

# Performance Evaluations and Comparative Electromagnetic Compatibility Measurements on Compact Fluorescent Lamps

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**Abstract** — When compared to standard incandescent light bulbs, compact fluorescent lights (CFL) provide multiple benefits and give much longer lifetime and lower power consumption. Available in a wide variety of models and various wattages, efficiency types and prices, nowadays CFL seems to successfully replace the use of incandescent lights. On the other hand, disadvantages like dangerous electromagnetic pollutions and harmful ultraviolet radiations made CFLs the subject of many debates concerning their performances.

Several electromagnetic compatibility measurements were performed in order to point out the high level of radiated and conducted disturbances of CFLs. The first set of experiments were made in the frequency band of 1 MHz to 500 MHz, and then reduced to 1 MHz - 300 MHz, 1 MHz - 100 MHz and 1 Hz - 50 KHz frequency intervals. Comparative EMC measurements on three different compact fluorescent bulbs were made using a specific test setup (as described in chapter 4). For CFL emissions testing, we used an anechoic chamber, which is a shielded enclosure with radio absorbing materials on ceiling and walls. The results obtained were then compared to the CISPR22 standard limits.

**Index Terms** — anechoic chamber, common mode current, compact fluorescent lamp (CFL), electromagnetic compatibility (EMC), electronic ballast

## I. INTRODUCTION

The market of CFLs has rapidly grown within the last few years, due to the benefits provided. This leads to cost reductions and variety of CFL models and quality also. The energy-saving CFL last up to 15 times longer than standard light bulbs and consume up to 80% less. They give the same amount of visible light and reduce CO<sub>2</sub> emissions.

The main issues of CFLs are the harmful ultraviolet radiations and the electromagnetic disturbances exposure. As specified in CISPR 15 F/399/CDV amendment [1], the principal responsible for disturbance emissions is the common mode current, which generates conducted radiations transmitted in the power supply network.

The conducted and radiated emissions of three different CFL types were measured using a log-periodic antenna, a Line Impedance Stabilization Network (LISN), an EMI Test Receiver and calibrated RF cables. The compact lamp and the electronic ballast modules were then separately tested in order to establish which part of CFL is responsible for electromagnetic disturbances producing. The EUT (Equipment under Test) was placed on a 0.8 m height non-conductive table, at a distance of 1 m away from the receiving antenna. After we have measured the emissions of

both CFL modules, we placed the compact lamp in a ferrite enclosure, keeping the same test configuration as mentioned above. It has been noticed that when switched ON then OFF for several times, fluorescent lamps produce dangerous radio signals which radiate to electrical wiring and surrounding environment. The high level of CFL radiations may lead not only to signals interference but to human exposure issues as well.

## II. COMPACT FLUORESCENT LAMPS (CFL)

The main components of CFL are the compact lamp and the integrated ballast. The first module is a glass tube which contains mercury vapour and is covered in the interior with phosphor. In operation, a voltage is applied at the end of the tube, causing the mercury vapours to be ionized. When ionized, the vapours emit ultra violet light, converted then to visible light by the inside coating of the glass tube.

The second part of CFL is the integrated ballast. It works as a current limiter which prevents the damage of CFL when the current increases (as a result of the negative impedance of the ionized gas from the glass tube). There are two types of ballasts named magnetic ballast and electronic ballast. The first type of the ballast provides minimum functions for operation of CFL and is not as efficient as the electronic ballast which operates at high frequencies up to 50 KHz. The electronic ballast is more complex than magnetic ballast and it typically contains a voltage fed half-bridge quasi resonant circuit, a current fed half-bridge resonant circuit or a push-pull resonant circuit [2].

