Characterization of Power Line Communications Disturbed by Impulsive Noise

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***Abstract*— With the great demand for connectivity, new transmission medium has been in mind. One of these, largely distributed around the entire world, it's the power line, with the Power Line Communications (PLC). The main objective of this work is to make better transmissions in this so disturbed medium that has been seen like an advance possibility. PLC signal uses frequency bands from 2 to 30 MHz [1]. The Impulsive Noise (IN) has duration up to some milliseconds in this band, causing the loss of many data bits in the transmission. It's very important to research the perturbation level of each Chanel affected by most of the referred noises; this study will be made by improving the accuracy of a model of the IN in the power line, based in valid theories, computer simulations and laboratory measurements.**

***Index Terms*— Impulsive Noise, Modeling, PLC, Filters**

I. Introduction

At first, Power Line Communications was developed to control power distributions system, in order to protect it. [2] The occurrence of Impulsive Noises (IN) creates several issues to transmission, traffic and receiving of the information. In an medium like the electric grid, the signal is subject to various types of noises and attenuations. To make the signal immune to noises interference, one should find a model that represents them, possibiliting to know how to work with them, making the use of the medium more efficient.

II. Objectives

This work has as objective to obtain a mathematical model for the influence of the Impulsive Noises of the power grid over the data communication using Power Line Communication tecnology, in order to decrease the information losses due to such interferences and any characteristics of the used medium. After the design of the model, diverses tools could be developed to ensure better transmissions, like filters.

III. Metodology

Impulsive Noise has both natural causes such as lightning and caused by human action, such as electric motors or switching sources. Appears in the form of a single impulse or in a series of diverse, called Burst, or Impulse Explosion [3]. It is classified as a Single Pulse when, after the first three voltage peaks, its amplitude is no longer significant, ie, represents less than 65% of the highest value obtained.

The main characteristics needed to the modeling of the impulsive noise can be separated in two categories [4]:

1. Temporal:

1.1. Maximum Amplitude (V): higher peak value during each pulse;

1.2. Length (s): time to extinction of noise;

1.3. Inter Arrival Time (IAT) (s): in Burst case, defines the time interval between two consecutive Maximum Amplitudes;

2. Spectral:

2.1. Autocorrelation: defined by statistical relationship between two points of a random sequence, ie how an event (in this case, the pulse) seems to depend on a previous one;

2.2. Power Spectral Density (PSD): distribution of the noise power in frequency domain, showing the bands which will be most affected during such occurrences.

These characteristics can be modeled, based on series expansions, like the sum of several exponentially damped cosines at several frequencies (α_1, α_2 , ...), with several exponential decays (β_1, β_2, ...) [5].

Considering the first Maximum Amplitude equal to one and normalizing all other amplitudes, for each cosine, we have the Relative Amplitudes; whether A_1, A_2, ...

In their studies, Mann concluded that when considering up to the third component, more than three quarters of the noise generated could be represented, i.e. if there would be only the first three installments in the sum of exponentially damped cosine, we obtain a model very close to the majority of impulsive noise that may arise.

Accordingly, and considering the described notations, can be defined a function, $\hat{R}(t)$, dependent on the Relative Amplitudes, the frequencies of each cosine and the exponential decay of each one, as in equation (1) (according to their autocorrelation) . That is the desired expression.

The Power Spectral Density of a periodic and deterministic signal is given by the Fourier Transform (2) off the equation (1). This way, could be deterrmined the PSD equation (3) [5].

With the PSD in hand, a filter able to extinguish the noise could be implemented, making them less nocive to the PLC communication system.

IV. Procedure

Was assembled in the laboratory of Mackenzie University a network with PLC equipment available (Fig. 1) for effectuation of the practical tests, such as checking and analysis functionality of external interference.

A network structure was accomplished and a sign of impulsive noise was implemented, emulated through the use of an electric drill motor with brush (the brush contact generates an impulsive noise signal).

The Fig. 2 shows the rate of transference in the PLC channel. With the ativation of the drill, impulsive noises are put into the line, lowering the speed of the transference.

There was wide variation in the data transfer rate (a decrease of about 50%) by injection of impulsive noise on the network. The drill has been replaced by other equipment and it was noted that facilities that do not have chokes, like most electronic devices, do not affect the system, since they do not generate noise with impulsive characteristic.

The points of the transmission data was saved into a table with a Tektronics DPO4104 osciloscope, and the results were analised in MATLAB, generating figures of real noises as showed in the Fig. 3. The PSD data was calculated in the software, generating Fig. 4.

V. Results

By the equations (1) and (3), a MATLAB program was developed to model, based on user entries, a Noise and its respectively PSD. As an example, was generated a noise with Relative Amplitudes of 23% and 70%, in the frequencies of 2, 3 and 6 MHz, with unitaries exponential decays.

