Calibration and Validation

for Automotive EMC

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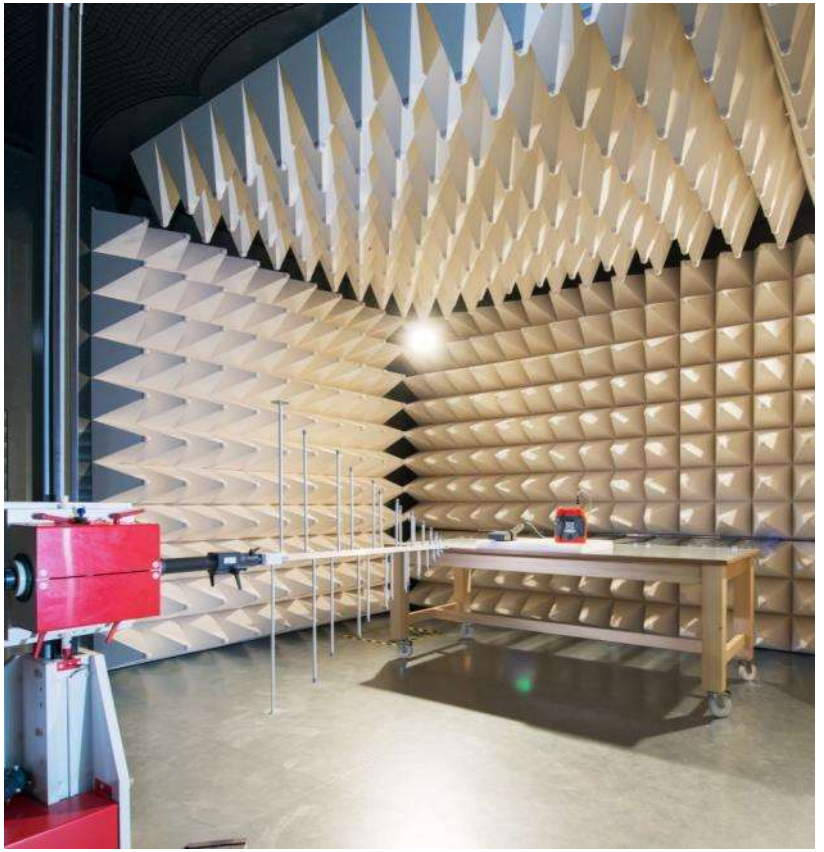
Overview

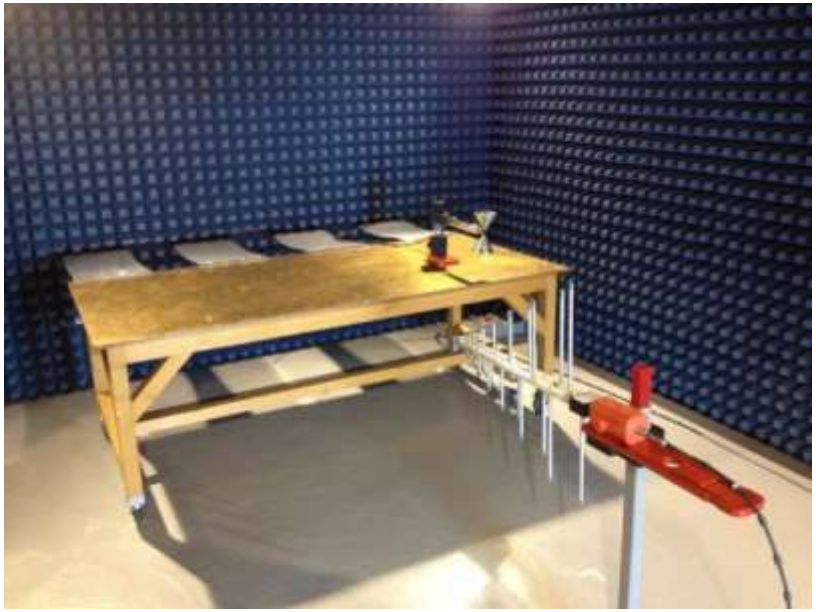
- **ALSE Performance Validation**
- Antenna Calibration
- LISN Calibration
- Field Probe Calibration
- System Check



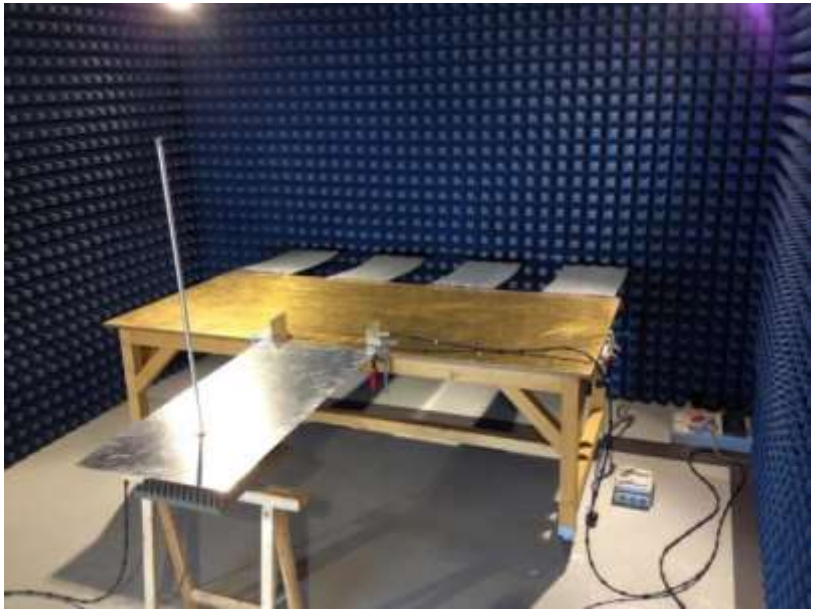
ALSE Performance Validation

- Standard: CISPR 25
- Frequency range: 150kHz – 1GHz
- Two methods:

reference measurement method



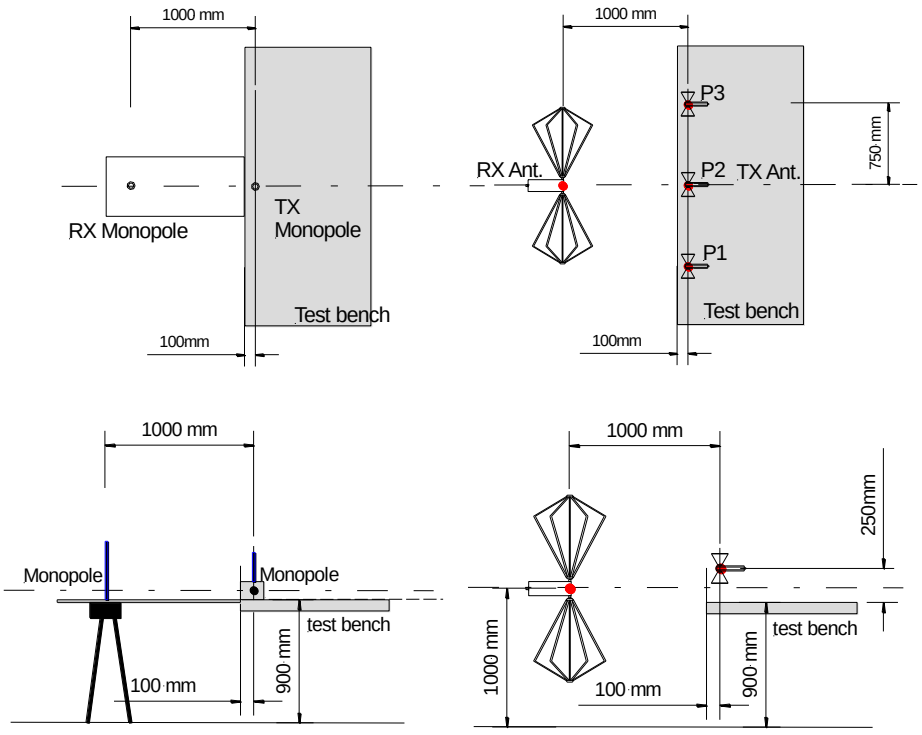
modelled long wire method



ALSE Performance Validation

Reference Measurement Method (RMM):

- Reference test site for calibration of Setup: OATS
- Transmit antennas: small monopole and small biconical antenna
- Corresponding measurements in ALSE
- ALSE measurements must be within defined tolerances



ALSE Performance Validation

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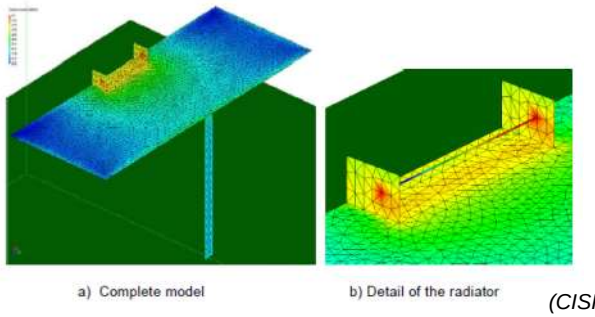
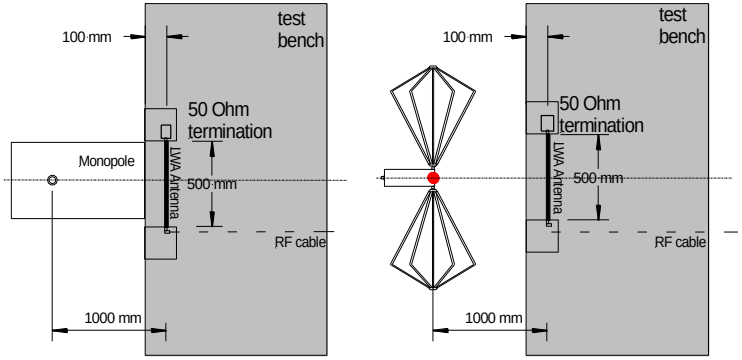
Modelled Long Wire Method (LWM):

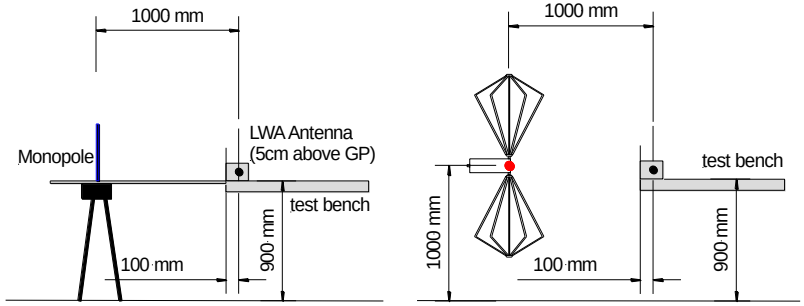
- 50cm long wire as TX antenna
- Measurements with the long wire in the ALSE
- Measurements are compared to the modelled (simulated) fields
- ALSE measurements must be within defined tolerances



a) Complete model b) Detail of the radiator

(CISPR 25)



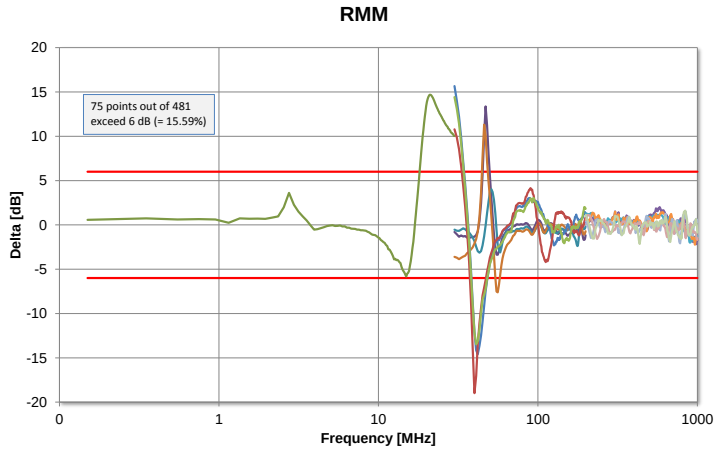


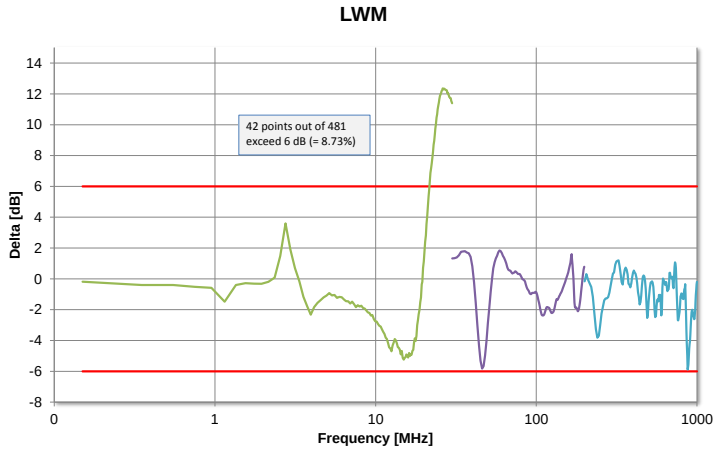
ALSE Performance Validation

Purpose of this Validation:

compare the radiation characteristic of the ALSE setup table with the reference data (calibration or simulation)

