The Effect of Multipath on the OFDM System

Bouamama Réda Sadouki
Electronics Department, Professor, University of Sidi Bel Abbès Telecom Laboratory
LTTNS, ALGERIA

Hichem Chaker
Electronics Department, Professor, University of Sidi Bel Abbès Telecom Laboratory
LTTNS, ALGERIA

Mouhamed Djebbouri
Electronics Department, Professor, University of Sidi Bel Abbès Telecom Laboratory
LTTNS, ALGERIA

ABSTRACT
A major problem in telecommunications is to adapt the information to be transmitted to the propagation channel. This, in order to obtain a good quality of wireless communications with high transmission rates , and the release cable users to allow them to move in large buildings. In this type of communication systems must be properly fight one effect of multipath, specifically the frequency selective fading. This led to the development and use of the technique of multiplexing by orthogonal frequency division (OFDM) appears to be a promising solution. For frequency-selective channels, a technique is the use of multi-carrier modulation in which a block of information is modulated by a Fourier transform. This known as OFDM (Orthogonal Frequency Division Multiplexing) technique has been very successful in recent years and is in the process of standardization in different standards without son (IEEE802.11a, WiMAX, LTE, and DVB). OFDM has the great merit to transform broadband multi-path channel into a set of simple to equalize sub channels single-path. Moreover, the ingenious utilization of the transmission cyclic redundancy reduces the complexity of the terminals through the use of algorithms based on FFT fast. The purpose of this chapter is to introduce the OFDM modulation. The general principles are described (transmission chain ...) and benefits (simplicity of the equalization algorithms use fast FFT) and disadvantages (lack of diversity).

Keywords
Bit error rate (BER), (Signal to Noise Ratio) (SNR), Quadrature Amplitude Modulation (QAM), Orthogonal Frequency Division Multiplexing (OFDM*)*.

1. INTRODUCTION
The goal of digital communications systems is to transmit a data stream carried by a signal to High Frequency (HF) from one point to another. The physical environment in which the flow passes is called a channel. The signal passed through the channel undergoes a number of deformations. Reflections generating the multipath effect, noise, attenuation, interference with other signals, the change in frequency (Doppler effect), delay and many other kinds of distortions are introduced by the channel.

The parameters of these characterize the channel distortion. However, they vary with time due to the mobility of some Elements in the channel as the transmitter, the receiver, and the obstacles. Their representation is then performed statistically. The first part of this chapter presents the effects of multipath on the received OFDM signal. These are called inter-symbol interference (ISI) and co-channel interference (IEC). We'll see how the addition of the cyclic prefix or zero padding to the issuance eliminates the IES. Then we show that the IES can be completely canceled upon receipt by the removal of the cyclic prefix or when filling by Zeros. Then, we present the advantages and disadvantages of zero padding compared to a cyclic prefix. At the end of this chapter we give a description of some examples of frequency selective channels to obtain significant results in the next chapter of simulation.

2. SIMULATION AND MATHEMATICAL MODEL
2.1 Introduction
We will determine the cyclic prefix insertion performance transmitter OFDM system for some models channel level. The simulations are divided into two sections corresponding to that earlier work, one with very selective channels and frequency selective channels with different frequency. To assess techniques in themselves and have acceptable calculation time, no channel coding is applied by default. Assume a perfect time and frequency synchronization. Finally, we have used B-PSK constellations, M-QAM, and the number of subcarriers N = 16, 64....

2.2 The first type channels highly selective
In this section we study the performance of OFDM in frequency-selective channels. The dispersive channel is that a time $\boldsymbol{h(\tau)}$may be that of $\mathbf{0 \le \tau \le \tau max}$. Where $\boldsymbol{\tau}$**max**: is the maximum delay spread of the channel. The received signal is:

$$\boldsymbol{r(t) = \int_{-\infty}^{+\infty} h(\tau) s(t-\tau)\, d\tau + n(t)} \quad \textbf{(1)}$$

$$\boldsymbol{r(t) = \int_{0}^{\tau} h(\tau) s(t-\tau)\, d\tau + n(t)} \quad \textbf{(2)}$$