The simulation results are showed in Fig. 5 (Noise) and Fig. 6 (PSD). There can be noted that the noise occupes the same frequency band that the PLC signal.

The resulted experiments obtained express a significant behavior of the single Impulsive Noise, what makes possible various tools of error preventions in the data transferences and bits loss in the medium.

VI. Considerations and Contribution

The noise on this paper is a model of a single impulse based on [4] and [5]; a new model, that simulates a Burst Impulse noise, is being developed, the equation (6) represents an attempt to approach the burst. A simulation was made for 10 impulses, with Inter Arrival Time of 0.1 ms, starting on 5ms, without DC component or phase disturbances and the result is on Fig. 8. Attempts to filter this model are being studied, still without full success.

After the modeling of the noise, a filter with window of length three was applied on a signal composed by a electrical signal (an 0.1 ms artificial sinusoid with frequency of 60 Hz), added to the real burst noise. The modulation wasn't considered.

The chosed filter was a median filter, that has the equation described by (4) in serie with the moble media described by (5), both with window three. The results of the filtering with 20 iterations are shown on the Fig. 7.

In this filter, the first and last point wasn't processed, due to the absence of neighbors to obtain their means. In the Fig. 7 this points wasn't processed by the filter.

Studies of these filters are in the beginning, the proposal is to optimize its application. The goal of applying the filter is to isolate the noise generated by network devices with reactance.

Was considered that the noise has a Gaussian distribution, but this can vary. A future propposal is to consider the alpha-stable distribution, that can model phenomena of impulsive nature [6] and the influence of the modulation (OFDM or WOFDM) on the grid and the noise.

Appendix

A. Equations

$$\hat{R}(t) = \cos(2\pi\alpha_1 t)e^{-\beta_1|t|} + A_2\cos(2\pi\alpha_2 t)e^{-\beta_2|t|} + A_3\cos(2\pi\alpha_3 t)e^{-\beta_3|t|} \quad (1)$$

$$\hat{S}(\omega) = \int_{+\infty}^{-\infty} \hat{R}(t)e^{-i2\pi\omega t}dt \quad (2)$$

$$\hat{S}(\omega) = \frac{\beta_1}{{\beta_1}^2 + (\omega - 2\,\pi\,\alpha_1)^2} + A_2\frac{\beta_2}{{\beta_2}^2 + (\omega - 2\,\pi\,\alpha_2)^2} + A_3\frac{\beta_3}{{\beta_3}^2 + (\omega - 2\,\pi\,\alpha_3)^2} \quad (3)$$

$$\hat{R}_{mn}(i) = MED(\hat{R}(i-1), \hat{R}(i), \hat{R}(i+1)), \quad (4)$$

Where MED(A) is the median value of the array A, and *i* is the i-th point of the signal $\hat{R}(t)$.

$$\hat{R}_{md}(i) = \frac{(\hat{R}(i-1) + \hat{R}(i) + \hat{R}(i+1)))}{3}, \quad (5)$$

$$R_b\,(t) = A_{DC} + \sum_{n=1}^{\max} A_{1n}\cos\left[2\,\pi\,\alpha_1\,(t-n) + \varphi_1\right]e^{-\beta_1|-t+n|} + A_{2n}\cos\left[2\,\pi\,\alpha_2\,(t-n) + \varphi_2\right]e^{-\beta_2|-t+n|} + A_{3n}\cos\left[2\,\pi\,\alpha_3\,(t-n) + \varphi_3\right]e^{-\beta_3|-t+n|} \quad (6)$$

B. Figures

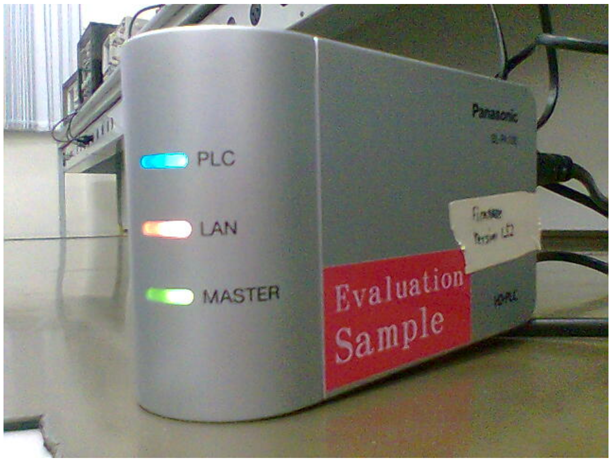

Fig. 1. HD-PLC Panasonic BL-PA100A

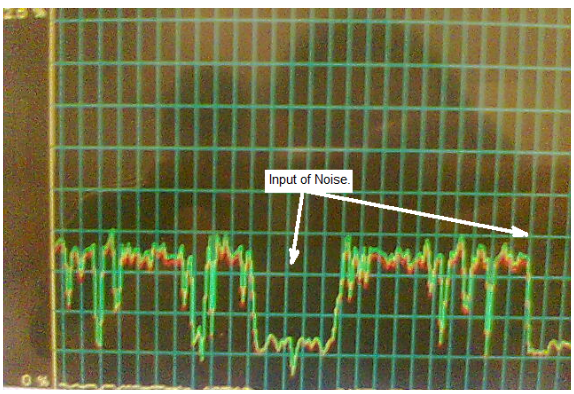

Fig. 2. Graphic of Transmission Rate variations whit impulsive noise.

