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Conducted noise measurement using the Tekbox 50µH LISN TBLC08 and Rigol EMI Software S1210

1 Introduction

This application note demonstrates how to carry out conducted noise pre-compliance measurements of mains operated LED luminaires using a Tekbox 50µH LISN TBLC08, a Rigol Spectrum Analyzer DSA815 and the Rigol EMI software S1210.

Choosing LED luminaires as DUT was rather random. Similar procedures can be applied to most mains operated equipment.

2 Applicable standards

In order to prepare the test set up for conducted noise pre-compliance measurement, it needs to be determined which standards apply to the DUT. Lightingeurope.org provides a document with information on all requirements for the conformity of luminaires. It can be downloaded from:

http://www.lightingeurope.org/uploads/files/LightingEurope_EU_Compliant_Requirements_Products_Sheets_for_LUMINAIRES_1st_Edition_29112013.pdf

The document lists EN55015, as applicable standard for electromagnetic compatibility. This standard corresponds to CISPR15.

Following limits are defined for conducted noise at the AC terminals of the luminary:

Frequency range	Limits [dBµV]	
	Quasi peak	Average
9 kHz – 50 kHz	110	-
50 kHz – 150 kHz	90 to 80	-
150 kHz – 500 kHz	66 to 56	56 to 46
500 kHz – 5 MHz	56	46
5 MHz -30 MHz	60	50

Table 1: EN55015 (CISPR15) limits for conducted noise

Conducted emission measurements are measured using two types of detectors– quasi-peak (QP) and average (AV). Typically there are two limit lines on measurement reports. Noise levels measured with the quasi peak detector should be below the QP limit line and the noise levels measured with the average detector should be below the AV limit line. Quasi peak measurements should be measured starting at 9 kHz, while average detector measurements should be started at 150 Hz.

Resolution bandwidth in the frequency range 9 kHz to 150 kHz: 200 Hz

Resolution bandwidth in the frequency range 150 kHz to 30 MHz: 9 kHz

3 Spectrum analyzer considerations

As 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 noise test, it is assumed that the tests are carried out with a spectrum analyser rather than with an EMI measurement receiver. With respect to EMI testing, a spectrum analyser has a few disadvantages compared to a measurement receiver. Consequently, a few things need to be considered upfront.

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Detector

The time constant of the quasi peak detector depends on the measurement equipment, however referring to its earlier specification in CISPR 16-1-1, 600ms is a good approximation. Consequently, a measurement sweep across the full range would be very slow. Usually, a first sweep is carried out using the faster standard peak detector instead of the quasi peak detector. This first sweep is also referred to as “pre-scan”. A final scan with the quasi peak detector would be carried out looking just at the peak values of the pre-scan. Average measurements are created only with the average detector.

Frequency span

Modern spectrum analyzers don't have a continuous sweep range. As an example, the Rigol DSA815 has 601 discrete sweep points across the selected sweep range.

When doing a pre-compliance measurement, we want to ensure that we don't miss any noise spurious in between two adjacent measurement frequency points. Looking at the range of 9 kHz to 150 kHz, the specified resolution bandwidth for the conducted noise measurement is 200 Hz. Consequently, two adjacent measurement frequency points should not be spaced further apart than 200 Hz. Furthermore, we want to ensure that any signal at the input of the spectrum analyser appears within the flat section of the filter. This requirement will further reduce the distance between two consecutive frequency points.

A good choice for a RBW of 200 Hz is to choose frequency steps of 100 Hz. Similarly, we will choose frequency steps of 4.5 kHz in the frequency range where a RBW of 9 kHz has to be applied.

The resulting (sub) spans for the Rigol DSA815 are $600 * 100 \text{ Hz} = 60 \text{ kHz}$ in the frequency range 9 kHz to 150 kHz and $600 * 4.5 \text{ kHz} = 2.7 \text{ MHz}$ in the frequency range 150 kHz to 30 MHz.

Sweep time

Relevant auto sweep time settings for the DSA815 are given in the table below:

