Study of the coexistence of VDSL2 and PLC by analysing the coupling between power line and telecommunications cable in the home network

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Abstract

PLC (Power Line Communications) and VDSL2 (Very high bit-rate Digital Subscriber Line) allow high bit-rate transmissions, through power line and copper pair respectively, but both technologies use the same frequency band. Consequently, these technologies could have to coexist in a home network inside the customer premises. This paper describes a theoretical analysis of the electromagnetic coupling between PLC and VDSL2 links. The effects of different parameters such as copper pair characteristics distance between the power line and the copper pair are presented.

1. Introduction

Nowadays PLC (Power Line Communications) technology allows high bit-rate transmissions in domestic network by taking advantage of the power grid abundance inside the customer premises. PLC is mainly used between the HG (Home Gateway) and the STB (Set-Top-box) to supply video service (IPTV). In the same time triple play services and applications are becoming widespread and need high data rates. So as to meet this growing need to high bit-rate, the next generation networks will be based on VDSL2 (Very high bit-rate Digital Subscriber Line) access technology [1] trough the copper pair. Nevertheless, the both technologies use band plans which overlap: [1.8 - 30] MHz for PLC and [0.138 – 30] MHz for VDSL2 generating electromagnetic compatibility issues [2]. In customer premises, the power line and the copper pair can be closely located. The power lines are not balanced and consequently some undesirable radiated emissions may occur during PLC transmissions. Such emissions could be coupled with copper pair and consequently may impact the VDSL2 performances. This paper describes a theoretical study of the coupling between PLC and VDSL2 links in the home network. In the first part the theoretical approach used to simulate and calculate the coupling is described. The second part is dedicated to the analysis of simulation results. Finally the impact of such coupling on VDSL2 data rates is discussed.

2. Theoretical approach

In order to study the coupling between VDSL2 and PLC links, we chose to use modeling tools based on transmission line theory (TLT). The mathematical and computational simplicity of the model, added to the good accuracy demonstrated by many different authors [3-4] basically justified this choice.

Figure 1 shows the reference configuration of the coupling study. PLC and VDSL2 links are presented as MTL: unshielded three-wire power line and unshielded 4-pair telephone cable for VDSL2 link, which are above an ideal ground plane. The conductors are assumed infinitely long and the ground plane is infinitely extended. *hj* corresponds to the height between the reference ground plane and the centers of both lines and is fixed to 3m.

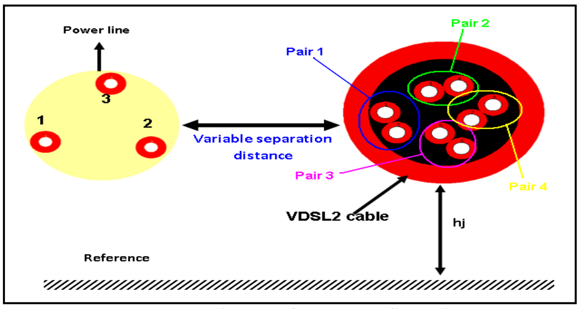

Fig.1 Reference configuration

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The data processing and calculations were realized by means of a simulation tool, developed and already used for similar studies in [5]. The power spectral density (PSD) used in order to simulate a PLC communication was -55 dBm/Hz. This level corresponds to the PSD mean value measured between two PLC modems. For the simulations, we used L-C parameters corresponding to three telecom cable types: untwisted wires, twisted wires of category 3 and of category 5 which are typically installed in French customer's access networks.

3. Analysis of simulation results

3.1. Effect of cable type

In this part, we analyze the influence of the copper pair type on PLC-VDSL2 coupling. The PLC and VDSL2 links were first assumed in contact. The coupling due to PLC is calculated for each cable type with a copper pair of 20m length. Figure 4 shows the induced PSD by PLC on the copper pair according to the cable type. As expected, the coupling is stronger on untwisted wires than on twisted wires. The results show that the mean level of coupled noise varies from -147.3 to -135 dBm/Hz and from -148.5 to -135.8 dBm/Hz, for category 3 and category 5 copper pair respectively. The coupled noise is stronger with category 3 than category 5 cable and can be explained by the difference of the unbalance of the two cables.

