A study on the impact of EMI lighting systems on 2.4 GHz Wi-Fi communication networks

Un estudio sobre el impacto de la EMI de los sistemas de iluminación en las redes de comunicación Wi-Fi de 2,4 GHz

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Recibido 23 de septiembre de 2021, aceptado 16 de noviembre de 2022
Received: September 23, 2021 Accepted: November 16, 2022

ABSTRACT

Wi-Fi technology is present in homes, universities, restaurants, and pubs worldwide, thus gaining notorious space in communication systems, especially due to smart technologies improvement. However, several devices can interfere with this network, reducing or even causing data loss on transferences. The Electromagnetic Interference (EMI) caused by lighting equipment is a bad-known and little-analyzed phenomenon in Brazil. The massive use of these technologies needs to be evaluated, remarking a critical analysis of its permitted limits. This study aims to verify and evaluate the possible influences that lighting technologies can generate on communication networks (Wi-Fi) through Electromagnetic Interference (EMI). The following article is the result of several tests under the influence of seven different types of lighting sources among thirteen samples to assess the influence of lighting systems on Wi-Fi networks. The tests were made in a shielded environment, on the LabLux - UFF (Laboratório de Luminotécnica da UFF), using the Iperf3 software.

Keywords: Communication Network; Electromagnetic compatibility and interference; Lighting systems; Wireless Network.

RESUMEN

La tecnología Wi-Fi está presente en universidades, restaurantes, pubs, alrededor del mundo, ganando así notorio espacio en los sistemas de comunicación especialmente debido a la mejora de las tecnologías inteligentes. Sin embargo, varios dispositivos pueden interferir con esta red, reduciendo o incluso provocando la pérdida de datos en las transferencias. La Interferencia Electromagnética (EMI) provocada por los equipos de iluminación es un fenómeno poco conocido y poco analizado en Brasil. El uso masivo de estas tecnologías necesita ser evaluado remarcando un análisis crítico de sus límites permitidos. Este estudio tiene como objetivo verificar y evaluar las posibles influencias que las tecnologías de iluminación pueden generar en las redes de comunicación (Wi-Fi) a través de la Interferencia Electromagnética (EMI). Para comprobar la influencia de los sistemas de iluminación en las redes Wi-Fi, el siguiente artículo es el resultado de varias pruebas bajo la influencia de siete tipos diferentes de fuentes de iluminación, entre

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trece muestras. Las pruebas se realizaron en un entorno blindado, en el LabLux - UFF (Laboratório de Luminotécnica da UFF), utilizando el software Iperf3.

Palabras claves: Red de comunicación, compatibilidad e interferencias electromagnéticas, sistemas de iluminación, red inalámbrica.

INTRODUCTION

According to [1], electromagnetic compatibility (EMC) is a field of science and engineering concerned with the design and operation of electrical and electronic systems/devices in a manner that makes them immune to specific amounts of electromagnetic interference (EMI), while at the same time keeping their EMI emissions within specific limits.

With the intensification of the use of electronic equipment, problems with electromagnetic interference have become more recurrent in the operation of this equipment. Many studies regarding this issue have been performed around the world. Some examples can be shown in [2], where the impacts on the LED lamps were analyzed in different industrial EMI noises, in [3] studies the conducted emission in the range from 2 kHz to 150 kHz during the charging cycle of electric vehicles and in [4] studies electromagnetic interference on medical equipment caused by a low-power mobile telecommunication system.

Sometimes, EMI shielding is necessary because of device sensitivity. The workspace, cables or devices are shielded from radiation from computers and telecommunications equipment to protect them. In [5-7], there are some examples of studies about composites to optimize the design of EMI shielding materials.

Despite using materials for electromagnetic shielding, it is necessary to establish standards that allow different equipment, circuits, and networks to operate in the same environment with less probability of interfering with each other. Thus, an electronic system or equipment will perform satisfactorily, being immune in an environment susceptible to electromagnetic fields, and will continue to operate without causing interference to other existing systems, a fundamental principle to ensure interoperability between systems [8].