Where $\boldsymbol{s(t)}$and the OFDM signal $\boldsymbol{n(t)}$ is Gaussian noise term. The lower limit of integration is due to the law of causality: $\boldsymbol{h(\tau)}$ 0 for τ <0. The upper limit is $\boldsymbol{\tau_{max}}$ since by definition the maximum propagation delay, $\boldsymbol{h(\tau)}$ for $\boldsymbol{\tau}$ >$\boldsymbol{\tau_{max}}$. The response of the channel impulse is:

$$\boldsymbol{h(t) = \sum_{l}^{l-1} a_l\, \delta(\tau - \tau_l)} \quad \textbf{(3)}$$

$\boldsymbol{a_l}$ Where: is the complex channel gain and $\boldsymbol{\tau_l}$ is time discrete propagation path$\boldsymbol{l}$, the total number of paths is represented by **L**, the propagation delay differences are:

$$\Delta_{\tau_l} = \boldsymbol{\tau_l} \qquad \boldsymbol{l = 1, 2, \ldots, l-1} \quad \textbf{(4)}$$

With each gain is complex valued, has a zero mean and variance

$$\sigma_{al}^2 = E\{|a_l|^2\} \qquad , \quad l = 1, 2, \ldots, l-1 \qquad (5)$$

The real and imaginary parts of path gains are Gaussian distributed so Envelope $|a_l|^2$ is a Rayleigh distribution. Also, channels are normalized such that [4]:

$$\sum_{l=0}^{l-1} \sigma_{al}^2 = 1 \qquad (6)$$

The relevant formulas are given below: The power spectral density:

$$S_{\tau\tau} = \sum_{l=0}^{l-1} \sigma_{al}^2\, \delta(\tau - \tau_l) \qquad (7)$$

Average waiting time:

$$S_{\tau\tau}^1 = \sum_{l=0}^{l-1} \sigma_{al}^2\, \tau_l \qquad (8)$$

Spread delay:

$$B_{\tau\tau}^2 = \sqrt{\sum_{l=0}^{l-1} (\sigma_{al}^2\, \tau_l)^2} - (B_{\tau\tau}^1)^2 \qquad (9)$$

Correlation functions of frequency:

$$r_{\tau\tau} = \sum_{l=0}^{l-1} \sigma_{al}^2\, e^{-2j\pi v \tau_l} \qquad (10)$$

The variable v is known as the variable range of frequencies,

2.2.1 Channel Model

In the first type we take four models of frequency-selective channels **[4]** Channel A and B are similar to channel models with two different paths have the secondary path arrives with a delay of 5 µ sec. as in channel A, low secondary path from the first power path (-10dB) and channel B the secondary path is stronger compared to the first fundamental path (-3dB). And the channel C has a spectral power density of the exponential time:

$$\sigma_{al}^2 = \begin{cases} c_{c_\tau}\, e^{\frac{\tau_l}{2\mu s}} & 0 \le \tau_l \le 8.75\mu s \\ 0 & ailleur \end{cases} \qquad (11)$$

Where:

$$c_{c_\tau} = \frac{1}{\sum_{l=0}^{35} exp(-\tau_l/2e^{-6})} = 0.18 \qquad (12)$$

Is the normalizing constant guaranteed (Equation 6). Note that the maximum delay spread is 8.75 (τ_max = 8.75µ sec). The latest model, Canal D, a spectrum of the power density constant time:

$$\sigma_{al}^2 = \begin{cases} c_{D_r} & 0 \le \tau_l \le 8.75\mu s \\ 0 & ailleur \end{cases} \qquad (13)$$

Where the normalizing constant is:

$$c_{D_r} = 1/36 \qquad (14)$$

Note that the D channel has a smaller coherence bandwidth

The simulation results of this study are to give more than four figures.

Figure 1 compares the performance of an OFDM system, with and without the cyclic prefix from the four channels (A, B , C, D) of the fixed modulation order M = 2 and SNRmax = 30Db, but we use in this work and selected the C channel. At this point, the performance of the OFDM system with cyclic prefix studied depends on the amount of frequency selectivity of the signal bandwidth (see FIG 1) and to channel C for the best without OFDM cyclic prefix. So the cyclic prefix insertion provides good performance for OFDM systems.

2.2.2 Strip consistency

If we go to the frequency domain, then we can define the coherence bandwidth of the channel. This band represents the set of frequencies for which the amplitude spectrum of the transmitted signal is modified in the same way and it is inversely proportional to the maximum delay, as shown in the following equation [1]:

$$B_{coh} = 1/\tau_{max} \qquad (15)$$

τ_{max} Maximum delay

Since the simulation and the C channel closer to reality (The power distribution function of propagation time is exponential), we simulate the rest of our work on channel C (**see Tab 1**).

