

Characterization of compact fluorescent lights RF emissions in the perspective of human exposure.

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Abstract: In a context where energy is valued, the use of Compact Fluorescent Light bulbs with low energy consumption (CFL) tends to generalize. However, the radio noise produced by these sources is currently the subject of many discussions, particularly about the issue of human exposure. This paper is dedicated to the characterization of the electric and magnetic fields radiated by various models of lamps. For this purpose, we have carried out tests in the immediate vicinity (near field) of these CFLs in order to identify the frequencies involved, and the EM fields produced at very short distance. These measurements were conducted in-situ to study the evolution of the electro-magnetic field over several minutes.

I. INTRODUCTION

The compact fluorescent lamp, also called "Fluocompact" or CFL, has been proposed in the 1970s when some researchers had the idea of folding up a fluorescent tube several times on itself and with the control circuit miniaturized enough to be integrated into the cap of a standard lamp (see Fig. 1).

A traditional incandescent lamp produces light when a tungsten filament carrying a current and locked in a bulb filled with an inert gas is brought to high temperature by Joule effect. This technology has a low efficiency. Moreover, the lifetime of that lamp is relatively low because the hot filament vaporizes gradually on the walls of the glass, and eventually breaks after a few hundred hours of operation.

The CFL works itself on the principle of the fluorescent tube that provides higher performance.

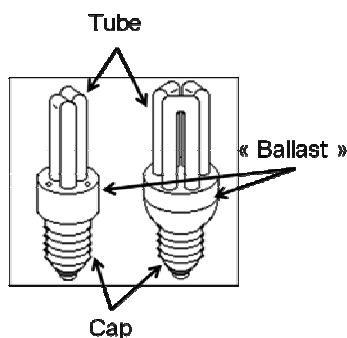


Fig 1: The compact fluorescent lamp.

The cap of the lamp contains an electronic control device called "Ballast" (Fig. 1 and 2) that generates an electrical

continuous discharge which generates an emission of ultra-violet light when mercury atoms in the tube are struck by electrons. A layer of fluorescent compound covers the internal wall of the tube and converts the UV light into visible light. This principle has a better energetic efficiency; the light of a CFL is equivalent to an incandescent bulb but consumes four to five times less energy, for example: a lamp of ~11W is equivalent to a conventional bulb of ~60W.

Compact fluorescent lamps are energy efficient, a lifetime longer than a conventional lamp. But they also have some drawbacks: they are more expensive, they contain mercury and radiate some radiofrequency signals mainly related to the electronic control circuit (Fig. 3).

This paper presents the results of the characterization of the radiated emissions of some CFL at short distances.

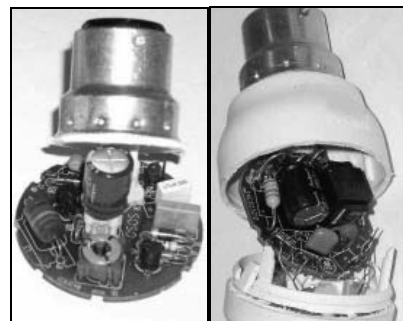


Fig. 2: Examples of "ballast" circuits.

Lamps of different brands, shapes and electrical powers in the range from 5 to 20 W, have been tested (Fig. 5).

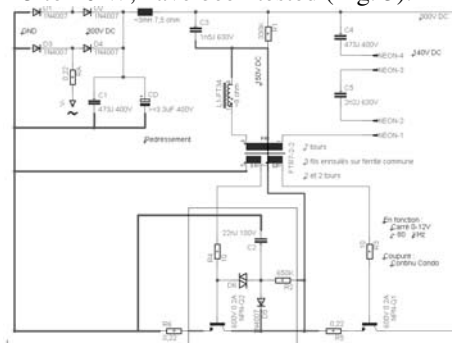


Fig.3: Example of electrical diagram of a "ballast" circuit.

II. PROTOCOL USED FOR THE MEASUREMENT

A dual approach was used for this study. Firstly, it was necessary to identify the fundamental frequency of the radio emission. This has been achieved with a calibrated loop EMCO 7604 covering the frequency range 20 Hz to 1 MHz connected to a digital oscilloscope Agilent Infiniium with a wide bandwidth (1.5 GHz). Afterwards, once the signal frequencies involved being identified, we have connected the loop to a spectrum analyzer type Agilent E4407b (Fig. 4a and 4b).

