A Framework for Characterizing Electromagnetic Interference from Indoor Power Line Communications

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Abstract

Power Line Communications (PLC) are commonly used in the indoor environment to set up a broadband network while using the existing electrical infrastructure. However, asymmetries in the electrical network are responsible for the conversion of the differential mode injected current into common mode current, which in turn generates undesired electromagnetic (EM) radiation. This paper presents a parametric study of the EM emissions due to indoor PLC, on the basis of Finite Difference Time Domain (FDTD) simulations and using a realistic coupler model. Results show the influence of the different parts of the electrical network and of the building structure on the radiated field.

1. Introduction

In the indoor residential or office environment, the Power Line Communication (PLC) technology reuses the low voltage electrical infrastructure to transmit HF signals in the frequency range from 1 MHz to 100 MHz. The communication channel between the transmitter and receiver is a difficult channel, generating a strong attenuation as well as multiple propagation paths. This paper emphasizes one of the main limitations linked with the PLC technology, namely the undesired radiation of electromagnetic (EM) signals. Indeed, the wires forming the electrical network were not initially designed to propagate communication signals at frequencies above 1 kHz. As a consequence, the PLC technology possibly generates a non-negligible EM radiation, which raises electromagnetic compatibility (EMC) issues. The impact of the PLC transmission on the EMC was studied, for instance, in the expert group ETSI Specialist Task Force 410 [1].

In this paper, a parametric study is conducted to analyse the EM radiation generated by PLC systems in an indoor environment. Section 2 presents the EMC issue linked with the PLC technology. The tools and models used for simulating the EM emissions from the electrical network are described in Section 3. Finally, Section 4 presents a parametric study of the radiation observed in different configurations.

2. Sources of EM emissions in the indoor PLC network

EM radiation from electrical wires is mainly due to the asymmetric nature of the power lines [2]. The impedance variation of the loads connected to the network, as well as the unbalanced length of the phase and neutral wires (for instance in the case of single pole lighting switches) contribute to the conversion of the differential mode PLC signal in common mode signal flowing throughout the network. The electrical wires transmitting the common mode signal act as an antenna, and part of the transmit power is radiated.

3. Simulation tools and models

3.1. Electromagnetic simulation tool

Several mathematical tools are available to resolve Maxwell's equations in a complex environment. One can cite the Finite Difference Time Domain method, the Method of Moments (MoM), or the Transmission Line Matrix (TLM) method. We chose to use a method in the time domain, able of treating volumes in order to process inhomogeneous environments. Among the tools available in our lab, we selected the software Time ElectroMagnetic Simulator (TEMSI), developed in the French laboratory XLim (UMR CNRS 7252). This tool based on the FDTD method also allows a specific processing of thin wires, using the formalism of Holland and Simpson [3]. It is thus particularly adapted to the simulation of wired networks in a complex environment.

3.2. Modelling the injection coupler

One of the key elements for a realistic assessment of the EM radiation due to PLC is the modelling of the signal injection coupler. In practice, the impedance that this device presents between the phase, neutral and protective earth wires is not symmetric, which plays a major role in the generation of common mode current. Figure 1 presents the injection coupler model used in our study.

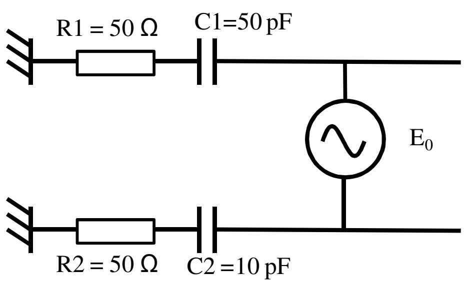

Fig. 1. Injection coupler model

In order to validate this model, we conducted a measurement of the electrical field at a distance of 0.50 m from a linear electrical network of length 3 m. The signal with a power of 0 dBm is injected using a laboratory coupler. Figure 2 shows a good agreement between the measured electrical field and the simulation using the coupler model.