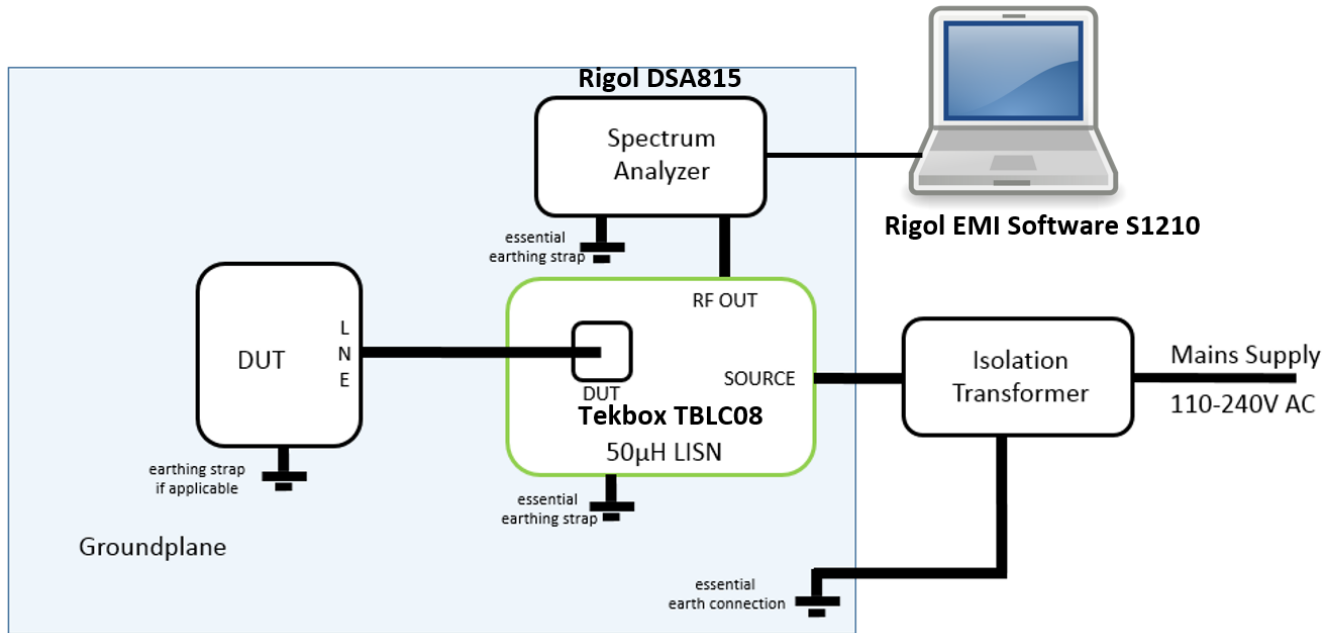
Detector	Frequency span	RBW	Sweep time
Average	60 kHz	200 Hz	2.77 s
	2.7 MHz	9 kHz	67 ms
Peak	60 kHz	200 Hz	2.77 s
	2.7 MHz	9 kHz	67 ms
Quasi Peak	60 kHz	200 Hz	1200 sec
	2.7 MHz	9 kHz	540 sec

Table 2: DSA815 auto sweep times

In case that sweep time is configured manually, it shall not be set any faster than the auto sweep time. Based on table 2, the measurement time for single frequency points in QP mode at 200Hz RBW would result in $1200/601 = 20 \text{ sec}$ in case of 200Hz. The result for 9kHz RBW is 890ms.

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4 Measurement Set up



The setup is not standard conformant, given the available space may be limited. In case that there is sufficient space, the relevant CISPR or EN standards contain descriptions and pictures of standard conformant set-ups. It is essential to use an isolation transformer for any 50 μ H LISN. The internal capacitors draw much blind current and would cause the ground protection switch to trip without isolation transformer.

DUTs

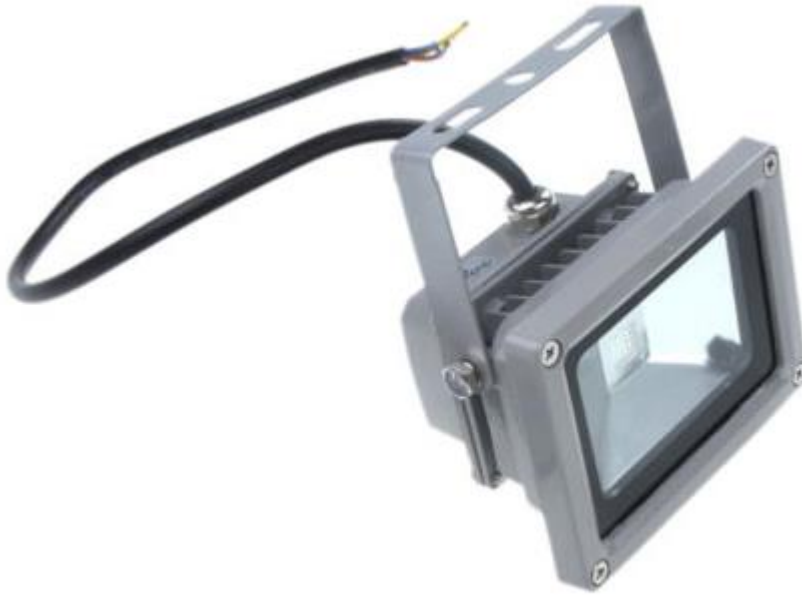
The test shall investigate two LED luminaires.

- 1) A Philips LED tube, 10W, Model 9290002968D



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- 2) A 10W LED flood light, no label



Spectrum Analyzer

Rigol DSA815 TG with EMI option. The EMI option enables additional RBW settings of 200Hz and 9 kHz plus a Quasi peak detector.

LISN

Tekbox TBLC08

PC software

Rigol S1210 EMI pre-compliance test PC software

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5 Software configuration

Before executing a conducted noise scan with the Rigol S1210 EMI pre-compliance software, a few things need to be configured:

LISN frequency response

In order to compensate the frequency response of the LISN, a correction file with the attenuation data of the LISN needs to be created. The frequency response has to be entered as attenuation, means with positive sign.

