

# An Electromagnetic Interference Problem via the Mains Distribution Networks

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**Abstract**—The paper presents an electromagnetic interference problem, due to the proximity of two radio broadcasting stations which injected especially common mode conducted emissions over the maximal limits specified by the national regulations in the public low voltage mains network. These emissions determined the malfunction of the gas heating centrals Themaclassic Saunier Duval installed in the area. The problem was solved by the retro fitting of an extra EMI filter for the mains network, as presented in the paper.

**Index Terms**—electromagnetic interference, conducted emissions, EMI filter, transfer characteristic

## I. INTRODUCTION

Electromagnetic interference (EMI) is a serious and increasing form of environmental pollution. The threat of EMI is controlled by adopting the practices of electromagnetic compatibility (EMC), which has two complementary aspects: it describes the ability of electrical and electronic systems to operate without interfering with other systems and also describes the ability of such systems to operate as intended within a specified electromagnetic environment.

## II. A CONDUCTED EMISSION PROBLEM [3]

In the situation presented below we have analyzed and solved a severe problem of conducted RF emissions, occurred in a village, at 25km from the town of Cluj-Napoca, Romania, due to the presence in the neighborhood of two radio broadcasting stations (amplitude modulated, with carrier frequencies  $f_1=1152$  kHz,  $f_2=909$  kHz, and output powers  $P_1=400$  kW,  $P_2=200$  kW).

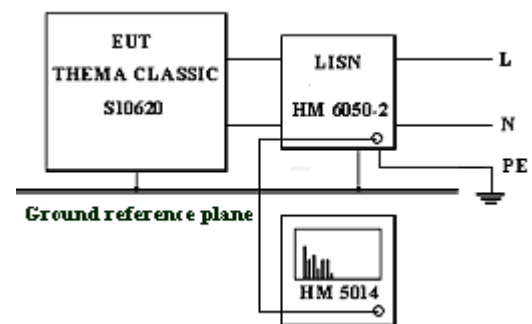


Figure 1. Setup for measuring conducted interference on the mains network

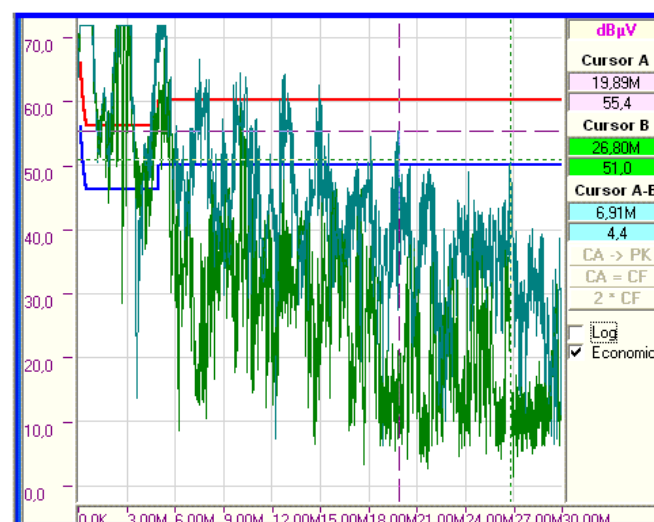


Figure 2. RF conducted emissions injected on the public mains network by the radio broadcasting stations

Interference can propagate from a source to a victim via the mains distribution network to which both are connected. This is not well characterized at high frequencies, especially since connected electrical loads can present virtually any RF impedance at their point of connection [2].

Because of the proximity of the stations, the gas heating centrals Themaclassic Saunier Duval (heating power of 24 kW), installed in the houses of the village, presented malfunctions, and gave error messages on the interface display.

We have measured the RF noise level injected in the mains network (using the spectrum analyzer HM 5014 and the line impedance stabilization network HM 6050-2, from Hameg Instruments) with the setup presented in fig. 1, in which the LISN connection is reversed.

According Romanian specifications, the maximum allowed RF noise level injected in the public low voltage network in the frequency range 150 kHz -30 MHz, must be 52dB $\mu$ V.