Table 1: Specification of parameters used for the simulation of channels (A, B, C, and D) highly selective

parameter	value
Sampling frequency	8 * 500kHz = 4MHz
Échantionnage factor J	8
OFDM symbol duration T_u	64 * 8 ∗ Ts = 128µ sec
Length of the cyclic prefix = T_{CP} T_{garde}	5 * 8 ∗ Ts = 10µ sec
OFDM symbol duration $T_{OFDM} = T_B$	69 * 8 ∗ Ts = 138µ sec
Number of data subcarriers N	69 *8 ∗ Ts = 138µ sec
Subcarrier spacing δ_f	8 *7.8kHz = 62.5kHz

The increase in propagation delay (delay spread) introduced decreasing the coherence band, it degrades the system performance.

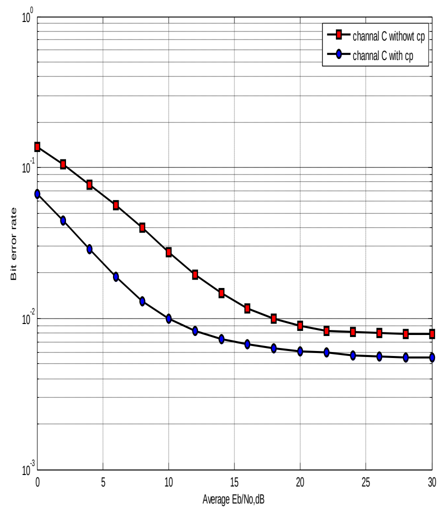

Fig. 01 performance results for OFDM channel C with and without CP

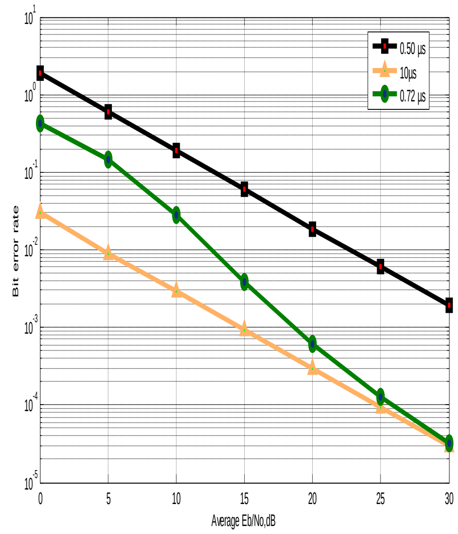

Fig. 02 Comparison of results with different values for OFDM modulation τ_{rms}

2.2.3 Cyclic Prefix

Figure 2 represents the magnitude of CP (cyclic prefix) from increasing τ_{rms} , (with direct trays indicating the channel C with CP trais and dotted line indicates the C channel without CP).

We note that for τ_{rms} = 0.5µ sec adding cyclic prefix does not have much influence on the BER for (Eb/N0 = 25dB the BER with cyclic prefix ≃ 10-2). But τ_{rms} = 10µ sec adding cyclic prefix is greatly improved (when compared to Eb/N0 = 25dB, BER with cyclic prefix ≃ 10-4). Next, Figure 3 shows the variation of BER as a function of Eb/N0 for different types of modulation (M = 2, 4, 8), (size constellations) . In this case used in the amplitude modulation, the constellation points located in the real part. There is performance degradation when the number of states of the constellation used increases. This results from the decrease of the Euclidian distance between the different states for the constellations of increasing size.

And notes between the two previous figure shows the importance of added cyclic prefix with M = 2 as a function of propagation delay (τ_{rms}) (with direct trais which indicates the channel with CP). And shows that for the channel without cyclic prefix , the BER is very low for a delay spread of the very small (as zero) , and for increasing the spread of the propagation time , and the BER increases rapidly takes a steady state, that is to say the points of the constellation are completely interfered . And when adding the cyclic prefix, the last it improves the BER.

