ASSESSMENT OF HIGH-FREQUENCY CONDUCTED DISTURBANCES PRODUCED BY MODERN LAMPS

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Due to their operating principle, practically all nonlinear receivers inject in the network both low and high-frequency disturbances. The high-frequency (HF) conducted disturbances are measured, according to the relevant EMC standards, in the range of 9 kHz up to 30 MHz, using dedicated circuits which extract these frequencies from the supplying voltage of the appliance. The paper is centred on the parameters influencing the level and spectrum of the disturbances injected in the aforementioned frequency range by modern lamps and the cumulative effect of several consumers of this type injecting disturbances simultaneously in the same low voltage network. A new weighting quantity is proposed to evaluate the HF spectrum of a given consumer, namely the integral of the noise's peak level vs. frequency.

Keywords: high-frequency conducted disturbances, artificial main network, LED lamp, compact fluorescent lamp

1. Introduction

The pollution of the low voltage networks with HF conducted disturbances affect the operational environment of any equipment supplied from the same network, including other useful signals which use the same path, such as power line communications (PLC). The PLC operation can be affected mainly in three ways: by means of poor quality of power which supply its emitter (and the receiver also), by superposing of undesired disturbances into the transmission channel [1-5] and by the variation of loads' impedances, which modify the propagation conditions. The causes, as well as the bandwidths of the HF conducted disturbances in the supply networks are defined in IEC TR 1000-2-5:2017 RLV [6]. So, the main sources of this type of disturbance are: direct conducted continuous waves (CW) worn by the network and signalling voltages produced by network communication equipment, HF-induced waves, unidirectional transient or oscillatory transient phenomena produced mainly by switching operations. The high-frequency conducted emission limits are also intended to protect the radio spectrum (under 30 MHz) from the fields radiated by the AC power cables of equipment.

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For disturbances produced by different appliances in the frequency range 9 kHz to 30 MHz, the measuring procedures are described in the CISPR 16-2-1 standard [7]. In the meantime, specific limits within this frequency range are imposed to network-powered devices by various standards, such as CISPR 15, [8] for lighting equipment or CISPR 32, [9] (or EN 55022, [10]) for IT equipment. It should be mentioned that fault conditions are not covered by these standards.

Since signalling or communications voltages represent, from the point of view of the electromagnetic compatibility, disturbances transmitted through the network, they have also limits imposed by standards, such as IEC 61000-3-8 [11], with its European counterpart EN 50065- 1 [12].

Having the same nature and sharing the same frequency bandwidths, both unintentional disturbances and useful signals transmitted over the network are significantly attenuated as their frequency increase. Depending on the case, this behaviour can be regarded as a disadvantage (for example, due to the shortening of the maximum allowable distance between the PLC emission point and the receiving one), or as a benefit (for example, the natural attenuation of unintentional disturbances prevents their long-distance propagation). According to [13] the typical losses' values in the low voltage networks, for PLC, are 1.5...3 dB/km at 100 kHz and 160...200 dB/km at 10 MHz, the actual value inside the above-mentioned ranges depending on the cable (line) type, the loading conditions etc. For higher voltages and in the case of overhead lines, the specific losses decrease generally with an order of magnitude comparing to the LV network.

The paper intends to answer the following questions:

- the HF conducted disturbance characteristics could be correlated to the type of equipment and its absorbed power?
- which are the factors influencing the level and the shape (in a given frequency band) of HF conducted disturbances?
- which is the composition law (if any) of disturbance levels produced by several devices fed simultaneously from the same network?

2. Measuring of high-frequency conducted disturbances

The reference standard dealing with the issue of equipment and methods for measuring high-frequency conducted disturbance is CISPR 16-2-1 [7]. When the goal is to measure the disturbances injected in the power supply network, the equipment under test (EUT) is connected to the network by means of an artificial mains network (AMN). This device introduces, on the one hand, known and stable impedance between the power supply and the tested equipment and, on the other hand, provides a radio frequency noise measurement port. It also blocks radio frequency interference that may come from the public power supply. For the power supply ports, the most used AMN is so-called 50 Ω/50 μH, "V" mains network.

