DIMMING OF COMPACT FLUORESCENT LAMPS AND ONE OF ITS RELATED ASPECTS – ELECTROMAGNETIC COMPATIBILITY

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ABSTRACT

The replacement of the disappearing incandescent lamps will be realized at a significant scale by compact fluorescent lamps (CFLs). Light regulation is a popular feature that is easily provided by incandescent lamps using a simple electronic equipment, the dimmer. Dimming can be achieved by (dimmable) CFL lamps as well, however this is done in a completely different way than in case of the former. This different method relates to different electromagnetic emission characteristics and electromagnetic compatibility (EMC).

Keywords: *dimming, compact fluorescent lamps, electromagnetic compatibility*

1. INTRODUCTION

According to the new regulations of the EU, the incandescent lamps will be phased out from the market gradually. This procedure has started in 2009 with the ban of sales of incandescent lamps with a rated input power of 100W and above. The next one are the >75W types in the following year and later on the smaller types. Even the 7W incandescent types will disappear from the market by 2012. The replacement will be realized at a significant scale by CFL lamps. Today's CFLs are very close to incandescent lamps in aesthetics and are much (4-5-times) more energy efficient than those. There are some special requirements that are very easily solved with incandescent lamps and in order to gain the satisfaction of the customer, they need to be fulfilled by CFL lamps as well. Here we can think of - among other features – the regulation of the light output (so called dimming) of the lamp. This feature has two aspects: visual comfort and energy saving. As light generation is done in the form of incandescence (light radiation through heating up the filament) in case of incandescent lamps, dimming is easily achieved by the control of the filament current. This is usually done through a phase-cut circuit, which is adjusted by a potentiometer. The phase-cut sine wave of the input voltage results in a similar waveform of the input current as the load is of resistive type.

2. DIMMING IN CASE OF CFL LAMPS

We have seen the principle of light regulation in case of incandescent lamps. Compact fluorescent lamps generate light through a low-pressure gas discharge. The electrons that maintain the discharge are emitted by the emission mix (e-mix) coated cathode filament. The role of cathode/anode is changed in every half-cycle between the two electrodes. The thermionic emission - which is the emission type that represents the arc discharge - assumes a sufficient temperature of the cathode surface. This is usually obtained at the nominal lamp (arc) current that flows through the cathode filament. At decreased lamp current the operation of the arc becomes instable due to the insufficient heating effect of the lower current level. In order to maintain the stability of the arc, an additional cathode heating current is applied which flows through the filament only, thus does not feed the lamp current. All of these requirements are fulfilled by the electronic ballast that feeds the lamp.

