Application Note

MEASUREMENTS IN REVERBERATION CHAMBER USING R&S® ELEKTRA

Products:

► R&S®ELEKTRA

Narayanan Raman | 1AEP4 | Version 1.1 | 03.2025

https://www.rohde-schwarz.com/product/elektra

Contents

1 Overview

Reverberation Chambers (RVC) have become popular as an alternative to Anechoic Chamber (AC) facilities for electromagnetic emission & immunity tests. Unlike AC, RVC reflects waves creating multipath environment. EMC testing using reverberation chamber is accepted in various EMC test standards across different industries. The RVC is cost effective allowing high field strength generation without excessive amplification needs, eliminates the need for complex positioning of antennas and DUTs increasing test speed and simulates real-world electromagnetic environments more accurately. To ensure accurate and efficient testing, specialized EMC test software is required for data acquisition, automation, and analysis.

This application note describes how to setup Elektra and perform measurements in RVC.

2 Scope

This application note is based on Elektra v5.10. In Elektra v5.10, the following standards for performing radiated immunity measurements are supported.

- EN 61000-4-21 (Mode Tuned only)
- ISO 11452-11 (Mode Tuned only)

This version of application note explains how to configure the hardware setup and test templates to perform the RVC calibration, Equipment Under Test (EUT) checks & EUT test in mode tuned operation.

3 R&S® ELEKTRA Licenses

The following R&S ELEKTRA licenses and options are required to perform radiated immunity measurements.

- EMS Test Software (Radiated) – ELEMS-R
- EMS Extension to System – ELEMS-S
- EMS Rotating-Tuner Reverberation Measurements – ELEMS-RVC
- EMS Extension to Automotive/MIL – ELEMS-AMEX (optional, required for ISO 11542-11 support)

4 Radiated Immunity Testing in Mode-Tuned

The mode-tuned operation is described in the IEC 61000-4-21 [1] & ISO 11542-11 [2]. It consists of the following steps

- Chamber Calibration Procedures
- EUT Test Procedures

Before describing the chamber validation & EUT test procedures, let us look at the calibration setup.

4.1.1 Calibration Setup

The calibration setup is described in the appropriate section of the EMC standard.

The test volume (see **Error! Reference source not found.**), which from [1]) of the RVC is defined by the eight points at which the field probe will be placed during calibration. The test volume maintains a distance of at least λ/4 distance away from the chamber walls and any other metallic object (antenna or stirrers) within the chamber.

Here the field probe is positioned at the first corner of the test volume and every single axis of the triaxial field probe shall point inside the test volume. The receiving antenna is positioned inside the test volume. It shall point to a random location directed outside of the test volume and cross polarized with that of the transmitting antenna.

During calibration, the lower frequency range utilizes the log-per antennas, and the upper frequency ranges utilizes the horn antennas.

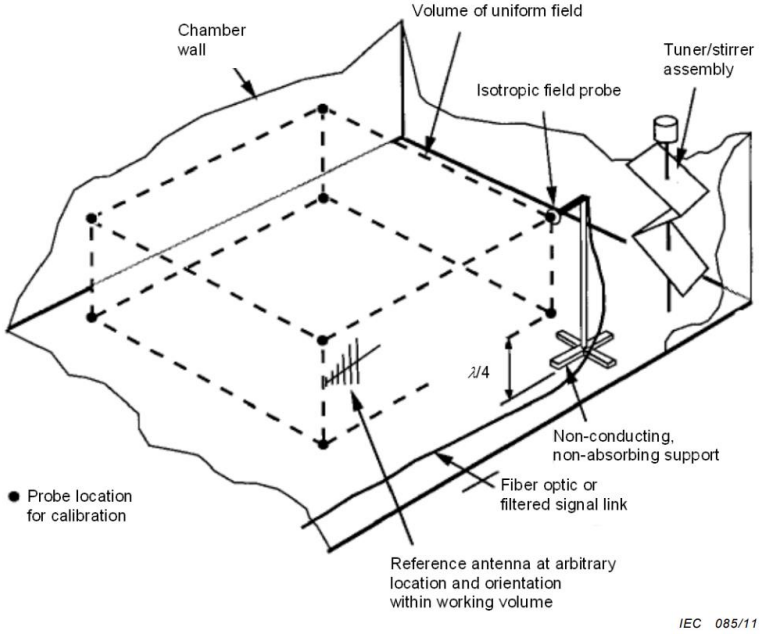


Figure 1 Test volume in RVC, SOURCE: IEC 61000-4-21 [1]

4.2 Chamber Validation Procedures

The Chamber Calibration procedures consist of three steps

- Unloaded Chamber Tests where the chamber field uniformity and input power requirements are determined with no EUT in the chamber. The test volume of the chamber is completely empty except for the necessary tri-axial field probes, transmit antenna, receiving (Reference) antenna and their respective cabling. All extraneous equipment (video monitoring system, foam test table) shall be removed. This calibration needs to be performed only once when chamber is installed or after major modifications of chamber.
- Loaded Chamber Tests where the chamber field uniformity and input power requirements are checked by simulated maximum loading. In addition to the necessary tri-axial field probes, transmit antenna and receiving (Reference) antenna, the chamber is filled with absorbing material to be fully loaded. Extraneous equipment that will be used for EUT testing can be added back to the chamber (e.g. video monitoring equipment, foam test table). This calibration needs to be performed only once when chamber is installed or after major modifications of chamber.
- EUT Check where chamber is calibrated with EUT in place and the Chamber Validation Factor (CVF, which is the average to input power ratio like AVF for unloaded chamber) is computed. From the CVF and AVF, the Chamber Loading factor (CLF) is derived. This calibration is performed before every EUT test.

The goal of unloaded and loaded chamber measurements is to check whether the reverberation chamber fulfills the requirements for a statically uniform field distribution as well as to find out the limits of the chamber (maximal loading). This data is required for the EUT Check and Measurement.

During the Unloaded & Loaded Chamber Tests, the max E-Field values (E_x, E_y, E_z) using the E-field probe, maximum & average received power using the reference antenna and input power (forward power averaged over a tuner rotation) are measured for each frequency, stirrer position and field probe/antenna location. From the E-Field measurements, the standard deviation for each probe axis & total data set (all probe axis) is determined. The standard deviations should not exceed the limits defined in the standard for the individual & total probe axis.

The average received power is used to compute the

- Receive antenna validation factor (AVF)
- Chamber Quality factor
- Time constant of the chamber (derived from Quality factor & needed to confirm the chamber is suitable for desired pulse waveform testing
- Power needed to generate the test levels.

The maximum of the received power is used to compute

- Estimated E Field
- Insertion loss (IL) in loaded chamber test
- Maximum load factor (which is the ratio of AVF_{Empty} to AVF_{Loaded})

During the chamber validation with EUT in place, only the received power is measured. E-Field measurements with probe are not required. The loading factor presented by EUT should be lesser than the maximum loading factor derived during loaded chamber test. The Chamber Validation Factor (CVF), (which is the average to input power ratio like AVF for unloaded chamber) is computed. From the CVF and AVF_{Empty}, the Chamber Loading factor (CLF) is derived. The CLF should be less than the maximum loading factor for all frequencies. Additionally, a value for the minimum pulse width is calculated. The applied pulse width shall not be below this value to inject sufficient power into the RVC.

The user is advised to consult the appropriate sections in the [1] and [2] for in-depth understanding of the concepts.

4.3 EUT Test Procedures

The EUT test procedures consist of

- EUT Qualification & Susceptibility tests as per standards. The forward input power required to setup the E-Field at every test frequency is derived from the Avg. Normalized Maximum E-field of unloaded chamber calibration & CLF derived with EUT in place.

4.4 EMS Hardware Setup Configuration

The hardware Setup describes the devices to be used in a measurement and how they work together. The hardware Setup is created manually. The Figure 2 below shows a setup as described in the standard.

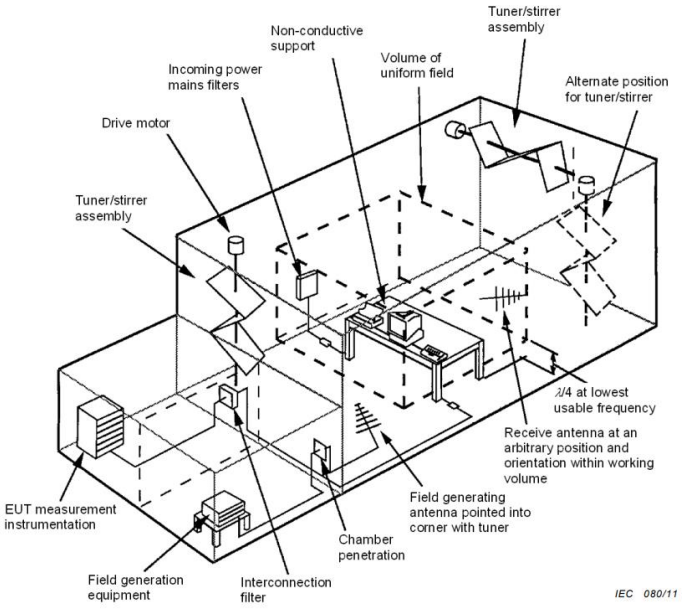


Figure 2 General Test Setup for Measurements in RVC, SOURCE: IEC 61000-4-21 [1]

In Elektra, radiated hardware setup of diagram type Reverberation Chamber is used to realize the recommended hardware setup in standard. Figure 3 & Figure 4 shows the Calibration & EUT view of a hardware setup with four subranges.

- Calibration View (200 MHz – 7.125 GHz) shown below in Figure 3

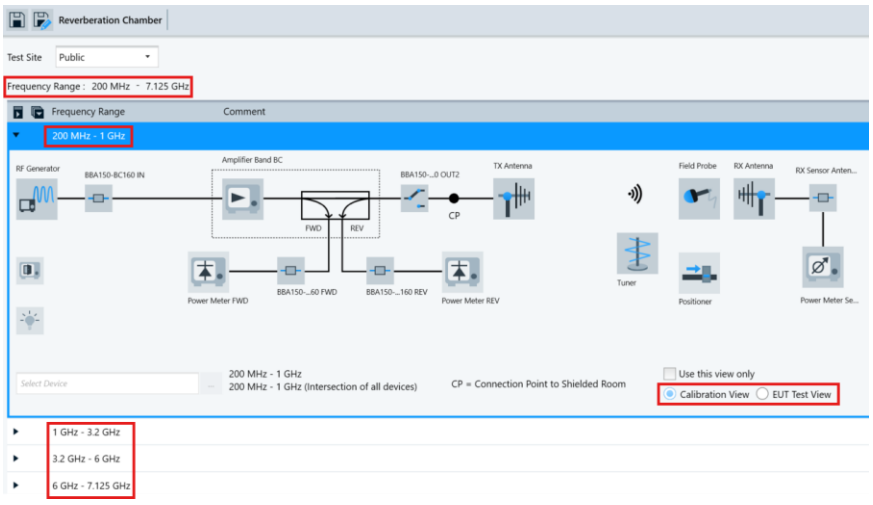


Figure 3 Calibration View (200 MHz – 7.125 GHz) of Hardware Setup

- EUT Test View (200 MHz – 7.125 GHz) shown below in Figure 4

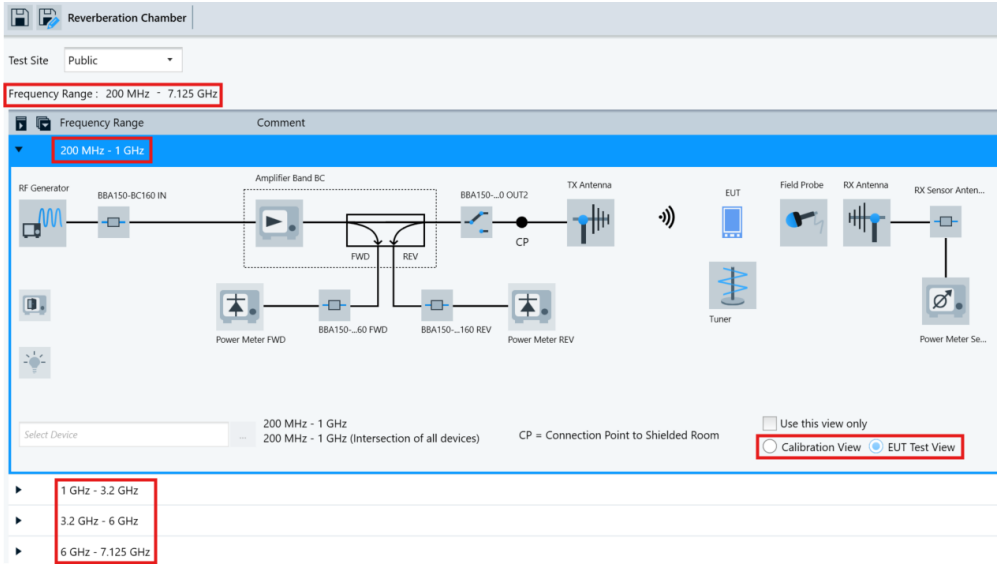


Figure 4 EUT View (200 MHz – 7.125 GHz) of Hardware Setup

Each subrange in the hardware set up is configured with devices matching the frequency range of the subrange/