This, because it provides a measurement port with 50 Ω output impedance and the series inductances on active conductors are of 50 μH. To measure the HF conducted disturbance, an EMI (electromagnetic interferences) receiver with 50 Ω input impedance must be connected at the measuring RF ports. Due to the stochastic character of HF conducted disturbances, the measuring procedure can assess the peak, average or quasi-peak values of the noise (in the specified range domain). In the testing standards, detailed indications are given regarding the arrangement of the EUT versus the ground plane, and the connections to its peripherals, if they exist, in order to ensure the reproducibility of tests.

The block diagram of measuring system is presented in Fig.1.

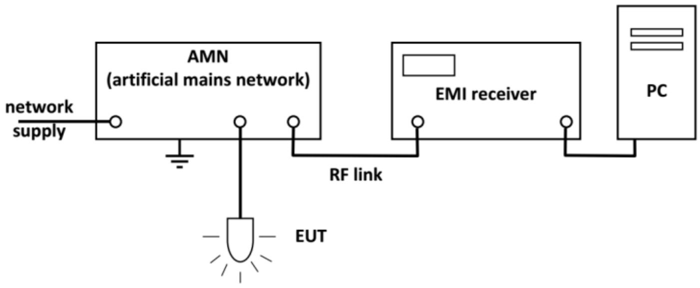

Fig. 1. The block diagram of measuring system: AMN - artificial mains network; EUT – equipment under test; EMI receiver; PC (for EMI receiver piloting and data storage).

A measuring process (and data processing) diagram is presented in Fig.2. The EMI receiver is piloted by a dedicated code installed in a PC connected with them. After the scanning parameters are set (type of used detector, frequency step, bandwidth, dwell time) the code is running, and the data are stored.

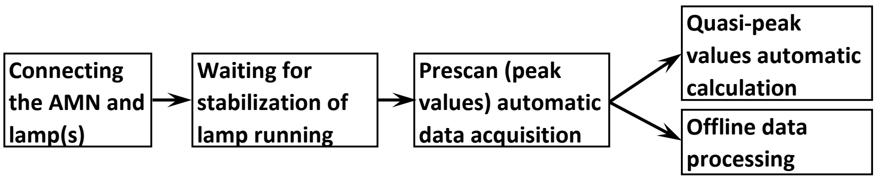

Fig.2. The measuring process diagram.

The recordings presented in the section 5 and the offline computed parameters have used the data files stored as stated above.

It should be mentioned that up to now, a method to measure the high frequency conducted disturbances in a whole installation does not exist. The available AMNs are used to measure HF disturbances of appliances operating in DC and AC (single phase or three phases) systems.

The performances of AMNs are guaranteed for a given range of the voltage and a maximum value of the current. Even if the rated currents of these devices shall increase, it is not possible to isolate an entire network from any external electromagnetic influence in order to evaluate only the disturbances due to the receivers connected to this network.

3. Experimental arrangement and requirements for measuring conducted high-frequency emissions of lamps

The matter of measuring high-frequency conducted and radiated emissions of lamps are presented in CISPR 15 standard. Regarding the compliance tests, the arrangement and also the limits in the given HF bandwidths are specified when measuring at “load terminals” and at “mains terminals”. In the present work, measurements have been performed at mains terminals only. The tested lamps have no dimmers, remote control or another outer intermediary circuit (for example, independent ballast, external drivers etc.).

The tested lamps were commercially available lamps for residential use. The tests were not intended to check the compliance with the EMC standards (they have the CE mark) but to find particular features of the lamps’ emissions and to compare their electromagnetic fingerprints in the HF range.

In order to be reproducible, the measurements shall be performed in specified conditions: the lamps must have a number of hours of operation before the tests (at least 100 hours for fluorescent and other discharge lamps), the supply voltage shall be within ±2 % of the rated voltage, the frequency shall be the rated one, and the measurement must start after a stabilization time (for example, 15 minutes for lamps that not include gas discharge technologies, i.e. based on LED). Regarding the harmonic content of the voltage supply, there are no specific mentions. The distance between the output terminals of the artificial mains network (V-network) and the terminals of the lamp (the load) must be 0.8 m ±20 %, and the lamp shall be connected by flexible power conductors. Regarding the environmental conditions for testing, the use of an anechoic chamber is not expressly specified.

The imposed condition refers to the background noise, which should be “preferably 20 dB but at least 6 dB below the desired measurement level”. Therefore, the tests have been performed in a laboratory provided with horizontal and vertical ground planes and far away from other intentional HF sources.

A picture of the test arrangement is presented in Figure 3 and it remained unchanged for all performed measurements. The distance between EUT and vertical ground plane was 0.4 m and against horizontal ground plane of 0.8 cm (as CISPR 15 specify).