The Comité International Spécial des Perturbations Radioélectriques (CISPR; English: International Special Committee on Radio Interference) [9] works with equipment and methods for measuring interference, establishing limits and immunity requirements, and prescribing methods of measuring immunity. Then they can promote a reduction in interference to radio and TV broadcasts from domestic, industrial and commercial appliances, motor vehicles and lighting fixtures [10].

The ABNT NBR IEC/CISPR 15 [11], with the same technical content, structure, and drafting as IEC CISPR 15: 2013 [12], is the Brazilian standard that defines limits and methods of measuring radio disturbances characteristic of electrical lighting equipment and similar equipment. The frequency range covered is 9 kHz to 400GHz, eliminating other frequency tests.

Taking into account the evolution of lighting systems as a result of the development of technology and the increasingly widespread use of wireless network communication systems, the following work investigates the influence of the EMI produced by seven different lighting technologies on the WI-FI (2.4GHz). Another research that considers these possible effects are present in [13].

METHODOLOGY

This chapter seeks to present the methodology used in the tests. For this purpose, the equipment, characteristics of the room where the tests were performed, the lamps, the assembly scheme, and the test conditions are presented.

For this, the work was divided into three parts. In the first part, a spectrum analyzer (wi-spy) was used to analyze the influence of each lamp model on some WI-FI channels available. In the second part, one wireless network with two routers was installed to check if there was a decrease in the data packet transfer rate due to possible electromagnetic interference. In the last part, all the tests were repeated for an extreme case, and the scene was set up in a seasoning of LED bulbs and compact fluorescents, with approximately 250 lamps.

The tests executed were performed at LabLux, a laboratory of Federal Fluminense University (UFF-RJ/Brazil); it has INMETRO accreditation to perform conformity tests on lighting products and has a great experience in research related to lighting devices, as reported in several academic documents [13-20]. The laboratory has a shielded room for conducting and radiated EMC tests and a seasoning room to measure LED and fluorescent lamp life. Both rooms were used in this work, the shielded room to attenuate external radio interference (first and second test) and the seasoning room to give an extreme case for the third test without shielding and with a lot of lamp interference.

Figure 1 shows the shielded room picture, and Figure 2 shows the seasoning room picture.

seven different lighting technologies were selected as samples to verify the impact of the main lamp technologies in the Wi-Fi data transmission frequency range, to obtain a representation of the most common types of lamps on the market, as shown in Table 1.

For this purpose, this work was divided into three parts: First, a spectrum analyzer (wi-spy) was used to analyze the influence of each lamp model on

Figure 1. Shielded room.

Figure 2. Seasoning Chamber.

Table 1. Lamps data.

Tested Lamps		
Sample	**Technology**	**Power (W)**
1	Halogen	50
2	Incandescent	60
3	LED (3000 K)	6
4	LED (6500 K)	9
5	LED (6500 K)	6
6	LED (6500 K)	12
7	Compact Fluorescent	15
8	Compact Fluorescent	22
9	Compact Fluorescent	42
10	Sodium Vapor	250
11	Sodium Vapor	400
12	Fluorescent Tubular	40
13	LED Tubular	18

available Wi-Fi channels. This test was made in a shielded room at LabLux - UFF. Second, one wireless network with two routers was installed to check the data packet transfer rate decrease, this test was made in a shielded room too. In the last part, the scenario was set up in a LED and compact fluorescent seasoning room with approximately 250 lamps. The first test with spectrum analyzer and second test to analyze the data packet transfer in Wi-Fi were repeated for this extreme case.

Tests 1 and 2 were made using seven different lamps technologies. The lamps' information is shown in Table 1.

Tests Description

The methodology used in this document considers three different tests to confirm the impact of electromagnetic interferences caused by lighting equipment in a data transmission network.

