



Construction des espaces de représentation adéquats pour l'analyse des signaux transitoires

Florin-Marian Birleanu

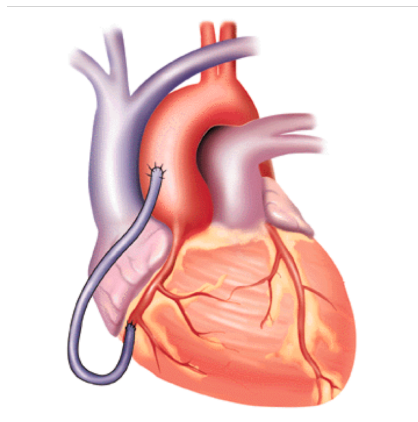
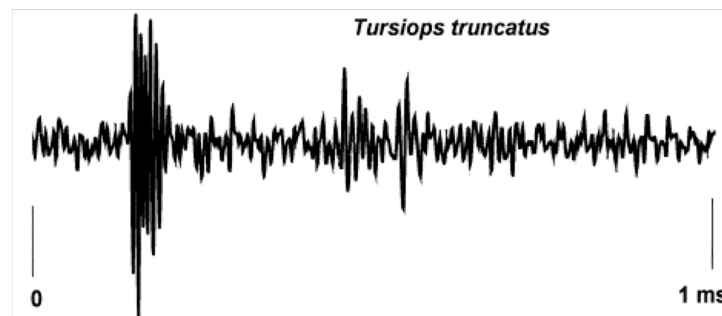


Construction des espaces de représentation adéquats pour l'analyse des signaux transitoires

Signaux transitoires

Ils sont différents du reste du signal !

- impulsifs
- éphémères
- très courts



Construction des espaces de représentation adéquats pour l'analyse des signaux transitoires

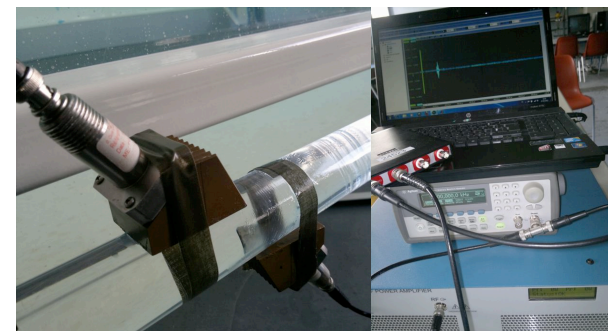
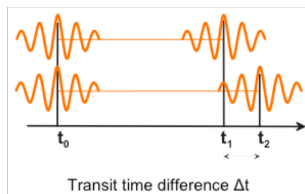
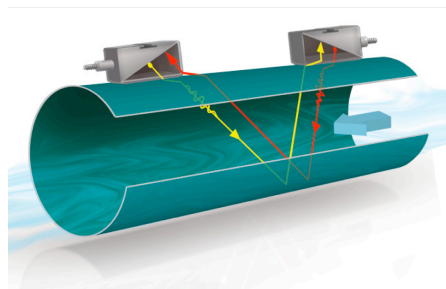
Contexte applicatif



L'investigation ultrasonore des conduites d'eau

=> analyse de signaux transitoires

=> des paramètres : temps d'apparition, fréquence, ...

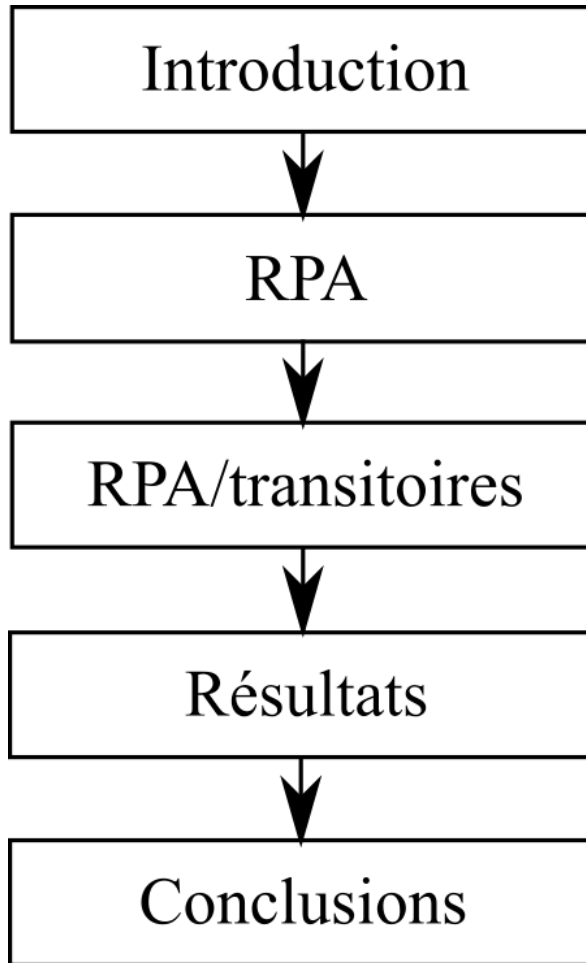


Objectif

Méthodes pour la détection et la caractérisation des signaux transitoires
génériques !