Regarding the measurements’ accuracy: the transmission loss of AMN transient limiter of 10 dB (connected during the tests) is +1.5 dB/–0.5 dB and the measurement error of EMI receiver is ≤ 1.5 dB (typical 1 dB).

The background noise of AMN (no load at its power output) at the rated voltage of the network supply (230 V) is presented in Fig. 4.

As it can be seen, the condition imposed to the background noise has been observed in the whole frequency range, as the recorded noise is smaller than 20 dBµV except for a 33…34 dBµV peak at 18 kHz, which appears practically with the same value on all recordings, regardless the tested equipment.

The imposed limits for HF conducted emissions of lamps are specified both in quasi-peak values and average values respectively for two bandwidths (A and B, according to CISPR specifications). These limits are presented in Table 1, according to [8].

But the real operating conditions can be substantially different from the standardized ones. For this reason, the tests have been performed considering as parameters the applied voltage and the length of the line between AMN and the lamp(s).

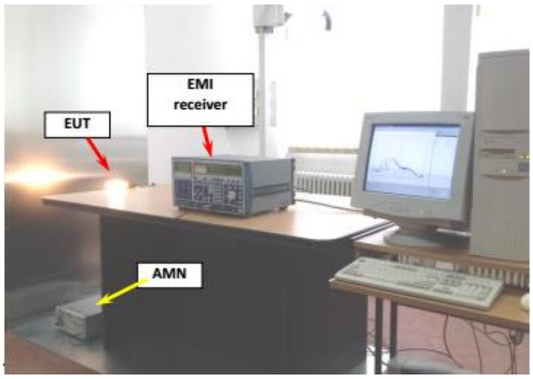

Fig. 3. The test arrangement.

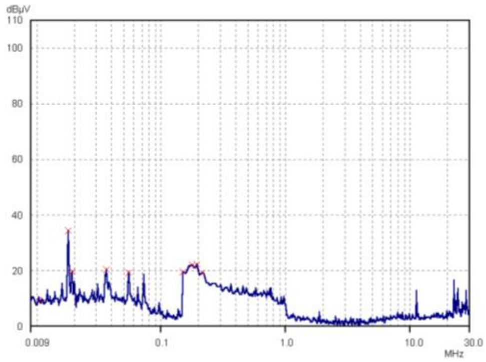

Fig. 4. The background HF noise of AMN.

Another checked influence parameter was the rated power of the lamps. The measured disturbances have been produced by a single lamp, and by combinations of lamps of similar or different types. As it is well known, the general composition law when no inter influences appear between the disturbance sources is a quadratic one:

$$L_{\text{overall}} = \sqrt{\sum_{k=1}^{n} L_{k,\text{individual}}^2} \tag{1}$$

where L_{overall} is the level of disturbances produced by all equipment simultaneously connected at the network and $L_{k,\text{individual}}$ – the level of disturbances produced by a single equipment.

The emissions of the equipment are described by several weighted quantities: peak, quasi-peak, average or r.m.s. values which are assessed by the measuring device (for example, an EMI receiver) during a given time interval (measuring or dwell time). So, they are not instantaneous values, even in the case of the “peak value” (in fact this is the maximum value of the envelope recorded during the measuring time).

Table 1

Disturbance voltage limits at mains terminals

Frequency range [MHz]	Limits [dBμV][*]	
	Quasi-peak	Average
0.009...0.050	110	-
0.050...0.150	90...80[**]	-
0.150...0.500	66...56[**]	56...46[**]
0.5 ...5	56	46
5...30	60	50

[*]at the transition frequency, the lower limit applies
[**]the limit decreases linearly with the logarithm of the frequency

For this reason, all these quantities reflect the monitored disturbances in a given bandwidth around a central frequency, during the scanning operation (with a specified step) into an interesting range of frequencies. The scanning step and the bandwidth allowed for each frequency step must cover conveniently all frequency range explored. The quantities defined by standards cannot offer an overall effect of disturbances on the electromagnetic environment, respectively on the low voltage supplying line.

In order to describe this effect, a criterion was proposed, defined as the "integral of peak levels vs. frequency", namely the quantity:

$$A = \int_{f_1}^{f_2} L_{peak}(f)\,\mathrm{d}f \quad [\mathrm{dB\mu V \cdot MHz}] \tag{2}$$

whose value depends upon the pattern of the noise generated by the HF disturbances in a given power line. If the "spikes" are substantially rare (even if they have high peak values) the integral has a low value, therefore it could be concluded that the noise is substantially located only around certain frequencies.

