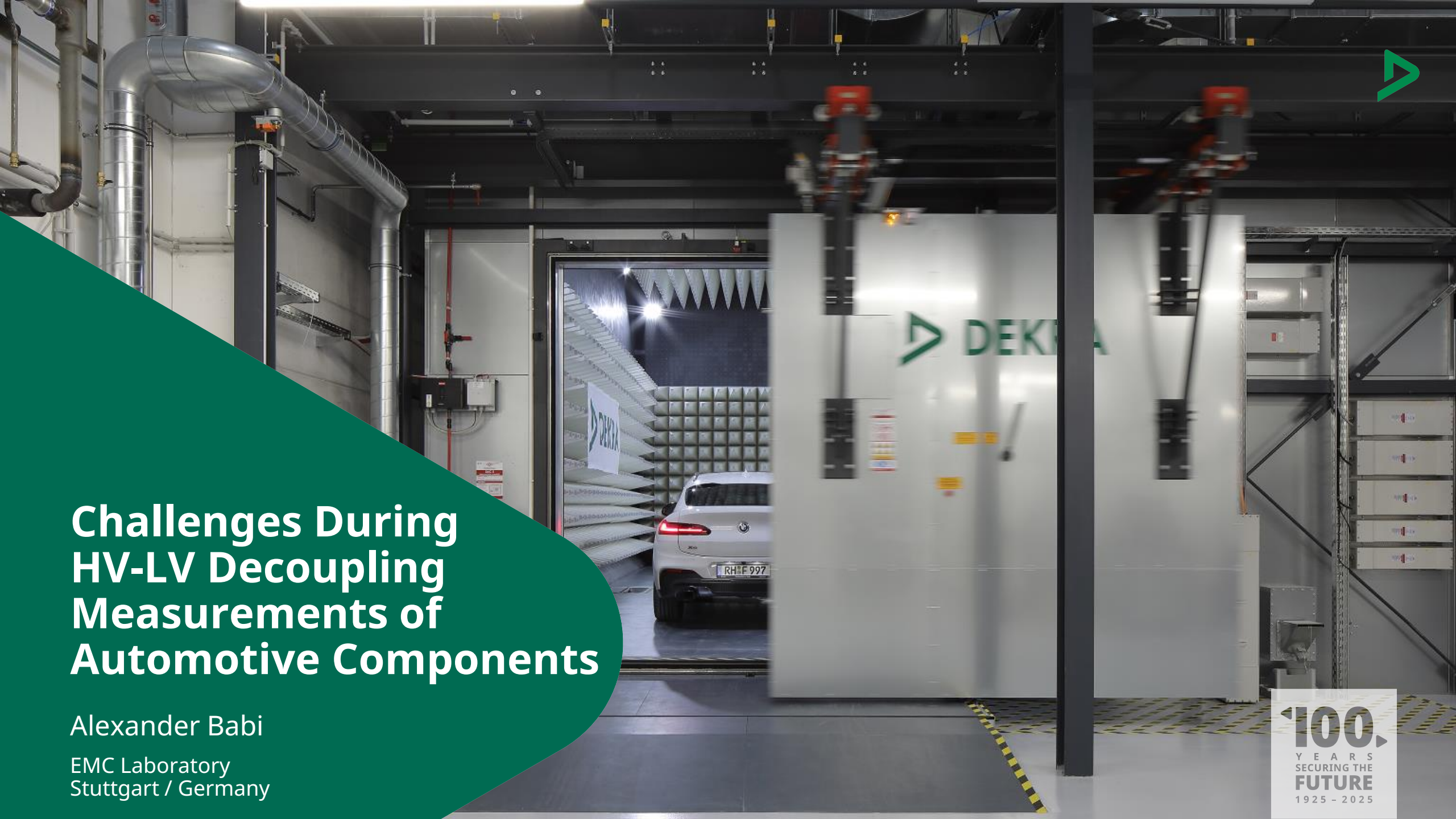

Challenges During HV-LV Decoupling Measurements of Automotive Components

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100 YEARS SECURING THE FUTURE 1925 – 2025

