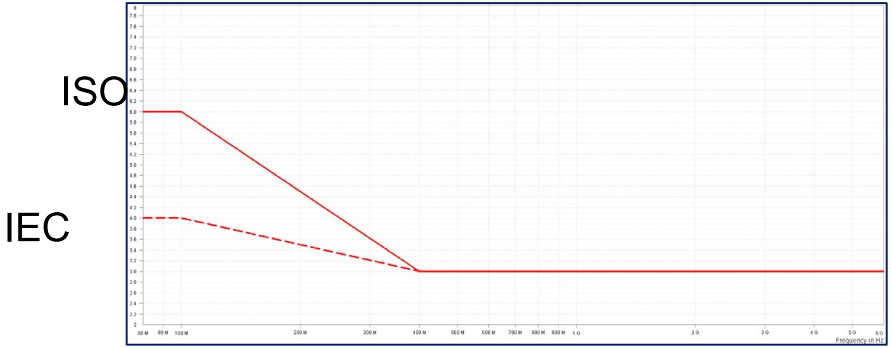
$$\sigma_{y,dB} = 20log_{10}\left(\frac{\sigma_y + \langle e_y \rangle}{\langle e_y \rangle}\right)$$

$$\sigma_{z,dB} = 20log_{10}\left(\frac{\sigma_z + \langle e_z \rangle}{\langle e_z \rangle}\right)$$

$$\sigma = 20log_{10}\left(\frac{\sigma + \langle e \rangle}{\langle e \rangle}\right)$$

$\langle e \rangle = E_{RC}$(if normalized maximum E-field used, $\langle e \rangle = G_{RC}$)

REVERBERATION CHAMBER METHOD C.5 FIELD UNIFORMITY



Frequency range	Tolerance requirements for standard deviation[a]
below 100MHz	6dB[b]
100MHz to 400MHz	6dB[b] at 100MHz decreasing linearly to 3dB at 400MHz
above 400MHz	3dB

[a] A maximum of three frequencies per octave may exceed the allowed standarddeviation by an amount not to exceed 1 dB of the required tolerance.
[b] The standard deviation requirement of IEC 61000-4-21 (4 dB at frequencies ≤ 100 MHz) may be necessary if required by the test plan. Additional tunersteps may be necessary to achieve this more stringent standard deviation requirement.

Table C.2 – Field uniformity requirements

REVERBERATION CHAMBER METHOD
ANNEX.C REVERBERATION CHAMBER CHARACTERISTICS

- **C.2 Number of independent stirring configurations**
- C.3 Coherent stirring configurations
- C.4 Minimum dwell time

REVERBERATION CHAMBER METHOD
C.2 NUMBER OF INDEPENDENT STIRRING CONFIGURATIONS

Frequency range	Recommended Number of tuner positions	Minimum number of tuner positions	Minimum number of frequencies for characterization^c
f_s to $3f_s$	50	12	20
$3f_{LUF}$ to $6f_{LUF}$	18	6	15
$6f_{LUF}$ to $10f_{LUF}$	12	6	10
>$10f_{LUF}$	12	6	20 per decade

f_s: lowest frequency for chamber characterization
f_{LUF}: lowest usable frequency of the chamber
^{c}: logarithmically spaced

Table C.1 – Recommended number of tuner positions for tuned-mode

REVERBERATION CHAMBER METHOD
C.2 NUMBER OF INDEPENDENT STIRRING CONFIGURATIONS

- To demonstrate a number of independent stirring configurations of $\mathrm{N_{ind}}$, at least 10 $\mathrm{N_{ind}}$ measurement samples are needed.
- For this (time) sequence, an analysis window for the calculation of the autocorrelation coefficients needs to be defined. This might be the complete sequence (useful for a single tuner or other periodic sequences)which then is periodized for the calculation (called “periodization” below, which is in the case of a single tuner the definition from IEC 61000-4-21:2021, Annex A) or only part of it (called “windowing” below), where the window length corresponds to the intended minimum dwell time of e.g. two seconds.
- Periodization:

$$r(l) = \frac{\sum_{i=0}^{N-1}(p(i)-\bar{p})(p((i+l)mod(N))-\bar{p})}{\sum_{i=0}^{N-1}(p(i)-\bar{p})^2}$$

- Windowing:

$$r(l) = \frac{\sum_{i=0}^{N-1}(p(i)-\bar{p})(p(i+l)-\bar{p})}{\sum_{i=0}^{N-1}(p(i)-\bar{p})^2}$$

N: size of sample sequence (e.g. 100 01);

$p(i)$: the i th measured received power value in W (or absolute value of an electric field component or the total electric field strength measured with a field probe in V/m);

$\bar{p}$: mean value over all $p(i)$;

mod(.) : modulo function;

l : is the normalized lag and corresponds e.g. to a rotational increment of a tuner in tuned mode or to a time increment in stirred mode.