The three procedures were done to measure before and after the tests. Measurements of the measured spectrum were carried out without the lamps' presence, to verify the ambient noise.

Test 1

The Wi-spy 2.4GHz frequency spectrum analyzer [21] was used in test 1 to analyze the 2.4 GHz frequency spectrum. The data were collected using the Chanalyzer 3.2 software, which identifies the channels and frequencies where the Wi-Fi devices, interfere and the inSSIDer software.

The tests were performed in a shielded room to attenuate the external signals., The environmental conditions required by ABNT - NBR IEC / CISPR-15 [11] were guaranteed during the test.

The procedure took place using one sample at a time on the test table and collecting with the analyzer for 2 minutes, or the spectrum irradiated by the sample. Figure 3 shows the test 1 scheme.

Test 2

Figure 4 shows the scheme of test 2, and Figure 5 shows the wireless routers and one of the types of lamps measured. In this test, the Iperf tool generated a data stream with a 10 Mbits/sec data transfer rate.

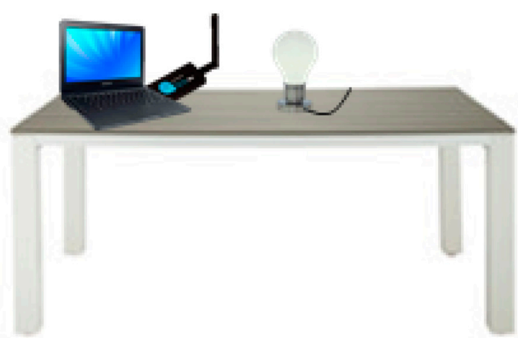

Figure 3. Test 1 Scheme.

Figure 4. Test 2 scheme.

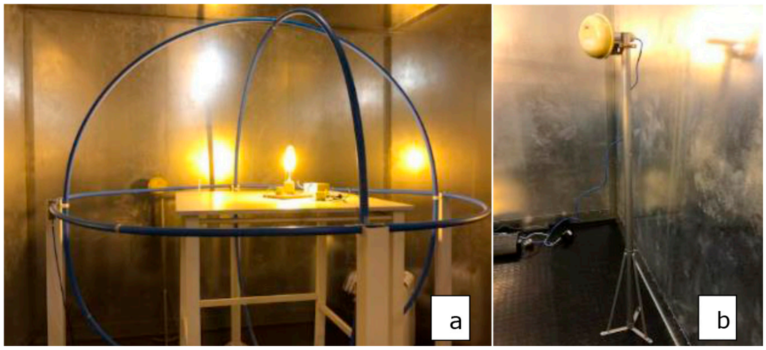

Figure 5. (a) Shows the stand where the lamps under test are arranged.
(b) Shows one of the wireless routers with the antenna.

Test 3

Unlike the others, the place of the last test did not have electromagnetic shielding. This test was performed in the seasoning chamber with place conditions according to INMETRO Ordinance nº 389 [22]. The test room is shown in Figure 2. The measurement was performed during normal operation of the seasoning chamber, where about 250 lamps (LED bulbs and compact fluorescents) were cycled.

Before and after the tests, the noises present in the room were measured. Figure 6 shows some signals in the 2.4 GHz spectrum when the 250 lamps were turned off. These signals come from nearby wireless networks, and their characteristics can be observed by the software inSSIDer (Figure 7), where the twenty-one Wi-Fi signals are described.

Two wireless routers were configured on channels 1, 6, and 11 with a power of 0dBm and 10 dBm to verify the data transmission rate in the cycling room measurement. Figure 8 shows the variation presented by the software Chanalyser during data transmission on channel 6, and Figure 9 shows the graph of measurement of the data transmission rate of routers.

Tests Results

Figure 10 shows the result obtained with Chanalyser software for the 2.4 GHz spectrum without lamps, and Figure 11 shows, 2.4 GHz spectrum with a 9W LED lamp for test 1.