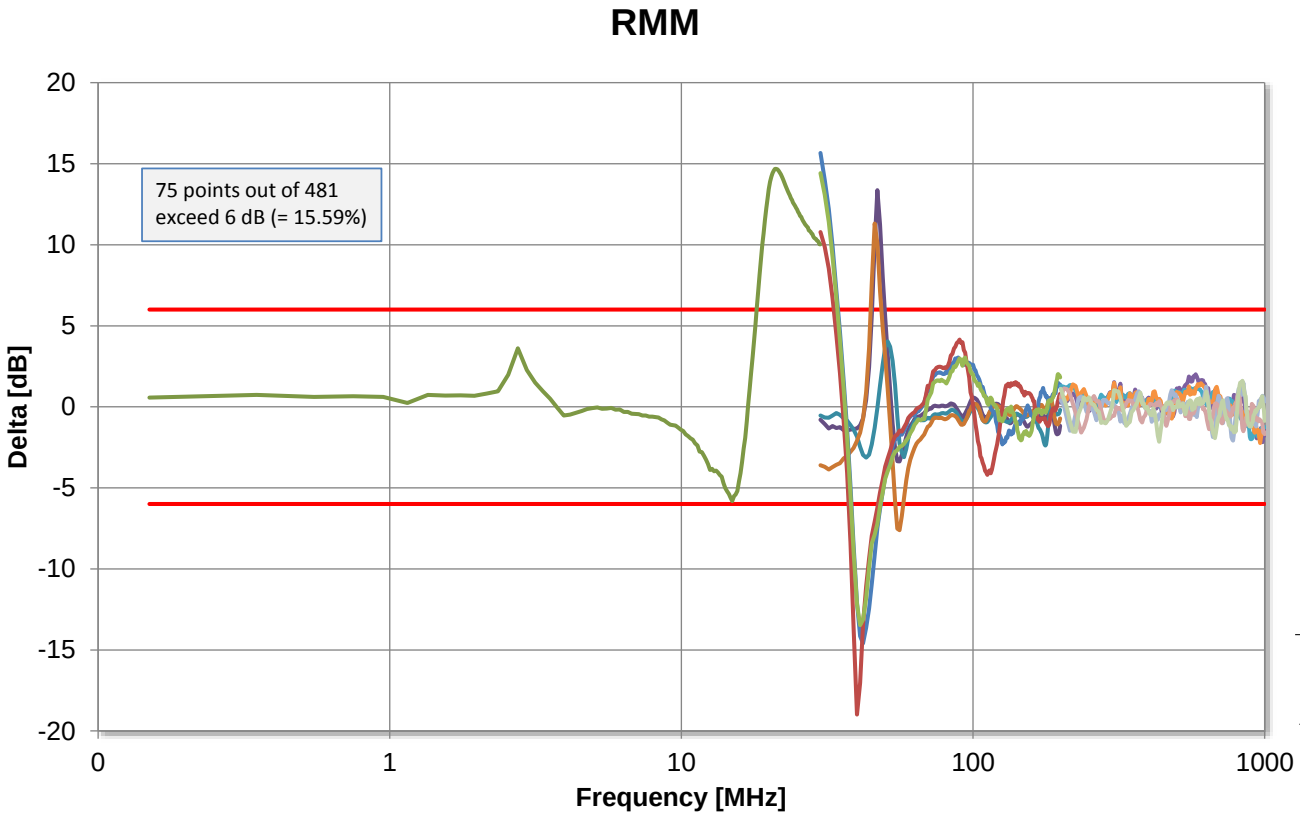
- Limit: ±6dB
- Criterion: ≥90%of measured points within limit

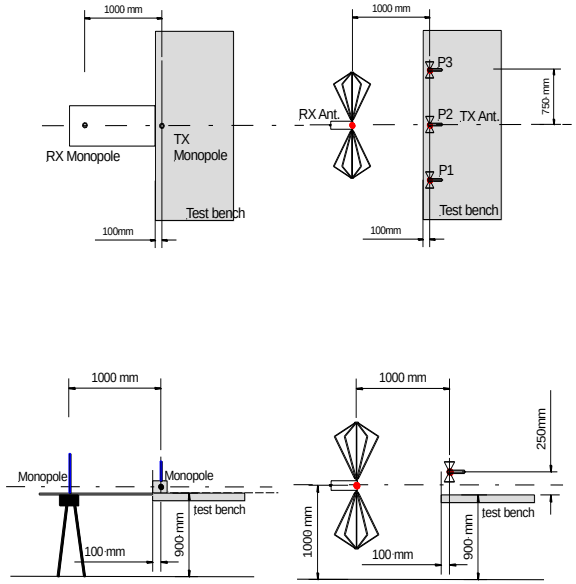




ALSE Performance Validation

Results RMM: OUT OF SPEC!!!





ALSE Performance Validation

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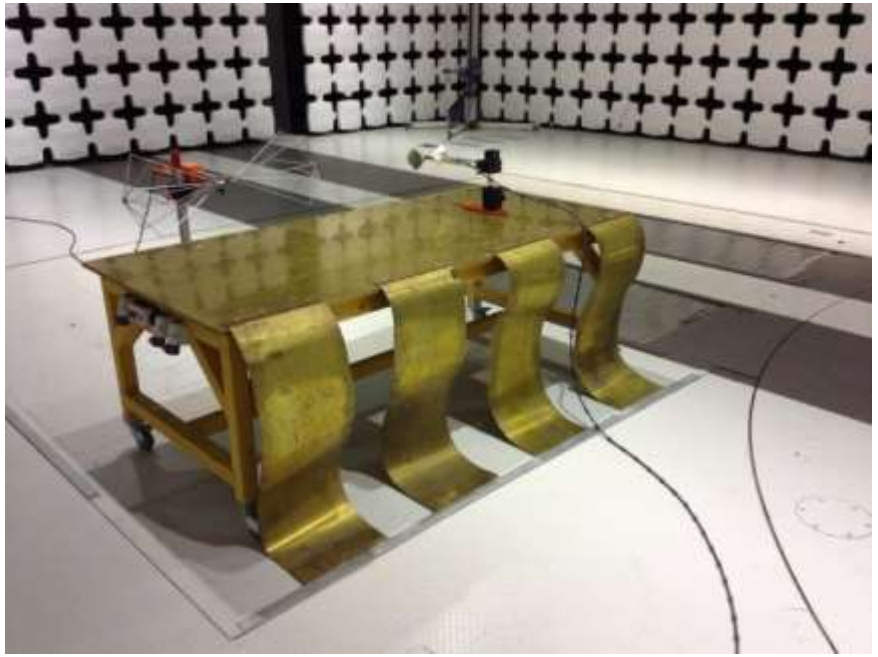
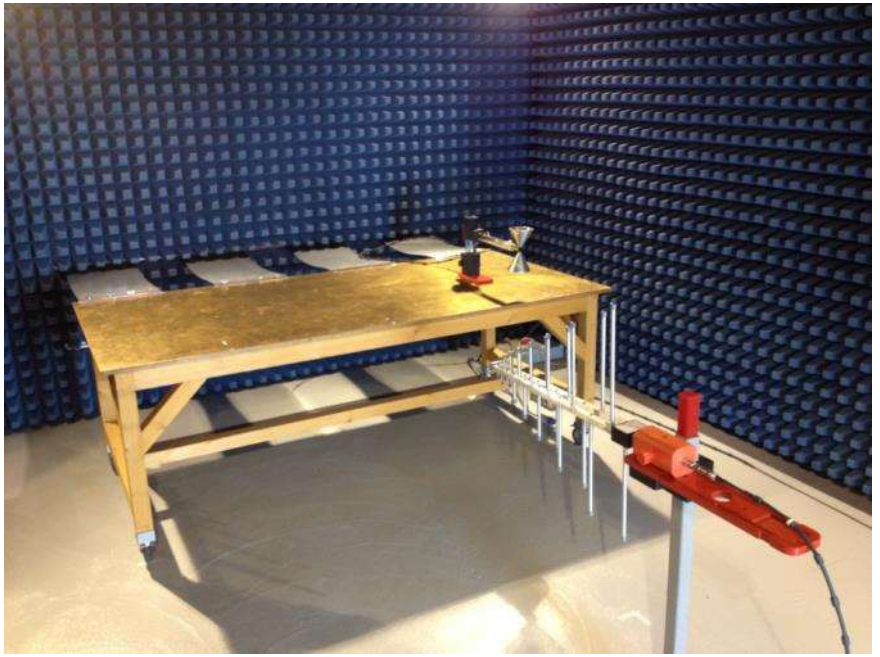
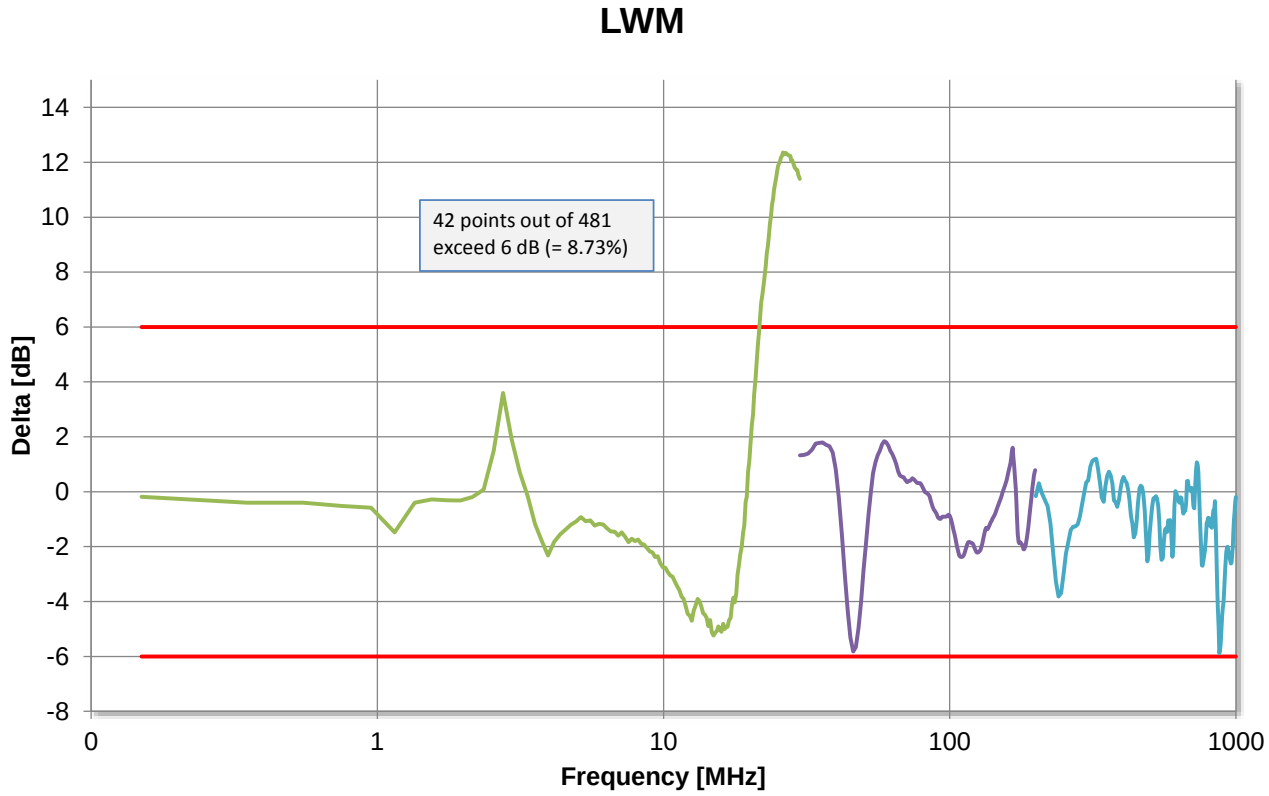
Results RMM: OUT OF SPEC → bonding is critical!!!





