

Characterization of the Electromagnetic Interferences due to a Public Lighting System

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Abstract – With a view to characterize the electromagnetic interferences (EMI) due to a model of Light Emitting Diode (LED) lamp used in street lighting, measurements of radiated emissions were conducted both in situ and in an Electromagnetic Compatibility (EMC) laboratory. The in situ measurements were carried out using an Anritsu MS2724B spectrum analyzer in conjunction with a directional antenna, in the frequency range from 20 MHz to 200 MHz, at 10 m distance from a number of LED lamps. The EMC laboratory measurements were conducted in compliance with the European Standard EN 55015, “Limits and methods of measurement of radio disturbance characteristics of electrical lighting and similar equipment”. The paper presents measurement results obtained in the two situations, which indicate that the emissions from the considered LED lamps exceed the imposed EMC limits and so EMI problems appeared by using these products.

Keywords – LED lamp, electromagnetic interference, radiated emissions, in situ measurements, EMC laboratory measurements

I. INTRODUCTION

Nowadays, everybody tries to save energy and be part of making a greener world. As the latest and most exciting technological development in the lighting industry, the LED devices have a number of advantages over incandescent, neon and compact fluorescent lighting devices, such as much longer life span (up to 60,000 hours), better energy usage (up to 90% more efficient), reduced maintenance costs and higher safety. They are also recyclable and considered earth-friendly [1].

However, while the LEDs themselves do not generate any detectable noise, the switching power circuitry driving the LEDs operate at high frequencies, which, when are not properly filtered, can result in electromagnetic interferences. Based on the reported problems, the radiofrequency (RF) services most likely to be affected include [2-4]: FM broadcast radio (87.5 MHz

– 108 MHz), Digital Audio Broadcast (DAB) radio (174 MHz – 240 MHz), 2-meter band amateur radio (144 MHz – 146 MHz), VHF marine radio (156 MHz – 162.025 MHz), Airband radio (118 MHz – 136.975 MHz), baby monitors (118 MHz – 136.975 MHz) and high frequency services operating in the frequency band 3 MHz – 30 MHz, such as amateur radio allocations, Citizens’ Band radio, wireless devices working at 27 MHz, etc.

Most of the EMI problems are a direct consequence of the product design. As EMI mitigation inevitably increases the overall cost of the LED products by adding additional components to a design, some manufacturers reduce or cut these costs, so they can lower the price of their products to appear more attractive to the consumers. Such LED lighting devices will potentially be the most problematic in terms of interference, but they will also be the preferred choice for many consumers [3].

The present paper investigates EMI problems caused by a high-power LED lamp model used in street lighting. These LED lamps have been suspected to disturb the proper operation of the audiovisual program retransmission and data transmission network in a rural commune. Preliminary in-situ measurements of radiated emissions, followed by EMC laboratory measurements conducted according to the relevant international standards, confirmed this assumption.

II. MATERIALS AND METHODS

The experiment realized on the LED street lights involved both in-situ and laboratory measurements of radiated emissions, in the general frequency range from 9 kHz to 300 MHz. This section describes the measurement methodology adopted in the two situations, with special emphasis on the EMC laboratory measurements.

A. In situ measurements

The instrumentation used for in situ measurements mainly consisted of an Anritsu MS2724B spectrum analyzer, 9 kHz – 20 GHz, in conjunction with an R&S HE300 directional antenna, 20 MHz – 7.5 GHz. The measurements were carried out in terms of electric field

strength [5, 6], at a distance of 10 m from a number of installed LED lamps. The distance between the LED lights and the network cables was about 1.5 m.

At each location, two sets of “max hold” measurements were taken with the lightning system switched on / off, in the frequency range 20 MHz – 200 MHz (far-field conditions). The electric field values obtained with the lighting system in operation were roughly compared to the limits given in the European Standard EN 55015 (CISPR 15), “Limits and methods of measurement of radio disturbance characteristics of electrical lighting and similar equipment” [7].

Table 1. Electric field limits in the frequency range 30 MHz – 300 MHz at a measuring distance of 10 m [7].