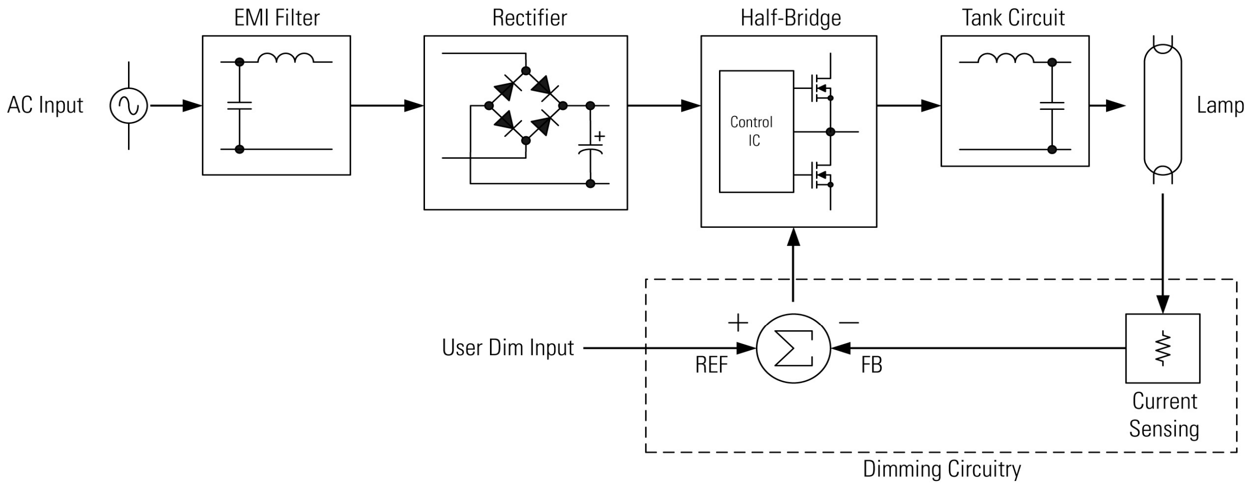


Fig. 1 Dimmable CFL system [1]

There are different methods for controlling the dimming, e.g. digital dimming; 1-10V DC dimming; transformer adjusted input voltage. However, the most widespread method is the phase-cut dimming, similarly to the incandescent dimming systems. The overview of a dimmable CFL system can be seen in Fig. 1. The system exists of a control unit (the dimmer), the light source (a dimmable CFL) and the wires between them. As mentioned above, the dimmer in our case is a phase-cut dimmer (see Fig. 2). The phase is cut by a triac at a phase angle that is controlled by a potentiometer that is set by the customer. This phase-cut sine wave is present on the wire between the dimmer and the lamp.

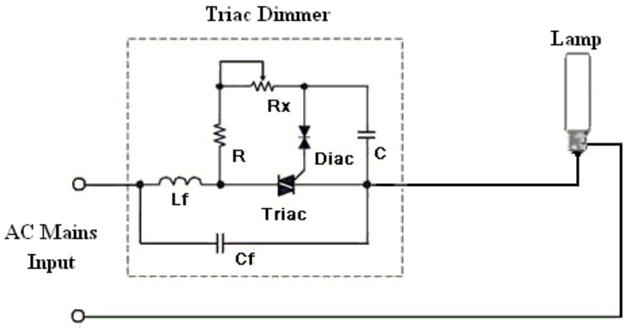


Fig. 2 Phase-cut dimmer [2]

The electronic ballast perceives the control information through the phase angle of its input voltage, then it transforms to a reference voltage that will be proportional to the desired light output level. All parameters of the dimming process are controlled by a special integrated circuit (IC). Different manufacturers have their own dimming IC in their product portfolio. However, the basic functions of these circuits are common.

3. OPERATION OF DIMMABLE CFL LAMPS

A resonant RCL output stage in the ballast is used to control the fluorescent lamp. The resonant behavior of the circuit is used to preheat, ignite and dim the lamp. During preheat, the lamp is not conducting and the circuit is a high-Q series L and C. The frequency is held constant and above resonance for a fixed time to preheat the filaments with a given current. After preheat, the frequency is swept down smoothly towards resonance to generate a high voltage for ignition (Fig. 3). After ignition, the lamp is conducting and the circuit is an L in series with a parallel R and C. The frequency continues to decrease to the final frequency where 100% brightness is achieved. For dimming, the frequency is increased to decrease the lamp current and the Q-factor of the circuit changes depending on the lamp resistance [3]. Additional cathode heating shall be used during dimming in order to maintain the stability of the arc and to protect the e-mix on the filament from the sputtering, thus preventing early life issues. Besides these, an instable arc results in EMC problems.