ALSE Performance Validation

Results LWM: **WITHIN SPEC!!!**

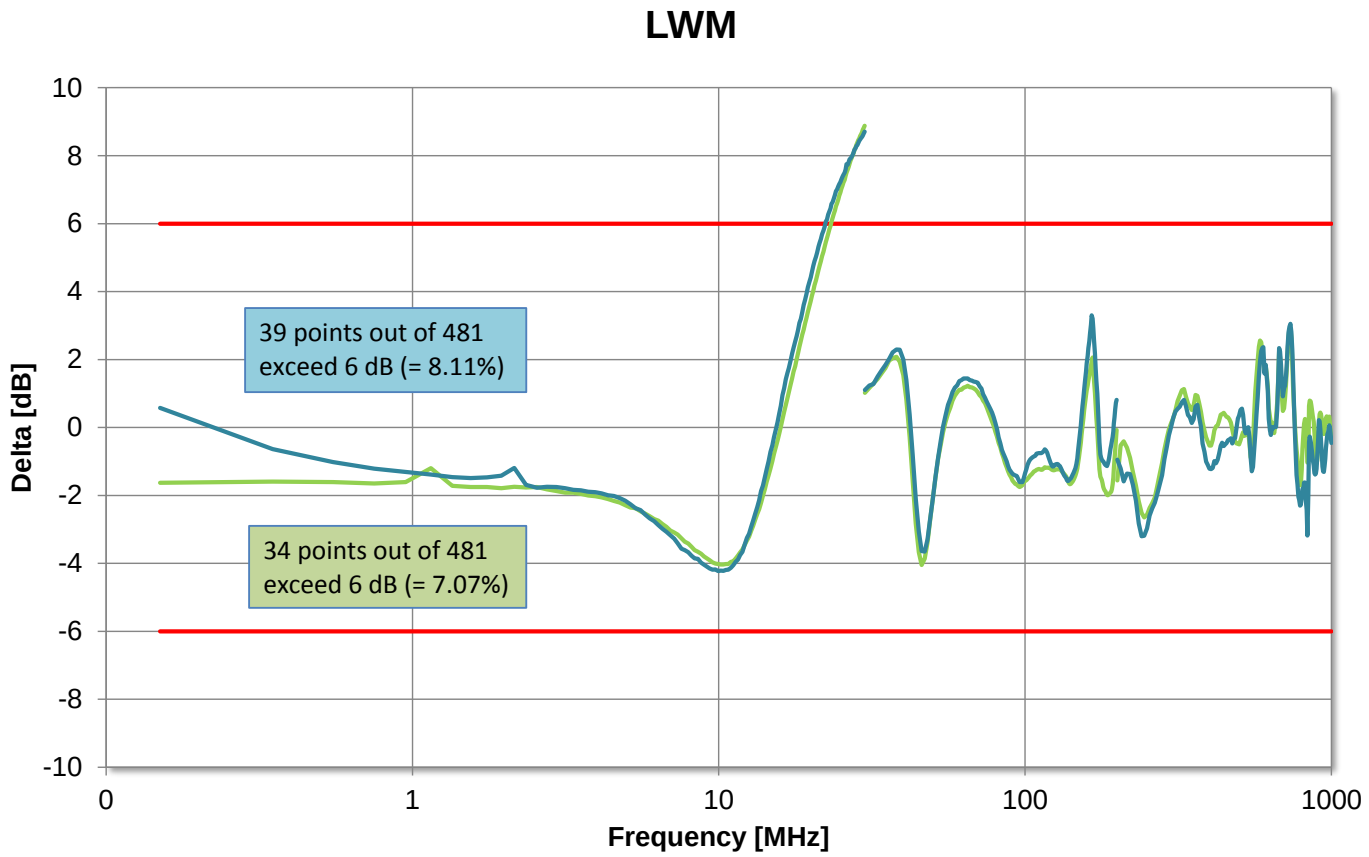


Regular ALSE Re-Calibration

Regular Re-Calibration of ALSE

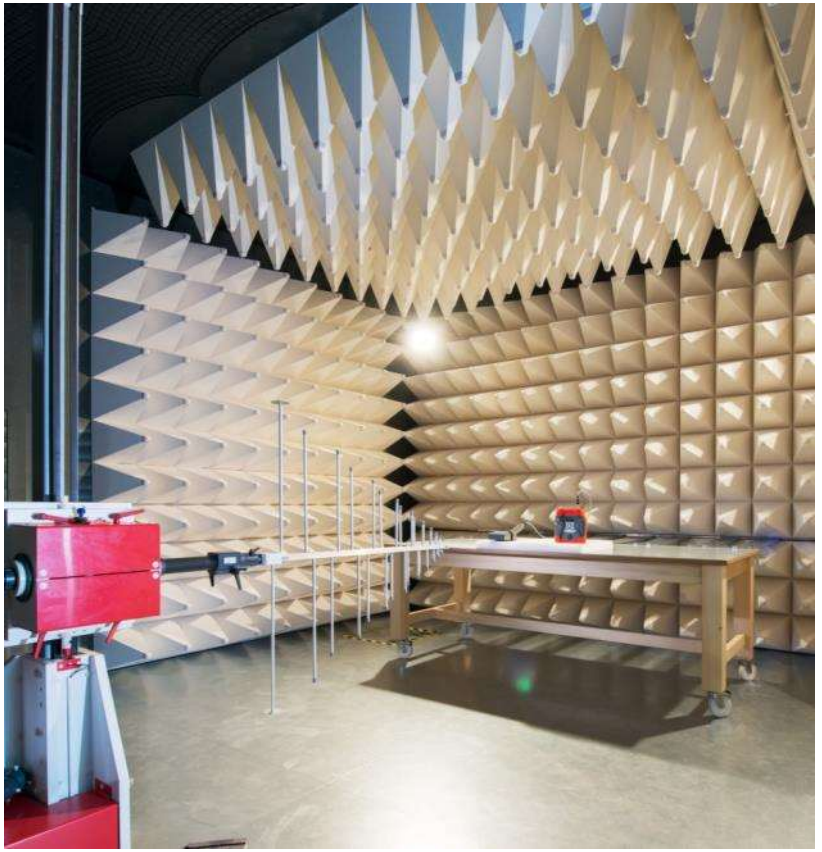
- ALSE is test equipment
- Needs regular calibration (ISO 17025 requirement)
- Certain time interval (1 - 5 years)
- Anytime a change in the ALSE is made:
  - Setup Table
  - Bonding
  - Antennas
  - Absorbers

Regular ALSE Re-Calibration



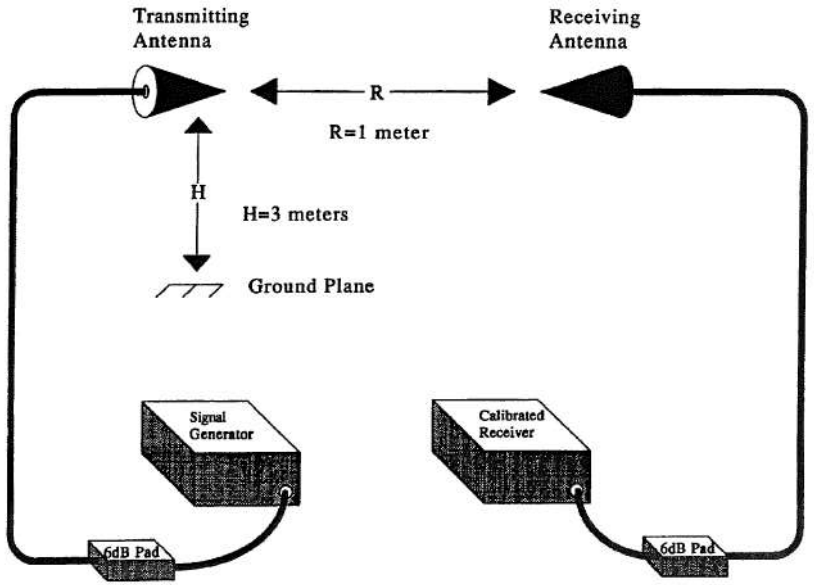
Overview

- ALSE Performance Validation
- **Antenna Calibration**
- LISN Calibration
- Field Probe Calibration
- System Check

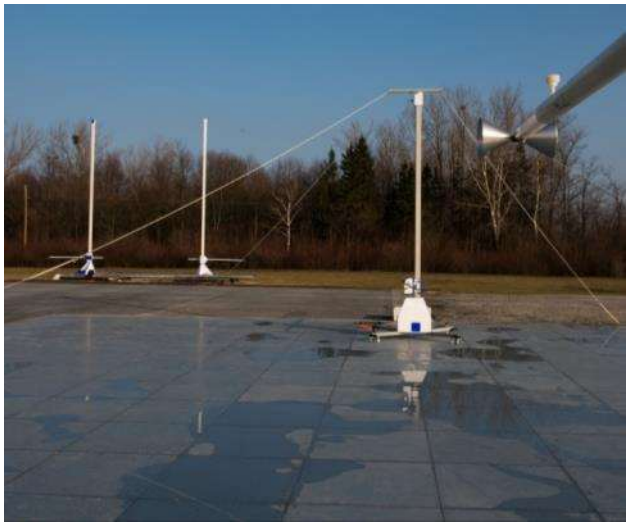


Antenna Calibration

- Standard: SAE ARP 958
- Determining the Antenna Factor (AF)
- OATS (d=1m; h=3m)



(SAE ARP 958)



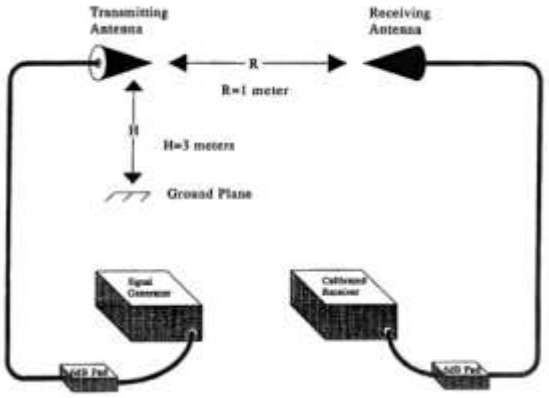
Antenna Calibration (SAE ARP 958)

- Determining AF (d=1m; h=3m)

  E = AF + U (E…[dBµV/m]; U…[dBµV]; AF [dB/m])

- Using two **identical** antennas

$$G = \frac{4\pi r}{\lambda}\frac{V_R}{V_T} \qquad AF(dB) = 20 * log\frac{9.73}{\lambda} - 10 * \log(G)$$



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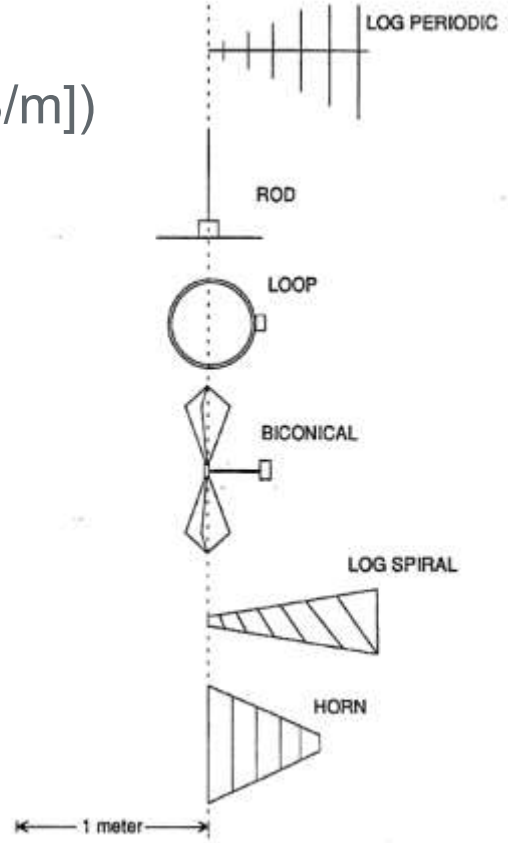


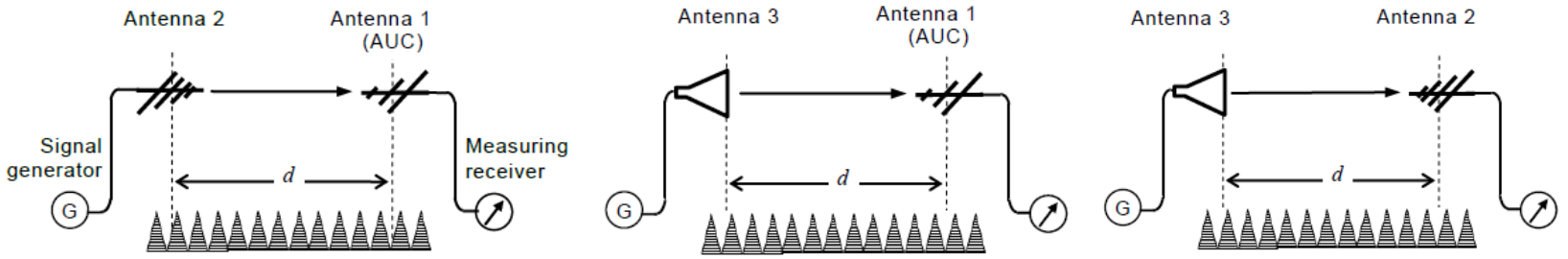
(SAE ARP 958)

Antenna Calibration (SAE ARP 958)

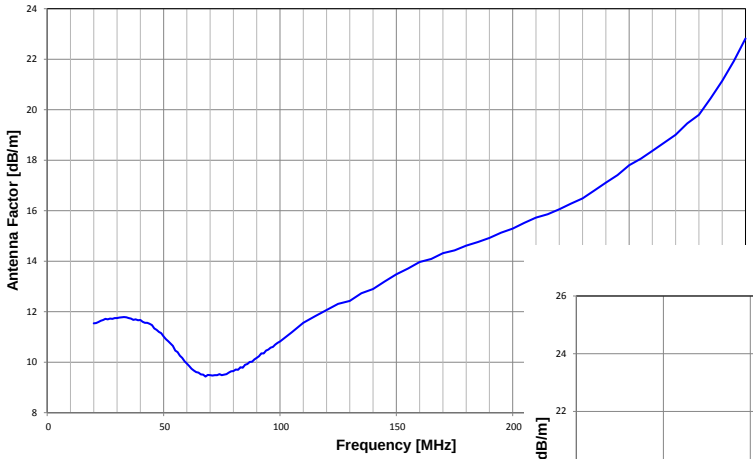
Three antenna method:

- antennas can be different
- 3 measurements: A2-A1, A3-A1, A3-A2

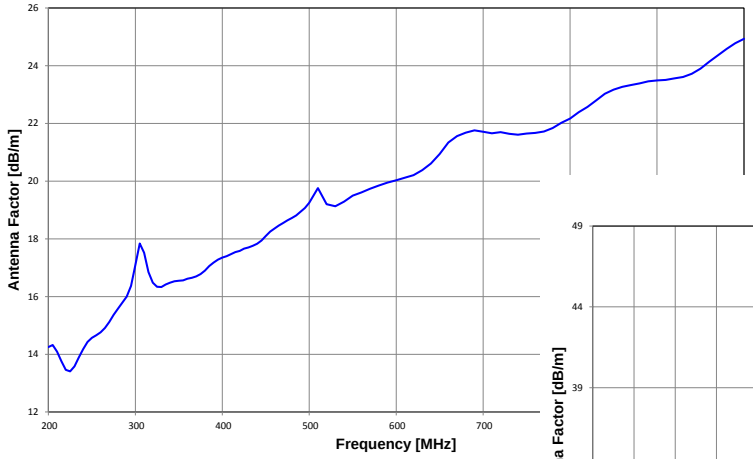
$$AF_1(dB) = 10\log(f_M) - 24.46 + 0.5\,((E_D{}^{max}) + A_1 + A_2 - A_3)$$
$$AF_2(dB) = 10\log(f_M) - 24.46 + 0.5\,((E_D{}^{max}) + A_1 + A_3 - A_2)$$
$$AF_3(dB) = 10\log(f_M) - 24.46 + 0.5\,((E_D{}^{max}) + A_2 + A_3 - A_1)$$



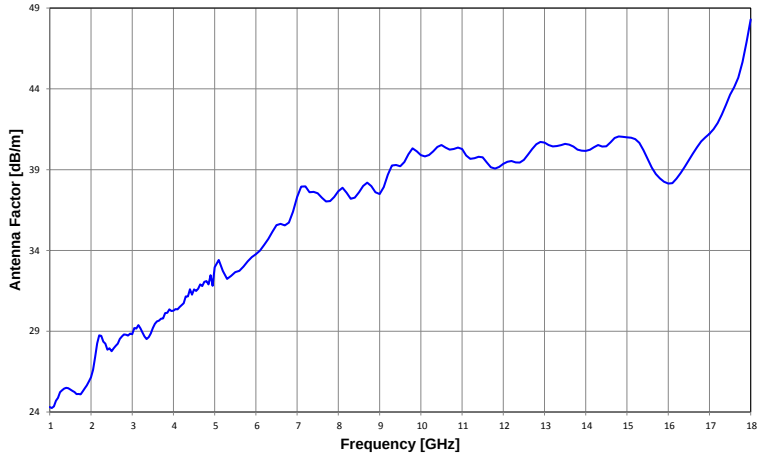
Antenna Calibration (SAE ARP 958)



Biconical antenna



Log. Per. antenna



Horn antenna

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- **LISN Calibration**
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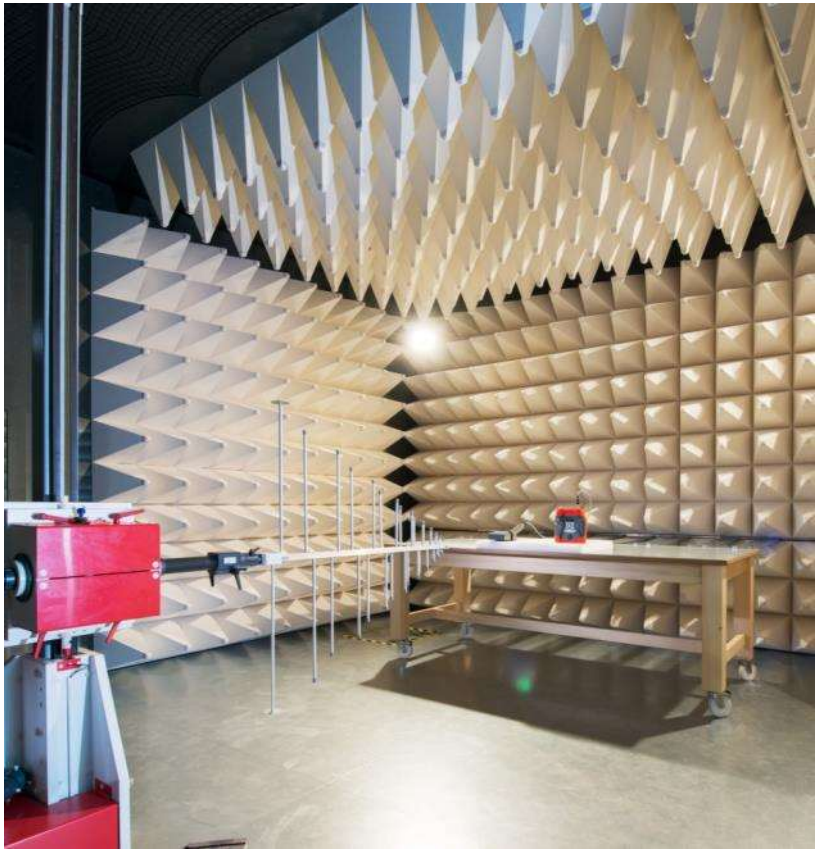
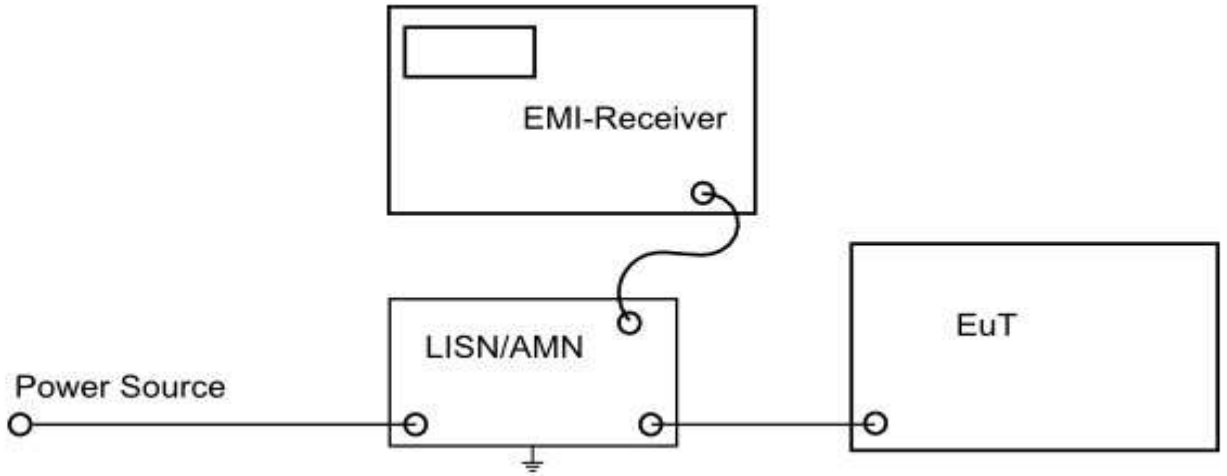


LISN Calibration

- LISN – Line Impedance Stabilization Network
- Used for Conducted Emission Measurement
  - To supply the EUT with proper power
  - To suppress the RF voltage of the mains
  - To conduct the RF voltage to the EMI receiver
  - To terminate the power cord with a defined impedance



LISN - Defined Impedance?

- Impedance between conductor and reference earth
- Device: mains plug
- Automotive components: cable shoe or plug

LISN - Calibration Jig

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LISN - Calibration procedure

- Set vector network analyzer (VNA) to S11
- Perform 1-Port Open-Short-Load calibration
- Connect LISN via calibration jig
- Calculate impedance using

$$\underline{Z} = 50\,\frac{1+\underline{S_{11}}}{1-\underline{S_{11}}}$$

- $\underline{Z}$ is impedance of LISN

LISN - Requirement of CISPR 16-1-2

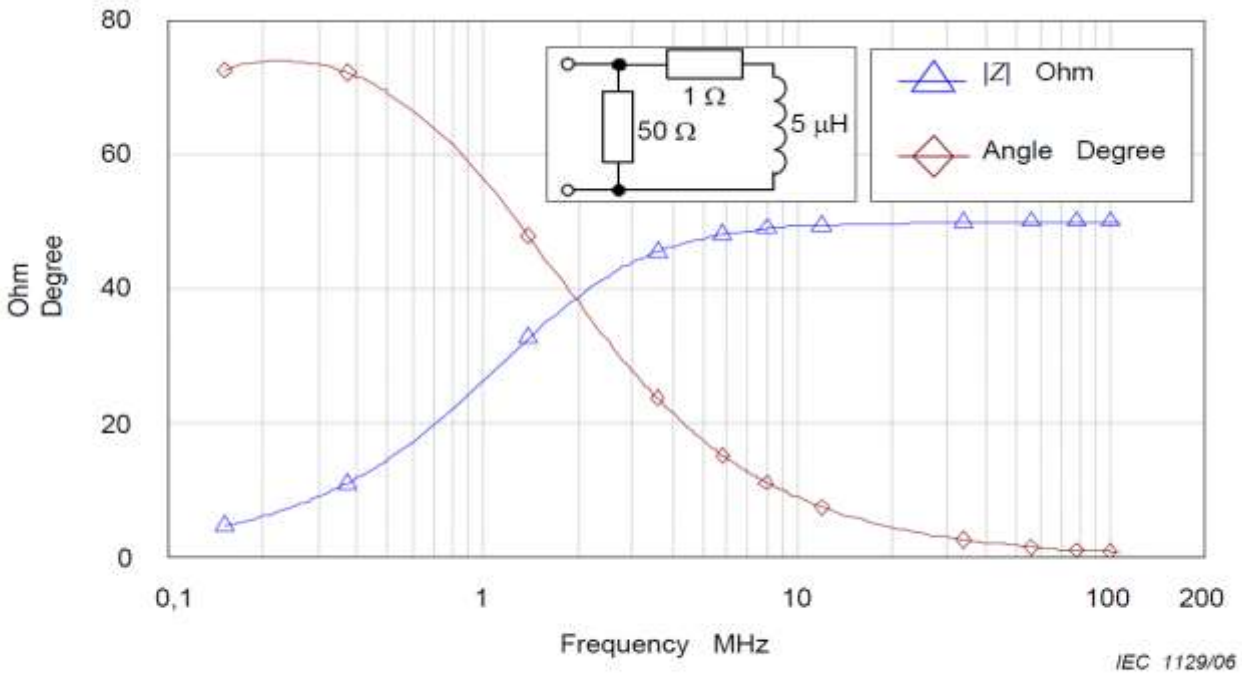


Figure 2 – Impedance (magnitude and phase) of the V-network for bands B and C (from 0,15 MHz to 108 MHz; see 4.5)

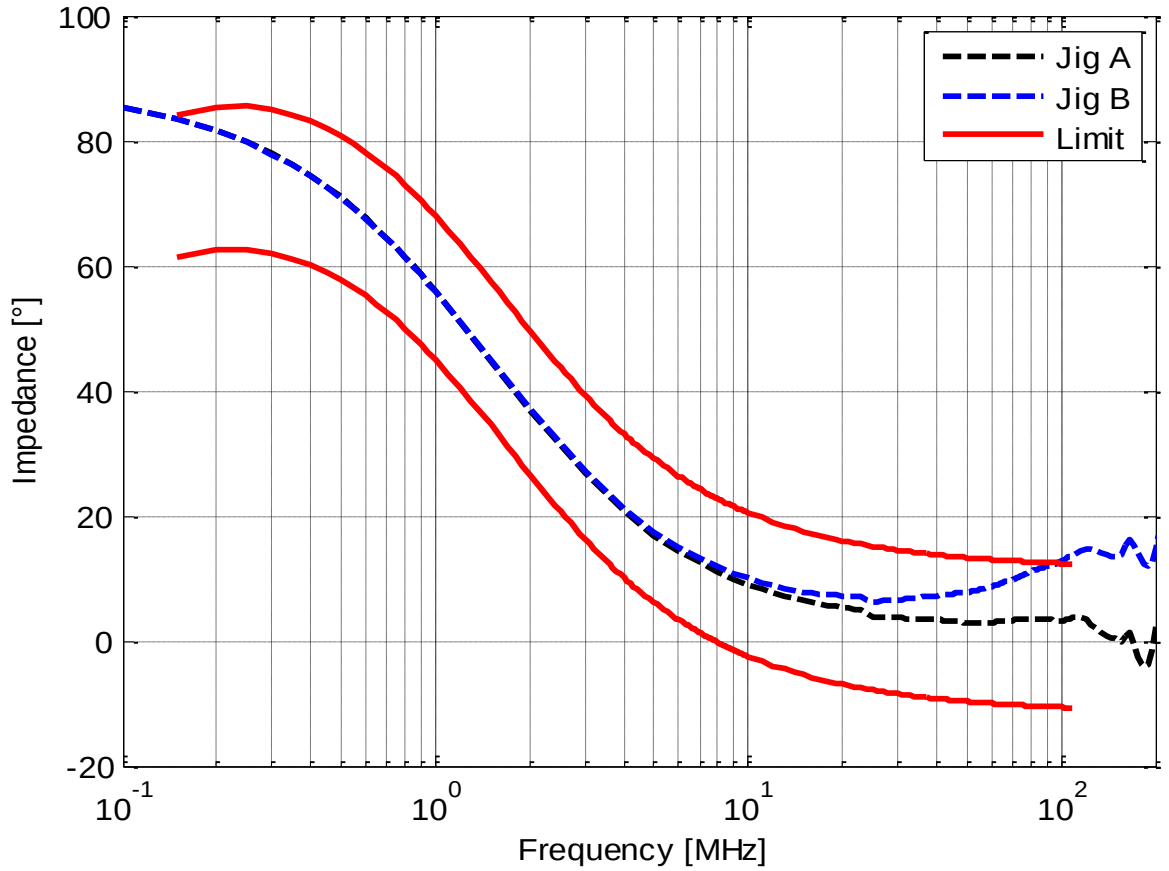
- Tolerance
  - Absolute ± 20 %
  - Phase ± 11.5 °