4. Some features of modern lamps

Nowadays the most used lamps in the world are compact fluorescent lamps (CFL) and LED lamps, the latest being (at least for the moment) in the most attractive position for the future. Apart from the advantage of low energy consumption and longer lifespan compared to other lighting sources, both these types have disadvantages regarding the "reaction" on the supplying network: pollution with harmonic currents, conducted and radiated high-frequency disturbances and undesired effects to the human eye.

For all kind of appliances, the EMC standards impose limits for both conducted (in low-frequency range – current harmonics – and high-frequency range) and radiated emissions.

The CFLs operate at high-frequency voltage produced by a dedicated high-power oscillator supplied from a rectifier circuit. Even if the principle is the same, there are different schemes used by manufacturers, more or less compact, depending on the rated power of gas discharge tubes. The operating frequency is at least 20 kHz, in order to avoid the audible noise produced by its own circuit. The ignition voltage of a CFL is substantially lower than the rated one.

Regarding the LED lamps, there are a lot of drivers types used to supply the array/string of LEDs, generally based on switched-mode power supply (SMPS). Depending on its driver type, a LED lamp can operate in a large supplying voltage range. For example, the tested lamps can operate (as their manufacturer specify) into the range 85 V ... 255 V. So, the luminaires using this type of lighting source can be also a serious source of high-frequency disturbances transmitted by conduction.

5. Measurements results

5.1. High-frequency recorded disturbances due to CFLs

The settings of the EMI receiver were performed according to CISPR 15 specifications, taking also into account the requirements of CISPR 16-2-1. The reference measurement was performed according to the above-quoted standards, but the rest of the measurements were performed in different conditions.

The high-frequency emissions of three CFLs with 11 W, 15 W and 36 W rated powers, coming from different manufacturers, have been measured. For each lamp, the reference measurement has been performed under a voltage within the specified range (±2% of the rated voltage), and after the necessary stabilization time.

Additional tests have been performed either at voltages outside the recommended range for compliance tests, but generally accepted by the networks operation codes (i.e. 90% below the rated voltage), or before the required stabilization time runs out. The objective was to explore the features of the real emissions of this type of consumers in a given network.

The pre-scan measurements were performed with the peak detector of the EMI receiver and the final scan with the quasi-peak detector. HF disturbances were recorded on the phase conductor (“line”– L). The measurements on the neutral (N) were proved to be practically identical with those on the line, and for this reason, they do not present a particular interest.

All the diagrams presented further contain graphical representations of disturbances’ peak values (obtained using the peak detector embedded in the EMI receiver during the pre-scan operation).

The HF conducted disturbances produced by a 36 W CFL lamp at the rated voltage and at 90% of the rated voltage (207 V), measured after the required stabilization time, are presented in Fig. 5.

The stabilization time specified for lamps which operate based on gas discharge technologies is 30 minutes.

It can be observed that the voltage level has weak or no influence on the HF disturbances. The CFL 11W has the same behaviour.

The noise level vs. frequency for the 11 W and 36 W CFLs tested in reference conditions (stabilized operation, rated voltage) is plotted in Fig. 6. As it can be seen, the influence of the rated power on the noise is more important, and can be disjoint in two emission modes:

(a) in the range 9 to 150 kHz (A band), the spectral power is mainly concentrated at particular frequencies which are lower for the 36 W lamp compared to the 11 W lamp, with differences of 2 to 7 dB between the peak values of the noise (the 11 W lamp having higher values);

(b) in the 1 MHz to 30 MHz range (B band) the spectral power is distributed continuously over the entire frequency range (broadband coloured noise), the spectrum has a negative slope and the noise emitted by the 36 W lamp is on average 10 dB higher than that emitted by the 11 W lamp.

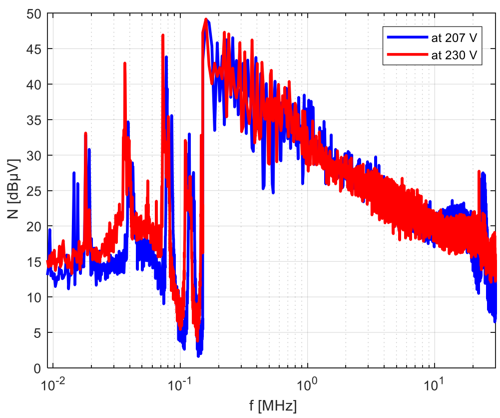

Fig. 5. Recordings of HF disturbances produced by the CFL 36 W, at two applied voltages.