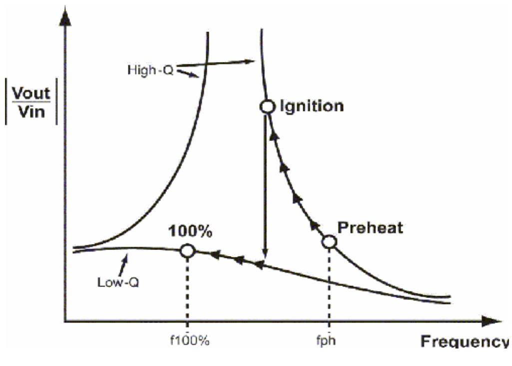


Fig. 3 Bode plot of the resonant tank operation [3]

4. EMC ASPECTS OF DIMMING

4.1. Conducted low-frequency emissions

Electromagnetic emission behavior of dimmable CFL systems is tested in European Union against the EN55015 and IEC61000-3-2 standards. As dimming of CFLs is a relatively new requirement, dimmable CFL systems are not controlled by the standard. This means, dimmers are to be tested when operated together with incandescent lamps. Similarly, dimmable CFLs are to be tested without dimmer, in their normal (undimmed) operation mode. Fig. 4 shows the behavior of the system tested together for the input current harmonics and waveform. As the system's active input power is <25W, the Amendment 2 might be used which allows the EUT to be tested for the input current waveform and the 3rd and 5th harmonics' amplitude. The system will necessarily fail this test in case the triac is turned on after the specified current flow phase angle limit values defined by IEC61000-3-2 (the current should begin to flow before 60°, has its last peak before 65° and not stop flowing before 90°).

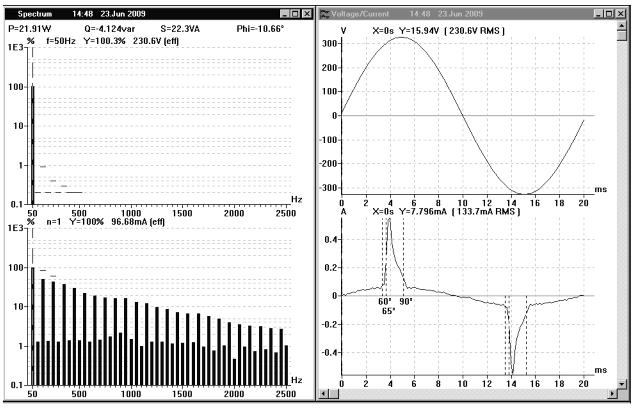


Fig. 4 Input current harmonics of the system

4.2. Conducted radio-frequency emissions

You can find the conducted radio frequency (RF) disturbance test results of a dimmer (Fig. 5a) and the dimmable CFL (Fig. 5b) in the following. It can be seen that both meet the requirements of the standard and the measured disturbances are below the limit. However, if we test the dimmer and the dimmable CFL as a system, the emitted disturbance voltage might exceed the limit (Fig. 5c).

One of the reasons why the emission is over the limit line is the ringing of the input current (so called multiple ignition of the triac) as you can see in Fig. 6. When the input current drops below the hold current during this ringing, or crosses zero, the triac is turned off. After some time the triac is ignited again and then switches off again. This phenomenon might be prevented by using a power factor corrector (PFC) circuit in the ballast that provides a continuous current consumption that is over the hold current of the triac.