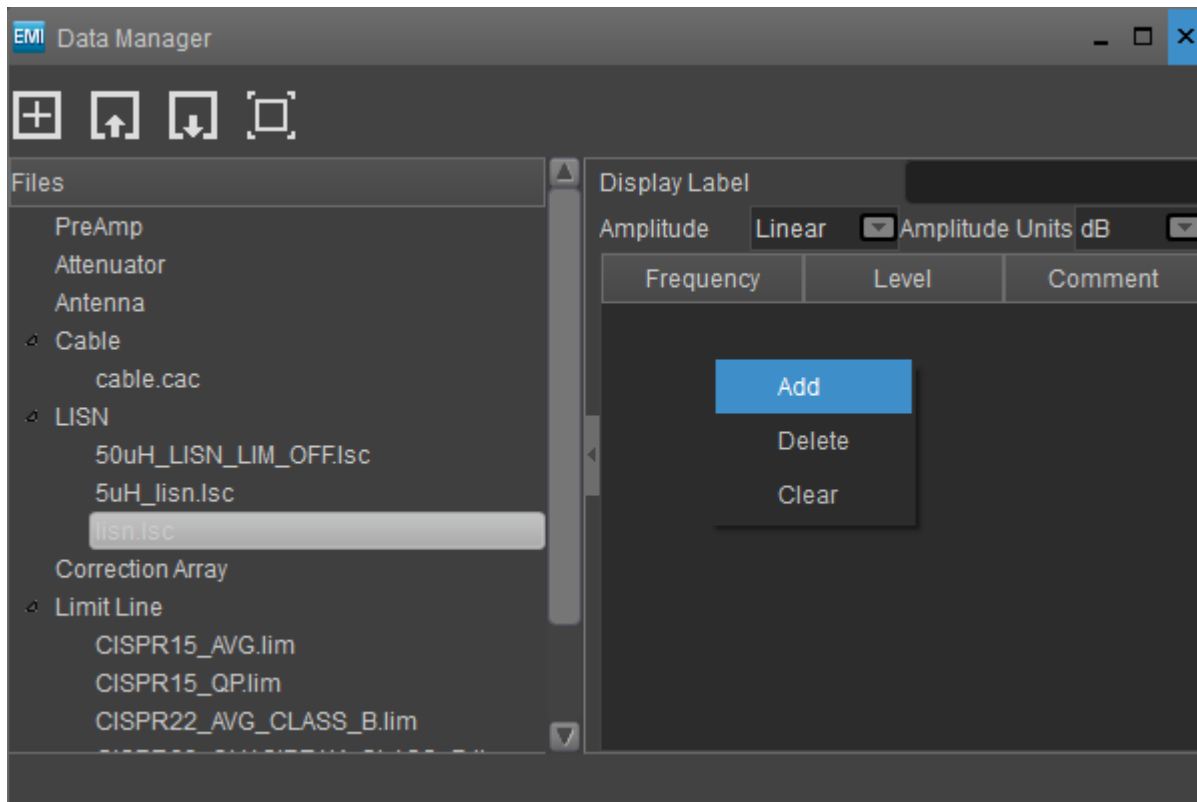
The data with the frequency response of the LISN are available in the TBLC08 manual that can be downloaded from the Tekbox website. Tekbox also provides the necessary configuration files for conducted noise measurements with the TBLC08 and S1210 SW for download. There are two LISN files, one with the Attenuator/Limiter OFF and a second one with the Attenuator/Limiter ON. If you download the configuration files, you can skip the instructions below.

In order to create the LISN file, start the S1210 software.

In the top menu line, click *Tools* and then *Data Manager*

The Data Manager window will pop up. Right click *LISN* and then *Add*

The data manager will then add a line *liscn.lsc*



Click on *liscn.lsc* and then right click in the right window. Click on *Add* and start adding frequency points and the corresponding attenuation values given in the TBLC08 manual.

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After completing the list, add a display label and click the *Export* symbol in the data manager to save the LISN correction file. **Preferably, use the LISN set to Attenuator/Limiter OFF, after validating that the emissions of the DUT are not overloading the spectrum analyzer. The limiter diodes are not biased and can create third order intermodulation products that may falsify the measurement result.**

Cable frequency response

In order to compensate for the coaxial cable between the LISN and the spectrum analyzer, a cable correction file can be created. It can also be downloaded from the Tekbox web site.

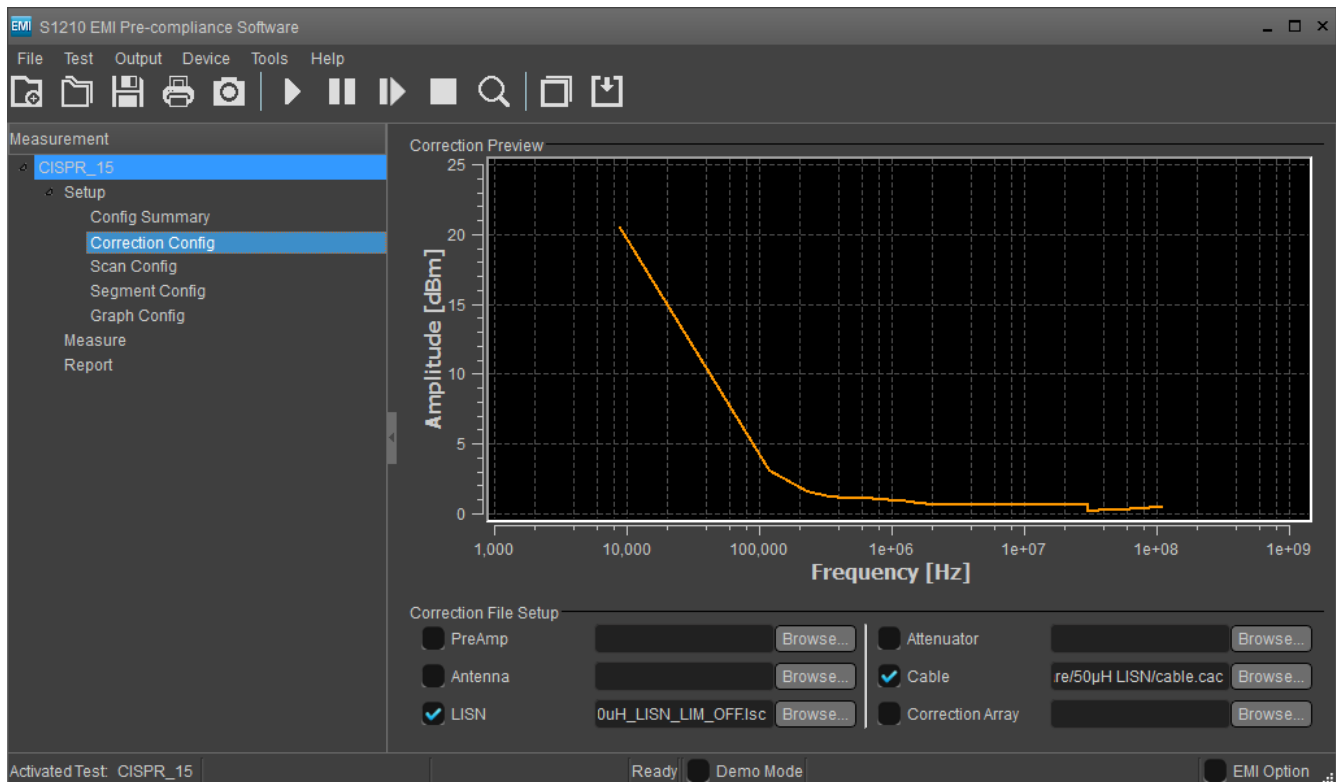
Proceed similar as with the creation of the LISN correction file. The file provided by Tekbox consists of two data points only: 0.1 dB attenuation at 9 kHz and 0.5 dB attenuation at 110 MHz.

