Conducted emission measurement using the Tekbox 5µH LISN TBOH01

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1 Introduction

This application note is intended to serve as an introduction to engineers who are dealing with conducted emission compliance requirements as part of product development or approval. The application note is by no means a substitute for the contents of various relevant standards. It investigates various aspects of pre-compliance conducted emission measurements that can be performed in a standard electronic product development laboratory environment using a 5H LISN and a low cost spectrum analyzer. What is the function of a LISN? How are conducted emissions measured? Which standards specify conducted emission measurements with a 5µH LISN? What are the requirements for the spectrum analyzer? What is the influence of ground plane dimensions and supply cable length. What is the influence of ambient noise and how can the measurement be automated?

2 Purpose of a LISN

LISN is an abbreviation for Line Impedance Stabilisation Network.

- It is a low pass filter, typically placed between a power source and the supply terminals of a device under test (DUT).
- It indirectly supplies the DUT with power
- It provides a well-defined RF-impedance to the DUT
- It couples electrical noise generated by the DUT to an RF port, where it can be connected to a spectrum analyser or measurement receiver
- It suppresses electrical noise from the supply side towards the DUT
- It suppresses electrical noise from DUT side towards the supply
- It may offer a certain level of protection with respect to over-driving or damaging the RF input of the spectrum analyzer or measurement receiver

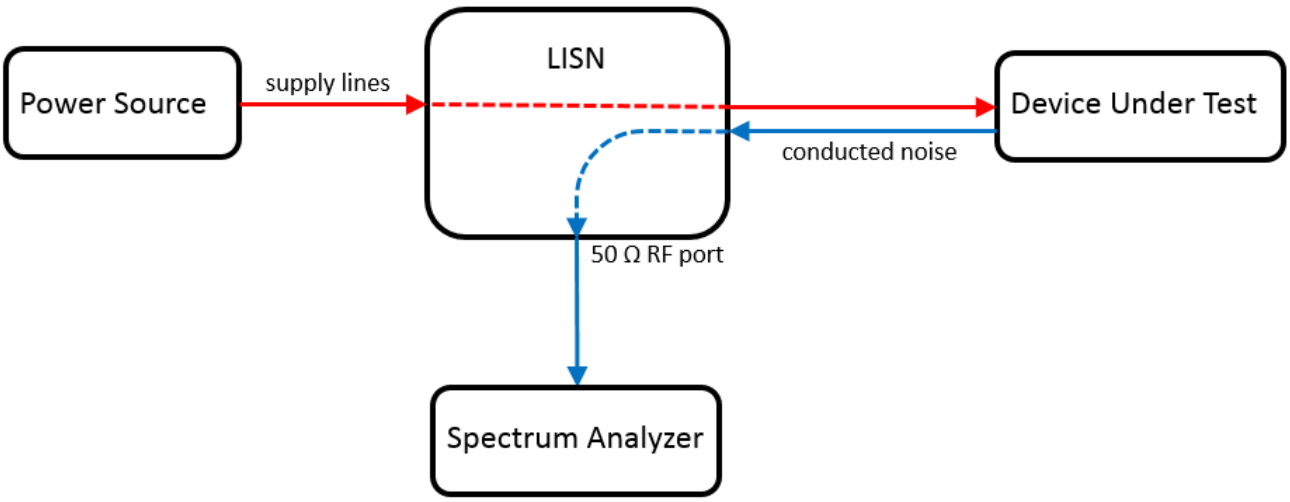

Figure 1: Basic diagram of a conducted emission measurement setup with a LISN

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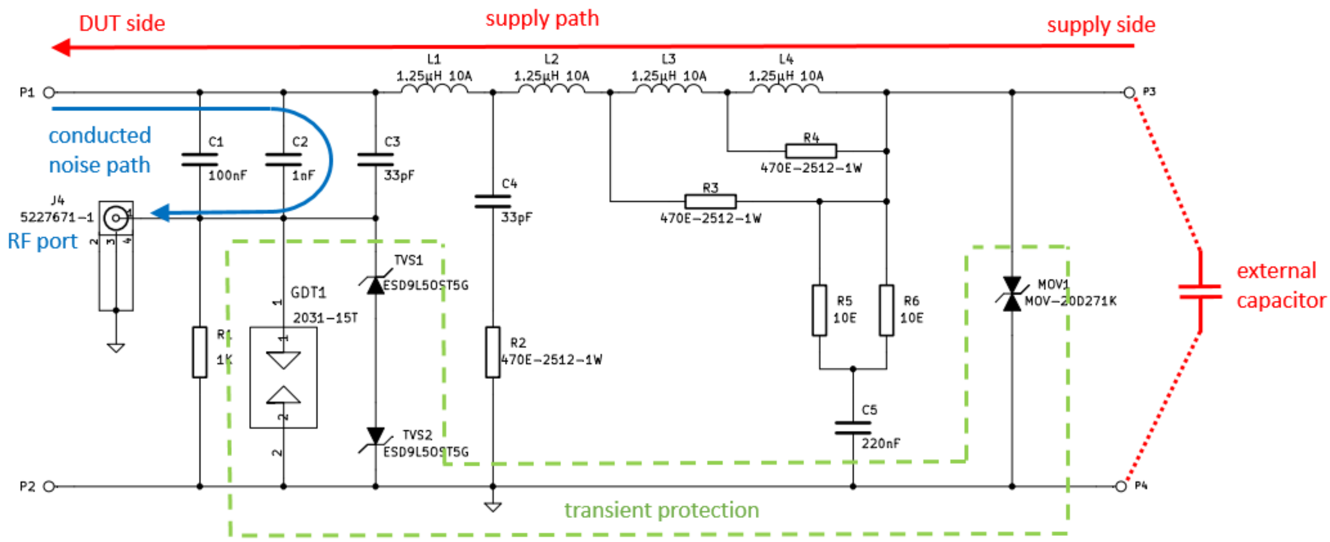

Figure 2: schematic of the Tekbox 5µH LISN TBOH01

The Tekbox 5µH LISN schematic above reveals some details such as transient protection based on a MOV, gas discharge tube and transient absorber diodes. To maintain the specified impedance by preventing unwanted resonances, the 5µH inductor is divided into sections and dampened.

There is also an external capacitor shown. This capacitor must be connected to the LISN's supply side externally. The value is determined by the applicable standard: CISPR 25 and ISO 11452-2/4/5 specify a 1µF capacitor to be connected in parallel to the source terminals. DO-160 specifies a 10µF capacitor in parallel to the source terminals. However, the TBOH01 is not specified for the full DO-160 frequency range.

The TBOH01 terminals have perpendicular holes for inserting and clamping the pins of the external capacitor. ISO7637-2 does not specify an external capacitor.
In the case of a set-up with two LISNs, one in the positive supply path and one in the negative supply path, an additional 1000F capacitor must be connected between the two LISNs' red terminals. It is discussed in greater detail in Chapter 4.

3 Conducted emission measurement set up, voltage method

CISPR 25 specifies two measurement configurations:

If the DUT is grounded to the vehicle chassis via a power return line shorter than 20 cm in length, a single 5H LISN is sufficient, and the conducted noise is measured only on the positive supply line.
If the DUT's power return line is longer than 20 cm, two 5H LISNs are required. One LISN connects the positive supply line to the DUT, and another LISN connects the power return line to the DUT. On both lines, conducted emissions are measured. In fact, it is measured on one LISN at a time, with the other LISN's RF port terminated with a 50 resistor.

Conducted emission measurement using the Tekbox 5µH LISN TBOH01

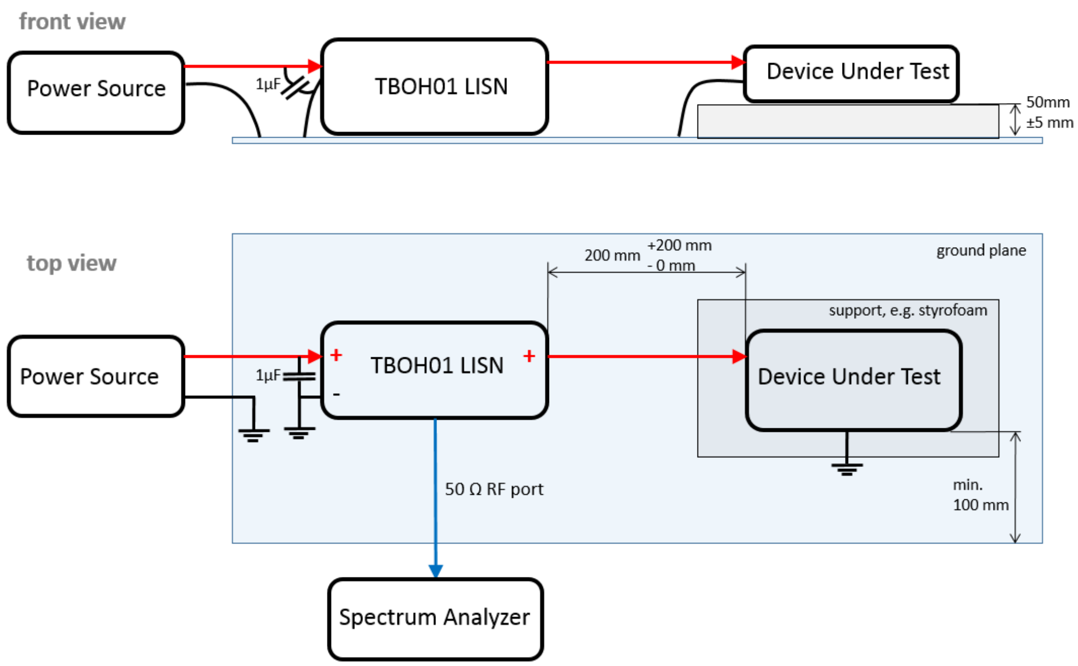

Figure 3: conducted emission measurement, voltage method, DUT with power return line locally grounded

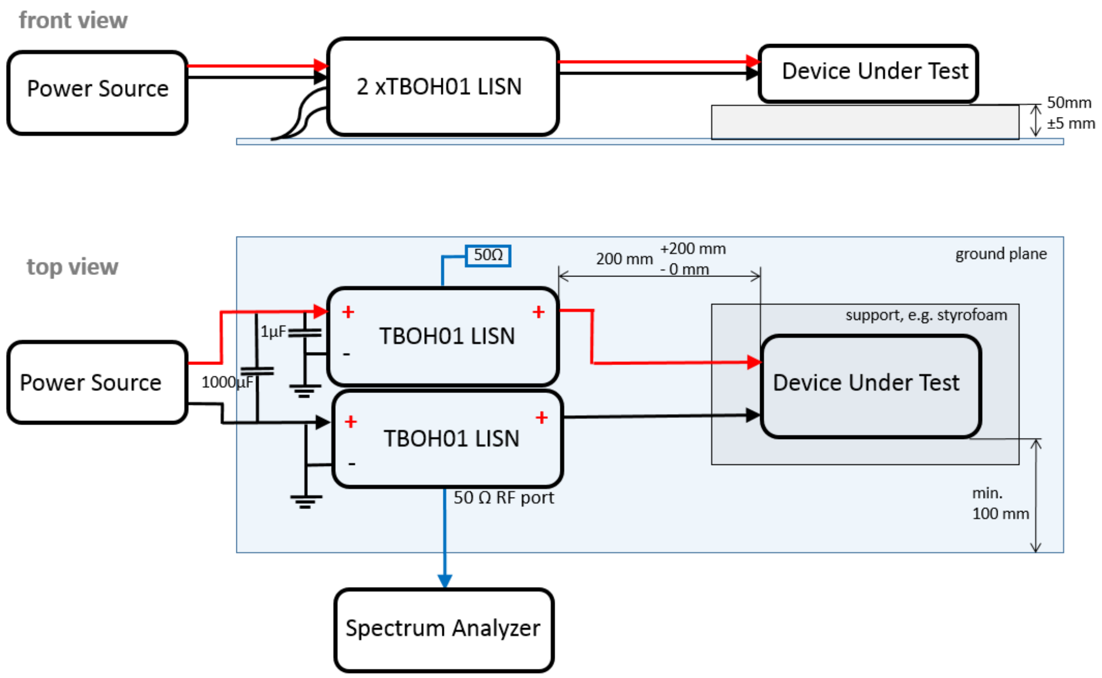

Figure 4: conducted emission measurement, voltage method, DUT with power return line remotely grounded

Figures 3 and 4 depict conducted noise measurement setups using the voltage method, as specified in CISPR 25. If the DUT is connected to other peripheral devices, they should also be connected or simulated using a load box. If a remotely powered DUT's housing anticipates chassis grounding, it should also be grounded to the ground plane. The grounding lead should be no more than 150mm long.