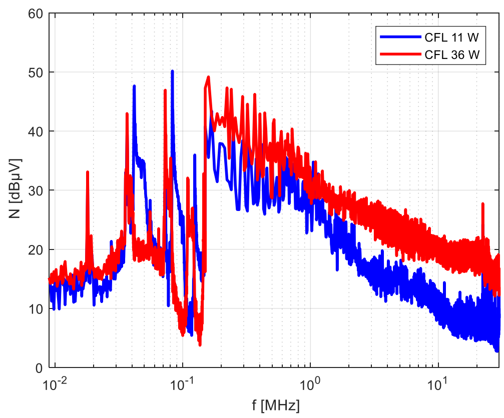

Fig. 6. Recordings of HF disturbances produced by the CFL 11 W and 36 W in reference conditions.

An outline of the measurements performed on CFLs in standard or altered conditions highlights the following:

(a) the HF conducted disturbances have generally a stable pattern regardless of the power of the lamp, with the highest peak in the A band or at the border between the two bands (near 150 kHz); however, for the 15 W CFL, 4U shaped, the maximum peak was located at 5 MHz in the B band;

(b) when measurements were performed in the first minutes after the energization of the lamps, the maximum quasi-peak levels recorded exceed those of the reference case;

(c) the operation at a lower voltage than the rated one (but in stabilized conditions), gives similar emissions as shown when comparing the peak values;

(d) in order to refine the assessment of the overall impact of lamps’ emissions on the network, the criterion defined in equation (2) was calculated and the results are summarized in Table 2.

Table 2

Integrals of peak levels vs. frequency (for CFLs)

Lamp	Band A (9 kHz...150 kHz) [$dB_{\mu V}\cdot MHz$]	Band B (150 kHz...30 MHz) [$dB_{\mu V}\cdot MHz$]
CFL 11 W	2.9	317.6
CFL 15 W	2.7	481.8
CFL 2×15 W	4.7	527.2
CFL 36 W	2.5	604.7

As it can be observed, the criterion's values have the same order of magnitude in both bands, with more closely spaced values in the A band.

In the B band, even if the peak and the quasi-peak values are close to each other, the value of the criterion increases with the rated power of the lamp (or combination of lamps).

Regarding the "congestion" of the supplying line, it is clear that the impact increases with the power of the consumer whether this is a lamp or a combination of lamps, even if the associated peak or quasi-peak noise values are comparable with those of the lamp having a lower power.

For the tested lamps, the total harmonic distortion of the absorbed current (THDi) was measured, using a power quality analyzer built according to EN 50160 standard. The relative values (expressed in percentages) cover a relatively narrow range (118%...137%).

5.2. High-frequency recorded disturbances due to LEDs

For this set of measurements, three lamps have been selected (with strings of LEDs) having different rating powers: 5 W, 6 W and 15 W.

The values of the criterion defined in equation (2) computed for both CISPR bandwidths are given in Table 3.

Table 3

Integrals of peak levels vs. frequency (for LEDs)

Lamp	Band A (9 kHz...150 kHz) [$dB_{\mu V}\cdot MHz$]	Band B (150 kHz...30 MHz) [$dB_{\mu V}\cdot MHz$]
LED 5 W	1.85	1186
LED 6 W	3.83	1346
LED 15 W	2.78	1219
Overall average	2.82	1250

The criterion's values computed for the B band are within the range (–5% ...+8%) from the overall average values. The maximum (peak and quasi-peak) values are also higher than of CFLs.

The influence of the lamp rated power on the noise pattern is illustrated in Fig. 7 where recordings for the 5W and 15 W LED lamps are overlaid.

In the A band, the LED emissions have the same pattern as the CFLs lamp namely a "coloured noise" with a few notches having high peak values, denoting the concentration of the spectral power at some particular frequencies.