In all the cases tested (thirteen lamp samples), similar results were found. No electromagnetic interference was found in the 2.4 GHz electromagnetic band.

Figure 12 shows the 2.4 GHz spectrum with Wireless routers on channel 6 and power 10 dBm, and Figure 13 shows the graphic measuring the data transmission

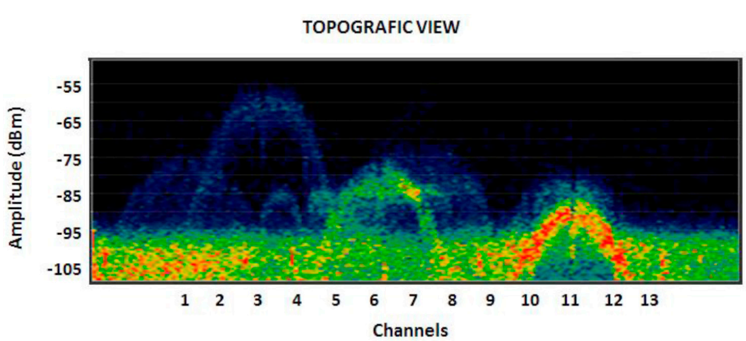

Figure 6. 2.4 GHz spectrum from the seasoning chamber with lamps off - ambient noise.

Figure 7. Image captured with inSSIDer software in the seasoning chamber and lamps turned off - ambient noise.

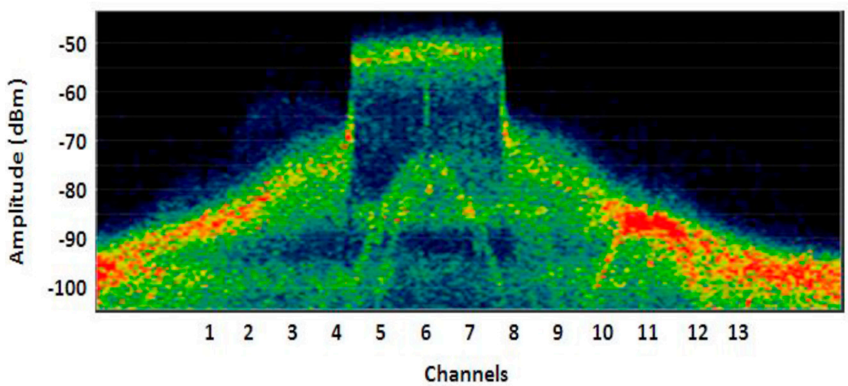

Figure 8. 2.4 GHz spectrum from the seasoning chamber with lamps off and two wireless routers communicating on channel 6.

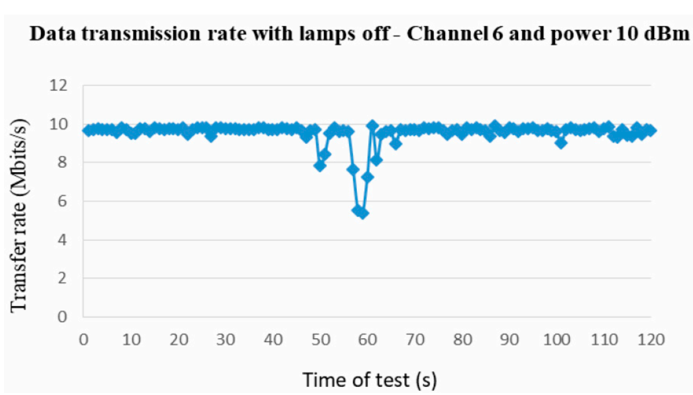

Figure 9. Graphic of the data transmission rate measuring in the seasoning chamber with routers on channel 6 and 10 dBm power and lamps turned off.