The Table 1 shows the devices must be selected from the device list and assigned to the respective placeholders

Device Name	Device Category/Type	Special Settings
RF Generator	Generator	No special requirements.
Amplifier Band A	Amplifier	Depending on whether a directional coupler is used, the value of the directional coupler attenuation must be appropriately measured and set. If necessary, multiple amplifiers may be used to cover the measured frequency range.
Power Meter FWD	Power Meter	If a two-channel power meter is used channel A shall be set for the measurement of the forward power.
Power Meter REV	Power Meter	If a two-channel power meter is used, channel B shall be set for the measurement of the reverse power. If the power meter supports dual channel measurement (coupling of channel B to A), the feature should be activated to improve the measurement speed.
Tx Antenna Rx Antenna	Antenna	Enter the frequency parameters for each antenna and the respective antenna efficiency factor. Antenna efficiency is the ratio of the total power radiated by an antenna to the net power accepted by the antenna from the connected transmitter.
Tuner	Turntable/Comtest tuner or Generic Turntable	Comtest is a manufacturer type of tuners for RVC. Tuners are classified as a type of Turntable
Field Probe		The field probe must support the simultaneous measurement of all three axes. Enter the values of the probe calibration (frequency response and linearity correction) if available.
Power Meter Sensor	Power Meter/Spectrum Analyzer	No special requirements.
Switch unit		The signal paths of the switching unit with their respective settings are defined here
Interlock		An interlock device must always be available in the device list. If no physical device is available, select the interface NONE.
Positioner	Positioner/Manual Positioner	Manual positioner to prompt user to change the Rx antenna /Field Probe position (only in Calibration View)

Table 1 Devices used in Hardware Setup

Depending on the power required, multiple amplifiers are used to cover the frequency range. Typically, a set of transmitting and receiving antennas is required. For the frequency range up to 1 GHz, logarithmic periodical antennas are utilized. For frequencies above 1 GHz, horn antennas are used to cover the required frequency range. The transmitting antennas shall point to a corner of the chamber and their position shall not be changed after the calibration has been completed.

For measuring the transmitted antenna forward and reverse power, either NRX or single probes are used.

The generated field strength is measured by the field probe and a receiving antenna that is connected to the spectrum analyzer/field probe for the measurement of the received power.

4.5 EMS Test Template Configuration & Test Execution

The following sections describe the test template configuration for the different calibration & EUT tests. The hardware setup must be created before configuring test templates.

4.5.1 Unloaded Chamber Test Template Configuration

The Table 2 shows the typical parameters configured for Unloaded chamber test template for ISO 11452-11 test standard. This configuration is applicable for EN 61000-4-21 standards as well.

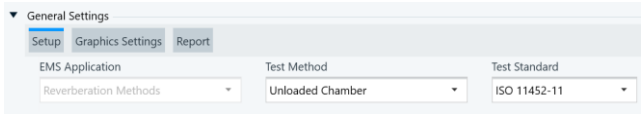
Parameter	Setting	Location in User Interface (UI)
EMS Application	Reverberation Methods	General Setup => Setup
Test Method	Unloaded Chamber	General Setup => Setup
Test Standard	ISO 11452-11	General Setup => Setup
Level On	Transducer Power	Measurement Settings => Leveling Mode
Power Control	Forward Power	Measurement Settings => Leveling Mode
Level Conservation for Modulation	CW Carrier = Modulation Carrier	Measurement Settings => Leveling Options
Power Limitation	Not Active	Measurement Settings => Power Level Limitation
Frequency Range	200 MHz – 7.125 GHz	Subrange Header
Frequency Steps	5.6%, LOG (200 MHz – 600 GHz) 5.6%, LOG (600 MHz – 1 GHz) 5.6%, LOG (1 GHz – 1.2 GHz) 5.2% LOG (1.2 GHz – 2 GHz) 1.45% DECLIN (2 GHz – 7.125 GHz)	Subrange Header
Test Level	5 W	Subrange => Test Level
Modulation	Off	UI not activated
Leveling Tolerance	0 dB – 0.4 dB	Subrange => Test Level
Tuner	12	Subrange => Reverb Settings
Sensor	8	Subrange => Reverb Settings
Accessory Settings	Priority 1 => Frequency Priority 2 => Tuner Priority 3 => Position (Sensor)	Accessory Settings
Input Evaluation Data	Tolerance of Standard Deviation: ISO 11452-11 Max Std Deviation Chamber Volume: 179.237 m^3 (depends on chamber) Relative Permittivity: 8.8595 pF/m (depends on chamber)	Data Evaluation => Input Data
Output Evaluation Data	Calibration Result Table: ISO 11452-11 Unloaded Chamber Norm Max E-Field Table: LUF200 Averaged Max E-Field E&C	Data Evaluation => Output Data
Evaluation Graphics	Insertion Loss Standard Deviation Antenna Correction Factor E-Field Comparison Chamber Q	Data Evaluation => Evaluation Graphics
System Monitoring	Test Level Received Antenna Power Sensor Level Transducer Reverse Power	System Monitoring

Table 2 Typical Parameters of Unloaded Chamber Test Template

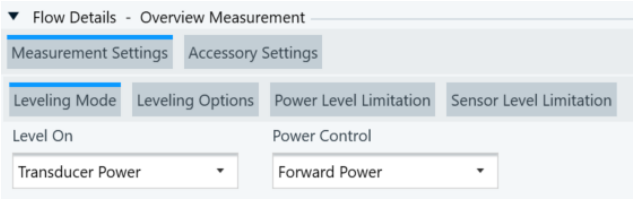
4.5.1.1 Unloaded Chamber Test Template UI Previews

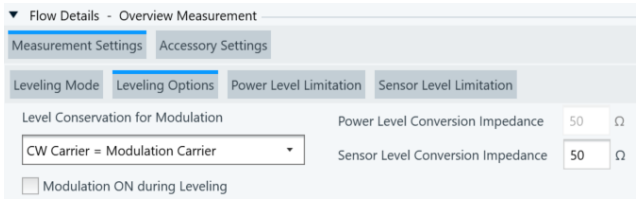
In this section, the UI to configure various parameters of unloaded chamber listed in Table 2 are shown.

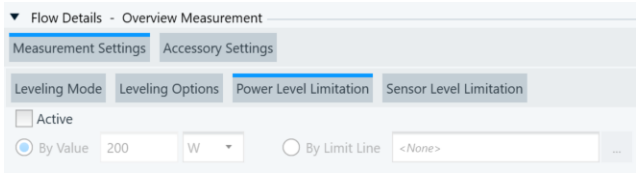
Configuring the test method and test standard



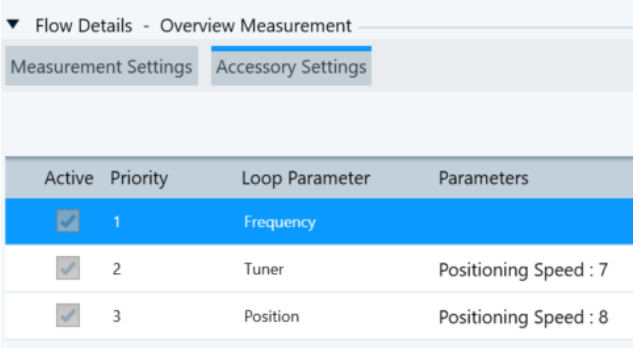
Configuring the measurement settings





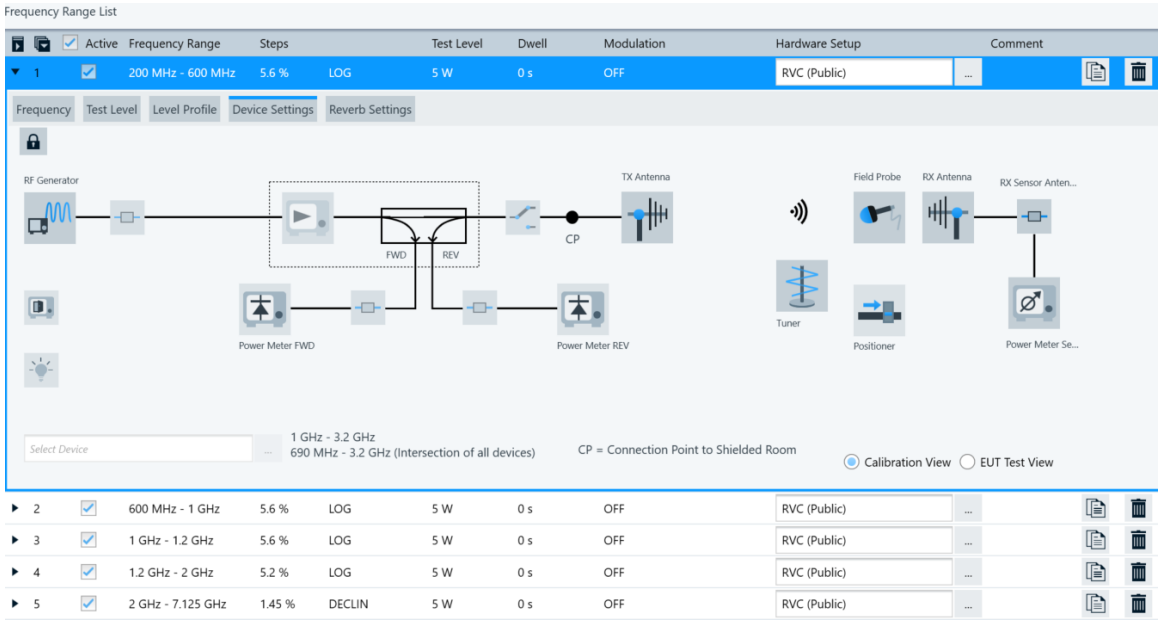


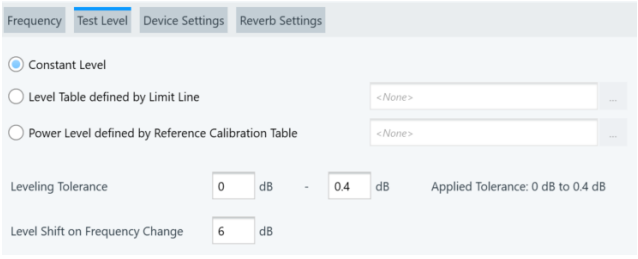
Configuring the accessory settings

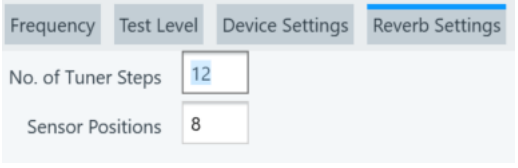


As shown above, the unloaded chamber test is performed for various combinations of tuner and sensor positions.