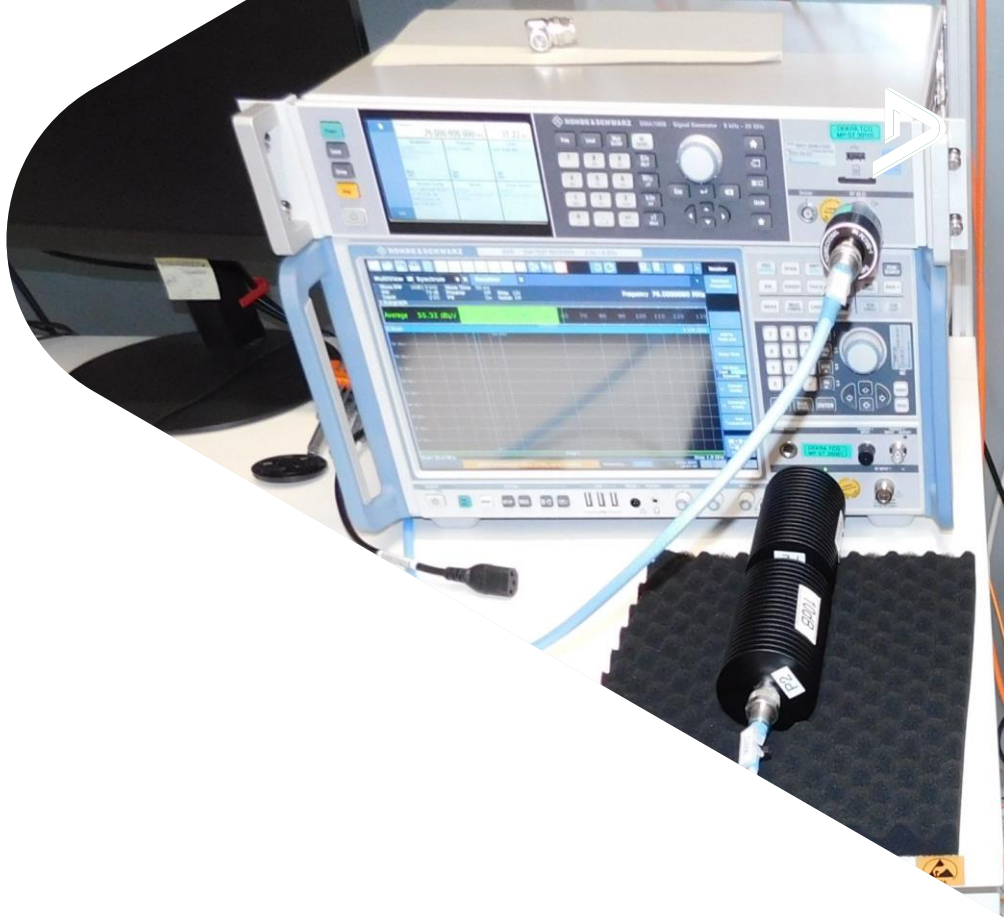
Agenda

100 YEARS SECURING THE FUTURE 1925 – 2025

Introduction

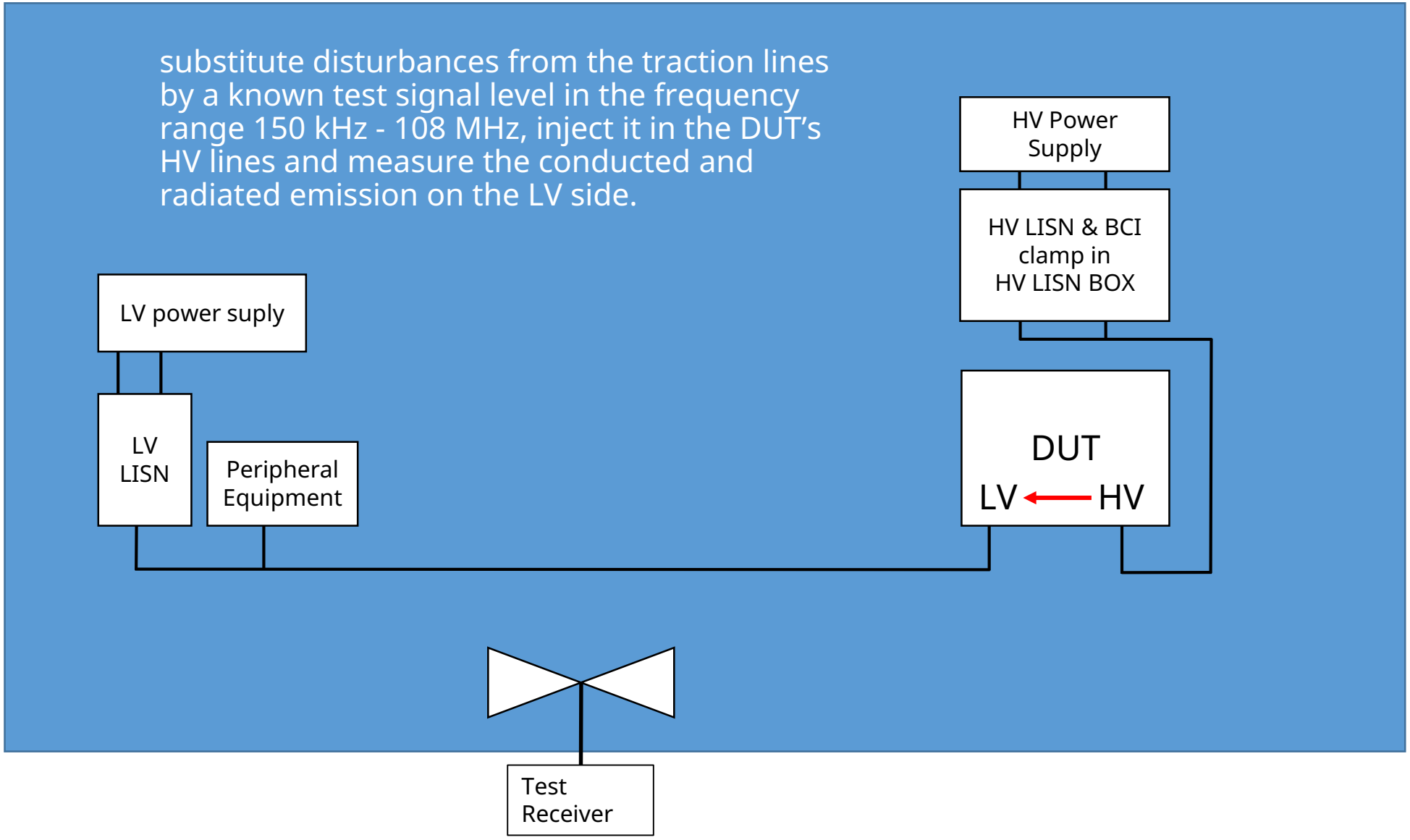
- In electric vehicles low voltage (LV) and high voltage (HV) devices are located in the same environment
- HV devices do all have LV interface(s) in order to operate e.g. gate driver of inverter, CAN communication, sensors, µ-chips
- In HV component dU/dt is very high. Occurring EMC interferences are much more significant than those in LV system
- As EMC design in LV components is developed for lower interferences levels compared to HV part, coupling from HV side to LV side would cause uncontrollable EMC issues in LV system and thus propagate in the complete vehicle
- As a result strong decoupling between both the LV and HV side is mandatory to fulfill the general OEM’s requirement

Note: although the HV-LV decoupling method can be mandatorily required, most OEMs are aware that the results can only be used as indicators and will not compulsorily prevent vehicle tests.



General Consideration

Set-up schematic



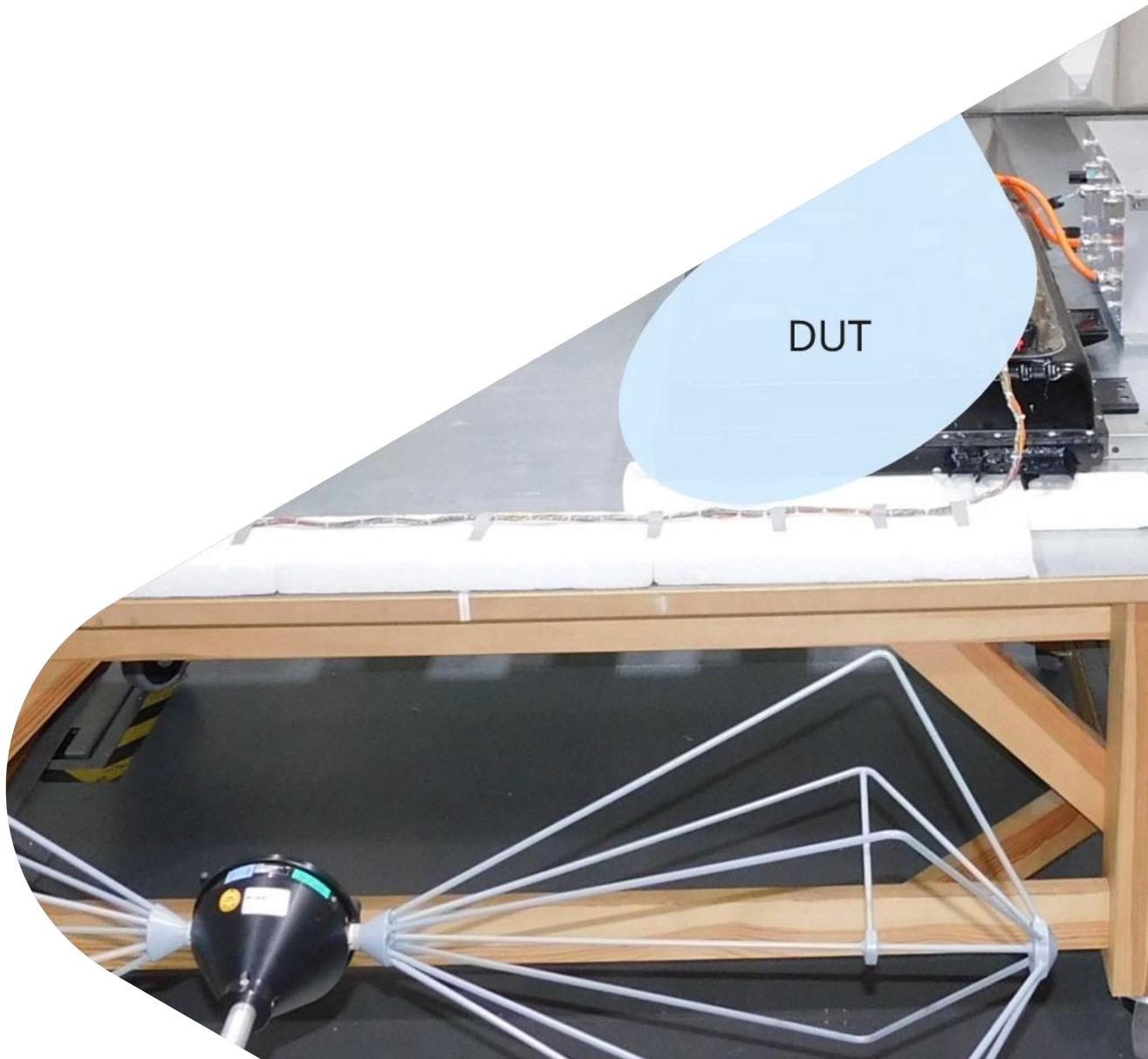
General Consideration

Test sequence

- In order to reach the goal of measuring the disturbances coupled from the HV side into the LV side, preparative tests have to be done.
- These preparative tests uncover weak set-up and DUT own disturbances that in case of disregard leads to wrong interpretation of results.