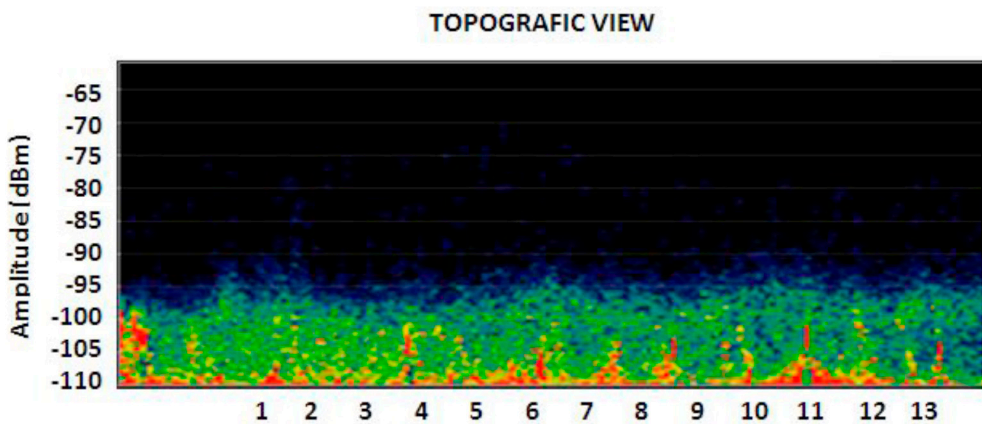

Figure 10. 2.4 GHz spectrum captured by the Chanalyser in the shielded room without lamps.

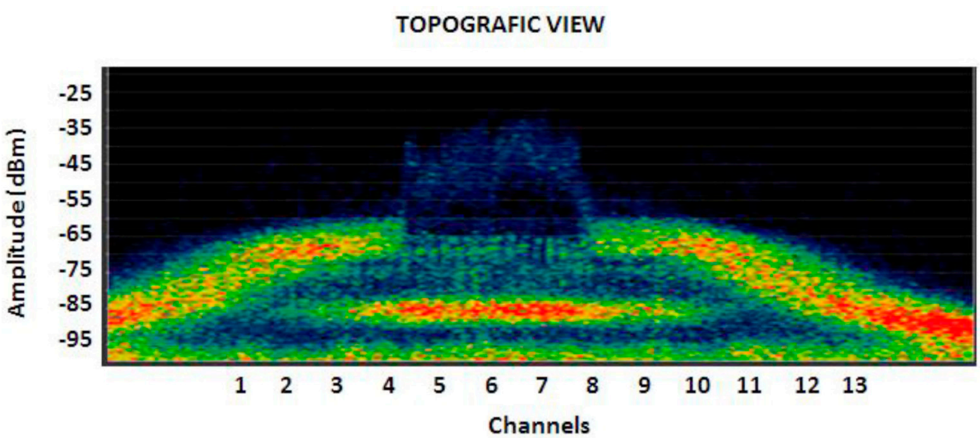

Figure 11. 2.4 GHz spectrum from the shielded room with lamp 4, LED 9W. The uniform spectrum that accompanies the axis x of the graphic indicates that there is no interference.

