Analysis of EMC issues and throughputs of the PLC systems up to 100 MHz

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Abstract

In home networks advanced communication technologies has allowed the Power Line Communication (PLC) channel to be a transmission medium that enables the transferring of high-speed digital data over the classical indoor electrical wires. Nowadays, the increase of the customer's demand in terms of services leads to the fact that the 200 Mbps theoretical rates of the Homeplug AV specification are no still sufficient for transferring Internet, voice, HD videos, and data services simultaneously through the electrical support, especially as real data merely exceed 70 Mbps.

This paper deals with an Electromagnetic Compatibility analysis and throughput calculation of the PLC systems. The frequency band up to 30 MHz, characterizing actual PLC modems, is here pushed up to 100 MHz. The investigation is aimed to take into account the EMC constraints in order to increase PLC throughputs by extending the frequency band above 30 MHz.

1. Introduction

The Power Line Communications (PLC) appointed for future wideband wired services in the 2-30 MHz frequency band envisage data transmission rates up to 200 Mbps [1]. Generally, effective data rates do not exceed 70 Mbps. In order to increase much more the data rates, the PLC equipment suppliers are studying the possibility of extending the PLC frequency band up to 100 MHz. The successful implementation of this solution requires a detailed knowledge of signal propagation modes inside this enlarged band.

In this paper a brief EMC analysis and throughput calculation of the Power Line Communications systems is carried out. First, the EMC analysis is based on the results of experiments related to the evaluation of the electromagnetic radiation due to the PLC signals; secondly throughputs are calculated for 144 transfer functions of PLC channel measured in 7 different sites.

Regarding Electromagnetic Compatibility (EMC), the electromagnetic emission limits for information technology equipment (ITE) are specified as conducted emission limits in frequency range below 30 MHz and as radiated emission for the frequencies above 30 MHz.

The issue of regulation versus the standardization of Power Line Communications is of high importance and is still under discussion within several standardization bodies and more especially in CIPSR I where the main target is to amend the EN 55022 standard [2].

In the 30 MHz – 100 MHz frequency band the allowed radiated emission limits are defined for two classes of environment:

- Class A radiated emission limits: intended to protect commercial/industrial environments.
- Class B radiated emission limits: intended to protect residential environments.

The first step of our work leads to the determination of the power emitted by the PLC modem in order to be compliant with the above limits in the frequency band up to 100MHz. Once the optimal Power Spectral density of the modem is determined, the next step is dedicated to the Capacities calculations of the whole measured PLC channels in order to demonstrate their throughputs.

2. EMC analysis

Within the framework of this study we carried out electric field measurement at a distance of 3 m from a 15 m long experimental PLC line which is not connected to the mains. Thanks to a biconical antenna the electric field is measured for several differentially injected PSD (Power Spectral Density) levels, as shows Figure 1.