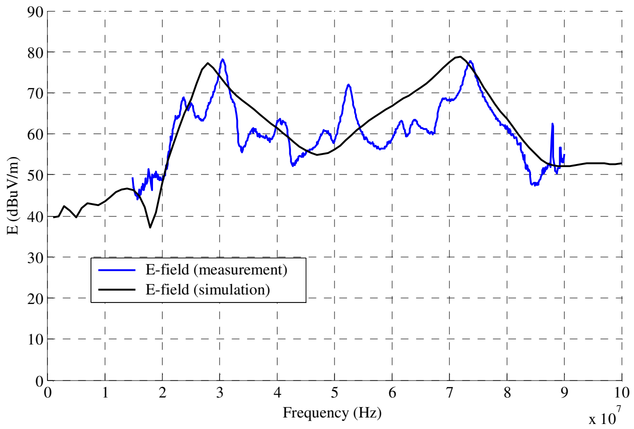

Fig. 2. Electrical field : measurement and simulation

4. Parametric Study

4.1. Influence of the electrical network

In a first step, the influence of the electrical network structure on the radiated field was studied by simulation. Several elements were considered, including the cable length, network branches length and the modeling of the electrical outlets [4]. As an example, Figure 3 shows the radiation generated by a two-wire cable of length 12 m at 60 MHz. We could highlight a resonance phenomenon as the cable length takes integer values of half-wavelengths, generating a stronger radiation.

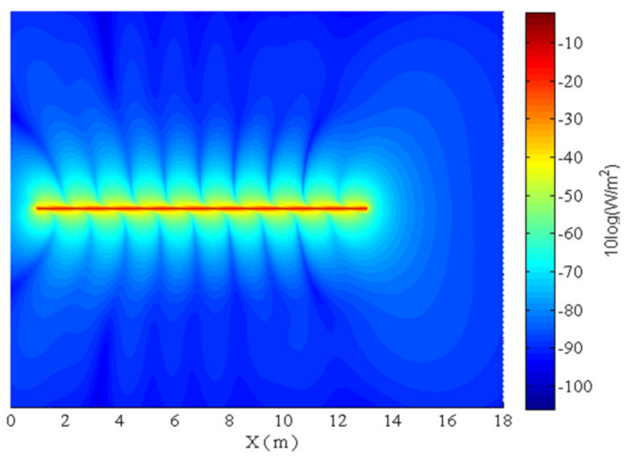

Fig.3.Radiation of a cable of 12 m

4.1. Influence of the environment

The second step of the parametric study focused on the analysis of the radiation due to an electrical network placed in a typical building architecture [4]. Figure 4 represents the electrical field simulated at 60 MHz in a building. We could observe that the walls, windows and doors affect the level of electrical field, independently from the presence of electrical wires in their vicinity.

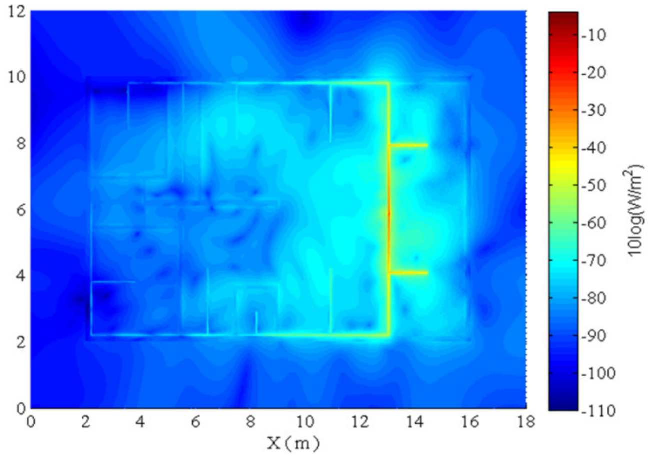

Fig.4.Influence of the building structure on the radiation

5. Conclusion

This paper presents a framework for studying EM emissions generated by the PLC systems in the frequency band 1 MHz to 100 MHz. This radiation is linked to the conversion of differential mode current in common mode current, which is due to unbalances in the indoor electrical network. Simulations were conducted using the FDTD method coupled with the formalism of Holland and Simpson, with a realistic coupler model. The parametric study shows that different network elements, such as the cable lengths and the impedance of the outlets, play an important role in the distribution of the generated EM radiation. In addition, the level of the perceived electrical field varies depending on the structure of the surrounding building. Future work will focus on the development of equivalent electrical network models in order to reduce the simulation complexity.

References

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