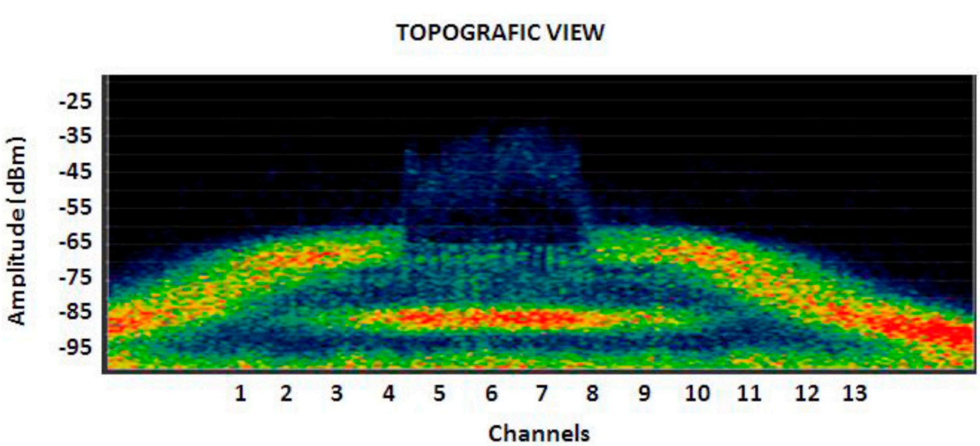

Figure 12. 2.4 GHz spectrum from the shielded room with Wireless routers on Channel 6 and 10 dBm power and without a lamp.

rate obtained with the IPERF tool for test 2. In this part of the test, there is no lamp connected.

Figure 14 shows the 2.4 GHz spectrum with Wireless routers on channel 6 and power 10 dBm with sample 4 (LED lamp 9W) turned on, and Figure 18 is the graphic of the data transmission rate obtained with the Iperf tool.

Figure 15 shows the results of the Chanalyser software during signal transmission between routers with the seasoning room lamps on for Test 3. When comparing this capture (Figure 15) with the measurement result obtained when the lamps were off (Figure 8), it is possible to see that there was not enough variation in the spectrum to signal electromagnetic interference caused by the lamps in the seasoning room.

Figure 16 shows the measurement graphic of the data transmission rate of the routers when the 250 lamps were turned on.

RESULTS DISCUSSION

In test 1, despite the attenuation of the electromagnetic signal through the shielded room, it is possible to observe that there is still a low-power network in the test space. The noise in the spectrum captured with the chanalyser software was described by inSSIDer software, as shown in Figure 17, where five different Wi-Fi are shown.

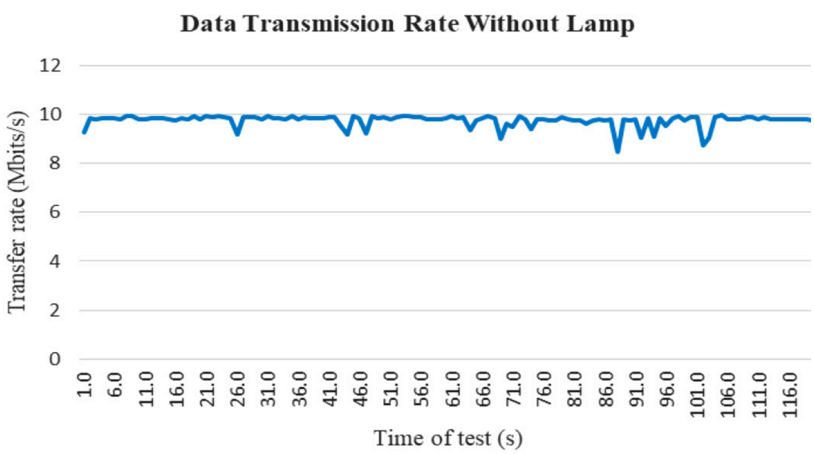

Figure 13. Graphic of measuring the data transmission rate without a lamp.