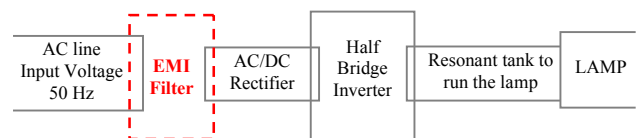


Figure 1 - Electronic ballast circuit block diagram

The electronic ballast operates at a higher frequency than the mains, therefore EMI are transmitted in the supply network [2]. Since a power factor correction (PFC) is required, high power ballasts can incorporate active power factor correction circuits, but the high frequency operation and the inverter stage causes more conducted and radiated noise. In response of the electromagnetic noise generation and for prevention of interference with other systems, an EMI filter in the electronic ballast circuit is required.

### III. CONDUCTED AND RADIATED PERTURBATIONS MEASUREMENTS

The both conducted and radiated emissions measurements were performed in a semi-anechoic chamber, so the results not to be affected by other radio disturbances from the surrounding environment. The conducted emissions were measured using a Line Impedance Stabilization Network (LISN), while the levels of perturbations were recorded using an EMI Test Receiver. The results obtained were then compared to EN 55022 standard limits. The three CFL used in our tests are shown in the figure below.



Figure 2 - CFL tested: 13 W, 21 W and 24 W

TABLE I. COMPACT FLUORESCENT BULBS

CFL type	Description
13 W	60 W equivalent; 230-240 V; 50 Hz
21 W	100 W equivalent; 230-240 V; 50 Hz
24 W	120 W equivalent; 230-240 V; 50 Hz
ENERGY class A	

The experimental results are detailed in chapter V.

### IV. TEST SETUP

In this chapter are described the test configurations used in our experiments. For the first set of measurements, the compact fluorescent lamp was connected to LISN (figure 3), while the conducted perturbations were recorded using the EMI Test Receiver (in spectrum analyzer mode).

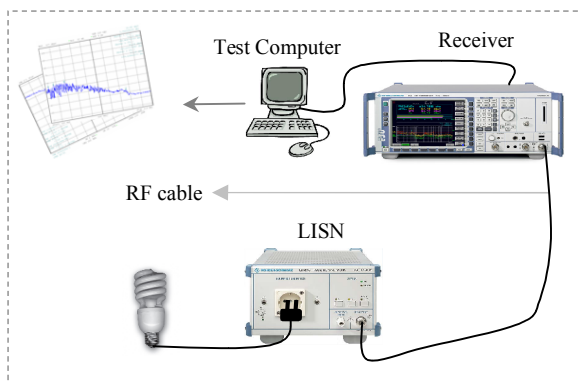


Figure 3 - Test setup for CFLs conducted perturbations measurements (anechoic chamber)

For radiated emissions testing the CFL was placed on a 0.8 m height non-conductive table at 1 m distance away from the receiving antenna. The test setup described above is depicted in figure 4.

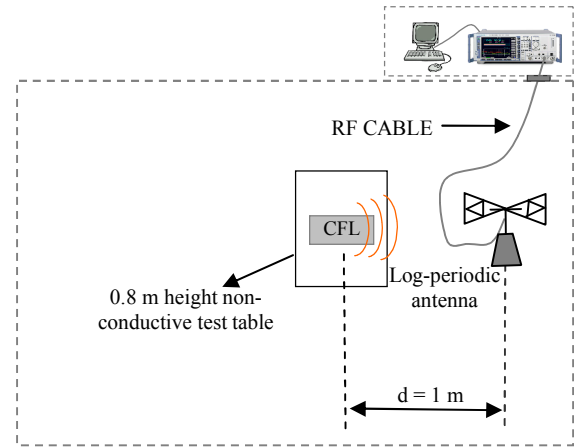


Figure 4 - Test setup for CFLs radiated emissions measurements (anechoic chamber)

In the second part of this work, the main CFL modules of a 21 W compact fluorescent bulb were separated and connected via AWG 24 twisted pair wires (figure 5).