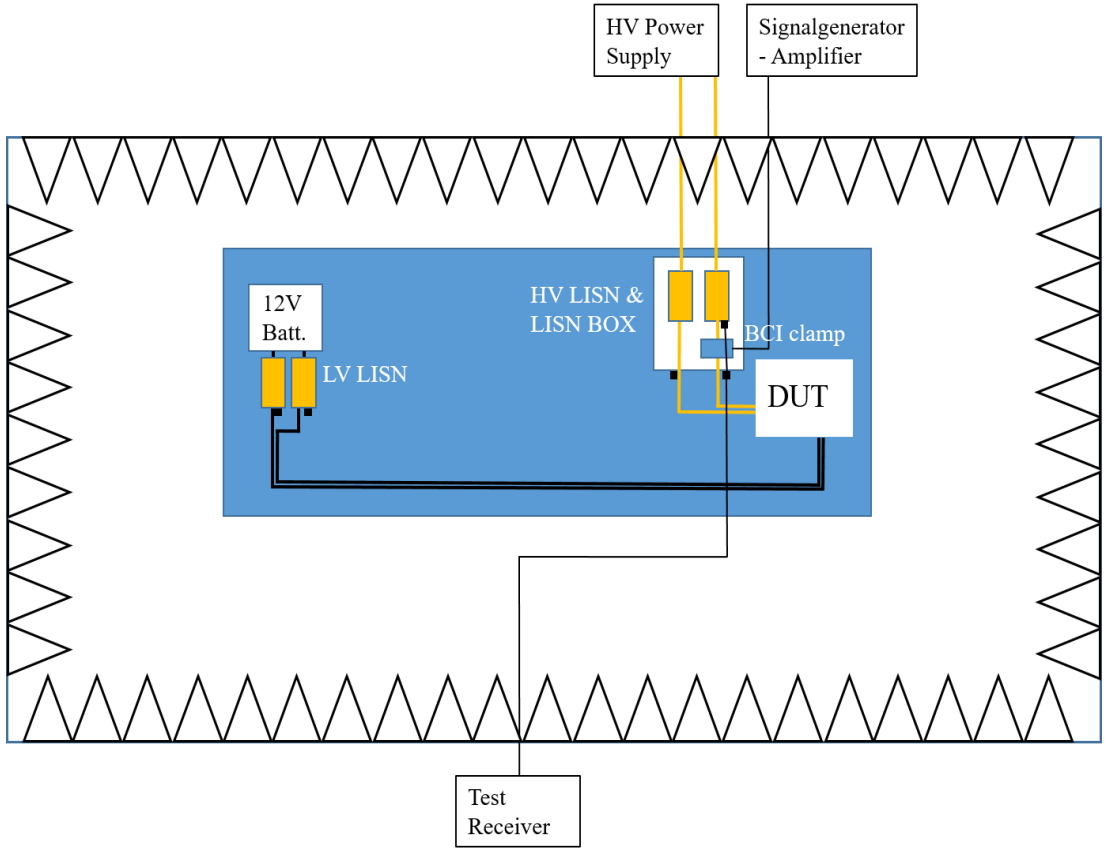
A meaningful test sequence is:

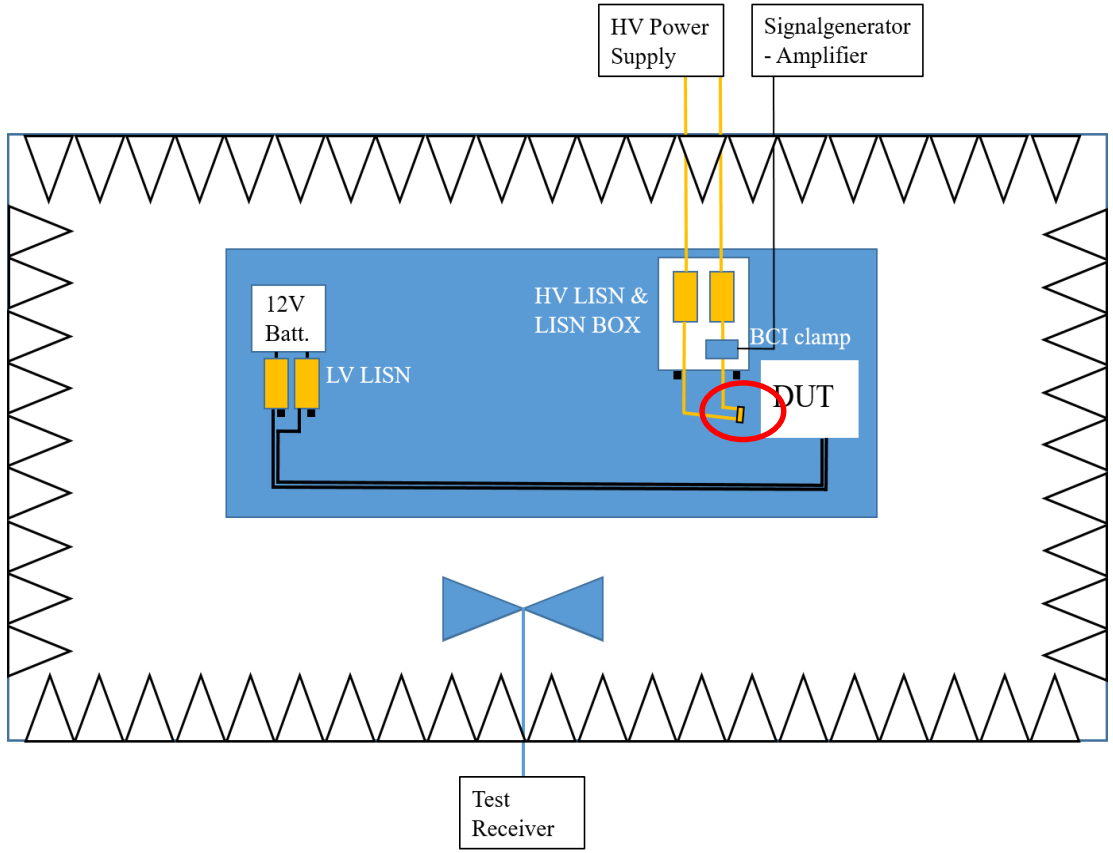
1. Calibration of test signal
2. Determine reference measurement without DUT
3. Determine DUT own disturbance emissions
4. Determine HV-LV decoupling