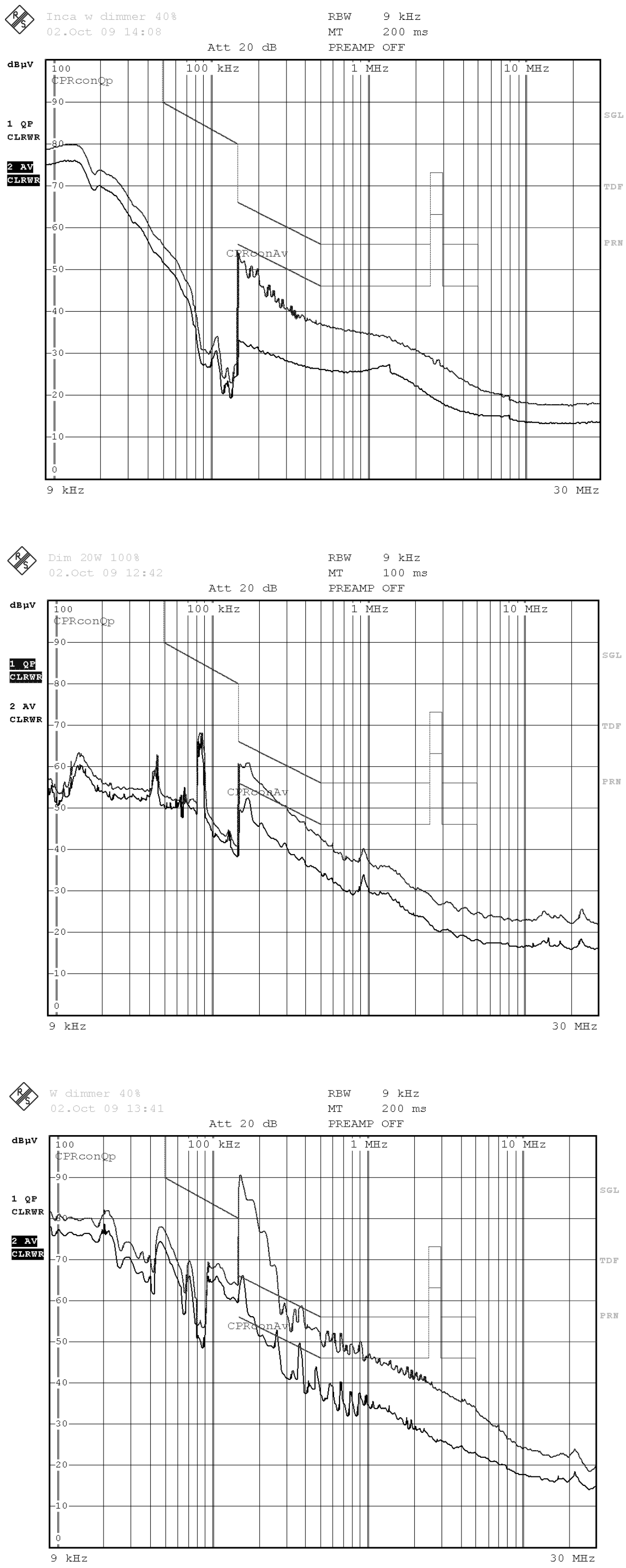


Fig. 5a/b/c Conducted RF emission from a dimmer; a dimmable CFL; and a CFL dimming system

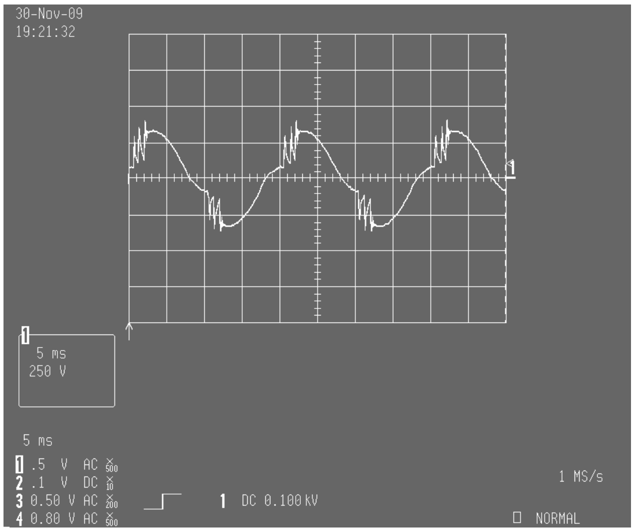


Fig. 6 Multiple ignition

A significant amount of RF emission is caused by the pulse-shaped input current of the CFL, which gets to a higher extent with the lower dimming levels. Fig. 7 shows the phase-cut input voltage (Ch 1), the input current (Ch 2) and the spectrum of the input current (Ch B) at the minimum dimming level. As we can see, the spectrum ranges up to 20 kHz. This frequency range has an effect on the results of both conducted emission tests (the mains harmonics and RF disturbance voltages) and furthermore, on the radiated RF fields of the system.