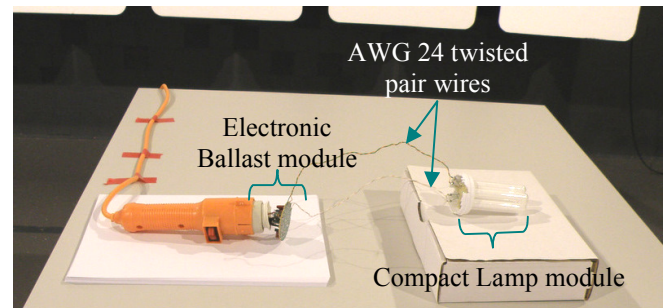


Figure 5 - CFL measurements (experimental test setup)

The compact lamp module was then introduced in a ferrite enclosure and the radiated emissions of CFL were measured using the same test setup as described in figure 4. This configuration was chosen in order to determine which part of compact fluorescent bulb is responsible for radiations emission.

### V. EXPERIMENTAL RESULTS

#### A. CISPR22 standard limits

The CISPR22 [3] standard limits for conducted perturbations and radiated emissions are listed below.

TABLE II. CONDUCTED DISTURBANCES LIMITS

FREQUENCY (MHz)	CISPR22 LIMITS [3] (dBuV) quasipeak	EUT Class B
0.15 ... 0.5	66 to 56 dBuV	
0.5 ... 5 MHz	56 dBuV	
5 ... 30 MHz	60 dBuV	
Conducted Disturbances (CISPR22, cap. 6 [3])		

TABLE III. RADIATED EMISSIONS LIMITS

FREQUENCY (MHz)	CISPR22 LIMITS [dB(uV/m)] quasipeak	EUT Class B (3 m distance)
30 ... 230 MHz	40 dBuV	
230 ... 1000 MHz	47 dBuV	
30 ... 230 MHz	50 dBuV	EUT Class A (3 m distance)
230 ... 1000 MHz	57 dBuV	

## B. Conducted Disturbances Measurements

In figures 6, 7 and 8 we have three screen captures taken from EMI Test Receiver during the conducted emissions measurements (test setup according to figure 3).

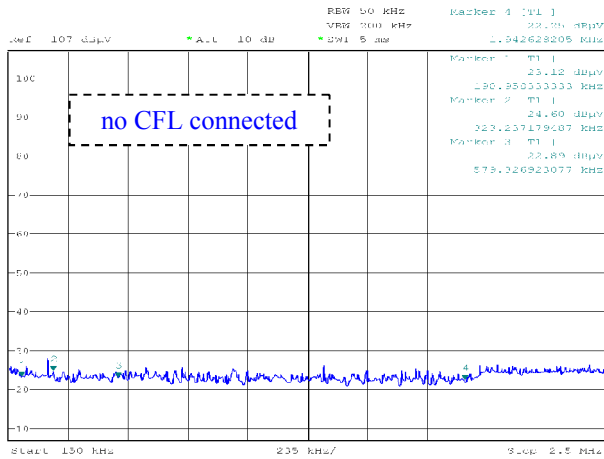


Figure 6 - Conducted disturbances (no CFL connected)

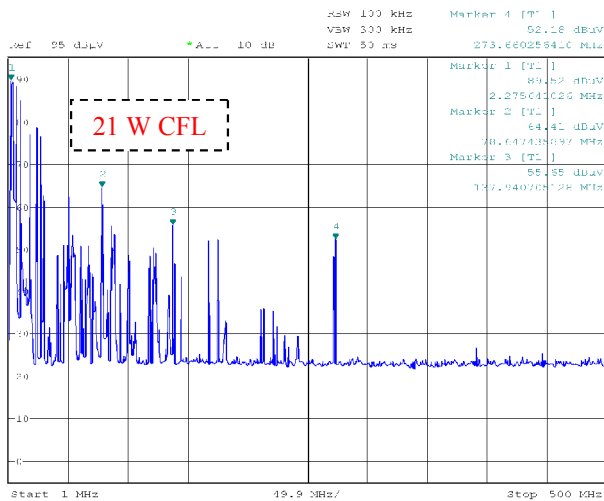


Figure 7 - Conducted disturbances measurements in the frequency band of 1 MHz - 500 MHz (21 W CFL)

