Practical Considerations Concerning Conducted Electromagnetic Interferences for a PC

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Abstract— **The paper refers to theoretical and practical considerations concerning conducted electromagnetic interferences (IEM). The standards used for measuring of conducted emissions (CE) are presented and discussed. FCC and CISPR standards are approached. A line impedance stabilization network (LISN) must be inserted between the AC power cord of the device under test and the commercial power outlet. Due to the difference in the regulated frequency ranges between the FCC and CISPR 22 Standards, the LISNs for both of them have similar layouts, but the component values are different. Standards used for test setup CE measurements are presented to understand the test procedures used to measure CE. Test instruments used for measuring CE are presented. A laptop was selected as the equipment under test (EUT). It is basically a noisy source containing a switched mode power supply. The standard requirements for CE and configuration of the test setup measurements were investigated in this case. Also the test instruments used for accurate measurements and suitable comparison to the limits provided in the required standards are discussed. The equipment used for the measurements were: a LISN, a measuring EMI receiver and specialized software - EMC32. In fact the conducted disturbance voltages were measured by using the methods required by CISPR 22, that was applied considering the frequency range from 150 kHz to 30 MHz. The results for the CE measurement are presented. The quasi-peak and average values during testing do not exceed the allowed limits and comply with the standard required. The tests revealed that the values obtained with the EMC32 software comply with the standards, therefore the equipment tested can be validated.**

I. INTRODUCTION

All electric devices or installations influence each other when are interconnected or close to each other. Sometimes we observe interference between our TV set, our GSM handset, radio and nearby washing machine or electrical power lines.

Electromagnetic compatibility (EMC) testing is required to demonstrate if that the equipment will operate properly in its proposed operational electromagnetic environment, if it has acceptable safety limits or if it satisfies required standard levels of immunity and/or emissions.

The first EMC Directive provides limits for the equipment' electromagnetic emissions, in order to ensure that, when used for specific tasks, it will not disturb neither radio transmissions and telecommunication, nor other equipment. This directive also approaches the immunity of such equipment relative to interference. It must be consulted by the equipment designer and manufacturer in order to make sure that the equipment is not disturbed by radio emissions during its operation.

The purpose of providing the electromagnetic compatibility (EMC) is to keep all the side effects under reasonable control.

An equipment (apparatus and fixed installations) needs to comply with EMC requirements when it is introduced on the market and/or taken into service.

In general, the conducted electromagnetic interference (EMI) emissions exist in most of the electronic products and affect the electromagnetic environments. Manufacturers of electronic products are highly interested in the EMI requirements. The compliance with the EMI requirements is critical to the success of the product in the marketplace [1].

The conducted electromagnetic interference affects the neighbouring equipment by means of power line or signal line. Therefore, the aim of conducted EMI test is to measure the noise of an electronic circuit and require it to be electromagnetic compatible with other devices [1], [2].

II. CONDUCTED EMISSIONS MEASUREMENTS FOR A LAPTOP

A. Standards used for measuring conducted emissions

Conducted emissions are regulated by the FCC over the frequency range 450 kHz to 30 MHz, and the CISPR 22 conducted emissions extends the lower limit to 150 kHz.

Most CISPR standards establish the limits and measurement methods to restrict the electromagnetic emission from electric and electronic equipment and to protect the existing radio services. In general, the frequency band for the conducted emission is from 150 kHz to 30 MHz. For the radiated emission it is above 30 MHz [2].

In generally the CISPR standards only relate to EMC emission test methods and limits.

1) CISPR 16-1, Specification for radio disturbance and immunity measurement apparatus and methods - Part 1: Radio disturbance and immunity measuring apparatus
2) CISPR 16-2, Specification for radio disturbance and immunity measurement apparatus and methods - Part 2: Methods of measurement of disturbances and immunity.
3) CISPR 22, Information technology equipment - Radio disturbance characteristics - Limits and methods of measurement.
4) EN 55 022, European limits and methods of measurement of radio disturbance characteristics of information technology equipment.

The above mentioned standards attempt to standardize the products' EMC performance, relative to radio interference for electrical equipment.

The radio-frequency (RF) emissions standard for information technology, telecommunications equipment and business machines is CISPR 22. It has been adopted in the European Union (EU) as EN 55022 [1] and listed under the Electromagnetic Compatibility Directive (EMCD). Even though EN 55022 is a product family standard in its own right, it's test methods are often called up as a basic test method by other emission standards (generic, product, and product-family) [3].

