EMI in PLC: New Results on Predicting Transmission and Radiation Effects

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Abstract

Power distribution grids are exploited by Power Line Communication (PLC) technology to convey information in the context of Smart Grids and In-Home environments [1]. Their feature of using the existing cable infrastructure has the advantage for utilities of being proprietary and for residential users of granting wider range and possibly higher coverage compared to wireless technologies. On the other hand, the structure of such power line networks causes a relevant part of the high frequency signals traveling through them to be radiated instead of being conducted. This induce not only electromagnetic interference (EMI) with devices located next to power line cables, but also a consistent deterioration of the signal integrity. Although this phenomenon is known by the PLC community since its foundation, only few research papers deal with it [2], [3]. Since existing PLC channel models do not take into account losses due to radiation phenomena, this paper responds to the need of developing accurate network simulators.

In the paper [4] we proposed a comprehensive model of power line networks (PLNs) based on the physical description of both the conducted and radiated phenomena, with particular emphasis on broad band PLC that uses frequency in the range 2-86 MHz and is characterized by complex topologies as those found in home PLC networks. Such a model enables the simulation of complex networks in order to develop and improve PLC communication algorithms that can cope with both radiation losses and mode conversion. Eventually, it can be used to analyze the interaction of PLC with wireless communication technologies.

In order to characterize the conducted and radiated phenomena that occur along every branch of a PLN we make use of the transmission line super theory (TLST) [5]. In particular, we first consider the case of a two-wire transmission line surrounded by an homogeneous dielectric and extend the work of [6], including both differential and common mode signaling. We derive an analytic expression of the radiated power and propose an equivalent per-unit-length (PUL) model of the cable including the radiation losses, which we name multiple transmission and radiation line (MTRL) model. This model is applicable for beyond two conductors PLC networks. A scalable representation of a PLN can thereafter be made relying on the microwave network analysis theory. We show that an equivalent mixed-mode transmission matrix can be derived from the MTRL model of each branch. Moreover, all the devices that cannot be physically modeled due two their complex geometrical and circuit structure (couplers, sockets, etc. . .) can be still represented by an equivalent mixed-mode transmission matrix (MMTM). The chain rule of transmission matrices finally allows the cumulative analysis of the network properties. Therefore, the herein proposed approach allows the development of a bottom-up PLC channel model that accounts for both conducted and radiated fields, which significantly extends state-of-the-art PLC channel models presented in the literature [7].

The outcomes of this work allows each network element to be described by a mixed-mode transmission matrix. Furthermore, the classical per-unit-length equivalent circuit of transmission lines is improved to incorporate radiation resistances. The results of this paper enhance the knowledge for the future developments of comprehensive power line network models that incorporate conducted and radiated phenomena.

References

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