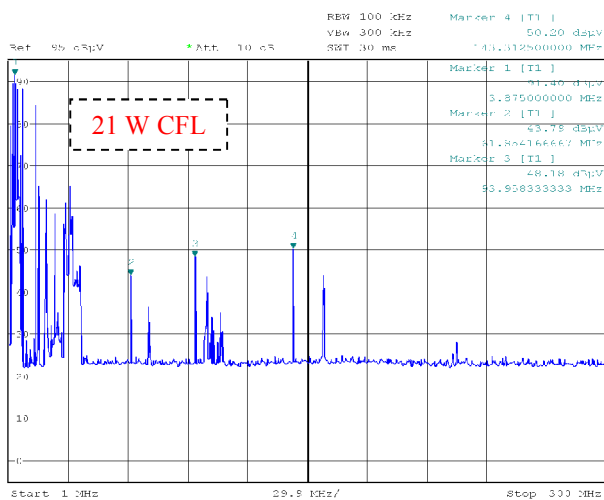


Figure 8 - Conducted disturbances measurements in the frequency band of 1 MHz - 300 MHz (21 W CFL)

As it is also apparent from the screen captures above, several conducted perturbations are introduced in the power

network supply. In figures 7 and 8 we have the conducted emissions levels recorded via EMI Test Receiver when the CFL was turned ON for 5 seconds, then switched OFF. We repeated this action for 10 times.

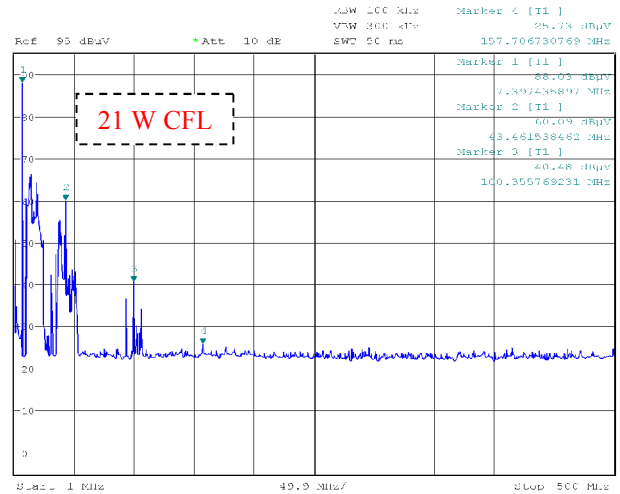


Figure 9 - Conducted disturbances measurements - normal operation of CFL (turned ON for 5 minutes)

In normal operation (turned ON for 5 minutes and then switched OFF: figure 9), the compact fluorescent lamp continues to emit, but the level of perturbations is much lower. A maximum electromagnetic radiations level is recorded only when the CFL is switched ON.