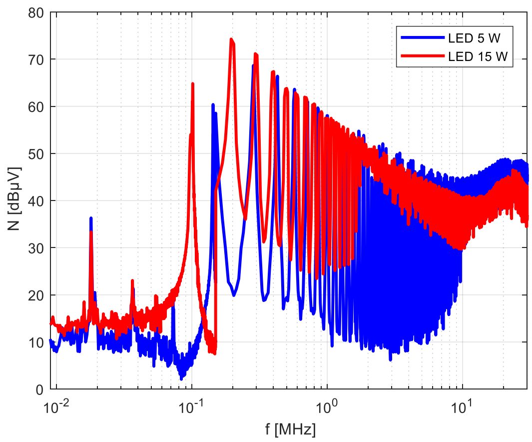

Fig.7. The recording of HF disturbance produced by the LEDs with a rated power of 5 W and 15 W.

The increase of the rated power determines the decrease of the central frequency of the notches (from about 150 kHz to 100 kHz in Fig. 7) and a negligible increase of the notch's peak value. When comparing with the CFL's noise in the A band (Fig. 6), the peak values of the notches are of comparable magnitude, even though the rated powers of tested LEDs are smaller than the CFLs rated powers.

In the B band, compared to CFLs' noise which can be qualified as continuous coloured noise with peak-to-peak amplitude smaller than 10 dB, the LEDs' noise can be qualified as a periodic impulsive noise, asynchronous to the mains frequency, with portions exhibiting successive notches having estimated repetition rates of 50–200 kHz and peak-to-peak amplitudes of about 30 dB for the 5 W LED to 40 dB for the 5 W LED. Such a noise can be related to the use of switching power supplies, [14]. This kind of noise contains considerable energy and thus can seriously affect high-speed communication (PLCs). The increase of the rated power from 5 W to 15 W does not change the pattern of the noise in the B band (Fig. 7) but decrease the peak-to-peak amplitude of the noise envelope from about 40 dB for the 5 W LED to about 30 dB for the 15 W LED.

The differences between LEDs and CFLs HF emissions' features commented above, suggest that LEDs can be qualified as a more "noisy" consumers than CFLs in both A and B bands.

Regarding the total harmonic distortion of absorbed current, the relative values were in a narrow range, 150%...161%, but higher than the values recorded for CFLs. Another remark is the slow decrease of harmonic currents higher than 9 ranks up to 49 ranks.

5.3. Parallel operation of different lamp types

To investigate specific changes in the HF disturbances emissions when different types of lamps are energized on the same circuit, several scenarios have been considered.

Scenario 1. 2 × 5 W LEDs, standard test conditions

The noise emitted by 2 LEDs of the same rated power (5 W) was overlaid in Fig. 8 on the noise emitted by a single 5 W LED. The increase of the supplied power by grouping 2 LEDs do not change the noise pattern which remains practically the one of the basic 5 W LED type, the differences in amplitude and shape being minimal; however, a little compensation effect can be observed in the B band when 2 LEDs are operational. Thus, the usual quadratic composition law in (1) applied to assess the overall level of noise when several independent disturbance sources are present apparently does not apply in this case.

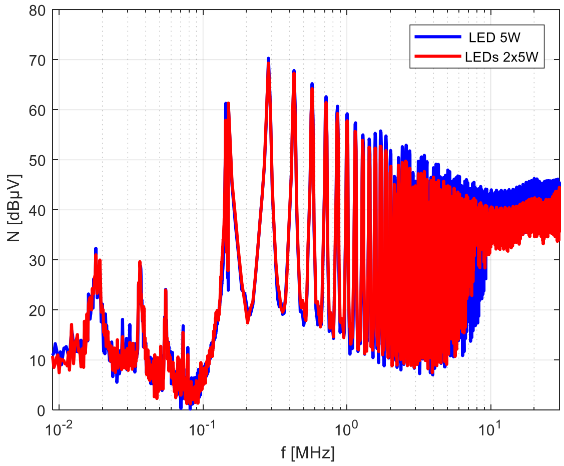

Fig. 8. Comparative recordings of HF disturbances produced by 2 x 5 W LEDs and a single 5 W LED.

Scenario 2. 2 × 15 W CFLs, standard test conditions

The lamps have the same rated power (15 W) but different shape: one of them spiral-shaped and the other 4U shaped, each coming from different manufacturers. To compare, Fig. 9 presents the superposition of the noise recorded when both lamps operate in parallel with the recording of a single CFL 15 W (4U shaped).