- The distance between the lamp under test and the loop was variable, just as the orientation of the loop which was optimized to obtain a maximum value of the H field at each point of measurement.
- Some time was allowed to the lamp in order to stabilize (thermal effect in particular), the waiting time varied between a few seconds to several minutes after the light is on.
- For some measurements, it was preferable to use a Faraday's anechoic chamber to eliminate external emission.



Fig. 4a: Measurement system in anechoic chamber



4b: Measurement system in situ.

III. RESULTS

The results greatly depend on the construction of the cap, within the ballast circuit and lead to very different results. In the rest of this work, we have optimized precisely the relative position of the lamp and the antennas or probes to obtain the maximum measured field values. The influence of the type of socket will also be considered (Fig. 5).



Fig 5: Samples of tested CFLs.

The radio frequency signals from the CFLs are shown in Fig. 6. The maximum RF fieldstrength was measured in a zone located between the cap of the lamp (containing the "ballast" circuit system) and the middle of the fluorescent tube. This is a complex signal which spectrum covers a band from a few tens of kHz to less than 1 MHz.

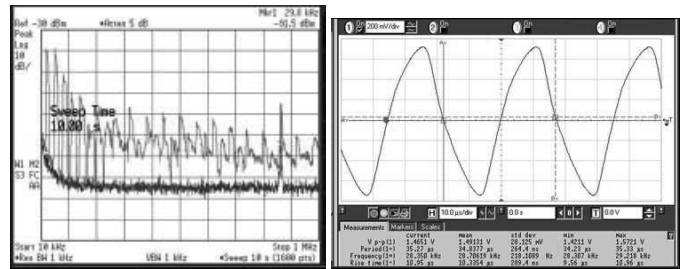


Fig. 6: Radiated spectrum and time-domain aspect of the radio emission of a typical CFL.

A. Measurement of the magnetic fieldstrength spectrum

The measurement of magnetic fieldstrength is usually the most appropriate and easy signal to characterize, taking into account the frequencies involved as well as the measurement distance. The following figures show the magnetic fieldstrength spectrum of significant amplitude contained in the radio signal (Fig. 7 and Fig. 8) for two samples of CFL chosen in two categories (classes) of CFLs. In fact, two classes (A and B) of CFLs have been defined in our study because we could distinguish two very different behaviors (in time domain, harmonics, RF levels, see Fig. 9) depending on the tested CFLs

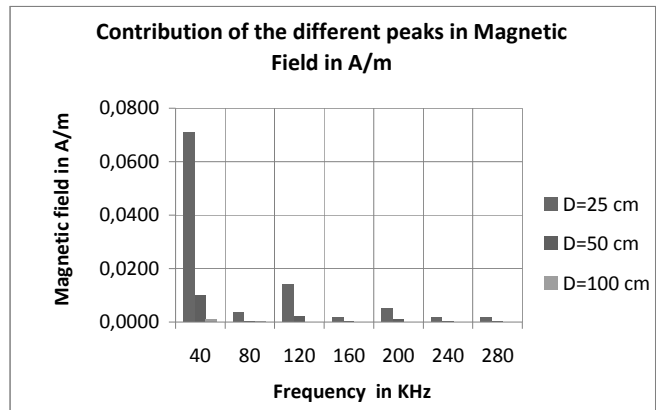


Fig. 7: Distribution of the H fieldstrength vs. frequency for one sample of type A CFL at three distances.

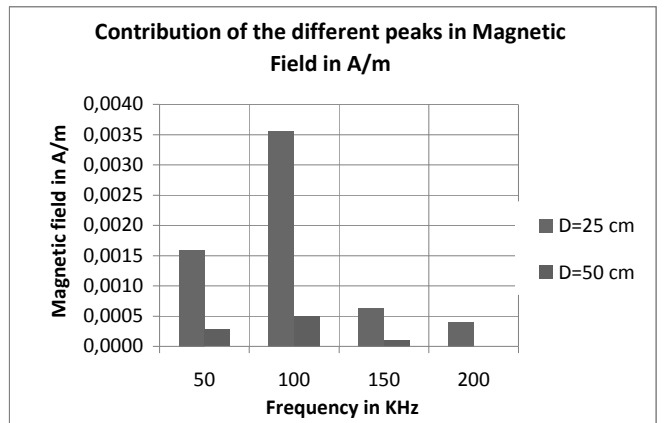


Fig. 8: Distribution of the power of H field vs. distances lamp-loop for a CFL type B.

B. Comparison of the global results

Now, we take into account the contributions of all frequencies for the calculations of total magnetic fieldstrength. The results of measurements are summarized in table 1.

