Electromagnetic Fields Radiated by Fluorescent and Compact Fluorescent Lamps

Daniel Sebastião, Carla Oliveira, Gonçalo Carpinteiro, Diana Ladeira, Mónica Antunes,
Luís M. Correia, Carlos Fernandes

Instituto de Telecomunicações/Instituto Superior Técnico, Av. Rovisco Pais 1, 1049-001 Lisboa, Portugal
Phone: +351-218418455, Fax: +351-218418472
e-mail: monit@lx.it.pt

***Abstract* — In the scope of the monIT Project, it was found that fluorescent and compact fluorescent lamps are also important sources of radiation. More than increasing EMF levels in a particular environment, the radiation from ballasts may cause electronic interference with other devices. Two different lamps are analysed, in terms of both their radiated frequency spectrum and their compliance with European EMF recommended exposure levels. As expected, the analysis of results shows that, in the immediate vicinity of a lamp, EMF levels radiated by lighting devices depend on the lamp power. Finally, one can conclude that EMF emissions from both lamps are in compliance with the EMF reference thresholds.**

I. Introduction

monIT [1] is a Portuguese project on risk communication aiming at providing public information on exposure to Electromagnetic Fields (EMFs) from mobile communication systems. The Project's main information vehicle is its website (www.lx.it.pt/monit), where all activities are presented, namely, relevant information regarding EMF and results from measurement campaigns performed near mobile communications base station antennas. Although these measurements are always performed near the antennas of mobile communications networks, it was found that fluorescent and compact fluorescent lamps are also important sources of radiation to be considered in indoor environments.

With the purpose of saving energy, modern fluorescent and compact lamps use electronic ballasts operating at high frequencies (from 20 to 100 kHz). However, the high frequency currents generated to increase lamp efficiency can originate significant radiated noise (an increase of EMF levels), since the whole lamp acts like an antenna. More than increasing EMF levels in the surrounding environment, the radiation from ballasts may cause interference with other devices. There are several reported cases of electromagnetic interference in noise-sensitive equipments, like those present in airplanes [2], hearing aids [3], [4], infrared TV remote controls [5], among others [6], [7].

With the purpose of analysing EMFs radiated by compact fluorescent lamps, a case study was carried out. Two different lamps were analysed, in terms of both their radiated frequency spectrum and their compliance with European EMF recommended human exposure levels [8].

This paper is composed by four more sections, besides the current one. The following section describes the work carried out, and the next two present the results and analyse the compliance with the EMF thresholds, respectively. In the last section, the main conclusions are drawn.

II. Objectives and Description of the Study

The objective of this study is twofold: on the one hand, it intends to analyse EMF spectrum radiated by compact fluorescent lamps, and on the other, it aims at evaluating compliance of EMF levels originated by these lamps with the European EMF exposure thresholds [8].

The EMF levels originated by two examples of compact lamps are analysed, according to a specific measurement procedure developed for this case study, within the [0.1, 5] MHz band. Fig. 1 shows the lamps under study, and Table I presents their technical characteristics.

a) Lamp 1.

b) Lamp 2.

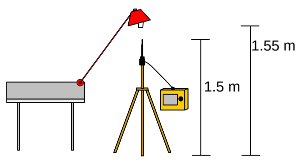
Fig. 1. Lamps under study.

Table I
Technical characteristics of the lamps under study.

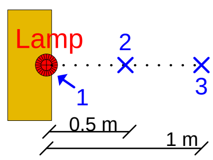
	Lamp 1	Lamp 2
Manufacturer	IKEA	OSRAM
Luminance [lm]	600	1 200
Power [W]	11	21

A specific measurement procedure was developed in order to conduct the study, Fig. 2. Measurements were performed at three positions for increasing distances from the lamp. At Position 1, exactly under the lamp, measurements were conducted considering three states:

- State DISC: Device disconnected from power supply;
- State LOFF: Device connected to power supply and light off;
- State LON: Light on.



a) Lamp and measurement heights.



b) Measurements positions.

Fig. 2. Measurement site.

At Positions 2 and 3, respectively 0.5 and 1 m away from the lamp, measurements were performed only in the state LON; only this state is considered mainly because lower EMF levels are expected at these distances. As the dimension of the lamps under study is very small compared to the involved wavelengths (in the order of hundreds of metres), measurements were performed in the near-field zone.

For all scenarios, detailed frequency measurements were carried out using the Narda SRM-3000 spectrum analyser [9] with uniaxial electric, *E*, and magnetic, *H*, field probes, both working in the [0.1, 300] MHz band.

Other transmitters were also identified inside and outside the measurement room:

- Inside: other light devices located on the ceiling, which may influence the measurement;
- Outside: mobile, broadcast radio and television communication systems, which are not expected to influence the measurement, as their EMF levels fall outside the measurement frequency band.