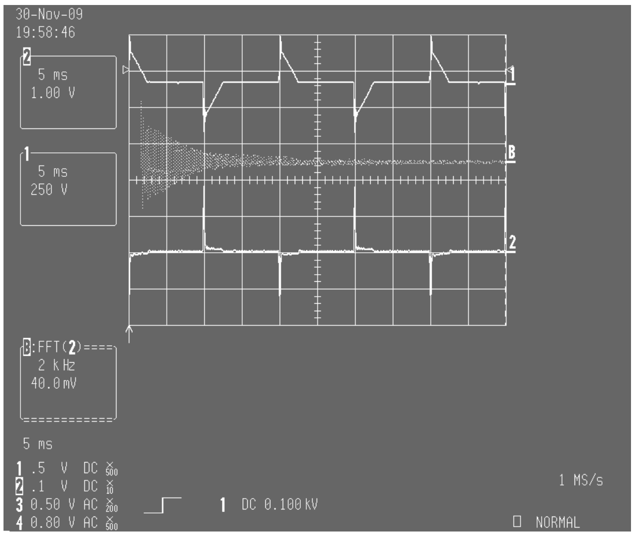


Fig. 7 Spectrum of the input current at minimum dimming level

Dimming with a transformer is a theoretical solution. The same dimming level might be achieved by using an input voltage transformer. Here a sinusoidal input voltage is supplied for the CFL while the amplitude of the voltage is decreased so as the average of the voltage is the same as in case of using the triac dimmer, so the reference voltage (dimming level) that is connected to the relevant pin of the dimming control IC is the same in both cases. In this case the input current waveform depends on the CFL ballast only (it is not affected by the ignition angle of the triac) and there is no multiple ignition either. The conducted RF test results are to be found in Fig. 8.

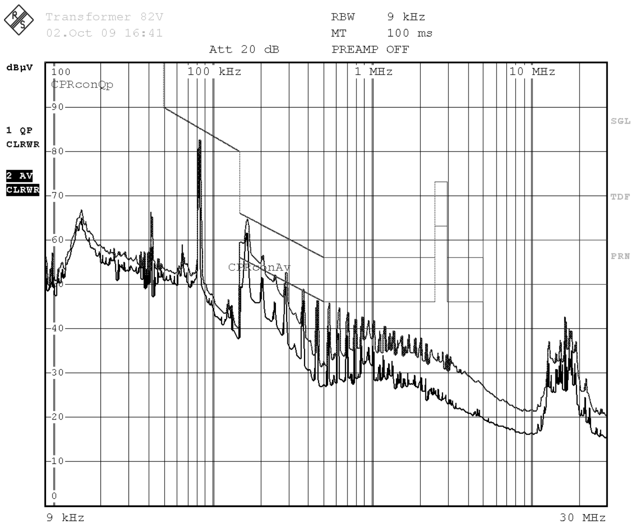


Fig. 8 Dimming with transformer

As per Fig. 3 the operation frequency is shifted to higher values when the lamp is dimmed. This might cause issues with meeting the conducted RF emission limits above 150 kHz (the limit value drops by 14dBµV at this frequency). If the 3rd harmonic of the fundamental frequency is over it (the fundamental frequency is over 50 kHz), there is a bigger chance that the system will exceed the limit at this range.

4.3. Radiated emissions

The EN55015 requires the radiated RF emission to be tested in the 3 orthogonal planes of a Van Veen Loop Antenna (Fig. 9a/b/c) in the frequency range of 9 kHz – 30 MHz. This type of antenna is intended to measure the magnetic field generated by the EUT in the near field. As it can be seen, the perceived signal is low in all planes (the sharp change at 150 kHz is caused by the changing of the resolution bandwidth of the receiver's detector from 200 Hz to 9 kHz); practically we only see the emission line at the operation frequency and the background noise.