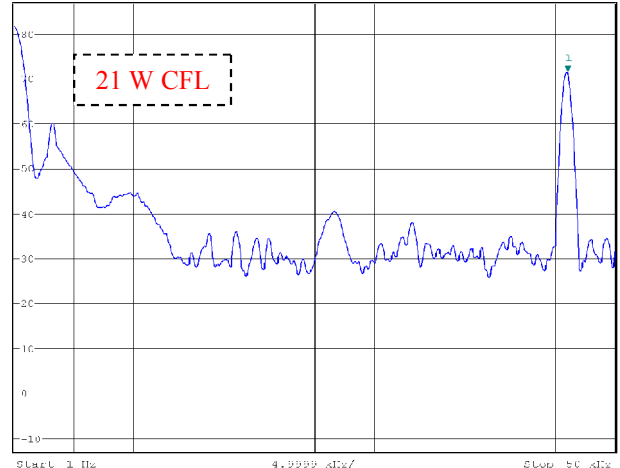
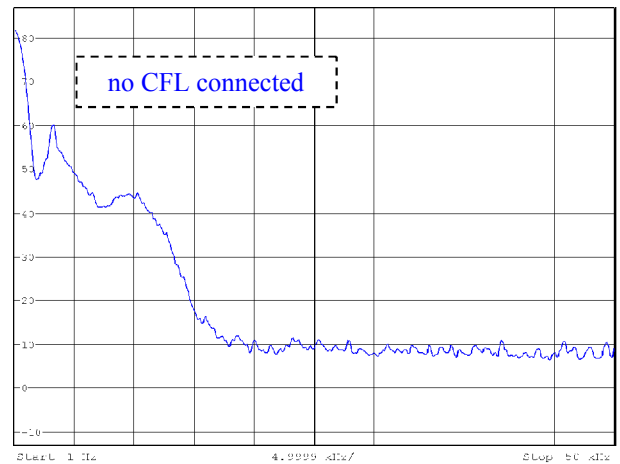


Figure 10 - Conducted disturbances measurements in the frequency band of 1 Hz - 50 kHz

### C. Radiated Emissions Measurements

The radiated emissions of three different types of CFL were measured using the test setup according to figure 4.

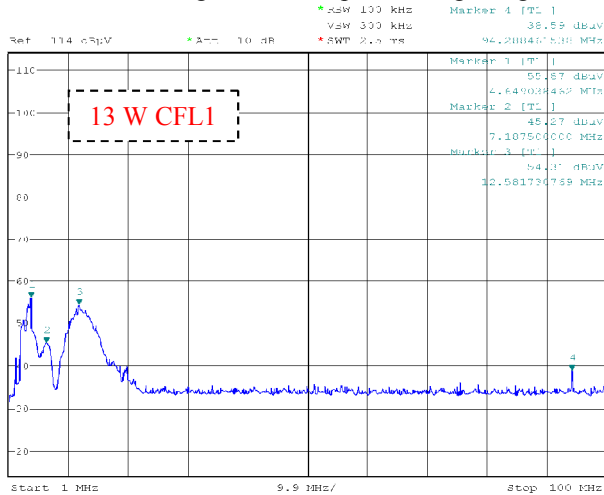


Figure 11 - Radiated emissions measurements (CFL1 = 13 W) frequency band 1 MHz to 100 MHz

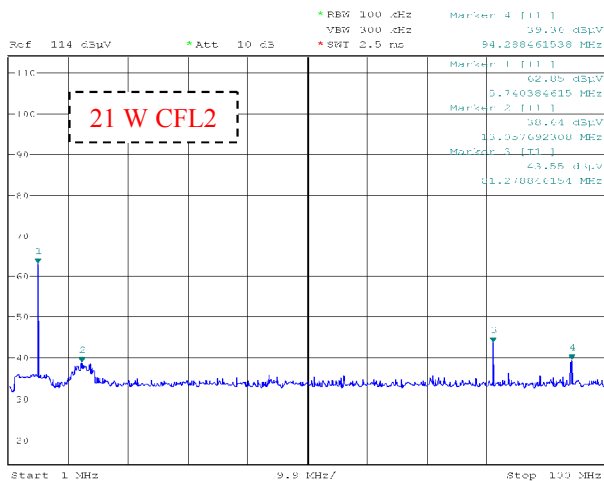


Figure 12 - Radiated emissions measurements (CFL2 = 21 W) frequency band 1 MHz to 100 MHz

In figures 11 and 12, the CFLs were switched ON for 5 minutes, while the radiated perturbations were recorded. This situation corresponds to continuous operation of CFL.