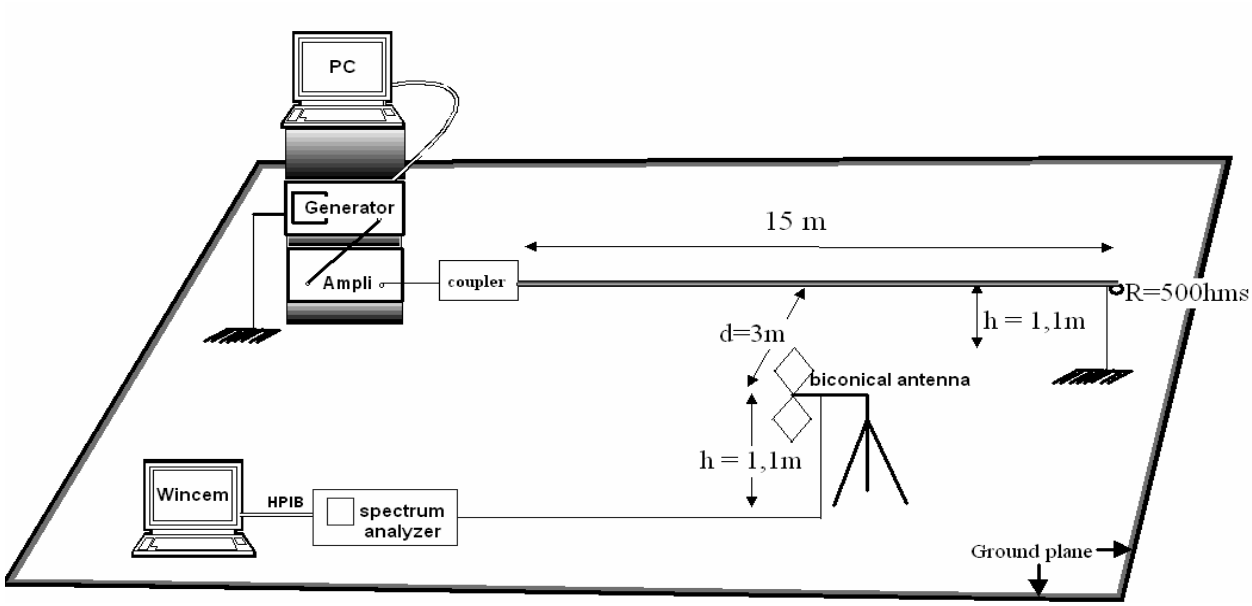

Fig. 1: E-field measurements set-up

A signal generator, connected to a laptop, is used to inject different PSD levels in the bands 2 MHz – 30 MHz and 30 MHz – 100 MHz, on the PLC cable installed in open area test site. A 40 dB amplifier is connected to the output of the signal generator in order to make the injected PSD levels comparable to those injected by a PLC modem. The collected data are recorded on a PC connected to the spectrum analyzer through a GPIB bus and controlled by dedicated software called WinCEM.

In order to validate our experimental protocol we have first carried out measurement of the radiated field inside an anechoic chamber in the 30 MHz – 100 MHz frequency band and using an Olitec PLC modem in the stand-up mode as reference.

Figure 2 shows the signal PSDs injected respectively by the PLC modem in the frequency band 2 MHz -30MHz and by the signal generator in the frequency band 2 MHz -100MHz.

Thanks to the amplifier at the output of the signal generator, the PSD of the signal generator output is almost 25 dB higher than that of the Modem, in the 30 MHz – 100 MHz frequency band.

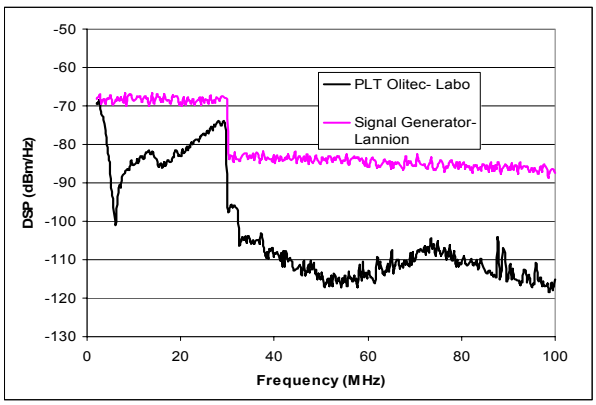

Fig. 2: PSD injected

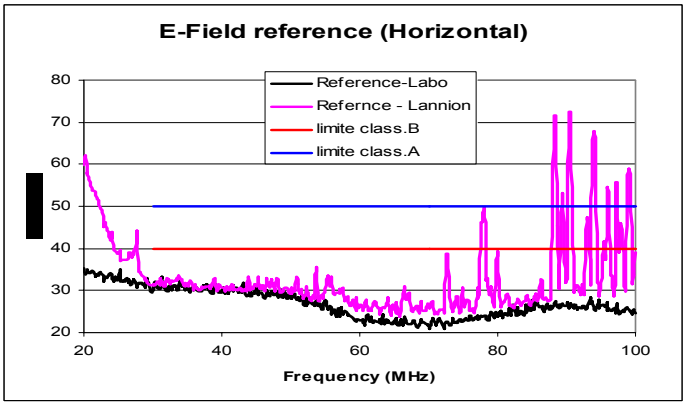

Fig. 3: Reference E-fields

Figure 3 gives the horizontal reference E-field (with no PLC signal injected in the cable) measured in the anechoic room and in the open area test site. This figure already demonstrates that injection in the [88– 100 MHz] band will not be facilitated since the presence of several FM radio emissions. We have also represented on this figure the class A radiation limit of the EN 55022 standard and the class B limit which is 10 dB lower.

As example the curves of figure 4 give the vertical component of the radiated E-field measured on the two sites for the injected signals of Figure 2.