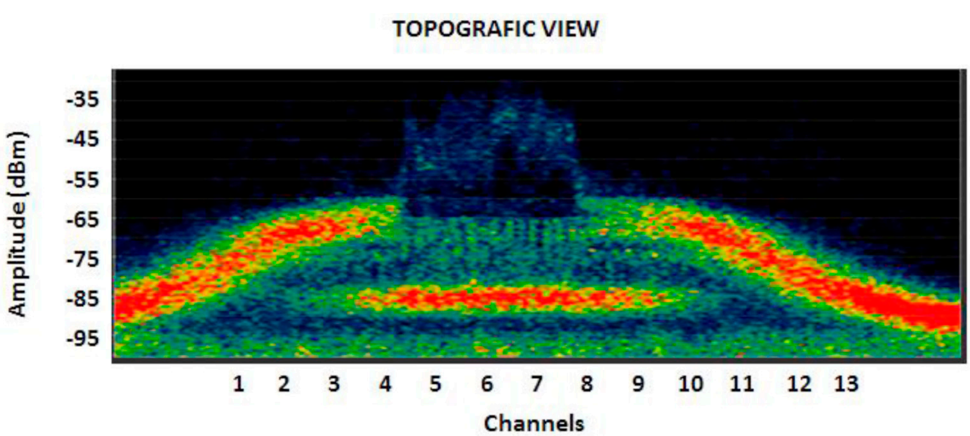

Figure 14. 2.4 GHz spectrum from the shielded room with Wireless routers on Channel 6 and 10 dBm power and with sample 4 (LED lamp 9W) on.

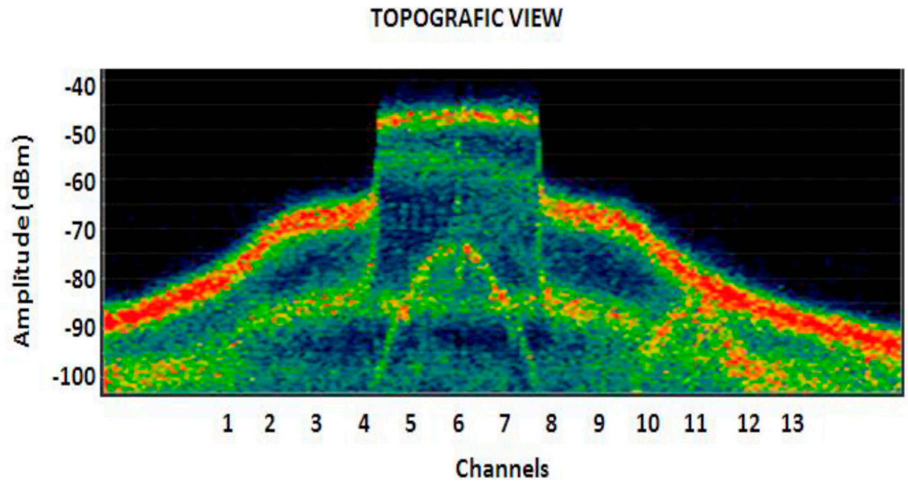

Figure 15. 2.4 GHz spectrum from the seasoning chamber with lamps on and two wireless routers communicating on channel 6.

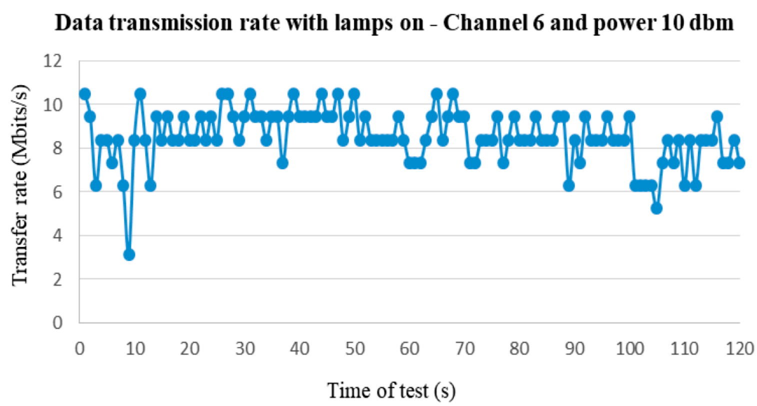

Figure 16. Graphic of measuring the data transmission rate in channel 6 and 10 dBm power when the lamps are on.