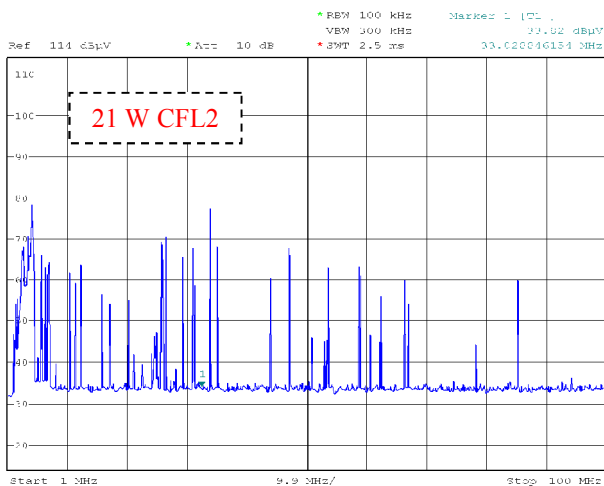


Figure 13 - Radiated emissions measurements (CFL2 = 21 W) frequency band 1 MHz to 100 MHz

In figure 13, the 21 W CFL was switched ON for 5 seconds and then turned OFF, repeating this action for 10 times. As it is also apparent from the screen capture, more radiated electromagnetic perturbations occurred.

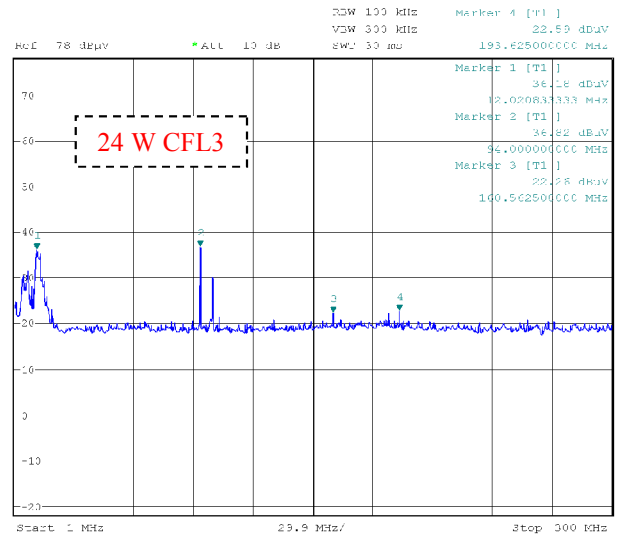


Figure 14 - Radiated emissions measurements (CFL3 = 24 W) continuous operation for 5 minutes

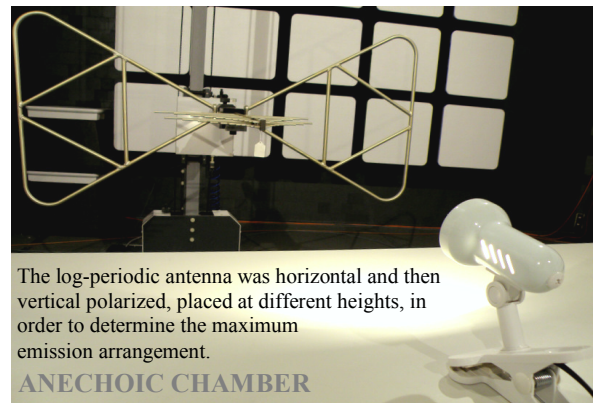


Figure 15 - Photo of experimental test setup

Next, the two modules of the 21 W CFL were separated and connected via AWG 24 twisted pair wires (as described in figure 5). The radiated emissions were measured using the same test setup according to figure 4.

