Effect of the interaction between two LED lamps on conducted emission tests

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Abstract. There is a growing global demand for LED lamps and light fixtures. This demand inevitably leads to a greater demand for electromagnetic compatibility tests. These tests, for reasons related to standards that regulates them - CISPR 15 -, are performed individually in each lighting equipment. Still, what can be observed in situations where the equipment is commonly used is the connection of two or more units in parallel. As this type of use is not foreseen by standard it would be of interest that tests are conducted to investigate if there is indeed any risk in these cases. To this end, conducted emissions tests were conducted to verify how a lamp that exceeds the permitted emission limits has interacted with one that complies with regulatory requirements.

Keywords: LED Lamp, EMI, CISPR15, EMC

1. Introduction

Lamps and light fixtures using LED technology are increasingly common in homes and businesses, both in Brazil and around the world. Amongst their main benefits are better energy efficiency and longer service life, especially compared to its incandescent and fluorescent predecessors, saving up to 61% in comparison with the equivalent halogen light [1]. It is very common for this type of equipment to use switched-mode power supply. This is very beneficial in terms of energy dissipation, but - due to intrinsic characteristics of the source - its use causes more electromagnetic interference [2]. Therefore, electromagnetic compatibility (EMC) testing is required to ensure that emission levels do not exceed the specified limits.

EMC tests for lamps and light fixtures are determined by the current CISPR 15 standard [3]. It describes some tests to verify the radio frequency (RF) emission levels that are conducted and irradiated by the equipment under test (EUT). These analyses differ precisely in the propagating medium by which the disorder spreads until it reaches a possible victim. The test for irradiated emissions - see Figure 1 (a) - has air as its propagation medium and it is necessary to analyze emissions from 9 kHz to 300 MHz. Conducted emissions - see figure 1 (b) -, in turn, are routed through the equipment cables and are observed from 9 kHz to 30 MHz. In the case of light bulbs, the cables investigated are generally the power cables of the switched-mode power source. In this article the focus of testing and analysis will be on conducted emissions.

Emission testing is important to ensure that the EUT does not interfere with adjacent equipment or the power grid to which it is connected. This is because electromagnetic disturbances are a two-way street: all devices emit disturbances related to their operation and receive disturbances from adjacent
devices. If a device is not immune to certain levels of electromagnetic radiation, it may have undesirable failures. Therefore, ensuring that both irradiated and conducted emission levels are as low as possible is essential for compatible operation across multiple EUT.

![Figure 1. Schematic of radiated (a) and conducted (b) emissions tests [4].](image)

The National Institute of Metrology, Standardization and Industrial Quality (INMETRO) – responsible for the regulation and accreditation of various types of equipment for sale and use in Brazilian territory – postponed in its Ordinance No. 389 the minimum requirements for safety, efficiency and electromagnetic compatibility [5]. Therefore, it is mandatory for all lighting equipment sold in Brazil to comply with the complementary documents indicated by the Ordinance. One of these documents – and the one that matters for this paper – is the CISPR 15:2013 Limits and Methods of Measurements of Radio Disturbance Characteristics of Electrical Lighting and Similar Equipment [3].

One determination of the standard is that only one sample must be tested at a time - except for those that require other instruments for full operation, in which case the system is to be tested overall. Everyday use of most equipment, however, is not isolated from other accessories. This case is even more evident when we look at the use of lamps in homes, businesses, clinics etc. It is rare for a slightly large environment to achieve satisfactory illumination with the use of one lamp only. In fact, even smaller environments usually use at least two lamps. Considering warehouses, for example, the parallel use of different light sources becomes even more extensive. Therefore this study aims to address the possible effects of the interaction of two tubular LED lamps connected at the same outlet and thus measure their RF emissions.

2. Methodology
The employed methodology is quite straightforward, as it is based on tests already determined by the standard. Briefly, conducted emissions measurements were carried for two LED tube lamps individually, to see what would be their result in a standard laboratory measurement. Then the measurements were made for the two lamps connected in parallel, which would not happen in a normal test, but approximates a situation of routine use of this type of equipment.

Before delving further into the methodology itself, it is important to highlight some information about the tests that were performed. The first concerns the ambient conditions of the laboratory at the time of testing. The temperature of the shielded chamber where they occurred ranged from 22.2 ºC to 23.6 ºC. Relative humidity in the same environment ranged from 57% to 65%. Both values allowed within normative limits.