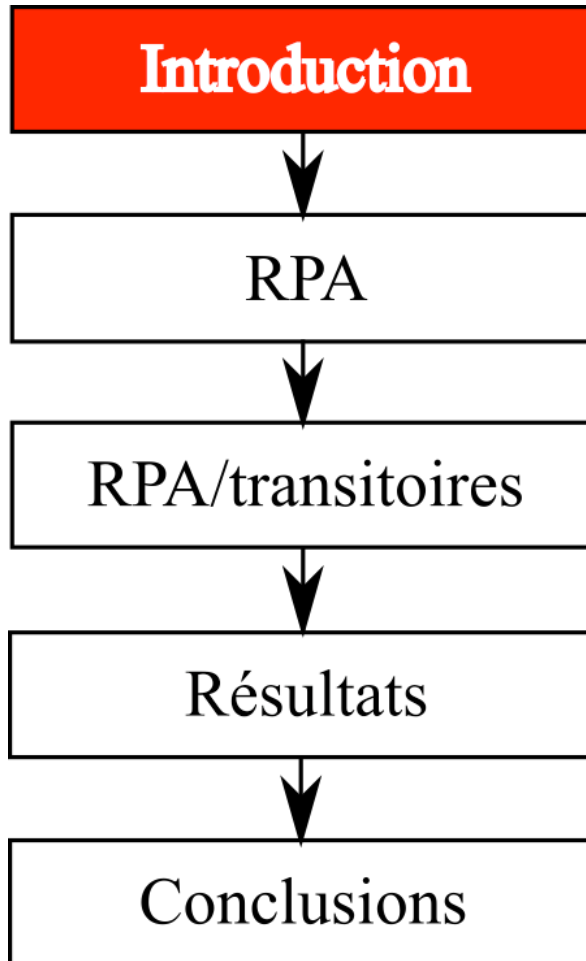
Plan



1. Introduction
2. RPA
3. RPA/transitoires
4. Résultats
5. Conclusions



Plan



1. Introduction

- Approche

2. RPA

3. RPA/transitoires

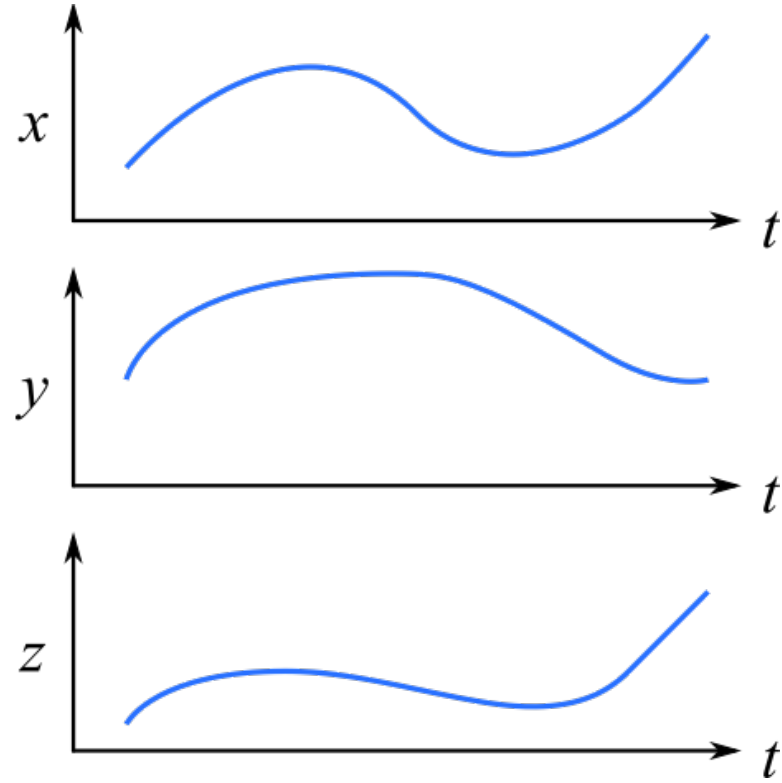
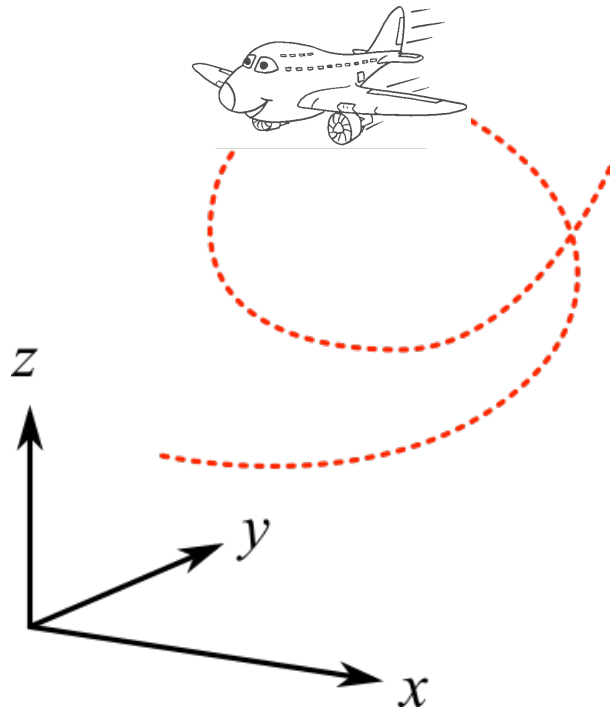
4. Résultats

5. Conclusions

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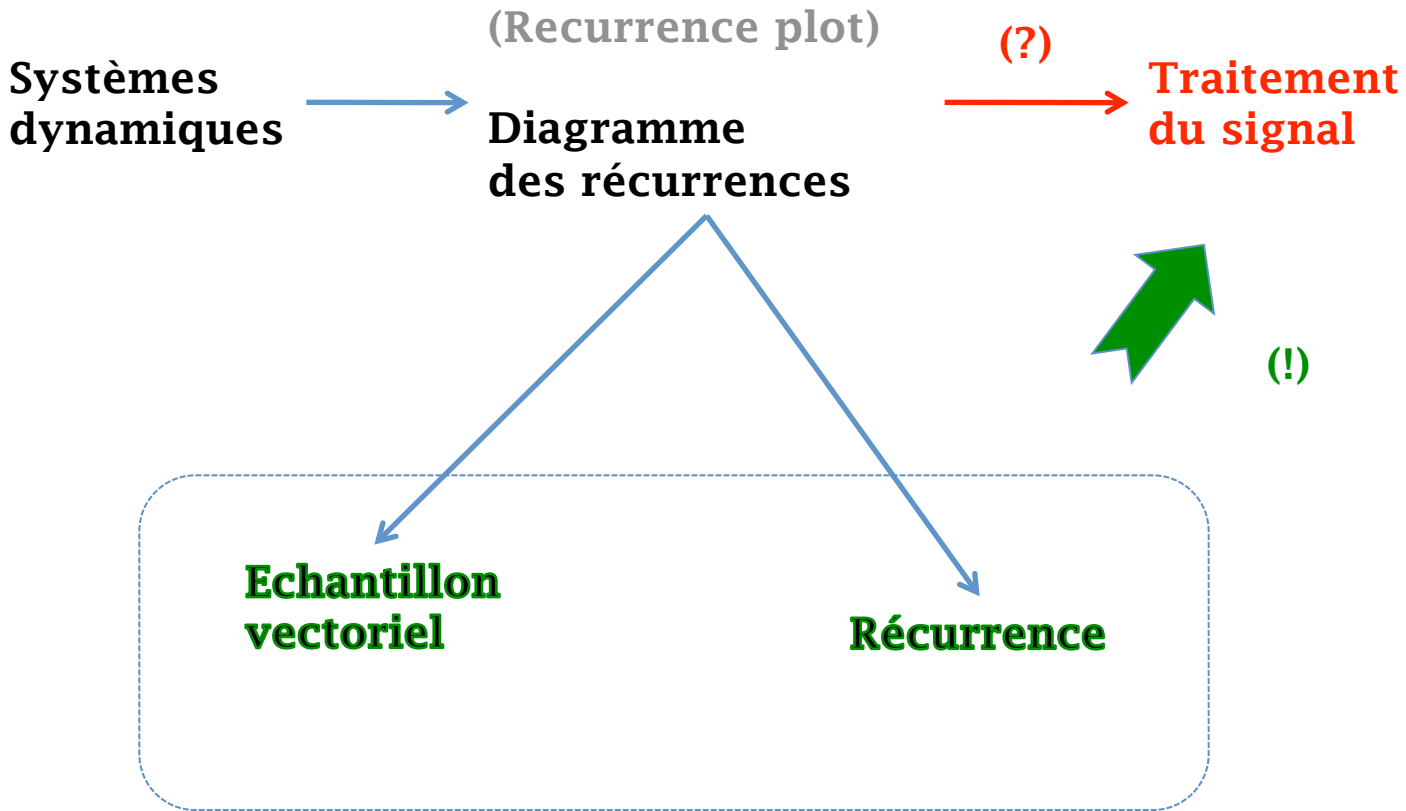


Approche



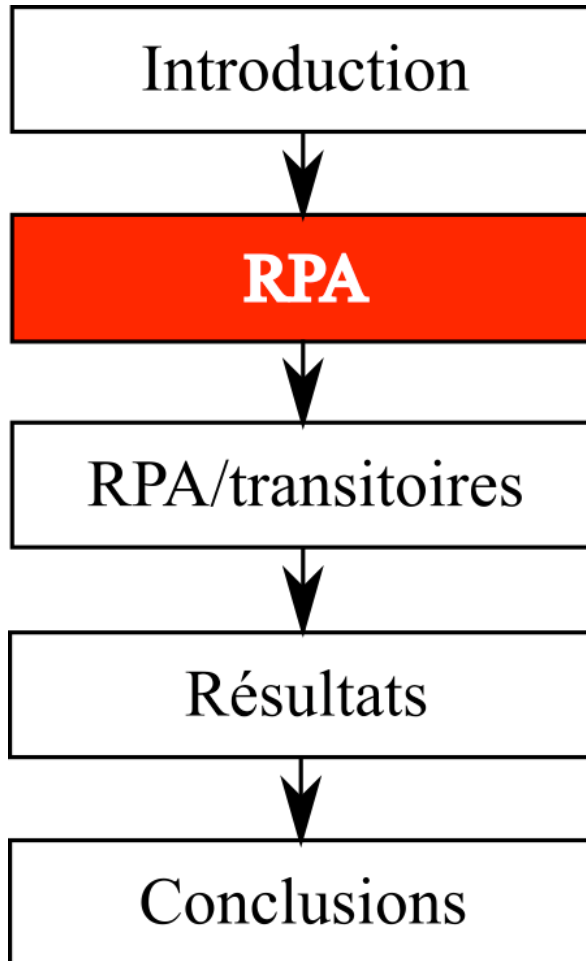


Approche





Plan



1. Introduction

2. RPA

- Description de la méthode
- Echantillons vectoriels et *distances*
- Mesures VeSP
- Mesures RQA
- Choix du rayon de récurrence

3. RPA/transitoires

4. Résultats

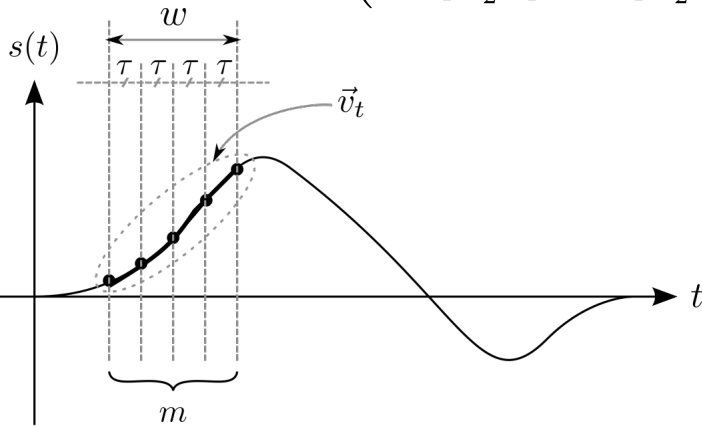
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Description de la méthode RPA

$$\vec{v}_t = \left(s_{t - \lfloor \frac{w-1}{2} \rfloor}, s_{t - \lfloor \frac{w-1}{2} \rfloor + \tau}, \dots, s_{t - \lfloor \frac{w-1}{2} \rfloor + (m-1)\tau} \right)$$