When testing a device for compliance with the FCC and CISPR 22 regulatory limits, a line impedance stabilization network (LISN) must be inserted between the AC power cord of the device under test and the commercial power outlet. Due to the difference in regulated frequency ranges between the FCC and CISPR 22 regulations, the LISNs for both of them have similar layouts, but the component values are different [4],[5].

B. Standards used for test setup conducted emissions measurements

The specialists in EMC must understand the test procedures used to measure conducted emissions. The term "conducted emissions" refers to the mechanism enabling the electromagnetic energy to be created in an electronic device and couple it to the AC power cord. Similarly to the radiated emissions, the conducted emissions from electronic devices are controlled by regulatory agencies. If a product passes all radiated emissions regulations but fails a test on conducted emissions, the product cannot be legally sold. The first reason why conducted emissions are regulated is that the electromagnetic energy coupled to a product's power cord can find its way to the entire power distribution network the product is connected to, and use the larger network to radiate more efficiently than the product could by itself [4], [5].

The levels of conducted emissions are measured as a voltage at the output of the line impedance stabilization network (LISN). The role of this voltage is to stop the interference entering in the system under test from the supply network and to propagate a high frequency current drawn by the equipment under test (EUT) through a 50 Ω impedance [4]. This is useful when a test laboratory conducts the emissions' measurements in order to certify the tested products. EN 55022 standard is normally applied for measuring conducted emissions from the information technology products [1]. This standard is common for all the information technology equipment, rather then a specific standard for any particular product.

The requirements relative to the test site for conducted emissions are very relaxed as compared to the problems of radiated testing. A simple arrangement of metal plates can be sufficient if the ambient noise of the site is low enough in the frequency range to be measured. The test set-up for conducted emissions specified in CISPR 16-2-1 Standard is shown in Fig.1 [6].

The EUT should be placed 80 cm from the Vertical Ground Plane (VGP). The mains cable length shall be 1m long. If it exceeds 1m, the excess cable should be bundled at the center and can be shortened in length. The bundling of the cable should not exceed 0.4m in length.

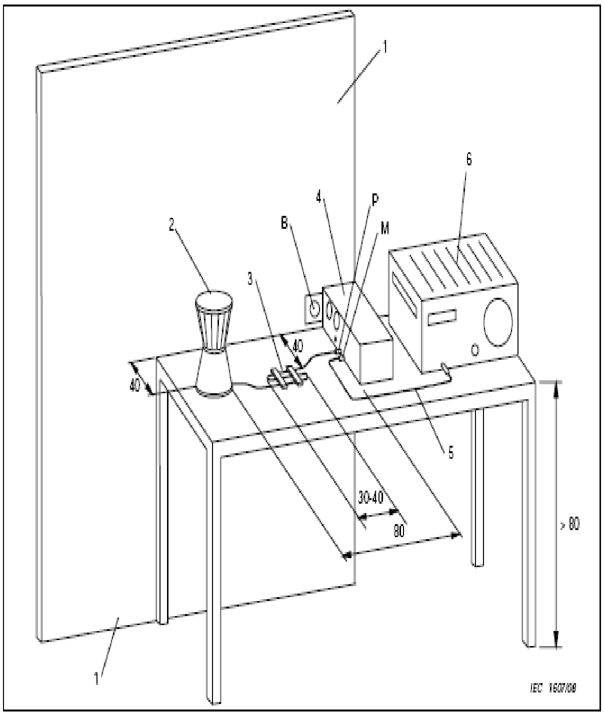


Fig. 1. Test Set-up for Conducted Emission Measurement for tabletop equipment according to CISPR 16-2-1: 1- Metallic wall 2 m x 2 in; 2 - EUT; 3 - Excess power cord (e.g., 2 cm by 30 cm forming a meander); 4- LISN; 5 - Coaxial cable; 6 -Measuring receiver; B - Reference ground connection; M – Measuring receiver input; P - Power to EUT.

LISN should be kept at 80 cm from the EUT and at 80 cm from other units or other metallic planes. EUT shall be placed on the non-conductive table and the height of the non-conductive table is 80 cm from the horizontal ground plane. EUT should be configured in the normal operating condition during the measurement. The test configuration for tabletop equipment is given in the standard [6].