REVERBERATION CHAMBER METHOD
C.2 NUMBER OF INDEPENDENT STIRRING CONFIGURATIONS

- Auto correlation threshold:

$$r(l_{ind}) < 0.37(1 - \frac{7.22}{N^{0.64}})$$

- Number of independent stirring configurations:

$$N_{ind} = \frac{N}{L_{ind}}$$

- C.3 Coherence time:
  - For time lags $l \leq \min(l_{ind})$ the stirring configurations are said to be coherent, i.e. they are not statistically independent.

$$t_{coh} = \Delta t \times \min(l_{ind})$$

- C.4 Minimum dwell time:

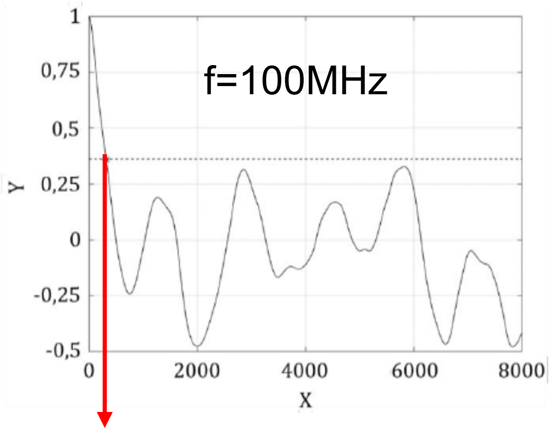
$$t_{dwell} = \max((t_{dwell,ISO11452-1}; 12t_{coh}; \Delta t\mathrm{N}_{\min,12}))$$

REVERBERATION CHAMBER METHOD
N_{ind} EXAMPLE

Window length: 800ms + Sampling rate: 10k sample/s

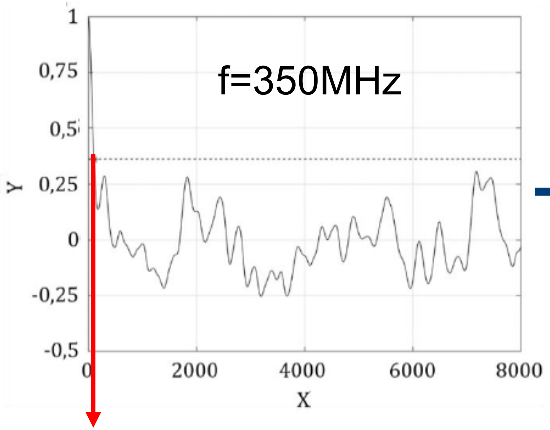
Number of samples: 800ms * 10k sample/s = 8000 samples (8001)

Autocorrelation threshold: $r(l_{ind}) < 0.37\left(1 - \frac{7.22}{8001^{0.64}}\right) \approx 0.3615$



$L_{ind} = 316$

$N_{ind} = 8001/316 \approx 25$



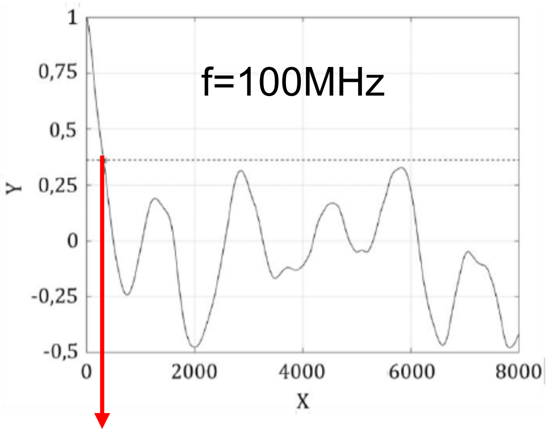
$L_{ind} = 104$

$N_{ind} = 8001/104 \approx 77$

Graph plotted by the following equation:

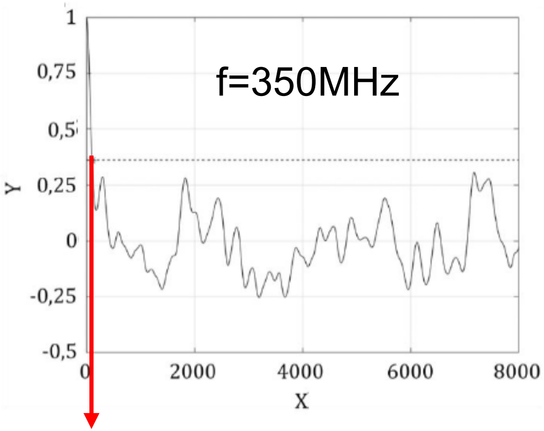
$$r(l) = \frac{\sum_{i=0}^{N-1}(p(i)-\bar{p})(p(i+l)-\bar{p})}{\sum_{i=0}^{N-1}(p(i)-\bar{p})^2}$$