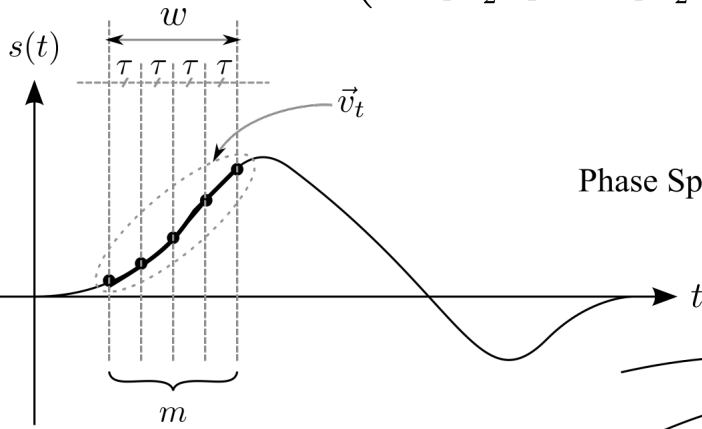


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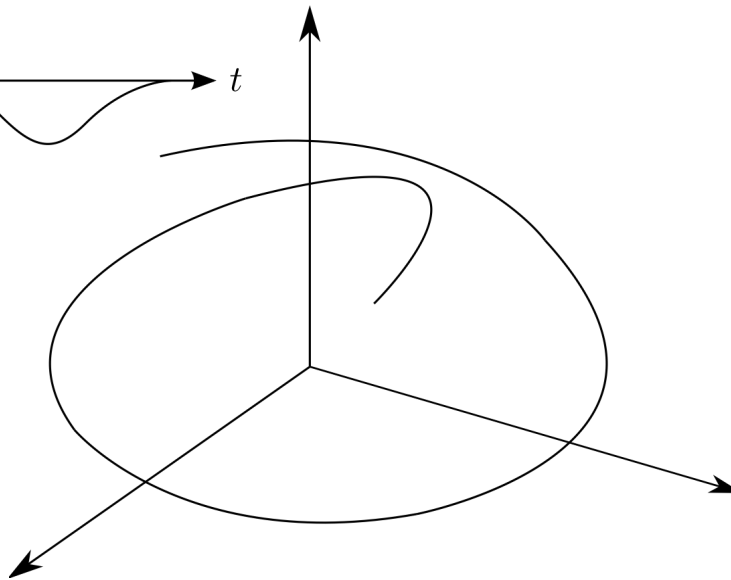


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Phase Space Representation

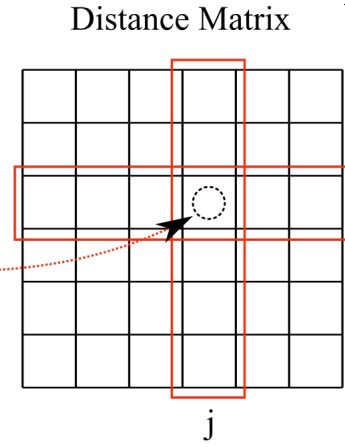
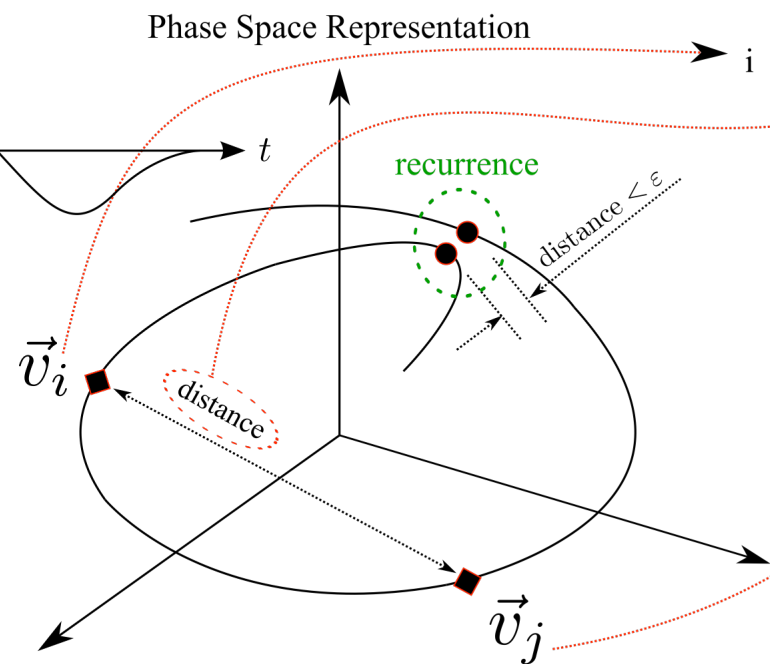
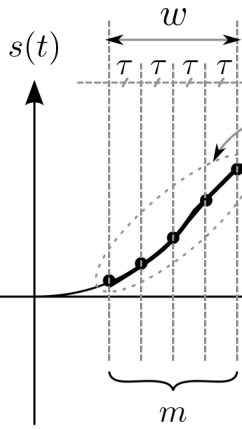




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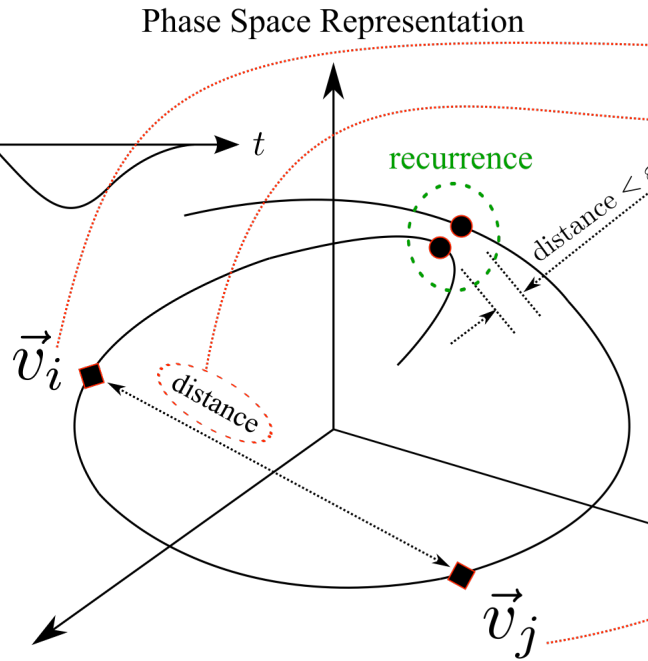
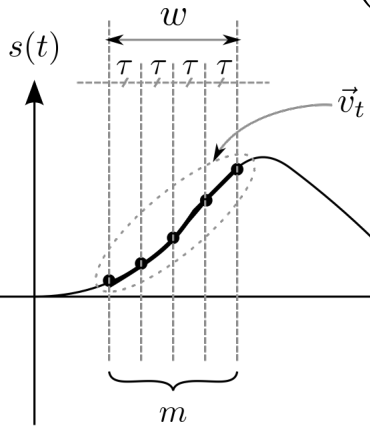
$$D_{i,j} = \mathcal{D} \{ \vec{v}_i, \vec{v}_j \}$$



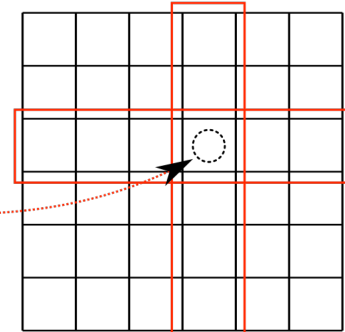


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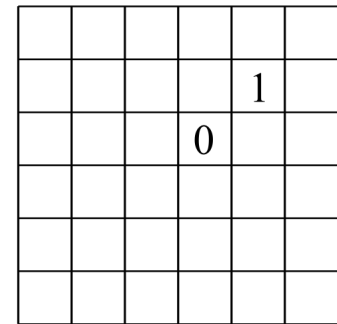
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$$D_{i,j} = \mathcal{D} \{ \vec{v}_i, \vec{v}_j \}$$