Measurement Procedure and Test Set-up

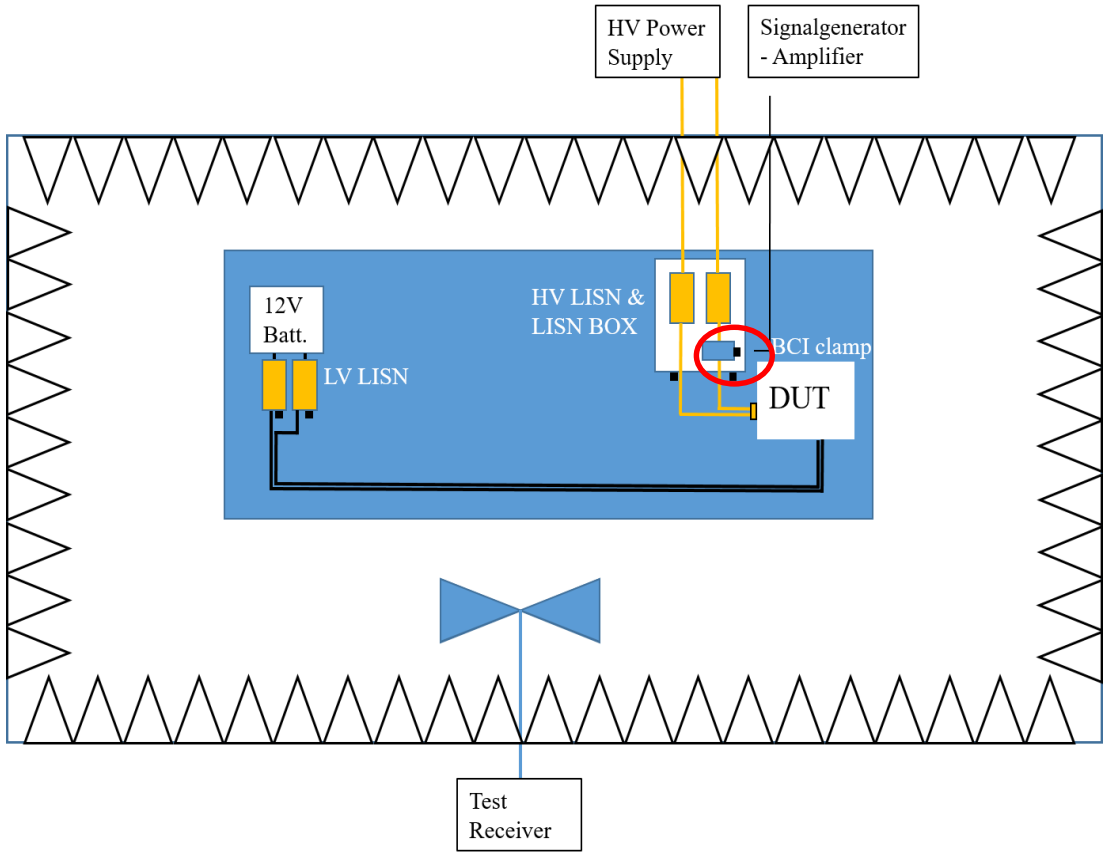
1: Calibration of test signal (left), 2: reference measurement without DUT (right)

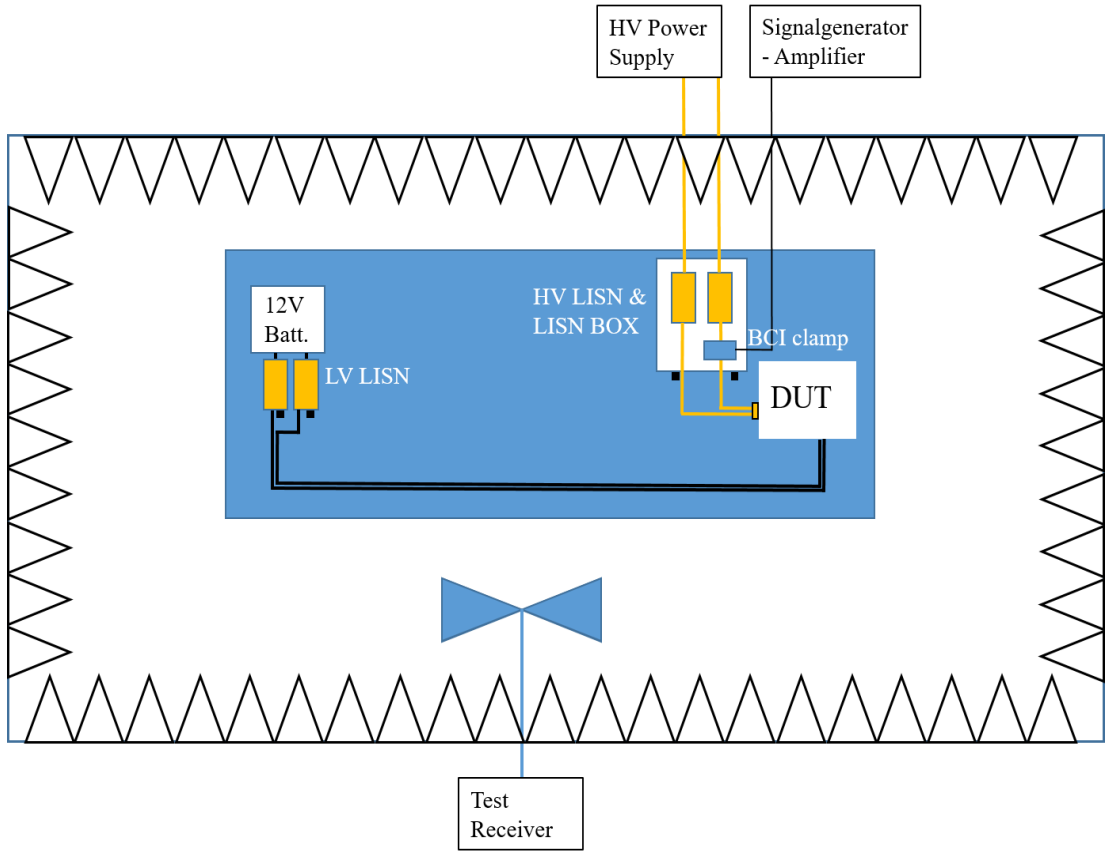




Measurement Procedure and Test Set-up

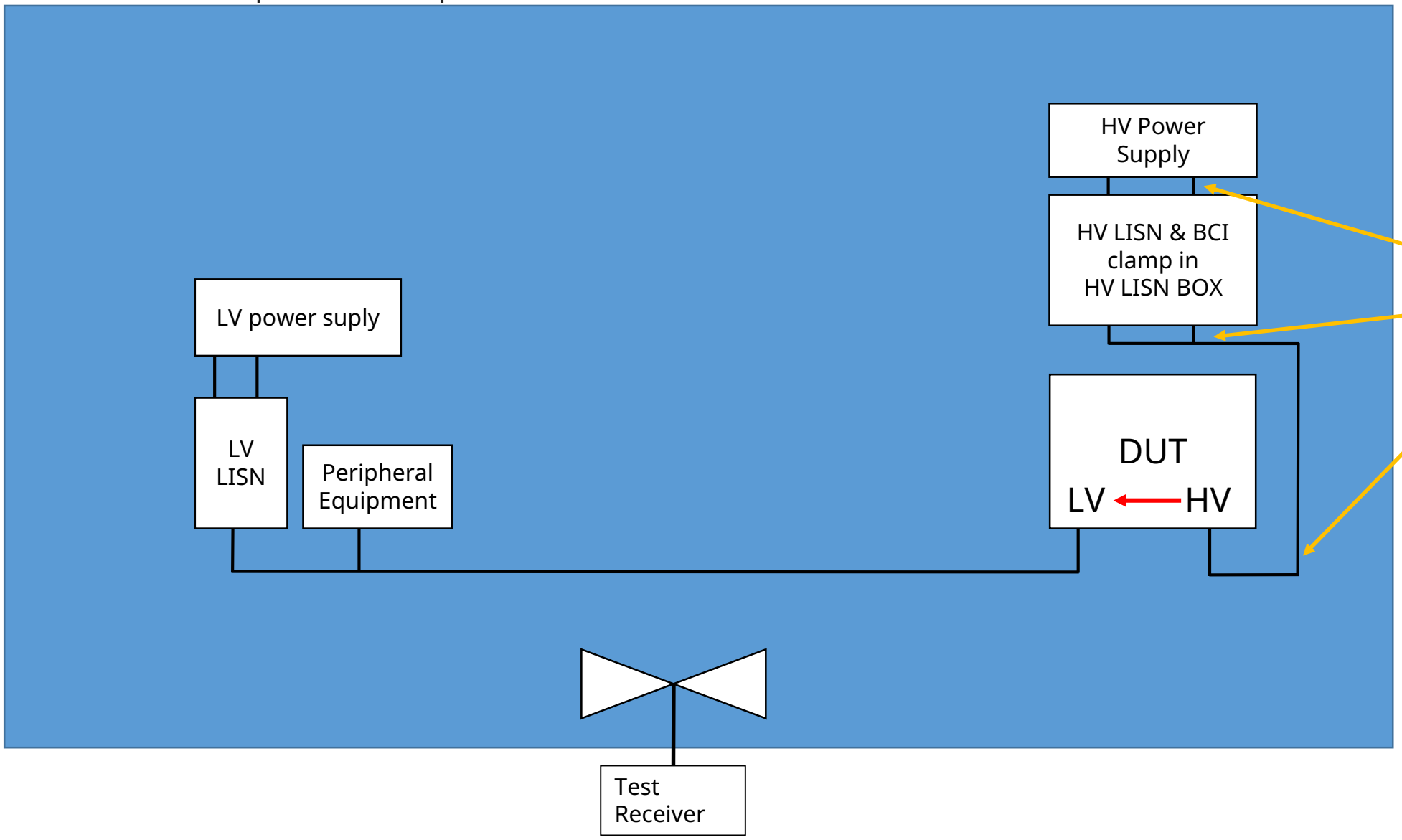
3: DUT own disturbances (left), 4: HV-LV decoupling measurement (right)