Limit lines

Limit lines show the limits of the conducted emission levels specified by the corresponding standard. The S1210 SW displays two limit lines. In case of conducted noise measurements of luminaires, the CISPR 15 limits for Quasi-Peak and Average need to be entered. In order to enter steps, enter two frequency points very close to each other. Create the limit lines with the Data Manager of the S1210 SW or download limit lines from the Tekbox web site.

Correction Configuration

Under *Setup*, click *Correction Config*.



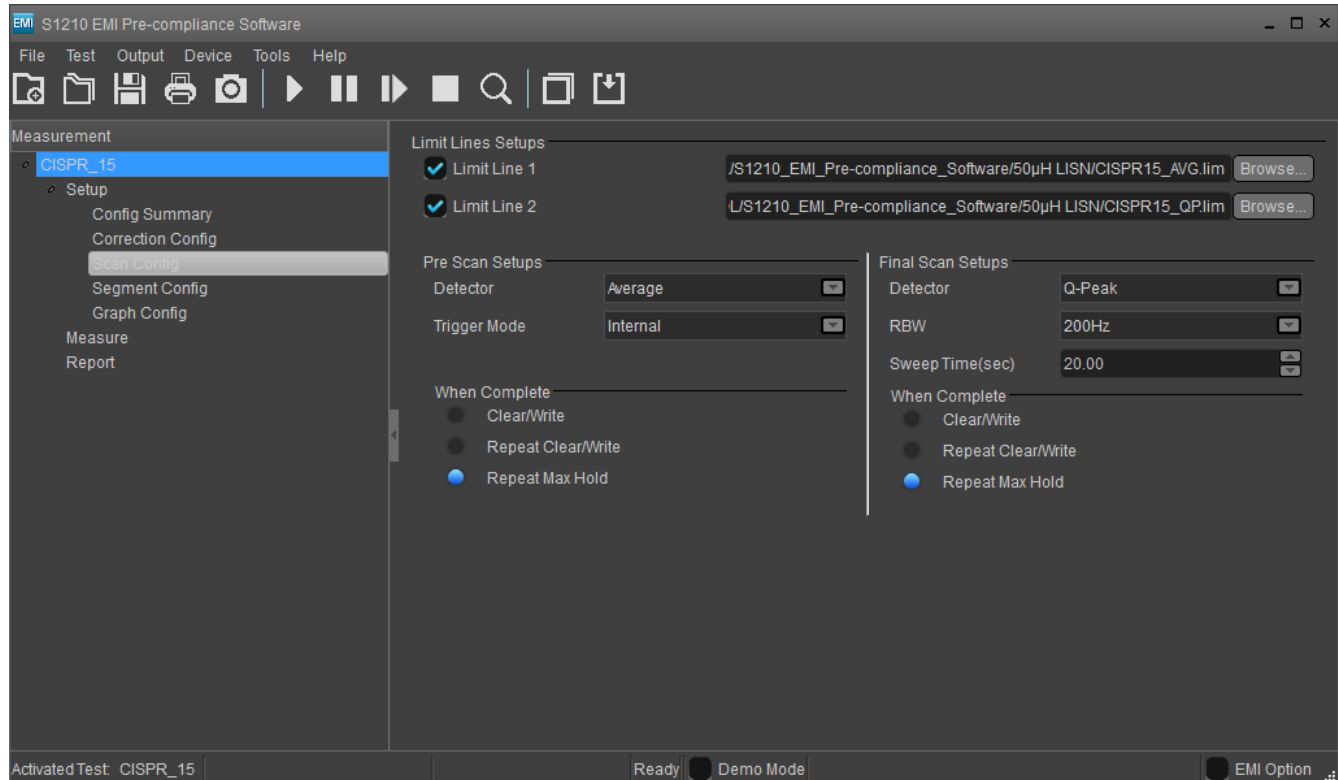
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Tick the *LISN* check box and then click the *Browse* button to load the LISN configuration file with the Attenuator/Limiter off. Click the *Cable* check box and proceed accordingly.