Recurrence Matrix

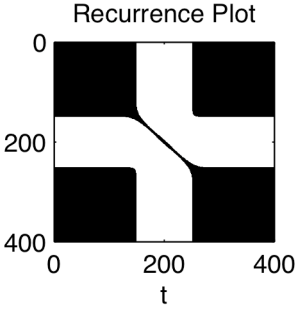
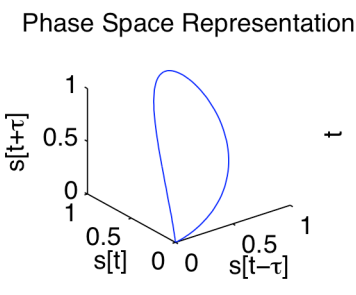
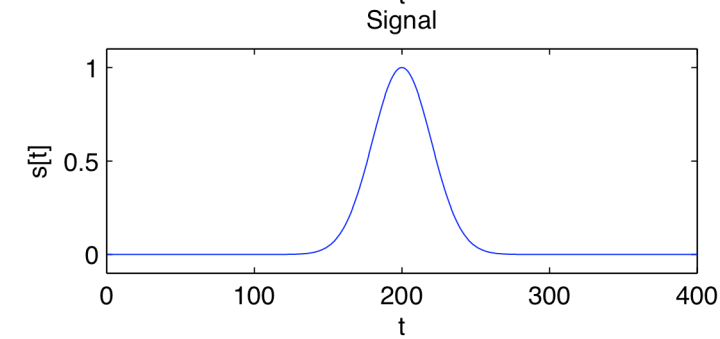
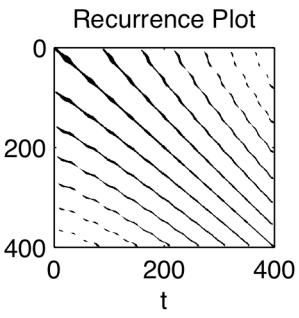
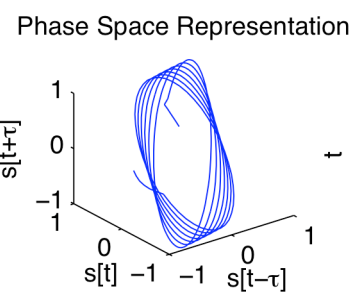
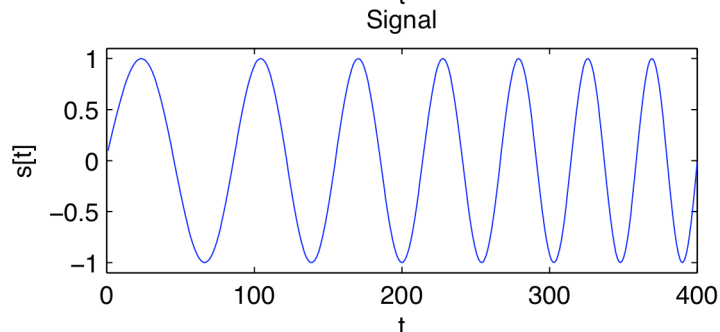
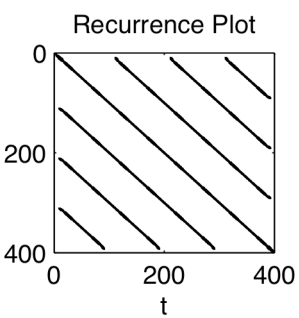
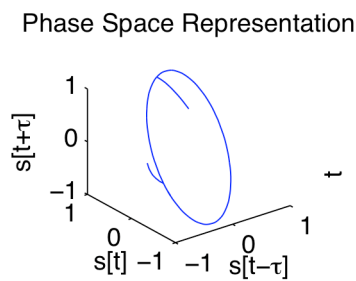
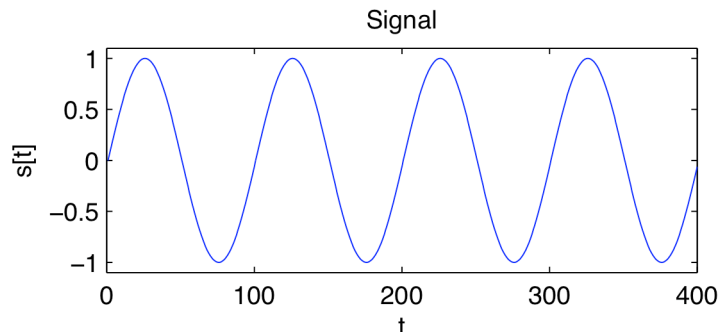


$$R_{i,j} = \Theta (\epsilon - D_{i,j})$$

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Description de la méthode RPA



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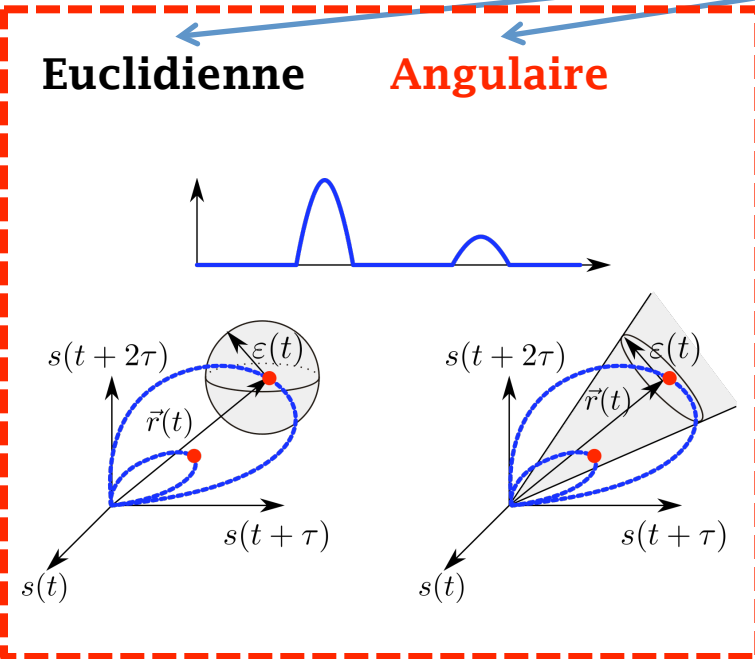
Echantillons vectoriels et *distances*

Echantillons vectoriels



le développement des opérations avec échantillons :

distances





Echantillons vectoriels et *distances*

Echantillons vectoriels



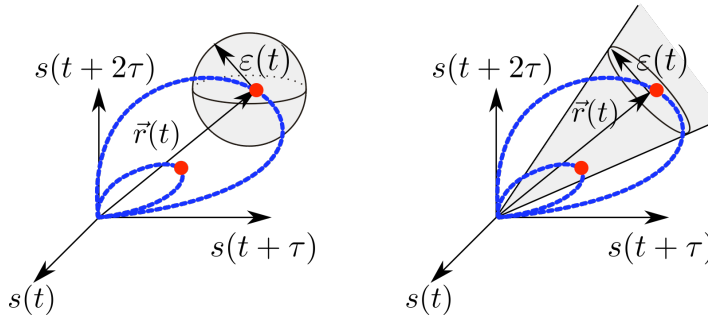
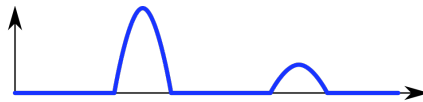
le développement des opérations avec échantillons :

distances

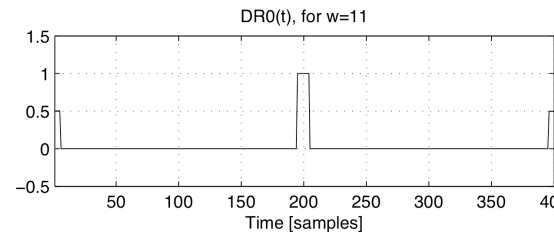
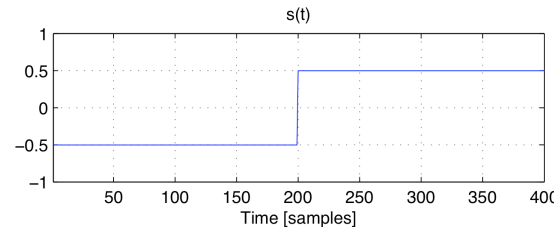
Euclidienne

Angulaire

Gamme dynamique



$$DR0[n] = \max_k \{ \bar{s}_n^{(w)}(k) \} - \min_k \{ \bar{s}_n^{(w)}(k) \}$$





Echantillons vectoriels et *distances*

Echantillons vectoriels



le développement des opérations avec échantillons :

