Conducted emission measurement using the Tekbox 5µH LISN TBOH01

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1   Introduction

This application note shall serve as an introduction to engineers confronted with conducted emission compliance requirements during product development or product approval. The application note is by far no replacement to the contents of various relevant standards. It looks into various aspects of pre-compliance conducted emission measurements that can be carried out with a 5µH LISN and a low cost spectrum analyzer in a standard electronic product development laboratory environment. What is the purpose of a LISN? How can conducted emissions be 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

The abbreviation LISN stands 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
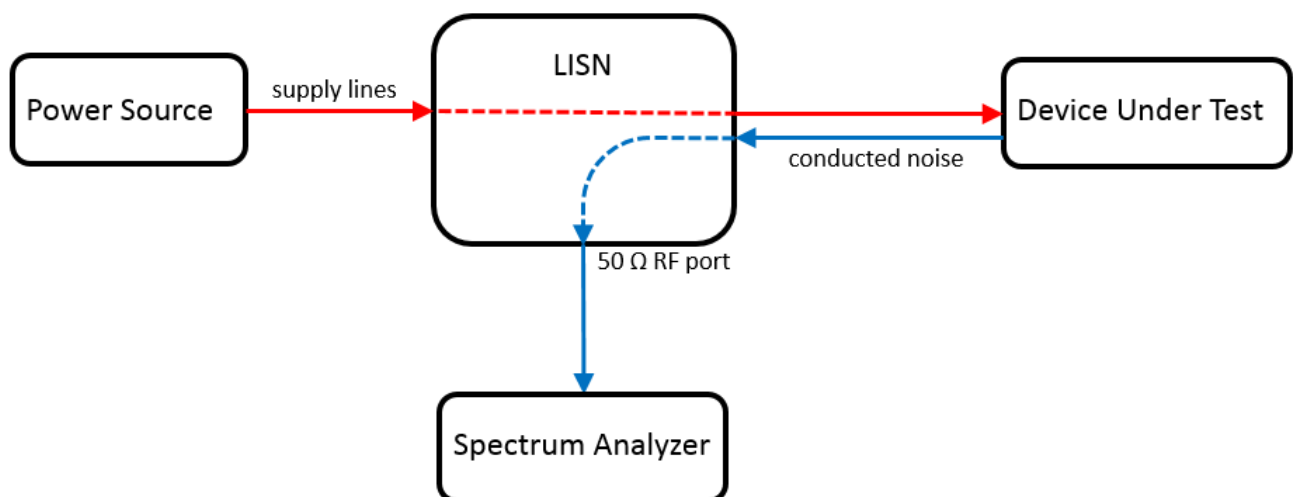

Figure 1: Basic diagram of a conducted emission measurement setup with a LISN

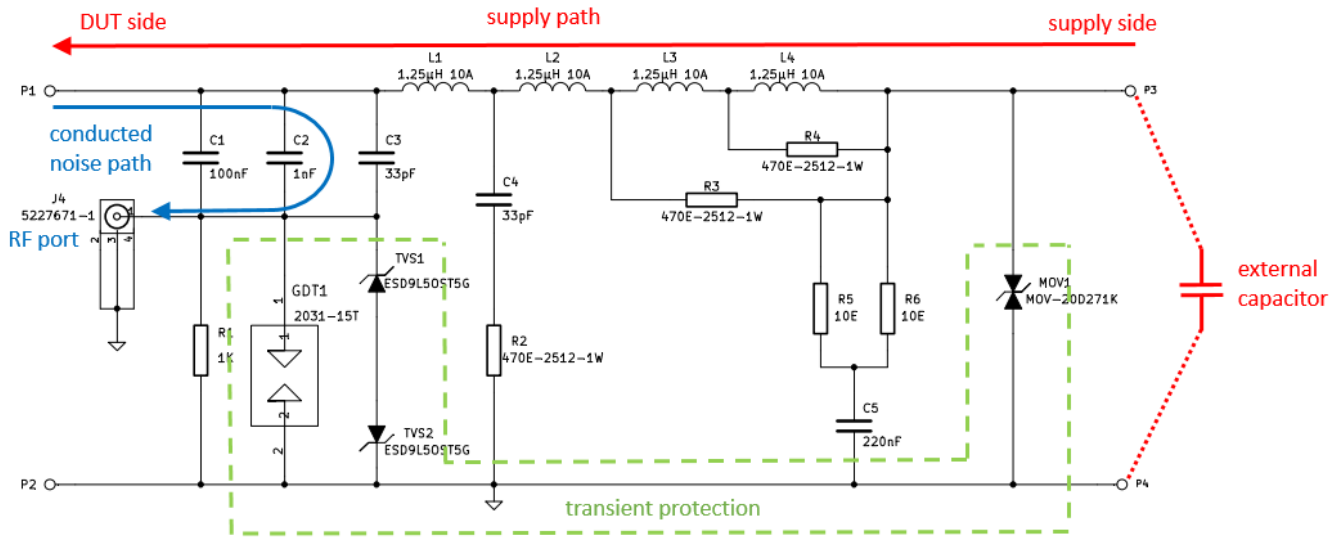# Conducted emission measurement using the Tekbox 5µH LISN TBOH01

Figure 2: schematic of the Tekbox 5µH LISN TBOH01

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

It also shows an external capacitor. This capacitor has to be connected externally to the supply side of the LISN. The value depends on the relevant 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, consider that the TBOH01 is not specified for the full DO-160 frequency range.

The TBOH01 terminals have perpendicular holes to easily insert and clamp the pins of the external capacitor. ISO7637-2 does not specify an external capacitor.

In case of a set up with two LISN, means one in the positive supply path and another one in the negative supply path, an additional 1000µF capacitor has to be connected in between the red terminals of the two LISNs. It is explained in more detail in chapter 4

3   Conducted emission measurement set up, voltage method

Taking CISPR 25 as an example, there are two measurement configurations specified by the standard:

If the DUT is grounded to the vehicle chassis with a power return line shorter than 20 cm, a single 5µH LISN is sufficient and the conducted noise will only be measured on the positive supply line.

If the power return line of the DUT is longer than 20 cm, two 5µH LISNs are required. The positive supply line is connected to the DUT via one LISN and the power return line is connected to the DUT via another LISN. Conducted noise is measured on both lines. In fact, it is measured on one LISN at a time, while the RF port of the other LISN is terminated with a 50 Ω resistor.