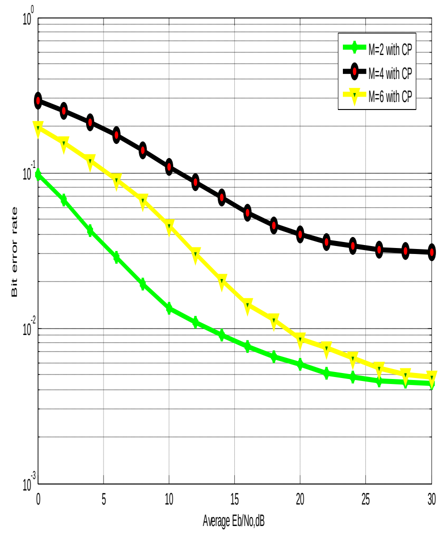

Fig. 03 Influence of the constellation size (M = 2, 4, 8) for the C channel

2.3 The second type: selective channels

2.3.1 Channel Model

We have seen the following, the usefulness of the cyclic prefix in the presence of frequency selective channels. To avoid inter-symbol interference (ISI), just choose a cyclic prefix longer than the length of the channel impulse response length. was chosen so that the prefix 1.2 µs is just sufficient to completely avoid the ISI channel C. the length of the impulse response of the channel exceeds the length of the cyclic prefix and the result of inter-symbol interference degrading system performance. The length of the cyclic prefix is noted exceeds the length of the impulse response of the channel , and the channel C (LOS) , the length of the cyclic prefix of the lower length of the impulse response of the channel , which gives the same performance , the channel C is commonly used to model channel path having a very high amplitude relative to the other paths , there is the influence of direct path in terms of bit error rate if the same cyclic prefix length is less than the length of the channel impulse response .

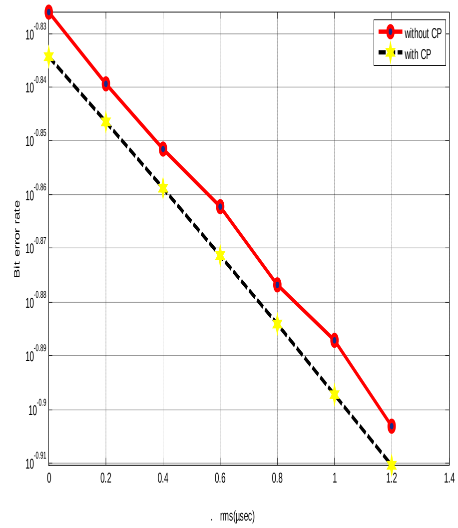

Fig. 04 The influence of the cyclic prefix based τ_{rms}

2.3.2 Number of subcarriers

Figure 5, shows the performance for different values of N, the number of subcarriers (obviously with the same bandwidth). It is found that performance improves significantly when the number of subcarriers increases. However, increasing the number of subcarriers has certain disadvantages. First, a larger delay and a higher complexity for / IFFT pair FFT.

Then, channel estimation is complex. Finally, the symbol duration is proportional to the number of subcarriers; it can become significant compared to the channel coherence time. The increased number of subcarriers decreases the width of each band of subcarriers, so the latter for less than the width of the coherence band which improves the performance of the OFDM system.

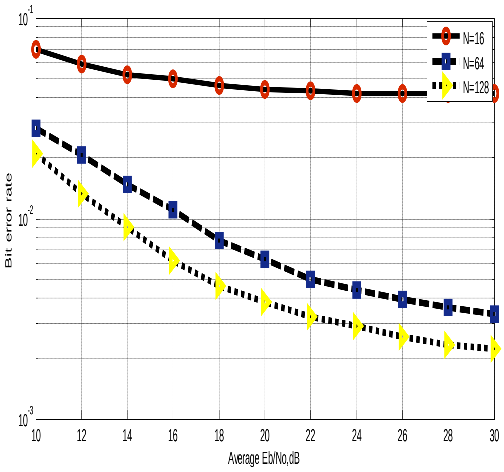

Fig. 05 Influence of the number of subcarriers (16-QAM Channel C)

2.3.3 Size of the constellations

The error rates for different constellations are shown in Figure 6. There is performance degradation when the number of states of the constellation used increases. This results from the decrease of the Euclidian distance between the constellations for different states of increasing size, except for the passage of a BPSK constellation in a constellation for QPSK in this case, the distances are identical (exploiting only the BPSK while the actual constellations QPSK (or more) part also exploiting the party imaginary.