In order to have a higher sensitivity and the emission is considered to be rather of electric type, a GTEM (gigahertz transversal electromagnetic) test cell was utilized. Similarly to the Van Veen-loop testing, 3 orthogonal orientations were used. Only the X-plane results will be presented, as the radiation pattern is very similar in all planes.

Fig. 10a shows the radiated field of the dimming CFL system at 100% dimming level. Fig. 10b shows the same settings, although the dimmed lamp type is an incandescent 60 W lamp. The measured field when the latter is dimmed is practically the background noise of the test system. The change at 150 kHz is caused again by the change of the resolution bandwidth of the detector. It's easy to recognize the emitted spectrum lines at the operation frequency and its upper harmonics.

The most significant noise source was to be identified. Therefore each individual parts of the system were shielded. The shield was connected to the ground (the floor of the GTEM test cell). No significant difference was found compared to the above when the mains cable and the dimmer were shielded (see Fig. 11a). In case when

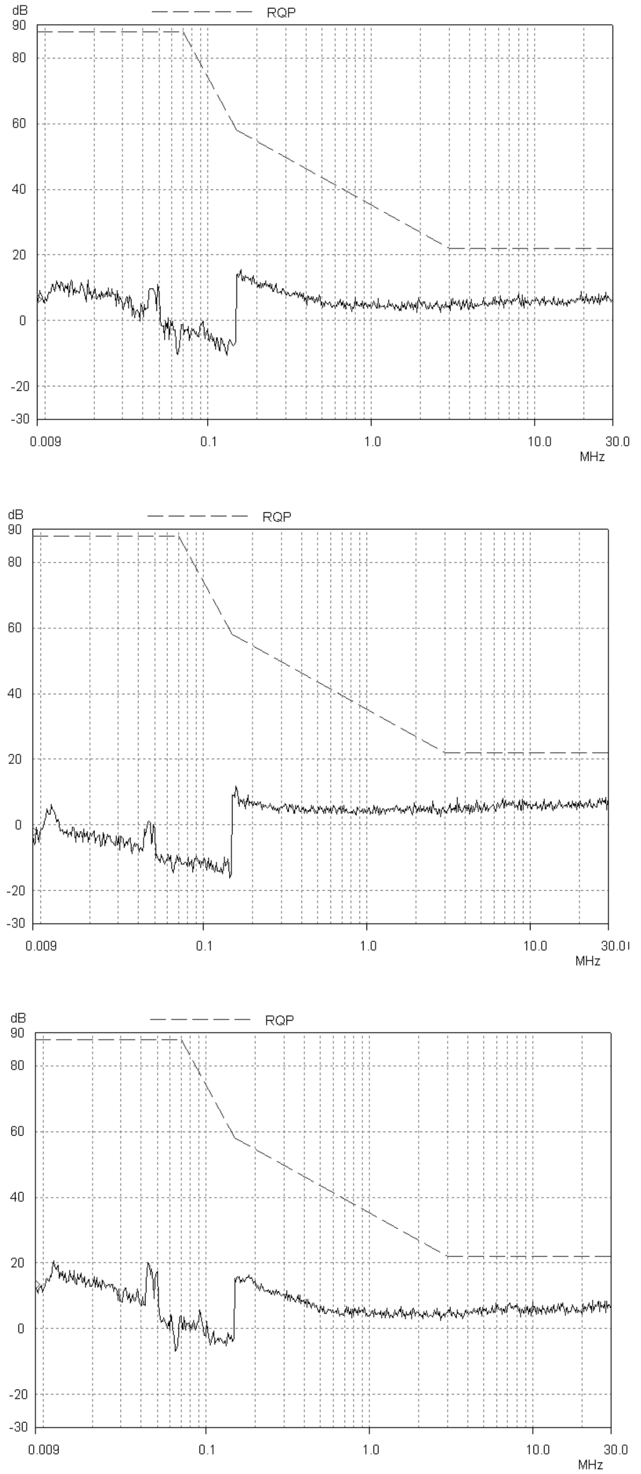


Fig. 9a/b/c Radiated electromagnetic field test results in 3 planes

the wirelamp was shielded, we managed to decrease the radiation level to almost the background level (compare with Fig. 11b). The peak at ~15 MHz is caused by cable resonances.