Conducted emission measurement using the Tekbox 5µH LISN TBOH01
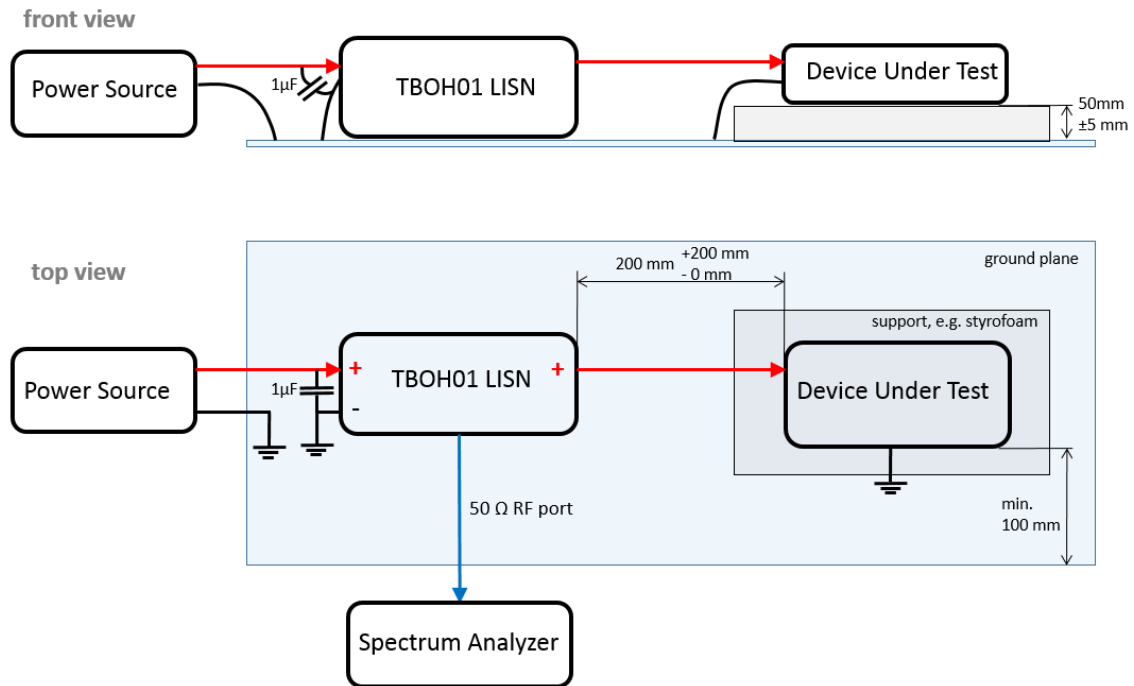
Figure 3: conducted emission measurement, voltage method, DUT with power return line locally grounded
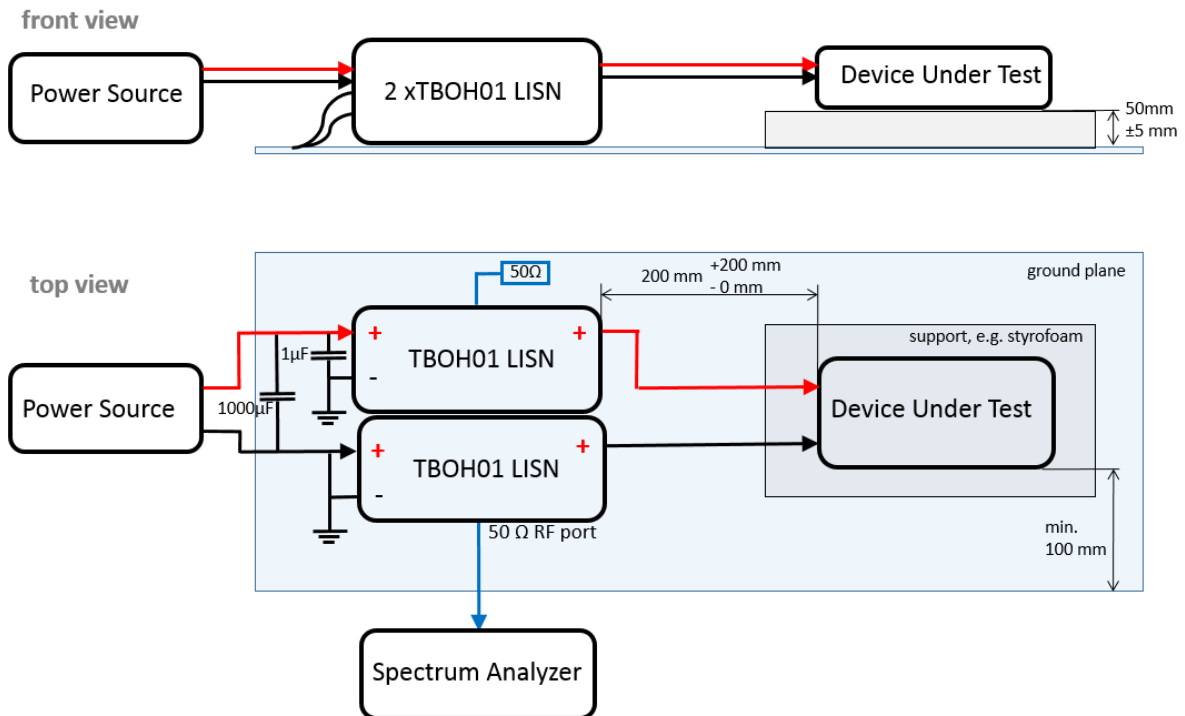
Figure 4: conducted emission measurement, voltage method, DUT with power return line remotely grounded
Figure 3 and figure 4 show conducted noise measurement set ups, voltage method, according to CISPR 25. In case that the DUT is connected to other peripheral devices, they should be connected as well, or simulated with a load box. If the housing of a remotely powered DUT foresees chassis grounding, it should be grounded to the ground plane as well. The grounding lead should not be longer than 150mm then.

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A set up according picture 4 is more common, as most devices are remotely grounded.
The measurement needs to be alternatively carried out on both the positive and negative power line then.
The unused RF port is always terminated with 50 Ohm.
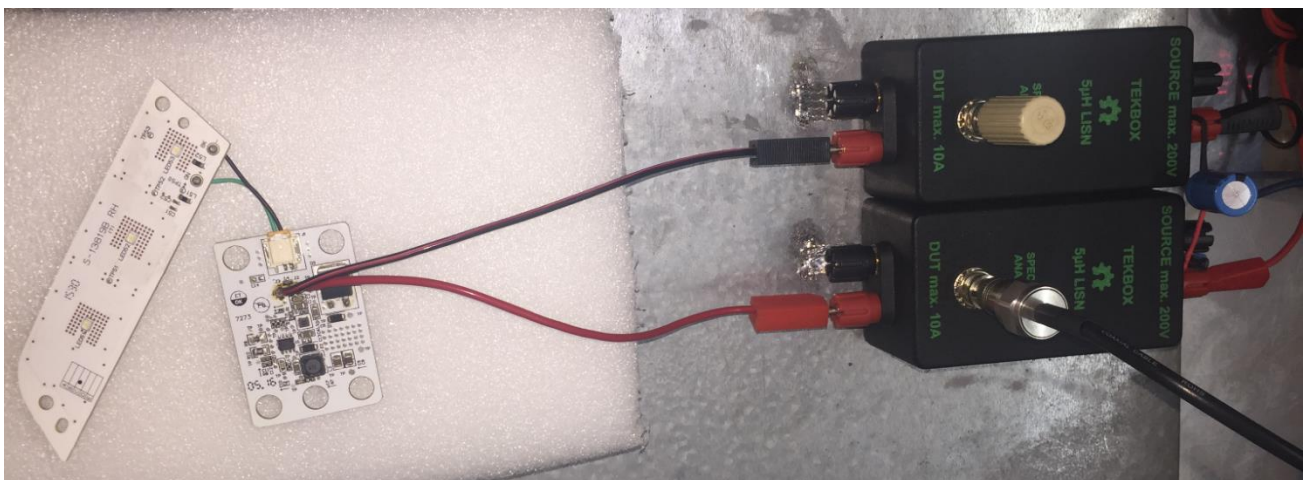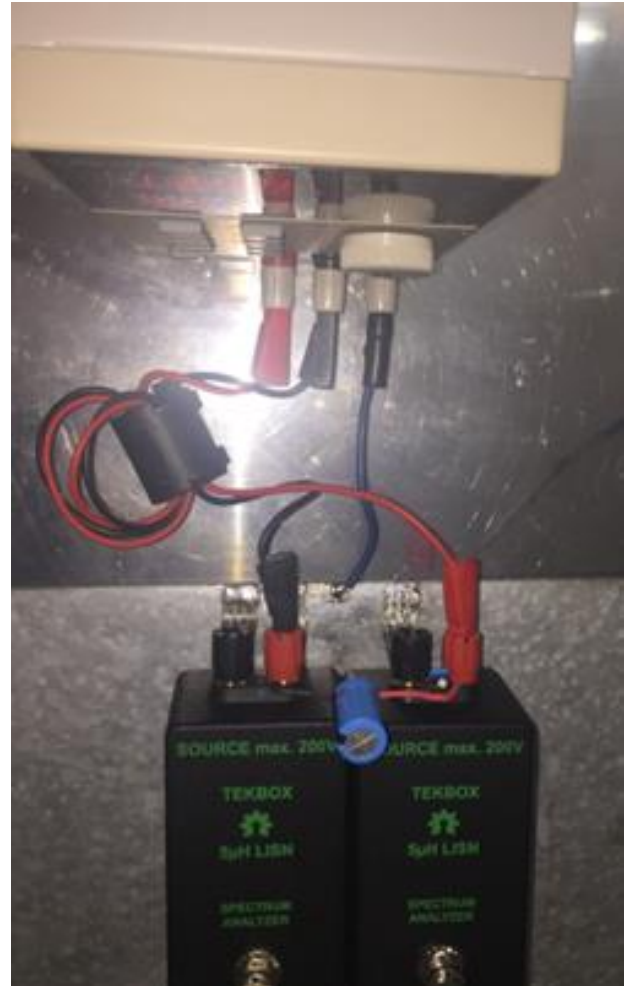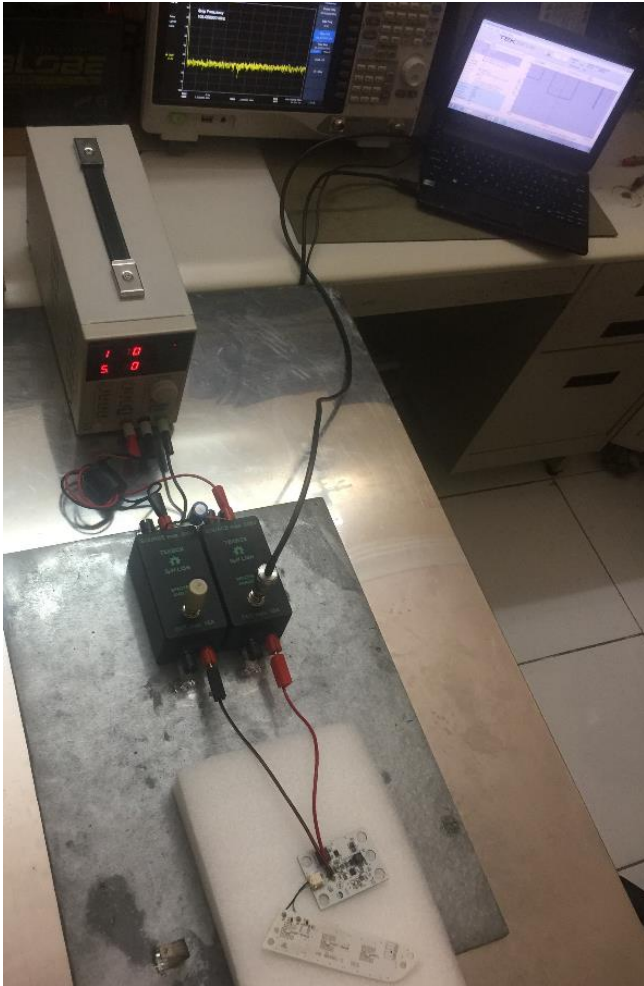
Picture 1: simple pre-compliance conducted emission measurement set up, voltage method