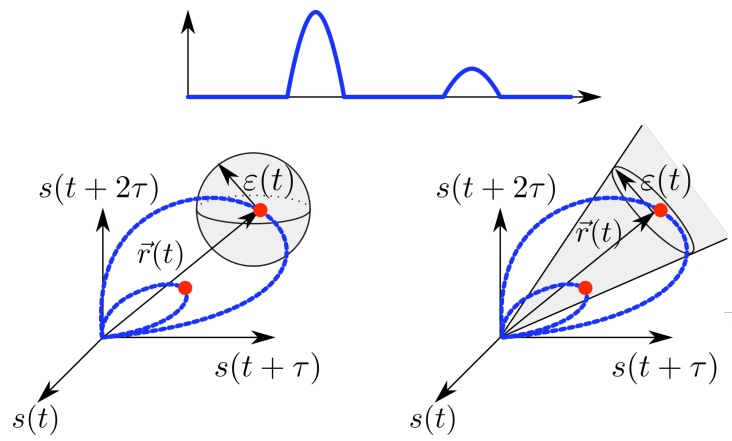
distances

Euclidienne

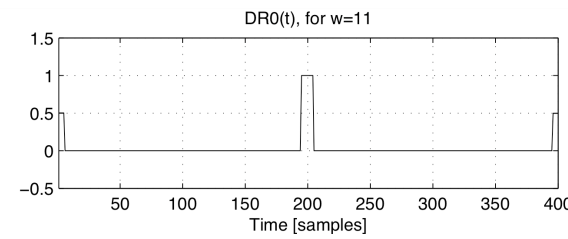
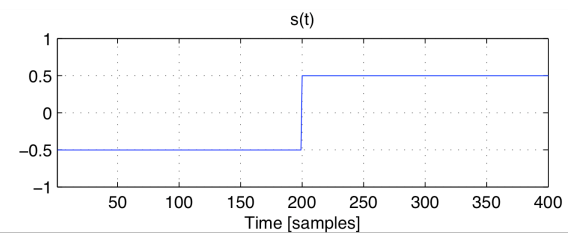
Angulaire

Gamme dynamique

Produit scalaire



$$DR0[n] = \max_k \{ \bar{s}_n^{(w)}(k) \} - \min_k \{ \bar{s}_n^{(w)}(k) \}$$



$$D \{ \vec{v}_i, \vec{v}_j \} = \vec{v}_i \cdot \vec{v}_j$$

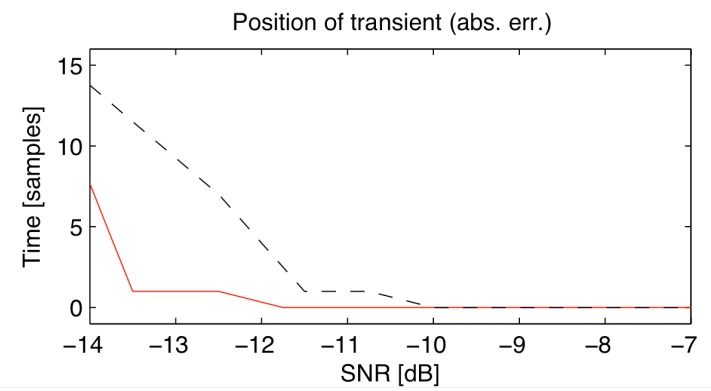
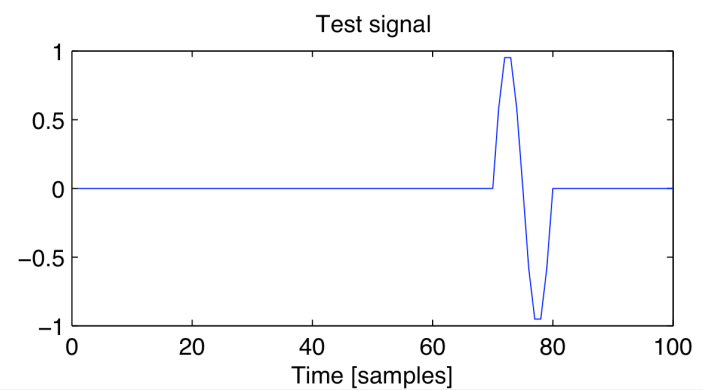
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Mesures VeSP

Corrélation

$$C = \frac{1}{N} \sum_{i=1}^N (s_i - \langle s \rangle) \cdot (r_i - \langle r \rangle) \xrightarrow{\text{VeSP}} C^{(w)} = \frac{1}{N} \sum_{i=1}^N \left(\vec{s}_i^{(w)} - \langle \vec{s}^{(w)} \rangle \right) \cdot \left(\vec{r}_i^{(w)} - \langle \vec{r}^{(w)} \rangle \right)$$



Légende :

— VeSP C (w=10)

--- C

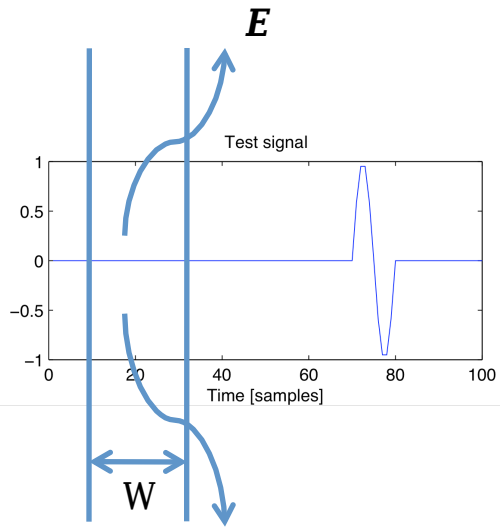
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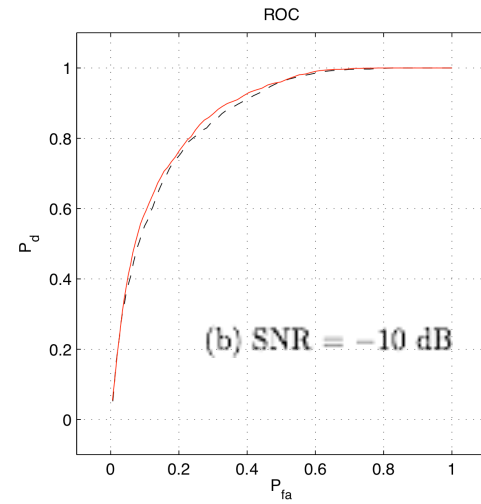
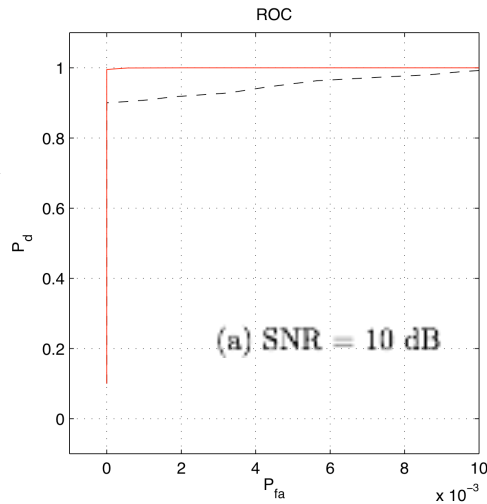
Mesures VeSP

Energie

$$E = \sum_{i=1}^N s_i^2 \xrightarrow{\text{VeSP}} E^{(w)} = \sum_{i=1}^N \bar{s}_i^{(w)} \cdot \bar{s}_i^{(w)}$$



VESP E



Légende :

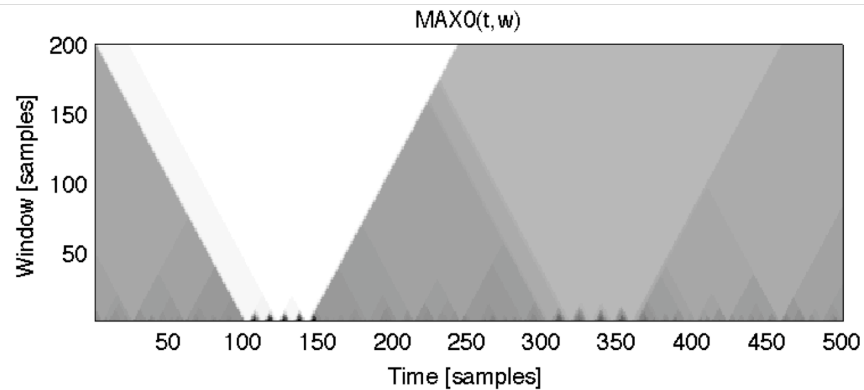
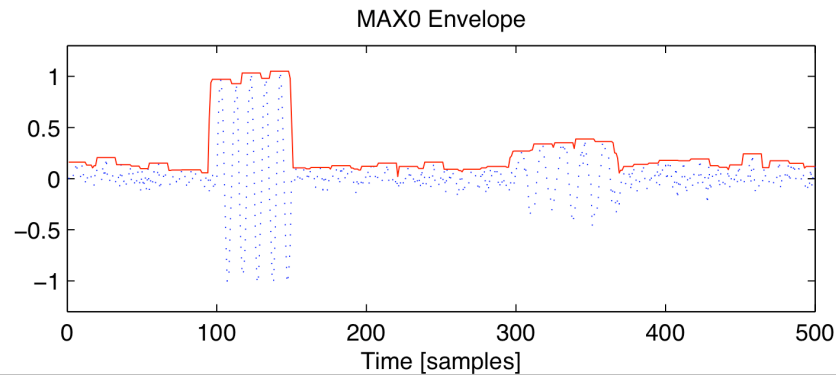
- **VeSP E (w=10)**
- - - **E**