REVERBERATION CHAMBER METHOD COHERENCE TIME & MINMUM DWELL TIME EXAMPLE



$L_{ind} = 316$

$N_{ind} = 8001/316 \approx 25$



$L_{ind} = 104$

$N_{ind} = 8001/104 \approx 77$

- $\Delta t = \frac{800ms}{8000} = 100\ us$
- Coherence time:

$t_{coh} = \Delta t \times \min(l_{ind})$

@100MHz: $100\ us * 316 = 31.6\ ms$

@350MHz: $100\ us * 104 = 10.4\ ms$

- Minimum dwell time:

$t_{dwell} = \max((t_{dwell,ISO11452-1}; 12t_{coh}; \Delta t\mathrm{N}_{\min,12}))$

@100MHz: $t_{dwell} = \max((2s; 12 * 31.6\ ms = 379.2\ ms; \Delta t\mathrm{N}_{\min,12}))$=2s

@350MHz: $t_{dwell} = \max((2s; 12 * 10.4\ ms = 124.8\ ms; \Delta t\mathrm{N}_{\min,12}))$=2s

REVERBERATION CHAMBER METHOD

- 8.5.2.2 Substitution method with empty chamber calibration
  - 8.5.2.2.2 Field calibration of the empty chamber
    - For each test frequency, calculate the receiving antenna characterization factor of the empty chamber $A_{ACF,empty}$ using Formula (4);

$$A_{ACF,empty} = \frac{1}{8}\sum_{p=1}^{8}\frac{\langle P_{rvc,p}\rangle_{sc}}{\langle P_{f,p}\rangle_{sc}}$$

    - For lowest test frequency f_c that fulfils the field uniformity requirement, determine the number of independent stirring configurations N_{ind} according to C.2. A separate measurement (e.g. with a vector network analyser or with small in-between steps between stirring configurations) might be needed to accomplish this. In case N_{ind} ≥12, the lowest usable frequency of the empty chamber is found $f_{LUF,empty}$= f_c Otherwise, check the next larger test frequency, until the requirement N_{ind} ≥12, is met and the lowest usable frequency for the empty chamber is found.

REVERBERATION CHAMBER METHOD

- 8.5.2.2 Substitution method with empty chamber calibration
  - 8.5.2.2.3 Determination of the maximum loading factor
    - In the working volume of the chamber install a sufficient amount of absorber to load the chamber to at least the level expected during normal testing.
    - Each chamber is unique. The easiest way to determine the amount of absorber necessary is by trial and error. Repeat the characterization outlined in 8.5.2.2.2 using the eight locations of the E-field probe.
    - If the chamber loading results in a rectangular component of the fields exceeding the allowed standard deviation, or if the standard deviation for all vectors (i.e. σ) exceeds the allowed standard deviation (see table C.2) or the number of independent stirring configurations becomes less than 12, then the chamber has been loaded to the point where the performance of the chamber is unacceptable. In this case the amount of chamber loading shall be reduced and the loading effects evaluation shall be repeated, or the chamber is only used above $f_{LUF,maxload}$.
    - Repeat the calculation of the field uniformity using the data from the (at least) eight locations of the E-field probe.
    - Determine the maximum chamber loading factor F_{MLF} by comparing the antenna characterization factor (ACF) from the empty chamber $A_{ACF,empty}$ to that obtained from the "maximum loaded" chamber $A_{ACF,maxload}$ using Formula (5):

$$F_{MLF} = \frac{A_{ACF,empty}(Formula(4))}{A_{ACF,maxload}(Formula(4))}$$

REVERBERATION CHAMBER METHOD

- 8.5.2.2 Substitution method with empty chamber calibration
  - 8.5.2.2.4 Determination of the chamber loading effects
    - This procedure shall be carried out prior to each test, unless the test is performed with an already used DUT of the same DUT class. In this case a new determination of the loading effects is not necessary.
    - For each test frequency, calculate the mean forward power $\langle P_f \rangle_{sc}$, and the mean received power $\langle P_{rvc,p} \rangle_{sc}$ over all stirring configurations.
    - If the value of $\langle P_{rvc,p} \rangle_{sc}$ is within (i.e., neither greater nor less than) the values recorded for all eight locations during the field calibration of the empty chamber (see 8.5.2.2.2), calculation of the CLF is not necessary and the value of F_{CLF} should be assumed to be 1.
    - For each test frequency, calculate the chamber characterization factor A_{CCF} using Formula (6):

$$A_{CCF} = \frac{\langle P_{rvc} \rangle_{sc}(Formula(1))}{\langle P_f \rangle_{sc}(Formula(2))}$$