Conducted emission measurement using the Tekbox 5µH LISN TBOH01

4 Conducted emission measurement set up, current probe method
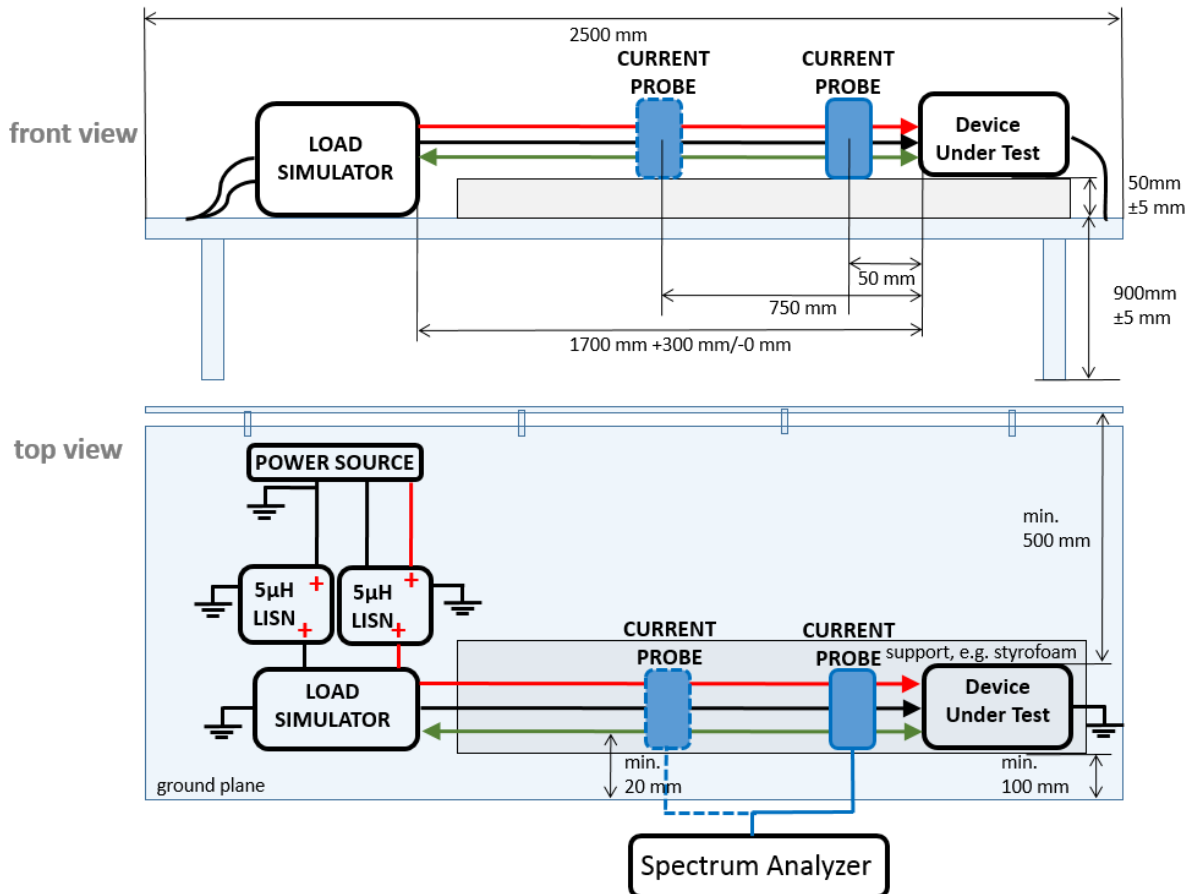
Figure 5: conducted emission measurement according to CISPR 25, current probe method

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. However, it is also used by some automotive manufacturers to measure power supply lines instead of applying the voltage method. Measurements are typically taken on various lines – plus, minus, control signals, plus + minus, plus + minus + control lines.

The current probe measurement is carried out with the probes positioned in 50 mm distance and in 750 mm distance from the EUT in order to cover resonance effects of the cable harness.

The current probe method according to CISPR 25 covers the frequency range 0.15 MHz to 108 MHz. However, there are automotive manufacturers who significantly extend the upper frequency limit in their own standards.

A current probe picks up the conducted emissions. Two LISNs are required to establish a defined impedance on the power lines. The load simulator is an individual device that simulates the load present at the signal/control interface of the DUT.

Conducted emission measurement using the Tekbox 5µH LISN TBOH01
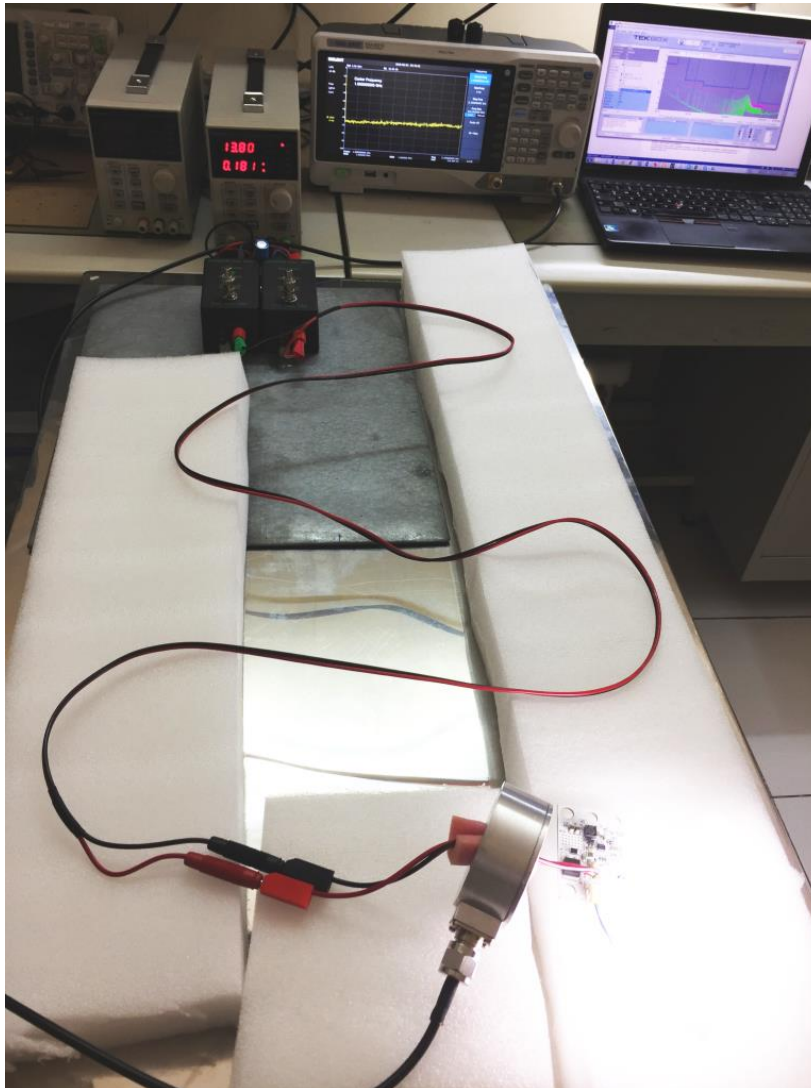
Picture 2: simplified set up for pre-compliance conducted emission measurement using the current probe method

Picture 2 shows a simple set up for current probe based conducted emission measurement. Due to space constraints, the set up was done on a small ground plane. Consequently, the supply cable had to be laid out meandered. The RF current probe is placed in the 50 mm position.

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5 Applicable standards

CISPR 16-1-2 and CISPR 25 specify the technical requirements for 5µH LISNs and the corresponding conducted emission measurement set-ups.

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 following tables are a simplified summary, not 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 looks at how to carry out pre-compliance measurements in a development lab environment and not how to set up a 100% compliant conducted emission test. Hence, it is assumed that the tests are carried out with a spectrum analyzer rather than with an EMI measurement receiver. CISPR 16, CISPR 25 and other standards give recommendations how to configure spectrum analysers, when it is used as a replacement to a measurement receiver.