III. Measurement Results

In Figs. 3 and 4, *E* and *H* field measurements results are presented for the three states (DISC, LOFF and LON), for Lamp 1 in Position 1. Measurements for Lamp 2 have similar values with the same behaviour.

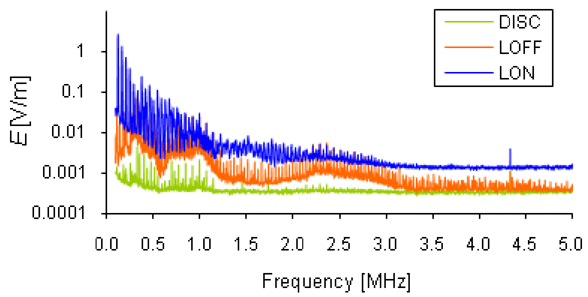


Fig. 3. *E* field for the three states: [0.1, 5] MHz (Lamp 1, Position 1).

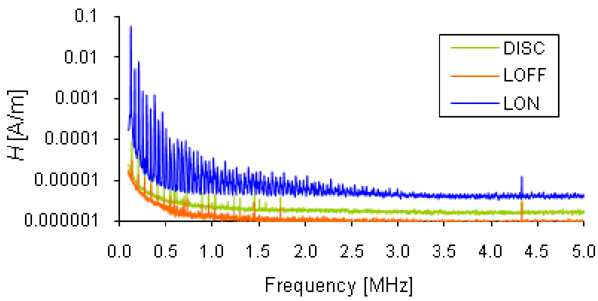


Fig. 4. *H* field for the three states: [0.1, 5] MHz (Lamp 1, Position 1).

Measurements show that lamps exhibit significant EMF levels. Moreover, results show an increase of *E* field levels when a lighting device is simply connected to power supply with the light off; although this does not happen with the *H* field. This result was expected, as when in state LOFF, there is no electric current flow, thus, no considerable magnetic field exists. When the light is turned on, a significant increase of both *E* and *H* field levels is observed. These results were observed for both lamps, although with slight different frequency spectra.

For both lamps, a significant contribution of EMF levels in the [0.1, 1] MHz band can be observed. This is valid for both *E* and *H* fields, and for all the three states. Even in the DISC state, one can identify peaks in this frequency band, probably coming from the lamps on the ceiling of the room (which were in the LOFF state).

So, additional measurements were performed in the [100, 800] kHz band, in order to identify the various harmonics in a more accurate way, Fig. 5, being seen that they are spaced 40 kHz from each other.

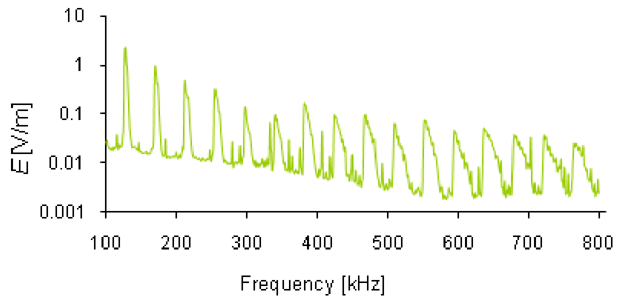


Fig. 5. *E* field: [100, 800] kHz (Lamp 1, Position 1, LON).

Regarding the distance to the lamp, Figs. 6 and 7, one can observe *E* and *H* fields, respectively, within the [0.1 , 5] MHz band, at the three positions, for Lamp 1.

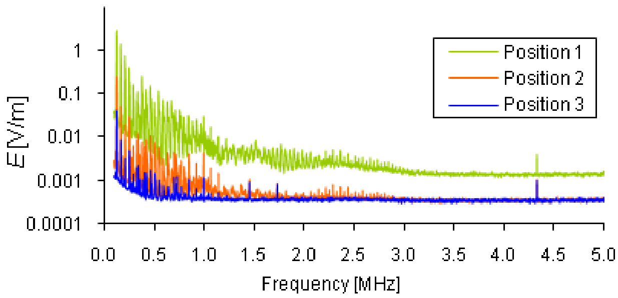


Fig. 6. *E* field, at three different positions: [0.1, 5] MHz (Lamp 1, LON).

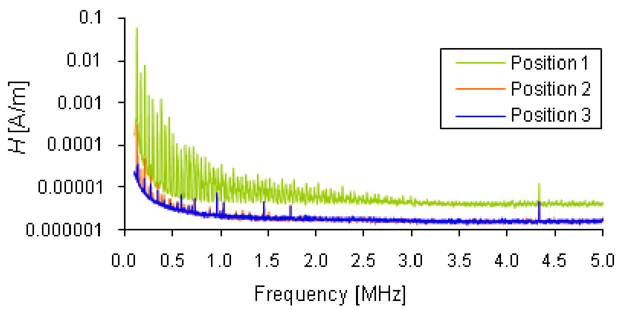


Fig. 7. *H* field, at three different positions: [0.1, 5] MHz (Lamp 1, LON).