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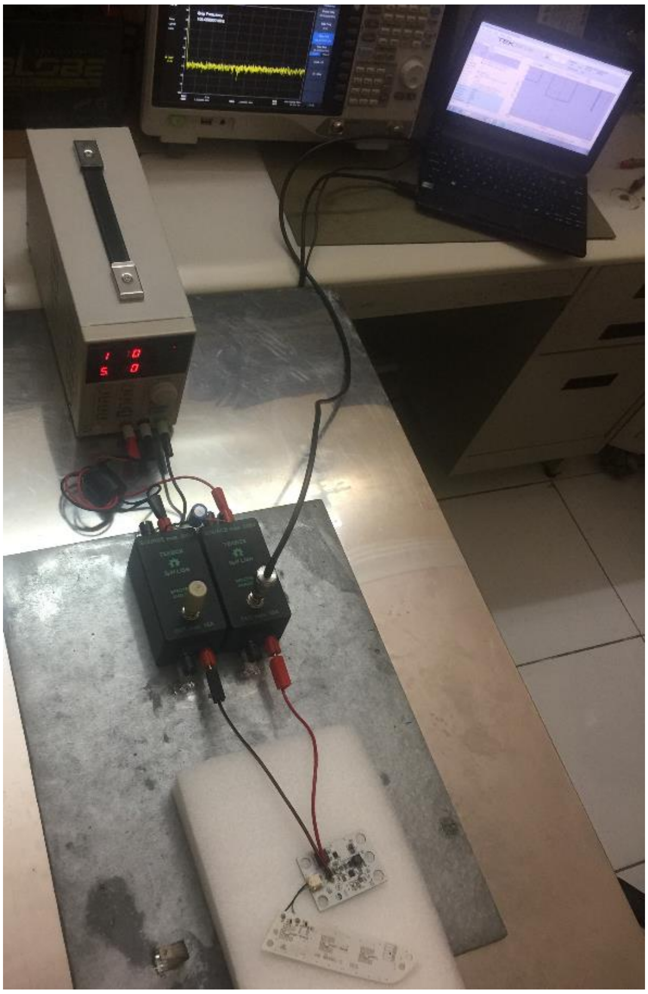
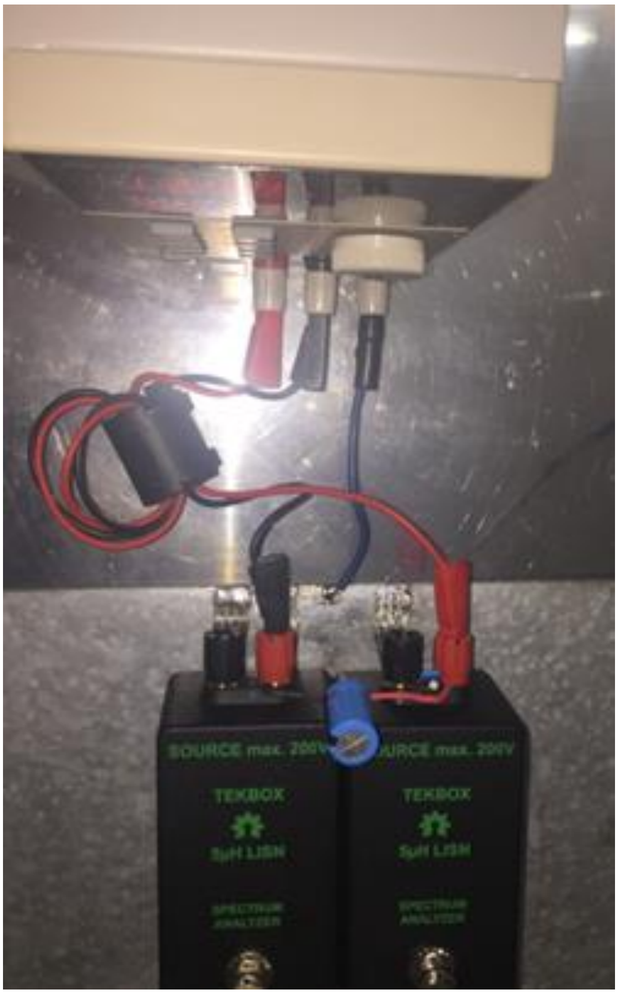
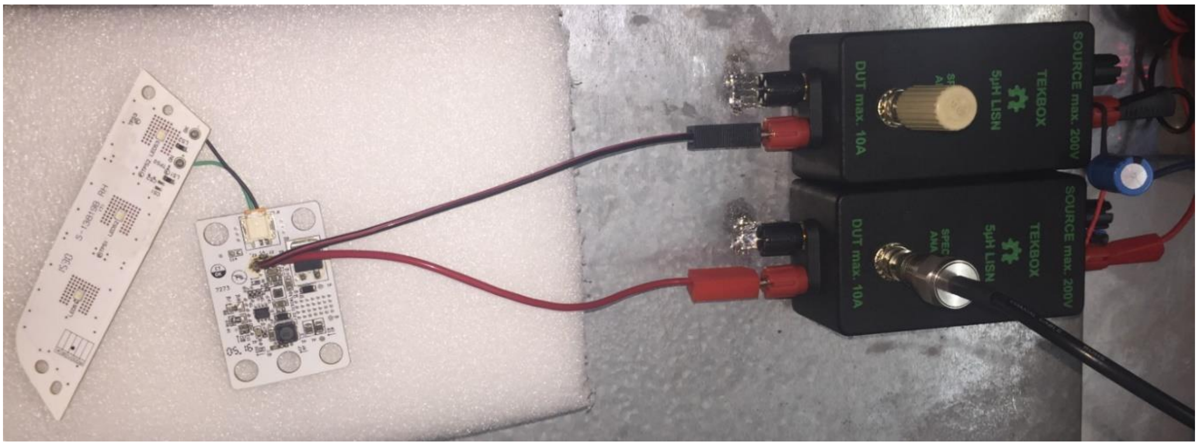
Because most devices are remotely grounded, the configuration shown in Figure 4 is more common. The measurement must then be performed alternately on both the positive and negative power lines. The unused RF port is always connected to a 50 Ohm termination.







Picture 1: simple pre-compliance conducted emission measurement set up, voltage method

