# Comparison of in-house and in-vehicle noise characteristics in PLC systems

*V. Degardin[1], F. Rouissi[2], M. Lienard[1], P. Degauque[1], A. Zeddam[3]*

[1]University of Lille, Lab. IEMN /TELICE, Bldg P3, 59655 Villeneuve d'Ascq Cedex, France,
virginie.degardin@univ-lille1.fr
[2]Ecole Supérieure des Communications de Tunis (SUP'COM), Lab. CIRTACOM, Tunisia,
rouissi.fatma@supcom.rnu.tn
[3] France Telecom R&D, 2, avenue Pierre Marzin 22307 Lannion, France,
ahmed.zeddam@orange-ftgroup.com

## Abstract

This paper deals with the analysis and the characterization of impulsive noise measured on the power line network either in a house or in few cars. The objective is to make a comparison between in-house and in-vehicle impulsive noise, in terms of their characteristic parameters as amplitude, frequency content and duration, and the possible impact of such pulses on a high bit rate communication.

## 1. Introduction

Power Line Communication (PLC) is now a common way of communication on indoor network and a lot of modems based on HomePlug [1] or OPERA [2] specifications are on the market. A theoretical bit rate of 150 Mbit/s can be achieved. This is the reason why, for automotive applications, a PLC solution has also been envisaged by car manufacturers. Indeed, the ever growing development of safety and comfort equipments needs high bit rate and this also leads to an increase of the communication wires with a negative impact on reliability.

One of the differences between indoor and car environments is the compatibility which must be insured with secure equipments connected to the car network. To cope with this difficulty, the emitted power would be lower than the authorized one in indoor environment. The other difference is the communication channel itself; the in-vehicle power line network supplies numerous electric systems, with cable lengths smaller or on the order of few meters. Furthermore, contrary to the case of an in-house power line, the power DC line usually belongs to a cable bundle behaving as a multi conductor transmission line. In this paper, we do not consider the characterization of the channel transfer function but we emphasize impulsive noise aspects.

## 2. Impulsive Noise Measurement Systems

Measurement systems have been developed by France Telecom R&D and IEMN/Telice for in-house and in-vehicle environments, respectively. They are based on the storage of successive events, the triggering level being adjusted from 100 to 300 mV. The sampling frequency is 100 MHz. After triggering, the width of the observation window is about 650 µs. The system also allows measuring the time interval between successive pulses.

Experiments have been carried out in a house and in 5 up market vehicles, the car moving in an urban environment. The raw data must be processed in order to extract the impulsive noise from the white background noise whose spectral density is -140 and -130 dBm/Hz for indoor and in-vehicle networks. It clearly appears that the transients can be divided into two classes: single transients looking like a damped sinusoid, and bursts defined as a succession of elementary pulses. Typical recorded bursts are shown in Fig. 1a in a house and in Fig. 1b in a vehicle. For these two groups, a statistical analysis is performed, based on the pulse characteristics as its frequency content, peak amplitude, duration and on the time interval between successive pulses.

## 3. Impulsive noise characteristics

In this part, a comparative study is presented. The main criteria for pulses classification are their temporal shape, amplitude, frequency content, power, mean duration and, lastly, interarrival time, i.e. the time interval between two successive pulses. In the last paragraph 3.3, only pulses whose pseudo-frequencies are within the 4 – 21 MHz frequency band are taken into account, this band corresponding to the usual frequency content of OFDM/PLC systems following the standard HP1.0 [1].

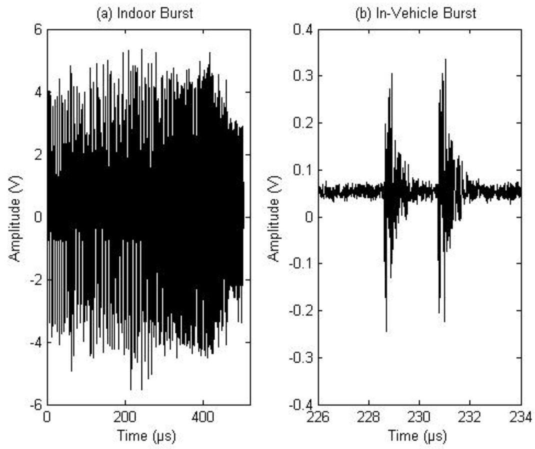


Fig. 1: Typical Burst recording: (a) Indoor environment, and (b) In-Vehicle environment

## 3.1 Pulse shape

From a preliminary study on the temporal shape of the impulsive noise, the percentage of occurrence of single transients and of bursts is given in Table 1 for both environments. It appears that the vehicle electric network is characterized by a very high probability to get single transients. On the contrary, in-house, the burst occurrence is the highest one.

| | Single Transient | Burst |
|---|---|---|
| Indoor | 41.8% | 58.2% |
| In-vehicle | 89.8 % | 11.2% |

Table 1. Percentages of single transients and bursts in indoor and car environment

## 3.2 Power and frequencies

To point out the main differences between pulses measured in both environments, we have determined their amplitude, duration and pseudo frequencies. Figures 2 and 3 show the scatter plots in the peak amplitude-pseudo frequency plane, and in the duration-pseudo-frequency plane, respectively, deduced from measurements made in one car. In this case, since the statistical distribution appears not to be dependent on the pulse shape, no distinction has been made between single pulses and bursts.