Analysis of Test Set-up

General Overview – possible weak points



Example 1 feedthrough

Example 2 feedthrough

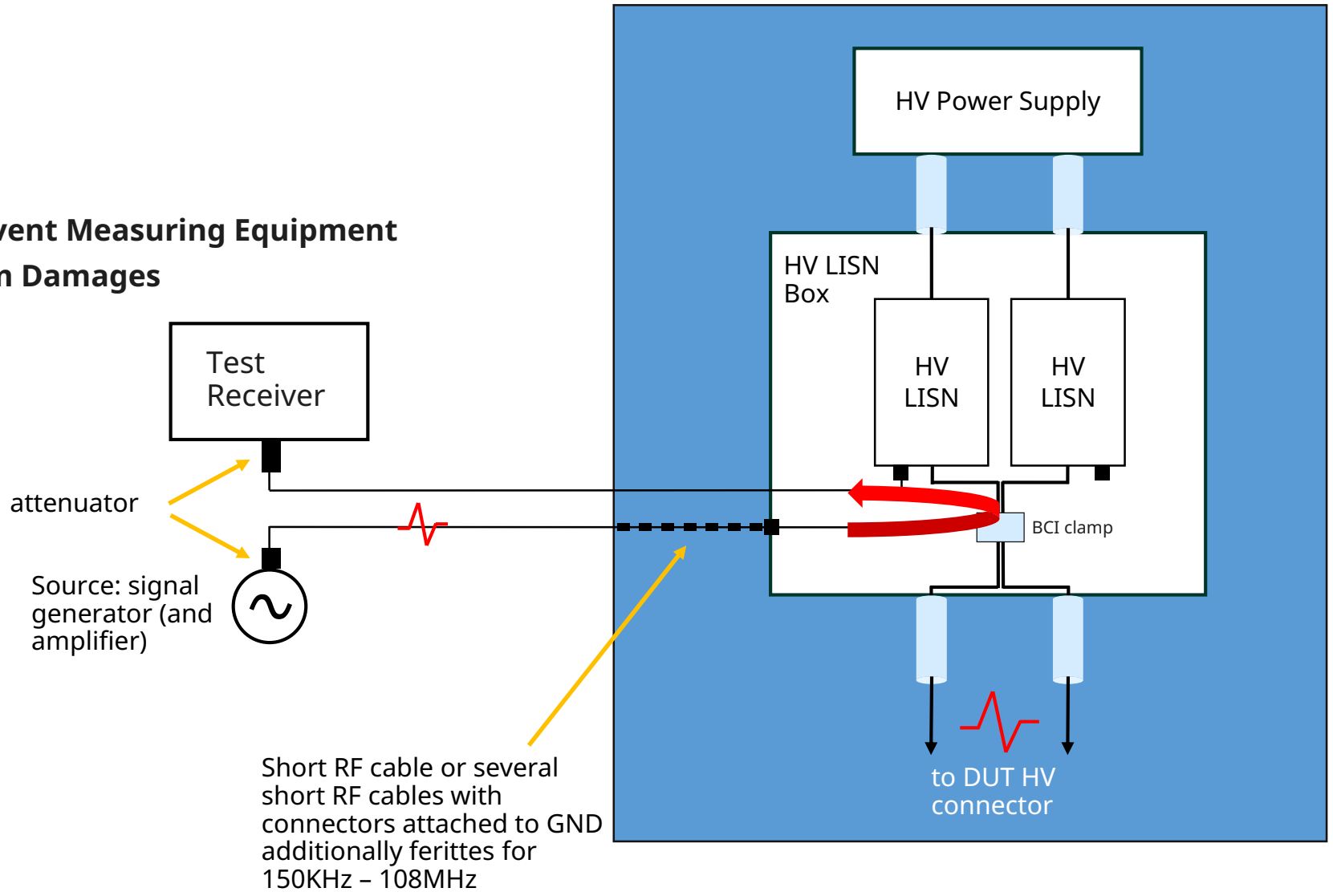
Example 3 feedthrough

Example 4 feedthrough

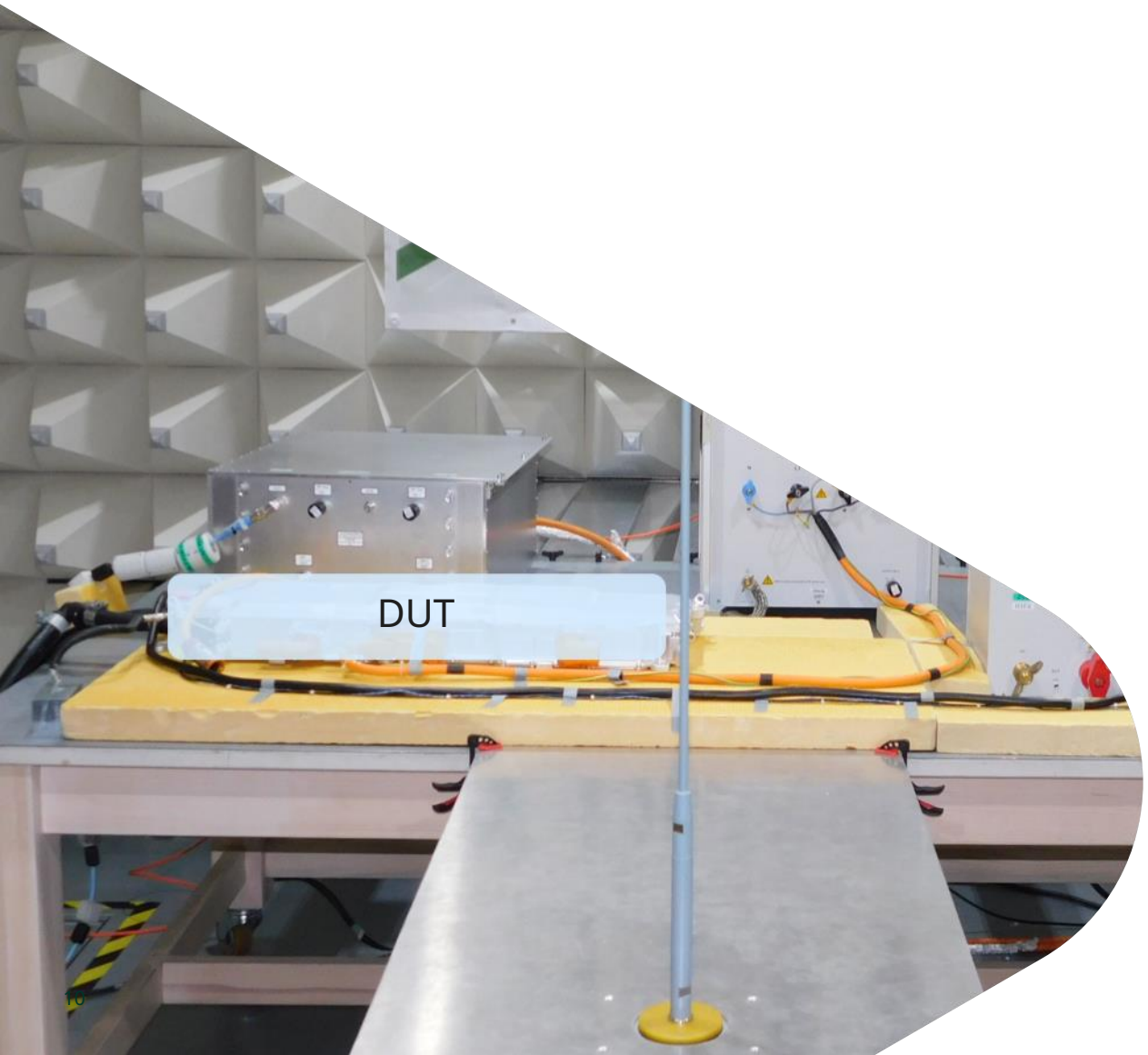
Analysis of Test Set-up

Simulate disturbances on HV lines - possible weak points - how to prevent damages