Frequency range (MHz)	Quasi-peak limits (dB μ V/m)
30 – 230	30
230 – 300	37

B. EMC laboratory measurements

Because of the high emission levels recorded in situ (exceeding the limits in Table 1), further measurements of radiated emissions were carried out in a controlled environment, namely an accredited EMC laboratory. These measurements were conducted in compliance with the methodology specified in the standard EN 55015. EN 55015 applies for both conducted and radiated emissions, but here we will present only measurement results regarding the radiated emissions.

In the frequency range from 9 kHz to 30 MHz, EN 55015 calls for measuring magnetic field emissions with a 2-m, 3-m or 4-m triple-loop antenna (sometimes called the Van Leen Loop), which surrounds the equipment under test (EUT). The currents induced in the three orthogonal loops are to be measured separately, with the quasi-peak detector, and compared to the limits given in Table 2. For the frequency band 9 kHz – 150 kHz, the IF bandwidth of the measurement receiver has to be set to 200 Hz, while, for the frequency band 150 kHz – 30 MHz, the IF bandwidth has to be set to 9 kHz.

Table 2. Quasi-peak limits of the magnetic field emissions in the frequency range 9 kHz – 30 MHz [7].

Frequency range (MHz)	Limits for loop diameter (dB μ A)		
	2 m	3 m	4 m
0.009 – 0.07	88	81	77
0.07 – 0.15	88 to 58 ^a	81 to 51 ^a	75 to 45 ^a
0.15 – 3	58 to 22 ^a	51 to 15 ^a	45 to 9 ^a
3 – 30	22	15 to 16 ^b	9 to 12 ^b

^adecreasing linearly with the logarithm of the frequency

^bincreasing linearly with the logarithm of the frequency

The test setup for radiated emissions in the frequency range 9 kHz – 30 MHz is shown in Fig. 1, where the LED

lamp is placed on a wooden table, at the centre of a common 2-m triple-loop antenna, model TLA-300 (AFJ). EUT was powered at 230 V / 50 Hz and tested under appropriate operation conditions.



Fig. 1. Test setup for radiated emissions in the frequency range from 9 kHz to 30 MHz [8]

The radiated emissions in the frequency range 30 MHz – 300 MHz were measured using the CDN (Coupling – Decoupling Network) method specified in the Annex B of EN 55015 (Fig. 2), which represents an alternative to the electric field measurements performed on an open area test site (OATS) or in a semi-anechoic chamber. Assuming that the only connection to an equipment is via a single cable (normally the power feed), and that any radiated emissions are actually from the cable (rather than the equipment itself), measuring the level of interference signal on the cable, as it leaves the equipment, we can get a measure of what the radiated emission level will be. Intensive studies for comparing the two methods, CDN and OATS, concluded that the results correlate within acceptable tolerances [9].

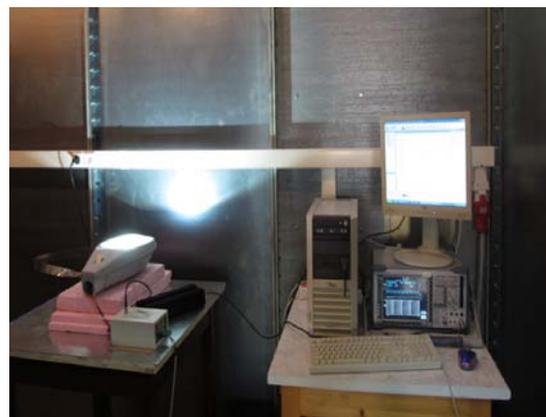


Fig. 2. Test setup for radiated emissions in the frequency range from 30 MHz to 300 MHz [8]

According to EN 55015, the common mode voltage measured at the RF output of the CDN (in our case, a CDN-M3 type, for three power lines) should not exceed the limits given in Table 3. This disturbance voltage must

be measured with the quasi-peak detector and 120 kHz IF bandwidth of the receiver.

Table 3. Common mode terminal voltage limits, CDN method [7].