Conducted emission measurement using the Tekbox 5µH LISN TBOH01

4 Conducted emission measurement set up, current probe method

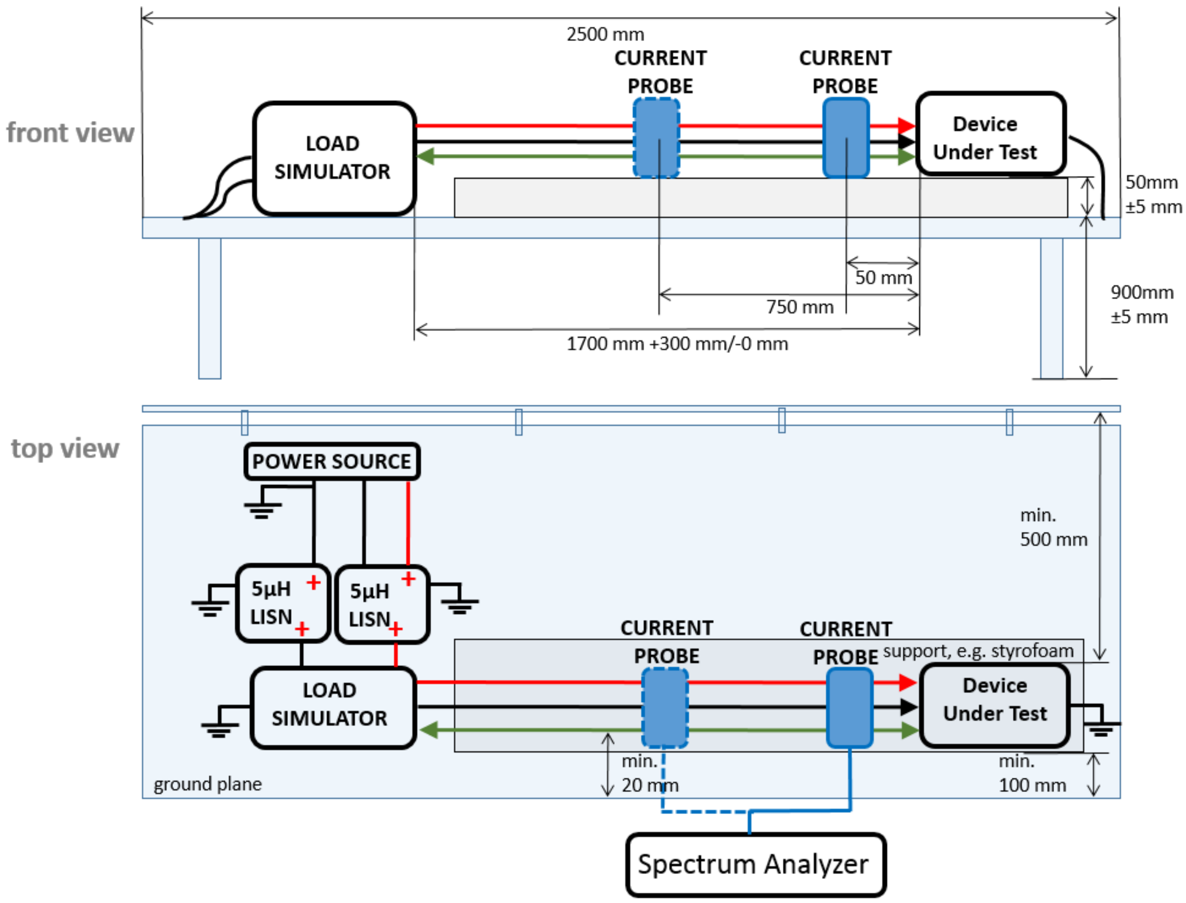


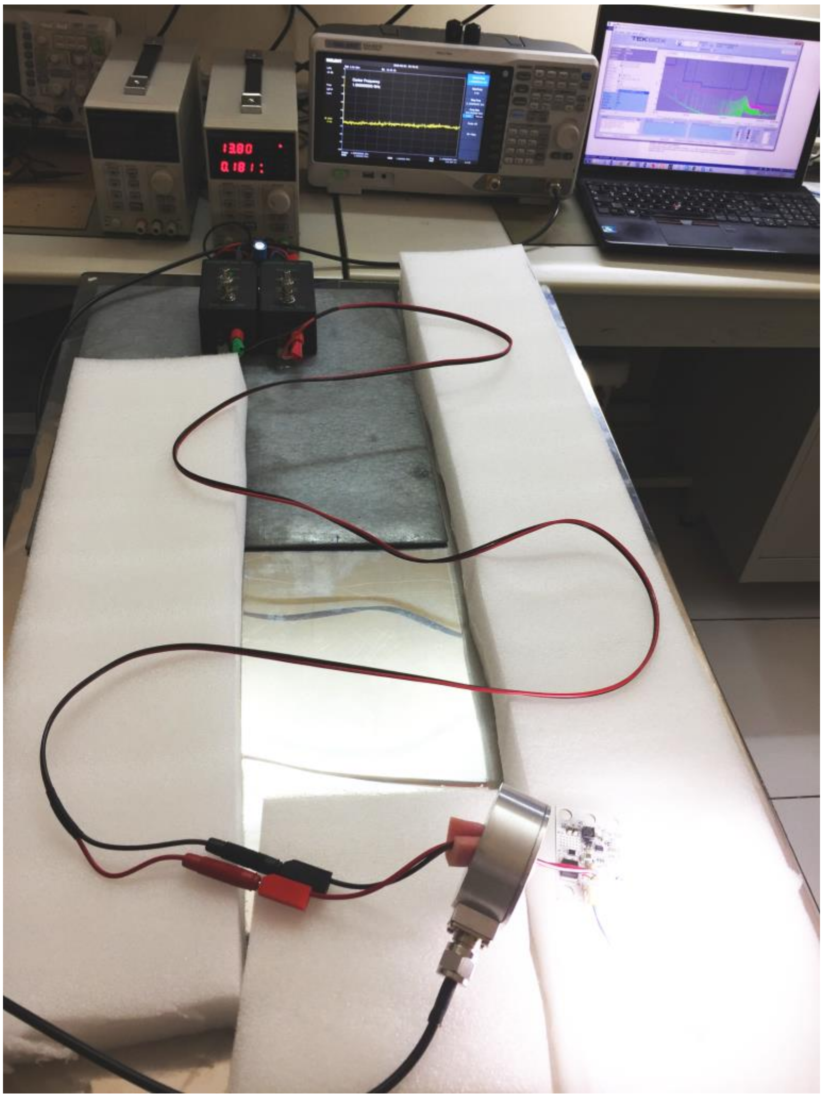
Figure 5: conducted emission measurement according to CISPR 25, current probe method

The current probe measurement according to CISPR 25 is used to measure conducted emissions on a wire harness including control/signal lines of a DUT. Some automotive manufacturers, however, use it also to measure power supply. Measurements are typically taken on various lines – plus, minus, control signals, plus + minus, plus + minus + control lines.

The current probe measurement is performed with probes positioned 50 mm and 750 mm away from the EUT to account for cable harness resonance effects.
The CISPR 25 current probe method covers a frequency range of 0.15 MHz to 108 MHz. However, some automakers significantly exceed the upper frequency limit in their own standards.

The conducted emissions are detected by a current probe. To establish a defined impedance on the power lines, two LISNs are required. The load simulator is a device that simulates the load present at the DUT's signal/control interface.

Conducted emission measurement using the Tekbox 5µH LISN TBOH01



Picture 2: simplified set up for pre-compliance conducted emission measurement using the current probe method

Figure 2 depicts a straightforward setup for measuring conducted emission using a current probe. The setup was done on a small ground plane due to space constraints. As a result, the supply cable had to be laid out in a meandering fashion. The distance between the RF current probe and the DUT is set at 50 mm.

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5 Applicable standards

The technical requirements for 5H LISNs and the corresponding conducted emission measurement setups are specified in CISPR 16-1-2 and CISPR 25.

Following standards specify limits for conducted emission tests based on 5µH LISNs:

CISPR 25: Vehicles, boats and internal combustion engines – Radio disturbance characteristics – Limits and methods of measurement for the protection of on-board receivers
ISO 7637-2: Road vehicles -- Electrical disturbances from conduction and coupling -- Part 2: Electrical transient conduction along supply lines only
DO-160: Environmental Conditions and Test Procedures for Airborne Equipment
This standard has different requirements with respect to the 5µH LISN and is not subject of this application note
Manufacturer specific EMC standards: Most car manufacturers have their own EMC standard. Some manufacturer specific standards refer to CISPR 25 with respect to conducted emission testing. Other manufacturers have different requirements, in most cases different limits than specified in CISPR 25. Car manufacturer may also apply different limits for electronic and electro-mechanical devices. Most car manufacturers specify the "voltage method" using a 5µH LISN for conducted emission testing. A few car manufacturers specify the "current method" using a RF current probe to measure conducted emissions.
General testing: Most devices, which are supplied with DC from an external power supply, are not tested for conducted emissions on their DC supply lines, but rather as a complete system on their AC supply side. However, any conducted emissions on DC supply cables are very likely to radiate, as the supply cable acts as an antenna. This means that conducted noise turns into radiated emissions, which then may negatively affect the result of the radiated emission test of the DUT. Consequently it is advisable to take a LISN and a spectrum analyser and have a look at the conducted noise spectrum on the DC supply cable of any device, before going to the test house.

6 CISPR 25 limits for conducted emissions

The tables below are a simplified summary rather than an exact representation of the corresponding CISPR25 tables.

6.1 Quasi Peak or Peak limits – voltage method

Class	Levels in dB(µV)											
	0.15 -0.3 MHz		0.53 - 1.8 MHz		5.9 - 6.2 MHz		26 - 41MHz		41 - 88 MHz		88 - 108 MHz	
	P	QP	P	QP	P	QP	P	QP	P	QP	P	QP
1	110	97	86	73	77	64	68	55	58	49	62	49
2	100	87	78	65	71	58	62	49	52	43	56	43
3	90	77	70	57	65	52	56	43	46	37	50	37
4	80	67	62	49	59	46	50	37	40	31	44	31
5	70	57	54	41	53	40	44	31	34	25	38	25

Table 1: CISPR 25 quasi-peak and peak limits for conducted disturbances – voltage method

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6.2 Average limits – voltage method

Class	Levels in dB(µV)					
	0.15 -0.3 MHz	0.53 - 1.8 MHz	5.9 - 6.2 MHz	26 - 41MHz	41 - 88 MHz	88 - 108 MHz
1	90	66	57	48	42	42
2	80	58	51	42	36	36
3	70	50	45	36	30	30
4	60	42	39	30	24	24
5	50	34	33	24	28	28

Table 2: CISPR 25 average limits for conducted disturbances – voltage method

6.3 Quasi Peak or Peak limits – current probe method

Class	Levels in dB(µA)											
	0.15 -0.3 MHz		0.53 – 1.8 MHz		5.9 – 6.2 MHz		26 – 41MHz		41 – 88 MHz		88 – 108 MHz	
	P	QP	P	QP	P	QP	P	QP	P	QP	P	QP
1	90	77	58	45	43	30	34	21	24	15	28	15
2	80	67	50	37	37	24	28	15	18	9	22	9
3	70	57	42	29	31	18	22	9	12	3	16	3
4	60	47	34	21	25	12	16	3	6	-3	10	-3
5	50	37	26	13	19	6	10	-3	0	-9	4	-9

Table 3: CISPR 25 quasi peak and peak limits for conducted disturbances – current probe method

6.4 Average limits – current probe method

Class	Levels in dB(µA)				
	0.15 -0.3 MHz	0.53 – 1.8 MHz	5.9 – 6.2 MHz	26 – 68MHz	68 – 108 MHz
1	70	38	23	14	8
2	60	30	17	8	2
3	50	22	11	2	-4
4	40	14	5	-4	-10
5	30	6	-1	-10	-16

Table 4: CISPR 25 average limits for conducted disturbances – current probe method

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7 Spectrum analyzer considerations

This document focuses on how to conduct pre-compliance measurements in a development lab setting rather than how to set up a 100% compliant conducted emission test. As a result, it is assumed that the tests are performed using a spectrum analyzer rather than an EMI measurement receiver. When used as a replacement for a measurement receiver, CISPR 16, CISPR 25, and other standards provide recommendations on how to configure spectrum analyzers.

7.1 RBW and sweep time

An excerpt from CISPR 25 specifications concerning spectrum analyzers is provided below:

Service/Frequency range [MHz]	Peak detection		Quasi-peak detection		Average detection	
	RBW at -3 dB	Scan time	RBW at -6 dB	Scan time	RBW at -3 dB	Scan time
0.15 MHz – 30 MHz AM broadcast and mobile services	9/10 kHz	10 s/MHz	9 kHz	200 s/MHz	9/10 kHz	10 s/MHz
76 MHz – 108 MHz FM broadcast	100/120 kHz	100 ms/MHz	120 kHz	20 s/MHz	100/120kHz	100 ms/MHz
30 MHz – 1GHz Mobile services						
41 MHz – 88 MHz TV band I						
174 MHz – 230 MHz TV band III						
470 MHz – 890 MHz TV band IV/V						
171 MHz – 245 MHz DAB						
470 MHz – 770 MHz DTTV	100/120 kHz	100 ms/MHz	Does not apply	Does not apply	100/120kHz	100 ms/MHz
1000 MHz – 2500 MHz Mobile service	100/120 kHz	100 ms/MHz	Does not apply	Does not apply	100/120kHz	100 ms/MHz
1567 MHz – 1583 MHz GPS L1 civil	Does not apply	Does not apply	Does not apply	Does not apply	9/10 kHz	1 s/MHz

Table 5: RBW and sweep time settings

Using the list above, we would need to set a sweep from 0.15 MHz to 30 MHz, with an RBW of 9 kHz and a sweep time of 300 seconds. Then we'd have to switch to a sweep from 30 MHz to 108 MHz, set the RBW to 120 kHz, and set the sweep time to 7.8 seconds.
So far, this appears to be a reasonable effort to be carried out manually, but there are additional requirements to be considered that will result in a different conclusion.

The sweep times specified for quasi-peak detection may not be appropriate for all low-cost spectrum analyzers. Set a sub-span range's and RBW manually. Set the detector to the quasi-peak mode. The spectrum analyzer will then automatically configure the sweep time. If the sweep time does not match the requirements specified in CISPR 25, use the auto sweep time instead.

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7.2 RBW and frequency span

Spectrum analyzers typically take 600 to 800 measurement points per sweep. It is usually equal to the number of pixels on the frequency axis. The default number for the RIGOL DSA 815 is 601 frequency points and the default number of SIGLENT spectrum analyzers is 751 frequency points.
With the Rigol DSA 815 and a span of 0.15 MHz to 30 MHz, two adjacent frequency points are nearly 50 kHz apart. Given the CISPR 25 RBW of 9 kHz, it is obvious that the analyser would skip over emissions. The RBW filter curves of adjacent frequency points should overlap to simulate a measurement receiver. In fact, adjacent measurement points should not be separated by more than half the RBW.
When we calculate the maximum span for the DSA815 with 601 points and 9 kHz RBW, we get 4.5 kHz * 601 = 2.7 MHz. Instead of sweeping across the frequency range 0.15 MHz to 30 MHz in a single shot, we must limit the span to 2.7 MHz and divide the measurement into many subranges across the required frequency range.