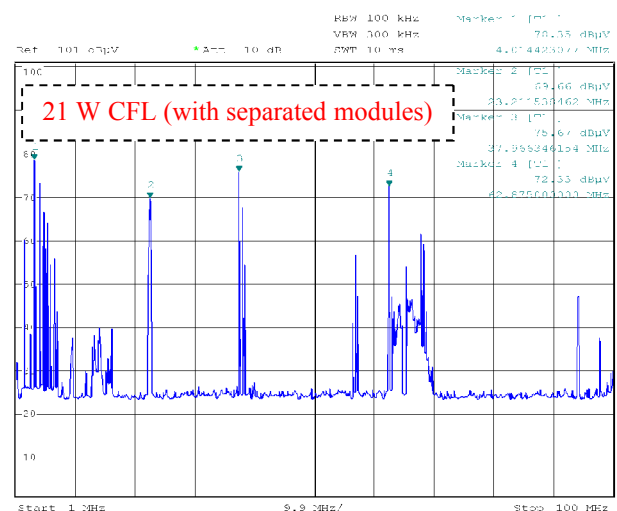


Figure 16 - Radiated emissions measurements



The maximum levels recorded in the frequency band of 1 MHz - 100 MHz are listed in table IV.

TABLE IV. CFL 21 W - RADIATED EMISSIONS LEVELS

MARKER freq.	LEVEL recorded	CISPR22 limit*
4.01 MHz	78.35 dBuV	40 dBuV (50 dBuV)
23.21 MHz	69.66 dBuV	40 dBuV (50 dBuV)
37.96 MHz	75.67 dBuV	40 dBuV (50 dBuV)
62.87 MHz	72.33 dBuV	40 dBuV (50 dBuV)

\* only for informative purpose

In order to determine which part of CFL is responsible for those electromagnetic radiations producing, we placed the compact lamp module in a special ferrite enclosure, keeping the same test configuration (see figure 17). It has been noticed that the most of radiated emissions from the frequency band of 10 MHz - 100 MHz disappeared.

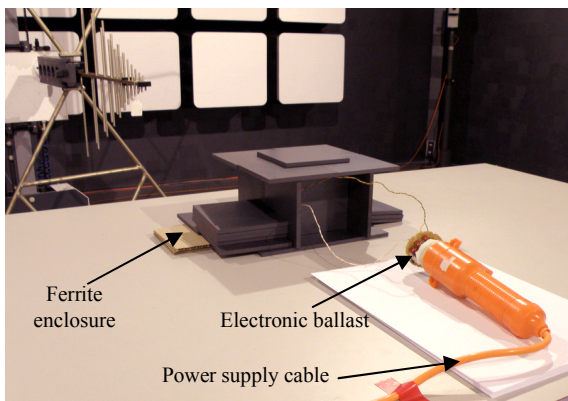


Figure 17 - Radiated emissions measurements (shielded compact lamp module)

At frequencies up to 1 GHz, the ferrite materials act as an absorber for the electromagnetic waves, while at frequencies above 1 GHz ferrite may reflect EM waves [10]. Anyway, the ferrite enclosure constructed suppresses the compact bulb emissions, so that only the electronic ballast radiations were recorded - from 1 MHz to 100 MHz (figure 18).

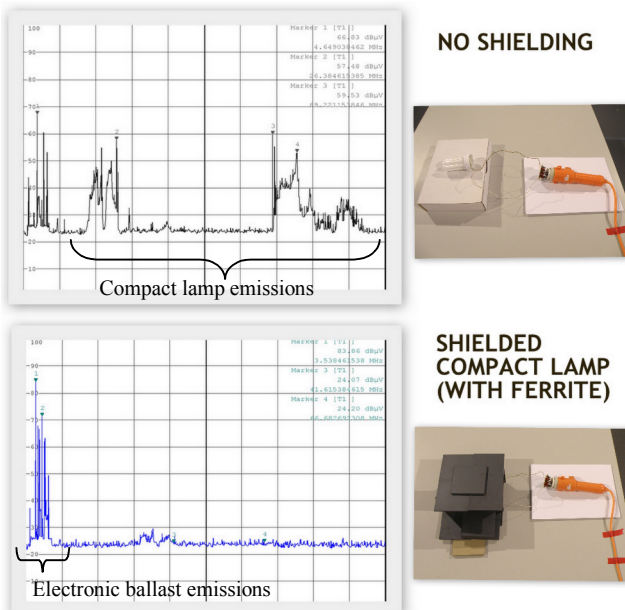


Figure 18 - Comparative radiated emissions measurements

Based on the results obtained, we can conclude that the compact lamp module acts as an antenna and radiates electromagnetic waves in the frequency range of 10 MHz - 100 MHz.