Prevent Measuring Equipment from Damages



Conclusions from Set-up Analysis



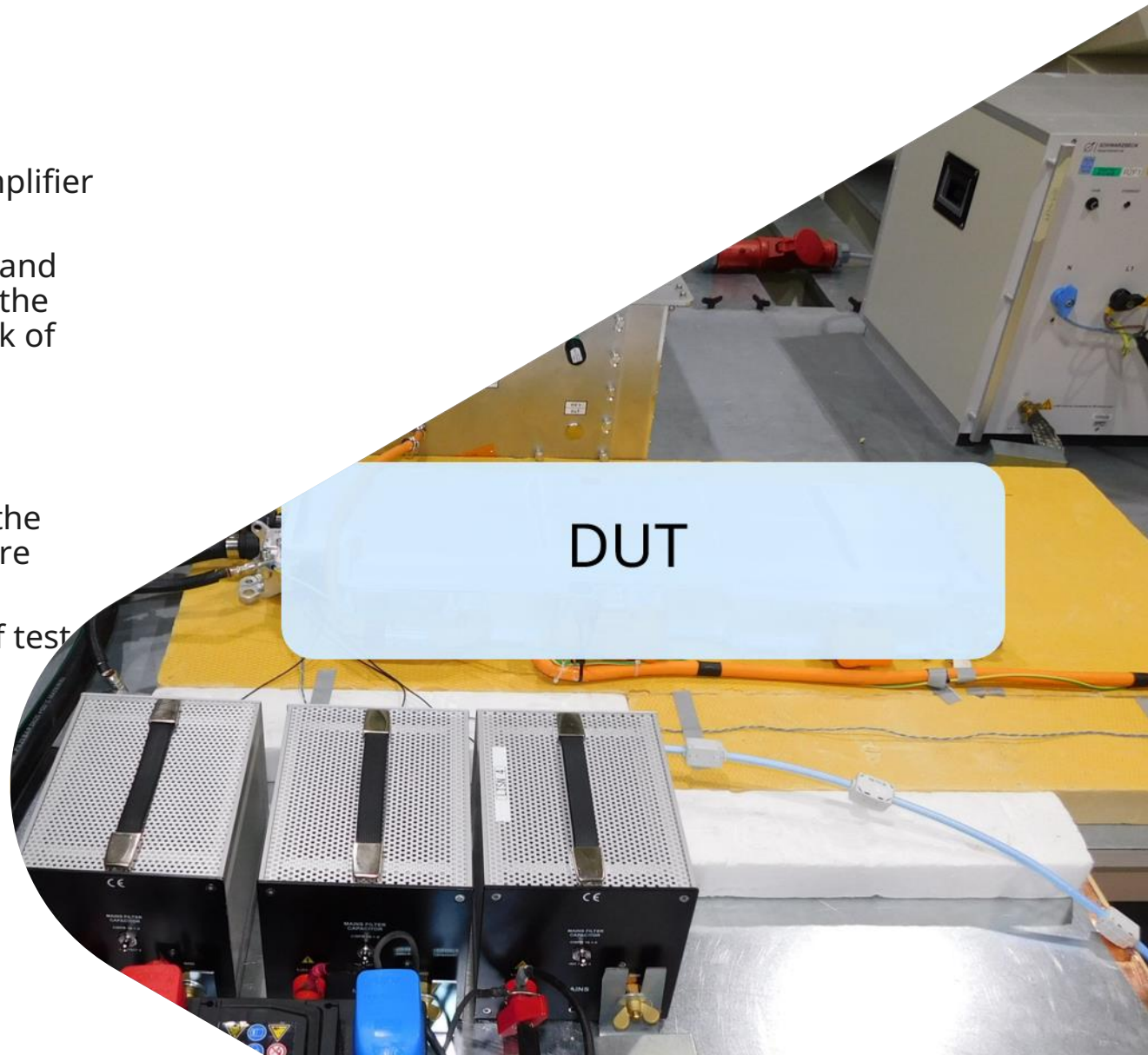
1. Start with Antenna method to detect weaknesses of the shielded system, before performing other methods to prevent set-up changes later
2. Aim is to measure LV emissions, thus all potential other influences shall be reduced to a minimum:
   a. use of short HV cables
   b. ideal shield connections
   c. good and intact shielded HV and RF cables
   d. appropriate* ferrites on injection cables
   e. Injection cable as short as possible or several short cables with grounded connections

*: make sure not only to rely on information of specifications or standards, but to select the ferrites needed to reduce all interferences from injection cable

Conclusions from Set-up Analysis

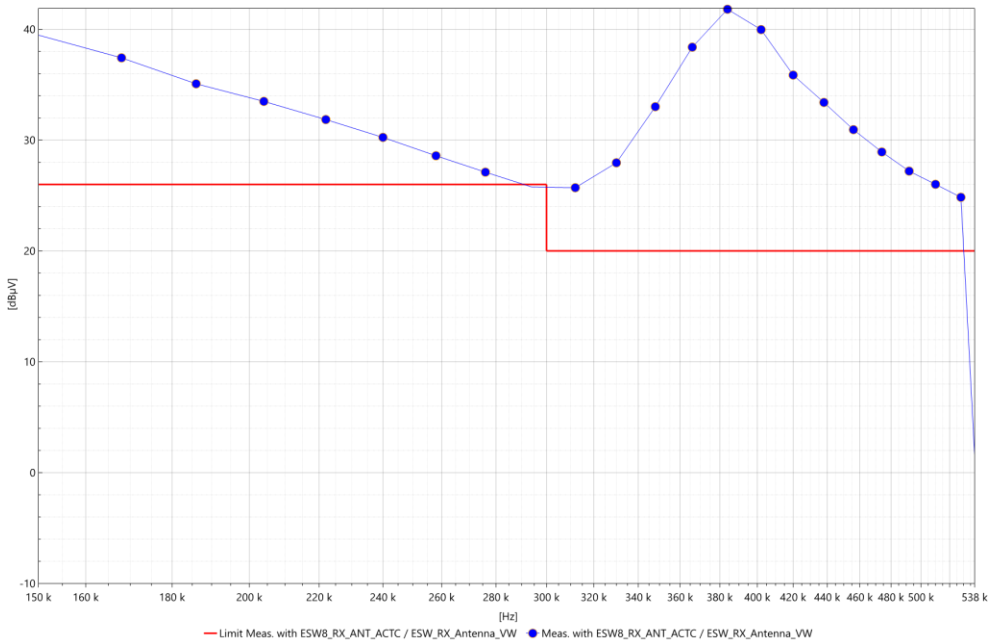
3. Equipment protection
   a. In a worst case situation max. possible power of the amplifier is transmitted to the test receiver
   b. the BCI clamp is reciprocal so that switching transients and RF disturbances from the DUT are being transferred to the amplifier or signal generator. If no amplifier is used, risk of damage of the signal generator.
   c. Use of attenuator for a. and b. is highly recommended

4. The EMC laboratory should always and independently of the requirements make sure that complete preparative test are done
5. Careless or unfocused work inevitably lead to damages of test equipment