It is also relevant to make some observations about the lamps used. Although they are from different manufacturers, both have rated power of 20 W, use G13 connector and have a voltage of 127 Vac and 220 Vac. The laboratory mains frequency is 60Hz. All measurements were performed in the shielded chamber of the Electrical and Optical Equipment Laboratory (LEO) of the Institute for Technological Research.
2.1. How to perform the Emission Test

The setup for an emission test is relatively simple. The sequence for signal acquisition is: the EUT is connected to a line impedance stabilization network (LISN), which transmits data to a receiver connected to a computer. The computer, equipped with the R&S EMC32 Measurement Software will automatically generate the graphics of interest. Further up is a brief explanation of what the LISN and the receiver are and what they do.

The graphs generated, shown in the next section of the article, are of maximum peak and average curves. When a Quasi-peak (Qp) occurs, its location will also be shown. The following subsections aim to elucidate the main parameters and equipment of the conducted emission test.

2.1.1. Average. CISPR 15 standard establishes limit values for noise emissions. These limits are analyzed through two detectors: Average (150 kHz at 30 MHz) and Quasi-peak (9 kHz at 30 MHz). The receiver scans the spectrum at the previously determined frequency limits, starting from the smallest frequency value with an increment of 1% from the previous value, with a dwell time of 10 milliseconds for each one, measured in dBµV. A mean of all values obtained for each frequency is made to find the value of Average (AV).

2.1.2. Quasi-peak. Qp, on the other hand, does not have a trivial methodology to be obtained. Although it is not the goal of this paper to explain what the function of Qp is or how it is obtained, it is important to know that for each frequency value it takes 2 seconds of analysis to obtain this emission level, which makes the process quite time consuming. For that reason it is possible to use Max-peak values to speed up the process. The method is similar to the one to get the Average values: data is taken for 10 milliseconds, however in this case the average calculation is not done, but the highest value amongst those obtained is saved. Then a computational analysis is performed which, by means of the Max-peak values, scans at localized frequencies, where there is a greater probability of the existence of Qp – this analysis occurs at points where Max-peak is 4 dB less than the normative limit for Quasi-peak. In short, the methodology consists of making a first scan to find the worst cases at Max-peak and a second to confirm if there is Qp in the regions determined in the previous scan, saving the time it would take to scan the entire spectrum.

2.1.3. Line Impedance Stabilization Network. This equipment is a normative requirement, as it is responsible for maintaining a known impedance and providing an output for reading radio frequency noise. In the case studied, the lines are L1 and N and the previously described scan for maximum peak, AV and Qp is made for each one of them, determining the worst case of each one to make a graph that represents the worst situation of each one.

2.1.4. EMI Test Receiver. This equipment is responsible for all data collection and processing from the LISN to the software. It has an embedded system responsible for carrying out the balances and verifications described above, in order to send to the computer the data already processed, that is, lighter and easier to be manipulated by a user.

2.2. Setup for conducted emissions of individual LED lamps

Having a better understanding of what the conducted emissions test is, it is necessary to show the setup of the equipment at the time of testing. The tests were performed as described above for each of the lamps individually. Measurements were then taken for the case of parallel connection between them.
The lamps hereinafter referred to as Sample 1 and Sample 2 were tested in the configuration shown in Figure 2 and 3. This is determined by the standard, detailing how far the EUT should be from the wall, which must be made out of a properly grounded conductive material. The tested lamp in both cases was turned on fifteen minutes before data acquisition. This is not a normative requirement of CISPR 15, however it is important to maintain a standard between the measurements and to assure the electronic circuit stabilization.

2.3. Setup for conducted emissions of two simultaneous LED lamps
As explained in the first section of the article, there is no normative precedent for testing two devices as it was done in this paper. Therefore the arrangement of equipment is not described in the standard either. Thus the same emission test was performed in two different setups, as can be seen in the comparison between Figures 4 and 5.
Figure 4. Setup for parallel distribution.

Figure 5. Setup for testing in angled distribution.

As with the individual lamp, test the EUT was switched on fifteen minutes before measurement. Simultaneous connection of the light fixtures with the LISN was made in order to guarantee their parallel operation. The connection of samples 1 and 2 was called Sample 3. The configuration of Figure 3 closely approximates the view in Figure 4. Basically the lamps are arranged in parallel with each other, which is a common distribution in light fixtures. In the following image there is an angle of approximately ninety degrees between them, simulating a possible but not common distribution.