Frequency range (MHz)	Quasi-peak limits (dB μ V)
30 – 100	64 to 54 ^a
100 – 230	54
230 – 300	61

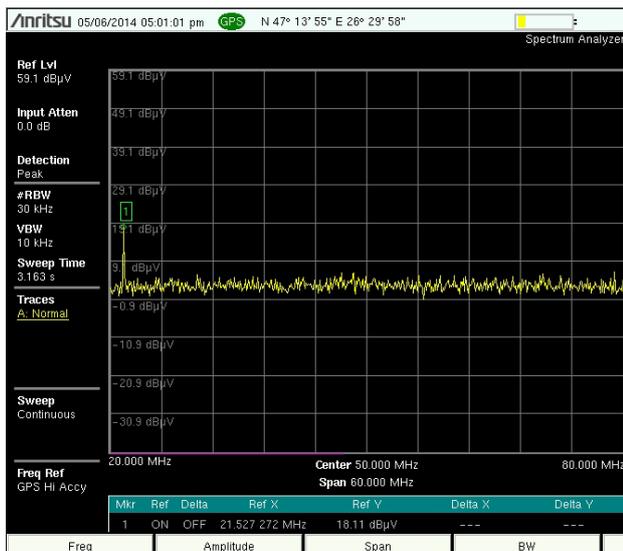
^adecreasing linearly with the logarithm of the frequency

III. RESULTS AND DISCUSSIONS

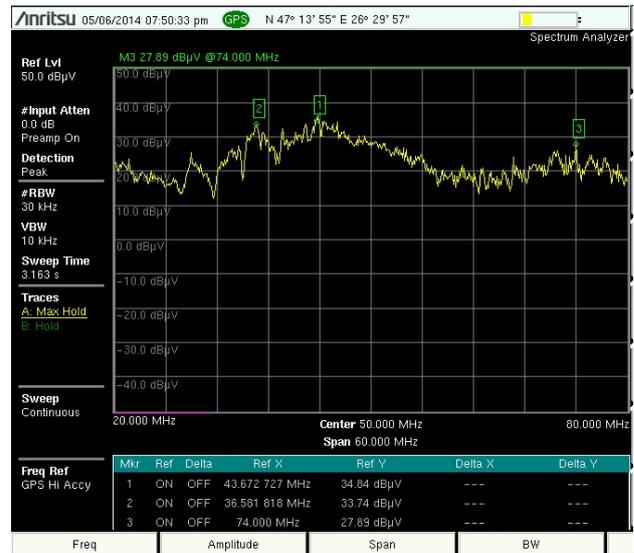
Both in situ and EMC laboratory measurements revealed a high-level interference signal, with large frequency spectrum, extended up to 200 MHz. As in the previous section regarding the measurement methodology, the results obtained in the two situations (in situ and in the EMC laboratory) will be discussed separately, in the following.

A. In situ measurements

Fig. 3 illustrates the difference in the signal measured across the 20 MHz – 80 MHz frequency range at a particular location, when the lightning system is operating and when it is switched off. As it can easily be seen, the LED lights cause significant radiation over the entire frequency range. The maximum emission level can be observed at the frequency of 43.67 MHz (marker 1), namely 63.84 dB μ V/m. This value exceeds the quasi-peak limits given in Table 1 with more than 30 dB. Note that all in situ measurements were performed with the peak detector, which “always” leads to a higher reading compared to the quasi-peak detector.



a)

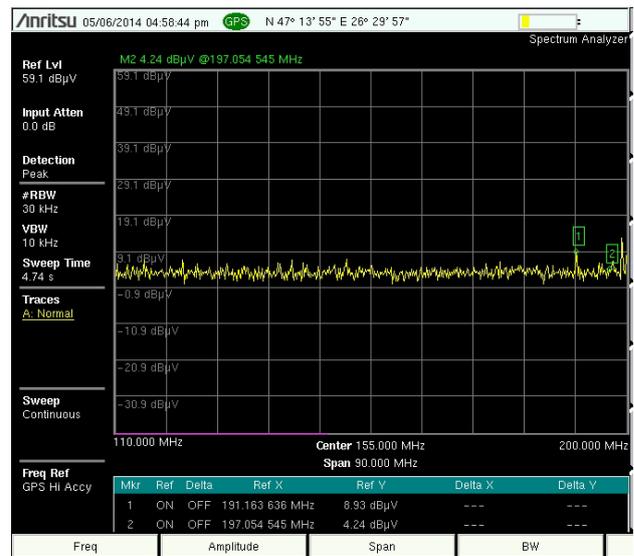


b)