Scan Configuration

Under *Setup*, click *Scan Config*.

Load the limit lines for the measurement with Average detector and Quasi Peak detector.



In *Pre Scan Setups* set *Detector* to *Average*, *Trigger mode* to *Internal* and *Repeat Max Hold*. In *Final Scan Setups* set the *RBW* to 200Hz and the *Sweep time* to 20 seconds (according to chapter 3).

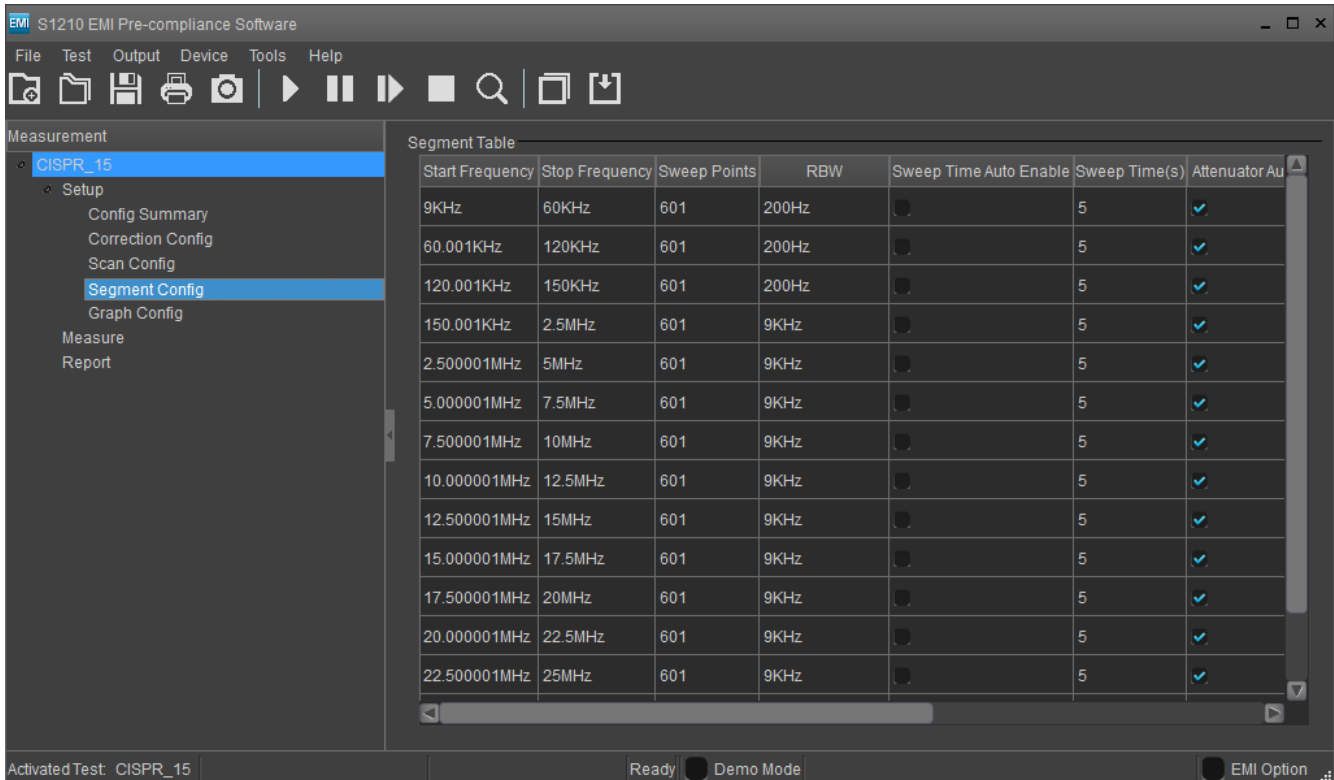
Note that the S1210 does not permit to enter two different resolution bandwidths for Quasi Peak as required by CISPR standards. Consequently, the final scan cannot be carried out over the complete frequency band. It needs to be carried out twice, once with 200Hz and then with 9 kHz RBW, or it needs to be split into separate scans across sub bands with appropriate RBW settings. The final scan is not a full sweep, but just a measurement of peaks, which can be selected after carrying out a Pre Scan.

Another workaround would be carrying out another Pre Scan with Detector set to Quasi Peak. The sweep time would need to be configured in *Segment Config* according to chapter 3 of this manual. A full sweep from 9 kHz to 30 MHz would take nearly 3 hours. The Quasi Peak scan could not be displayed together with the associated Average scan in one graph, as the S1210 SW displays only a single Pre Scan.

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Segment configuration

Click *Segment Config* and configure the segments of the measurement frequency range. Consider the limitations given in chapter 3 of this documentation.



Give sufficient margin for the sweep times of the segments, auto enable the attenuator and disable the amplifier.

Graph Configuration

Though the CISPR 15 conducted noise measurement covers the frequency range from 9 kHz to 30kHz, set *X Axis Min* to 1 kHz and *X Axis Max* to 100 MHz. The graph can be zoomed manually later on. As the highest CISPR15 value is 110 dBμV, set *Y Axis Min* to 0dBμV and *Y Axis Max* to 120 dBμV.

Set the *Frequency scale* to *Log*.