A biconilog antenna was used for measuring the radiated emissions of the dimming CFL system in the frequency range of 30 MHz – 1 GHz according to the EN55022 standard. You can see in Fig. 12a that in contrast with our expectation (we are far above the operation frequency) emission lines can be found between 50 and 200 MHz in vertical polarization. No emission was

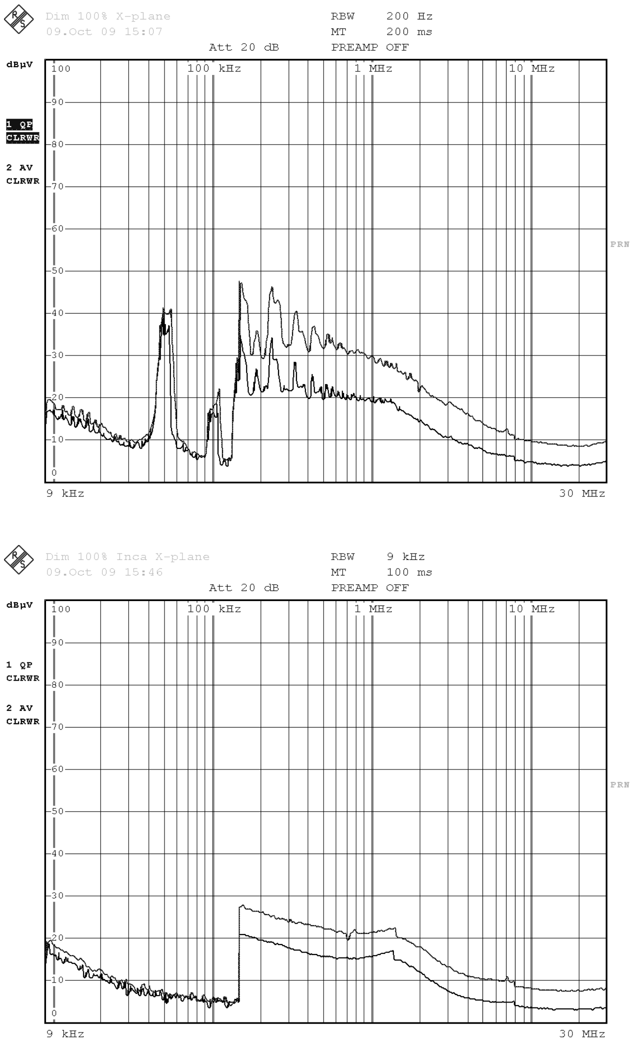
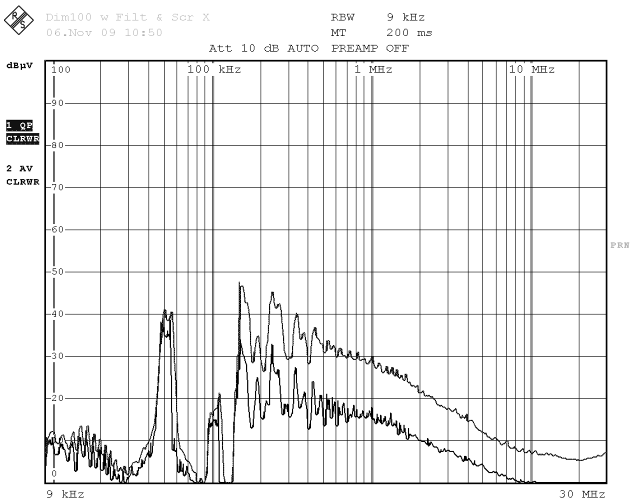


Fig. 10a/b Radiated emission from a CFL and an incandescent dimming system

found in horizontal polarization. The source of the radiation is the mains cable and the difference in the test results with horizontal and vertical orientations agrees well with its orientation. The shielding of the mains cable blocked the radiation; the result can be seen in Fig. 12b. No emission can be observed. This denotes that the wirelamp does not radiate in the frequency range of 30 MHz – 1 GHz.