Example DSA 815 and SSA30xx:

Frequency range	RBW	Sub range DSA 815, 601 points	Sub range SSA 30xx, 751 points
0.15 – 30 MHz	9 kHz	max. 2.7 MHz	max 3.38 MHz
30 – 108 MHz	120 kHz	max. 36 MHz	max 45 MHz

Table 6: maximum frequency span per sweep

In order to cover the complete 0.15 MHz to 108 MHz range, it requires 14 sweeps with a DSA815 and 10 sweeps with a SSA30xx spectrum analyzer.

7.3 Video bandwidth

The video bandwidth must be at least three times the resolution bandwidth, according to CISPR 25.

7.4 Spectrum analyzer noise floor

The noise floor of a scanning receiver / spectrum analyzer must be at least 6dB lower than the applicable limits, according to CISPR 25.
To investigate, we must first examine the lowest limits for conducted emissions, voltage method, as specified in CISPR 25:
Below 30 MHz; CISPR 25, class 5, limit for average detection in the 28 MHz – 30 MHz range: 24 dBµV
Above 30 MHz; CISPR 25, class 5, limit for average detection in the 68 MHz – 108 MHz range: 18 dBµV

Spectrum analyzer	Frequency span	Sweep time	RBW	attenuator	Min. CISPR 25 limit (average detector)	Pre-amplifier	Spectrum analyser noise floor
Example: 1st generation RIGOL DSA 815	28 MHz – 30 MHz	27 s	9 kHz	0 dB	24 dBµV	off	14 dBµV
						on	-11 dBµV
	30 MHz – 102 MHz	7.2 s	120 kHz	0 dB	18 dBµV	off	25 dBµV
						on	0.5 dBµV
Example: 1st generation SIGLENT SSA3021	26.7 MHz – 30 MHz	33 s	9 kHz	0 dB	24 dBµV	off	-3 dBµV
						on	-22 dBµV
	30 MHz – 108 MHz	7.8 s	120 kHz	0 dB	18 dBµV	off	7.8 dBµV
						on	-10 dBµV

Table 7: example noise floors

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In order to meet the CISPR25 noise level criteria, a pre-amplifier may be required. In this case, the measurement result must be carefully examined for potential measurement errors caused by non-linear distortions caused by the spectrum analyzer pre-amplifier.
On the other hand, it can be seen that there is enough margin in certain configurations to engage the internal attenuator in order to prevent potential IF overload situations and improve immunity to non-linear distortions.
Always compare the noise floor of your spectrum analyzer to the applicable measurement limits. Then decide on the internal attenuator settings and whether or not a pre-amplifier is required.

7.5 Non-linear distortions

As discussed in the previous chapter, it may be necessary to reduce the internal input attenuation and activate the spectrum analyzer's pre-amplifier in order to reduce the base noise level sufficiently below the limit line.
It is a good strategy to keep the input attenuation higher in the lower frequency range, where the emissions have typically a higher amplitude and the limit lines are at a higher level.
For a comparison measurement with higher input attenuation, it is also recommended to disregard the base noise level. Compare the results of a measurement with input attenuation set to, say, 10 dB to the results of a measurement with zero input attenuation. If the spurious levels of both measurements are the same, there is no intermodulation and you can trust the measurement result.
Another issue that may arise in the presence of strong signals is ADC overload. A message on the analyzer display and a warning beep indicate this. Interrupt the measurement by switching off the pre-amplifier and/or increasing the internal attenuation.

7.6 Spectrum analyzer RF input protection

Maximum input ratings for spectrum analyzers are typically in the +20 dBm to +30 dBm range. If your DUT contains inductive loads, insert at least a 20dBm attenuator at the spectrum analyzer's input to ensure that the spurious levels do not exceed the spectrum analyzer's maximum input ratings. The majority of high amplitude spurious originate from motors or switched mode regulators in the DUT's power management section. Check the frequency range up to the 5th harmonic, depending on the switching frequency. Use a slow sweep with the detector set to peak and the trace set to maximum hold. If the levels are within the analyzer's RF input limits, you can proceed.
It is also good practice to keep the analyzer RF input disconnected when turning on or off the DUT.

8 LISN frequency response / LISN calibration

Because a LISN is essentially a well-defined low pass filter, we must consider the frequency response. It must be used to correct the outcome of the emission measurement. As an example, if the frequency dependent loss (voltage division ratio) of the LISN is -3dB at 500 kHz, the conducted emission level must be increased by + 3dB. This procedure must be performed across the entire frequency range of the measurement. Even though the major frequency section has a fairly flat response, manual compensation would be inconvenient. As a result, many spectrum analyzer manufacturers, including Tekbox, provide software to automate EMC measurements.

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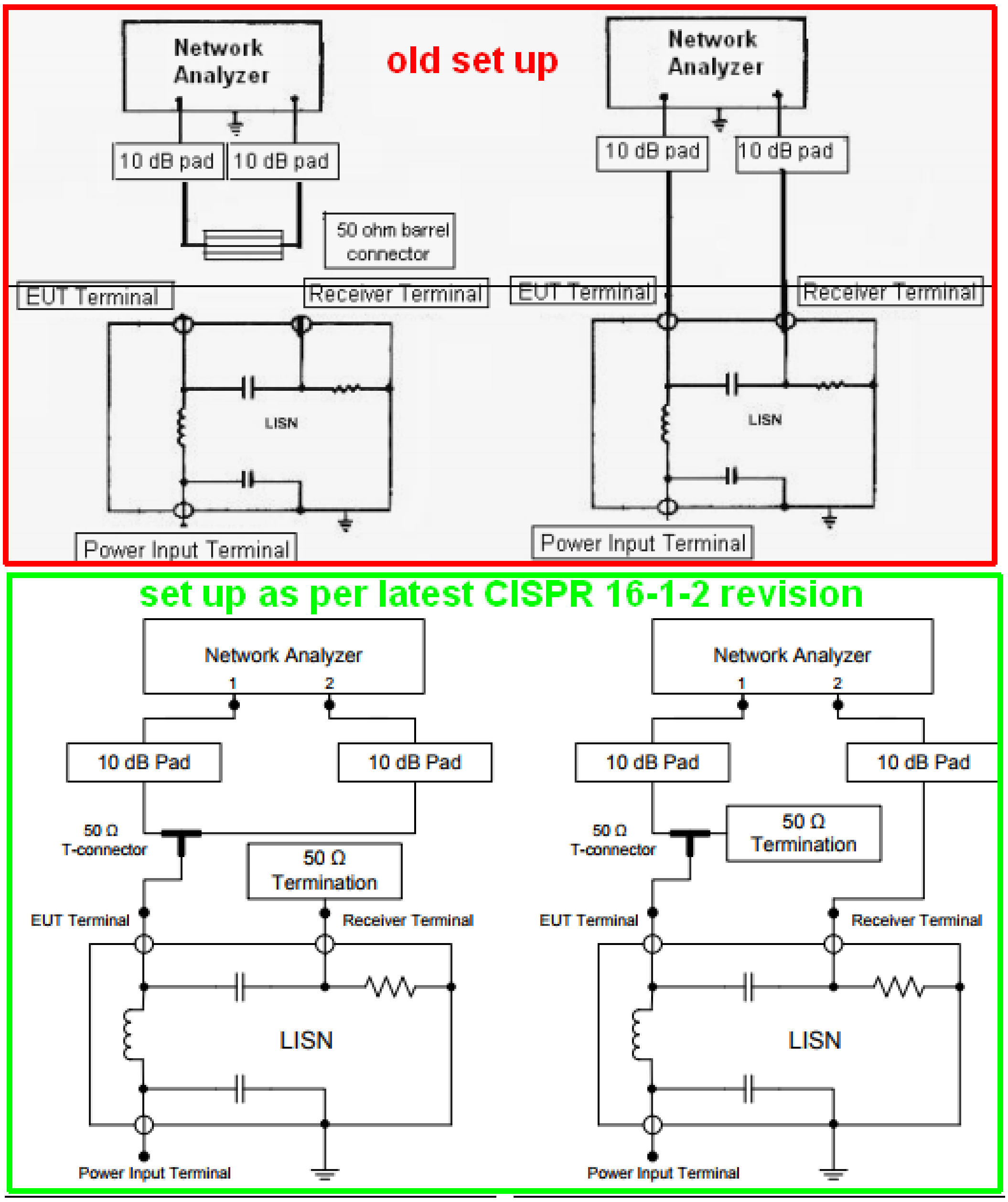
An intuitive approach would be looking at the insertion loss from the DUT port to the RF port and measure it with a network analyzer. However, CISPR 16-1-2, Annex A8 specifies a different approach, which they name "Measurement of the voltage division factor". The result is kind of a perceived insertion loss.



(b.1) ~~Reference transmission measurement~~ Reference measurement setup using network analyzer.

(b.2) ~~LISN transmission measurement~~ Transmission measurement setup using network analyzer.

Figure 6: measurement of LISN insertion loss

Conducted emission measurement using the Tekbox 5µH LISN TBOH01

Picture 3: LISN insertion loss, left – calibration set up, right – measurement set up

The set up above is not perfect. Ideally, the coaxial cable had to be brought directly to the terminals at the PCBA. The BNC to Banana-plug adapter will add some loss at higher frequencies. This is obvious in the table below and can be considered as a bit of margin with respect to the emissions of the DUT.

Frequency [MHz]	Insertion loss CISPR-25 and ISO1145-2/4/5 (1µF across source terminals) [dB]	Insertion loss DO-160 (10µF across source terminals) [dB]	Insertion loss ISO7637-2 (no capacitor across source terminals] [dB]
0.03	-3.9	-3.6	-3.53
0.05	-1.8	-1.77	-1.7
0.1	-0.6	-0.53	-0.56
0.5	-0.1	-0.09	-0.08
1	-0.1	-0.19	-0.17
10	-0.15	-0.16	-0.13
20	-0.25	-0.26	-0.25
30	-0.42	-0.44	-0.43
40	-0.61	-0.63	-0.62
50	-0.84	-0.85	-0.85
60	-1.07	-1.09	-1.07
70	-1.3	-1.33	-1.3
80	-1.56	-1.58	-1.57
90	-1.86	-1.88	-1.86
100	-2.15	-2.2	-2.19
110	-2.33	-2.37	-2.35
120	-2.55	-2.6	-2.57
130	-2.73	-2.79	-2.74

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140	-2.91	-3.05	-3
150	-3.1	-3.17	-3.12
160	-3.3	-3.37	-3.34
170	-3.5	-3.59	-3.55
180	-3.71	-3.79	-3.77
190	-3.9	-3.95	-3.92
200	-4.05	-4.13	-4.07

Table 8: LISN calibration data

9 Measurement automation with PC software

It is possible to perform conducted noise measurements by manually controlling the spectrum analyzer, but it is inefficient. Manual control makes sense only when working to reduce emissions within a narrow frequency band. To control the spectrum analyzer and process the measurement data if you want to make a measurement across the entire frequency range, you will need "EMC" software. Such software is available from a few spectrum analyzer manufacturers. The emission measurements documented in this application note were performed using Tekbox's EMCview..