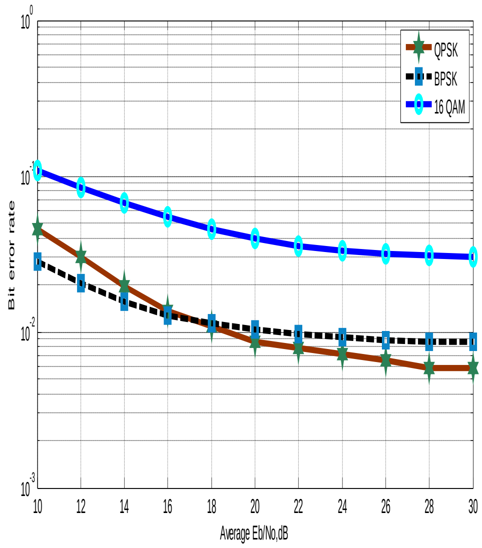

Fig. 06 Influence constellation size (N = 64 Channel C).

2.3.4 Cyclic Prefix

Figures 7 shows the evolution of the error rates for different levels of noise. A saturation effect is observed: when the prefix length exceeds the length of the impulse response, there is no ISI and further increase is unnecessary and even harmful in the sense that the prefix consumes some of the bandwidth. For N = 64, 256 QAM. This is because the last path of the impulse response has a little power and generates a large ISI negligible. For the 16 - QAM modulation and 64 - QAM cyclic prefix without the BER is very high which means that the constellation points are completely interfered. And when adding the cyclic prefix, the latter improves the BER. By cons for QPSK the Euclidean distance between the different states of constellations bigger. The system it does not reach much influence.

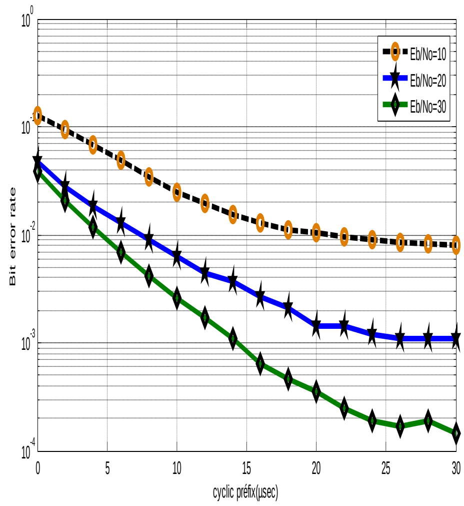

Fig. 7 Influence of the length of the cyclic prefix for the channel C.

3. CONCLUSIONS

In conclusion in this work, we simulated the particular interest of the cyclic prefix in an OFDM system, and we evaluated its performance in terms of bit error rate for different channels and different types of modulation used (B -QPSK and QAM). We have shown, from these simulations that the insertion of cyclic prefix allows to better results in terms of signal to noise ratio. For channels tested, inserting a cyclic prefix leads to good performance always better than those obtained with channels which do not use the cyclic prefix. OFDM seems like a good solution for multipath a cyclic prefix (Guard Interval) is then added to the beginning of the symbol and the prefix is identical to the segment of the same length at the end of the symbol. The length of this interval is selected to be greater than the maximum value of delay due to the multipath effect. OFDM has high simplicity in the modulation and demodulation requiring a single modulator and single demodulator. This occurs where the different fundamentals are properly selected numerous orthogonal carriers, guard interval, constellation and good information on the state of the channel.

4. REFERENCES

[1] S. RAGUSA, "Écrêtage inversible pour l'amplification non-linéaire des signaux OFDM dans les terminaux mobiles", Jui, 2006, thèse. Université Joseph Fourier. Http: //tel.ccsd.cnrs.fr/docs/00/08/46/58/PDF/thesis.pdf.

[2] B. THI MINH TU, "Performances des modulations multiporteuses OFDM/QAM suréchantillonnées en environnement radio-mobile", Jui, 2005. Mastère Signal Image Parole Télécommunications SIPT, Laboratoire des Images et des Signaux, Équipe Signal Images et Communications SIC. http ://www.lis.inpg.fr/pages_perso/siclet/rapport_mastere_bui.pdf.

[3] S. TRAVERSO, "Transposition de fréquence et compensation du déséquilibre IQ pour des systèmes multiporteuses sur canal sélectif en fréquence", Nov, 2007, thèse. Université de Cergy- Pontoise. http ://publi-etis.ensea.fr/2007/Tra07.