C. Test instruments used for measuring conducted emissions

A laptop was selected as the EUT that is basically a noisy source including a switched mode power supply.

For the performed tests, the following equipment was used:

1) a personal computer (PC) with dedicated software installed for conducted emission tests (EMC32 Program);
2) LISN NNB 51 [7];
3) measuring & receiver Rohde & Schwarz [8].

A LISN having the rated impedance characteristic is required for conducted emission measurements. The ports of the measuring instrument (the receiver) are terminated into a 50 Ω impedance. Fig. 2 shows the circuit diagram of LISN [9].

LISN stabilizes the impedance of the mains for the required RF frequencies, and does not allow the interference from the power source to affect the EUT or vice versa. Emissions emanating from the EUT on the power mains cable were detected using LISN and were fed to the EMI receiver.

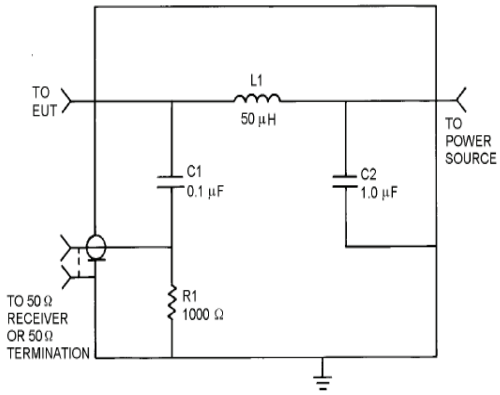


Fig. 2. Circuit diagram of LISN to provide impedance for the 0.15 MHz to 30 MHz frequency range.

The conducted interferences, in both differential and common mode, can be determined by measuring the voltage developed across the LISN impedance without the need for a current transducer. The specifications for the LISN are defined in CISPR 16 [1].

The LISN specifications are:

- Dual-line-V-LISN;
- Compliant to CISPR 16-1-2, MIL-STD-461, FCC Part 15, ANSI C63.4;
- Current up to 16 Amps;
- Frequency range 9 kHz to 30 MHz;
- Hand and remote operated;
- Massive grounding bars [7].

LISNs such as NNB 51, are used to measure distortion signals on the mains cord of an EUT. The distortion signals are usually generated or picked up inside of the EUT and the mains cord acts as an antenna. European and international EMC regulations define maximum admitted signal levels and frequency bands for such distortion signals [7].

EMI measurements require a different approach than other types of general RF tests. Since each new device under test (DUT) will be different, having the correct tools for the characterization of the EMI signals is of key importance. Two instruments are used for EMI testing, spectrum analyzers and test receivers. Each requires a different approach to the test, and each has advantages and disadvantages [8].

The instrument we used for our tests is a Rohde & Schwarz ESCI EMI Test, 9 kHz to 3 GHz. It is a measuring receiver appropriate for EMC measurements according to commercial standards in the frequency range 9 kHz - 3 GHz. This receiver complies with the most recent version of the standard CISPR 16-1-1 [6].

Table I gathers the values of an important EMI receiver setting - the required resolution bandwidth (RBW), for different frequency ranges based on CISPR 16-1-1 [6].

To carry out a frequency scan, certain parameters, such as the start and stop frequency, as well as bandwidth and measurement duration, are defined and programmed into the test receiver. During the actual scan, the measured level values are transferred to the controlling computer, assigned to the corresponding frequencies and displayed in the diagram as trace.

TABLE I.
CISPR 16-1-1 MEASURING RECEIVER
BANDS AND RESOLUTION BANDWIDHT (RBW) FOR EMI TEST RECEIVERS

CISPR Band	A	B	C	D	E
Frequency range	9 kHz - 150 kHz	150 kHz - 30 MHz	30M Hz - 300 MHz	300 MHz - 1 GHz	1GHz - 18 GHz
Resolution bandwidth	200 Hz	9 kHz	120 kHz	120 kHz	120 kHz

The peak search function is then used to calculate and display the highest level values [8].

The test procedure for receiver measurements was performed according to CISPR standard testing 16-1-1, in the frequency range 150 kHz-30 MHz, with the following requirements [4], [10], [11], [12]:

1) Measurement values detectors, quasi - peak and average values detectors;
2) Bandwidth used for measuring receiver : 9 kHz;
3) Frequency step: 4.5 kHz;
4) Step measurement time : 0.5 ms.