An “EMC” software carries out following tasks:

- Controlling the spectrum analyzer
- Concatenating the sub-ranges to a plot spanning the entire frequency range
- Compensating LISN frequency response
- Compensating the frequency response of external components such as cables, attenuators, amplifiers
- Transforming data based on transimpedance characteristics of current probes or antenna factor characteristics of antennas
- Saving data for documentation
- Loading data for comparison

Using EMCview to perform CISPR 25 conducted noise measurements is simple.
After launching EMCview, go to Device, look for the spectrum analyzer, select it from the list, and then go to Connect Visa. Then, select CN CISPR 25 Class5 PQ QP.prj from the File / Load Project menu. The measurement will then begin when you press the Play button. Two measurement runs can be overlaid in a single graph. The configuration data set 1 is referred to as measurement 1, and the configuration data set 2 is referred to as measurement 2. Newer versions of EMCview can measure both graphs in one shot, each using a different detector.

When you load the project file, it automatically loads all of the configuration files for the measurement. These files are listed in EMCview's configuration window and can be changed or modified as needed.

- **Limit1**: contains the limit lines for Measurement 1(Set1); in the above case it is the limit1 file CN_CISPR25_Class5_Peak.lim, which is the limit line for CISPR 25 Class 5 peak detection
- **Limit2**: contains the limit lines for Measurement 2(Set2); in the above case it is the limit2 file CN_CISPR25_Class5_QP.lim, which is the limit line for CISPR 25 Class 5 quasi-peak detection
- **Seg-Set1**: contains the spectrum analyser configuration and frequency segments for measurement 1, CISPR 25 conducted emission measurement with peak detection; in the above case it is the segment 1 file CN_CISPR25_SEGMENTS_PEAK.seg

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- **Seg-Set2**: contains the spectrum analyser configuration and frequency segments for measurement2, CISPR 25 conducted emission measurement with quasi-peak detection; in the above case it is the segment 1 file CN_CISPR25_SEGMENTS_QP.seg
- **LISN Cor**: Frequency response correction file for the TBOH01 LISN, Tekbox_TBOH01_CISPR16_1_2_A_8.lsc
- **Cable Cor**: cable insertion loss correction file for the coaxial cable in use
- **Amp Cor**: gain/attenuation of external amplifiers or attenuators if needed
- **Ant Cor**: antenna factor file for radiated emission measurements

The segment files are placed in the sub-directory **SRC** of EMCview.

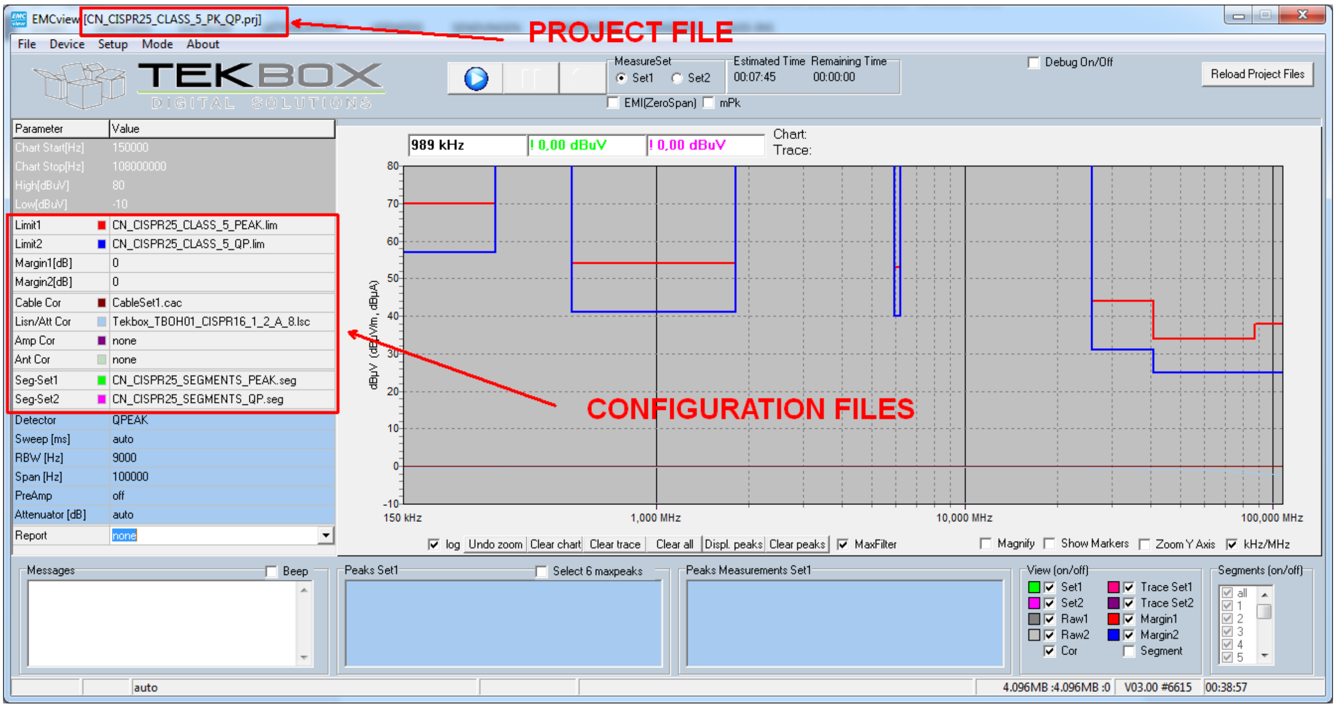

Figure 7: EMCview

Every configuration file is self-explanatory plain text. The files can be created or edited using EMCview's built-in editor or any text editor. As an example, see the segment file contents below.
CN_CISPR25_SEGMENTS_QP.seg

[Application]	
Software=TekBox RP-W32-D7	I
Version=Demo	I
Date=30/01/2017 6:56:06 PM	I HEADER
[General]	I
Name=CN_CISPR25_SEGMENTS_PEAK.seg	I
[Data]	I
FRQa__1=150.000	
FRQb__1=2.500.000	I Frequency segment 1, range: 150 kHz to 2.5MHz
BW____1=9000	I Resolution bandwidth: 9 kHz
Sweep_1=25000	I Sweep time: 25 s (=10 s/MHz as per CISPR 25)
Att___1=0	I Spectrum analyser attenuator set to 0 dB
PreAmp1=off	I Spectrum Analyzer pre-amplifier turned off
Detector1=POSPEAK	I positive peak detector selected