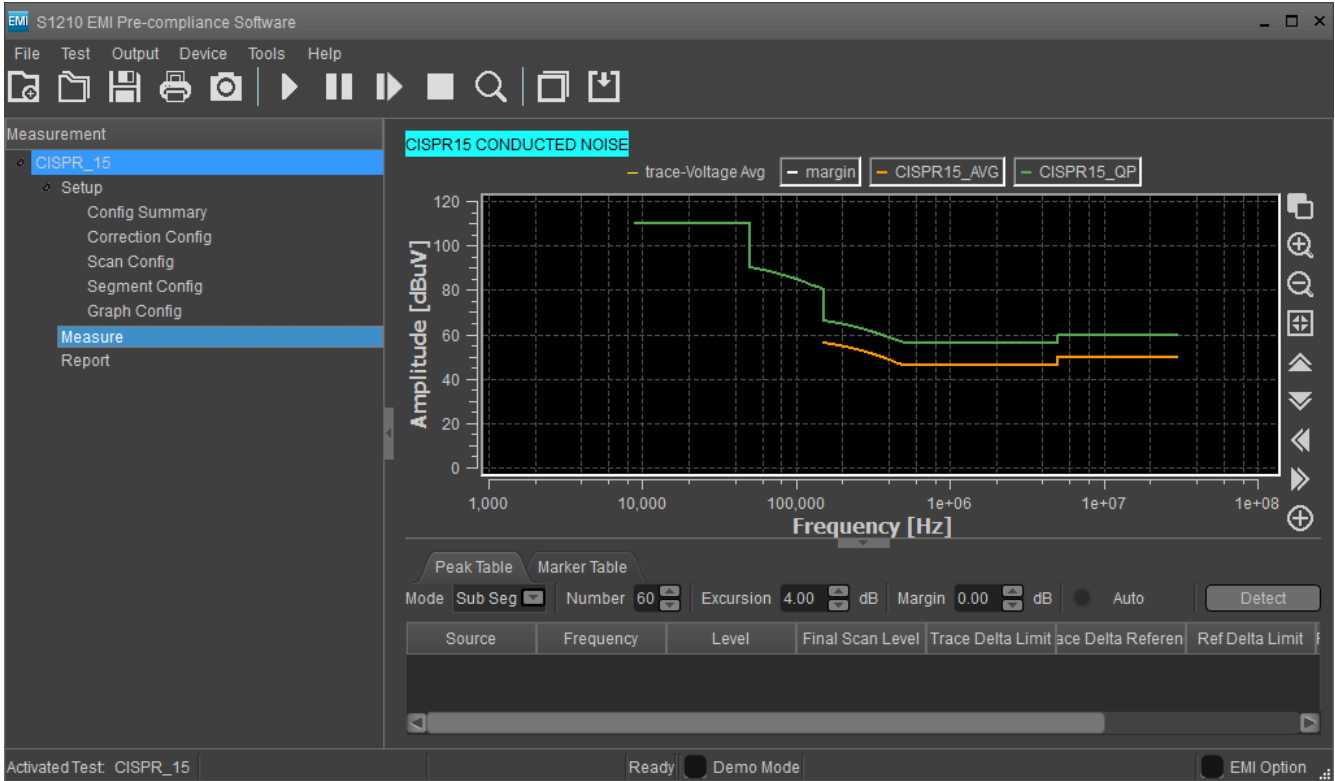
Check Configuration Summary

Click *Config Summary* and validate that the configuration is complete

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Check Limit Lines

Click on *Measure* and validate the limit lines



Note that the S1210 SW does not display beveled limit lines according to the standards. The standards specify beveled limit lines as “ decreasing linearly with the logarithm of frequency” Consider it in case of peak values close to the limit line.



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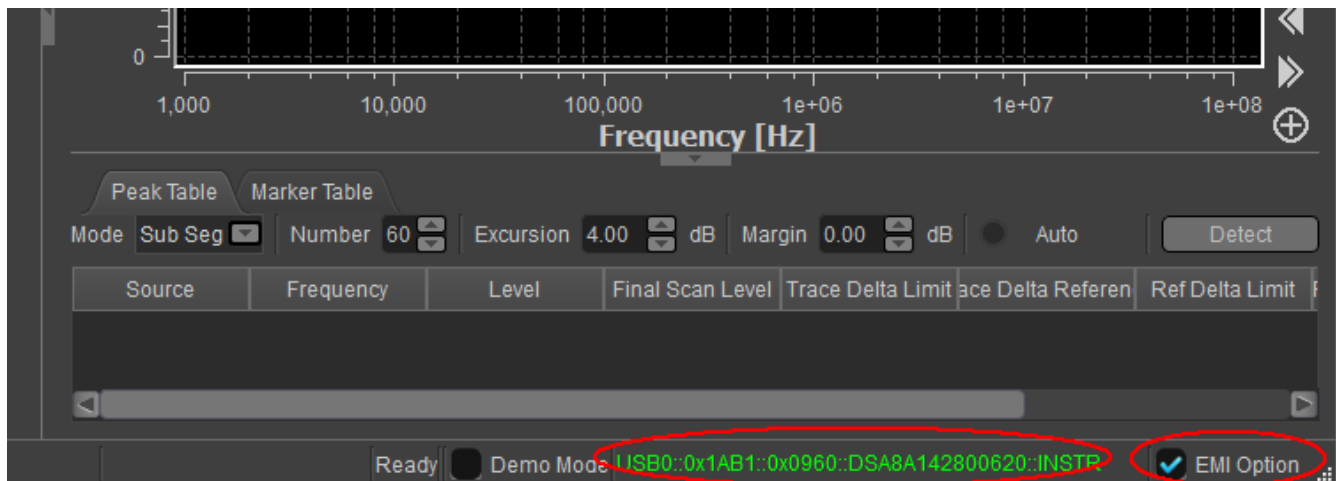
6 Turning on LISN & DUT