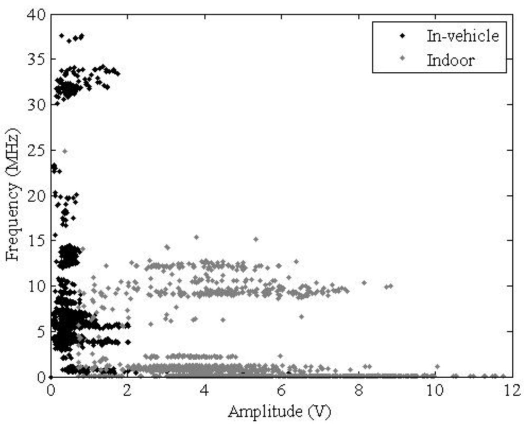


Figure 2. Scatter plot in the peak amplitude-pseudo frequency plane

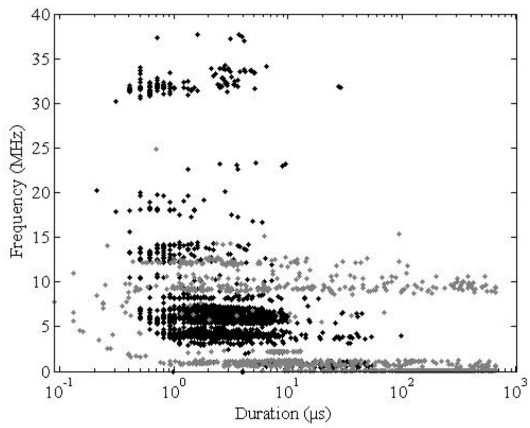


Figure 3. Scatter plot in the duration-pseudo-frequency plane

Fig. 2 shows that the pulses in indoor have amplitudes typically between 0.7 V and 10 V, thus much higher than in a vehicle where the amplitude remains smaller than 2.2 V. Furthermore, by examining Fig. 3, a similar conclusion can be given on the pulse duration which can reach 600 µs for indoor PLC, while on the vehicle network, duration greater than 20 µs have never been observed during the experiments.

Another interesting way to clearly point out the difference in the noise characteristics for the two environments is to plot the average and the maximum power spectral density (PSD) of the pulses, as shown in Figs. 4 and 5

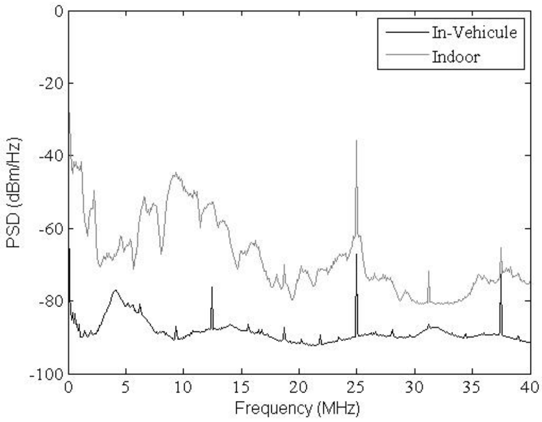


Figure 4. Mean power spectral density of pulses measured in in-house or in-vehicles.

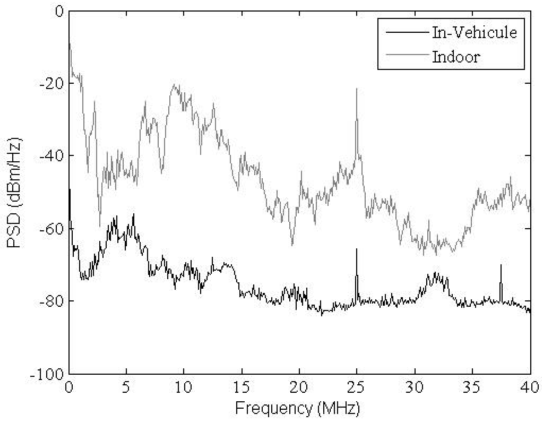


Figure 5. Maximum power spectral density of pulses measured in in-house or in-vehicles.