Ref. [1]

Same Calibration Result if…

- The calibration jig has no influence to the result…
- Everybody uses the calibration jig delivered by the manufacturer of LISN
- Everybody builds the calibration jig according to the design given by the manufacturer in the manual of the LISN
- If the systematic error from the calibration jig is corrected

Different calibration jigs will lead to…

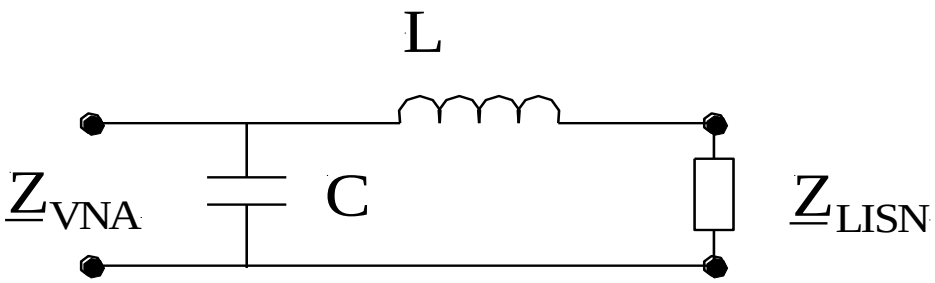


Scientific approach to solve problem

- Definition of the measurand
  - Calibration plane
- Development of a model for the calibration jig
  - Equivalent circuit
- Characterization of equivalent circuit
  - Calculation
  - Measurement
- Correction of systematic error

Correction

- Circuit

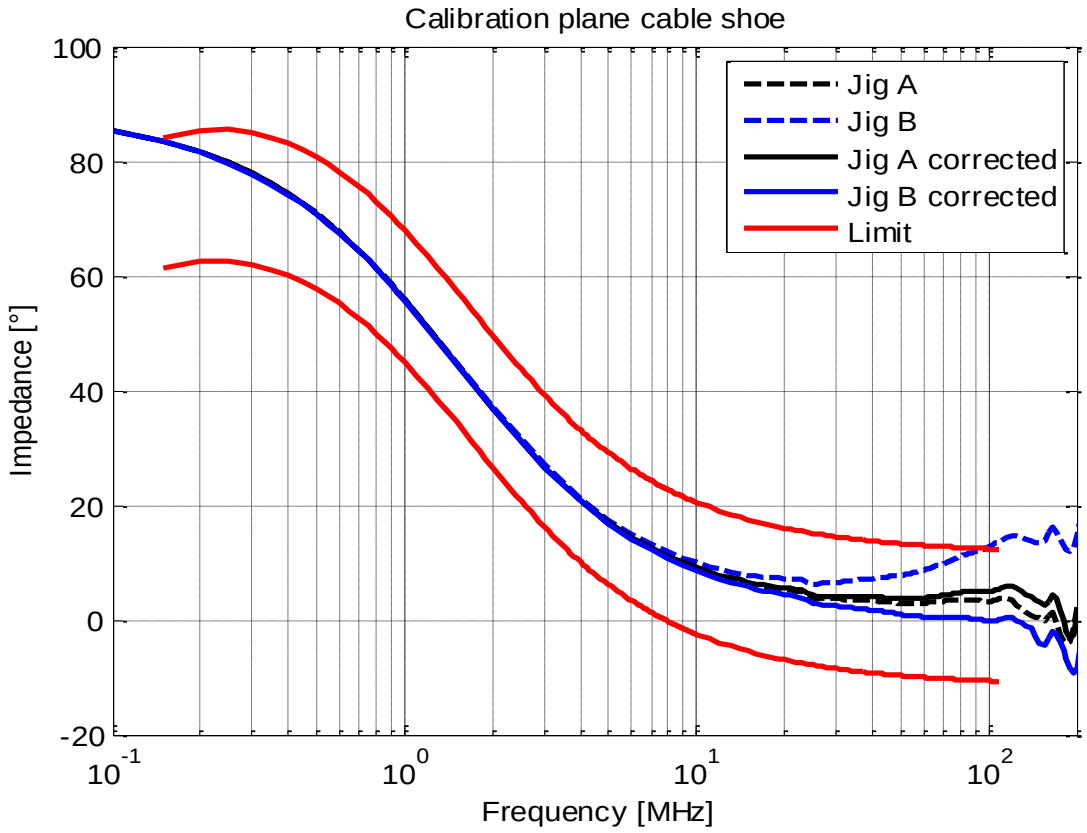


- Formula

$$\underline{Z_{VNA}} = \frac{1}{j\omega C + \frac{1}{j\omega L + \underline{Z_{LISN}}}}$$

$$\underline{Z_{LISN}} = \frac{1}{\frac{1}{\underline{Z_{VNA}}} - j\omega C} - j\omega L$$

Calibration plane: Cable shoe



LISN - Conclusion

- Calibration jig has influence on impedance result
  - Absolute value: small influence
  - Phase: large influence
- Characterization and correction possible
  - Simple C L Model
- Clear definition of the measurand required
  - Impedance
  - Calibration plane

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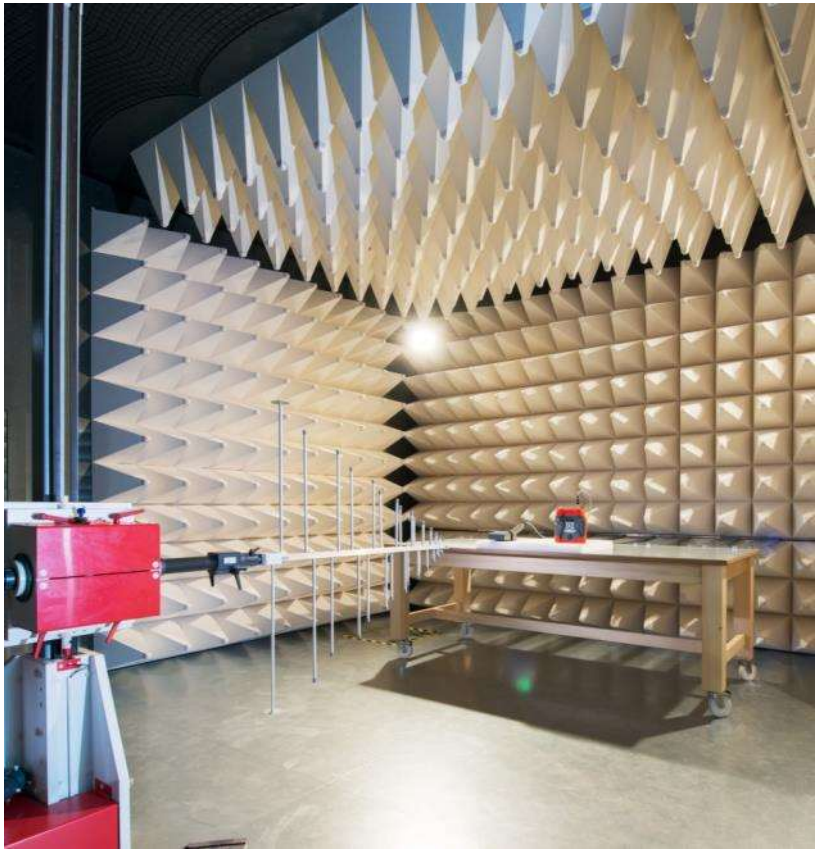

Field Probe Calibration

Calibration factor versus frequency

Calibration factor for different orientations

Isotropy test (setup depends on use of probe)

Frequency combinations (user defined)

Linearity at a certain frequency (user defined)

Calibration Methods

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- Calibration using **calculated field strengths**.

  The field sensor under test is placed in a calculated reference field based on the geometry of the field source and the field source's measured input parameters.

- Calibration using a **primary standard (reference) sensor**

  that contains no active or passive electronic devices and has its calibration traceable to a national standards laboratory based on international standards.

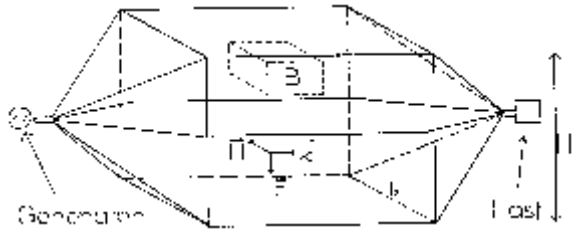
- Calibration using a **transfer standard**

  (a field sensor similar to the one being calibrated), that has traceability to a national standards laboratory.

Calibration Methods

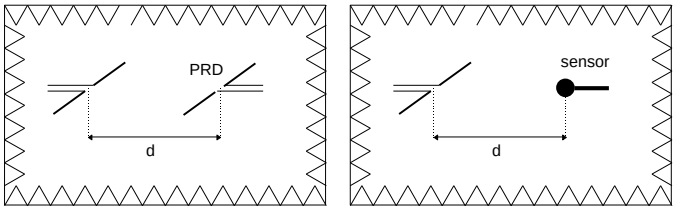
- Calibration using **calculated field strengths**.

  → **TEM Cell**



- Calibration using a **primary standard (reference) sensor**

  → **Precision Reference Dipole**



- Calibration using a **transfer standard**

  → **Substition Method**

Calibration Methods

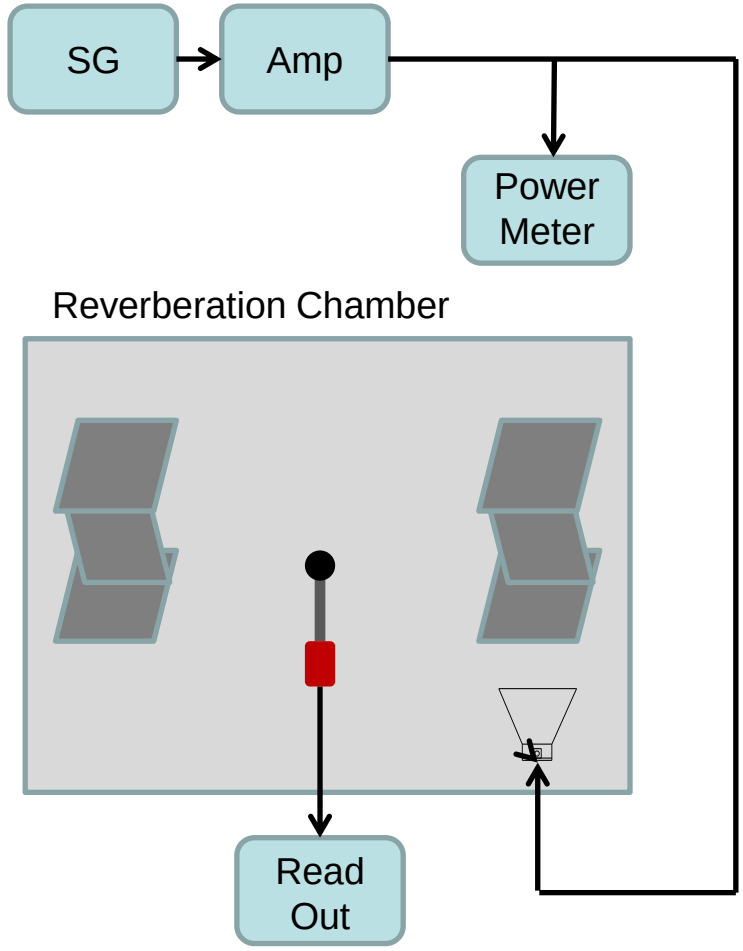
- Methods deliver relatively **low field strength**
- Automotive Company **standards require higher field strength**:
  - EMC-CS-2009.1 (Ford)
  - STD 515-0003 (Volvo)
  - GMW 3097 (GM)
  - GS 95002-2_07_2013 (BMW)
  - …