For maximum safety of equipment, proceed as follows:

- LISN line selector switch in OFF position
- Attenuator Limiter in ON position
- LISN Mains switch in OFF position
- Turn ON Spectrum Analyzer
- Turn ON the isolation transformer
- Turn ON the mains switch of the LISN
- Rotate the LISN line selector to position 1
- Check the spectrum analyzer for overload warning
- Ensure that the displayed signal levels are not hitting the top line
- Zoom into the frequency range which shows the highest levels and set the Trace to Max Hold
- After validating that the conducted noise is not exceeding 0 dBm, set the Attenuator/Limiter to OFF position to avoid intermodulation products caused by the limiter diodes

7 Starting the Pre-Scan

Click on *Device, Connect*. After establishing connection with the spectrum analyzer, a window with the instrument name pops up. Confirm with OK. The instrument and EMI option is now displayed on the bottom of the window.

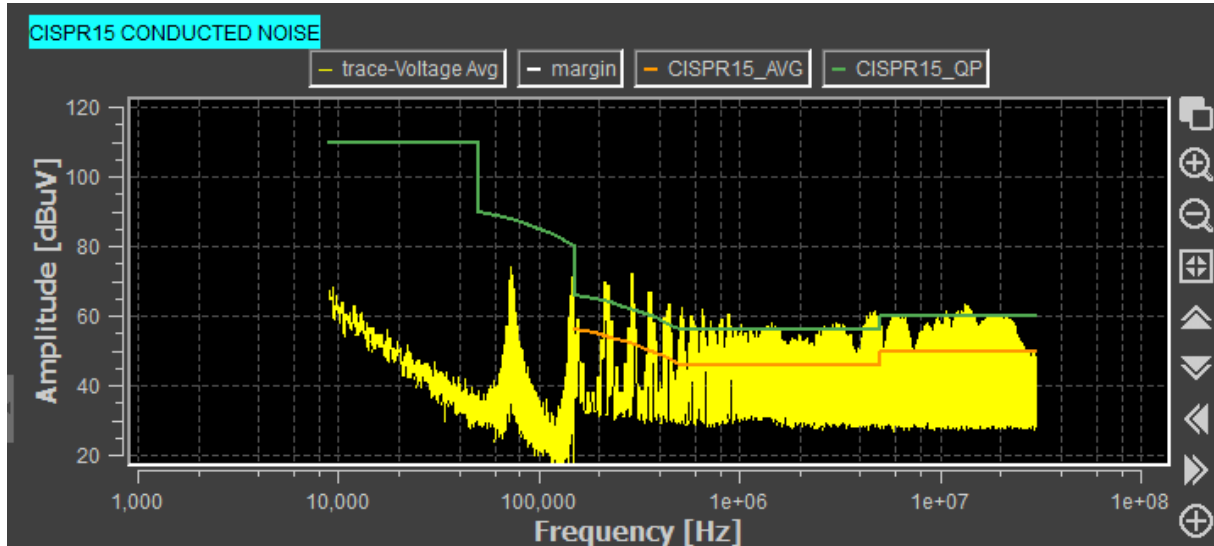


Next click *Test, Pre-Scan Start*. A warning window may pop up. Ignore it and hit the *Enter* button of the keyboard.

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8 Pre-Scan results

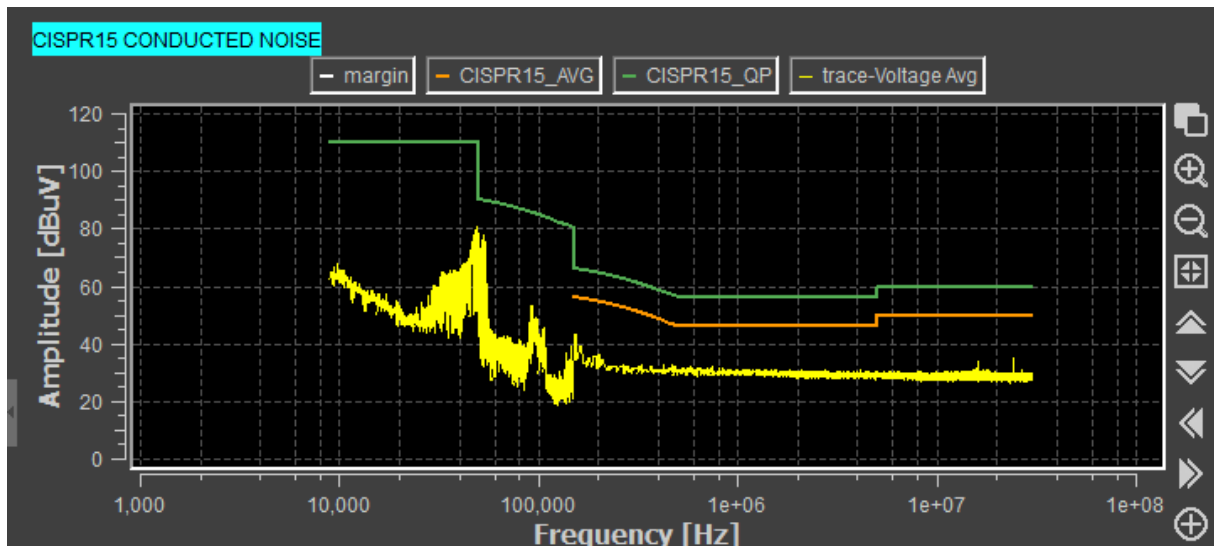
LED flood light



The conducted emissions of the LED flood light measured with Average detector significantly exceed the limit line (orange).