Measurements revealed a noise spectrum with levels exceeding 72dB $\mu$ V (20dB $\mu$ V in plus), at the carrier frequency and its odd harmonics, both on the L and the N conductors (fig. 2).

The immunity tests (surge, burst, dips and interruptions) carried out with the immunity testing equipment Best EMC (from Schaffner Instruments) for the electrical circuitry of the gas heating central revealed the conformity with the basic standard for electromagnetic compatibility, EN 61000-4.

The conducted emissions tests measured with a similar setup like the one from fig. 1 (LISN is now directly connected), also revealed the conformity with the basic standard for electromagnetic emissions, EN 50011, as it can be seen in fig. 3.

### III. EMI MAINS FILTERS

Mains filters carry potentially high currents at dangerously high voltages, so care is essential in their choice. The working voltage and current rating of components can be decided once the specification is known. The basic specification should also include mechanical details such as the enclosure size, method of king and any limit on its weight. The electrical specification should include the voltage and current rating. In addition the EMC performance and the allowable leakage current should be specified. The electrical specification must comply with national safety standards.

Filters work on the principal of providing a large discontinuity in the characteristic impedance seen by an unwanted signal. The intention is to reflect most of this unwanted energy back to its source.

If a filter contains lossy elements, such as a resistor or ferrite component, then the noise energy may be absorbed and dissipated within the filter. If it does not – i.e. if the elements are purely reactive – then the energy is reflected back to its source and must be dissipated elsewhere in the system. This is one of the most important features which distinguish EMI filter design from conventional signal filter design.

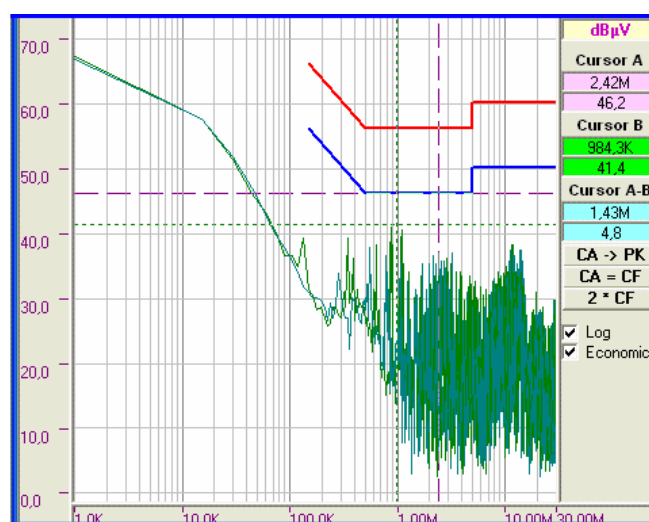


Figure 3. RF conducted emissions of the gas heating central Themaclassic

The noise levels are below the average and the cvasipeak values, according to the standard in the frequency range of 150 kHz- 30 MHz.

Although the gas heating central fulfils the EMC compliance, it can be seen that at the frequency of interest (1MHz and its following five odd harmonics) the emissions level is only 4dB $\mu$ V lower than the average value specified by the emission standard.

According to the reciprocity property of the passive filter, emission levels passed in the low voltage mains network represents also the capability of filter in rejecting the incoming emissions and that slight difference of only 4dB $\mu$ V explain the immunity problem of the gas heating central in the proximity of the radio broadcasting stations.

The filter fitted on the low voltage supply lines of the gas heating central Themaclassic is not enough to insure its immunity in these special conditions.

Mains filters are tested with a 50 $\Omega$  source and load impedance because most RF test equipment has a characteristic impedance of 50 $\Omega$ . This allows consistent test results and allows direct comparison between one design and another.

However, because the source and load impedance is not generally 50 $\Omega$  in practical situations, the attenuation predicted for a design based on this specification is generally optimistic compared with its performance in working equipment.

In the real applications, the source and load impedances,  $Z_s$  and  $Z_L$ , are complex and in general unknown at the frequencies of interest for suppression [1].

If either or both has a substantial reactive component then resonances are created which may convert an insertion loss into an insertion gain at some frequencies.