Table 1: Summary of the global results

D (m)	5W	9W	11W* ¹	11W* ²	11W* ³	11W* ⁴	15W	20W
D (m)	H (A/m)	H (A/m)	H (A/m)	H (A/m)	H (A/m)	H (A/m)	H (A/m)	H (A/m)
contact	x	0.133	0.41	5.8	X	x	x	x
0.25	0.058	0.004	0.013	0.07	0.093	0.08	0.016	0.19
0.5	0.01	0.001	0.002	0.01	0.019	x	x	x
1	x	X	x	0.001	x	x	x	x

Note:

- The x indicates that no measurement has been made,
- The distance referenced "contact" is the minimum distance between the loop and the lamp. It varies from less than 1 cm to 3 cm depending of the shape of the lamp (Fig. 5).

Fig. 9 shows that the amplitude of the magnetic fieldstrength does not depend on the electric power of the lamp. However, there is a great disparity between lamps of the same electric power. The different magnetic fieldstrengths between these two groups depend more on the design of the electronic ballast than on the tube length and the number of folding of the tube on itself and on the electric power. Class A corresponds to high levels of H field (as with the type of CFL of Fig. 7) and class B for a lamp with lower levels of H field (as with the type of CFL of Fig. 8).

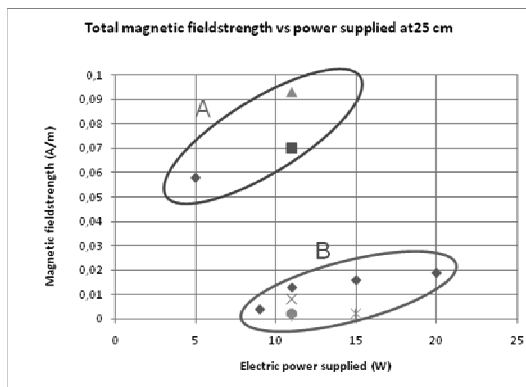


Fig. 9: Value of the total magnetic fieldstrength measured at a distance of 25cm according to the power of the lamp.

C. Evolution of the magnetic fieldstrength versus the distance

For this study, we took two samples of CFLs (one of Class A and one of Class B). The curves obtained are almost parallel, decreasing in $1/d^\alpha$ with α ranging from 1 to 2 (d: distance between the lamp and the measurement loop).

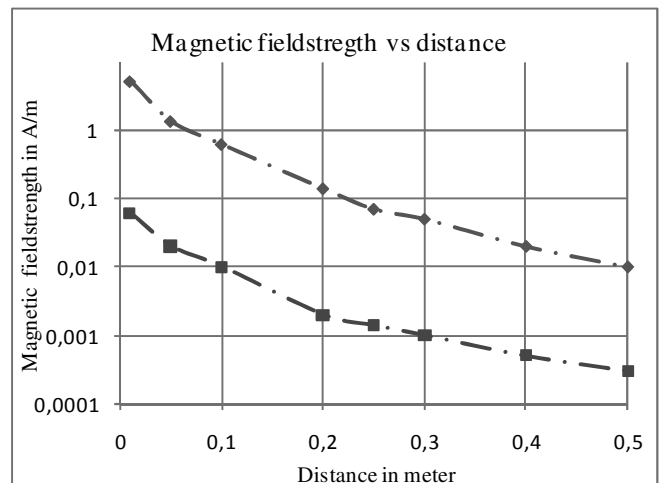


Fig. 10: Variation of the total magnetic fieldstrength measured with the distance.

We can notice (Fig 10) that the H fieldstrength decreases rapidly with the distance.

D. Study of the variation of the EM field versus time

In the time domain, compact fluorescent lamps as well as fluorescent tubes, have different transient phases: first, a peak of voltage appears just after switching the power on, then a slow drift of the fundamental frequency of the electromagnetic emission corresponding to the stabilization of the temperature of the tube (warm-up tube) and stabilization of the luminous flux (Fig. 11).

We have made in-situ measurements (Fig. 11) at 30cm of a 30W lamp during a period of several minutes. Fig. 12 shows the variation of the electric fieldstrength over a period of 140 seconds integrated in the band 5kHz - 100kHz, measured with a Narda 3-axis electric field probe.

When the light is off, the levels of ambient residual fields measured are: E = 0.3V/m ; B = 0.07μT (Fig. 12).



Fig. 11: In situ measurements

Around and close to the lamp, the electric field varies from 80V/m to 380V/m and the level of magnetic flux ranges from 0.2 to 0.6μT. The levels of fields are maximal near the ballast in the cap of the lamp.