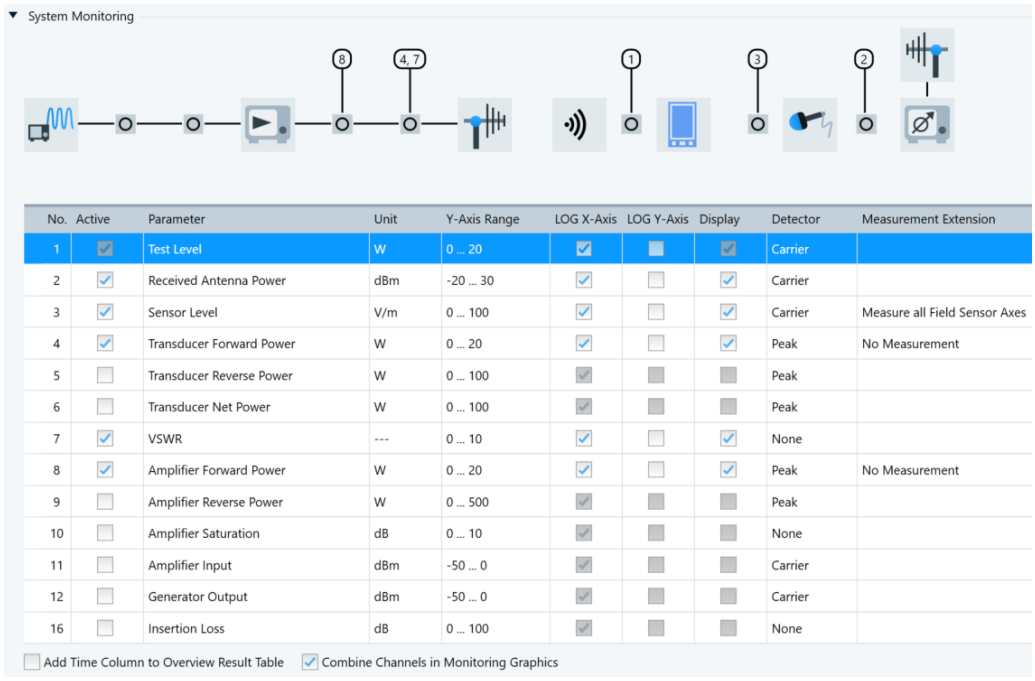
Configuring the subrange





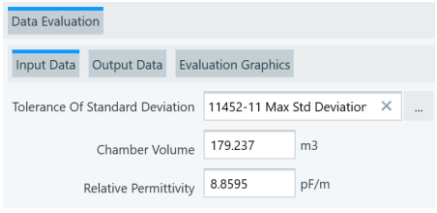


Configuring the system monitoring

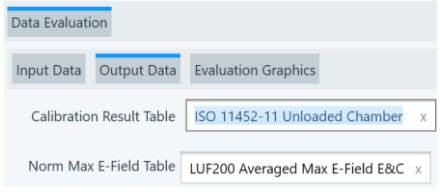


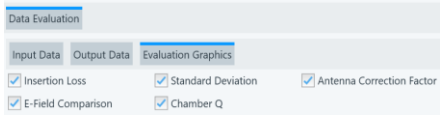
No.	Active	Parameter	Unit	Y-Axis Range	LOG X-Axis	LOG Y-Axis	Display	Detector	Measurement Extension
1	☑	Test Level	W	0 ... 20	☑	☐	☑	Carrier	
2	☑	Received Antenna Power	dBm	-20 ... 30	☑	☐	☑	Carrier	
3	☑	Sensor Level	V/m	0 ... 100	☑	☐	☑	Carrier	Measure all Field Sensor Axes
4	☑	Transducer Forward Power	W	0 ... 20	☑	☐	☑	Peak	No Measurement
5	☐	Transducer Reverse Power	W	0 ... 100	☑	☐	☐	Peak	
6	☐	Transducer Net Power	W	0 ... 100	☑	☐	☐	Peak	
7	☑	VSWR	---	0 ... 10	☑	☐	☑	None	
8	☑	Amplifier Forward Power	W	0 ... 20	☑	☐	☑	Peak	No Measurement
9	☐	Amplifier Reverse Power	W	0 ... 500	☑	☐	☐	Peak	
10	☐	Amplifier Saturation	dB	0 ... 10	☑	☐	☐	None	
11	☐	Amplifier Input	dBm	-50 ... 0	☑	☐	☐	Carrier	
12	☐	Generator Output	dBm	-50 ... 0	☑	☐	☐	Carrier	
16	☐	Insertion Loss	dB	0 ... 100	☑	☐	☐	None	

Configuring the data evaluation



Chamber Volume & Relative Permittivity are used to calculate the Quality Factor (Q-Factor) of the chamber from the average power measurements. Relative Permittivity is used for estimating the Q-Factor from the averaged field strength readings





4.5.2 Unloaded Chamber Test Execution

4.5.2.1 Test Creation

In the first step of the RVC calibration process, the field strength distribution in the test volume of the unloaded chamber is verified. Before the test is initiated, the field probe is positioned at sensor position 1 (the single axis shall point into the test volume). The receiving antenna is placed to a random position inside the test volume (Please note that the receiving antenna should have no direct illuminating path to the transmitting antenna and that it should also be cross polarized to the transmitting antenna).

On clicking “Create Test from Template” within the unloaded chamber test template, the unloaded chamber test is created as shown in Figure 5. In the measurement flow control, the test flow is grouped based on the antenna/tuner positions. In the example shown below in Figure 5 , all subranges used the same Transmit antenna & same number of tuner/sensor positions. In case, the antenna or tuner positions are different in the few subranges, the measurement flow ill be grouped based on antenna/tuner steps to optimize the test flow.

Figure 5 Unloaded Chamber Test View

4.5.2.2 Test Execution

The RVC calibration runs with several measurement loops. As shown in 4.5.1.1, the accessory setting is defined with three accessories namely frequency, tuner & Position (Sensor). Additionally, if the templates in HW Setup uses multiple antennas, the software groups & executes subranges based on antenna. The combination of the various accessories leads to many repetitions with unique accessory positions. Some accessory settings do not require any user interaction, but others like the sensor position, or the subrange antenna, must be set manually. Therefore, dialogs shown in Figure 6 will appear.

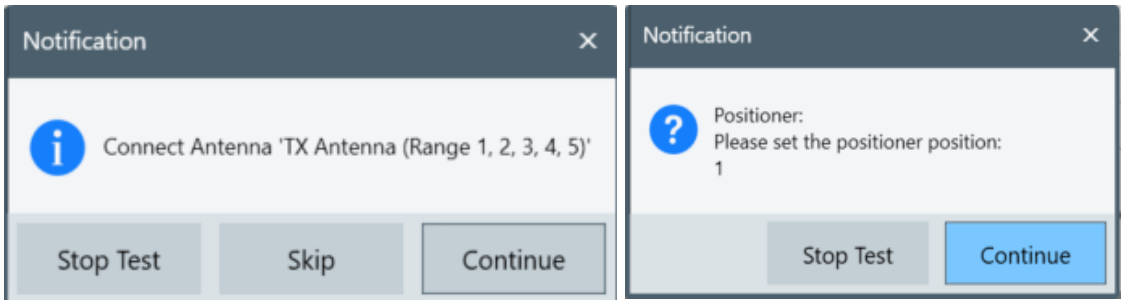


Figure 6 User Dialogs during Unloaded Calibration Test

There are two distinct phases during the measurement run

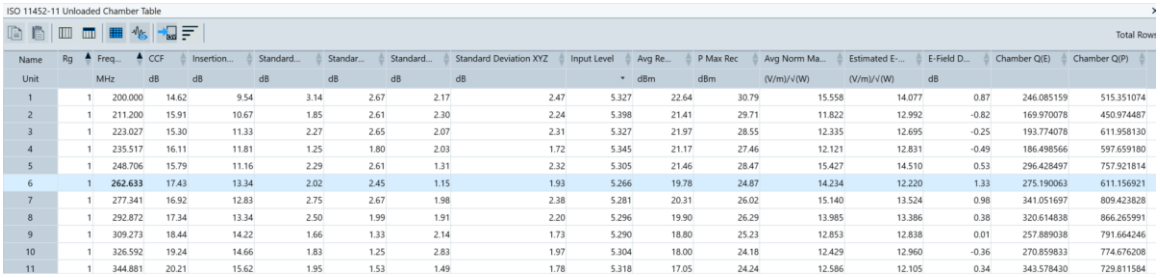
- Data Collection phase where the test levels are set at every frequency/tuner/sensor position & the system monitoring points are measured. After each complete scan the measurement results are copied to the “Loop Results” folder
- Data Evaluation phase where the evaluation is performed to generate an unloaded chamber evaluation result table (Figure 8) and a transducer correction Average Normalized E-Field Table (see Figure 9). In the Average Normalized E-Field Table, the Unloaded insertion column is populated during this test run. Additionally, the evaluation graphics selected in the template are also generated.

During the run of the measurement, the current state of the measurement loops, accessory movements, test levels are displayed in the respective panels as shown in Figure 7.

Figure 7 Unloaded Test view during measurement

Figure 8 shows the various columns of the unloaded test calibration results &

Table 3 describes the unloaded chamber result columns.



ISO 11452-11 Unloaded Chamber Table

Total Rows

Name	Rg	Freq...	CCF	Insertion...	Standard...	Standar...	Standard...	Standard Deviation XYZ	Input Level	Avg Re...	P Max Rec	Avg Norm Ma...	Estimated E-...	E-Field D...	Chamber Q(E)	Chamber Q(P)
Unit		MHz	dB	dB	dB	dB	dB	dB		dBm	dBm	(V/m)/√(W)	(V/m)/√(W)	dB		
1	1	200.000	14.62	9.54	3.14	2.67	2.17	2.47	5.327	22.64	30.79	15.558	14.077	0.87	246.085159	515.351074
2	1	211.200	15.91	10.67	1.85	2.61	2.30	2.24	5.398	21.41	29.71	11.822	12.992	-0.82	169.970078	450.974487
3	1	223.027	15.30	11.33	2.27	2.65	2.07	2.31	5.327	21.97	28.55	12.335	12.695	-0.25	193.774078	611.958130
4	1	235.517	16.11	11.81	1.25	1.80	2.03	1.72	5.345	21.17	27.46	12.121	12.831	-0.49	186.498566	597.659180
5	1	248.706	15.79	11.16	2.29	2.61	1.31	2.32	5.305	21.46	28.47	15.427	14.510	0.53	296.428497	757.921814
6	1	262.633	17.43	13.34	2.02	2.45	1.15	1.93	5.266	19.78	24.87	14.234	12.220	1.33	275.190063	611.156921
7	1	277.341	16.92	12.83	2.75	2.67	1.98	2.38	5.281	20.31	26.02	15.140	13.524	0.98	341.051697	809.423828
8	1	292.872	17.34	13.34	2.50	1.99	1.91	2.20	5.296	19.90	26.29	13.985	13.386	0.38	320.614838	866.265991
9	1	309.273	18.44	14.22	1.66	1.33	2.14	1.73	5.290	18.80	25.23	12.853	12.838	0.01	257.889038	791.664246
10	1	326.592	19.24	14.66	1.83	1.25	2.83	1.97	5.304	18.00	24.18	12.429	12.960	-0.36	270.859833	774.676208
11	1	344.881	20.21	15.62	1.95	1.53	1.49	1.78	5.318	17.05	24.24	12.586	12.105	0.34	343.578430	729.811584

Figure 8 Unloaded Chamber Calibration Result

Column Name	Description	Unit
Rg	Subrange Number	None
Frequency	Frequency	Hz
CCF	Chamber Correction Factor (B.8)	dB
Insertion Loss	Insertion loss (B.9)	dB
Standard Deviation X, Y, Z	Standard deviation of the E-field for the x axis in dB (B.4 & B.5)	dB
Standard Deviation XYZ	Standard deviation of the E-field for the x axis in dB (B.6 & B.7)	dB
P_{input}	Input power into the transmitting antenna	dBm
P_{AveRec}	Average power received by the receiving antenna measured with the receiver device	dBm
P_{MaxREC}	Maximum power received by the receiving antenna measured with the receiver device	dBm
Avg Norm Max E-field	Calculated average normalized maximum E-field (B.3) in V/m	V/m/SQR(W)
Estimated E-field	Estimated E-field using the maximum received power (A.6)	V/m/SQR(W)
E-field Delta	Difference between 'Avg Norm Max E-field' and 'Estimated E-field' column	dB
Chamber Q(E)	Estimated chamber Q factor using the chamber volume, the chamber wall permittivity and the averaged field strength values	None
Chamber Q(P)	Calculated chamber Q factor using the chamber volume, the chamber wall permittivity and the averaged power	None

Table 3 Unloaded Calibration Result Table Column Description

Figure 9 shows the various columns of the Average Normalized E-Field Table & Table 4 describes the Average Normalized E-Field Table columns based on [1]. The insertion loss (unloaded) column is populated during this test run.