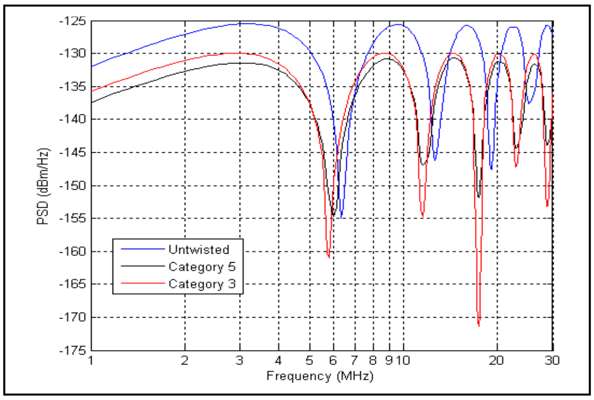

Fig.2 Induced noise by PLC on the adjacent copper pair according to the copper pair type

3.2. Effect of coexistence length

In home networks, according to the customer premises power and copper pair grids the coexistence length between PLC and VDSL2 links is a variable parameter. For this reason, the coupling induced by PLC is calculated for the twisted category 3 copper pair with four lengths: 1, 5, 20 and 40m. The power line and copper pair are still considered in contact. Figure 5 shows the induced PSD of the coupling noise by PLC on the copper pair according to the cable length. The results show that the mean level of the coupled noise varies from -147.3 to -135 dBm/Hz when the cable length varies from 1 to 40m. Moreover we observed that the level of the coupling noise is increasing with frequency. The notches frequencies vary according to the copper pair length.

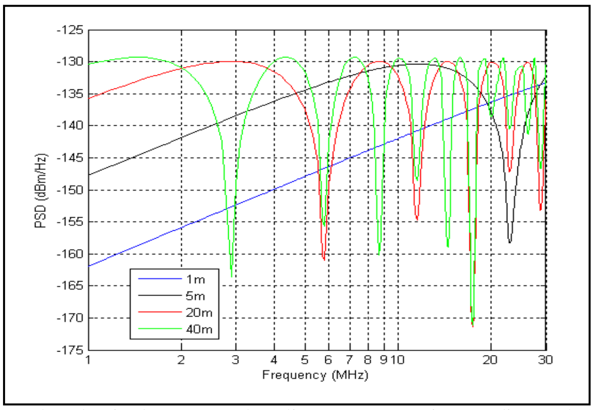

Fig.3 Induced noise by PLC on the adjacent copper pair according to the copper pair length

3.3. Effect of distance separating power line and copper pair cable

In this part, we study the influence of the distance separating PLC and VDSL2 links. This parameter is very important for the assessment of the noise induced by PLC on copper pair. Figure 6 presents the induced noise PSD for a 20m category 3 copper pair when it is distant 0, 1, 6 and 20cm away from the power line. The induced noise decreases significantly when the distance between power line and copper pair cable increases. The level of coupled noise varies from -151.2 dBm/Hz when the cables are 20 cm separated to -134.9 dBm/Hz when they are in contact.

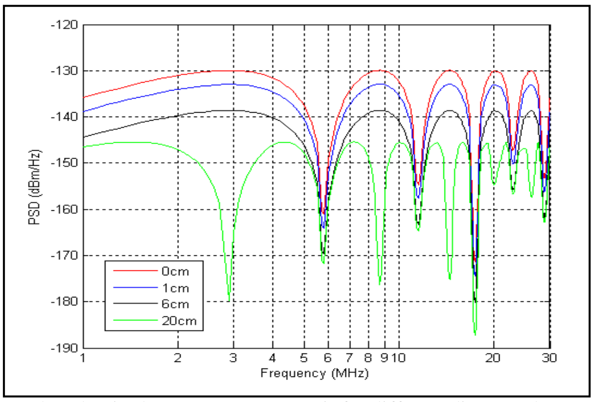

Fig.4 Induced noise by PLC on copper pair for different distances between them

4. Coexistence of VDSL2 and PLC : impact of induced noise on VDSL2 data rates

In order to assess the effects of the simulated PLC coupling noises, we calculate the VDSL2 theoretical data rates. For the simulations, we have considered a FTTCab (Fiber To The Cabinet) configuration with VDSL2 parameters compliant with ITU-T G.993.2 standard [1]. The frequency band plan was “998ADE17”. The cable parameters, for attenuation calculation, are of shielded cable series 298 [6] corresponding to category 3 copper pairs. The data rate calculation is fulfilled according to the P.S. Chow algorithm [7], used in xDSL systems, which is based on the Shannon's capacity formula:

$$B = \sum_{i=1}^{N} \log_2\left(1 + \frac{SNR_i}{\left[\Gamma(Pe) + \gamma_m\right](dB)}\right) \tag{1}$$