[4] S. THOMPSON, "Constant envelope OFDM phase modulation", 2005, thèse. University of Californi, San Diego. www.zeidler.ucsd.edu/pubs/C136.pdf.

[5] J. DUPLICY, "Etude d'un réseau WLAN à base de MIMO-OFDM et de beamforming adaptatif conjoint", Jui, 2003, thèse. Université Catholique de Louvain. Http : //www.tele.ucl.ac.be/publi/1354.pdf.

[6] S. DOUKALI, "Estimation du canal pour un système OFDM", Juin, 2007. Mémoire Ingénieur, Université Djillali Liabes de Sidi Bel-Abbes.

[7] J. NAKAD, "Allocations de ressources radio dans un réseau local sans fil (WLAN) de type OFDM", Dec, 2003,thèse. Université Libanaise, Université Saint-Joseph. www.telecomparistech.fr/_data/files/docs/id_627_1163155426_271.pdf.

[8] V. DEGARDIN, "Analyse de la faisabilité d'une transmission de données haut débit sur le réseau électrique basse tension", Dec, 2002,thèse. Université des Sciences et Technologies de Lille. France. www.telice.univlille1.fr/publications/docs/theses/virginiedegardin_these.pdf.

[9] C. LENGOUMBI, "Algorithmes d'allocation de ressources en OFDMA : cas de la voie descendante d'une cellule radio isolée", Oct,2006,thèse. Ecole Nationale Supérieure des Télécommunications – Paris. www.telecom-paristech.fr/_data/files/docs/id_627_1163155426_271.pdf.

[10] I. OUACHANI, "Analyse de performance de systemes de communications sans-fils exploitant micro- et macro-diversite", Jui,2005,thèse. Université de Paris XI Orsay. www.lss.supelec.fr/~publi/SWxoZW0gT1VBQ0hBTkk=_I_Ouachani_phD_report.pdf .

[11] É. JANDOT, "Applications du codage spatio-temporel à des réseaux sans fils", Des,2006,thèse. Ecole Doctorale D'informatique, Télécommunications Et Electronique De Parisé. www.pastel.paristech.org/2519/01/these_Danjou.pdf.

[12] T. YIUCEK, "Channel, spectrum, and waveform awareness in OFDM-based cognitive radio systems", Jul,2007,thèse. University of South Florida. http ://kong.lib.usf.edu :8881///exlibris/dtl/d3_1/apache_media/111872.pdf.

[13] A. DELEUZE, "Contributions à l'étude des systèmes ultra large bande par impulsions", Fév,2006,thèse. Ecole Doctorale D'informatique, Télécommunications Et Electronique de Paris. http ://pastel.paristech.org/1668/01/these_al_deleuze.pdf.

[14] L. AZIZI, "Contribution à l'étude : des systèmes de transmission multi-antennes, des turbo-codes associés à des modulations à haute efficacité spectrale", Avr,2004,thèse. Université de Limoges. http ://www.unilim.fr/theses/2004/sciences/2004limo0003/azizi_l.pdf.

[15] E. MINACK, "Evaluation of the influence of channel conditions on Car2X Communication", Oct,2005,thèse. Chemnitz University Of Technology. http ://archiv.tuchemnitz. de/pub/2005/0157/data/enrico_minack_diploma_thesis.pdf.

[16] A. HEBBAR, "Empirical approach for rate selection in MIMO OFDM", Dec,2004,thèse. Virginia Polytechnic Institute and State University in Partial Fulfilment. http ://scholar.lib.vt.edu/theses/available/etd 01082005153029/unrestricted/MasterThesisPdf.pdf.

[17] V. ROBERT, "Etude des canaux de Rayleigh et des canaux sélectifs diversité de transmission", Oct,2004. Master en Science de l'ingénieur Electronique et Systèmes de Communication ESCO, ENST. Paris. http ://perso.telecom-paristech.fr/~vallet/Cours/dom992000.pdf.

[18] V. LE NIR, "Étude et optimisation des systèmes multi-antennes associés à des modulations multiporteuses", Nov,2004,thèse. Institut National des Sciences Appliquées de Rennes. http ://homes.esat.kuleuven.be/~vlenir/THESE.pdf.