LUF200 Averaged Max E-Field ISO Table

Public

Name	Frequency	Avg Norm Max E-Field	Insertion Loss Unloaded	Insertion Loss Loaded
Unit	MHz	(V/m)/√(W)	dB	dB
Interpolation	Logarithmic	Linear	Linear	Linear
1	200.000	15.558	9.54	0.00
2	211.200	11.822	10.67	0.00
3	223.027	12.335	11.33	0.00
4	235.517	12.121	11.81	0.00
5	248.706	15.427	11.16	0.00
6	262.633	14.234	13.34	0.00
7	277.341	15.140	12.83	0.00
8	292.872	13.985	13.34	0.00
9	309.273	12.853	14.22	0.00
10	326.592	12.429	14.66	0.00
11	344.881	12.586	15.62	0.00
12	364.194	12.679	14.39	0.00
13	384.589	11.108	15.84	0.00
14	406.126	11.542	15.64	0.00
15	428.869	13.529	17.31	0.00
16	452.886	12.768	16.33	0.00
17	478.247	11.190	19.57	0.00
18	505.029	12.029	18.24	0.00
19	533.311	13.503	17.88	0.00
20	563.176	12.943	19.84	0.00
21	594.714	11.528	19.61	0.00
22	600.000	14.172	19.77	0.00
23	600.000	14.168	19.77	0.00
24	633.600	11.658	19.79	0.00
25	669.082	12.078	21.01	0.00
26	706.550	12.275	21.00	0.00
27	746.117	12.096	20.31	0.00
28	787.900	12.384	22.71	0.00
29	832.022	12.148	24.35	0.00
30	878.615	12.236	23.89	0.00
31	927.818	12.688	24.61	0.00

Figure 9 Average Normalized E-Field Table after Unloaded Calibration Test

Column Name	Description	Unit
Frequency	Frequency	Hz
Avg Norm Max E-field	Calculated average normalized maximum E-field (B.3) in V/m	V/m/SQR(W)
Insertion Loss (unloaded)	Insertion loss (B.9)	dB

Table 4 Average Normalized E-Field Table Colum Description

Figure 10 shows the various evaluation graphics generated during the data evaluation phase. These graphics are stored under the Evaluation Graphics folder in the test content explorer.

Figure 10 Unloaded Chamber Evaluation Graphics

4.5.3 Loaded Chamber Test Template Configuration

The typical parameters of the loaded chamber are mostly the same as unloaded chamber the except for the test method and evaluation settings. The following table gives the changes in parameters compared to the unloaded chamber

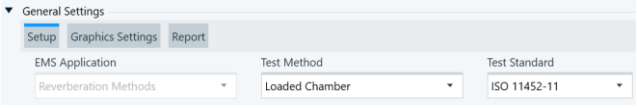
Parameter	Setting	Location in User Interface (UI)
Test Method	Loaded Chamber	General Setup => Setup
Input Evaluation Data	Tolerance of Standard Deviation: ISO 11452-11 Max Std Deviation Chamber Volume: 179.237m^3 (depends on chamber) Relative Permittivity: 8.8595 pF/m (depends on chamber) Norm Max E-Field Table: LUF200 Averaged Max E-Field Example (Public)	Data Evaluation => Input Data
Output Evaluation Data	Calibration Result Table: ISO 11452-11 Loaded Chamber	Data Evaluation => Output Data
Evaluation Graphics	Insertion Loss Standard Deviation Antenna Correction Factor Maximum Loading Factor Chamber Q	Data Evaluation => Evaluation Graphics

Table 5 Typical Parameters of Loaded Chamber Test Template

4.5.3.1 Loaded Chamber Test Template UI Previews

In this section, the UI for various parameters of loaded chamber listed in Table 5 are shown.

Configuring the test method and test standard



Configuring the measurement settings

The measurement settings are like the unloaded chamber test template

Configuring the accessory settings

The accessory settings are like the unloaded chamber test template

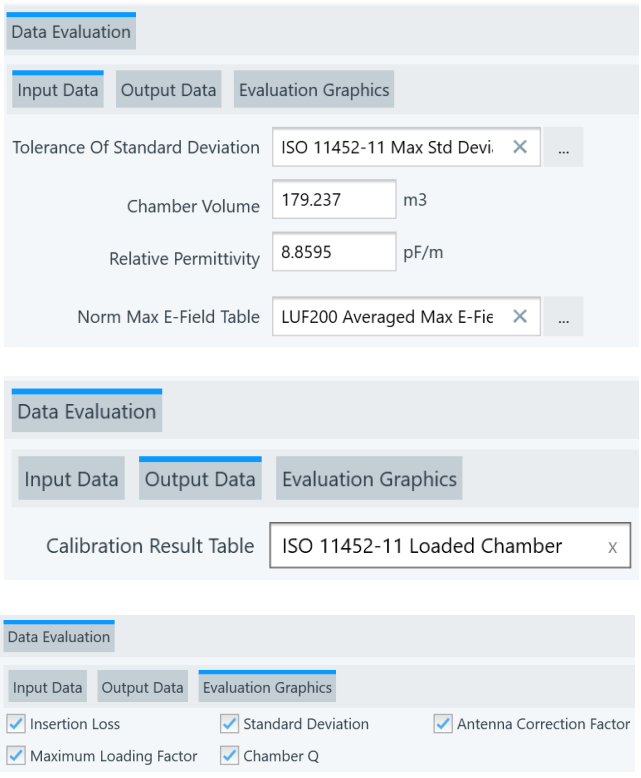
Configuring the subrange

The subrange settings are like the unloaded chamber test template

Configuring the system monitoring settings

The system monitoring settings are like the unloaded chamber test template

Configuring the data evaluation



4.5.4 Loaded Chamber Test Execution

The loaded chamber test creation & execution is the second step of reverberation chamber calibration process. It is very similar to unloaded chamber method but the field strength distribution in the test volume of the fully loaded chamber is verified. The receiving antenna is placed to a random position inside the test volume (please note that the receiving antenna should have no direct illuminating path to the transmitting antenna and that it should also be cross polarized to the transmitting antenna). However, before creating the loaded chamber test, a test application setting dialog (Figure 11) is shown to select unloaded chamber calibration result table.

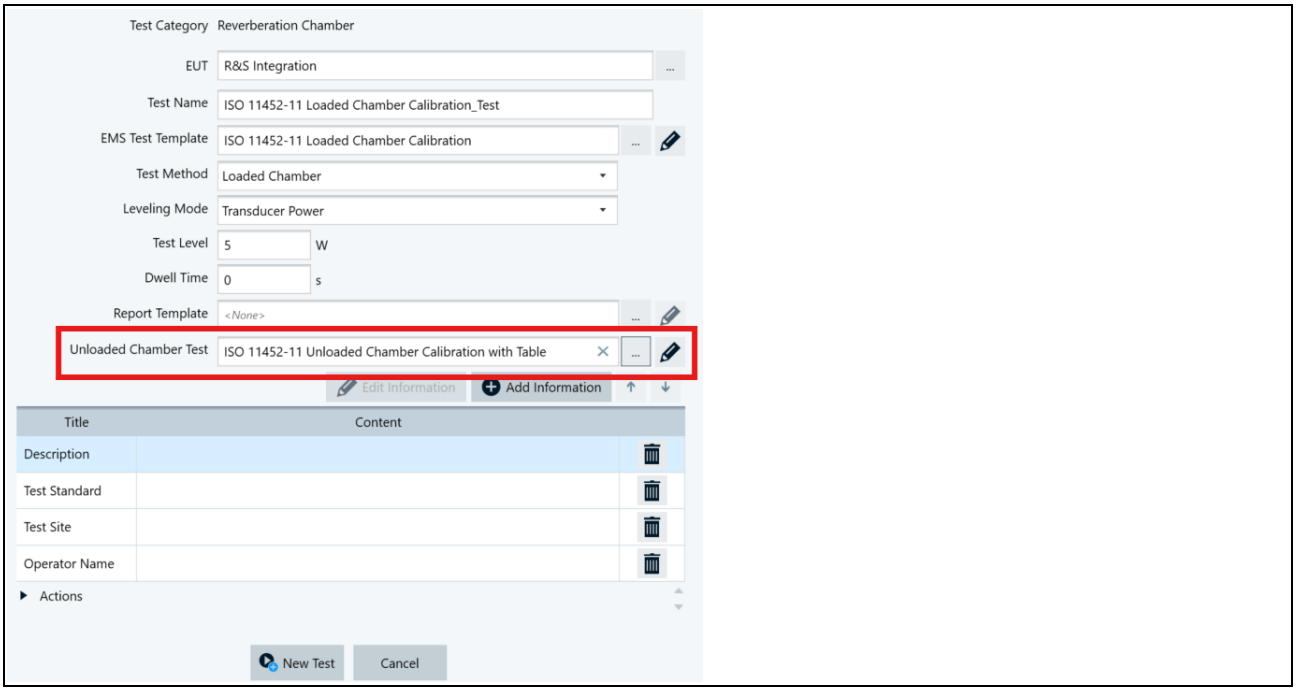


Figure 11 Test Application Setting View to select the unloaded chamber calibration result table

The user may proceed with test creation by clicking “New Test” even without selecting an unloaded calibration chamber result table. This is particularly useful if chamber calibration results are available from EMC32 Software & Elektra allows importing of calibration results from EMC32 within test as explained later.

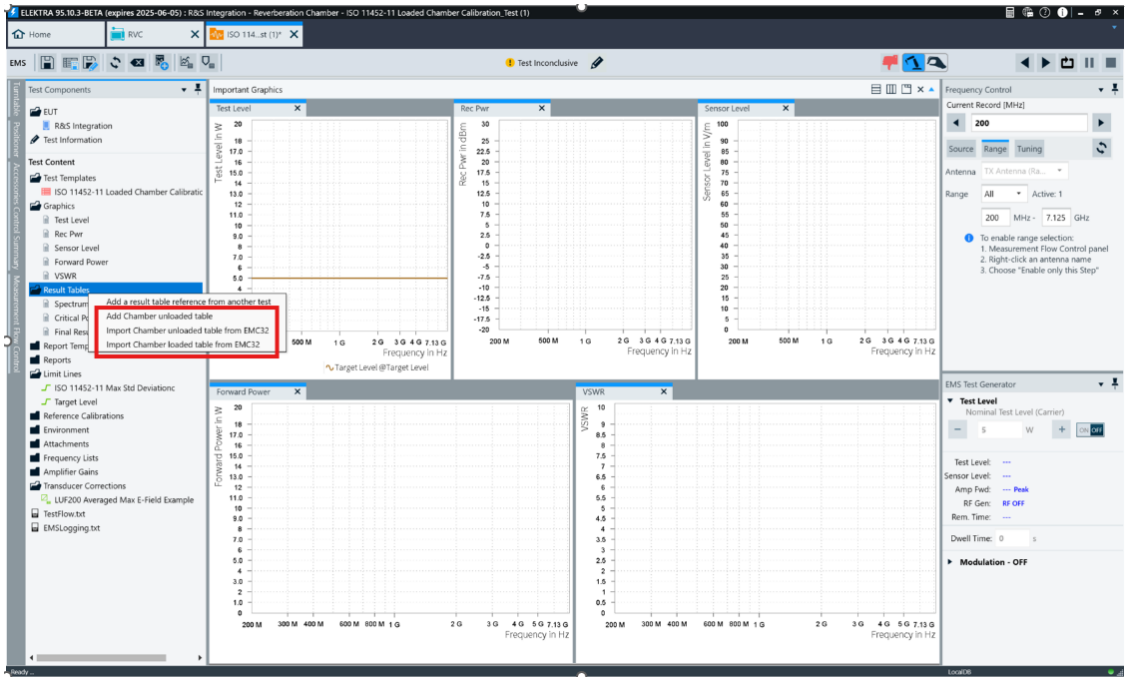


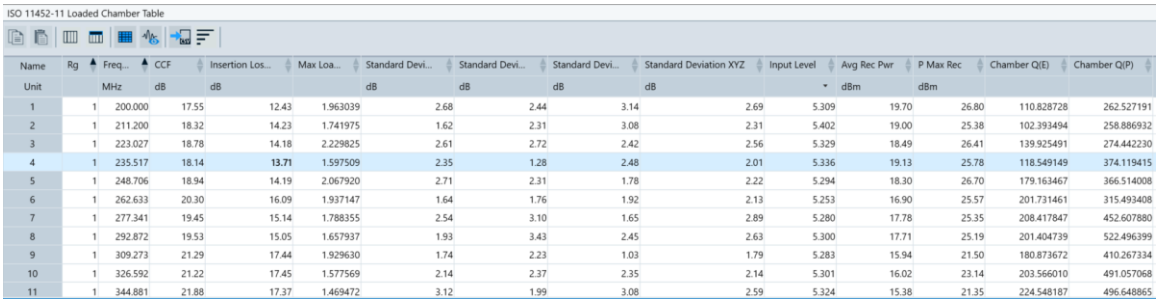
Figure 12 Selection of unloaded chamber calibration results inside the test

The unloaded calibration table can be selected within test within the test as shown in Figure 12. The menu allows import of calibration results generated using EMC32 Software thus saving time.