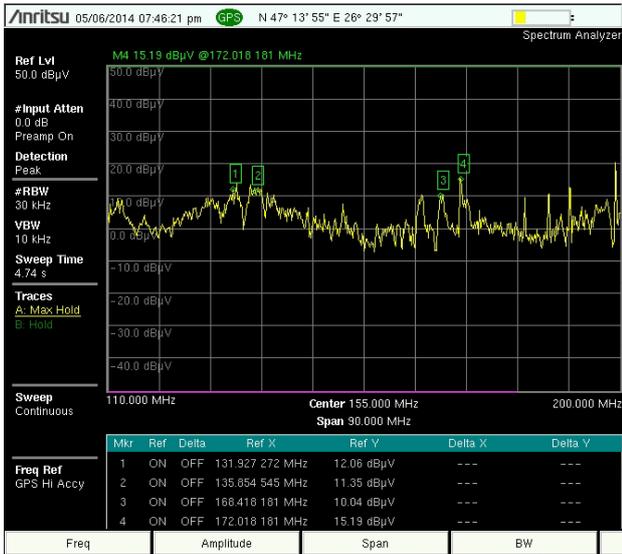
Fig. 3. Electric field measurements in the frequency range from 20 MHz to 80 MHz: a) lightning system switched off; b) lightning system in operation

The difference in the signal measured across the 110 MHz – 200 MHz frequency range at the same location is illustrated in Fig. 4. This time, the highest emission levels only slightly exceed the quasi-peak limits given in Table 1, with a maximum of 35.19 dB μ V/m at the frequency of 172.01 MHz (marker 4).

Similar results were also recorded at other locations (at 10 m distance from the LED lights). Thus, in order to accurately quantify the emissions radiated by this type of LED lamp and to check compliance with the limits given in EN 55015, a number of three devices were subjected to subsequent EMC laboratory measurements.



a)



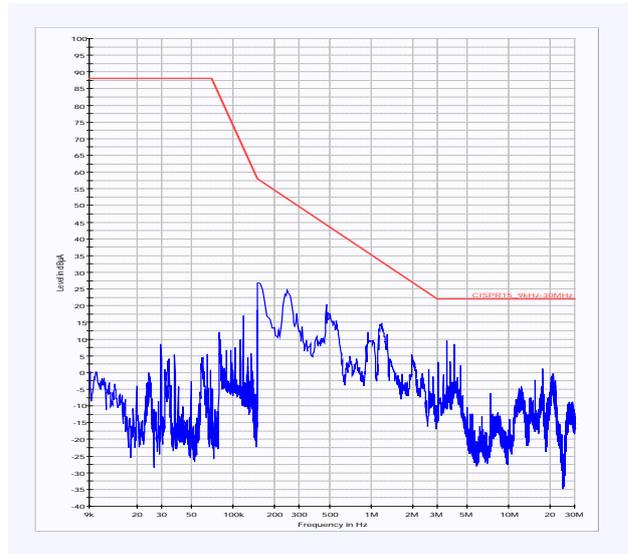
b)

Fig. 4. Electric field measurements in the frequency range from 110 MHz to 200 MHz: a) lightning system switched off; b) lightning system in operation