On the other hand, the high frequency operation of the electronic ballast circuit generates conducted noise in the power supply network and radiated emissions in the 1 MHz - 10 MHz frequency band.

## VI. CONCLUSIONS

Within the last few years, the new developments in the field of Compact Fluorescent Lights (CFL) have neglected the unintentional release of electromagnetic energy from these devices. They use less electricity and save money, last up to 15 times longer than standard light bulbs and reduce CO<sub>2</sub> emissions, but provide lots of disadvantages as well.

The operation of CFL at high frequencies up to 50 KHz eliminates the flicker effect (also known as the disturbing 50/60 Hz cycle mains hum) but produces high electromagnetic emissions.

Several radiated and conducted emissions measurements on different CFLs were made in order to point out the high level of compact fluorescent lights perturbations. A decrease of conducted disturbances may be obtained using an EMI filter in the electronic ballast circuit.

## REFERENCES

- [1] R. ISTOK, "Relation Between Disturbance Radiation of CFL and Resonant Frequency of Power Supply Cable", Advances in Electrical and Computer Engineering, ISSN 1582-7445, e-ISSN 1844-7600, vol. 7, no. 1, pp. 23-25, 2007
- [2] A. Vitanza, R. Scollo, A. Hayes, "Electronic fluorescent lamp ballast" (Application note), 2009
- [3] EN 55022 standard (CISPR22) - Information technology equipment - Radio disturbance characteristics - Limits and methods of measurement, 2007
- [4] Z. Wei, N.R. Watson, L.P. Frater, "Modeling of compact fluorescent lamps", 13<sup>th</sup> International Conference on Harmonics and Quality of Power, 2008
- [5] O. Montero, D. Baez, F. Alvarez, R. Alejos, G.E. Flores-Verdad. "Simulation and experimental results for a compact fluorescent lamp with electronic adapter", Proceedings of the 38<sup>th</sup> Midwest Symposium on Circuits and Systems, 1995
- [6] M.A. Shafi, R.A. McMahon, "Influence of voltage and frequency dimming on power losses in HF electronic ballasts for compact fluorescent lamps", IEEE Industry Applications Conference, 2006
- [7] L. Laskai, M. Ilic, "An approach for selecting switching devices for CFL ballasts", IEEE Transactions on Industry Applications, 2002
- [8] M.A. Shafi, R.A. McMahon, "Implementation and verification of CFL models for use in performance analysis in high frequency electronic ballasts", The 3<sup>rd</sup> IET International Conference on Power Electronics, Machines and Drivers, 2006
- [9] M. Poncc, I. Guerrero, J. Arau, J. Correa, J.M. Alonso, "Electronic ballasts for CFL operating at frequencies above of 1 MHz: design considerations and behavior of the lamp", Power Electronics Congress, 2002
- [10] EN 61000-4-3 standard - Electromagnetic Compatibility (EMC) - Part 4-3: Testing and measurement techniques - Radiated, radio-frequency, electromagnetic field immunity test, 2006
- [11] M.F. da Silva, G.W. Denardin, R.A. Pinto, J.P. de Lopes, M. Polonskii, A.R. Seidel, R.N. do Prado, "Dimmable Lighting System Strategy Based on Integral Compact Fluorescent Lamps with Digital Compensation", Industry Applications Society Annual Meeting, 2009