Mesures VeSP

Enveloppe

$$MAX0^{(w)}[n] = \max_k \{ \vec{v}_n(k) \}$$

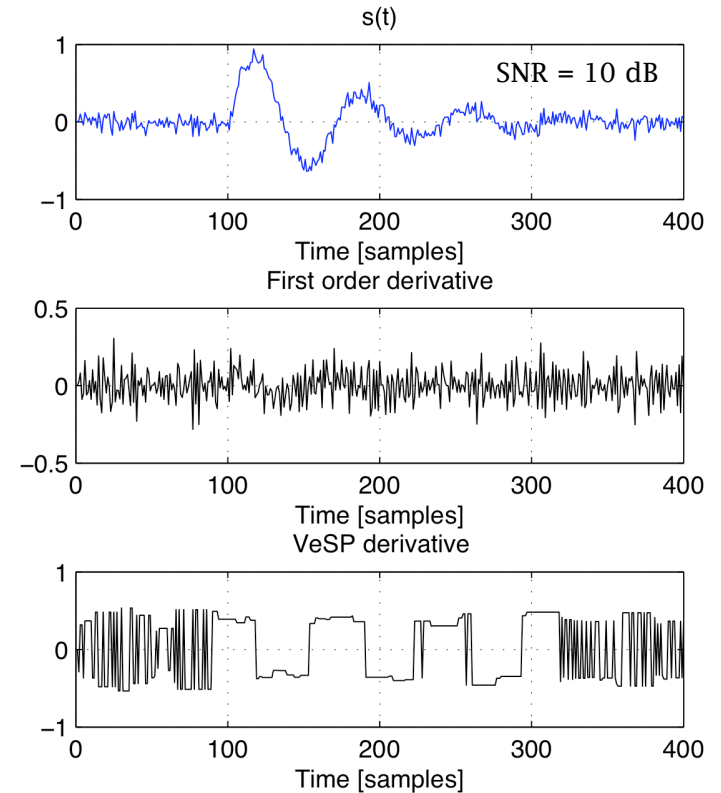
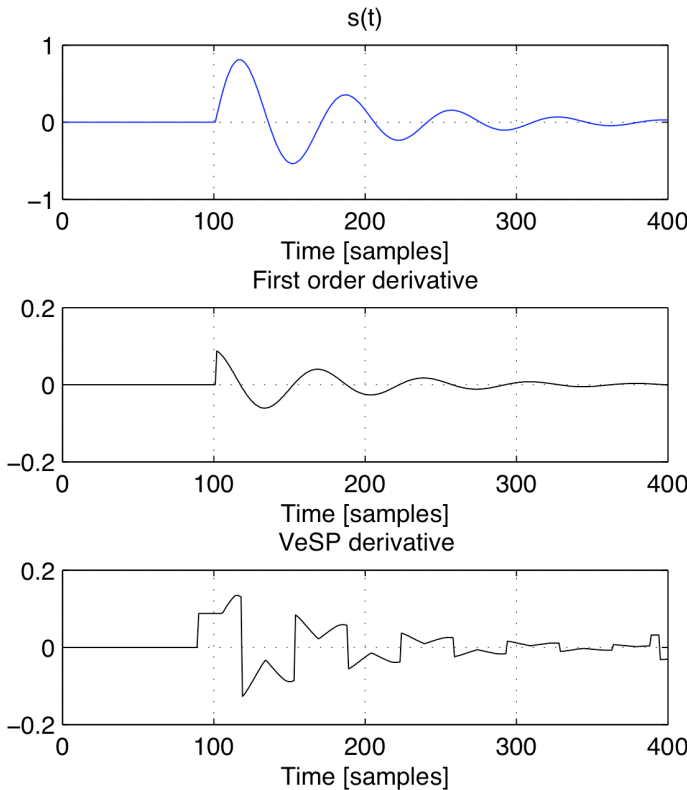


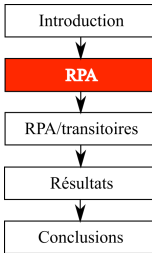


Mesures VeSP

Dérivée

$$\Delta\{s\}[n] = s_{n+1} - s_n \xrightarrow{\text{VeSP}} \Delta^{(w)}\{s\}[n] = \mathcal{D}\left\{\bar{s}_{n+1}^{(w)}, \bar{s}_n^{(w)}\right\}$$





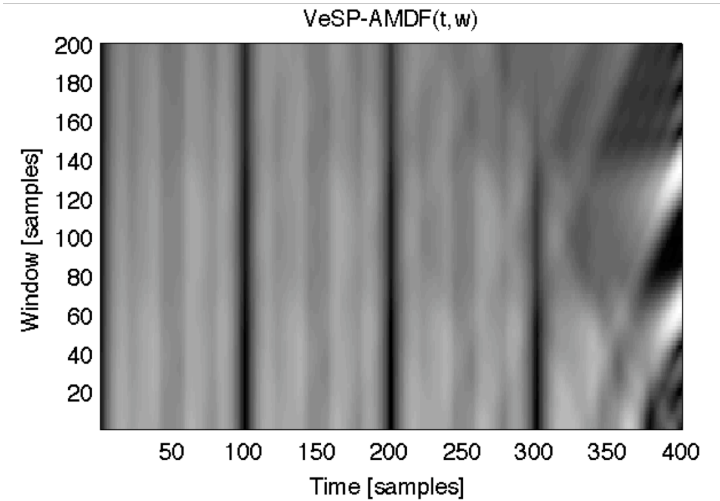
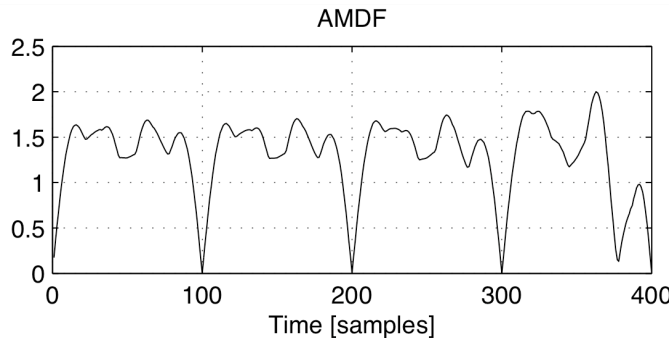
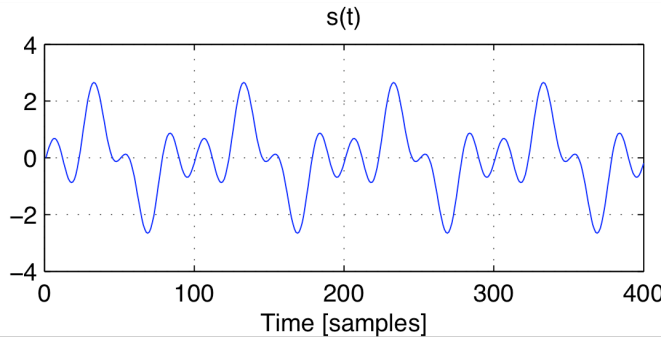
Mesures VeSP

Average Magnitude Difference Function

$$AMDF[n] = \frac{1}{N-n} \sum_{i=1}^{N-n} |s_{i+n} - s_i|$$

VeSP \longrightarrow

$$AMDF^{(w)}[n] = \frac{1}{N-n} \sum_{i=1}^{N-n} \left\| \bar{s}_{i+n}^{(w)} - \bar{s}_i^{(w)} \right\|$$





Mesures RQA

Auto-corrélation

$$ACF[n] = \sum_{i=1}^N s_i \cdot s_{i+n}$$

VeSP {

$$ACF^{(w)}[n] = \sum_{i=1}^N \bar{s}_i^{(w)} \cdot \bar{s}_{i+n}^{(w)}$$

$$ACF^{(w)}[n] = \sum_{i=1}^N \mathcal{D} \left\{ \bar{s}_i^{(w)}, \bar{s}_{i+n}^{(w)} \right\}$$

RQA {

$$ACF_n^{(w)} = \sum_{i=1}^N R_{i,i+n}$$

$$R_{i,j} = \Theta \left(\mathcal{D} \left\{ \bar{s}_i^{(w)}, \bar{s}_j^{(w)} \right\} - \varepsilon \right)$$