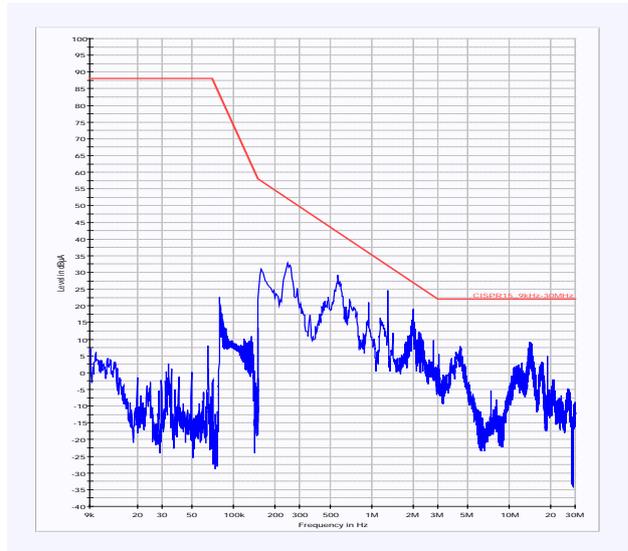
B. EMC laboratory measurements

In the frequency range from 9 kHz to 30 MHz, all three LED lamps presented radiated emissions below the EN 55015 quasi-peak limits given in Table 2. However, in the frequency range from 30 MHz to 300 MHz, all devices presented radiated emissions higher than the EN 55015 quasi-peak limits given in Table 3.

Fig. 5 shows the magnetic field emissions of a LED street light, measured in the frequency range from 9 kHz to 30 MHz, according to the methodology described in Section II, A. Since the initial pre-scan (with the peak detector) did not reveal peak emissions within 6 dB of the quasi-peak limit (red line), the radiated emissions (blue line) are specified in terms of peak values.



b)



c)

Fig. 5. Magnetic field emissions from a LED lamp, measured in the frequency range from 9 kHz to 30 MHz: a) on x-axis; b) on y-axis; c) on z-axis [8]



a)

Fig. 6 shows the disturbance voltage measured at the RF output of the CDN-M3 network over the frequency range from 30 MHz to 300 MHz, according to the methodology described in Section II, B (for the same LED light). And this time, the blue line indicates the peak values of the radiated emissions, while the blue dots (♦) correspond to the marginal values measured with the quasi-peak detector. As it can be observed, it is a severe case of radiated emissions caused by LED lightning products with inadequate EMI suppression.

The other two LED lights also featured excessive RF emissions in this frequency band, especially at frequencies below 100 MHz. The results are well

correlated with those recorded in situ, as suggested by Fig. 3 and Fig. 4.

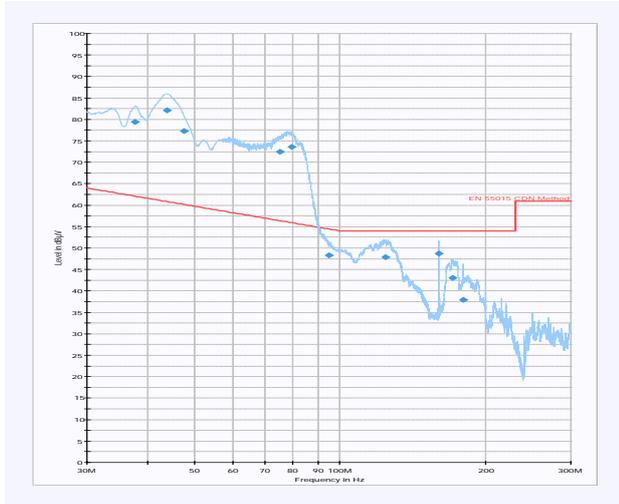


Fig. 6. Disturbance voltage measured at the RF output of the CDN-M3 network over the frequency range from 30 MHz to 300 MHz (for the same LED light) [8]

IV. CONCLUSIONS

The purpose of this paper is to raise awareness that some LED lighting products can cause significant radiation, which may affect various RF services operating in the VHF frequency band, and not only. Given the increasing variety of LED lighting products on the market, the authorities and consumers should be aware of potential EMI problems, especially from “cheaper” LED products. Testing of radiated emissions from LED lighting devices is still at the beginning, and therefore no extensive results are available.

In the particular case described here, both in situ and EMC laboratory measurements revealed a high-level interference signal, with large frequency spectrum, covering almost the entire VHF frequency band. This signal was capable to affect the audiovisual program retransmission and data transmission services in a rural

community. No EMI problems were reported after replacement of the LED lamp model used in the street lightning system subjected to investigations.

V. ACKNOWLEDGMENT

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