In the case of mains supplies, the source and load impedance varies widely with frequency. The source impedance is variable over time and can be anywhere from

2Ω to 2000Ω. The actual impedance is dependent on the loads that are connected to it and the frequency of interest. The characteristic impedance of the mains lead to the load is around 150 Ω, and the load itself may have variable impedance.

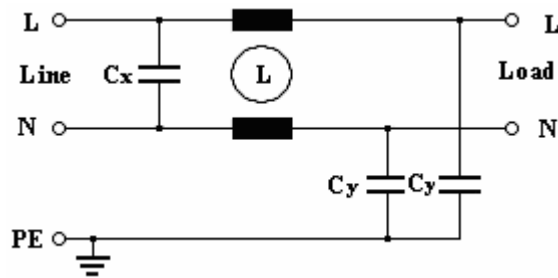


Figure 4. Typical mains filter

Differential mode impedances may be predictable if the components which make up the source and load are well characterized at RF, but common mode impedances such as are presented by cables or the stray reactances of mechanical structures are essentially unpredictable. Practically, cables have been found to have common mode impedances in the region of 100 Ω to 400Ω, except at resonance, and a figure of 150 Ω is commonly taken for a rule of thumb [2].

winding but safety requirements normally preclude this, dictating a minimum separation gap between the windings.

Capacitors CY attenuate common mode interference. The effectiveness of the CY capacitors depends very much on the common mode source impedance of the equipment. This is usually a function of stray capacitance coupling to earth which depends critically on the mechanical layout of the circuit and the primary-to-secondary capacitance of the mains transformer, and can easily exceed 1000pF. The attenuation offered by the potential divider effect of CY may be no more than 15–20 dB.

The common mode choke is the more effective component, and in cases where CY is very severely limited more than one common mode choke may be needed.

Capacitor CX attenuates differential mode only but can have fairly high values, 0.1 to 0.47mF being typical.

CY is limited in value by the permissible current which may flow in the safety earth, due to the mains operating voltage (or under certain fault conditions).

Values for this current range from 0.25mA to 5mA depending on the approvals authority, safety class and use of the apparatus.

For the chosen filter of this application, (F.A.M.D–.3600.ZC, Arcotronics Ltd.), the measured transfer characteristics, both in differential and common mode

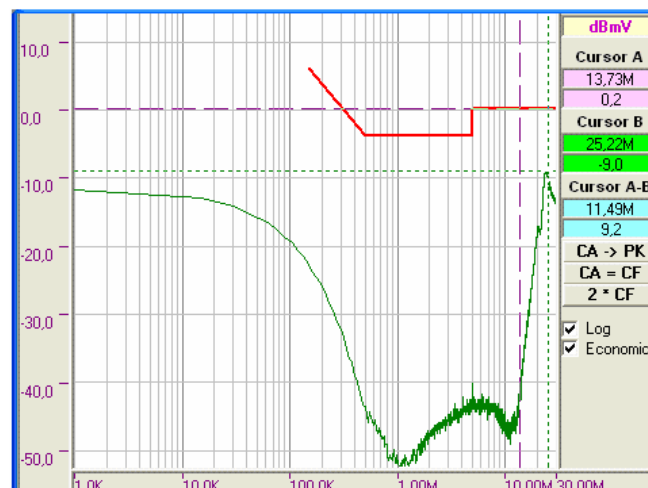


Figure 5. F.A.M.D–.3600.ZC transfer characteristics in differential mode

A typical ready-made filter (**F.A.M.D–.3600.ZC**, Arcotronics Ltd., fig. 4.) includes components to block both common mode and differential mode components.

The common mode choke L consists of two identical windings on a single high permeability toroidal core, configured so that differential (line-to-neutral) currents cancel each other.

This allows high inductance values, typically 1–10mH, in a small volume without fear of choke saturation caused by the mains frequency supply current.