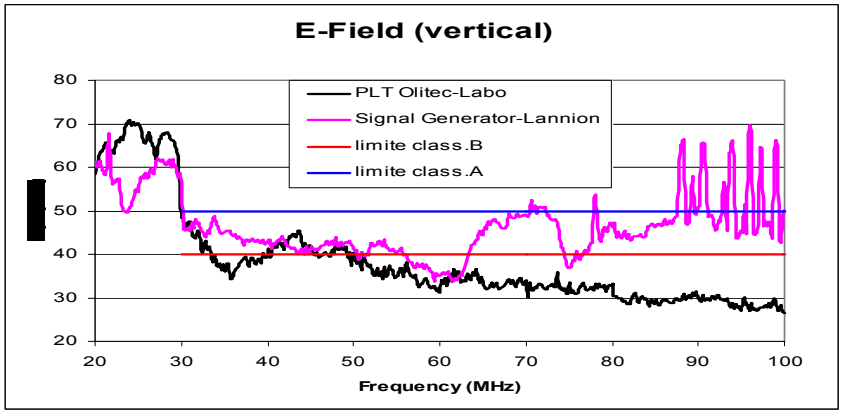

Fig. 4: Measurement of vertical component of E-field

Figure 4 demonstrates that the "weak" emitted level (almost equal to -85dBm/Hz) in the 30MHz-100MHz band, compared to the -50 dBm/Hz emitted by the PLC modems in the 2 MHz – 30 MHz band, is already non-conform to the class B limit. Class A limit is respected until 70MHz.

3. PLC channel characterizations up to 100 MHz

In order to assess the capacities of a PLC channel which respect the EMC constraints defined in the previous section we need to characterise the transfer function and stationary noise of PLC channels representative of real installations.

For such characterisation we have carried out measurement on different sites. The sites are different as they refer to country and urban, old recent and new, houses and apartments. The measured PLC transfer functions pertain to seven different sites and a total of 144 transfer functions were obtained.

We have classified the measured channels in different classes according to their Gaussian capacities given by the equation (1).

$$C = \Delta f \cdot \sum_{i=1}^{N} \log_2\left(1 + \frac{P_e \cdot |H(f_i)|^2}{P_b}\right) \text{ bits/s} \qquad (1)$$

Where :

Δf is intra-carrier frequency band and is equal to 25kHz, Pe is the -50dbm/hz transmitted power, and Pb is a -140dbm/hz white noise linear power.

The measured transfer functions were classified according to their capacities in 9 classes made up with a constant interval of 200 Mbps. The capacities are comprised between 1100 and 2700 Mbps.

The transfer functions of each class follow almost the same average frequency response as it can be seen on figure 5 which represents the transfer functions of class 2. The average attenuation is also represented on this figure.

As a consequence, we have proposed a channel attenuation model for each class. The curves of figure 6 show the gathered average attenuation models of the classes 1 to 9.

We have also carried out a lot of stationary noise measurements and built a model based on the statistical behavior of the recorded noises [3].

4. Capacities of the PLC channels

In this section, we suppose that respecting the Class A limit of the EN 55022 standard could be tolerated for the PLC modems under the following assumptions:

- 70MHz is fixed as an upper frequency limit, as the Class A isn't respected beyond.
- The transmitted PSD mask is equal to:
  - 50 dBm/Hz in the 2 MHz – 30 MHz band.
  - 80dBm/Hz in the 30 MHz – 70 MHz band.

Once the optimal Power Spectral density of the modem is determined, the next step is dedicated to the capacities calculations of the whole measured PLC channels in order to demonstrate their throughputs.

Throughputs are calculated for the 144 measured transfer functions, for the single stationary noise of figure 7, for a Discrete Multi-Tone (DMT) modulation whose carrier width is equal to 24.41KHz, for a Gap value equal to 9.9dB and for a bit loading [4] results that are discrete.