On the desk, Under the lighting (30cm, see. Fig 11)		
Average level measured	5kHz – 100kHz CFL lighting	Exposure limit
Electric field – E	17.7 V/m	87 V/m
Magnetic induction - B	0.2 μT	6.25 μT

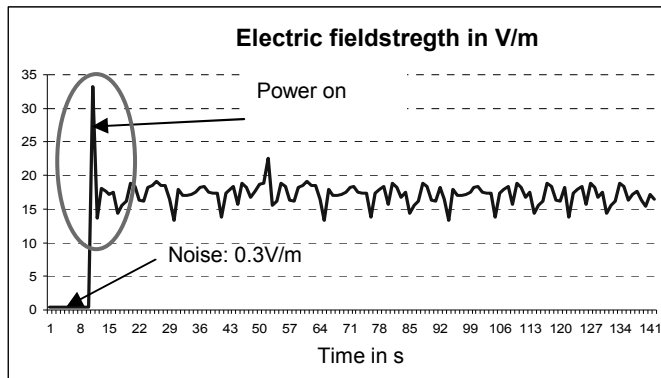


Fig. 12: Variation of the E fieldstrength vs time

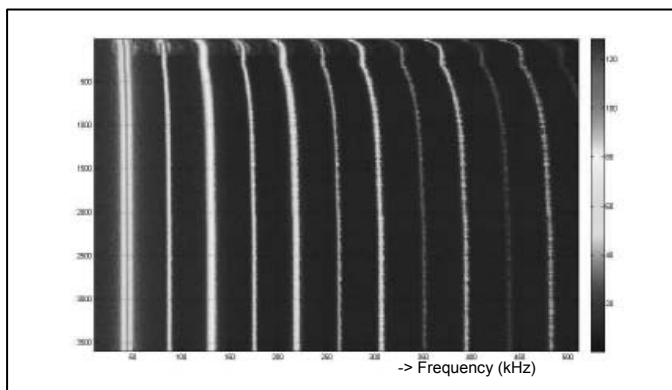


Fig. 13: Variation of the H fieldstrength spectrum lines versus time (over 1 hour)

We can notice that the values of the E field and the H field (Fig. 12 and Fig. 13) remain stable after the warm-up period.

IV. CONCLUSION

- We note that fluorescent lamps produce a significant electromagnetic field at frequencies between 10kHz and 500kHz, which is not the case of incandescent lamps. The maximum magnetic fieldstrength measurements are still less than 6A/m in contact and <0.1A/m at 25cm.
- For human exposure purpose, these values are compared with the exposure limits given by ICNIRP. In the band of interest (3kHz - 150kHz), the limit for the magnetic field H is 5A/m and the limit for the electric field E is 87 V/m.
- Emissions from these lamps could radiate RF interference in the radio broadcasting amplitude modulation bands (Fig. 14): LW (long wave) and MW (medium wave).

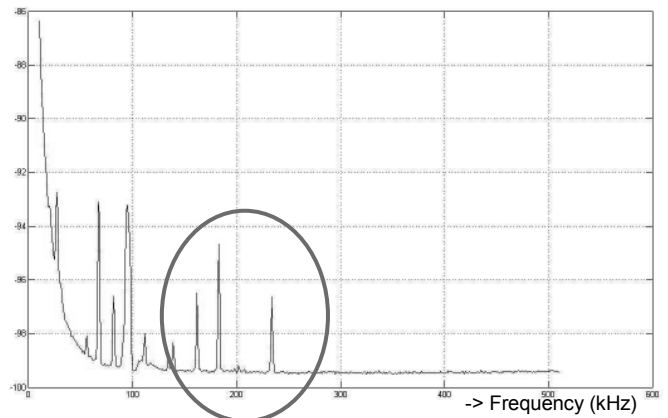


Fig. 14: Example of LW and MW radio broadcasting stations (red ellipse)

According to these results, we wanted to compare the CFLs to other devices with built-in low frequency switching mode power supply or with any oscillator able to radiate energy in the same band. Table 2 synthesizes all the results.

Table 2: Comparison of the total magnetic fieldstrength emitted by different electronic devices at 10cm.

Device	Total magnetic fieldstrength (A/m) at 10cm
CFL class A	0.8
CFL class B	0.06
Laptop	0.2
ISDN phone	0.016
Fluorescent bulb	0.006
Power supply (PC)	0.07

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