Note that during scan, the spectrum analyzer trace is shown in front of the limit line. In order to move the limit line to the front, stop the measurement by clicking the *Stop* button or by clicking *Test, Pre-Scan Stop*.

Philips LED tube



The conducted emissions of the Philips LED tube measured with Average detector is well within the limits, as expected from a brand product.

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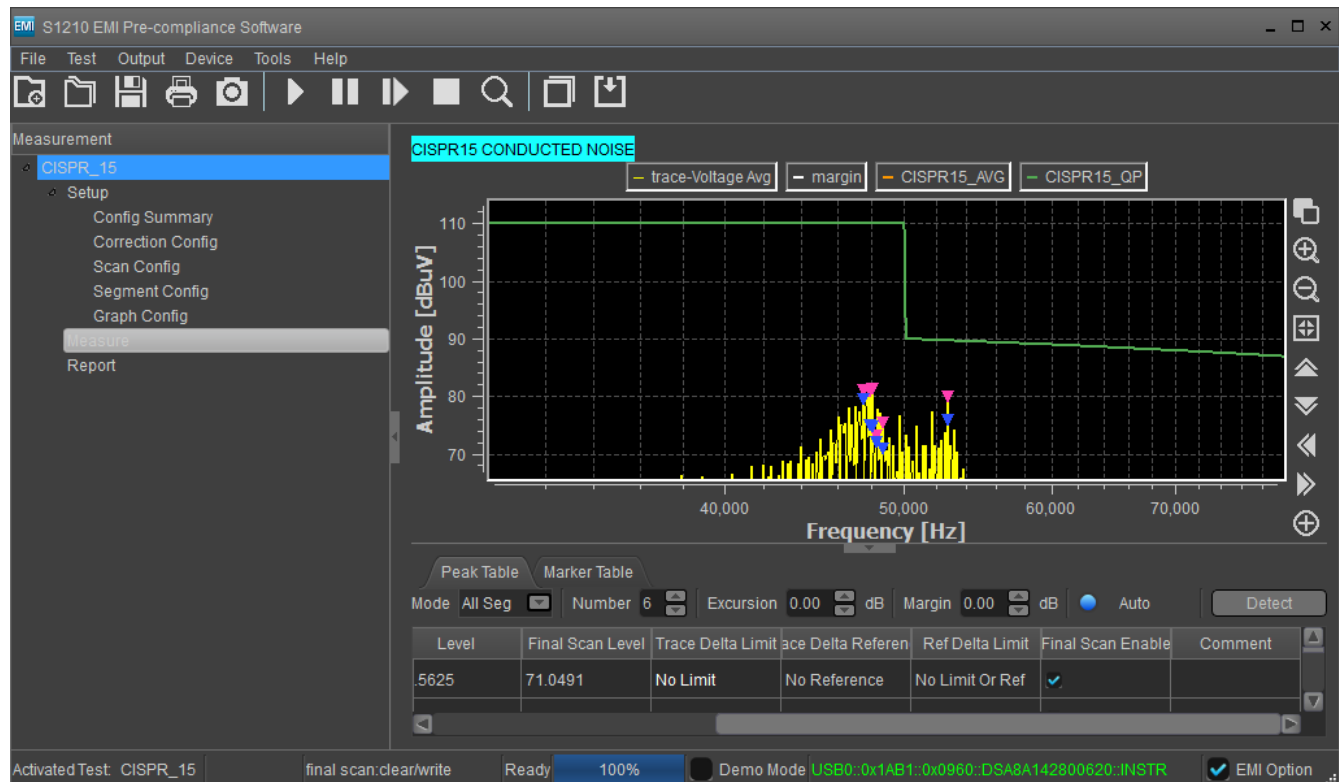
9 Final - Scan set up

The final scan is a measurement of certain peaks that may be critical. These peaks need to be defined in the peak table.

The peak table is on the bottom of the measurement window. The number of peaks was set to 6 in order to limit the peak search result to the most significant peaks. After clicking the *Detect* button, the S1210 software automatically selected the highest peaks and marked it with pink triangles. As all peaks were located around 50 kHz, the resolution bandwidth in the Final Scan Setup was set to 200Hz. The measurement time was set to 20 seconds.

Thereafter the final scan was started by clicking *Test, Final Scan Start*

The measurement was carried out with the Philips LED tube as DUT



The measurement result was then displayed with blue triangles. The final scan of the conducted emissions with Quasi Peak detector showed that the Philips LED tube was within the CISPR 15 limits again.

The LED flood light was not tested in Quasi Peak mode, as it was significantly outside limits in Average mode.

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10 Sources

http://www.lightingeurope.org/uploads/files/LightingEurope_EU_Compliant_Requirements_Products_Sheets_for_LUMINAIRES_1st_Edition_29112013.pdf

<http://www.rfemcdevelopment.eu/en/emc-basics/led-emc>

CEI EN 55015

CISPR 15

CISPR 16

CISPR 22

Rigol DSA800 series spectrum analyzer manual

11 History

Version	Date	Author	Changes
V1.0	5.9.2016	Mayerhofer	Creation of the document

Table 1 – History