In case, the unloaded chamber test result table is not available, the test execution validation will not allow the user to proceed with data evaluation phase of the test.

The data collection & evaluation phase of loaded chamber calibration is very similar to unloaded chamber calibration.

Figure 13 shows the various columns of the loaded test calibration results & Table 6 describes the unloaded chamber result columns based on [1]



ISO 11452-11 Loaded Chamber Table

Name	Rg	Freq...	CCF	Insertion Los...	Max Loa...	Standard Devi...	Standard Devi...	Standard Devi...	Standard Deviation XYZ	Input Level	Avg Rec Pwr	P Max Rec	Chamber Q(E)	Chamber Q(P)
Unit		MHz	dB	dB		dB	dB	dB	dB		dBm	dBm		
1	1	200.000	17.55	12.43	1.963039	2.68	2.44	3.14	2.69	5.309	19.70	26.80	110.828728	262.527191
2	1	211.200	18.32	14.23	1.741975	1.62	2.31	3.08	2.31	5.402	19.00	25.38	102.393494	258.886932
3	1	223.027	18.78	14.18	2.229825	2.61	2.72	2.42	2.56	5.329	18.49	26.41	139.925491	274.442230
4	1	235.517	18.14	13.71	1.597509	2.35	1.28	2.48	2.01	5.336	19.13	25.78	118.549149	374.119415
5	1	248.706	18.94	14.19	2.067920	2.71	2.31	1.78	2.22	5.294	18.30	26.70	179.163467	366.514008
6	1	262.633	20.30	16.09	1.937147	1.64	1.76	1.92	2.13	5.253	16.90	25.57	201.731461	315.493408
7	1	277.341	19.45	15.14	1.788355	2.54	3.10	1.65	2.89	5.280	17.78	25.35	208.417847	452.607880
8	1	292.872	19.53	15.05	1.657937	1.93	3.43	2.45	2.63	5.300	17.71	25.19	201.404739	522.496399
9	1	309.273	21.29	17.44	1.929630	1.74	2.23	1.03	1.79	5.283	15.94	21.50	180.873672	410.267334
10	1	326.592	21.22	17.45	1.577569	2.14	2.37	2.35	2.14	5.301	16.02	23.14	203.566010	491.057068
11	1	344.881	21.88	17.37	1.469472	3.12	1.99	3.08	2.59	5.324	15.38	21.35	224.548187	496.648865

Figure 13 Loaded Chamber Calibration Result Table

Column Name	Description	Unit
Rg	Subrange Number	None
Frequency	Frequency	Hz
CCF	Chamber Correction Factor (B.8)	dB
Insertion Loss	Insertion loss (B.9)	dB
Max loading	Calculated maximum loading factor (B.10)	None
Standard Deviation X, Y, Z	Standard deviation of the E-field for the x axis in dB (B.4) (B.5)	dB
Standard Deviation XYZ	Standard deviation of the E-field for the x axis in dB (B.6) (B.7)	dB
P_{input}	Input power into the transmitting antenna	dBm
P_{AveRec}	Average power received by the receiving antenna measured with the receiver device	dBm
P_{MaxREC}	Maximum power received by the receiving antenna measured with the receiver device	dBm
Chamber Q(E)	Estimated chamber Q factor using the chamber volume, the chamber wall permittivity and the averaged field strength values	None
Chamber Q(P)	Calculated chamber Q factor using the chamber volume, the chamber wall permittivity and the averaged power	None

Table 6 Loaded Calibration Result Table Column Description

Figure 14 shows the various columns of the Average Normalized E-Field Table & Table 7 describes the Average Normalized E-Field Table columns

LUF200 Averaged Max E-Field ISO Table

Name	Frequency	Avg Norm Max E-Field	Insertion Loss Unloaded	Insertion Loss Loaded
Unit	MHz	(V/m)/√(W)	dB	dB
Interpolation	Logarithmic	Linear	Linear	Linear
1	200.000	35.742	49.50	12.43
2	422.400	35.585	49.48	14.23
3	446.054	35.849	49.57	14.18
4	471.033	36.020	49.46	13.71
5	497.411	36.367	49.44	14.19
6	525.266	36.141	49.47	16.09
7	554.681	35.552	49.57	15.14
8	585.743	35.244	49.55	15.05
9	618.545	36.189	49.57	17.44
10	653.184	35.901	49.49	17.45
11	689.762	35.981	49.48	17.37
12	728.389	35.406	49.57	17.70
13	769.178	36.144	49.48	17.18
14	812.252	36.302	49.39	17.46
15	857.738	35.996	49.47	20.48
16	905.772	35.767	49.46	20.10
17	956.495	35.674	49.53	19.84
18	1,000.000	35.704	49.45	19.38
19	1,000.000	35.758	49.59	19.05
20	1,056.000	35.150	49.49	21.14
21	1,115.136	35.235	49.52	20.26
22	1,177.584	36.038	49.49	20.54
23	1,200.000	35.140	49.47	20.53
24	1,200.000	35.800	49.50	21.45
25	1,262.400	35.995	49.54	21.19
26	1,328.045	35.723	49.46	21.84
27	1,397.103	36.035	49.46	24.02
28	1,469.752	36.222	49.49	23.72
29	1,546.180	35.417	49.51	23.64
30	1,626.581	35.574	49.52	25.73
31	1,711.163	36.189	49.54	24.75

Figure 14 Average Normalized E-Field Table after Loaded Calibration Test

Column Name	Description	Unit
Frequency	Frequency	Hz
Avg Norm Max E-field	Calculated average normalized maximum E-field (B.3) in V/m	V/m/SQR(W)
Insertion Loss (loaded)	Insertion loss (B.9)	dB

Table 7 Average Normalized E-Field Table Column Description after loaded chamber calibration

Figure 15 shows the various evaluation graphics generated during the data evaluation phase. These graphics are stored under the Evaluation Graphics folder in the test content explorer.

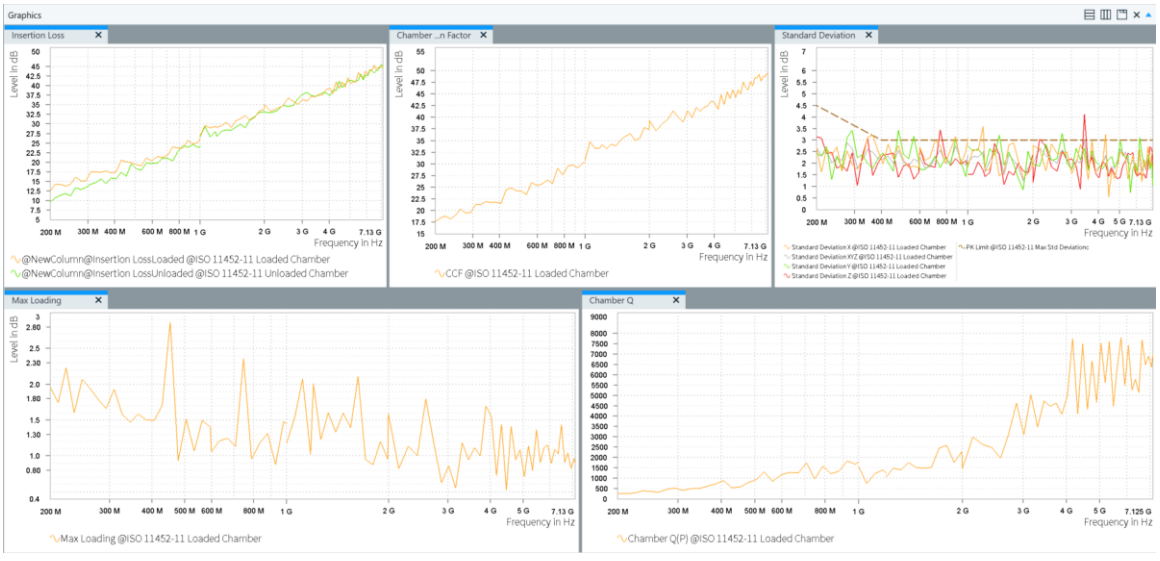


Figure 15 Loaded Chamber Evaluation Graphics

4.5.5 EUT Check Test Template Configuration

The typical parameters of the EUT check that are different from unloaded/loaded test template configuration are shown in Table 8

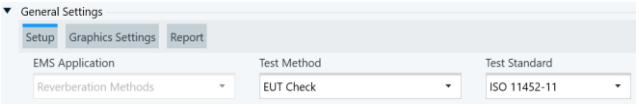
Parameter	Setting	Location in User Interface (UI)
Test Method	EUT Check	General Setup => Setup
Input Evaluation Data	Min Required Pulse Width: 2.4 µs Chamber Volume: 179.237m^3 (depends on chamber) Relative Permittivity: 8.8595 pF/m (depends on chamber)	Data Evaluation => Input Data
Output Evaluation Data	EUT Load Effect Table: EUT Load Effect Table Cahmber Loading Factor: Chamber Loading Factor	Data Evaluation => Output Data
Evaluation Graphics	Chamber Loading factor Chamber Calibration Factor Chamber Q Pulse Width	Data Evaluation => Evaluation Graphics

Table 8 Typical Parameters of EUT Check Test Template

4.5.5.1 EUT Check Test Template UI Previews

In this section, the UI for various parameters of EUT check listed in Table 8 are shown.

Configuring the test method and test standard

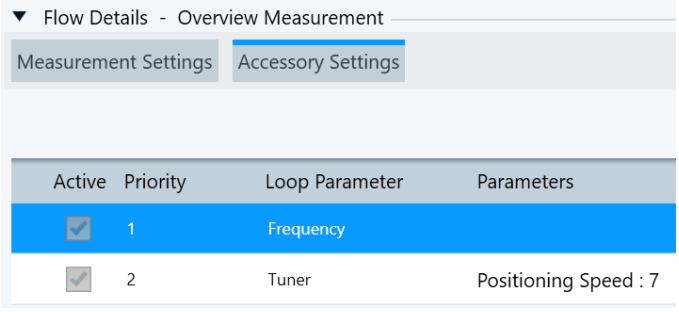


Configuring the measurement settings

The measurement settings are like the unloaded/loaded chamber test template

Configuring the accessory settings

For accessory settings, only the frequency & tuner loop is enabled.