As expected, it can be seen that EMF values rapidly decay when the distance to the device increases. In spite of this, at

0.5 and 1 m away from the lamps, one can still observe the spectral lines in the [100, 800] kHz band.

As the frequency of operation of electronic ballasts may vary from 20 to 100 kHz, and as the minimum frequency at which measurement probes can operate is 100 kHz, it was not possible to identify the frequency of operation of the lamps under test, although various harmonics are visible. So, additional measurements were performed in order to identify the frequency of operation.

The measurement procedure for this situation consisted of a single measurement exactly under the lamp, considering state LON. The measurement was carried out in a different room with other light devices located in the ceiling, and various laboratory equipment in close proximity, Fig. 8.

Fig. 8. Additional measurements.

The Anritsu MS2601B spectrum analyser [10] was used, working in the [0.009, 2200] MHz band. A common electronics cable was used as a receiving antenna.

For both lamps, measurements of received power, P, were conducted in the [10, 800] kHz band. The results for Lamp 1 are shown in Fig. 9. Note that, due to the inexistence of a hardware/software interface to download measurement data from the spectrum analyser, only the peak values are represented (orange dots), obtained manually from the equipment. The previous measurements, which were carried out with Narda SRM-3000 spectrum analyser for Position 1, state LON and [100, 800] kHz band, are represented by a continuous line in the figure.

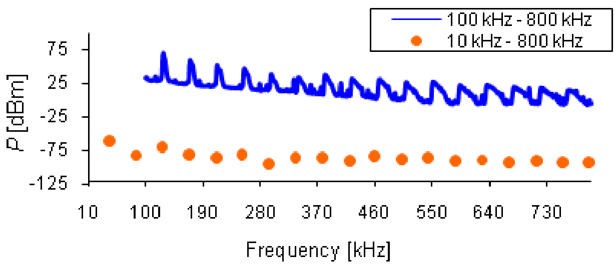


Fig. 9. Additional measurement results (Lamp 1).

There was no available information about the cable used as receiving antenna in this additional measurement campaign. A simple calibration procedure was performed in order to convert the power levels measured with the cable into E field values. This calibration procedure consisted of the comparison of results for frequencies above 100 kHz obtained by the additional measurement campaign with those obtained in the same conditions by the Narda SRM-3000; then, results were extrapolated for frequencies below 100 kHz. The step-by-step procedure is explained below:

- the first three peak values above 100 kHz from the two measurement campaigns were compared, Fig. 10;
- the average difference, F, between the considered peaks was estimated;
- the F factor was added to the power measurements for frequencies below 100 kHz.

The power values were converted into E field ones, according to the characteristics of the E field probe of the Narda SRM-3000 (short dipole, antenna gain of 1.76 dBi), the E field being obtained for the [10, 100] kHz band.

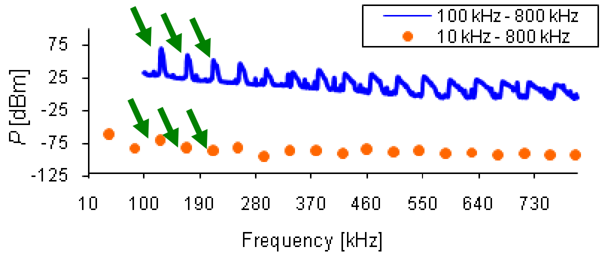


Fig. 10. Comparison of results.

IV. Evaluation of EMF Compliance

For the spectrum analyser, only the peak values exceeding a threshold level of 40 dB below the reference level were considered. The results correspond to Position 1 and to the state where the higher EMF levels were verified, which is state LON.

According to [8], the reference levels corresponding to the frequencies of significant radiation are $E_{\lim} = 87$ V/m and $H_{\lim} = 5$ mA/m. Tables II and III present the compliance evaluation for E and H fields for both lamps, for the recorded peak. For Lamp 2, there were no H field values exceeding the threshold level of 40 dB, thus, not being reported here.

Table II
Comparison between E field measurements and reference thresholds: [0.1, 5] MHz.

	Frequency [kHz]	**E_i [V/m]**	**E_i/E_{lim} [dB]**
Lamp 1	127.34	2.78	-29.90
Lamp 2	100.00	4.17	-26.39

Table III
Comparison between H field measurements and reference thresholds: [0.1, 5] MHz.