3. Results and discussions
Measurements were made at the two supply voltages declared by the manufacturer. Nevertheless the results obtained were not significantly different from each other, hence only results from the tests performed on 127 Vac will be shown.

The graphs to be displayed were automatically generated by the data acquisition software. The blue and green curves are the maximum value and average value measurements, respectively. The blue diamonds symbolize where the Quasi-peak measurements were taken. The red and magenta lines are the limits allowed by the standard for Qp and AV values, in that order.

3.1. Sample 1
Looking at Figure 6 below it is possible to see that the conducted emissions from the first sample are excessive and would cause a non-compliance in the case of a certification test. This non-compliance, in fact, would not only be due to the Quasi-peak of the limits being exceeded, but also to the average values of their respective limits. This illustrates a rather dirty spectrum.
3.2. Sample 2
The second sample, Figure 7, has a cleaner spectrum and is very close to what might be called ideal. The maximum value curve remained so far away from the quasi-peak limits that it was not even necessary for special measurement of these points. The mean values also remained far from the limit stipulated by the standard.

3.3. Sample 3
The third sample, Figure 8, - resulting from the combination of the two previous ones - finally, presented a spectrum of emissions that would constitute non-compliance with the requirements of CISPR 15. As in the case of Sample 1, non-compliance occurs for both Quasi-peak and average excess values. However, this time the spectrum presented has smaller emissions overall, presenting a cleaner spectrum.
Figure 8. Conducted emissions from Sample 3 with 127 Vac power and 60 Hz. Parallel positioning as seen on figure 4.

Moreover, it can be seen in Figure 9 below that the curve presented in the case of parallel arrangement compared to the ninety degree does not show significant changes either in emission values or in the non-compliance result.

Figure 9. Conducted emissions from Sample 3 with power of 127 Vac and 60 Hz. Positioning at ninety degrees as seen on figure 5.

3.4. Discussion
It can be noted from the graphs above that there is no absolute prevalence of either sample in the result presented. Another interesting observation to make about these graphs is the non-influence of the setup of lamps on the result for Sample 3. Both findings are for the studied case and should not be generalized.
A valid analysis to be made is about the failing point of the third sample in quasi-peak (approximately 150 kHz). Table 1 below presents the measured values for the three samples in Qp and AV, with their respective normative limits.

**Table 1. Quasi-peak and average values at 150 kHz**

| Sample | Freq. (kHz) | Qp (dBµV) | Qp limit (dBµV) | AV (dBµV) | AV limit (dBµV) |
|--------|-------------|-----------|-----------------|-----------|-----------------|
| 1      | 150         | 88.7      | 66              | 73.1      | 56              |
| 2      | 150         | 54.5*     | 66              | 35.9      | 56              |
| 3      | 150         | 71.5      | 66              | 58.6      | 56              |

*Sample 2 has no Qp value, so the maximum peak value is presented on the table.

It is rather intriguing to note that the Qp and mean values of sample 3 for the discriminated frequency are between the values of the first two samples. However, it is not possible to state if there is any rule that guarantees the location of these values or if it was a coincidence between the measurements.

In a study that is still crude and without a considerable amount of samples it is risky to make too many inferences. Nonetheless it can be said that the actual case of an approved lamp interacting with a failed lamp has generated a system that exceeds the limits specified by the current standard.

**4. Conclusion**

LED lamps and light fixtures are indeed a growing market that deserves attention from various regulatory areas. Electromagnetic compatibility needs to pay attention to interference caused by such equipment in conditions not yet specified by the valid standard. The present study has no conclusive power regarding the interference generated in the interaction of two tubular LED lamps, nor is it its objective. Inciting further debate and study of how this kind of interaction occurs is good enough.

There are, however, some studies that can be done with the data obtained or with some more tests. An evaluation of the interaction between lamps is a valid study to try to find a pattern in the formation of noise of lamps connected together. It is also possible to perform numerical analyzes of the data that is represented in the graphs presented in order to try to find patterns among the three samples.

One last suggestion, which needs a few more trials, is to try to find different cases from the one presented. For example, the case of two complying equipment that would fail together or even two failed equipment that would comply when working together. These studies become valid and necessary, as equipment is rarely used in isolation from others.

**References**

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