Where SNR_i denotes the signal-to-noise ratio for each sub-carrier i, $\Gamma(Pe)$ is the gap for a target error probability Pe, N the number of sub-carriers, and γ_m is the noise margin.
VDSL2 simulation parameters are:

- The target bit error probability Pe is fixed to 10^{-7}, as in most xDSL systems corresponding to $\Gamma(Pe) = 9.9$ dB [8].
- The noise margin γ_m is set to 6 dB.
- The Frequency band is [0.138 – 17.664] MHz with 2916 sub-carriers spaced by 4.3125 KHz.
- The transmitted PSD is set to -60 dBm/Hz.

In figure 7 we have reported, the theoretical data rates calculated by taking into account the induced noise by power line on category 3 copper pair for the following three cases:

- Case 1: coexistence length of 1m and distance separating the both lines of 20cm (optimistic case);
- Case 2: 5m of coexistence length and 1cm of separation;
- Case 3: 40m of coexistence length and lines were in contact (pessimistic case).

The mean level of induced noise by PLC for the case 1 is equal to -163 dBm/Hz. In a realistic home network, we can assume that this coupling level will not be harmful for the VDSL2 system and will be hidden by the coloured background noise of the copper pair. Theoretical data rates for the case 1 are then considered as the reference for VDSL2 data rates for comparisons with cases 2 and 3.
The PLC coupling leads to a data rate loss of about 40% and 60% for case 2 and case 3 respectively. These results are comparable to those given in [9] where the coupling noises induced by PLC were measured in real customer premises. This confirms the significant impact of PLC coupling on VDSL2 performances.

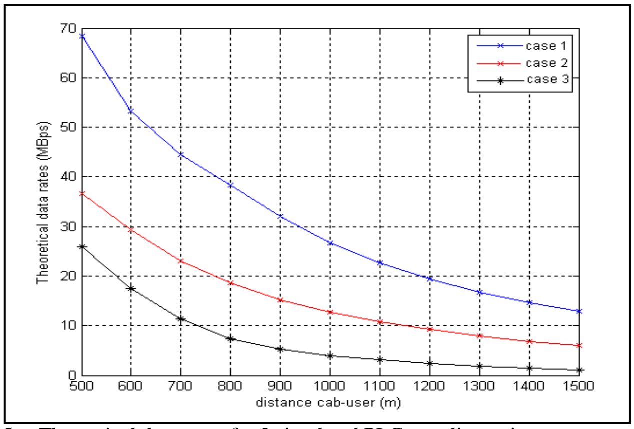

Fig.5 Theoretical data-rates for 3 simulated PLC coupling noises on copper pair

Starting from these observations and those ones presented in [10], mitigation techniques can be studied in order to ensure good performances of VDSL2 transmissions. Among possible mitigation techniques we can indicate: the adaptive interference cancelling filter and the spectral management [11].

5. Conclusion

This paper provides a theoretical analysis of radiated coupling between PLC and VDSL2 links both located in the customer premises. The simulation tool based on transmission line theory allowed us to have a good knowledge about the coupling mechanisms in home network. The results of a parametric study showed:

- The distance separating the power lines and copper pair cables has much influence on coupled noise, whatever the length. By separating the power lines and the copper pair cables by only 6cm, the mean level of the coupled noise considerably decreases.
- As expected, the coexistence length influences the coupling noise level, which increases with the length of the copper pair cable.
- For twisted copper pair cables, the unbalance of the pairs influences the level of coupled noise.
- The coupling noise induced by PLC in pessimistic cases 2 and 3 showed a significant impact on the theoretical VDSL2 data rates (data rate loss of about 60%).

Mitigation techniques have to be undertaken in order to allow good performances of VDSL2 transmissions.

7. References

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