Transmission on indoor power lines: from a stochastic channel model to the optimization and performances evaluation of multicarrier system

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Objective

- Analysis of the **Bit Error Rate**
  in the presence of narrow band noise &
  in time varying selective channel
  in the presence of impulsive noise

- Influence of **channel estimation methods**
  ⇒ Optimization of semi-blind techniques

- Optimization of **noise processing and channel coding**
Outline

I. Indoor Powerline channel : Measurements & model

II. System optimization in the presence of narrow band noise & in time varying selective channel
   - Transmission process
   - Semi-blind channel estimation
   - Simulation results

III. System optimization in the presence of impulsive noise
   - Noise processing and channel coding
   - Simulation results

Conclusion : software and demonstrator
1. Indoor powerline channel model

- Two classes of Noise
  - The stationary Noise: colored and narrow band noise
  - The impulsive noise
- The transfer function with 2 main characteristics
  - Multipath environment: frequency selective channel
  - Time varying channel
I. Indoor powerline channel model

- The stationary noise [0-30] MHz

⇒ Modelled by filtered gaussian noise and sinusoids characterized by their frequency, amplitude and phase (randomly distributed)
I. Indoor powerline channel model

- Idea: mobile platform for measuring impulsive noise
- Difficulties:
  * Programming (Measurement of interarrival time and data acquisition in real time)
  * System protection against overvoltages (attenuators et couplers) ⇒ frequency response must be flat in the band
I. Indoor powerline channel model

- Impulsive noise:
  Measurements have been performed in a house during 40 hours. Two types of impulses are given: Single transient & Burst impulse

\[ \Rightarrow \text{Damped sinusoid} \]

\[ \Rightarrow \text{Succession of damped sinusoids: higher pseudo-frequency higher amplitude} \]

\[ \Rightarrow \text{Bursts may degrade PLT systems} \]
I. Indoor powerline channel model

(a) Model of single transient

Characteristic parameters of single transient:
- peak amplitude
- pseudo-frequency
- damped coefficient
- duration
- interarrival time

(b) Model of burst impulse
I. Indoor powerline channel model

- Classification in time and frequency domain:

<table>
<thead>
<tr>
<th>Type</th>
<th>Class 1 (48%)</th>
<th>Class 2 (20%)</th>
<th>Class 3 (3%)</th>
<th>Class 4 (11%)</th>
<th>Class 5 (18%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1644 impulses</td>
<td>fo&lt;500 kHz</td>
<td>0.5 MHz &lt; fo &lt; 3MHz</td>
<td>fo&gt;3 MHz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single transient</td>
<td>(48%)</td>
<td></td>
<td>Class 4 (11%)</td>
<td></td>
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</table>

- Statistical study: characteristic parameters are approached by known analytical functions

Amplitude: Rayleigh distribution
I. Indoor powerline channel model

- Model validation: Comparison of mean spectral density of measured and generated pulses

![Graph showing comparison of measured and model-generated PSD (Power Spectral Density)]

Good agreement Measurement/Model ⇒ Validation of stochastic model of impulsive noise
I. Indoor powerline channel model

The measured transfer function:
intensive measurements were carried out on a specific installation comprising a line, 30 m long, with wall plugs.

⇒ Fading in each frequency band
⇒ Sudden channel variations: succession of stationary states
⇒ Modeled by a tap delay line filter, the amplitude being determined by a Rayleigh distribution and phase angle being uniformly distributed.
II. System optimization in the presence of narrow band noise & in time varying selective channel

- The OFDM process & semi-blind (SB) channel estimation ⇒ Simulation results
- The DMT process & extension of SB channel estimation ⇒ Simulation comparison
II. The OFDM process

Parameters:
256 subcarriers modulated in 4-QAM, prefix = 32 samples
Bit rate = 10 Mbit/s, Bandwidth = 5.5 MHz
Synchronization assumed to be ideal
II. Simulation results of OFDM processes: Influence of the channel estimation

- New algorithm based on a semi-blind (SB) estimation
- Performances comparison of different estimation methods

⇒ Efficient results for SB estimation & detection
⇒ Extension to the DMT?
II. DMT process & extension of SB estimation

The DMT principle:
OFDM link + Algorithm which optimizes the number of bits/symbol (size of constellation) versus the SNR in each subband

Extension of SB estimation not straightforward!
⇒ SB estimation not accurate when M<64
⇒ Because of unused subbands,

pilot arrangement (PTS) must be carefully done

Simulation results show that:
- For SNR < 20 dB, DMT & SB estimation gives better results than others schemes
- For higher SNR, DMT and OFDM (with SB estimation) give similar results
III. System optimization in the presence of impulsive noise

- Noise processing
- Channel coding
- Simulation results
III. Noise processing

- **Matsuo iterative process**: consist in determining at reception the largest amplitudes of bruit and subtract them.

  - M=3 largest amplitudes
  - Optimization: threshold As

- **Optimization**: amplitude (noise) >> amplitude (signal)

  ⇒ Possibility of determining a threshold As

Preprocessing: Remove noise > threshold (As=3.4 V)

Matsuo iterative process (M, number i of iterations)

Iteration n° 1

Iteration n° i > 1
III. Channel coding

- **The Reed-Solomon code:**
  This code adds \((255-K)\) parity bytes and correct up to \(t = (N-K)/2\) bytes. \((N=255, K=239, t = 8\) bytes\)

- **The interleaving:**
  \[\begin{array}{c|c|c|c|c|c|c|c|c|c}
  \hline
  1 & 2 & 3 & 255 & 256 & 257 & 258 & 511 & 512 & 765 \\
  \hline
  256 & 257 & 258 & 516 & 511 & 512 & 765 & 766 & 767 & \hline
  \end{array}\]
  \[2 \leq D \leq 64\]
III. Noise processing & Channel coding

The both techniques are associated in presence of Noise: $F_o$ (pulses) $\in$ signal bandwidth

$\Rightarrow P (BER<10^{-3}) = 77\%$ with $D=16$

$\Rightarrow P (BER<10^{-3}) = 96 \%$ with $D=64$

Choice of $D$ depends on:
- admissible BER
Conclusion of the study

- Simulation tool
- Demonstrator

Perspectives
Conclusion: Simulation Tool

- Software based on MATLAB (The Mathworks)
Conclusion: Demonstrator realization

- Characteristics:
  - 256 subcarriers
  - P = -50 dBm/Hz
  - Bit rate: 2.5 Mb/s

- Adaptative aspects of the system:
  - Transmission bandwidth [10-30] MHz
  - Injection Power
  - Number of subcarriers
  - Variable rate (following phase)

- The difficulties of the OFDM process:
  - Synchronization of the received symbols
  - Synchronization of the OFDM frames
  - OL synchronization
  - Peak power of the received signal
Conclusion: Demonstrator realization

Emission card
CPLD (e/s)
DSP (IFFT)

Impulsive noise
generator

Modulation

Demodulation

Time
Synchro

Horloge
card
Perspectives

- Transmission on powerline in subway stations
  Problem: low SNR, long lines (few hundred meters)
  ⇒ channel measurement and modeling

- PLC in cars (high bit rate)
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