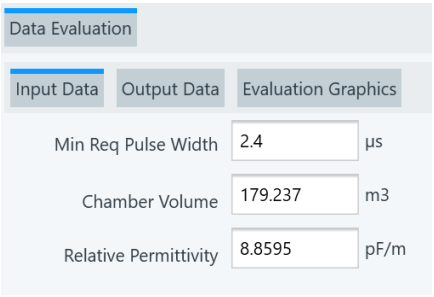
Configuring the subrange

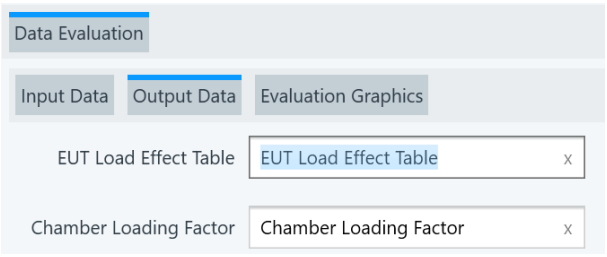
The subrange settings are like the unloaded/loaded chamber test template

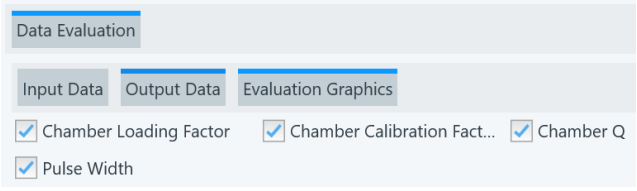
Configuring the system monitoring settings

The system monitoring settings are like the unloaded chamber test template

Configuring the data evaluation







4.5.6 EUT Check Test Execution

The EUT Check test creation & execution is the third step of reverberation chamber calibration process. It is very similar to loaded chamber method but the field strength distribution in the test volume of the chamber with the presence of EUT is verified. The receiving antenna is placed at a random position inside the test volume. Please note that the transmitting antenna should have no direct path of illumination to the receiving antenna and that the transmitting and receiving antennas are cross polarized. However, before creating the EUT Check test, a test application setting dialog (Figure 16) is shown to select unloaded & loaded chamber calibration result table.

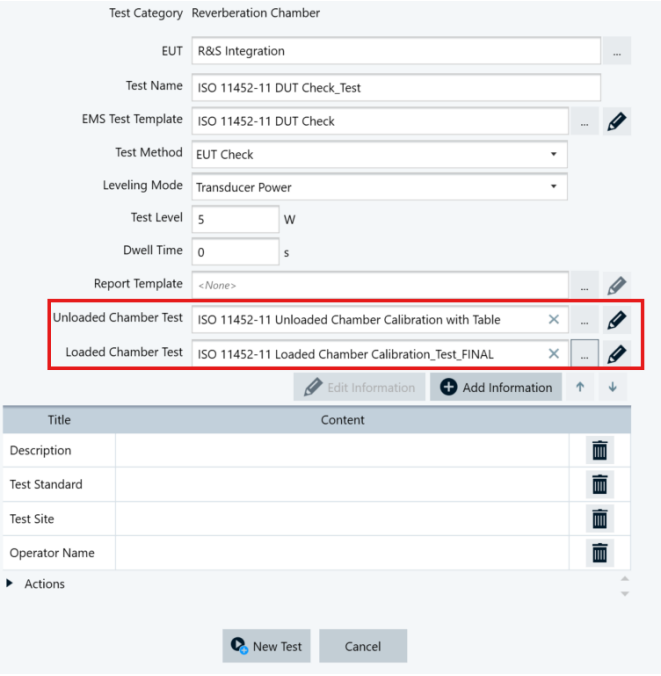


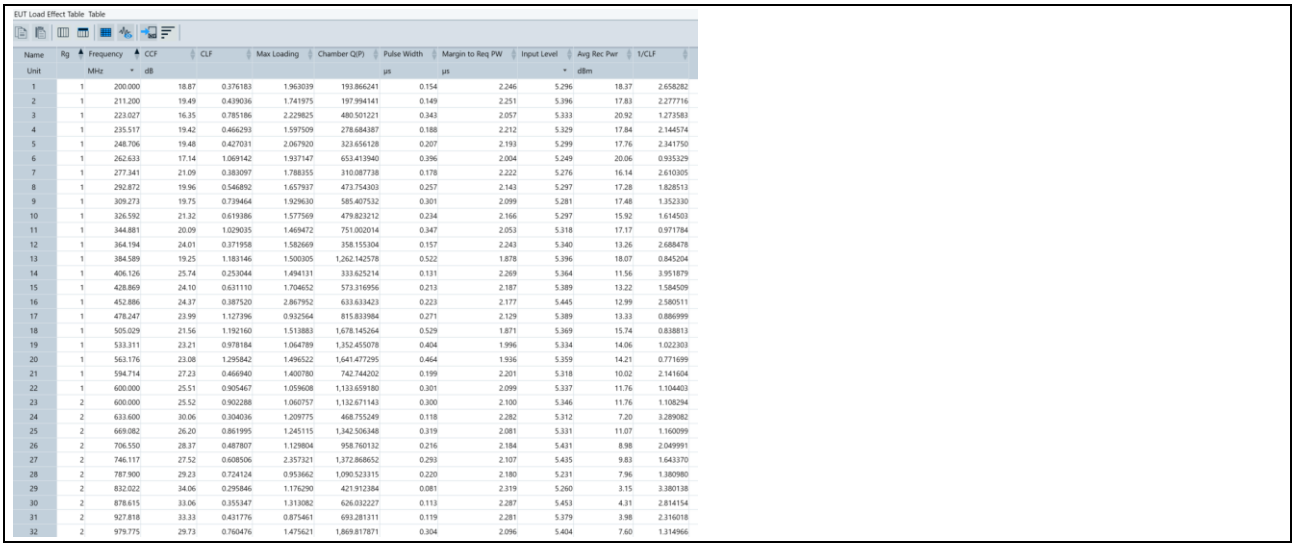
Figure 16 Test Application Setting View to select the unloaded chamber calibration & loaded chamber result table

The user may proceed to test creation by clicking “New Test” even without selecting an unloaded/loaded calibration chamber result tables and select them within the test as shown in Figure 12. The menu allows import of calibration results generated using EMC32 Software thus saving time.

In case, the unloaded/loaded chamber test result table is not available, the test execution validation will not allow the user to proceed with data evaluation phase of the test.

The data collection & evaluation phase of loaded chamber calibration is very similar to unloaded/loaded chamber calibration but for differences in measurement loops.

Figure 17 shows the various columns of the loaded test calibration results & Table 9 describes the EUT check chamber result columns based on [1]


EUT Load Effect Table Table

Name	Rg	Frequency	CCF	CLF	Max Loading	Chamber Q(P)	Pulse Width	Margin to Req PW	Input Level	Avg Rec Pwr	1/CLF
Unit		MHz	dB				µs	µs		dBm	
1	1	200.000	18.87	0.376183	1.963039	193.866241	0.154	2.246	5.296	18.37	2.658282
2	1	211.200	19.49	0.439036	1.741975	197.994141	0.149	2.251	5.396	17.83	2.277716
3	1	223.027	16.35	0.785186	2.229825	480.501221	0.343	2.057	5.333	20.92	1.273583
4	1	235.517	19.42	0.466293	1.597509	278.684387	0.188	2.212	5.329	17.84	2.144574
5	1	248.706	19.48	0.427031	2.067920	323.656128	0.207	2.193	5.299	17.76	2.341750
6	1	262.633	17.14	1.069142	1.937147	653.413940	0.396	2.004	5.249	20.06	0.935329
7	1	277.341	21.09	0.383097	1.788355	310.087738	0.178	2.222	5.276	16.14	2.610305
8	1	292.872	19.96	0.546892	1.657937	473.754303	0.257	2.143	5.297	17.28	1.828513
9	1	309.273	19.75	0.739464	1.929630	585.407532	0.301	2.099	5.281	17.48	1.352330
10	1	326.592	21.32	0.619386	1.577569	479.823212	0.234	2.166	5.297	15.92	1.614503
11	1	344.881	20.09	1.029035	1.469472	751.002014	0.347	2.053	5.318	17.17	0.971784
12	1	364.194	24.01	0.371958	1.582669	358.155304	0.157	2.243	5.340	13.26	2.688478
13	1	384.589	19.25	1.183146	1.500305	1,262.142578	0.522	1.878	5.396	18.07	0.845204
14	1	406.126	25.74	0.253044	1.494131	333.625214	0.131	2.269	5.364	11.56	3.951879
15	1	428.869	24.10	0.631110	1.704652	573.316956	0.213	2.187	5.389	13.22	1.584509
16	1	452.886	24.37	0.387520	2.867952	633.633423	0.223	2.177	5.445	12.99	2.580511
17	1	478.247	23.99	1.127396	0.932564	815.833984	0.271	2.129	5.389	13.33	0.886999
18	1	505.029	21.56	1.192160	1.513883	1,678.145264	0.529	1.871	5.369	15.74	0.838813
19	1	533.311	23.21	0.978184	1.064789	1,352.455078	0.404	1.996	5.334	14.06	1.022303
20	1	563.176	23.08	1.295842	1.496522	1,641.477295	0.464	1.936	5.359	14.21	0.771699
21	1	594.714	27.23	0.466940	1.400780	742.744202	0.199	2.201	5.318	10.02	2.141604
22	1	600.000	25.51	0.905467	1.059608	1,133.659180	0.301	2.099	5.337	11.76	1.104403
23	2	600.000	25.52	0.902288	1.060757	1,132.671143	0.300	2.100	5.346	11.76	1.108294
24	2	633.600	30.06	0.304036	1.209775	468.755249	0.118	2.282	5.312	7.20	3.289082
25	2	669.082	26.20	0.861995	1.245115	1,342.506348	0.319	2.081	5.331	11.07	1.160099
26	2	706.550	28.37	0.487807	1.129804	958.760132	0.216	2.184	5.431	8.98	2.049991
27	2	746.117	27.52	0.608506	2.357321	1,372.868652	0.293	2.107	5.435	9.83	1.643370
28	2	787.900	29.23	0.724124	0.953662	1,090.523315	0.220	2.180	5.231	7.96	1.380980
29	2	832.022	34.06	0.295846	1.176290	421.912384	0.081	2.319	5.260	3.15	3.380138
30	2	878.615	33.06	0.355347	1.313082	626.032227	0.113	2.287	5.453	4.31	2.814154
31	2	927.818	33.33	0.431776	0.875461	693.281311	0.119	2.281	5.379	3.98	2.316018
32	2	979.775	29.73	0.760476	1.475621	1,869.817871	0.304	2.096	5.404	7.60	1.314966

Figure 17 EUT Check Result Table

Column Name	Description	Unit
Rg	Subrange Number	None
Frequency	Frequency	Hz
CCF	Chamber Correction Factor (B.11)	dB
CLF	Chamber Loading Factor (B.12)	None
Max loading	Calculated maximum loading factor (B.10)	None
Chamber Q(P)	Calculated chamber Q factor (B.13)	None
Pulse Width	Calculated minimum pulse width (B.14)	µs
Margin to Req PW	difference between the calculated minimum pulse width and the limit defined in the input parameters	µs
Input Level	Input power into the transmitting antenna	dBm
P_{AveRec}	Average power received by the receiving antenna measured with the receiver device	dBm
1/CLF	Inverse CLF for comparison to the Max. Loading	None

Table 9 EUT Check Result Table Column Description

Figure 18 shows the various columns of the Chamber Loading Factor Table & Table 10 describes the corresponding columns

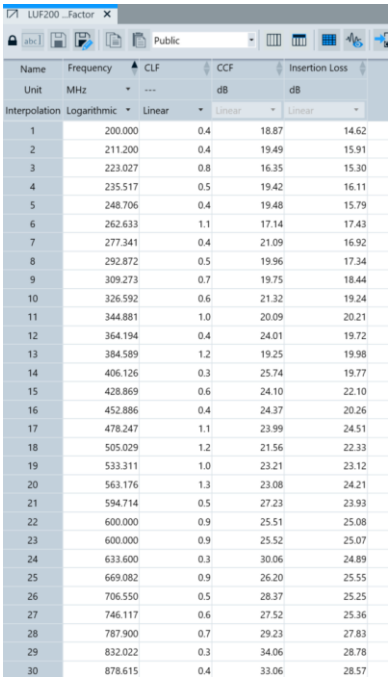


Figure 18 Chamber Loading Factor Table

Column Name	Description	Unit
Frequency	Test Frequency	Hz
CLF	Chamber loading factor (B.12)	None
CCF	Chamber calibration factor (B.11)	dB
Insertion Loss	Insertion loss (B.9) of the unloaded chamber	dB

Table 10 Chamber Loading Factor Table Column Description after EUT Check

Figure 19 shows the various evaluation graphics generated during the data evaluation phase. These graphics are stored under the Evaluation Graphics folder in the test content explorer.