Mesures RQA

Average Magnitude Difference Function

$$AMDF[n] = \frac{1}{N-n} \sum_{i=1}^{N-n} |s_{i+n} - s_i|$$

VeSP {

$$AMDF^{(w)}[n] = \frac{1}{N-n} \sum_{i=1}^{N-n} \left\| \vec{s}_{i+n}^{(w)} - \vec{s}_i^{(w)} \right\|$$

$$AMDF^{(w)}[n] = \frac{1}{N-n} \sum_{i=1}^{N-n} \mathcal{D} \left\{ \vec{s}_i^{(w)}, \vec{s}_{i+n}^{(w)} \right\} = \frac{1}{N-n} \sum_{i=1}^{N-n} D_{i,i+n}$$

RQA {

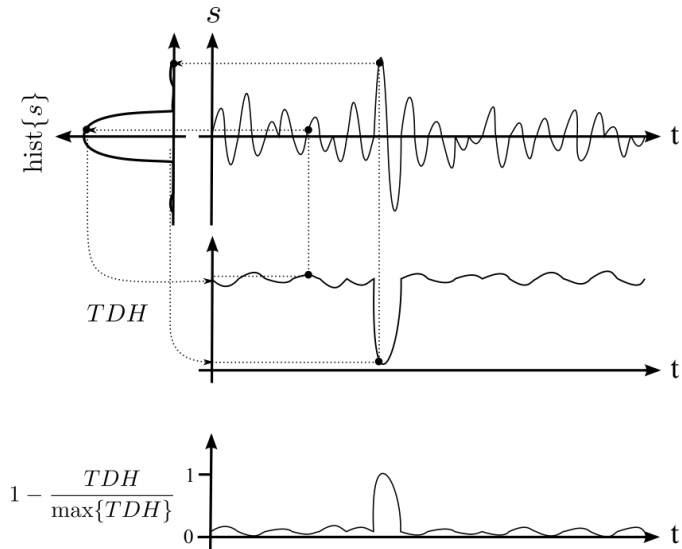
$$AMDF_n^{(w)} = \frac{1}{N-n} \sum_{i=1}^{N-n} R_{i,i+n}$$

$$R_{i,j} = \Theta \left(\varepsilon - \mathcal{D} \left\{ \vec{s}_i^{(w)}, \vec{s}_j^{(w)} \right\} \right)$$



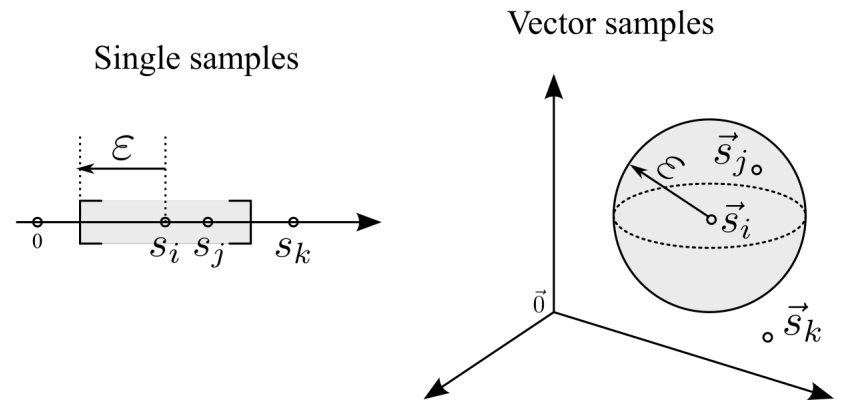
Mesures RQA

Time-Distributed Histogram



RQA →

$$TDH_n^{(w)} = \frac{1}{N} \sum_{i=1}^N R_{i,n}$$

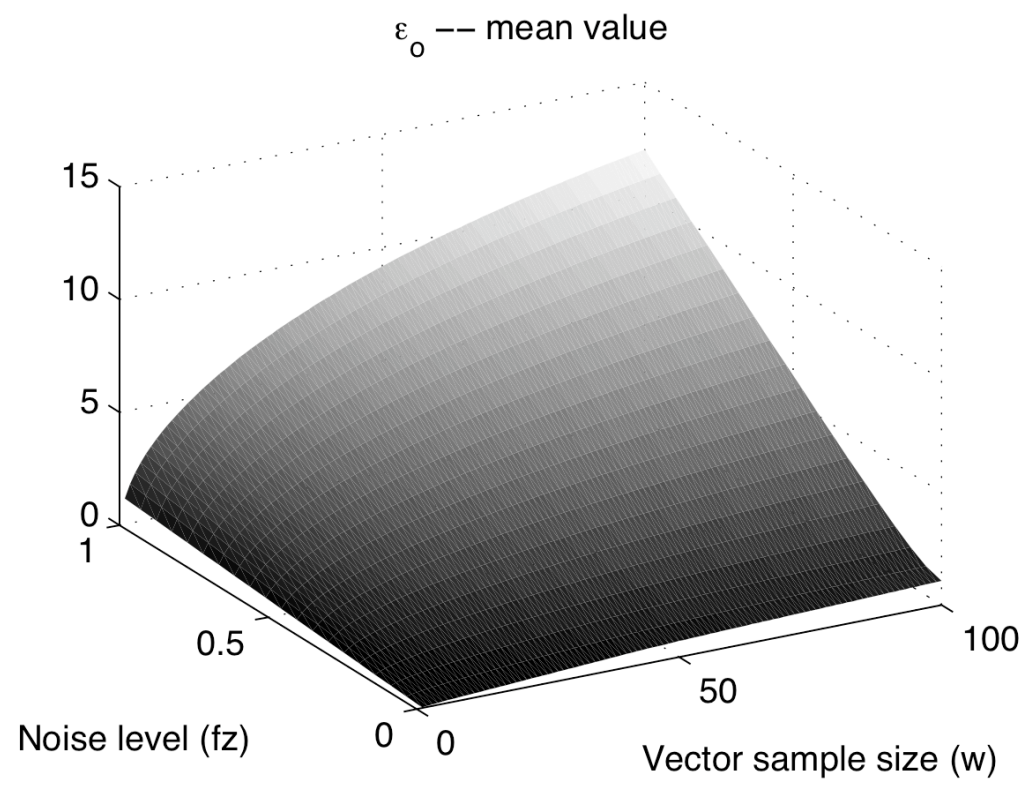


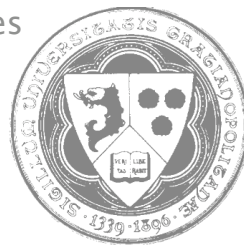
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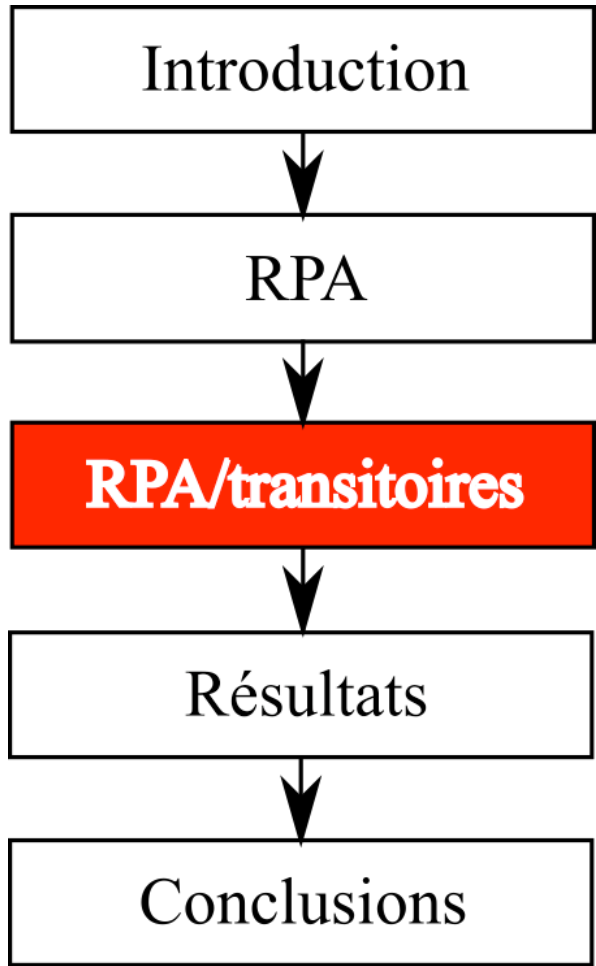
Choix du rayon de récurrence

$$\epsilon_0 = \frac{1}{N-1} \sum_{i=1}^{N-1} \|\vec{s}_{i+1} - \vec{s}_i\| \quad \leftarrow \text{S'adapte au niveau du bruit !}$$