The examination of these Figures may lead to the conclusion that the impulsive noise would be more critical in indoor. However, as already mentioned, one can expect that in-vehicle systems will have a lower transmitting level. This is not the objective of this contribution to propose figures for the maximum power spectral density (PSD) but let us recall that, at least, the system must comply actual EMC standards as, for example, CISPR 25 (Electromagnetic disturbances related to the electric/electronic equipment in vehicles) [3]. To obtain acceptable radio reception in a vehicle using typical radio receivers, it is recommended that the disturbing voltage at the end of the antenna cable should not exceed a limit on the order of 6 dBµV. Various measurements were thus carried out by injecting signals of different frequencies at various points in the vehicle's DC network and measuring the disturbing voltage on the antenna cable. The results of these preliminary tests show that, in order to conform to the voltage limitations, a PSD between - 60 and - 80 dBm/Hz must be chosen, the voltage at receiver terminal being strongly dependent on the point at which the signal is injected into the line. One can thus consider that this level is between 10 and 20 dB lower than the usual value of – 60 dBm/Hz, chosen for indoor PLC transmitting modems.

## 3.3 Distribution of pulse characteristic parameters

In this section, the distributions of the main parameters of the pulses are presented. Probability densities of the amplitude, duration, pseudo frequency and inter arrival time are given in Fig. 6. They have been deduced from measurements either in-house or on the electric network of 5 cars. The previous conclusions based on results on one vehicle remain valid for all other vehicles, the amplitude and duration of the pulses being much higher on the in-house network. The pseudo frequencies of "indoor" pulses are mainly between 8 and 14 MHz, while, in a vehicle, these frequencies cover the frequency band from 4 to 12 MHz. Finally, concerning the interarrival time (IAT), the corresponding curves in Fig. 6 show that the occurrence of the pulses is greater inside the vehicle and, consequently, such pulses may strongly disturb the communication link. Channel coding must be optimized accordingly.

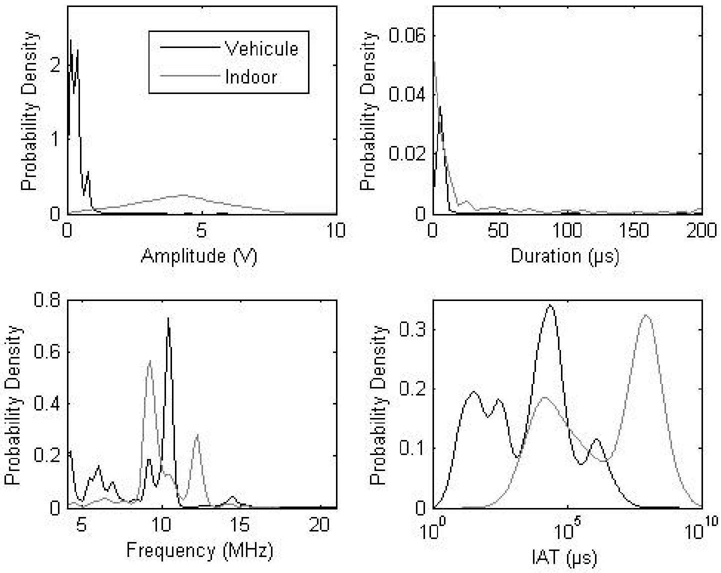


Fig 6. Probability density of the main characteristic parameters of the pulses

Table 2 summarizes the main pulse characteristics measured in the 5 vehicles, as well as those obtained on the indoor network. The first column of the Table gives the burst occurrence probability. In the next three columns, the 50th percentile of the amplitude; the duration and the frequency are given, with the 90th percentile in parentheses. For the IAT, it was more interesting to calculate the 10th percentile rather than the 90th percentile since the successive pulses with very low IAT values risk disturbing the link.

| | % of Bursts | Amplitude (V)<br>50th Percentile<br>(90th Percentile) | Duration (µs)<br>50th Percentile<br>(90th Percentile) | Pseudo Frequency (MHz)<br>50th Percentile<br>(90th Percentile) | IAT (µs)<br>50th Percentile<br>[*10th Percentile*] |
|---|---|---|---|---|---|
| vehicle | 11% | 0.32 (0.71) | 1.91 (4.41) | 9.76 (10.61) | $8\ 10^3$ [*21*] |
| indoor | 46% | 4.16 (6.47) | 3.62 (198.54) | 9.48 (12.24) | $11\ 10^6$ [$\mathit{7.1\ 10^3}$] |

Table 2: Summary of the in-vehicle and indoor characteristic parameters in [4-21] MHz

## 4. Conclusion

Extensive measurements were made on power networks either in-house or in-vehicles. The impulsive noise has first been extracted from the white Gaussian noise and a statistical analysis has been performed. It results that pulse amplitude and pulse duration are much greater on the indoor network but the interarrival time, i.e. the probability of pulse occurrence is higher in-vehicle. This point has to be kept in mind when optimizing the channel coding for in-vehicle PLC.

## 5. Acknowledgments

This work was done in the frame of “Safe Transportation - Science and Technology Research Center” (Pôle “Sciences et Technologies pour la Sécurité dans les Transports -ST2-”). The research was conducted in collaboration with PSA, Valeo and INSA-Rennes, and received financial support from PREDIT.

## 6. References

[1] http://www.homeplug.org
[2] http://www.ist-opera.org/
[3] CISPR-25: 2002 - Limits and methods of measurement of radio disturbance characteristics for the protection of receivers used on board vehicles.