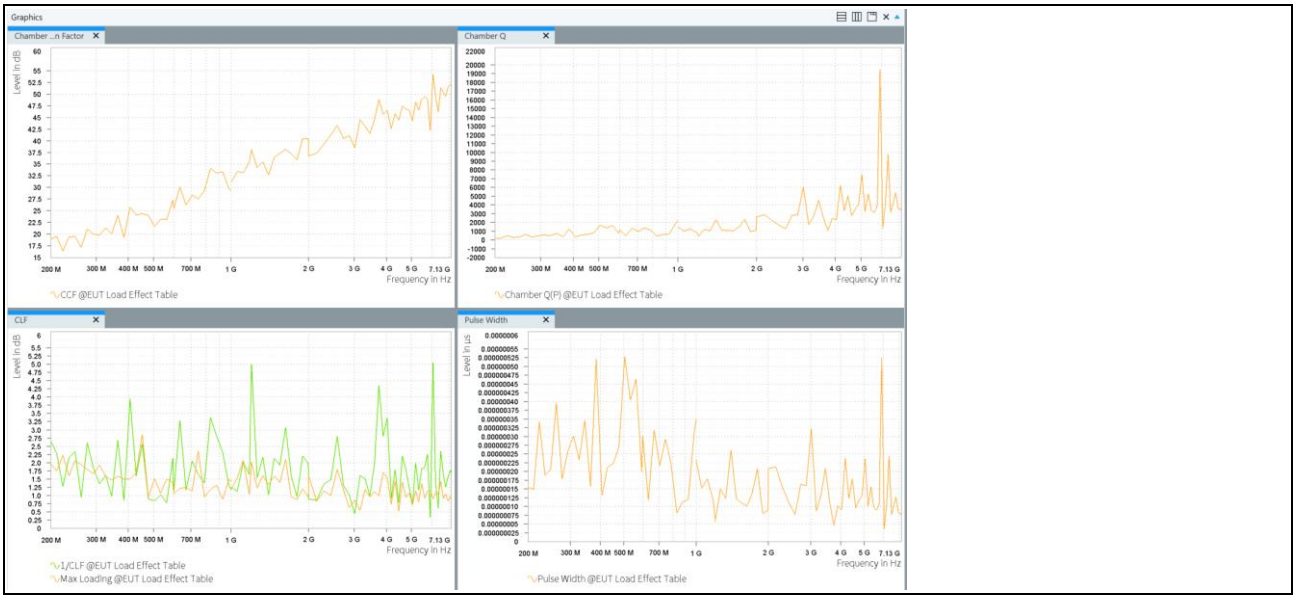


Figure 19 EUT Check Evaluation Graphics

4.5.7 EUT Test Template Configuration

The typical parameters for performing EUT qualification test in RVC is shown in Table 11.

Parameter	Setting	Location in User Interface (UI)
EMS Application	Reverberation Methods	General Setup => Setup
Test Method	EUT Qualification	General Setup => Setup
Test Standard	ISO 11452-11	General Setup => Setup
Level On	Power Relation	Measurement Settings => Leveling Mode
Power Control	Forward Power	Measurement Settings => Leveling Mode
Transducer Relation	pow(TESTNOMLEV(v/m) /RVCEFIELD, 2) / RVCCLF RVCEFILED is referenced from the Avg Norm Max E-field table generated by unloaded chamber test RVCCLF is referenced from CLF table generated by EUT Check	Measurement Settings => Calculate Transducer Power[W]
Avg Norm Max E-Field	LUF200 Averaged Max E-Field Example (updated from unloaded tests)	Measurement Settings => Avg Norm Max E-Field
Chamber Loading Factor	Chamber Loading Factor (updated from EUT Check test)	Measurement Settings => Chamber Loading Factor
Level Conservation for Modulation	CW Carrier = Modulation Carrier	Measurement Settings => Leveling Options
Power Limitation	Not Active	Measurement Settings => Power Level Limitation
Frequency Range	200 MHz – 7.125 GHz	Subrange Header
Frequency Steps	5.6%, LOG (200 MHz – 600 GHz) 5.6%, LOG (600 MHz – 1 GHz) 5.6%, LOG (1 GHz – 1.2 GHz) 5.2% LOG (1.2 GHz – 2 GHz) 1.45% DECLIN (2 GHz – 7.125 GHz)	Subrange Header
Test Level	100 V/m	Subrange => Test Level
Modulation	Off	UI not activated
Leveling Tolerance	0 dB – 0.4 dB	Subrange => Test Level

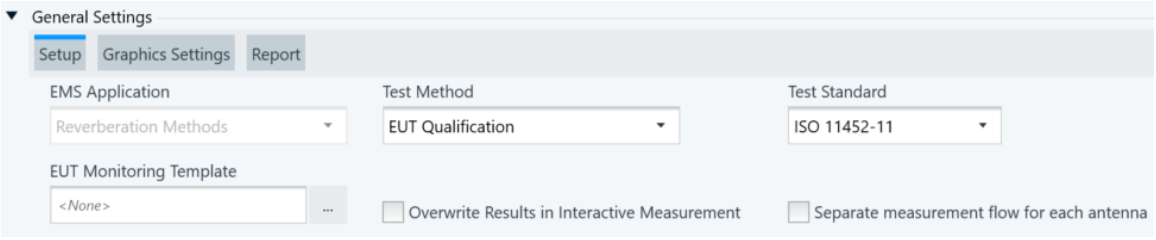
Parameter	Setting	Location in User Interface (UI)
Tuner	12	Subrange => Reverb Settings
Accessory Settings	Priority 1 => Frequency Priority 2 => Tuner	Accessory Settings
System Monitoring	Test Level Received Antenna Power Sensor Level Transducer Forward Power VSWR Amplifier Forward Power	System Monitoring

Table 11 Typical Parameters of EUT Qualification Test Template

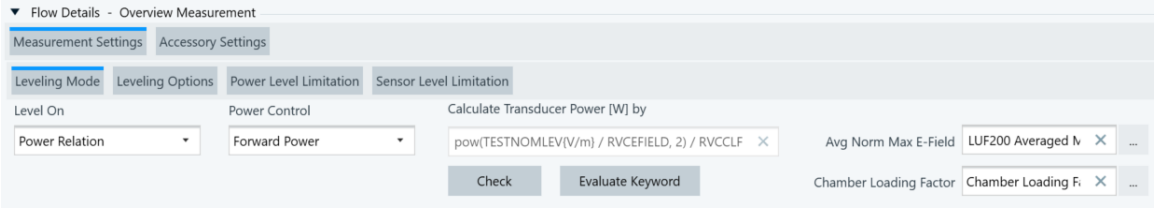
4.5.7.1 EUT Test Template UI Previews

In this section, the UI for various parameters of EUT listed in Table 11 are shown.

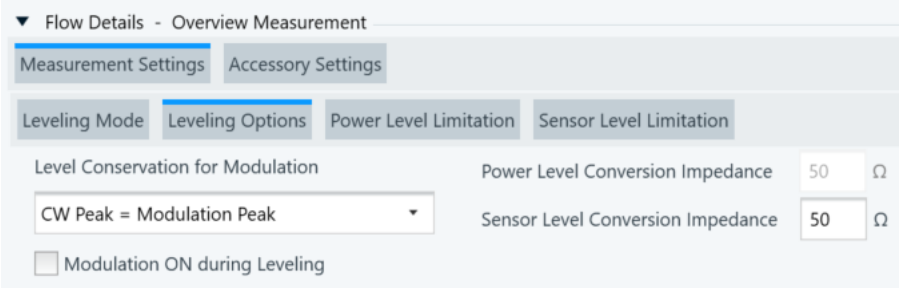
Configuring the test method and test standard



Configuring the measurement settings



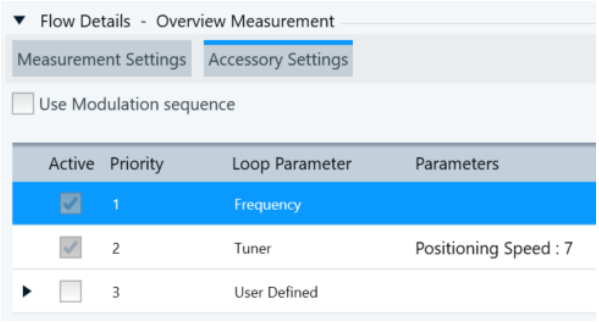
The formula to calculate the required forward power to generate the required electric field strength at each frequency is from [1]. However, the conversion factors are same as in [2] .



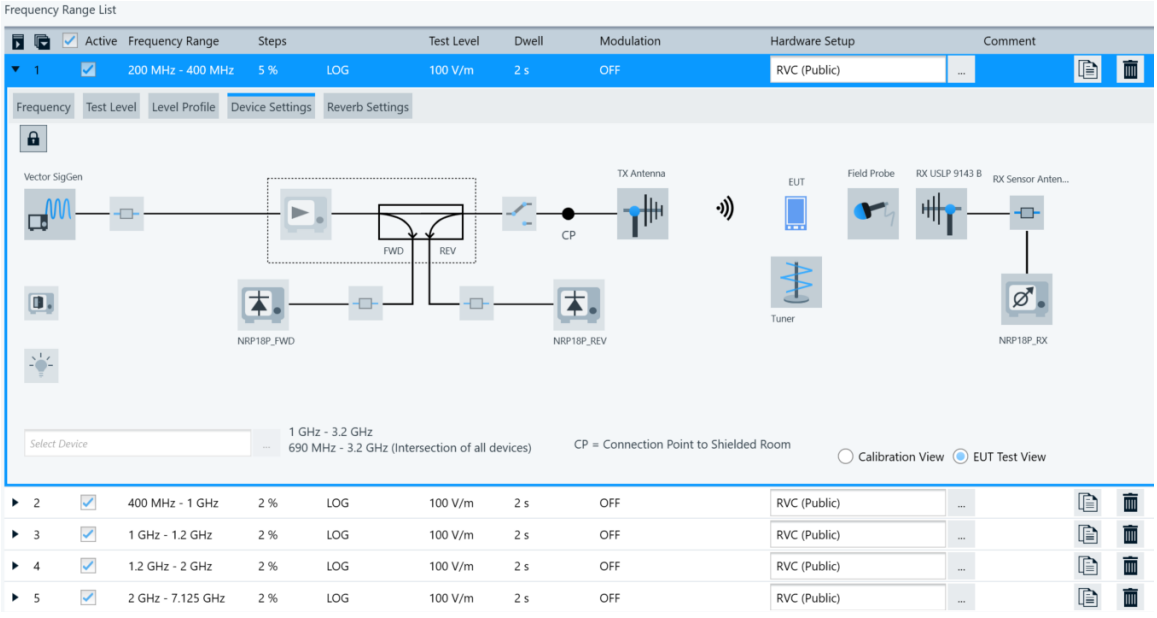
The level conservation needs to CW Carrier = Modulation Carrier for [1].

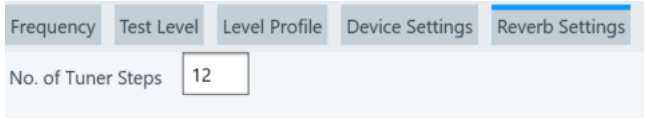
Configuring the accessory settings

For accessory settings, only the frequency & tuner loop is enabled.