7.1 RBW and sweep time

Below an excerpt of specifications concerning spectrum analyzers in CISPR 25:

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

Applying the list above to peak or average detection, we would need to set a sweep from 0.15 MHz – 30 MHz with a RBW of 9 kHz and a sweep time of 300 seconds. Then we would need to change to a sweep from 30 MHz – 108 MHz, set the RBW to 120 kHz and the sweep time to 7.8 seconds.
So far, this seems reasonable effort to be carried out manually, however there are further requirements to be taken into consideration that will end up with a different conclusion.

The specified sweep times for quasi-peak detection may not be suitable for every low cost spectrum analyzer. Set the span and RBW of a sub-range manually. Set the detector to quasi-peak. Then check the sweep time that was automatically configured by the spectrum analyzer. In case that the sweep time is longer than specified in CISPR 25, use the auto sweep time instead.

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7.2 RBW and frequency span

Spectrum analyzers typically make 600 to 800 measurements within the span. It typically corresponds to the number of pixels on the frequency axis. The default number for the RIGOL DSA 815 is 601 points and the default number of SIGLENT spectrum analyzers is 751 points.

Looking at the DSA 815 and a span of 0.15 MHz to 30 MHz, it would mean that two adjacent points are nearly 50 kHz apart. Given the 9 kHz RBW specified by CISPR 25, it is obvious that the analyser would skip over emissions. In order to mimic a measurement receiver, the RBW filter curves of adjacent frequency points should overlap. In fact, adjacent measurement points should not be more than half the RBW apart. Making a calculation for the DSA815 with 601 points and 9 kHz RBW, we get a maximum span of 4.5 kHz * 601 = 2.7 MHz. Instead of sweeping over the range 0.15 MHz to 30 MHz in one shot, we have to limit the span to 2.7 MHz and divide the measurement into many sub ranges 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 would require 14 sweeps with a DSA815 and 10 sweeps with a SSA30xx spectrum analyzer.

7.3 Video bandwidth

According to CISPR 25, the video bandwidth shall be set to at least three times the resolution bandwidth.

7.4 Spectrum analyzer noise floor

According to CISPR 25, the noise floor of a scanning receiver / spectrum analyser shall be at least 6dB lower than the applicable limits.

In order to investigate, we need to look at the lowest limits for conducted emissions, voltage method, 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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It may be necessary to use a pre-amplifier in order to achieve the noise level criteria of CISPR25. In this case, the measurement result needs to be critically inspected for potential measurement errors due to non-linear distortions that may be created by the spectrum analyzer pre-amplifier.

On the other hand it can also be seen that in certain configurations there is sufficient margin to engage the internal attenuator in order to prevent potential IF overload situations and to improve immunity to non-linear distortions.

Always check the noise floor of your spectrum analyzer with respect to the applicable limits of your measurement. Then decide upon the settings for the internal attenuator and whether a pre-amplifier is needed or not.

7.5 Non-linear distortions

As mentioned in the previous chapter, it may be necessary to reduce the internal input attenuation and turn on the pre-amplifier of the spectrum analyzer 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 typically have a higher amplitude and where the limit lines are at a higher level.

It is also advisable to ignore the base noise level for a comparison measurement with higher input attenuation. Compare the results of a measurement with the input attenuation set to for example 10 dB with a measurement taken with zero input attenuation. If the spurious levels of both measurements are identical, there are no intermodulation issues and you can trust your measurement result.

Another issue you may encounter is ADC overload in presence of strong signals. This is reported by a message on the analyzer display and a warning beep. Interrupt the measurement and turn off the pre-amplifier and / or increase the internal attenuation.

7.6 Spectrum analyzer RF input protection

Spectrum analyzers typically have maximum input ratings in the range +20 dBm to +30 dBm. If your DUT contains inductive loads, it is good practice to insert at least a 20dBm attenuator at the input of your spectrum analyzer in order to check if the spurious levels do not exceed the maximum input ratings of the spectrum analyzer. Most high amplitude spurious originate from Motors or switched mode regulators in the power management section of the DUT. Depending on the switching frequency, check the frequency range up to the 5th harmonic at least. Run the analyzer at a slow sweep with the detector to peak and the trace set to max. hold. If the levels are within the limits of the analyzer RF input, you can remove the external attenuator.

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

As a LISN basically can be considered a well-defined low pass filter, we have to look at the frequency response. It has to be used to correct the conducted emission measurement result. As an example - if the frequency dependent loss of the LISN would be -3dB at 500 kHz, it will be necessary to add + 3dB to the conducted emission level at 500 kHz. This procedure must be carried out over the complete frequency range of the measurement. Though the major frequency section has a quite flat response, it is obvious that a manual compensation would be cumbersome. For this reason, many spectrum analyzer manufacturers and Tekbox offer 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.
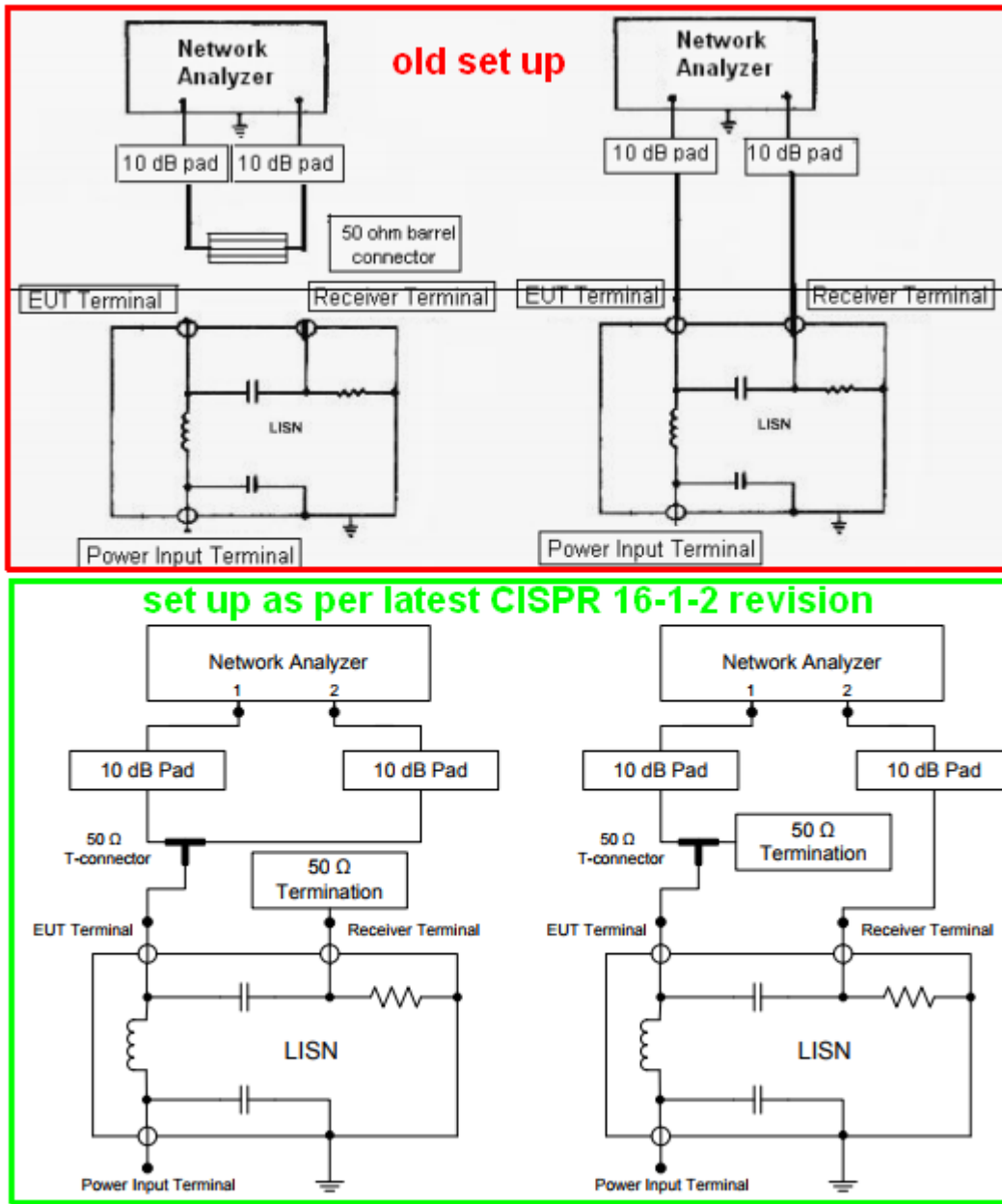
Figure 6: measurement of LISN insertion loss

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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

You can carry out conducted noise measurements by manually controlling the spectrum analyzer, however it is not efficient. Manual control makes only sense, if you work on reducing emissions within a small frequency segment. If you want to make a measurement across the entire frequency range, you will need an "EMC" software to control the spectrum analyzer and to process the measurement data. Most spectrum analyzer manufacturers provide such software. Conducted emission measurements documented in this application note were carried out with EMCview from Tekbox.