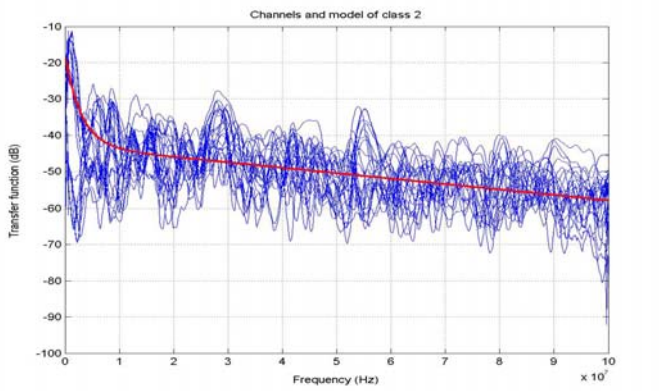

Fig. 5: Transfer functions of class 2

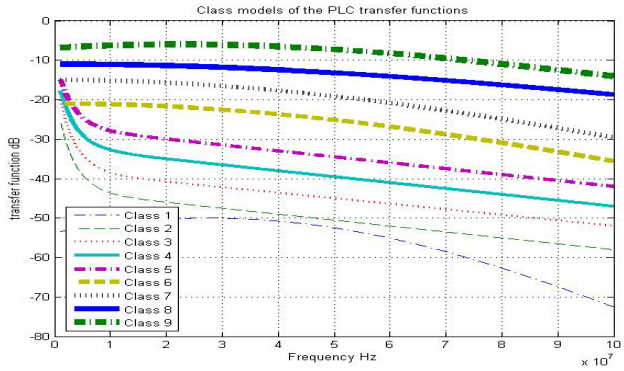

Fig. 6: Class models of Transfer functions

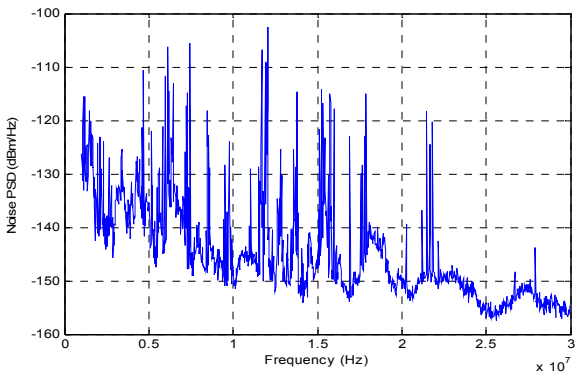

Fig. 7: Reference stationary noise

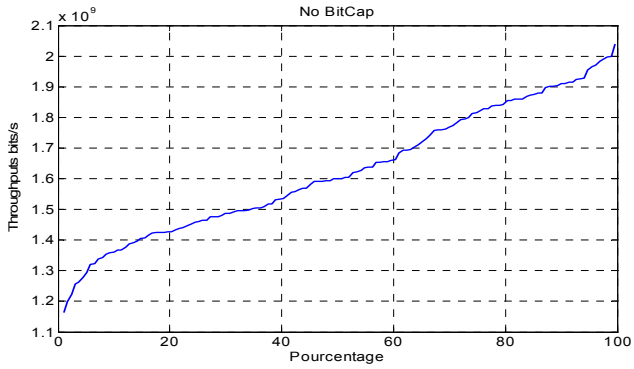

Fig. 8 : distribution of the measured channel capacities

In Figure 8 is depicted the distribution of the capacities of the measured transfer functions when no BitCap limit is considered [3]. Figure 8 demonstrate that the Gbps capacity is reached for the whole measured channels when the frequency band is enlarged to 70MHz, and when no BitCap limit is applied (50% of the channels have throughputs almost equal to 1.6Gbits/s).

5. Conclusion

A brief EMC analysis of the PLC systems has been carried out in the frequency band up to 100MHz. The investigation is aimed to study the possibility to extend the PLC frequency band above 30MHz. A primary observation demonstrates that the PSD level in the 30 MHz – 100 MHz would be around -80 dBm/Hz in order to respect the EMC constraints. Capacities calculations up to 70MHz demonstrated that the whole measured channels had throughputs higher than 1 Gbps, and that 50% of the channels have throughputs almost equal to 1.6 Gbps.

6. References

[1] Homeplug Powerline Alliance, "HomePlug AV Specification, Version 1.0.05", October 2006.

[2] EN 55022:1998 – "Information technology equipment – Radio disturbance characteristics – Limits and methods of measurement", includes CISPR 22:1997 and amendment A1:2000.

[3] M. Tlich,R. Razafferson, F. Gauthier, A. Zeddam, "Outline about EMC properties and throughputs of the PLC systems up to 100 MHz" , ISPLC proceedings , 2008, Singapore

[4] J.M. Cioffi, Lecture Notes for Advanced Digital Communications, Stanford, Fall 1997.