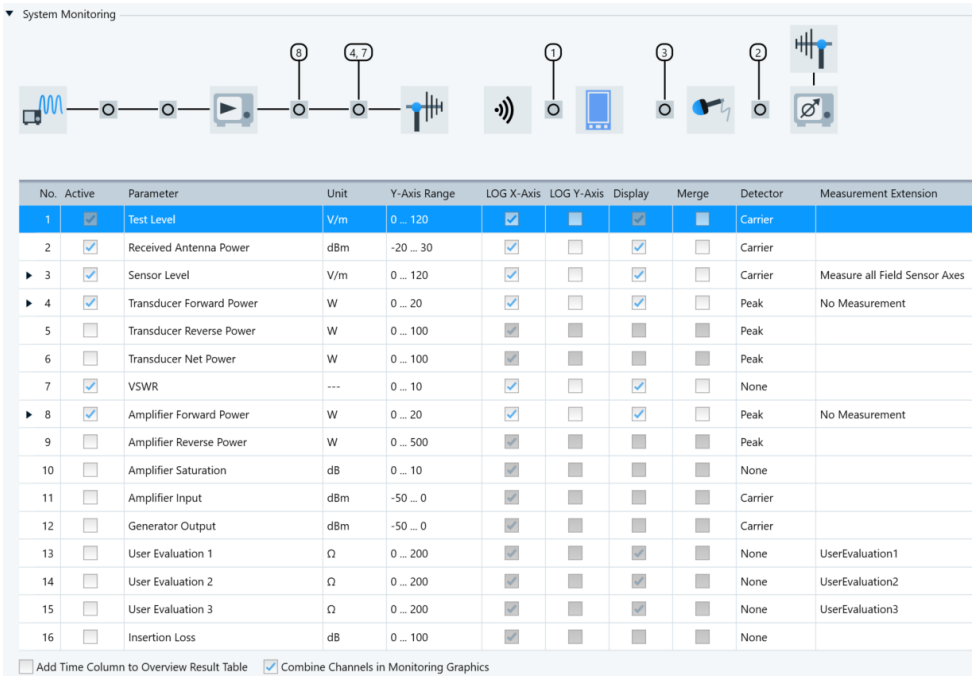


Configuring the subrange





Configuring the system monitoring settings

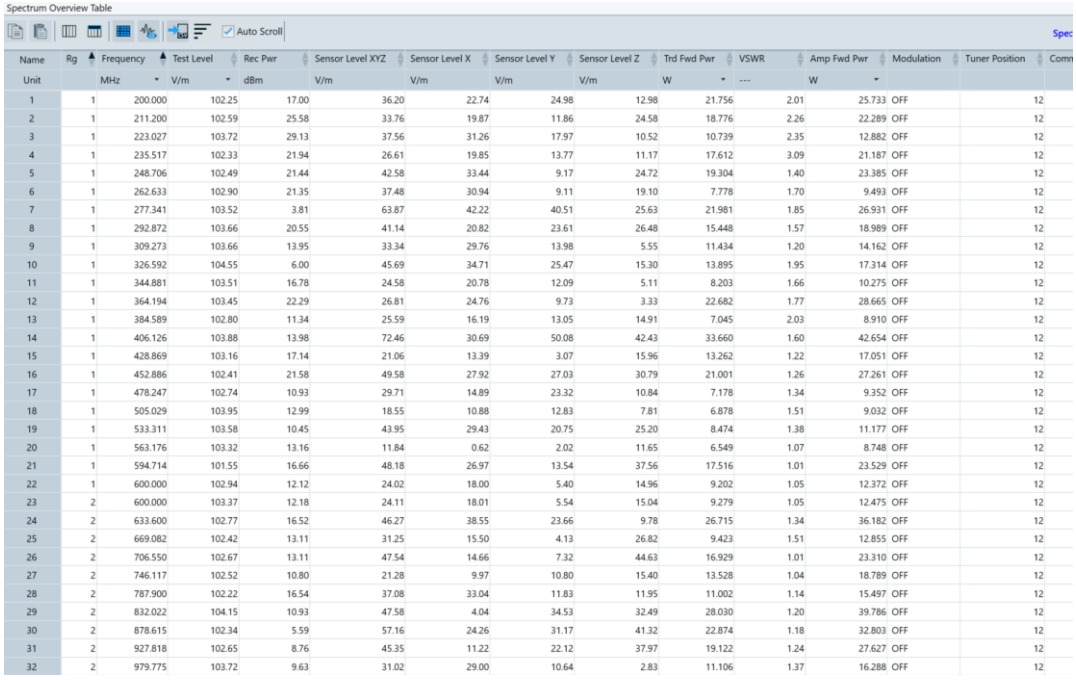


Configuring the data evaluation

The data evaluation settings are like any EUT tests done using Anechoic Chamber

4.5.8 EUT Test Execution

The EUT test creation & execution is like any EUT qualification/Susceptibility tests performed in Anechoic Chamber. Figure 20 shows the various columns of the EUT Qualification test in RVC



Name	Rg	Frequency	Test Level	Rec Pwr	Sensor Level XYZ	Sensor Level X	Sensor Level Y	Sensor Level Z	Trd Fwd Pwr	VSWR	Amp Fwd Pwr	Modulation	Tuner Position	Comm
Unit		MHz	V/m	dBm	V/m	V/m	V/m	V/m	W	---	W			
1	1	200.000	102.25	17.00	36.20	22.74	24.98	12.98	21.756	2.01	25.733	OFF	12	
2	1	211.200	102.59	25.58	33.76	19.87	11.86	24.58	18.776	2.26	22.289	OFF	12	
3	1	223.027	103.72	29.13	37.56	31.26	17.97	10.52	10.739	2.35	12.882	OFF	12	
4	1	235.517	102.33	21.94	26.61	19.85	13.77	11.17	17.612	3.09	21.187	OFF	12	
5	1	248.706	102.49	21.44	42.58	33.44	9.17	24.72	19.304	1.40	23.385	OFF	12	
6	1	262.633	102.90	21.35	37.48	30.94	9.11	19.10	7.778	1.70	9.493	OFF	12	
7	1	277.341	103.52	3.81	63.87	42.22	40.51	25.63	21.981	1.85	26.931	OFF	12	
8	1	292.872	103.66	20.55	41.14	20.82	23.61	26.48	15.448	1.57	18.989	OFF	12	
9	1	309.273	103.66	13.95	33.34	29.76	13.98	5.55	11.434	1.20	14.162	OFF	12	
10	1	326.592	104.55	6.00	45.69	34.71	25.47	15.30	13.895	1.95	17.314	OFF	12	
11	1	344.881	103.51	16.78	24.58	20.78	12.09	5.11	8.203	1.66	10.275	OFF	12	
12	1	364.194	103.45	22.29	26.81	24.76	9.73	3.33	22.682	1.77	28.665	OFF	12	
13	1	384.589	102.80	11.34	25.59	16.19	13.05	14.91	7.045	2.03	8.910	OFF	12	
14	1	406.126	103.88	13.98	72.46	30.69	50.08	42.43	33.660	1.60	42.654	OFF	12	
15	1	428.869	103.16	17.14	21.06	13.39	3.07	15.96	13.262	1.22	17.051	OFF	12	
16	1	452.886	102.41	21.58	49.58	27.92	27.03	30.79	21.001	1.26	27.261	OFF	12	
17	1	478.247	102.74	10.93	29.71	14.89	23.32	10.84	7.178	1.34	9.352	OFF	12	
18	1	505.029	103.95	12.99	18.55	10.88	12.83	7.81	6.878	1.51	9.032	OFF	12	
19	1	533.311	103.58	10.45	43.95	29.43	20.75	25.20	8.474	1.38	11.177	OFF	12	
20	1	563.176	103.32	13.16	11.84	0.62	2.02	11.65	6.549	1.07	8.748	OFF	12	
21	1	594.714	101.55	16.66	48.18	26.97	13.54	37.56	17.516	1.01	23.529	OFF	12	
22	1	600.000	102.94	12.12	24.02	18.00	5.40	14.96	9.202	1.05	12.372	OFF	12	
23	2	600.000	103.37	12.18	24.11	18.01	5.54	15.04	9.279	1.05	12.475	OFF	12	
24	2	633.600	102.77	16.52	46.27	38.55	23.66	9.78	26.715	1.34	36.182	OFF	12	
25	2	669.082	102.42	13.11	31.25	15.50	4.13	26.82	9.423	1.51	12.855	OFF	12	
26	2	706.550	102.67	13.11	47.54	14.66	7.32	44.63	16.929	1.01	23.310	OFF	12	
27	2	746.117	102.52	10.80	21.28	9.97	10.80	15.40	13.528	1.04	18.789	OFF	12	
28	2	787.900	102.22	16.54	37.08	33.04	11.83	11.95	11.002	1.14	15.497	OFF	12	
29	2	832.022	104.15	10.93	47.58	4.04	34.53	32.49	28.030	1.20	39.786	OFF	12	
30	2	878.615	102.34	5.59	57.16	24.26	31.17	41.32	22.874	1.18	32.803	OFF	12	
31	2	927.818	102.65	8.76	45.35	11.22	22.12	37.97	19.122	1.24	27.627	OFF	12	
32	2	979.775	103.72	9.63	31.02	29.00	10.64	2.83	11.106	1.37	16.288	OFF	12	

Figure 20 Loop result table of EUT Qualification in RVC

Figure 21 shows the various system monitoring graphics of the EUT Qualification test in RVC

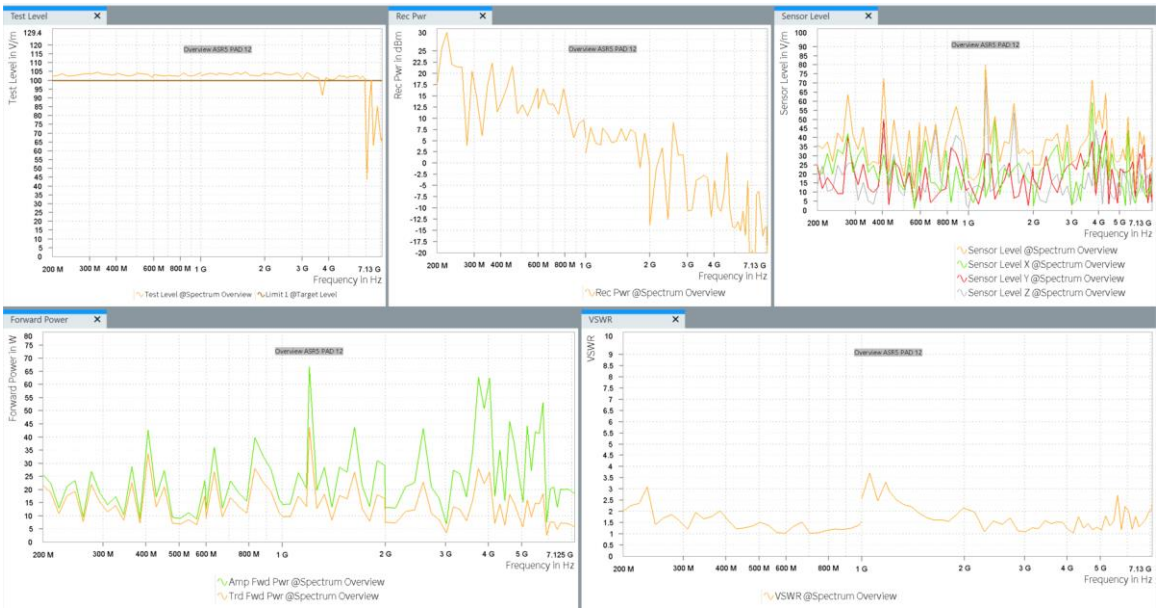


Figure 21 System Monitoring Graphics of EUT Qualification test in RVC

Evaluation of EUT failure mode either by operator intervention or using EUT monitoring template is like those performed with Anechoic Chamber and is not described in this application note.

5 Reference Documents

[1] IEC 61000-4-21 Edition 2.0 2011-01 Electromagnetic compatibility (EMC) – Part 4-21: Testing and measurement techniques – Reverberation chamber test

[2] ISO 11542-11 Edition 2010-09-01 Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 11: Reverberation chamber

Rohde & Schwarz

The Rohde & Schwarz electronics group offers innovative solutions in the following business fields: test and measurement, broadcast and media, secure communications, cybersecurity, monitoring and network testing. Founded more than 80 years ago, the independent company which is headquartered in Munich, Germany, has an extensive sales and service network with locations in more than 70 countries.

www.rohde-schwarz.com

Certified Quality Management
ISO 9001

Rohde & Schwarz training

www.rohde-schwarz.com/training

Rohde & Schwarz customer support

www.rohde-schwarz.com/support

PAD-T-M: 3572.7186.00/02.00/EN

1AEP4 | Version 1.1 | 03.2025
Application Note | MEASUREMENTS IN REVERBERATION CHAMBER USING R&S® ELEKTRA
Data without tolerance limits is not binding | Subject to change

www.rohde-schwarz.com