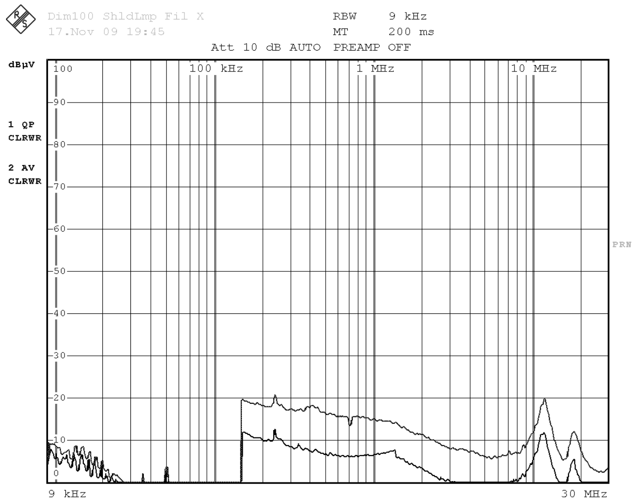


Fig. 11a/b Radiated emission from a CFL dimming system – shielded mains cable/shielded wirelamp

5. CONCLUSION

The operation of dimmable CFLs and CFL dimming systems was described and analyzed in the paper by EMC point of view. The increasing number of CFL dimming systems highlights the significance of the electromagnetic compatibility of these devices with other electric/electronic products in each operation states.

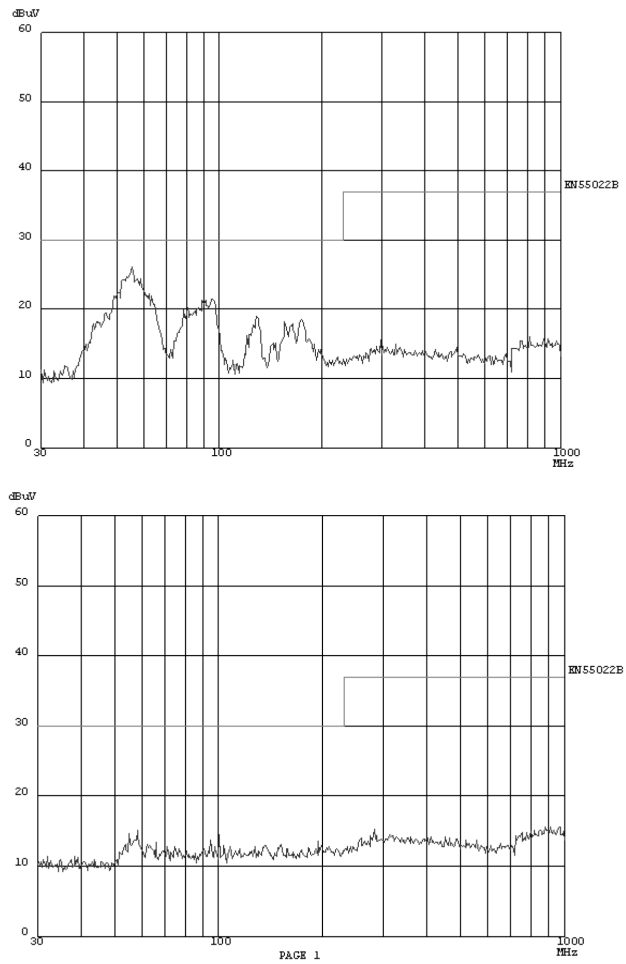


Fig. 12a/b Radiated emission 30 MHz -1 GHz, vertical polarization – normal and shielded mains cable

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