REVERBERATION CHAMBER METHOD

- 8.5.2.2 Substitution method with empty chamber calibration
  - 8.5.2.2.4 Determination of the chamber loading effects
    - For each test frequency, calculate the chamber loading factor F_{CLF} using Formula (7):

$$F_{CLF} = \frac{A_{ACF,empty}(Formula(4))}{A_{CCF}(Formula(6))}$$

    - For each test frequency, calculate the chamber gain $G_{RC,DUT}$ of the chamber with DUT using Formula (8);

$$G_{RC,DUT} = \frac{G_{RC,empty}}{\sqrt{\mathrm{F}_{CLF}(Formula(7))}}$$

REVERBERATION CHAMBER METHOD

- 8.5.2.2 Substitution method with empty chamber calibration
  - 8.5.2.2.5 DUT Test
    - Install the DUT, harness and all peripheral devices (e.g. load simulator, AN(s), power supply, battery, …) on the test bench.
    - The DUT shall be operated according to the test plan.
    - The test is conducted by subjecting the DUT to the test signal based on the calibrated value as specified in the test plan.
    - Calculate for each test frequency the necessary forward power $P_{f,test}$ into the transmitting antenna for the required test level $E_{RC,test}$ using Formula (9):

$$P_{f,test} = \left(\frac{E_{RC,test}(Formula\ B.1)}{G_{RC,DUT}(Formula(8))}\right)^2$$

REVERBERATION CHAMBER METHOD

- 8.5.2.3 Substitution method with calibration including the DUT
  - 8.5.2.3.1 General
    - This section describes a method to determine the chamber gain $G_{RC,DUT}$ with DUT present.
    - The method is performed in two phases:
      - Calibration procedure (see 8.5.2.3.2)
      - DUT test (see 8.5.2.3.3)

REVERBERATION CHAMBER METHOD

- 8.5.2.3 Substitution method with calibration including the DUT
  - 8.5.2.3.2 Calibration procedure
    - Place the field generating device(s) at the intended location(s). Place eight calibrated isotropic field probes at the reverb reference points, or perform several measurements consecutively to obtain the data in the eight reverb reference points.
    - For each test frequency, record the readings of the 24 electric field components in the eight reverb reference points, the forward power and the reverse power for all stirring configurations.
      - the reached test level E_{RC}in V/m according to Formula (B.1),
        - Formula (B.1) $E_{RC} = \frac{1}{24}\sum_{p=1}^{8}\left(Max\left(E_{x,p}\right) + Max\left(E_{y,p}\right) + Max\left(E_{z,p}\right)\right)$
    - For each test frequency, calculate the chamber gain GRC,DUT with DUT using Formula (10):

$$G_{RC,DUT} = \frac{E_{RC}(Formula\ B.1)}{\sqrt{\langle\ P_f\rangle_{sc}}(Formula\ (2))}$$

    - For each test frequency, check that the field uniformity requirements according to Table C.2 are met.
    - Determine the lowest test frequency f c that fulfils the field uniformity requirement.

REVERBERATION CHAMBER METHOD

- 8.5.2.3 Substitution method with calibration including the DUT
  - 8.5.2.3.2 Calibration procedure
    - For lowest test frequency f_c that fulfils the field uniformity requirement, determine the number of independent stirring configurations N_{ind} according to C.2. A separate measurement (e.g. with a vector network analyser or with small in-between steps between stirring configurations) might be needed to accomplish this. In case N_{ind} ≥12, the lowest usable frequency of the chamber with DUT is found $f_{LUF,DUT}$= f_c Otherwise, check the next larger test frequency, until the requirement N_{ind} ≥12, is met and the lowest usable frequency for the chamber with DUT is found.
    - Test frequencies below the lowest usable frequency $f_{LUF,DUT}$ cannot be used for testing of any DUT of the same class as the DUT present in the reverberation chamber during this calibration.

REVERBERATION CHAMBER METHOD

- 8.5.2.3 Substitution method with calibration including the DUT
  - 8.5.2.3.3 DUT Test
    - Install the DUT, harness and all peripheral devices (e.g. load simulator, AN(s), power supply, battery, …) on the test bench in accordance with 7.1 (Figures 1 to 4).
    - The DUT shall be operated according to the test plan.
    - The test is conducted by subjecting the DUT to the test signal based on the calibrated value as specified in the test plan. Calculate for each test frequency the necessary forward power $P_{f,test}$ into the transmitting antenna for the required test level $E_{RC,test}$ using Formula (11):

$$P_{f,test} = \left(\frac{E_{RC,test}(Formula\ B.1)}{G_{RC,DUT}(Formula\ (10))}\right)^2$$

    - The number of independent stirring configurations shall be at least 12 and at least 6 above $3f_{LUF,DUT}$ or $3f_{LUF,Maxload}$.

THANK YOU!

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