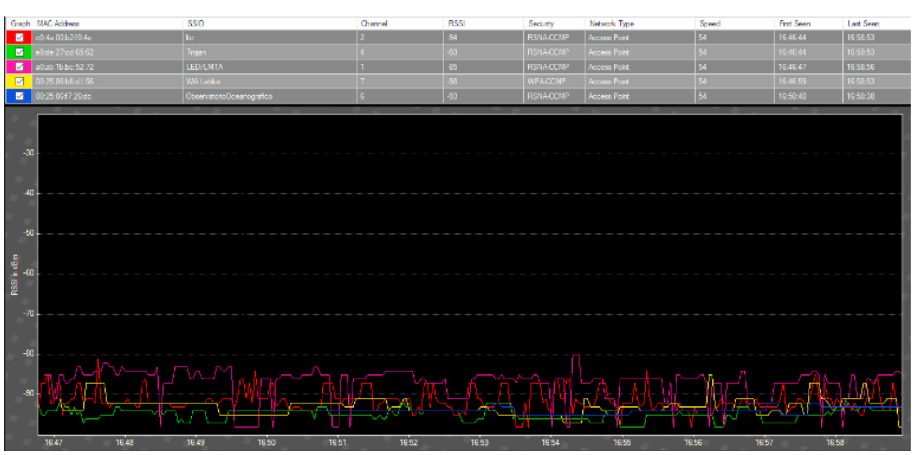

Figure 17. Image captured with inSSIDer software in the shielded room.

In test 2, in all 14 cases (13 individual lamps and all lamps together), there was no interference generated by lamps in the 2.4 GHz spectrum. Therefore, the data transmission rate values did not show a significant decrease, as can be seen in Figure 18.

From the analysis of the measurements made on test 3, it was possible to notice that despite the variations in data transfer rates in some moments. In the 2.4 GHz band, the lamps showed no interference, even in the worst-case scenario studied, which involved connecting multiple lamps between the two routers.

However, other Wi-Fi networks in the same environment impaired measurements on channel 11 for a while.

CONCLUSIONS

This work investigated the impact on the Wi-Fi network (2.4GHz) caused by a potential EMI interference source produced by seven lighting technologies.

The tests were divided into three parts. In the first, a spectrum analyzer (wi-spy) was used to check the influence of each lamp model on Wi-Fi channels. In the second part, one Wi-Fi network with two routers was installed to check the data transmission rate decay. In the last part, all the tests were repeated for an extreme case. The test was set in a seasoning room with approximately 250 lamps.

Test results showed that although electronic components cause electromagnetic interference at different frequencies, the bandwidth of the 2.4 GHz Wi-Fi network has not been affected by these different lamp technologies.

In addition, it was realized that the presence of other data transmission networks on the same frequency could cause reduced data traffic and packet loss. In this sense, equipment and data that require higher reliability should be carefully installed to avoid loss of communication.

The obtained results minimize society's concern since the norms are being applied effectively, and the quality of the products offered in the Brazilian market meets the requirements of the adopted standard. This article applies a testing methodology to lighting equipment; however, it could be extended to other equipment to check the impacts of EMI in Wi-Fi or even serve as a basis for other certification procedures to be developed and implemented.

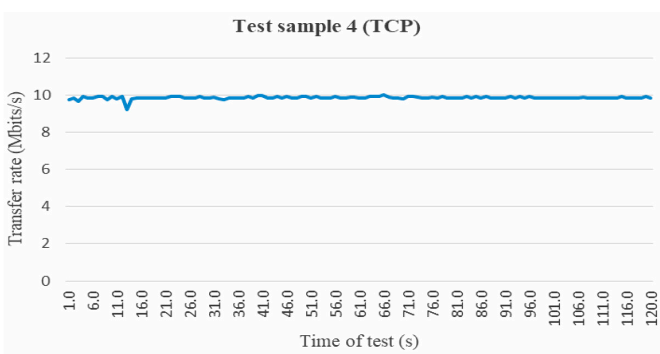

Figure 18. Graphic of measuring the data transmission rate with sample 4 (LED lamp 9W) connected.

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