	Frequency [kHz]	**E_i [V/m]**	**E_i/E_{lim} [dB]**
Lamp 1	127.3	0.06	-38.64

But, according to [8], when there is simultaneous exposure to fields of different frequencies, total exposure ratios referred to electrical stimulation effects and to thermal effect circumstances must be calculated, and should be lower than 1, Table IV. As it can be seen, the EMF values from both lamps are in compliance with the thresholds.

Table IV
Total exposure ratios.[1]

		Lamp1	Lamp2
Electrical stimulation effects	$\sum_{i=1\,\mathrm{Hz}}^{1\,\mathrm{MHz}} \left(\frac{E_i}{E_{\mathrm{lim}}}\right) + \sum_{i>1\,\mathrm{MHz}}^{10\,\mathrm{MHz}} \left(\frac{E_i}{E_{\mathrm{lim}_{\mathrm{sup}}}}\right)$	0.14000	0.26100
	$\sum_{j=1\,\mathrm{Hz}}^{150\,\mathrm{kHz}} \left(\frac{H_j}{H_{\mathrm{lim}}}\right) + \sum_{j>150\,\mathrm{kHz}}^{10\,\mathrm{MHz}} \left(\frac{H_j}{H_{\mathrm{lim}_{\mathrm{sup}}}}\right)$	0.11400	-
Thermal effect circumstances	$\sum_{i=100\,\mathrm{kHz}}^{1\,\mathrm{MHz}} \left(\frac{E_i}{E_{\mathrm{lim}_{\mathrm{inf}}}}\right)^2 + \sum_{i>1\,\mathrm{MHz}}^{300\,\mathrm{GHz}} \left(\frac{E_i}{E_{\mathrm{lim}_i}}\right)$	0.00052	0.00080
	$\sum_{j=100\,\mathrm{kHz}}^{150\,\mathrm{kHz}} \left(\frac{H_j}{H_{\mathrm{lim}_{\mathrm{inf}}}}\right)^2 + \sum_{j>150\,\mathrm{kHz}}^{300\,\mathrm{GHz}} \left(\frac{H_j}{H_{\mathrm{lim}}}\right)^2$	0.00020	-

Table V presents the compliance evaluation for the *E* field for both lamps, for the highest peak within the [10, 100] kHz band. This peak, for both lamps, is found at the frequency of operation of the electronic ballasts. Finally, the total exposure ratios, considering the additional measurements, are presented in Table VI. It can be seen that the total exposure ratios are larger for Lamp 2, which can be explained by its higher power.

Table V
Comparison between *E* field measurements and reference thresholds: [10, 100] kHz.

	Frequency	E_i [V/m]	E_i/E_{lim} [dB]
Lamp 1	43.20	2.21	-31.9
Lamp 2	49.50	3.28	-28.5

Table VI
Total exposure ratios.

		Lamp1	Lamp2
Electrical stimulation effects	$\sum_{i=1\,\mathrm{Hz}}^{1\,\mathrm{MHz}} \left(\frac{E_i}{E_{\mathrm{lim}}}\right) + \sum_{i>1\,\mathrm{MHz}}^{10\,\mathrm{MHz}} \left(\frac{E_i}{E_{\mathrm{lim}_{\mathrm{sup}}}}\right)$	0.18424	0.30367

V. CONCLUSIONS

Fluorescent and compact fluorescent lamps are one of the main sources of radiation present in indoor environments. With the purpose of analysing EMFs radiated by these lamps, a case study was carried out, where two lamps have been analysed, in terms of their radiated frequency spectrum and their compliance with European EMF recommended levels.

EMF measurements in the [0.1, 5] MHz band show that lamps used every day in homes, workplaces, subways, shopping centres, and so on, exhibit significant EMF levels at lower frequencies. For the two lamps under study significant EMF values were found within the [100, 800] kHz band. Additional measurements carried out in frequencies below 100 kHz enabled the identification of the frequency of operation of electronic ballasts: 43.2 kHz for Lamp 1 and 49.5 kHz for Lamp 2. Several harmonics, spaced about 40 kHz, were found for both lamps.

The two lamps under study were chosen with different powers. This allowed one to verify the relation between lamp power and EMF levels. As expected, the analysis of results shows that, in the immediate vicinity of a lamp, EMF levels radiated by lighting devices depend on the lamp power.

Finally, one can conclude that EMFs radiated from both lamps are in compliance with the EMF reference thresholds.

[1] $E_{\mathrm{lim}_{\mathrm{sup}}} = 87$ V/m, $H_{\mathrm{lim}_{\mathrm{sup}}} = 5$ A/m, $E_{\mathrm{lim}_{\mathrm{inf}}} = 87/f^{1/2}$ V/m, $H_{\mathrm{lim}_{\mathrm{inf}}} = 0.73/f$ A/m and E_{lim} and H_{lim} are the reference frequency dependent thresholds.

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