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

Carrying out CISPR 25 conducted noise measurements with EMCview only requires a few steps.
After starting EMCview, click **Device**, search for the spectrum analyser, select it from the list and click **Connect Visa**. Then click **File** / **Load Project** and select CN_CISPR_25_Class5_PQ_QP.prj. Thereafter, pressing the **Play** button will start the measurement. Note that two measurement runs can be overlaid in one graph. Measurement 1 refers to the configuration data set 1 and measurement 2 refers to the configuration data set 2.

Loading the project file automatically loads all necessary configuration files for the measurement. These files are listed in the configuration window of EMCview and can be changed or modified, if required

- **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

All configuration files are self-explanatory plain text files. The files can be created or edited with the built in editor of EMCview or with any text editor. As an example, below the contents of the segment file 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

Further details about EMCview can be read in the manual, which can be downloaded from the Tekbox web site.

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10 Carrying out conducted emission measurements

A Siglent SSA3021 will be used for the following measurements. Based on its noise floor characteristics treated in chapter 7.4, we turn off the pre-amplifier in the frequency range above 30MHz to reduce the risk of non-linear distortions for 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
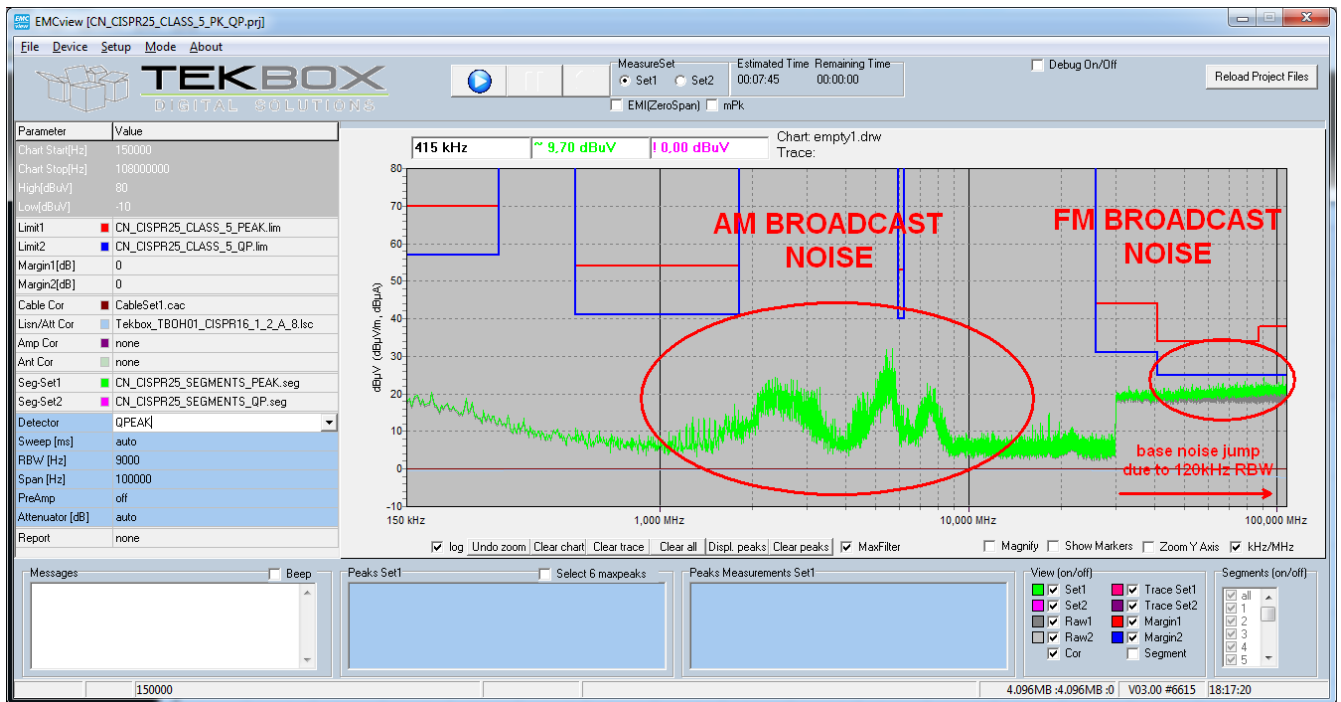
Figure 8: Peak detector measurement with DUT not powered

Figure 8 shows the measurement result with the DUT not powered. What can be seen is AM broadcast noise and FM broadcast noise that is picked up by the cables between DUT and LISNs. The sudden change of the noise floor at 30 MHz is caused by the RBW change from 9 kHz to 120 kHz according to CISPR 25. The ambient noise is well below the limits of the standard, so it is no big obstacle to the measurement. However, note that all equipment in the lab room, except what was needed for the conducted emission measurement, was turned off.

Also, note that the level of AM emissions varies over the daytime. The measurement was taken at noon when the levels are lower than in the later afternoon.

In order to have a better look at the FM noise, another measurement is carried out with the pre-amplifier turned on above 30 MHz.

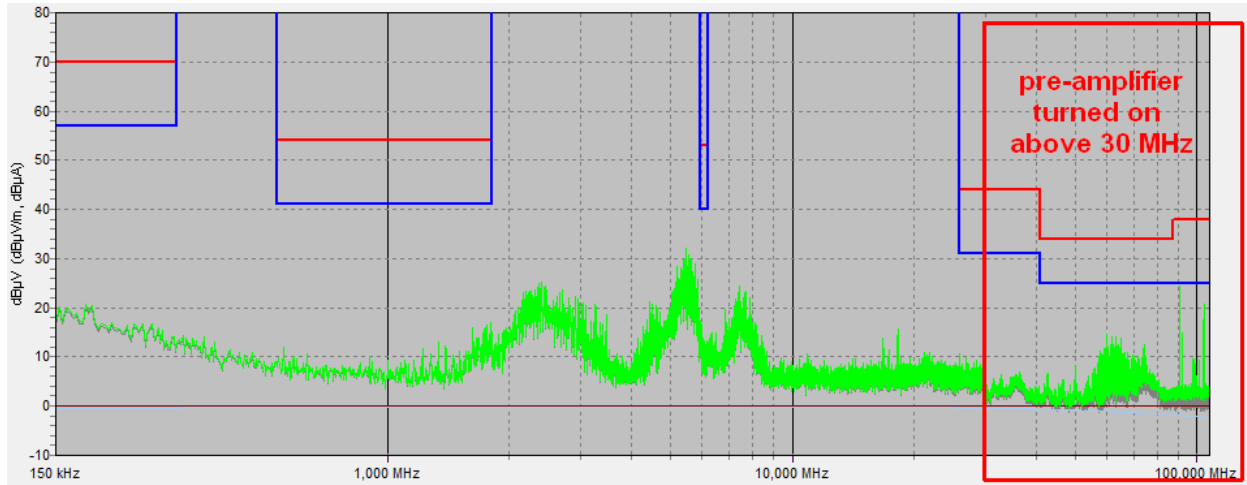# Conducted emission measurement using the Tekbox 5µH LISN TBOH01

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

After changing the pre-amplifier settings in the EMCview segment file CN_CISPR25_SEGMENTS_Peak.seg for the segments above 30 MHz, the base noise reduces approximately 20 dB. The measurement graph reveals more details with respect to ambient noise above 30MHz.
The measurements were taken both on the positive and negative supply line. Figure 8 and 9 show the results of the negative supply line, which were slightly higher than on the positive supply line.

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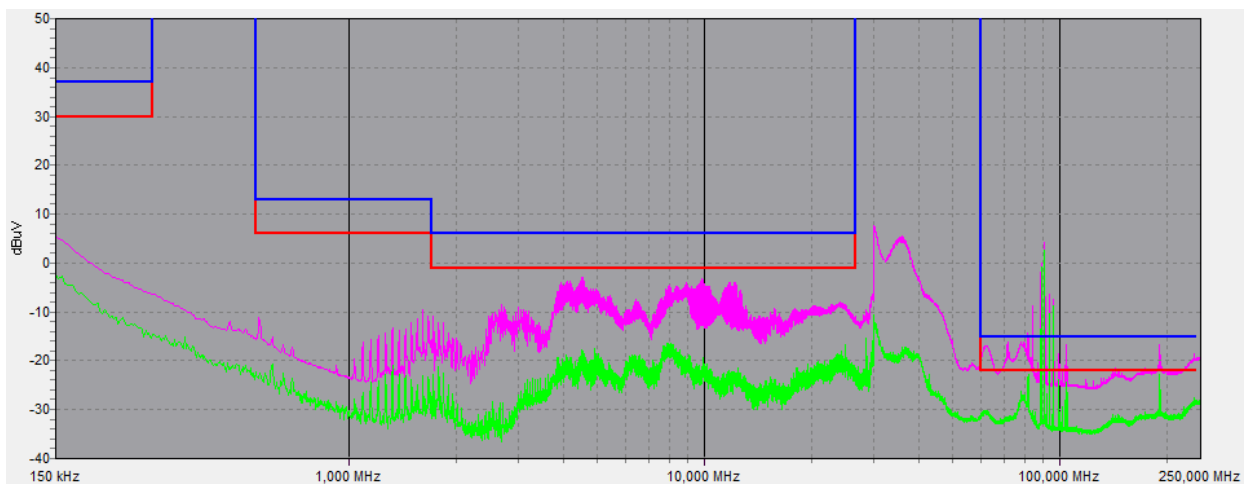
Figure 10: Peak detector (green) and quasi peak detector (pink) measurement with DUT not powered; pre-amplifier turned on above 30 MHz