A cumulative effect is observed in the frequency range 20 kHz...3 MHz. The maximum peak levels in the aforementioned range seem to obey to the quadratic composition law: for a single CFL the maximum peak is 46.9 dBμV and for both lamps is 68.6 dBμV, so their ratio is close to $\sqrt{2}$ (accepting that their contribution to the overall noise is equal).

For higher frequencies, the two lamps act as a single one from the point of view of conducted disturbances.

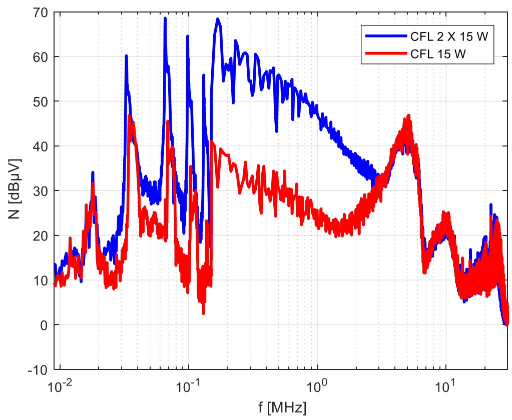

Fig. 9. Comparative recordings of HF disturbances produced by 2 x 15 W CFLs and a single 15 W CFL.

Scenario 3. 5 W LED + 11 W CFL, standard test conditions

When different types of lamps are combined (CFL and LED) the noisier device imposes its features. As an example, putting in parallel the 5W LED lamp with 11W CFL lamp, the calculated values of the criterion (integral of peak level vs. frequency) are of 2.96 dBμV ·MHz in A band and 1113 dBμV ·MHz in B band, values very close to the results obtained for 5W LED only. The noise pattern is clearly imposed by the LED lamp. The case is presented in Fig. 10.

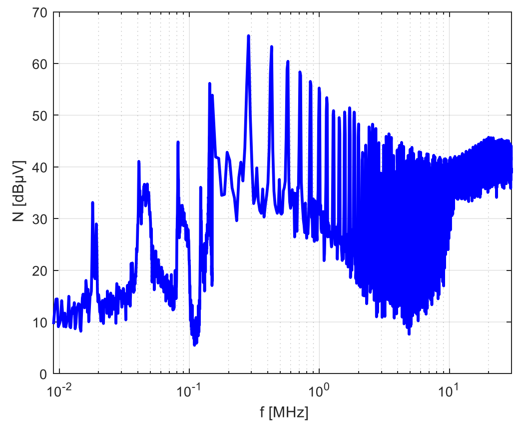

Fig. 10. Recordings of HF disturbances produced by a 5 W LED and an 11 W CFL operating in parallel.

5.4. Comparison between HF conducted emissions of CFLs and LEDs

The LED lamps produce higher disturbance levels even for lower rated powers than those of CFL lamps (a comparison is given in Fig. 11); the difference between the maximum peak values of the compared lamps are about 22 dBμV. Another example is given in Fig. 12 where a LED and a CFL with the same rated power (15 W) are compared and the difference between their behaviour is evident.

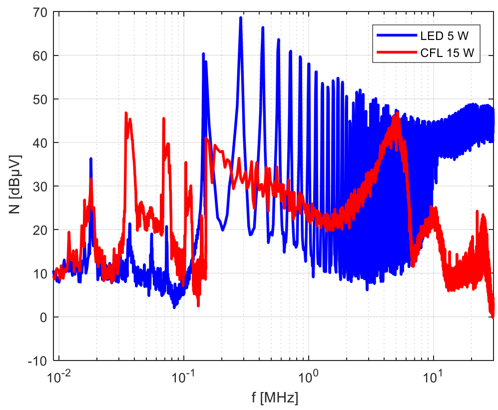

Fig. 11. Comparative recordings of HF disturbances produced by 5 W LED and a 15 W CFL.

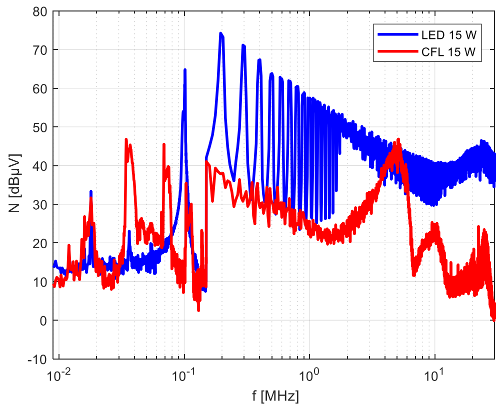

Fig. 12. Comparative recordings of HF disturbances produced by LED and CFL lamps having same rated power (15W).