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```
FRQa__2=2.500.000          | Frequency segment 2, range: 2.5MHz to 5MHz
FRQb__2=5.000.000          |
BW____2=9000               |
Sweep_2=25000              |
Att___2=0                  |
PreAmp2=off                |
Detector2=POSPEAK          |________________
FRQa__3=5.000.000          |
FRQb__3=7.500.000          |
.                          .
.                          .
.                          .
FRQa__12=27.500.000        |
FRQb__12=30.000.000        |
BW____12=9000              |
Sweep_12=25000             |
Att___12=0                 |
PreAmp12=off               |
Detector12=POSPEAK         |________________
FRQa__13=30.000.000        | Frequency segment 13 from 30MHz to 55MHz
FRQb__13=55.000.000        |
BW____13=120000            | Resolution bandwidth changed to 120 kHz
Sweep_13=25000             | Sweep time: 25 s (=1 s/MHz as per CISPR 25)
Att___13=0                 | Spectrum analyser attenuator set to 0 dB
PreAmp13=on                | Spectrum Analyzer pre-amplifier turned on
Detector13=POSPEAK         | positive peak detector selected
FRQa__14=55.000.000        |
FRQb__14=80.000.000        .
BW____14=120000            .
Sweep_14=25000             .
Att___14=0
PreAmp14=on
Detector14=POSPEAK
FRQa__15=80.000.000
FRQb__15=108.000.000
BW____15=120000
Sweep_15=25000
Att___15=0
PreAmp15=on
Detector15=POSPEAK
```

Syntax for detectors:
Quasi peak: QPEAK
Positive peak: POSPEAK
Negative peak: NEGPEAK
Normal: NORM
Average: VAV

More information on EMCview can be found in the manual, which can be downloaded from the Tekbox website.

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10 Carrying out conducted emission measurements

The following measurements will be taken with a Siglent SSA3021. We turn off the pre-amplifier in the frequency range above 30MHz based on its noise floor characteristics discussed in Chapter 7.4 to reduce the risk of non-linear distortions during initial measurements..
In the **SRC** sub-directory of EMCview, open the segment files CN_CISPR25_SEGMENTS_QP.seg, CN_CISPR25_SEGMENTS_Peak.seg, CN_CISPR25_SEGMENTS_AVG.seg with a text editor.
Search for the string “=on” and replace all with “=off”. Then save the modified segment files and start EMCview.
The electrical set up is according to picture 1. The DUT is an automotive position light PCBA.

10.1 Set-up validation - ambient emissions, voltage method

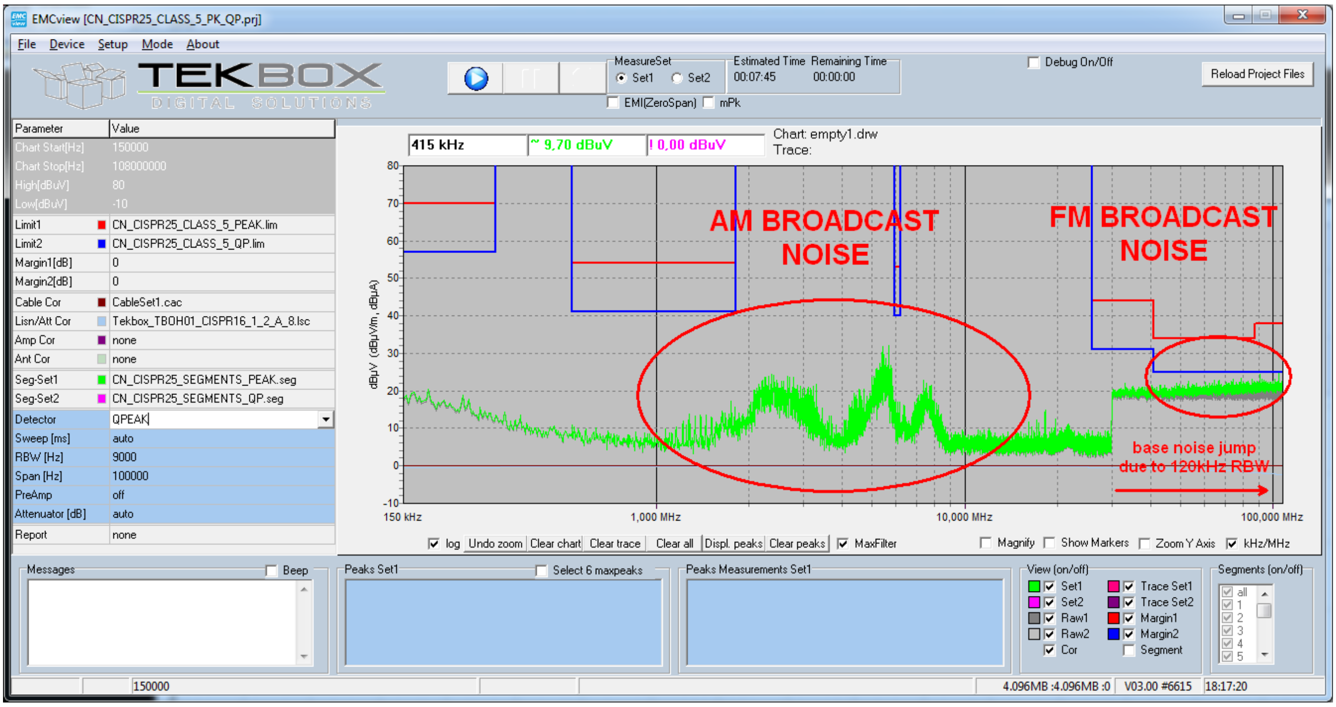

Figure 8: Peak detector measurement with DUT not powered

Figure 8 depicts the measurement result with the DUT turned off. What can be seen is AM and FM broadcast noise picked up by the cables connecting the DUT and the LISNs. According to CISPR 25, the abrupt change in the noise floor at 30 MHz is caused by an RBW change from 9 kHz to 120 kHz. The ambient noise is well below the standard's limits, so it poses no significant challenge to the measurement. However, except for the equipment required for the emission measurement, all equipment in the lab room was turned off.

Also, keep in mind that the level of AM emissions varies throughout the day. The reading was taken at noon, when the levels are lower than later in the afternoon.

Another measurement is performed with the pre-amplifier turned on above 30 MHz to get a better look at the FM noise.

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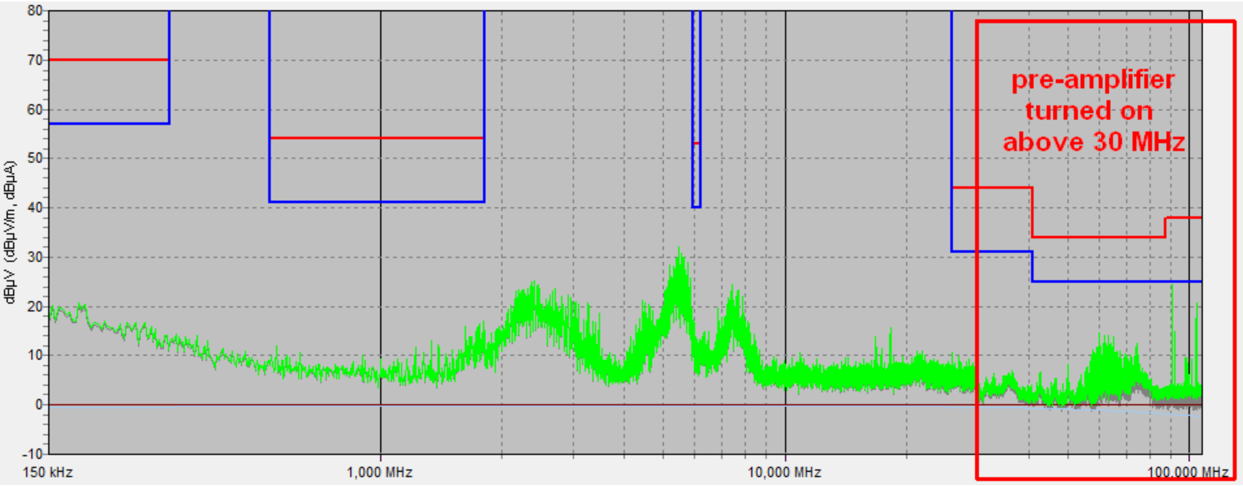

Figure 9: Peak detector measurement with DUT not powered; pre-amplifier turned on above 30 MHz

The base noise is reduced by approximately 20 dB after turning on the pre-amplifier in the EMCview segment file CN CISPR25 SEGMENTS Peak.seg for segments above 30 MHz. The measurement graph provides more information about ambient noise above 30MHz.
Measuring was done on both the positive and negative supply lines. Figures 8 and 9 show the negative supply line results, which were slightly higher than the positive supply line results.

10.2 Set-up validation - ambient emissions, current method

The set up shown in picture 2 was used to measure the ambient noise with the DUT not powered.
The internal attenuator was set to 0 dB and the pre-amplifier was turned on for all segments.

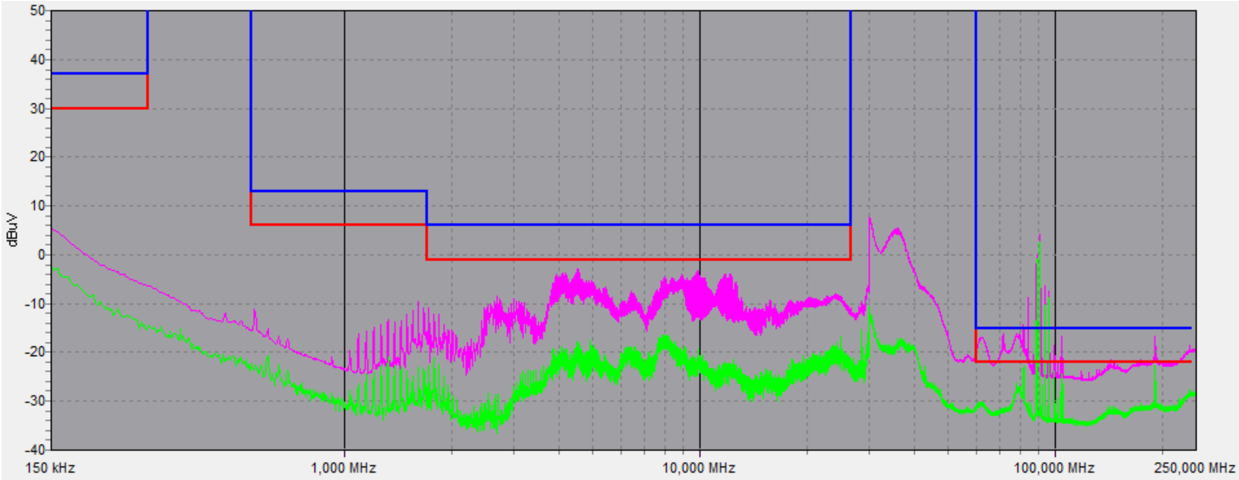

Figure 10: Peak detector (green) and quasi peak detector (pink) measurement with DUT not powered; pre-amplifier turned on above 30 MHz