D. *Test configuration for measuring conducted emissions*

EMI measurements are intended to determine if the EUT electromagnetic interferences exceed a defined limit.

Tests were carried out to check whether the test equipment works well when we study the emission limits imposed by the standard product class to which the equipment belongs, if it is a Class B product according to CISPR 22 (EN 55022) [12].

The general objective of defining a system test configuration for conducted emission measurements has the following key points:

1) avoiding common mode disturbance ground loops;
2) defining a configuration easy to duplicate;
3) decoupling lines not being measured from the line being measured;
4) arrangement of lines to minimize the influence of magnetic fields on emission measurements [9].

The site configuration used for measurements was made according to CISPR standard 16-2-1. We used the example optional for EUT test setup, with only a power cord attached.

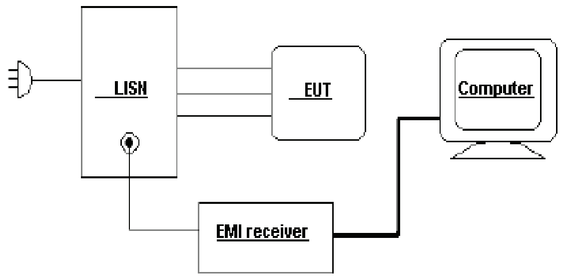
Fig. 3 shows a simplified block diagram of the conducted EMI testing system and a test setup in order to explain better the picture for Conducted Emission Test Setup , as depicted by Fig. 4 [4], [8], [10].

III. RESULTS OF THE EXPERIMENTAL TESTS

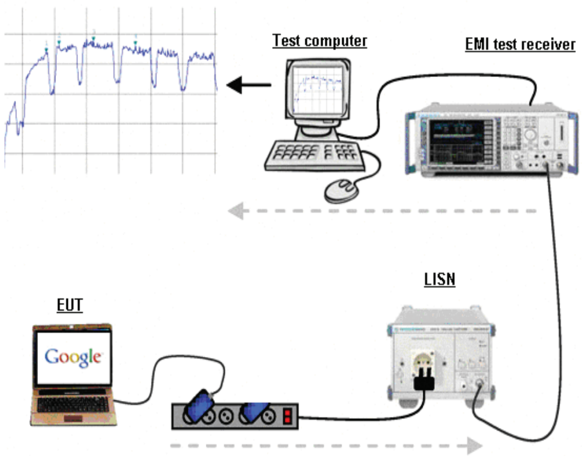
A. *Measurement detectors*

The layout of the EUT is usually defined in the specifications. If not, the system should be set up in a typical arrangement, giving maximum conducted emissions.

CISPR 16-2-1 specified that, in order to make an EUT pass the tests, the measured conducted emission must comply with both the quasi-peak and average limits. The tests may be performed using either path 1 or path 2 [4].



a)



b)

Fig. 3. a) Block diagram of the conducted EMI testing system; b) Test setup for conducted perturbations measurements (according to CISPR22 specifications)

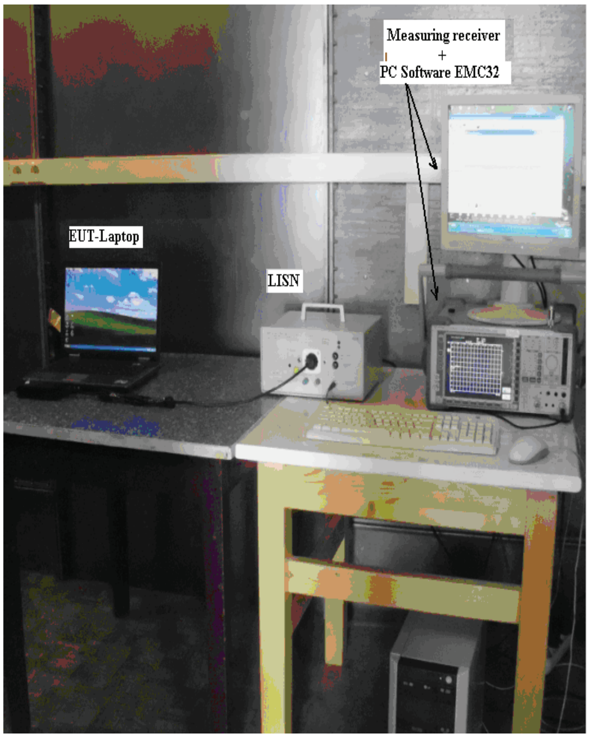


Fig. 4. Picture for Conducted Emission Test Setup.