Interpretation of Measurement Results

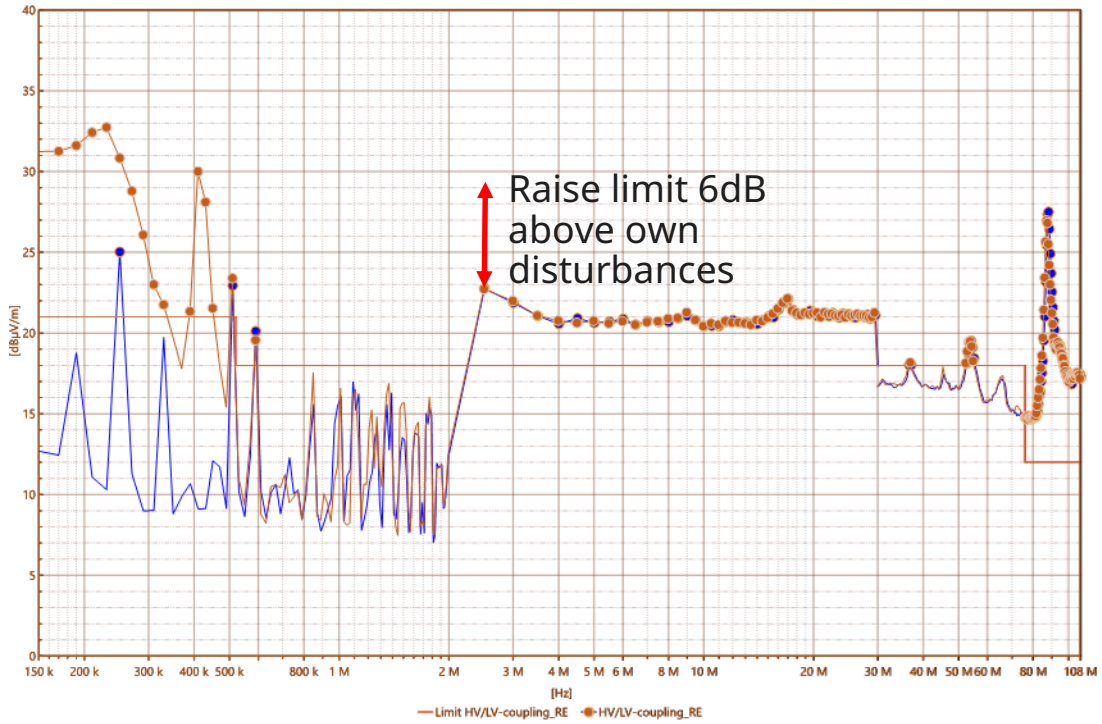
Reference measurement – fail 150kHz – 530kHz



- Limit exceedances of >20dB detected during reference measurement
- Without this measurement limit exceedances will be assigned to the DUT
- Root source analysis showed sheath current on the injection cable as reason
- Although ferrites where already attached to the cable, additional ones for the lower frequency range were necessary

Interpretation of Measurement Results

DUT own disturbances above the limit

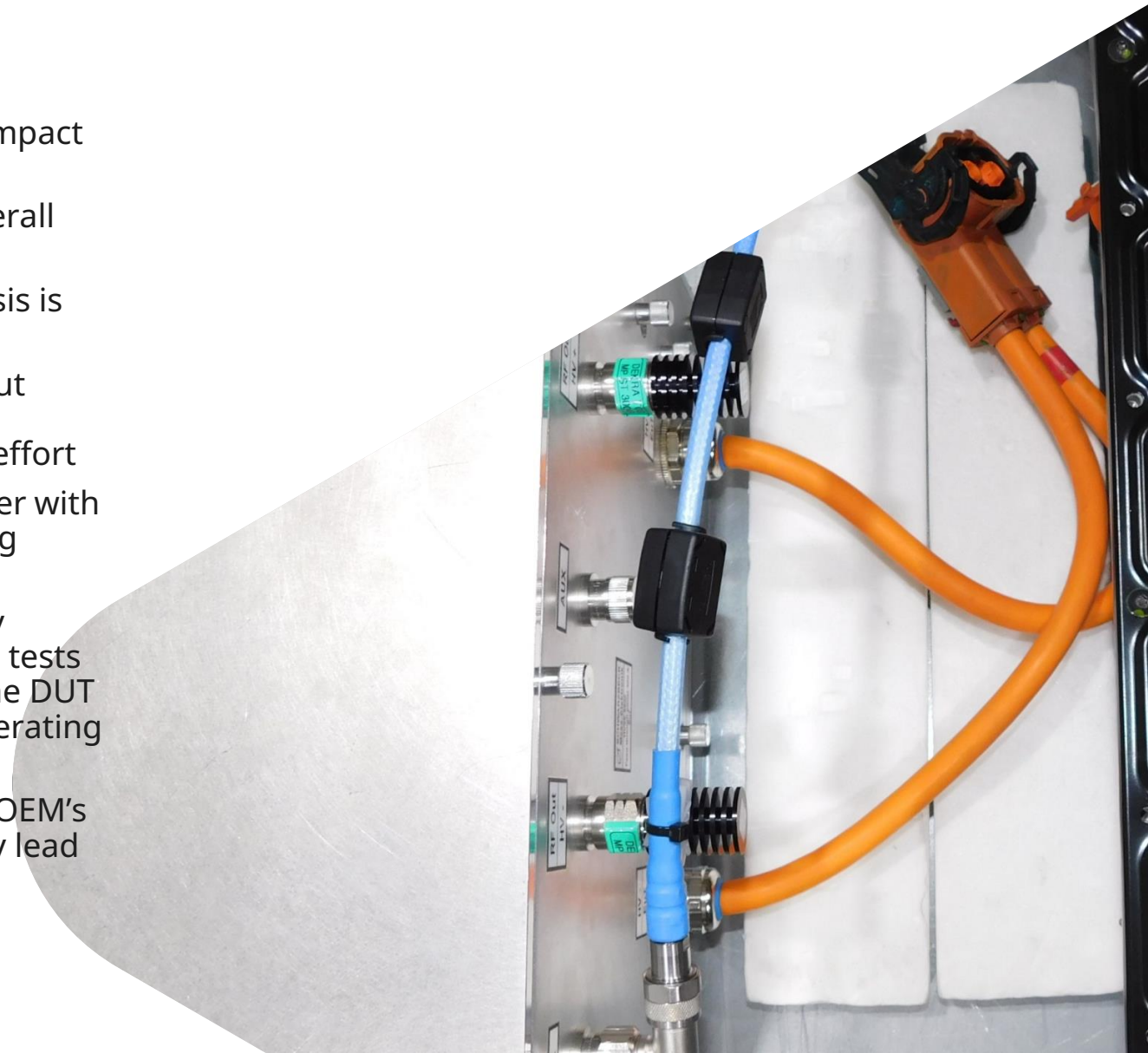


Blue: DUT own disturbances, brown: decoupling measurement

- Own disturbances of the DUT already above the limit
- 6dB margin from limit is not maintained
- evaluation of decoupling results is not possible. Up to date no recommendation for action is given in standards or specifications
- It is recommended to get back to the manufacturers EMC department.
- Technically, the limit should be raised by 6dB above the own disturbance level and the injection level accordingly