- → Solution: **Reverberation Chamber**

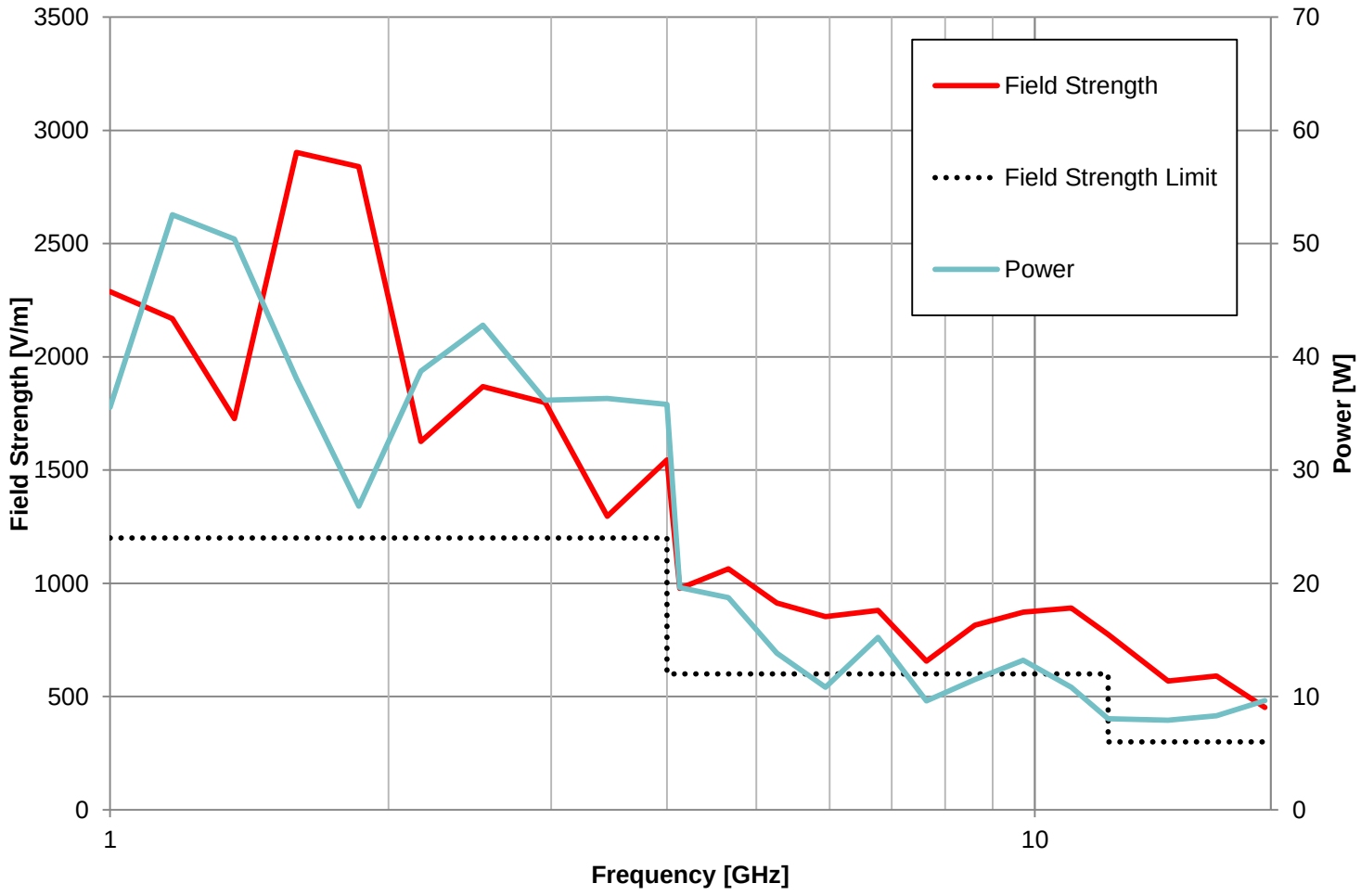
  High field strength resulting from repeated reflections from the conducting surfaces is a superposition of plane waves

Reverberation Chamber (RC)

SEIBERSDORF LABORATORIES



Reverberation Chamber (RC)



Achievable Field Strength:

1 – 4 GHz:
1200 V/m

4 – 12 GHz:
600 V/m

12 – 18 GHz:
300 V/m

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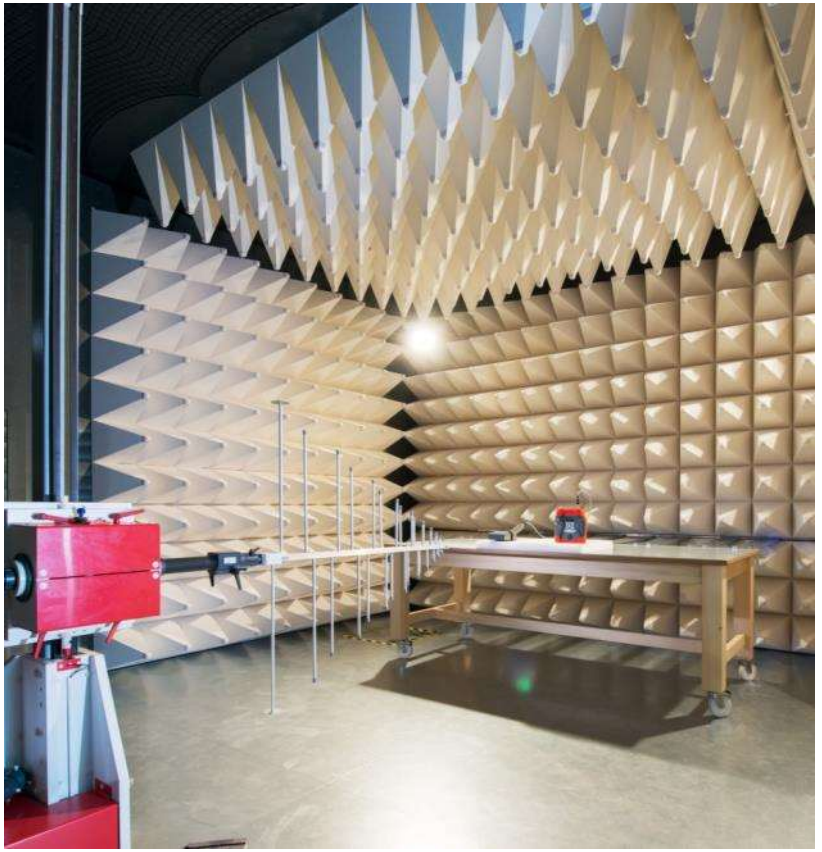


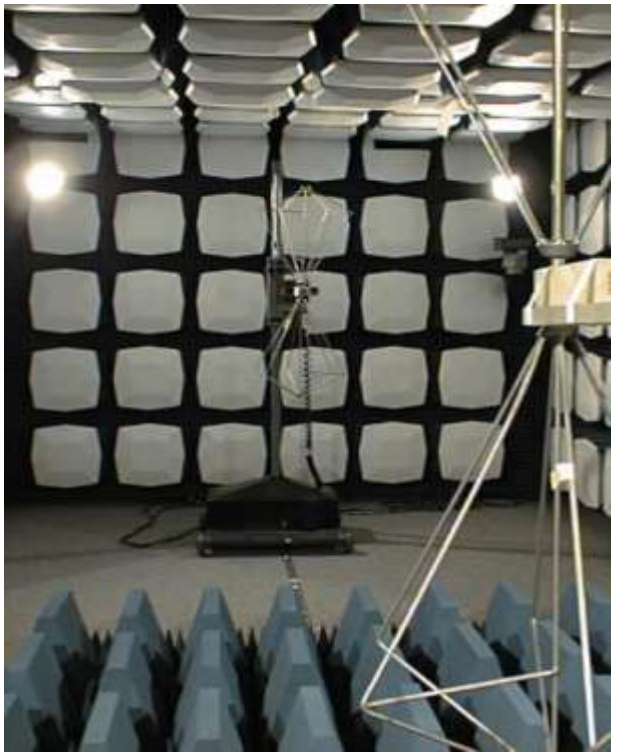
What is a System Check ?

A System Check is a quick and reliable method to increase the confidence in measurement results of the test engineer the test lab and the customer.

It detects failures in the measurement system: receive antenna, pre-amplifier, cable, spectrum analyzer, measurement software.

Comb generator is the ideal source for **emission tests**:

- Antenna
- Antenna Coupler
- LISN Coupler



SEIBERSDORF LABORATORIES

System Checkout Procedure

- Primary reference measurement
- Regular check measurement and computation of the difference to the reference.
- If deviation is less than a threshold the setup is OK otherwise the cause needs to be investigated.

RefRad X: Comb Generator & Field Source

3 Unique Features:

Generator is built into an antenna
⇨ field source with calculable radiation performance

Fibre Link for synchronization of generator and receiver
⇨ 30 dB more dynamic range

Frequency range starts from 10 kHz
⇨ system check for LISNs

The Antenna Coupler

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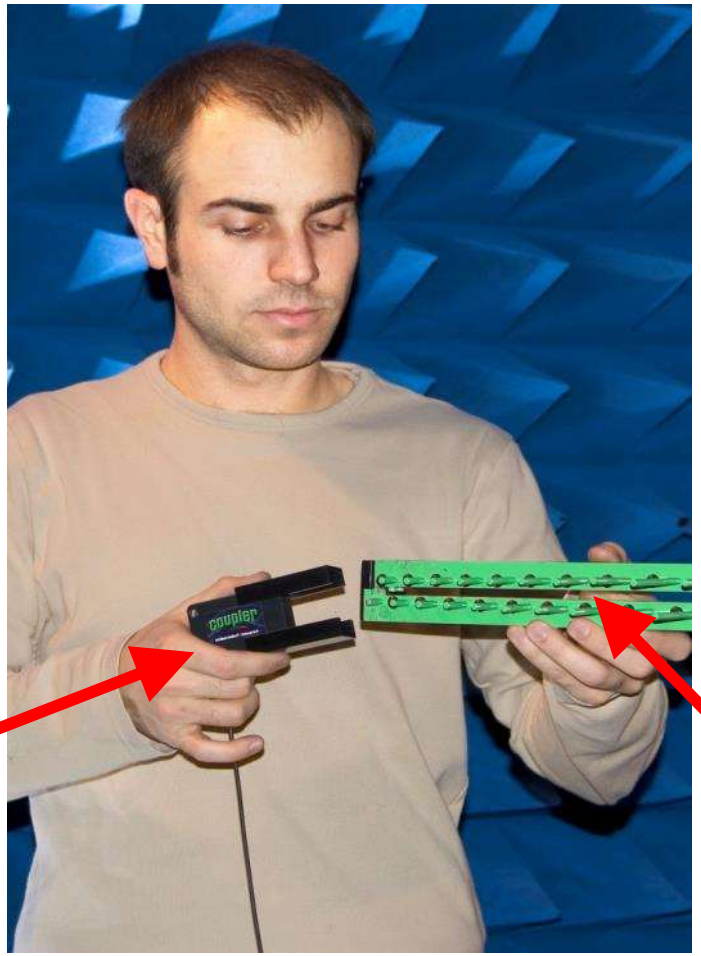
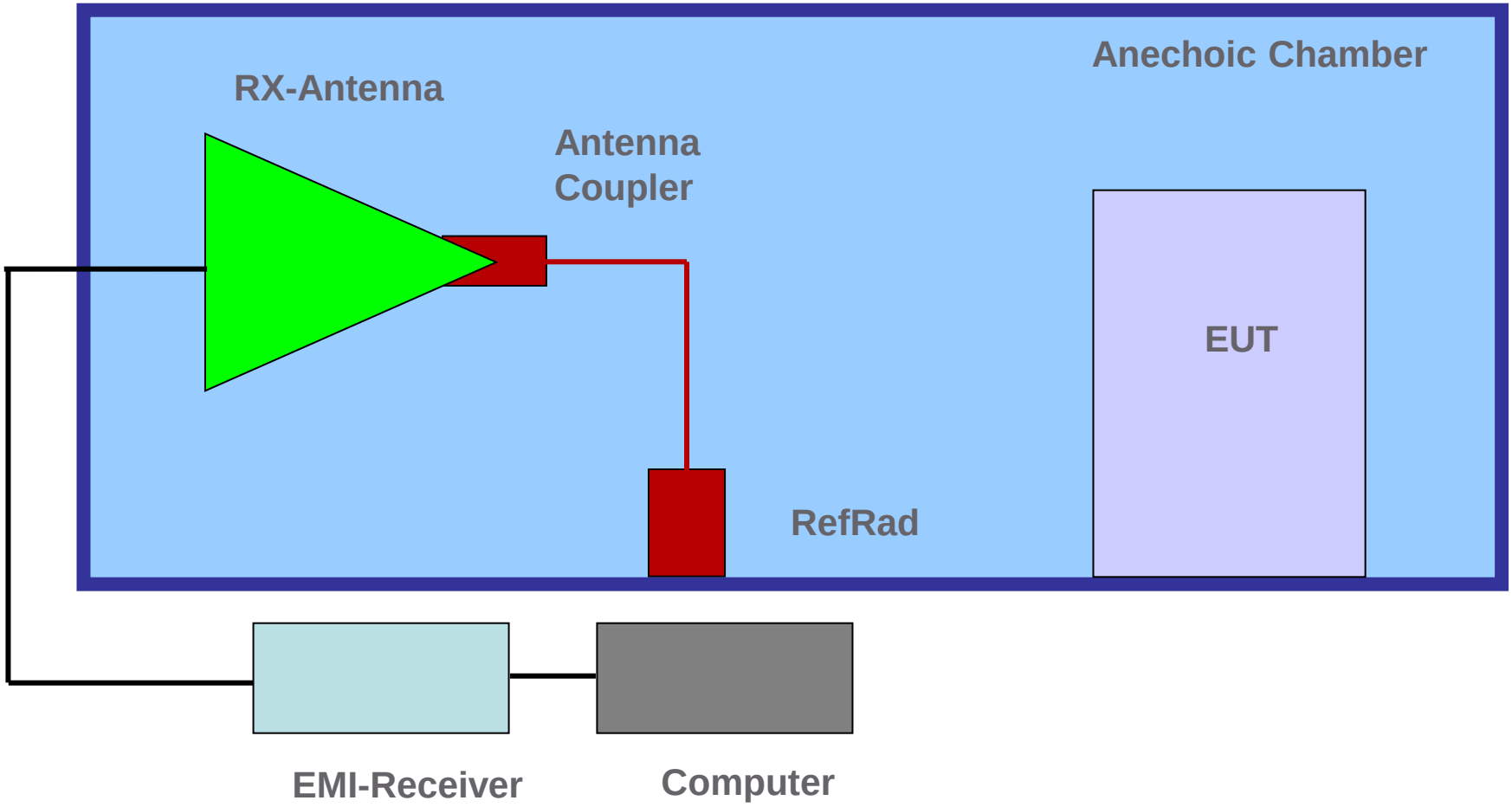
- Small dipole antenna
- Mechanically well defined positioning
- Close proximity to receive antenna