However, to optimize the speed of conducted disturbance measurements, path 1 is recommended. Path 2, starting with a quasi-peak measurement, is slower in situations where compliance with the quasi-peak limit can be determined from a peak measurement [6], [12].

The steps to be followed for verifying conducted emission limits specified in CISPR 16-2-1 are:

1) Start measurement with peak detector for rapid measurement.

2) Compare peak emission level to the average limit. If emissions are above limit: go to step 3. If emissions are below limit: EUT passes.

3) Compare peak emission level with quasi-peak limit. If emissions are above limit: go to step 4. If emissions are below limit: go to step 1.

4) Measurement with quasi-peak detector.

5) Compare quasi-peak emission level to the average limit. If emissions are above limit: go to step 6. If emissions are below limit: EUT passes.

6) Compare quasi-peak emission level to the quasi-peak limit, If emissions are above limit: EUT fails. If emissions are below limit: go to step 7.

7) Measurement with average detector.

8) Compare average emission level to the average limit. If emissions are above limit: EUT fails. If emissions are below limit: EUT passes [4], [6].

B. Measurement results

For accurate measurements and suitable comparison to the limits provided in the required standards, a receiver model compliant to CISPR 16-1-1 was developed. The test instruments used for the measurements were: LISN, a Measuring EMI Receiver and specialized software - EMC32.

It is considered that the EUT passes where emissions are below the measuring limit. They are measured with the average detector, and with quasi-peak values. As seen from the resulting graphs, the points for the average values are represented in green and the quasi-peak values in blue.

The conducted emission limits are stated for quasi-peak and average measuring detectors, both of which have defined time constants and parameters defined in CISPR 16.

CISPR 22 requires the measurement of common mode voltages on Information Technology cabling to determine emission levels over the 150 kHz to 30 MHz range [13].

Conducted emissions measurements results are depicted in Fig. 5 and Fig. 6, representing a screen capture from EMC32 EMI Test Receiver. The amplitude and frequency of the signals are displayed. The points for quasi-peak detector are represented in blue and for average detector in green [4].

The data processing is carried out with a specialized software according to the CISPR 22 measurement procedures.

In detail, for measuring in the frequency range from 150 kHz to 30 MHz, the program setup the quasi-peak and the average values of the LISN output signal.

These quantities are used in the CISPR simplified procedure to test the emission of electrical and electronic apparatus.