Summary and Conclusion

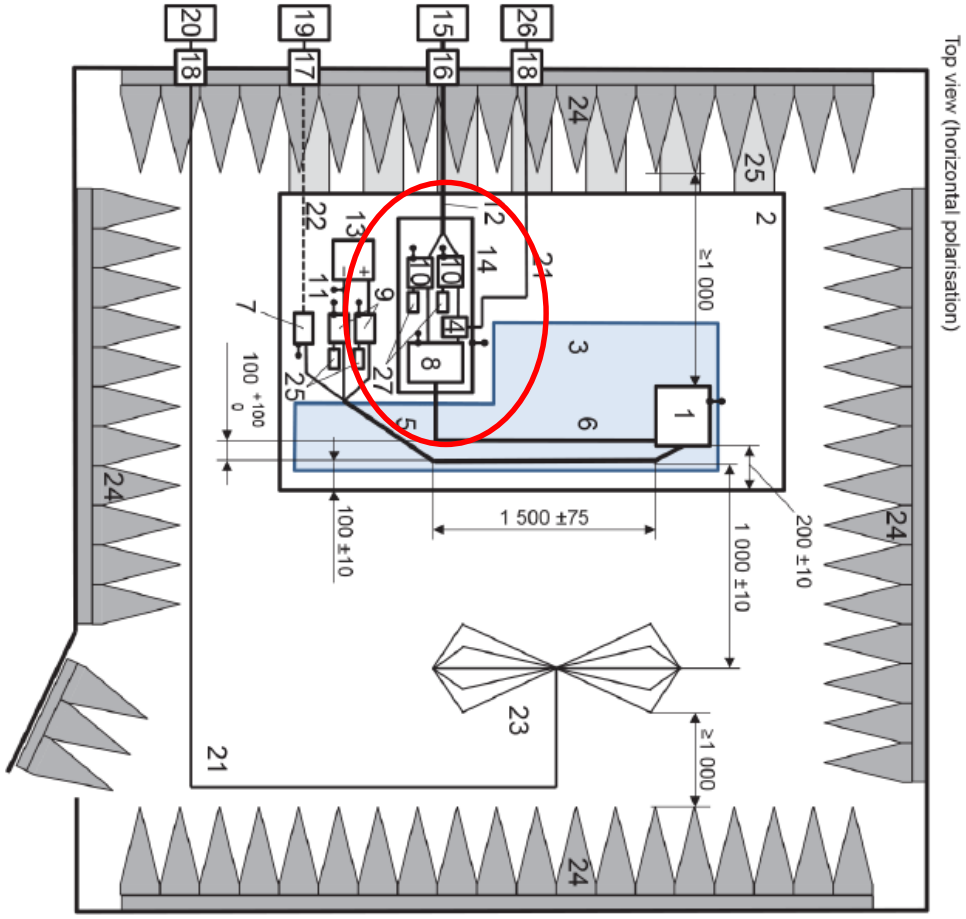
1. As faults in different places of the set-up do have major impact on the results, preparative measurements shall be done
2. Preparative measurements consumes approx. 70% of overall testing time
3. If results from preparative tests are fail, root cause analysis is mandatory
4. Finding the origin of fails without precise knowledge about week points of the set-up and exact understanding of the software can easily double or triple the time and budget effort
5. Understanding of each preparative measurement together with conscientious result interpretation is required. Performing measurements without questioning will lead to failures
6. OEM specifications and CISPR 25 all vary either in the way decoupling values are gathered or in the way preparative tests are performed or both. For instance, CISPR 25 requires the DUT to be off during calibration, while it shall be in normal operating mode according to several OEM specifications
7. In case own disturbances are above the limit consult the OEM's EMC department. Increase of limit and injection level may lead to analysable measurements

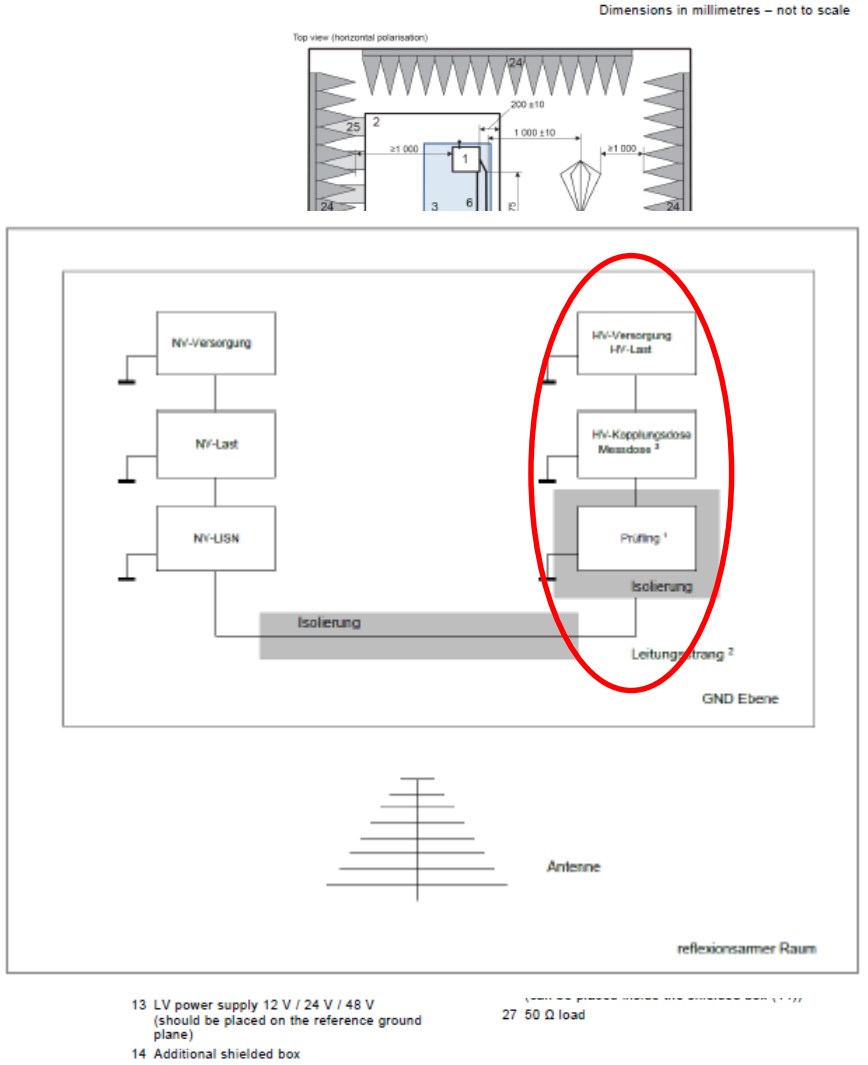


Thank you!

Set-up Comparison

CISPR 25:2021 and VW TL81000:2024





13 LV power supply 12 V / 24 V / 48 V (should be placed on the reference ground plane)

14 Additional shielded box

27 50 Ω load

Figure H.16 – Example of test setup for radiated emissions – ALSE method – measurement with biconical antenna with injection on HV supply ports

Comparison Reduction of sheath current on injection lines

CISPR 25 recommendation and sheath current in long wave band

H.6.2.5 HV-specific radiated emission test

The test shall be performed in an ALSE.

This method consists of measuring radiated emissions from the whole setup. The emission level shall be measured for each test signal injection configuration. The measured level shall not exceed the corresponding LV emission limits (same class than the one defined for HV level in H.6.2.2) defined in Table 7 (average) for 150 kHz to 108 MHz. The setup is shown in Figure H.16. The reference ground plane conditions defined in H.2.1 (radiated emission) apply.

The antenna to be used for the measurements shall be as defined in 6.5.2.2. In this subclause the test setup is shown with a biconical antenna as an example.

It is highly recommended that ferrites, with a minimum impedance of 50 Ω at 25 MHz and 110 Ω at 100 MHz, be placed on the cable from the RF generator to the test signal coupling element every 20 cm along its entire length within the ALSE.

Comparison of Limit Lines

Limit of HV-LV Decoupling vs. Radiated Emission Antenna Method

Frequenzbereich in MHz	Grenzwert E in db(µV/m)
0,15 bis 0,52	21
0,52 bis 3,85	18
3,85 bis 76	18
76 bis 108	12

1. Only base limits defined in range 1,73MHz – 76MHz
2. One result can be: DUT ok for radiated emission but fail with DUT own disturbances in HV/LV coupling
3. Discussion of results required