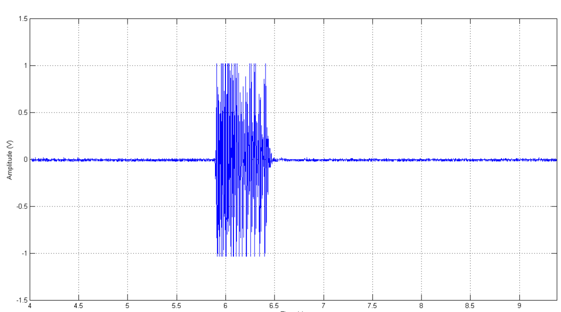

Fig. 3. Impulsive real burst noise in time, captured by the osciloscope into the modem.

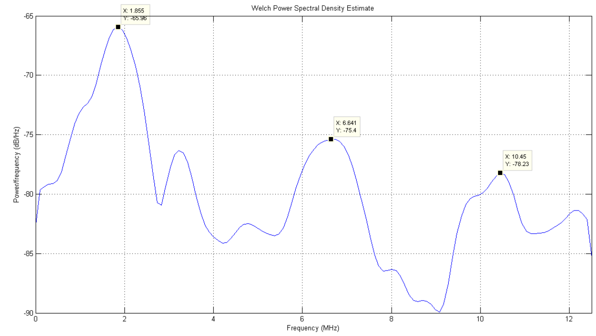

Fig. 4. Power Spectral Density of the real burst noise, obtained in MATLAB.

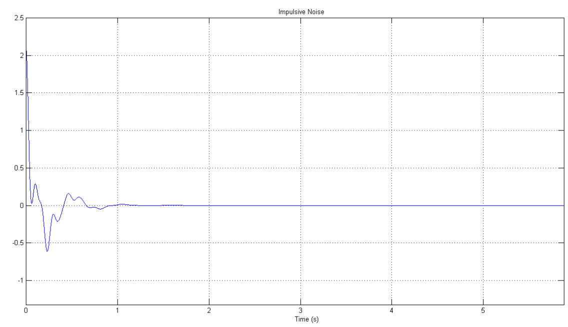

Fig. 5. Modeled Impulsive Noise

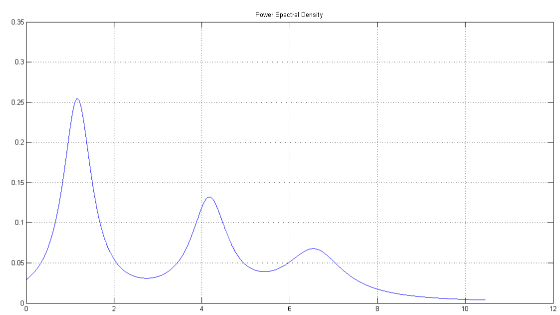

Fig. 6. Modeled PSD

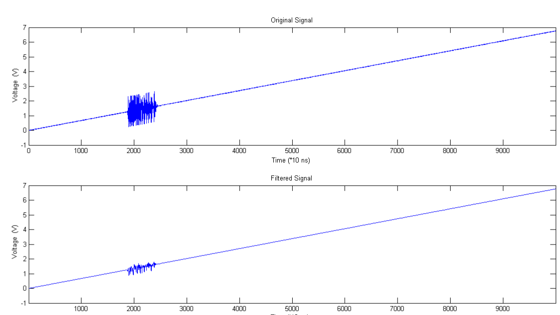

Fig. 7. Signal of the powerline added with the real burst noise and respectively filtered signal.

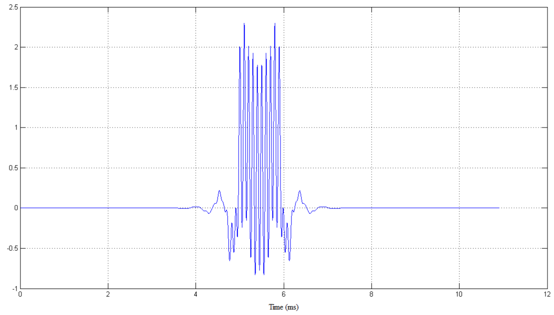

Fig. 8. Example of simulated burst without DC and $\varphi_n = 0$.

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