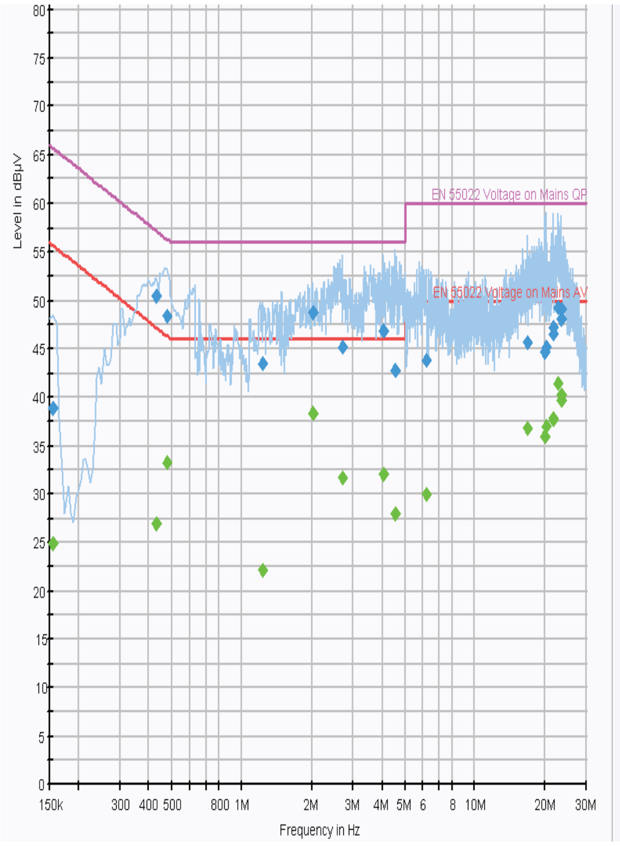


Fig. 5. EMC32 Report - Conducted Emission from EUT – Phase

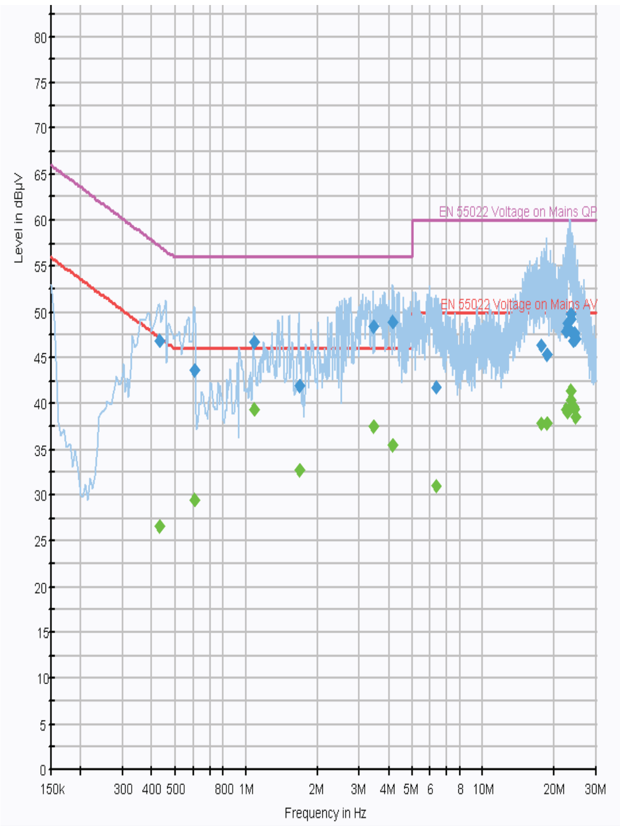


Fig. 6. EMC32 Report - Conducted Emission for EUT – Null

Table II shows the limits for conducted disturbances specified in CISPR 22 standard [14]. As can be seen, the peak and quasi-peak detectors show a wide-band interference that spans from 150 kHz to 30 MHz and exceeds the CE limit for class B devices [12], [14]. These limits are performed in the graphic results during the conducted emissions measurements for EUT. The measurements were performed both on phase and on the neutral power cable of the EUT respectively.

The analysis of results yielded by both methods of measurement revealed similar results.

The hardware setup from EMC32 for conducted emissions measurements is shown in Fig. 7. It is considered that it is a tool for controlling and monitoring the measuring receiver and it can be used for all electromagnetic interference measurements.

IV. CONCLUSIONS

The discussed measurements were performed in order to point out the conducted disturbances levels introduced by the tested laptop in the power supply network.

For the conducted emissions measurements, CISPR 16 and CISPR 22 Standards were applied.

We measured the voltages corresponding to the conducted disturbance by the methods specified in the CISPR 22 in the range from 150 kHz to 30 MHz.

TABLE II.
LIMITS OF DISTURBANCE VOLTAGE AT THE SUPPLY TERMINALS FOR CLASS B EQUIPMENT

Frequency range [MHz]	Limits [dB(µV)]	
	Quasi-peak	Average
0,15 to 0.50	66 to 56	56 to 46
0.50 to 5	56	46
5 to 30	60	50

Hardware Setup: CISPR22 - [EMI conducted]

Subrange 1	
Frequency Range:	150kHz - 30MHz
Receiver:	ESCI 3 [ESCI 3]
	@ GPIB0 (ADR 20), SN 100326/003, FW 4.32
Signal Path:	ESCI 3-LISN
LISN:	LISN
	Correction Table (Line 0): LISN
	Correction Table (Line 1): LISN

Scan Setup: TemplateFinalscan [EMI conducted]

Hardware Setup:	CISPR22
Level Unit:	dBµV

Subrange	Detectors	IF Bandwidth	Meas.	Receiver
150kHz - 30MHz	QuasiPeak; Average	9kHz	1s	ESCI 3

Fig. 7. Hardware setup EMC32 Report - Conducted Emission

Analyzing the values obtained for the quasi-peak and average values during testing, we could conclude that they do not exceed the admitted limits, therefore they comply with the required standard.

After the testing, we found that the values obtained with EMC32 software are in accordance with the standards, and the equipment tested is validated.

In conclusion, the equipment is operating at optimum and passes the conducted emission test.

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