Figure 10 depicts the outcome of the ambient noise measurement. More ambient noise is picked up as a result of using a longer supply cable. FM broadcast noise, in particular, is exceeding the limit lines.

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10.3 Set-up validation - non-linear distortions

In order to validate potential non-linear distortions; three measurements will be taken.

Set1: peak detector, attenuation 10dB and pre-amplifier off for all segments

Alternative Set 1: peak detector, attenuation 0dB and pre-amplifier on for all segments

Set 2: peak detector, attenuation 0dB and pre-amplifier off for all segments

For this purpose, three segment files will be created. A separate project file will also be created. A measurement with Set 1 will be made first in order to place all three results into a single graph for better comparison. The chart will then be saved clicking menu File, Utilities, Save Chart.

Following that, two measurement runs will be performed using alternative Set 1 and Set 2. Following completion, the first run's chart will be loaded as a reference chart, allowing three measurement runs to be displayed within a single graph for easier comparison.

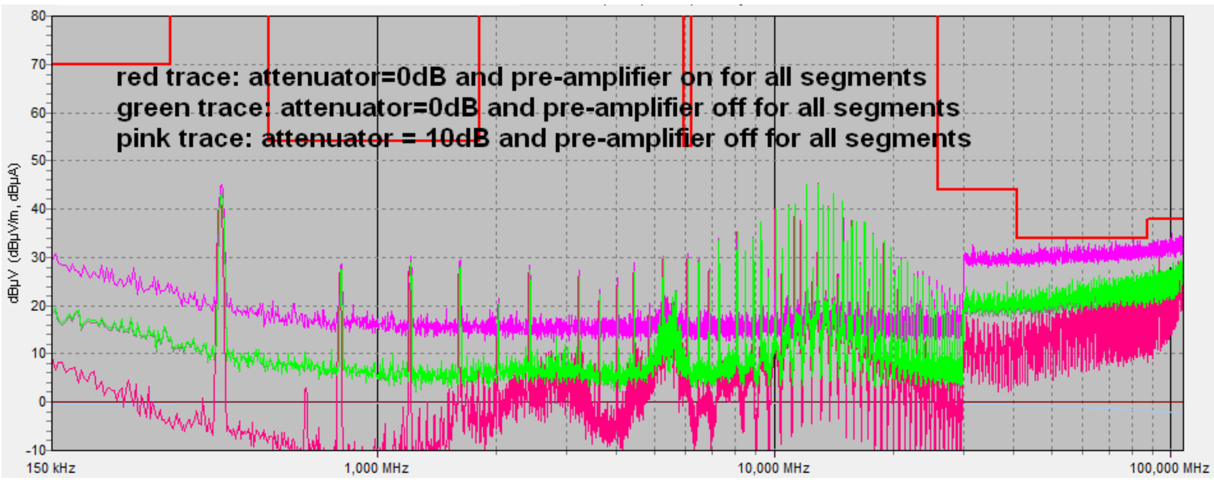

Figure 11: Peak detector measurement with DUT powered and various attenuator/pre-amplifier settings

Figure 11's traces show no evidence of intermodulation. Zoomed screenshots of the amplitudes of the various configurations are shown below.

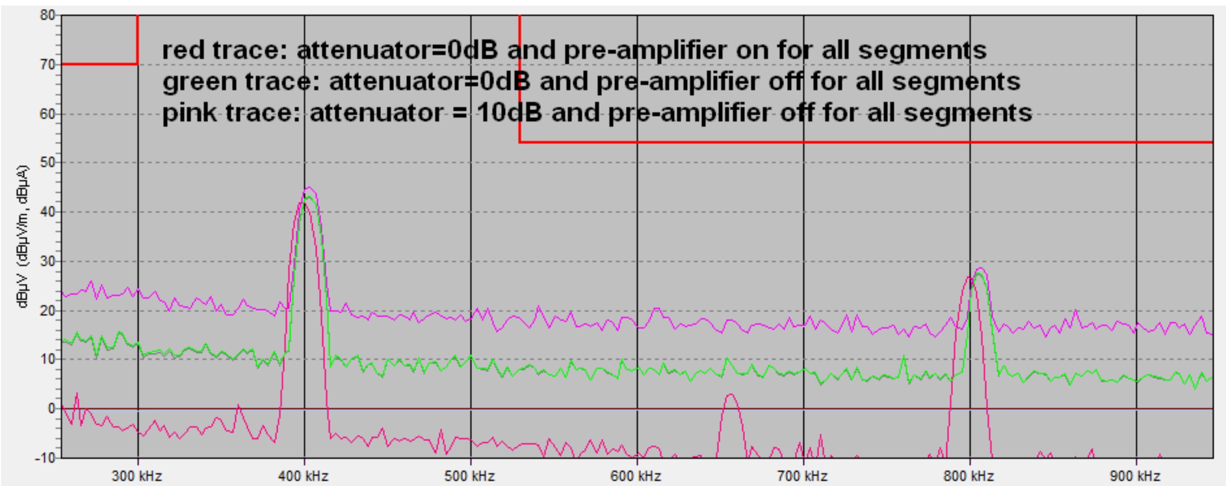

Figure 12: Peak detector measurement with DUT powered and various attenuator/pre-amplifier settings, zoomed

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The zoomed traces in Figure 12 show a frequency and amplitude mismatch for the measurement with attenuator = 0dB and pre-amplifier on for all segments. The frequency offset is caused by a drift of the switched mode regulator frequency, as the measurement was taken without a long warm up period. For the two measurements thereafter, the spurious are at exactly the same frequency. The amplitude offset may be caused by warm up of the spectrum analyser or by amplitude inaccuracy at lower frequencies.

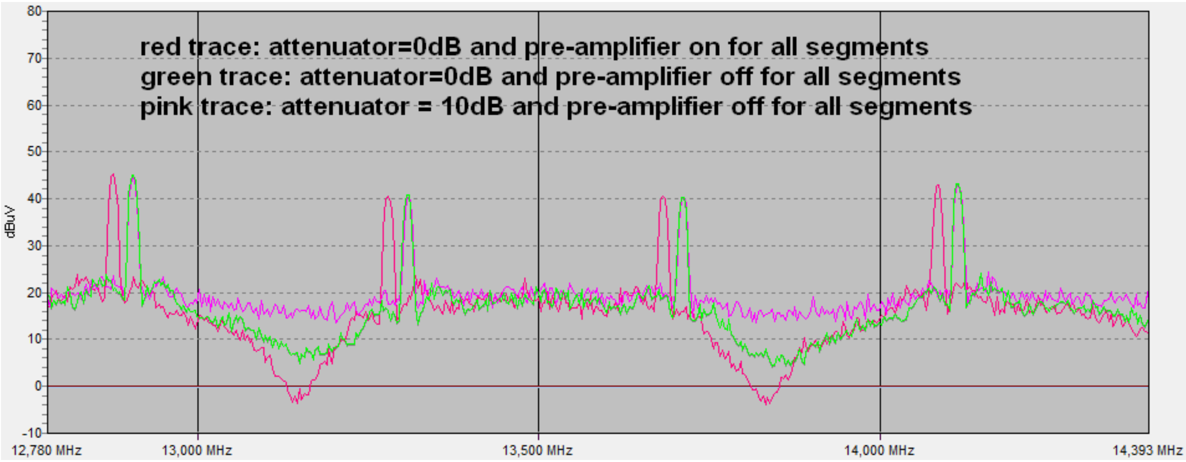

Figure 13: Peak detector measurement with DUT powered and various attenuator/pre-amplifier settings, zoomed

The zoomed traces in Figure 13 show a frequency mismatch for the measurement with attenuator = 0dB and pre-amplifier on for all segments. The frequency offset is caused by a drift of the switched mode regulator. As we are basically looking at harmonics of the switched mode regulator, the frequency offset is higher compared to what we see at lower frequencies. The frequency offset is multiplied by the number of the harmonic. The amplitudes of all three configurations match very well and the measurement is not degraded by non-linear distortion.

The DUT we looked at in figures 11 to 13 has rather low conducted emissions, well within the limits of CISPR 25, class 5. To get a better picture, the measurements are repeated with a “worse” DUT.

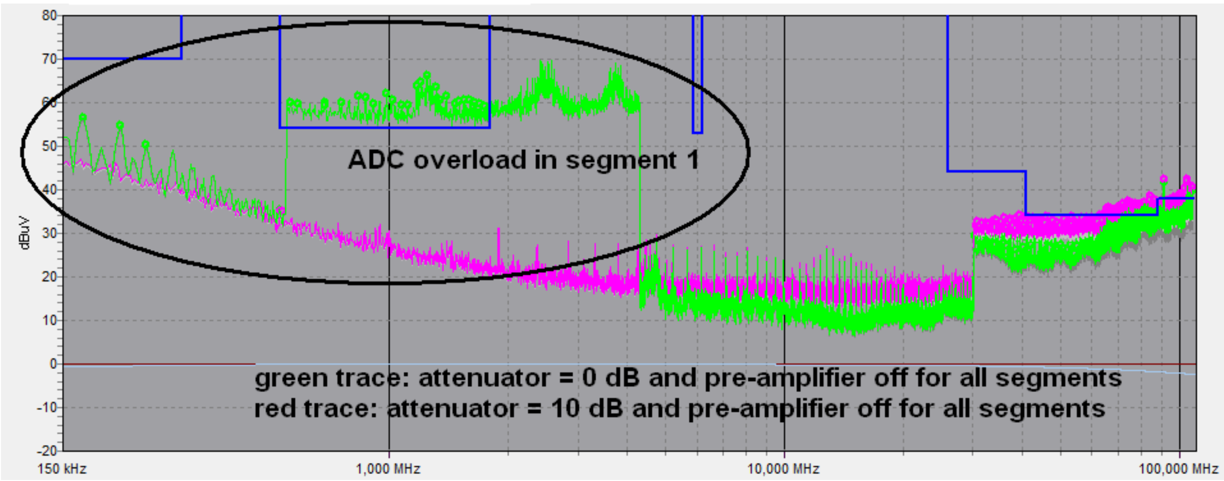

Figure 14: Peak detector measurement; a case of severe ADC overload in segment 1

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Figure 14 shows the measurement result of a DUT with high noise level in the segment up to 2.5 MHz. The spectrum analyser responded with an ADC overload message and a warning beep. In this case, the internal attenuator setting needs to be changed to 10dB, at least for segment 1. The other segments need to be zoomed in to investigate for distortions.

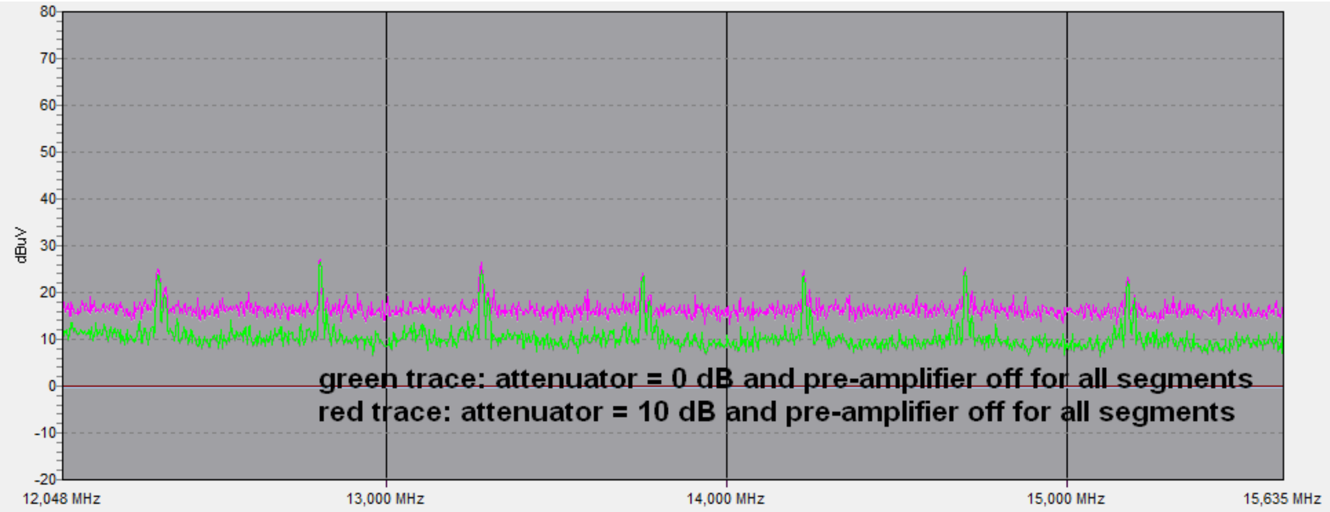


Figure 15: Peak detector measurement, zoomed

Zooming in on the trace revealed no non-linear distortion problems. It would be sufficient to change the first segment to 10dB attenuation. The other segments can be left at 0dBm, resulting in lower base noise..

10.4 Set-up validation – ground plane dimensions

10.4.1 Voltage method

As the distance between LISN and DUT is specified to 20 cm, the ground plane area set up in a design laboratory can be kept relatively small, e.g. 50 x 50 cm. Comparative tests with larger ground planes revealed no significant differences in the noise measurement results.