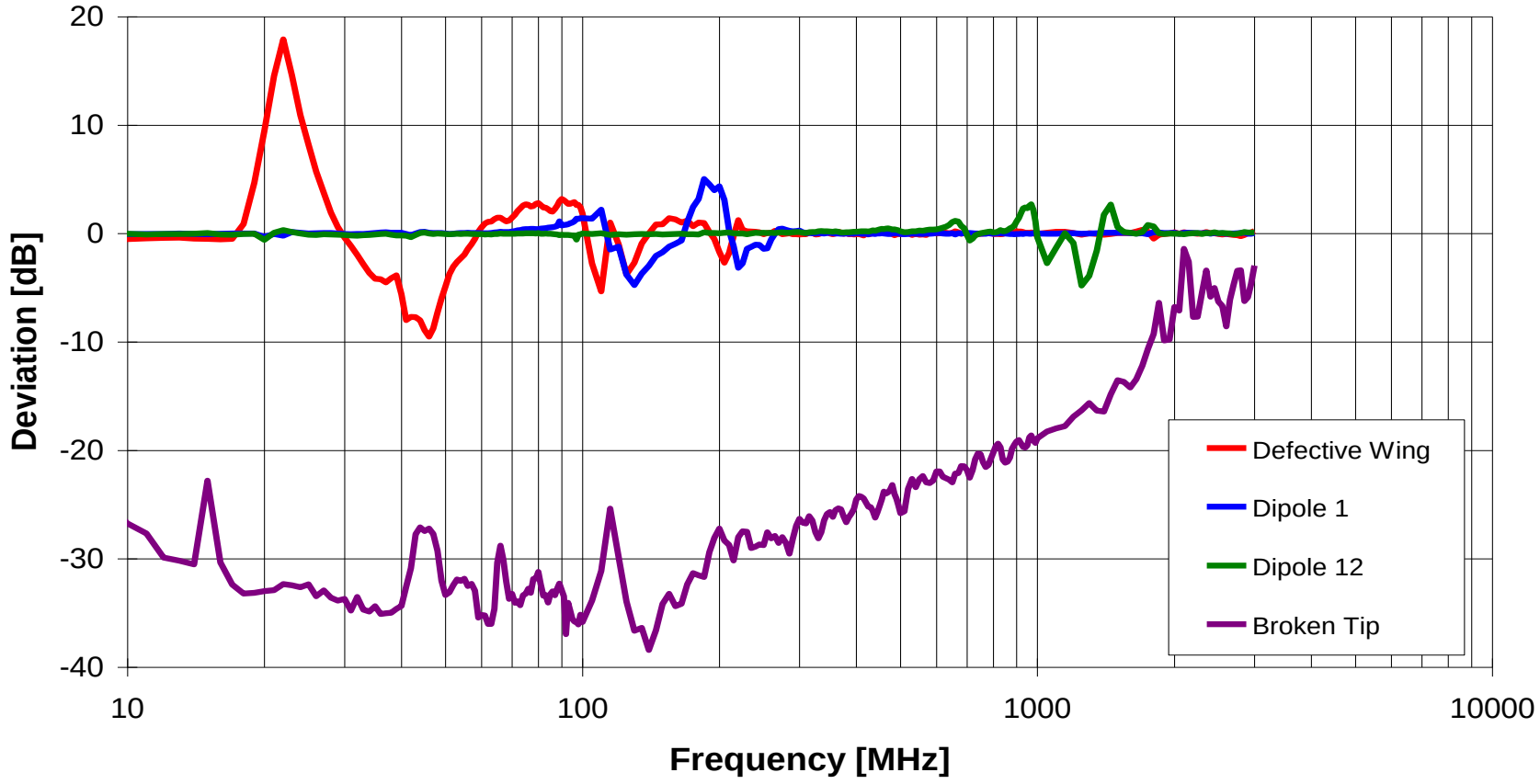
Antenna Coupler

Antenna

Setup


Anechoic Chamber
RX-Antenna
Antenna
Coupler
EUT
RefRad
EMI-Receiver
Computer

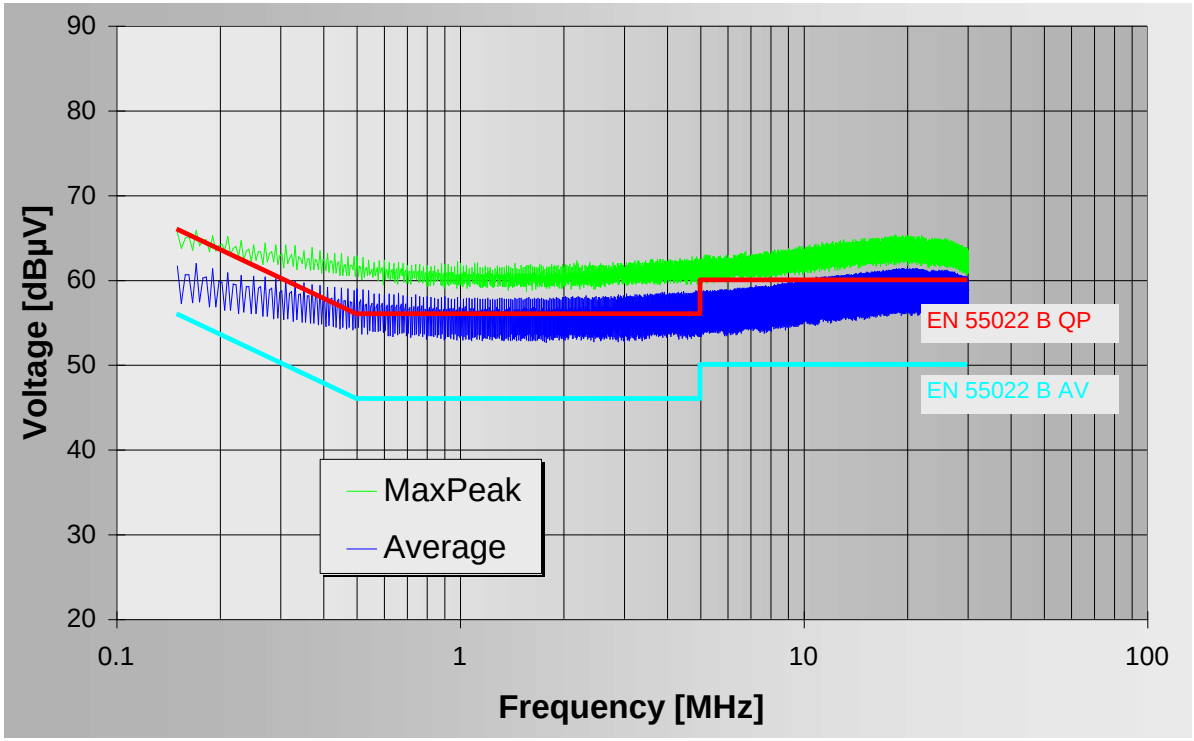
System Check Results



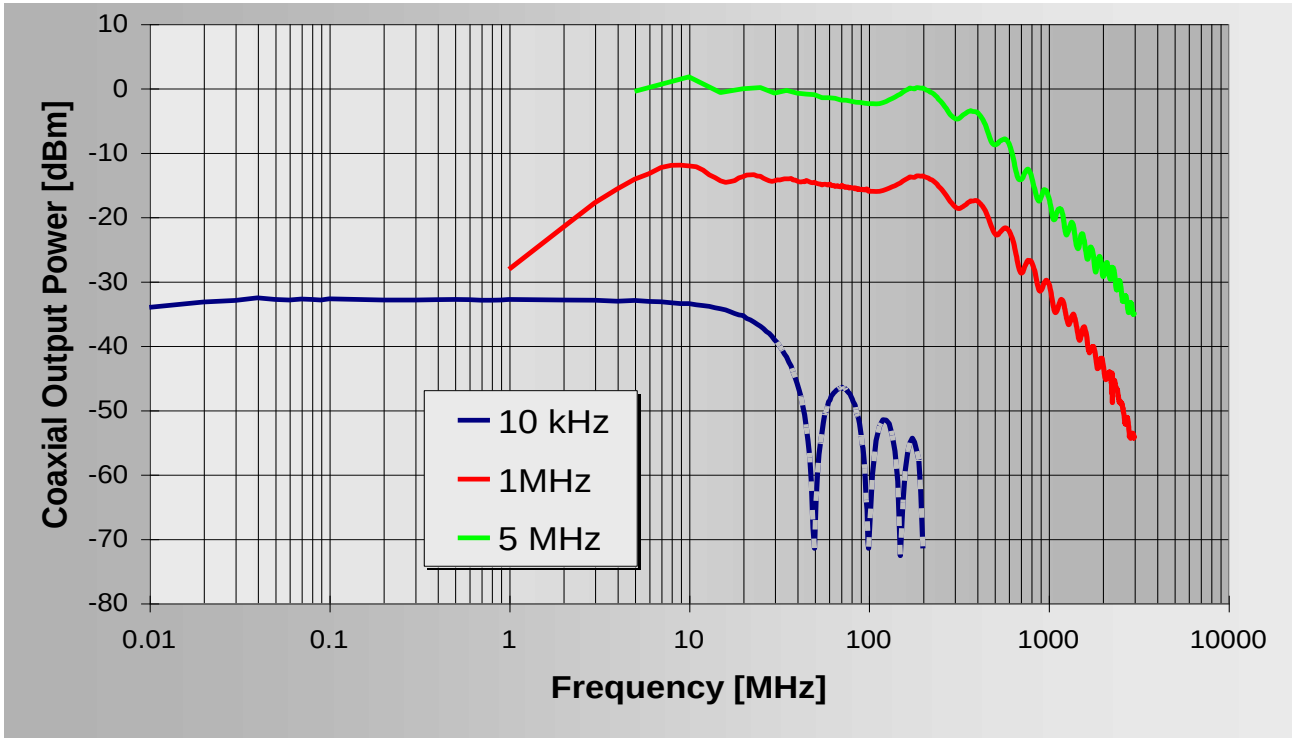
System Checkout Procedure for CE-Test

- Primary reference measurement
- Regular check measurement and computation of the difference
- If deviation is less than a threshold the setup is OK otherwise the cause needs to be investigated.