The full inductance of each winding is available to attenuate common mode currents with respect to earth, but only the leakage inductance will attenuate differential mode interference. The performance of the filter in differential mode is therefore severely affected by the method of construction of the choke, since this determines the leakage inductance. A high leakage inductance will offer greater attenuation, but at the expense of a lower saturation current of the core. Low leakage inductance is achieved by bifilar

(using the tracking generated and the spectral analyzer, from HM 5014, Hameg Instruments), are given in fig. 5 and fig. 6.

The filter parameters are: CX=0,6μF (X2 class), CY= 2x2500pF (Y2 class), L=2x1mH, the leakage current IL=2x0.23mA and the temperature range -25°C to +85°C.

In the frequency range of interest we can see an attenuation of more than 50dB in the differential mode and of more than 40dB in the common mode.

Because of the reciprocity of passive EMI filters, we have once again measured the level of the conducted emissions of the gas heating central with extra mains filter, and its new emissions level in the frequency range of 150 kHz-30 MHz is given in fig. 7.

Comparing fig. 7 with fig. 3, we can see a drop of the noise level by 20dBμV in the frequency range of interest, which is a good indication that the choice of the filter was the right one.

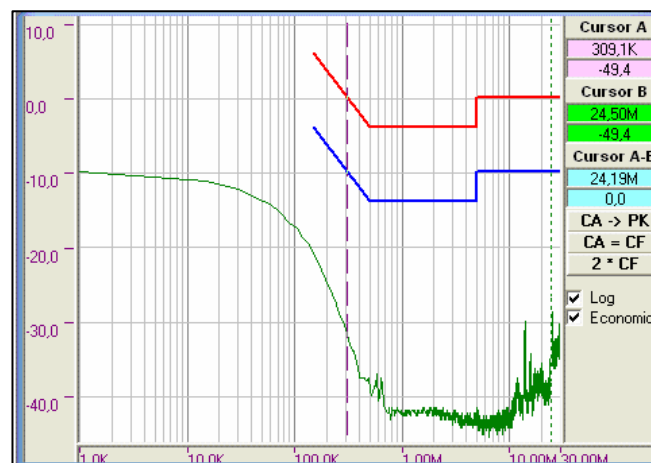


Figure 6. F.A.M.D-.3600.ZC transfer characteristics in common mode

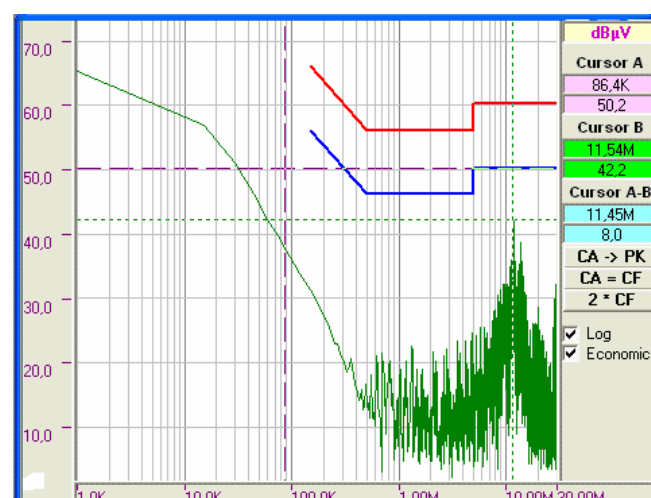


Figure 7. RF conducted emissions of the gas heating central Thema classic plus the extra EMI filter F.A.M.D-.3600.ZC

The installation of this extra EMI mains filter has solved the conducted immunity problem which occurred.

Similar problems have occurred in the proximity of other two radio broadcasting stations in Romania and the solution adopted was the same.

#### IV. CONCLUSION

Some of the reasons for the development and use of block mains filters are [2]:

- Mandatory conducted emission standards concentrate on the mains port
- Add-on “fit and forget” filters can be retro-fitted
- Safety approvals for the filter have already been achieved
- Many equipment designers are not familiar with RF filter design

In fact, the market for mains filters really took off with the introduction of regulations on conducted mains emissions, compounded by the rising popularity of the switch mode power supply.

With a switching supply, a mains filter is essential to meet these regulations and as we have seen, sometimes, in special conditions may be necessary an extra EMI filtering cell.

#### REFERENCES

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