10.4.2 Current probe method

A setup with a small ground plane, as shown in Figure 2, and another setup with a large ground plane, which allowed for a straight cable layout, were compared.

Figure 16 depicts a zoomed-in view of the worst-case variations. The measured amplitudes of the spurious were nearly identical in the frequency ranges below 30 MHz and above 60 MHz. However, the measurement results differed by up to 10dB in the frequency range of 30 MHz to 60 MHz. It is most likely caused by a shift in the cable's resonance frequency when laid out meandered on the small ground plane.

As a result, when measuring on a small ground plane, a larger margin to the limits should be considered.

Conducted emission measurement using the Tekbox 5µH LISN TBOH01

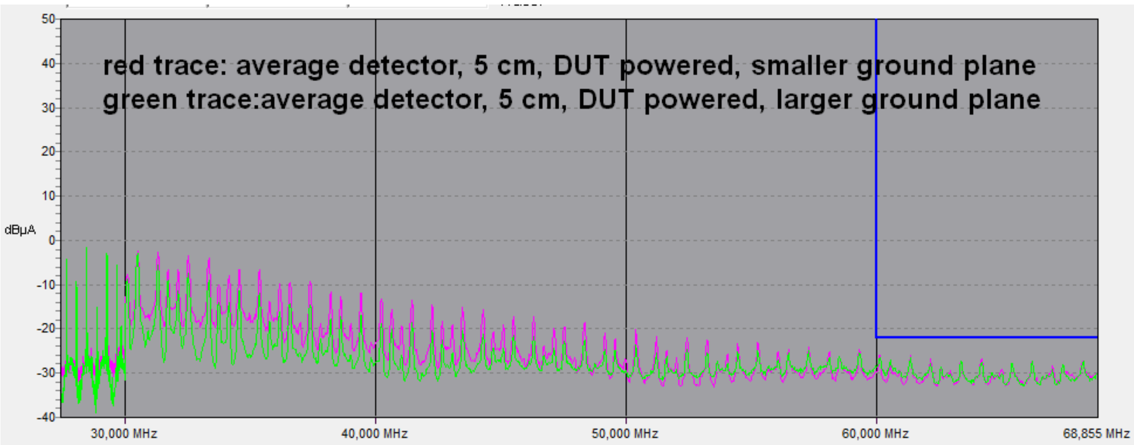


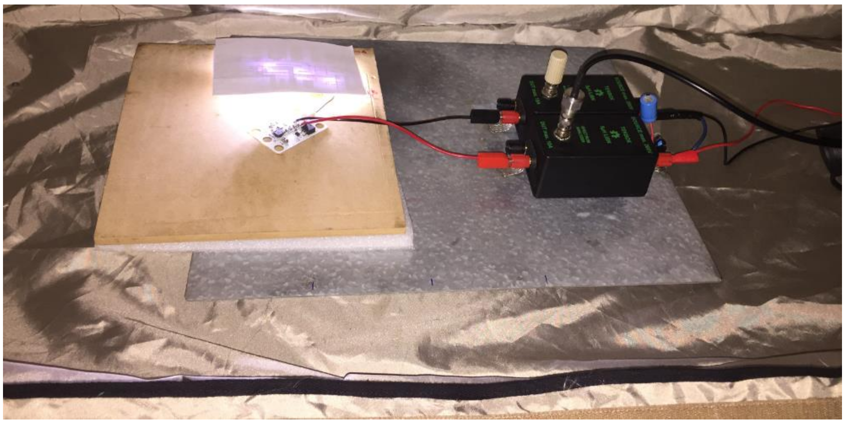
Figure 16: measurement variations due to dimensional variations of the ground plane

10.5 Final measurement, voltage method

The measurement is carried out with a Siglent SSA 3021X spectrum analyzer after the setup has been validated. In the average, peak, and quasi-peak segment files, attenuation is set to 0 dB for the entire frequency range, and the pre-amplifier is turned on for segments with 120 kHz RBW (30 MHz- 108 MHz).

The measurement was carried out using a shielded tent from Tekbox to suppress ambient noise..

Picture 4: Tekbox TBST120/60/60/2 shielded tent



Picture 5: set up inside the shielded tent

Conducted emission measurement using the Tekbox 5µH LISN TBOH01

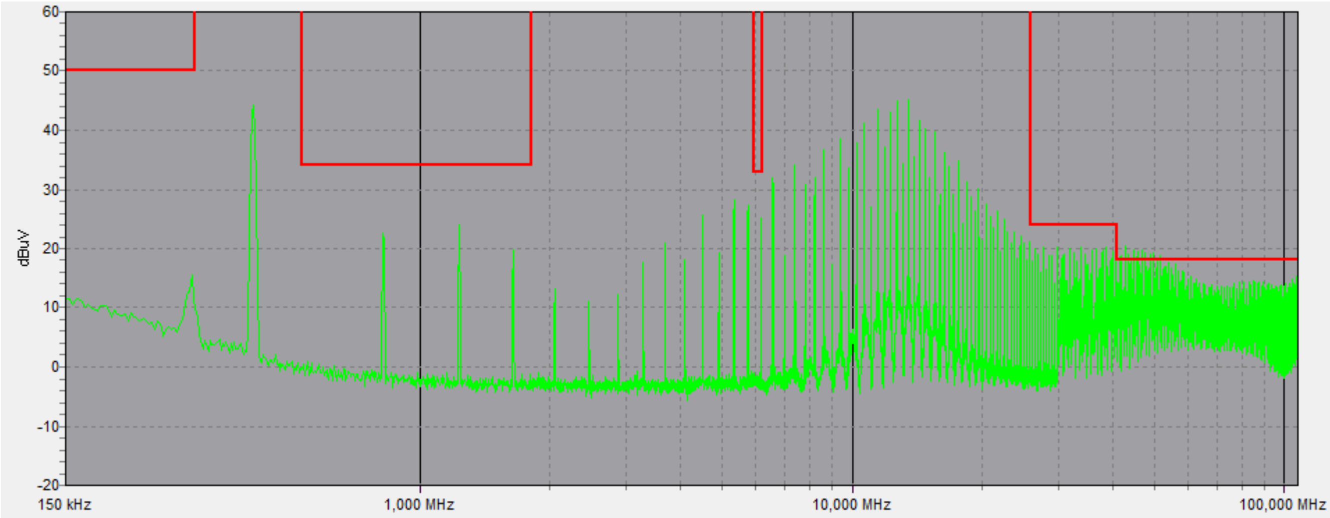


Figure 17: measurement result CISPR25 Class 5 average detector

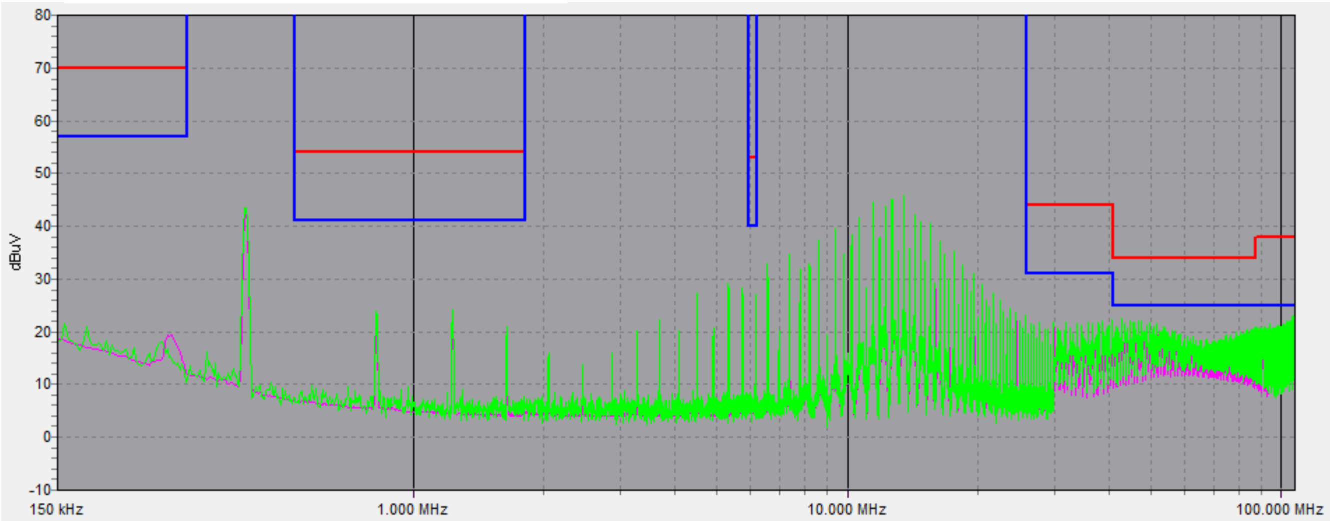


Figure 18: measurement result CISPR25 Class 5 peak detector (green) and quasi peak detector (pink)

The results are free of ambient noise and show the conducted noise on the positive supply line.
Each average or peak detector measurement takes approximately 9 minutes. The measurement takes 2 hours and 45 minutes using a quasi peak detector across the entire frequency range. To save time, the quasi peak measurement could be limited to re-measuring critical peaks, which cross the QP limits when measuring with a peak detector. EMCview displays critical frequencies where noise exceeds limits or a specified margin from the limits. These peak frequencies can then be selected to perform a quick quasi-peak scan.

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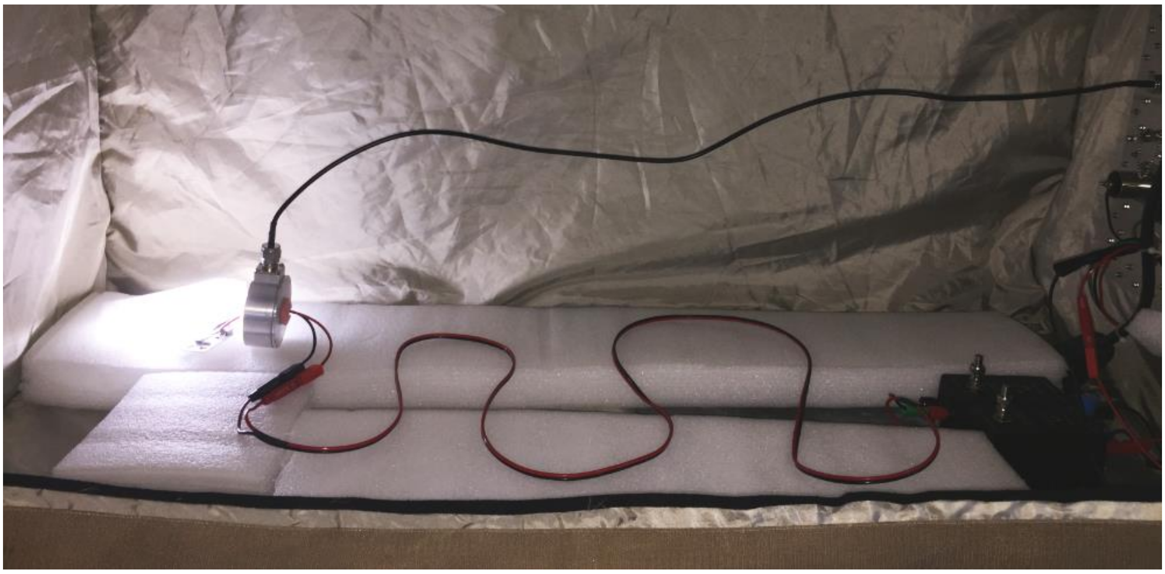
10.6 Final measurement, current probe method

Limits of an automotive manufacturer standard were used for the final measurement using the current probe method. The upper frequency limits are stricter than the CISPR 25 Class 5 limits.
The current probe has a transfer impedance of 15 dBΩ. There was no need for any load simulator, as the DUT is not connected to any other device. The measurement was carried out inside a shielded tent to eliminate ambient noise. The attenuator in the corresponding EMCview segment file was set to Off and the pre-amplifier was set to On for all segments. With this settings and the overall performance of the Siglent SSA 3021X spectrum analyzer there was sufficient margin to the base noise level and a useful result could be obtained even at higher frequencies where the limits are very low.
Figure 19 depicts the measurement results for the positive and negative supply lines at a distance of 5 cm from the DUT. To complete the measurement, additional runs with only the positive and negative supply lines must be added. The tests must also be performed at a distance of 75 cm from the DUT.



Picture 6: current probe measurement set up in a shielded tent

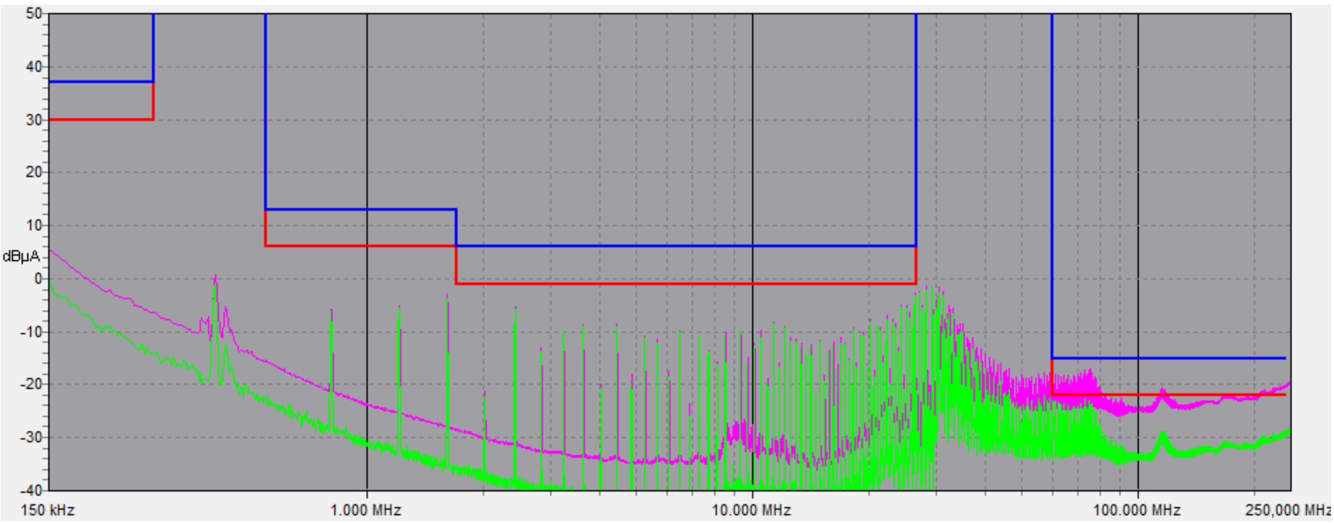


Figure 19: measurement result using an automotive manufacturer standard with tougher limits compared to CISPR25 Class5; peak detector (green) and quasi peak detector (pink); measured in 5 cm distance from DUT on positive and negative supply line; set up in shielded tent

Conducted emission measurement using the Tekbox 5µH LISN TBOH01

11 History

Version	Date	Author	Changes
V1.0	30.12.2017	Mayerhofer	Creation of the document
V1.1	18.09.2018	Mayerhofer	Corrected table 6
V1.2	22.04.2020	Mayerhofer	Updated drawings
V1.3	24.3.2022	Mayerhofer	Updated all chapters

Table 9 – History