Figure 10 shows the result of the ambient noise measurement. Due to the longer supply cable, the ambient noise is more dominant compared to the voltage method. Especially FM broadcast noise 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

Three segment files will be created for this purpose. A dedicated project file will be created as well. In order to place all three results into a single graph for better comparison, a measurement with Set 1 as above will be made first. The chart will then be saved clicking menu **File**, **Utilities**, **Save Chart**

Thereafter two measurement runs using alternative Set 1 and Set 2 will be taken. After completion, the chart from the first run will be loaded as reference chart in order to get three measurement runs displayed within a single graph for better comparison.
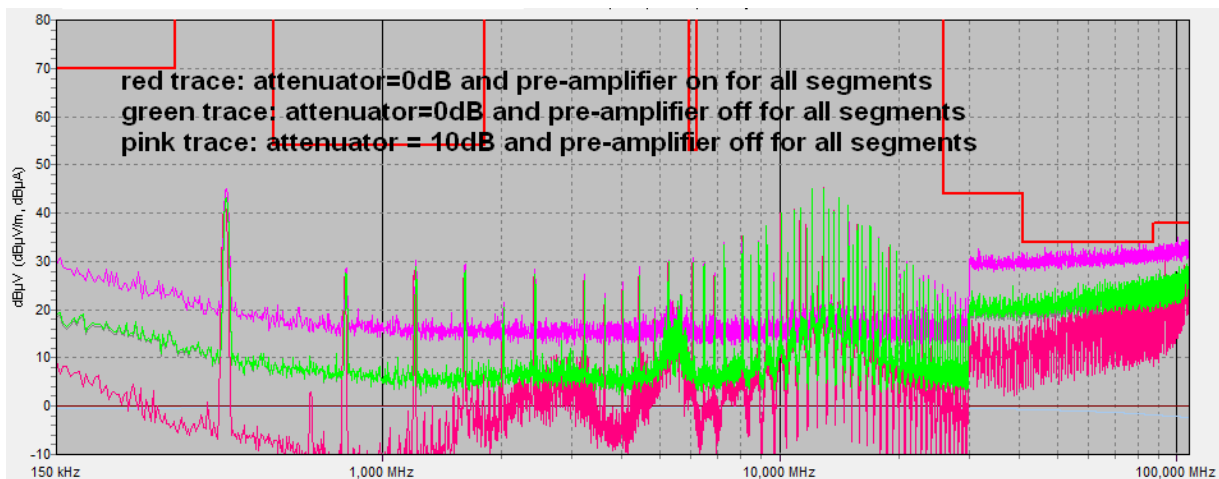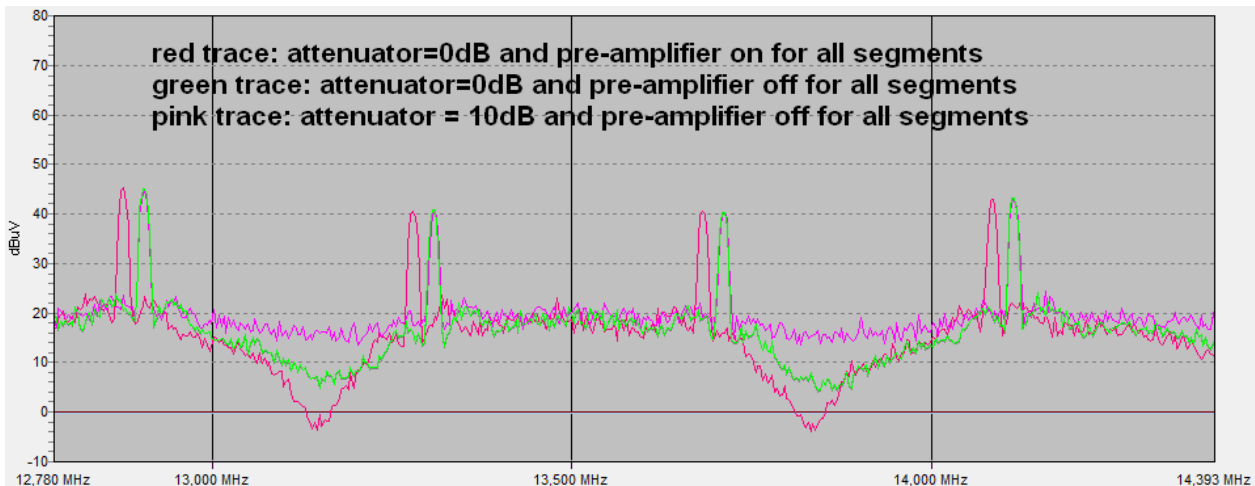

Figure 11: Peak detector measurement with DUT powered and various attenuator/pre-amplifier settings

The traces on figure 10 do not show any sign of intermodulation. Below zoomed screenshots to compare the amplitudes of the various configurations.
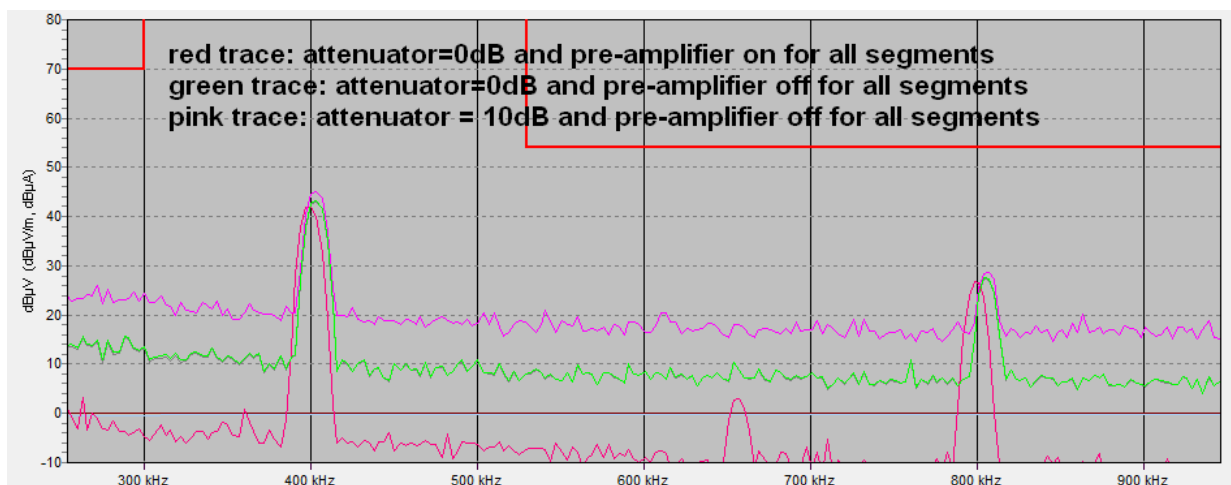
Figure 12: Peak detector measurement with DUT powered and various attenuator/pre-amplifier settings, zoomed

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The zoomed traces in Figure 11 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 12 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.