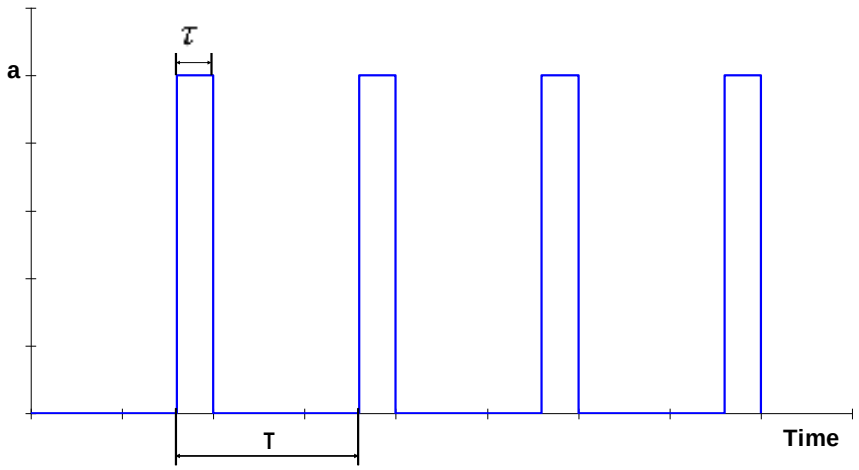
2-Phase LISN Coupler

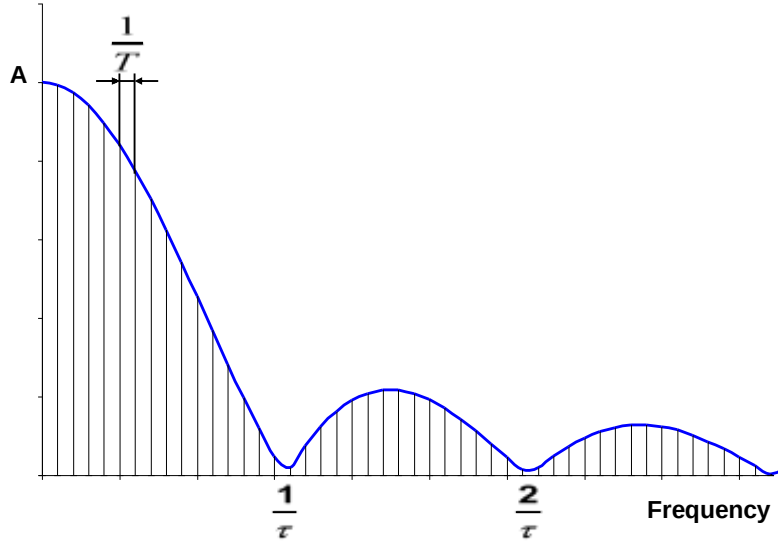


RefRad X: Output Signals



Time and Frequency Domain





How to Measure the Comb Spectrum

EMI Receiver

- Set: f_start, f_stop, f_step, RBW
- No control software required

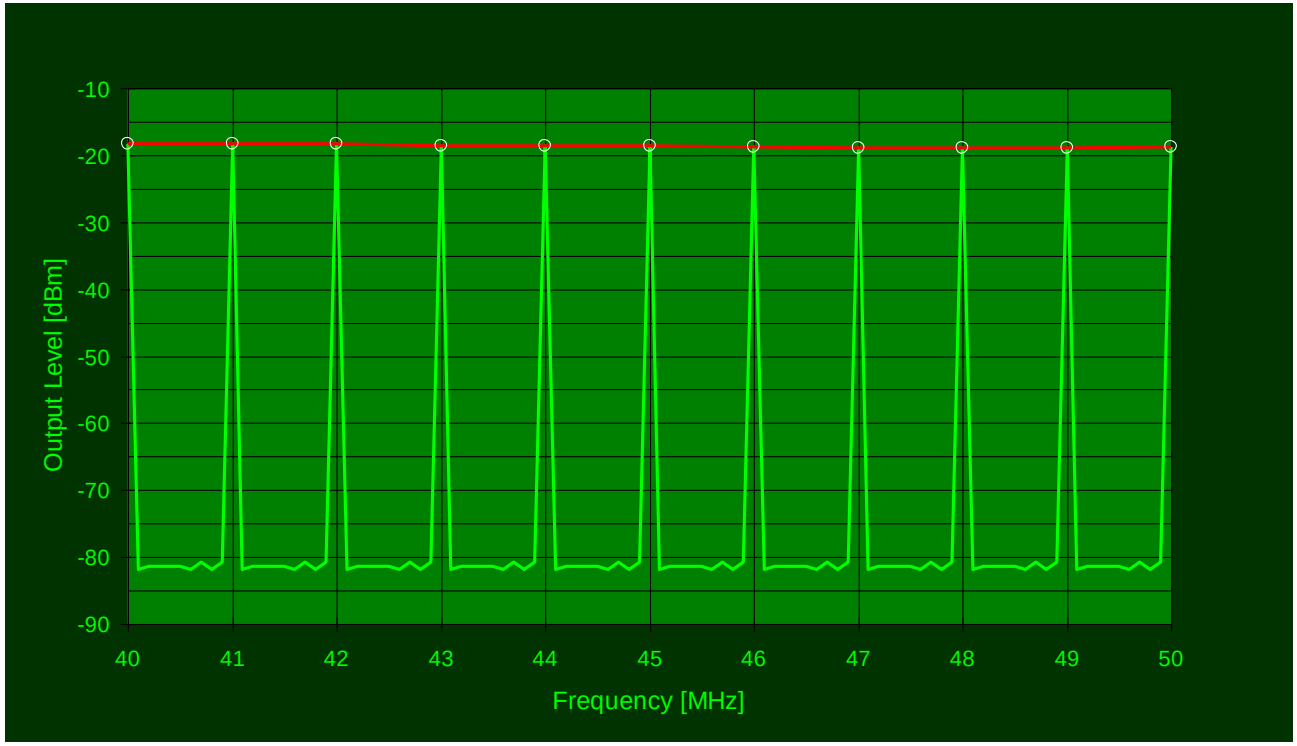
Spectrum Analyzer

- Set: span, RBW
- Control software sets f_center and reads marker

ONLY the amplitude at the comb peaks is relevant !!!

SEIBERSDORF LABORATORIES

Measurement of Comb Spectrum



Frequency Accuracy of Comb Generators

Comb Generator:

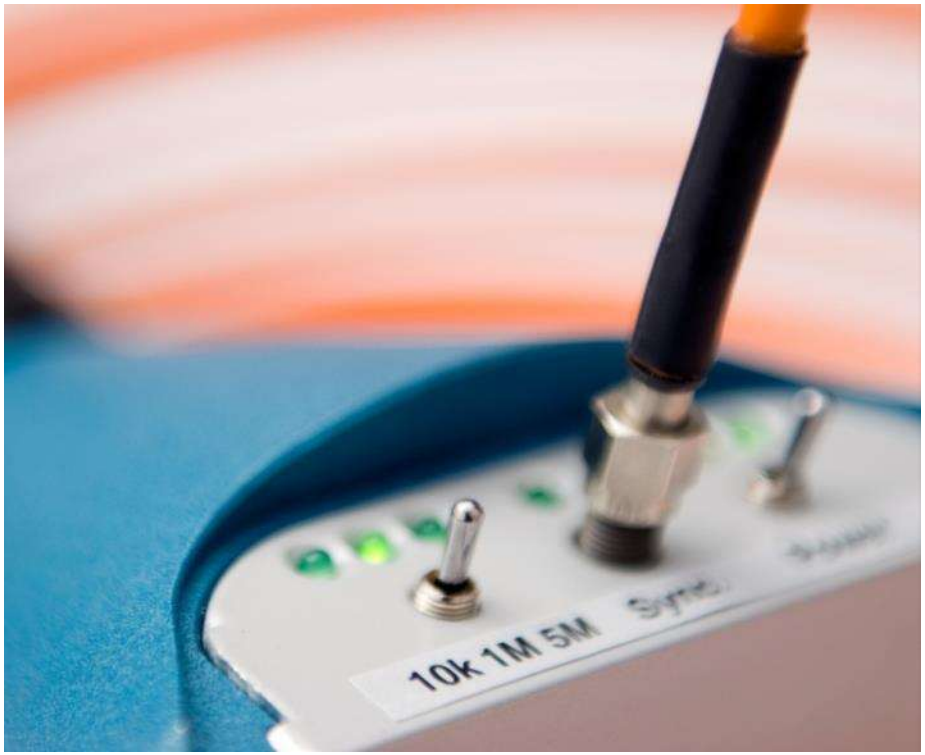
- 1 MHz crystal with 50ppm accuracy
  ⇨ **150 kHz** at 3 GHz

EMI Receiver:

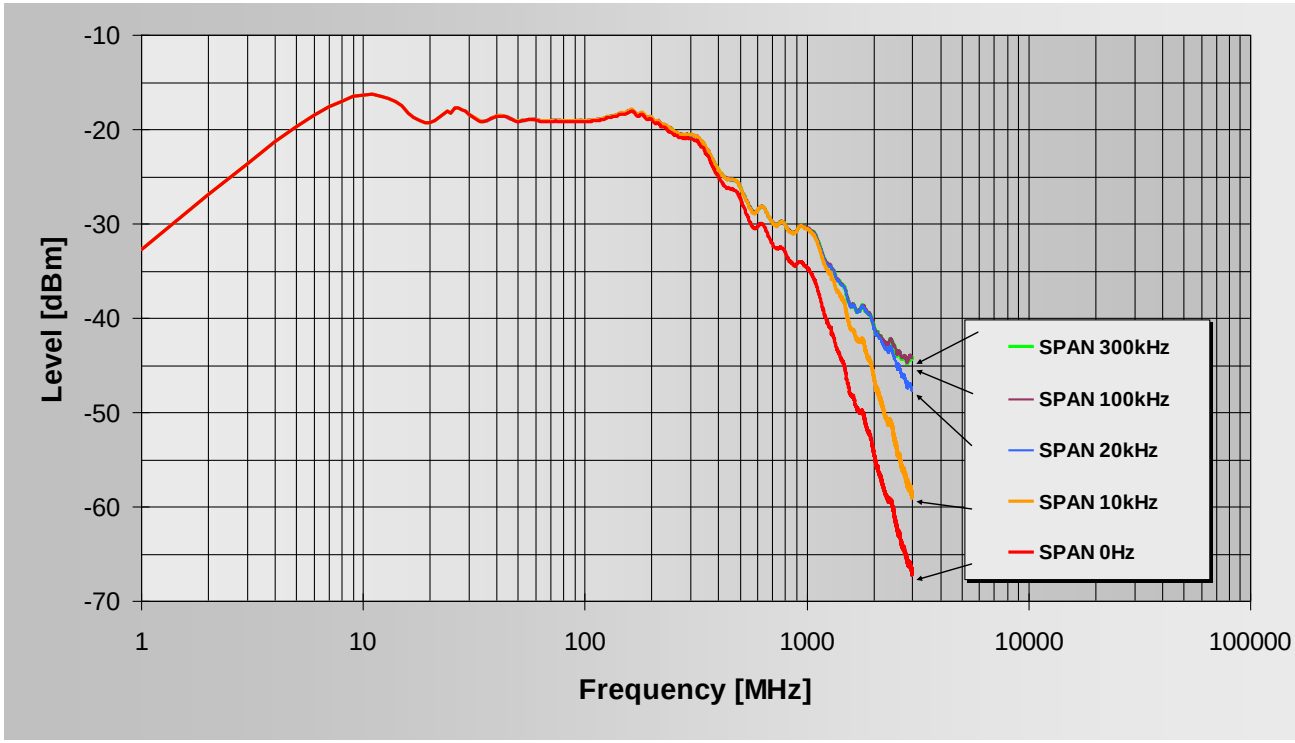
- RBW > 150 kHz

Spectrum Analyzer:

- RBW > 150 kHz, zero span
- RBW <<, span > 150 kHz
  good for low signal amplitude



Error Caused by Frequency Offset (RBW <<)

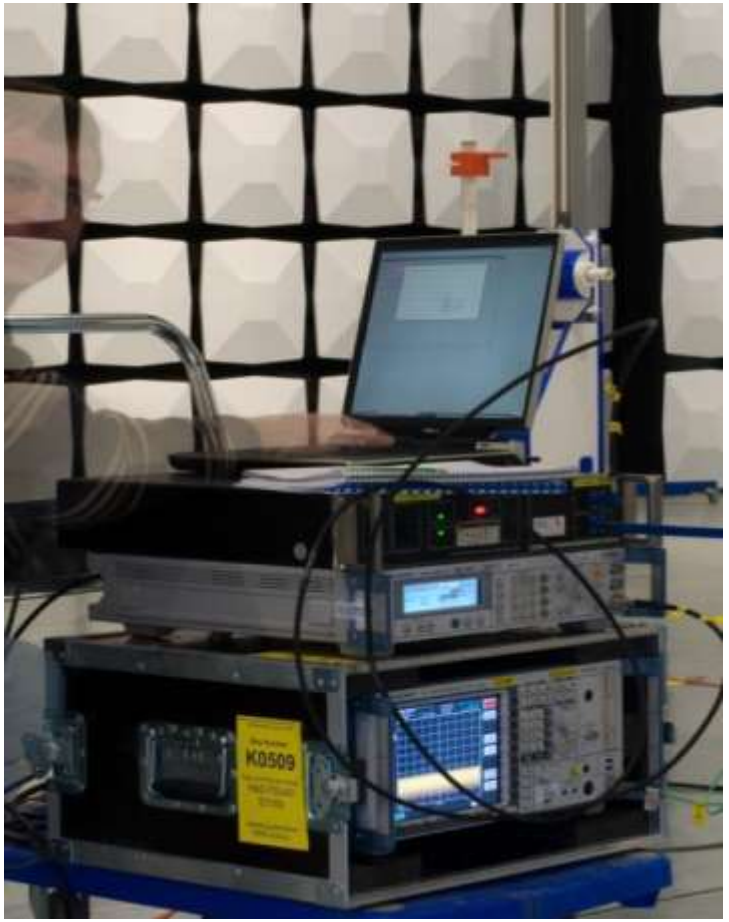


RBW Considerations

Large enough –
to measure the whole spectral energy of each pulse

Small enough –
to measure only one pulse

When changing the RBW within the suitable range the reading is nearly invariant



System Check

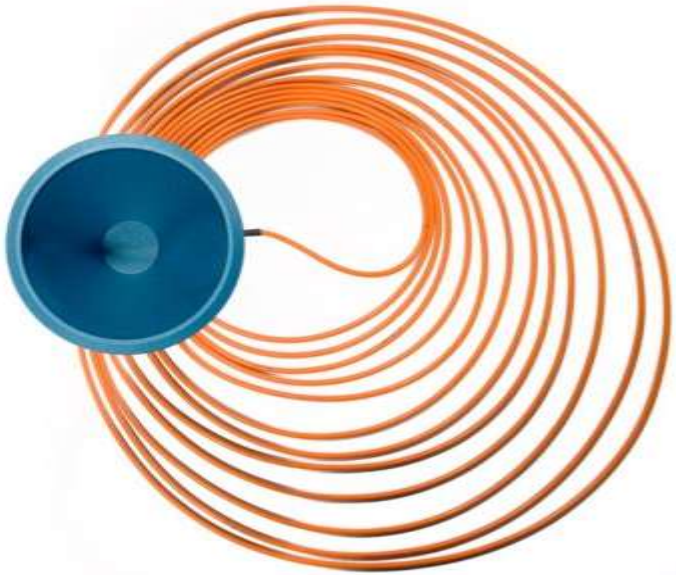
Comb generator is a powerful measurement tool

Special care on measurement settings of receiver

- bandwidth
- span
- amplitude

RefRad X offers 3 unique advantages

- Generator is built into an antenna
  ⇨ field source with calculable radiation performance
- Fibre Link for synchronization of generator and receiver
  ⇨ 30 dB more dynamic range
- Frequency range starts from 10 kHz
  ⇨ system check for LISNs




Thank you very much for your attention!

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