5.5. The HF conducted emissions during stabilization period

During the stabilization period (which generally is large, at least in the order of a few minutes) the emitted noise is higher compared to the noise emitted in a stabilized operation mode. An example is given in the Fig. 13 for the 5W LED. The noise emitted by the lamp just after the device was energized is overlaid to the noise emitted after the stabilization time has elapsed. While the noise characteristics in the A band do not change with the duration of the stabilization time, in B band the noise's notches are centred on the same frequencies but the noise envelope is translated with up to 10 dB toward higher values.

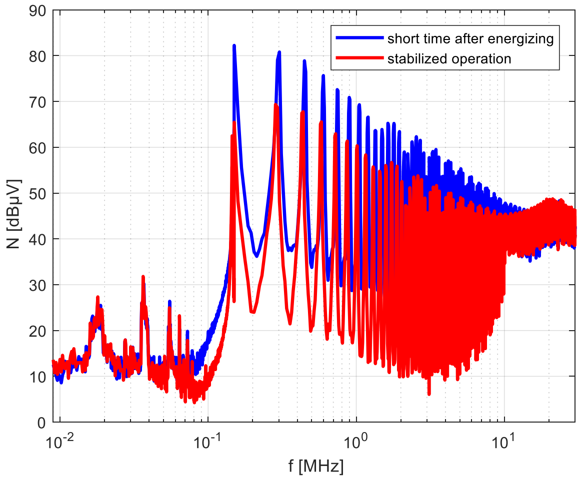

Fig. 13. Comparative recordings of HF noise produced by 5W LED just after energizing and in stabilized operation condition.

5.6. Influence of the length of the connection

A number of tests were performed supplying the tested lamps by means of 10 m two core cable, the position of the lamp remaining unchanged relative to the ground planes. The firsts 8 maximum peaks have been recorded at same frequencies and also the maximum disturbance's peak levels suffer an insignificant reduction. Only the quasi-peak values were about 2 dBµV lower, but not for the entire bandwidth monitored. So, the high-frequency conducted disturbances can travel inside a home with very weak attenuation between the location of their source and the connection point to the distribution network where a smart meter can be installed or, can affect the intra-building PLC.

6. Conclusions

When lighting equipment operates in actual conditions which could differ from those imposed during the compliance tests, some conclusions may be drawn regarding the high-frequency disturbances generated by them:

- the influence of the supplying voltage on the disturbances' level of CFLs and LEDs lamp (peak and quasi-peak) is weak, at least in the range ± 10% interval in which the parameters of AMN are also guaranteed;
- during the stabilization period the emitted noise is higher compared to the noise emitted in a stabilized operation mode. So, the very precise testing conditions prescribed by CISPR standards does not represent "the worst case" regarding the high-frequency emissions of lamps; as a consequence, at some point in time the network is travelled by higher disturbances than those measured in standardized

conditions, even for a single consumer;

- the LED lamps produce higher conducted disturbances, even for lower rated powers, than those of CFL lamps;
- the value of the criterion defined as “integral of peak levels vs. frequency” can be considered as a better parameter to assess the disturbance degree of the network, compared to the emission level itself, no matter the detector used to evaluate it;
- the presence of harmonic currents (up to 2 kHz) is correlated to HF conducted disturbances, as the lamps which have a higher THDi (namely LED-based), have also a higher level of high-frequency noise.

To generalize the above conclusions, for the modern lamps in residential use it is necessary to perform more measurements on a very large range of rated powers and a large number of different manufacturers. However, taking into account that the operation and drivers' principles are the same, the results should be similar.

In the battle CFL vs. LED, the winner seems to be clearly LED. But the problems raised by the LED bulbs at least from the point of view of conducted disturbances cannot be omitted. And to suppress “at the source”, more actively than it is in present, the disturbances produced by these items is clearly a costly action, even if it’s technically possible.

The electromagnetic environment, even in residential locations, became more complex and this tendency for the future is unstoppable.

Generally, the EMC of a complex installation (system) cannot be assessed by measurements: it must result using compatible components checked in the laboratory. The coexistence of the nowadays PLCs and the conducted high-frequency disturbances produced by modern equipment (including the luminaires based on LED or CFL) it's a subject which must be studied taking in consideration a larger safety coefficient.

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