However, the DUT we looked at in figures 10 to 12 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.
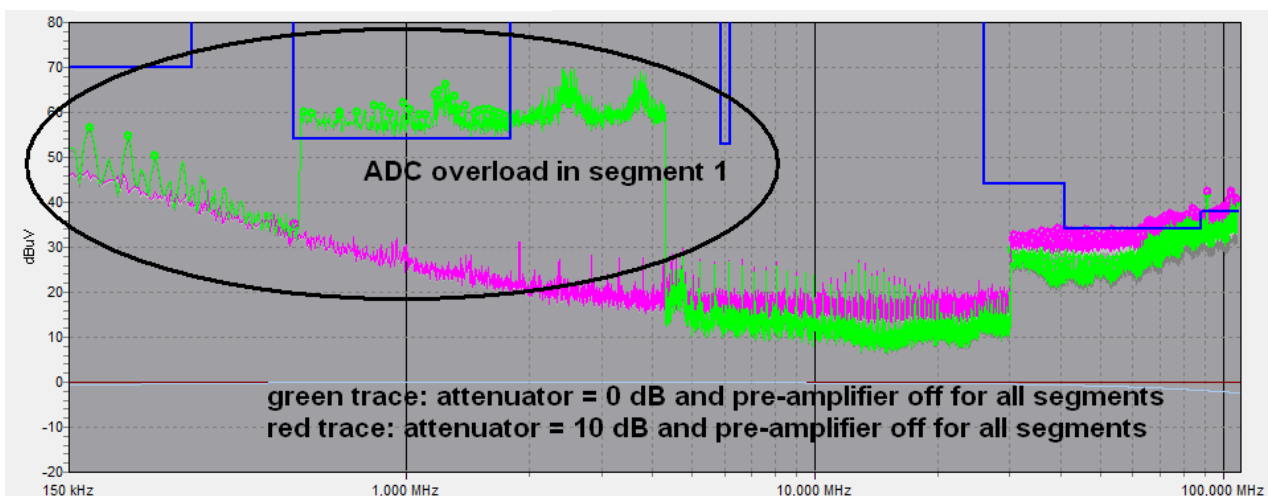

Figure 14: Peak detector measurement; a case of severe ADC overload in segment 1

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Figure 13 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.
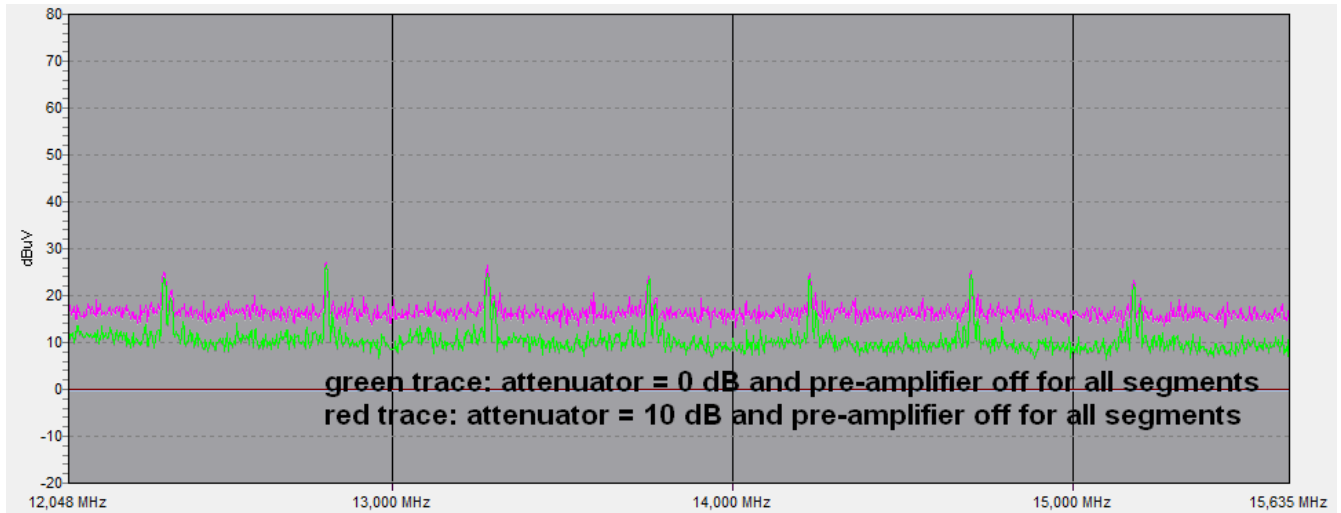

Figure 15: Peak detector measurement, zoomed

Zooming into the trace did not reveal any non-linear distortion issues. Changing the first segment to 10dB attenuation would be sufficient. The other segments can be left at 0dBm, giving the advantage of 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 did not reveal any significant difference with respect to the conducted noise measurement results.

10.4.2 Current probe method

A set up using a small ground plane according to picture 2 and another set up using a large ground plane, which permitted a straight cable layout, were compared.

Figure 15 shows a zoomed section of the worst-case variations. The measured amplitudes of the spurious in the frequency range below 30 MHz and above 60 MHz were nearly identical. However, in the frequency range from 30 MHz to 60MHz, the measurement results differed up to 10dB. Most likely, it is caused by a shift of the resonance frequency of the cable when laid out meandered on the small ground plane.

Consequently, a larger margin to the limits should be taken into account when setting up the measurement on a small ground plane.

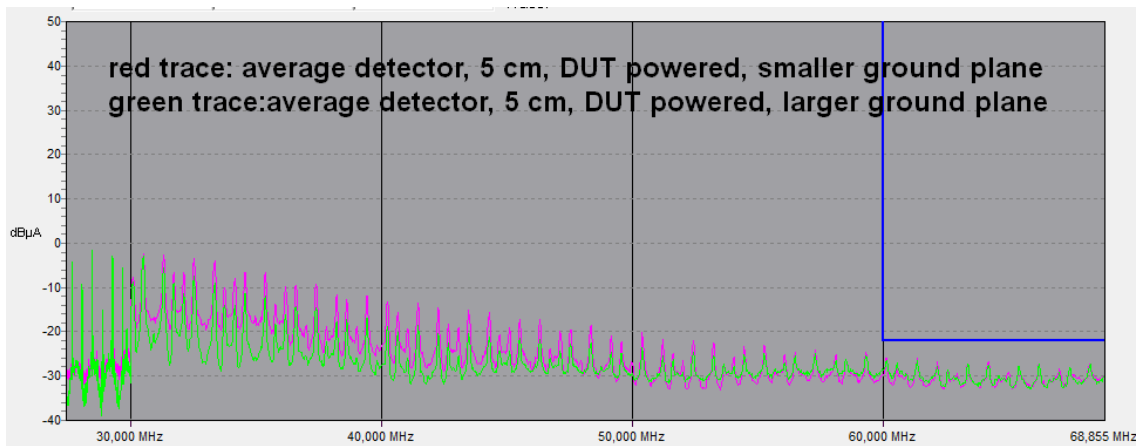# Conducted emission measurement using the Tekbox 5µH LISN TBOH01

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

10.5 Final measurement, voltage method

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

In order to eliminate any ambient noise, the measurement was carried out using a shielded tent from Tekbox.

Picture 4: Tekbox TBST120/60/60/2 shielded tent
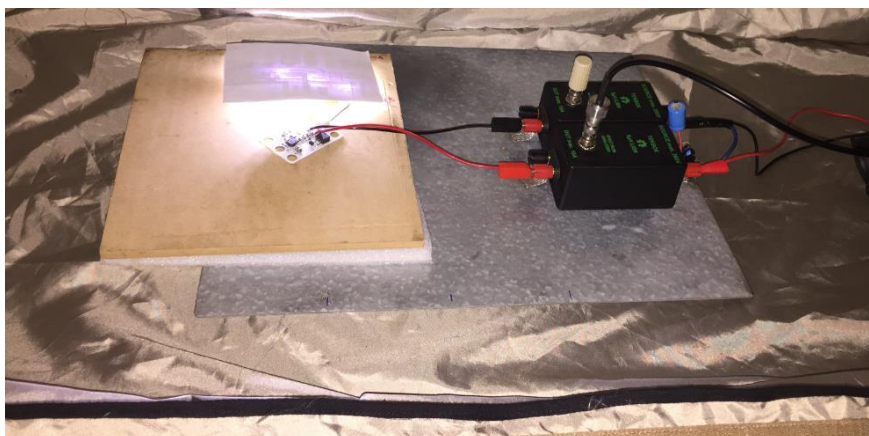
Picture 5: set up inside the shielded tent

Conducted emission measurement using the Tekbox 5µH LISN TBOH01
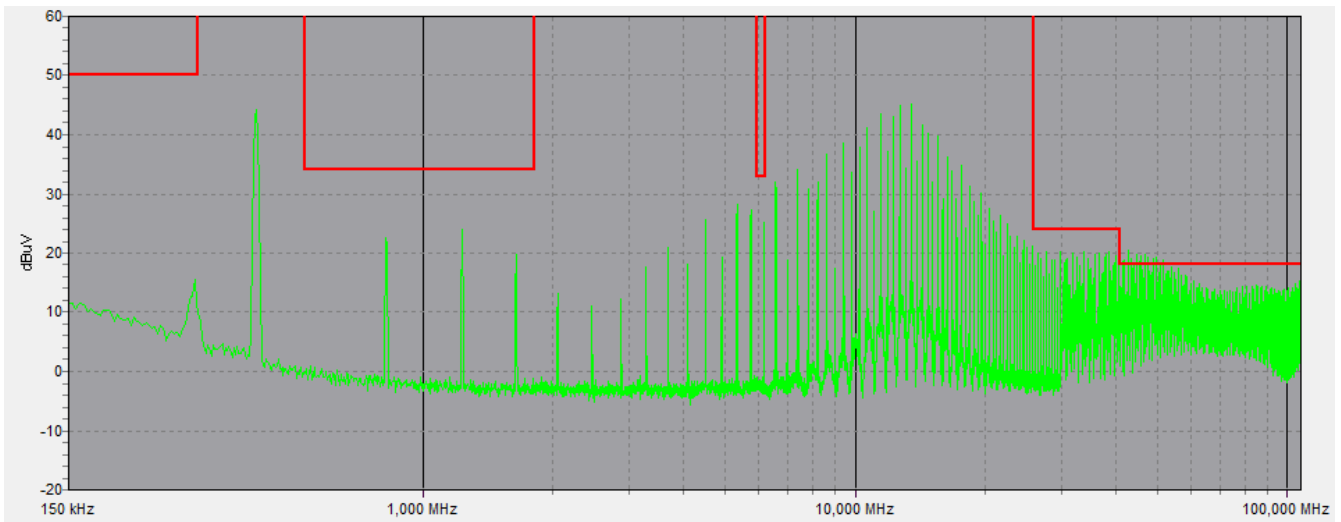

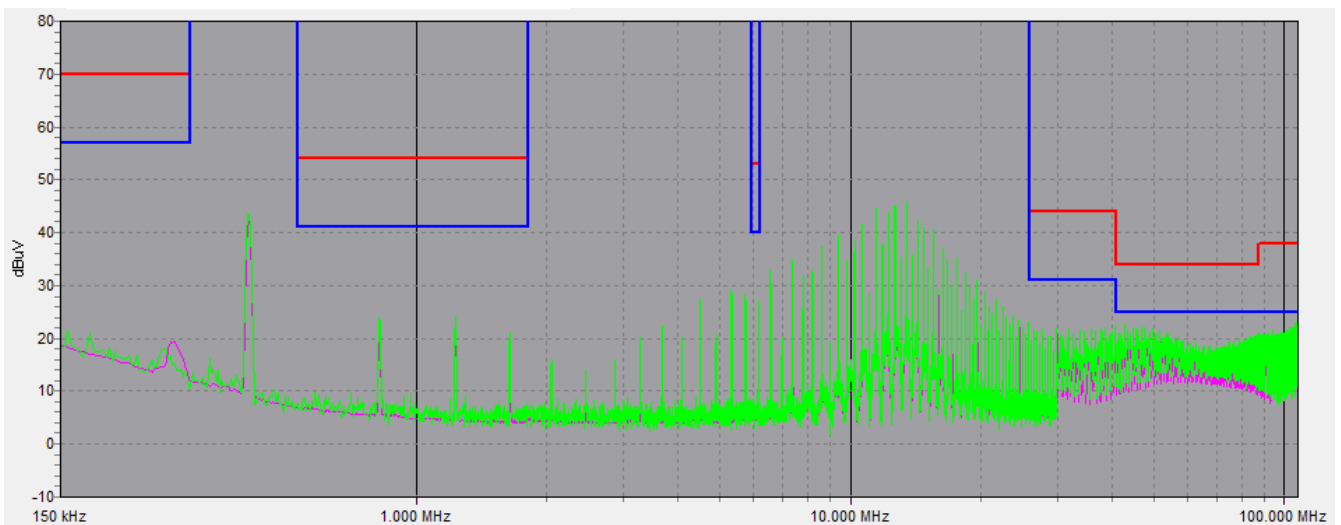Figure 17: measurement result CISPR25 Class 5 average detector

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

The results are free of any ambient noise and show the conducted noise on the positive supply line. The measurements using average or peak detector take approximately 9 minutes each. The measurement using quasi peak detector across the entire frequency range takes 2 hours and 45 minutes. In order to save time, the quasi peak measurement could be reduced to re-measuring critical peaks observed when measuring with average or peak detector. EMCview lists critical frequencies where the noise exceeds limits or a specified margin with respect to the limits. These peak frequencies can then be selected for a fast quasi peak scan.

Conducted emission measurement using the Tekbox 5µH LISN TBOH01

10.6 Final measurement, current probe method

For the final measurement applying the current probe method, limits of an automotive manufacturer standard were applied. In the upper frequency region, the limits are tougher than the limits of CISPR 25 Class 5.
The current probe is built by Tekbox, with 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 shows the measurement result for the positive and negative supply line in 5 cm distance from DUT. In order to complete the measurement, further runs with just the positive and just the negative supply line have to be added. The tests also have to be carried out in 75 cm distance from the DUT.
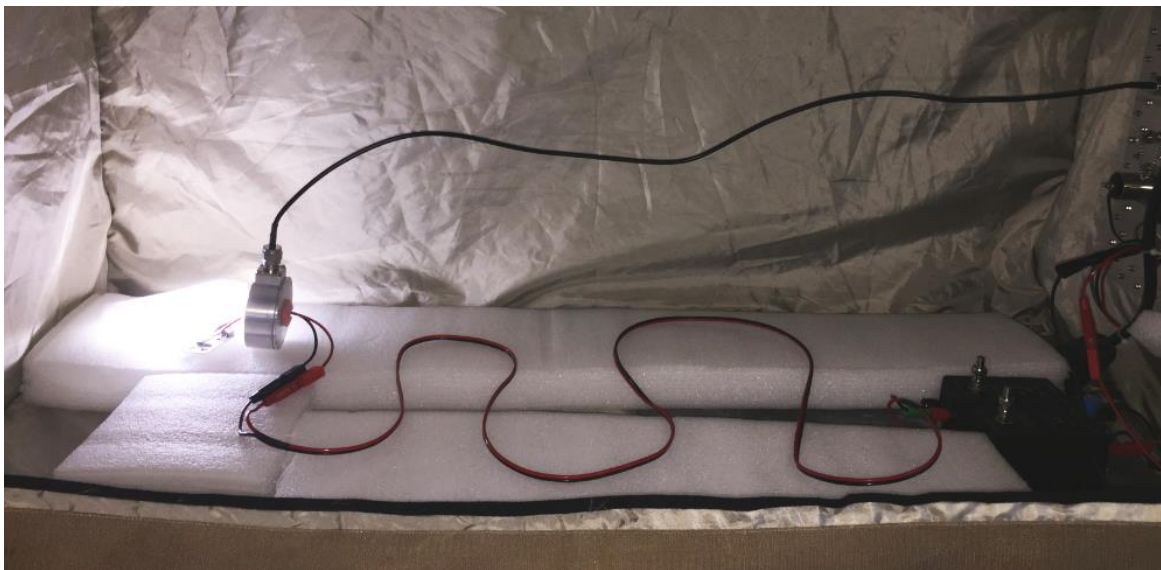
Picture 6: current probe measurement set up in a shielded tent
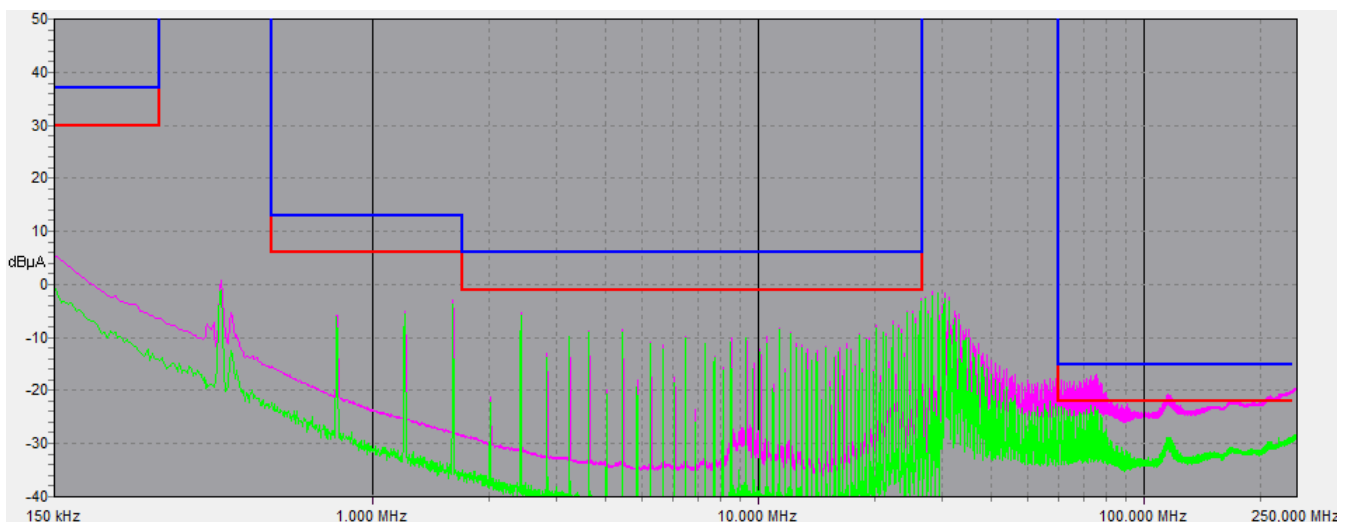

Figure 19: measurement result using an automotive manufacturer standard with tougher limits compared to CISPR25 Class5; peak detector (green) and quasi peak detector (pink); measured in 5 cm distance from DUT on positive and negative supply line; set up in shielded tent

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

Table 9 – History