Plan



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 - Les mesures génériques de quantification
 - Représentations temps – rayon de récurrence
 - Applications
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Les mesures génériques de quantification

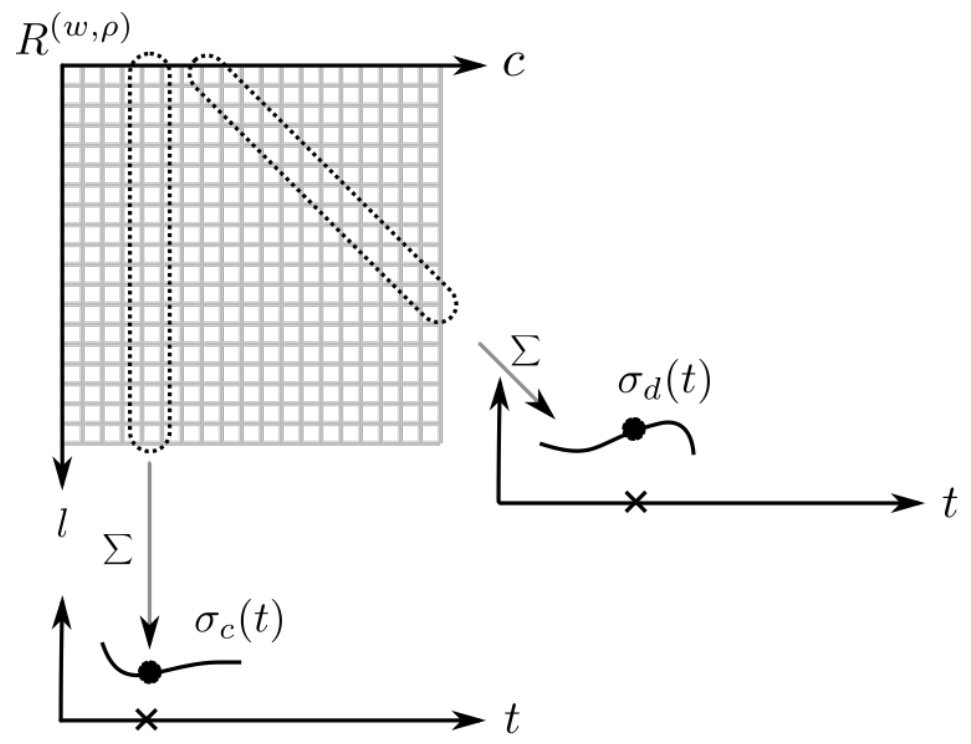
RQA ACF
 RQA AMDF ➔ **somme des diagonales**

$$ACF_n^{(w)} = \sum_{i=1}^N R_{i,i+n}$$

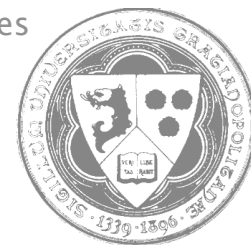
$$AMDF_n^{(w)} = \frac{1}{N-n} \sum_{i=1}^{N-n} R_{i,i+n} \sigma_d$$

RQA TDH ➔ **somme des colonnes**

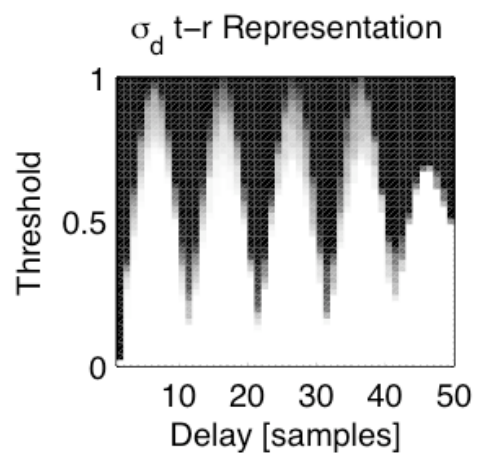
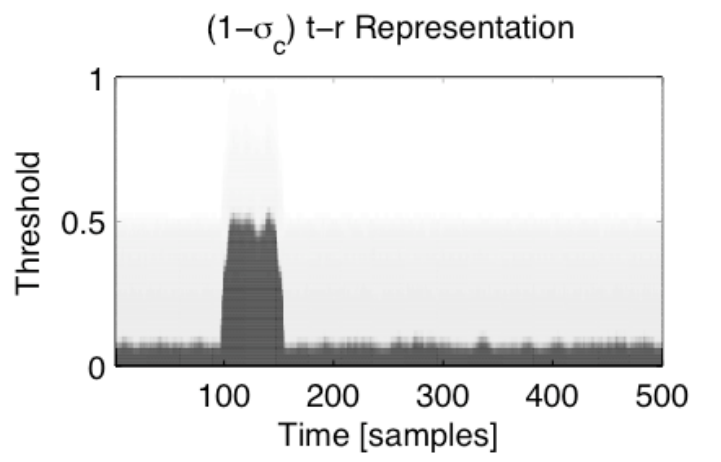
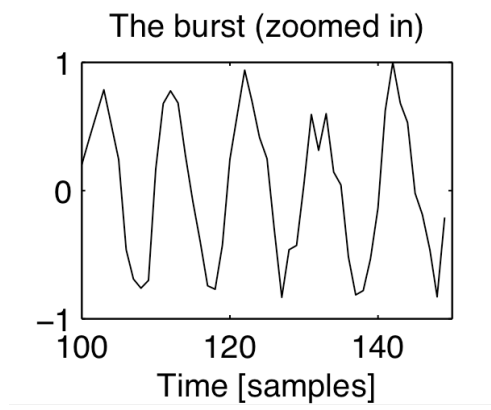
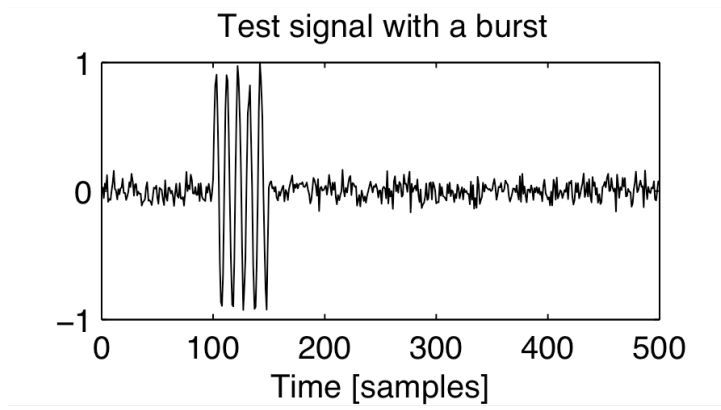
$$TDH_n^{(w)} = \frac{1}{N} \sum_{i=1}^N R_{i,n} \sigma_c$$



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Représentations temp - rayon de récurrence

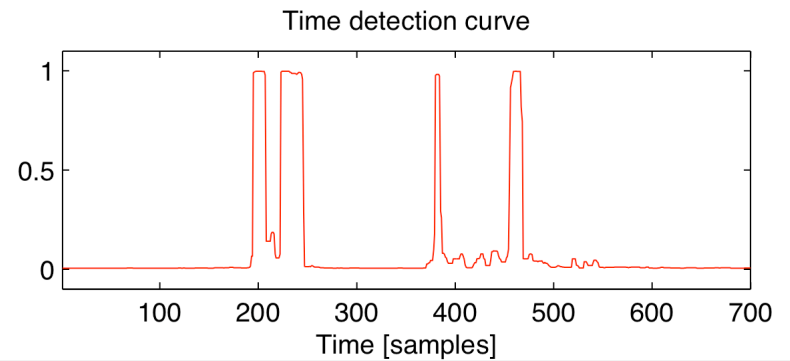
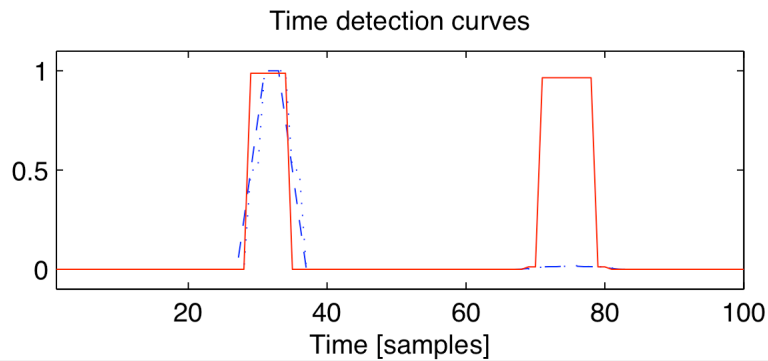
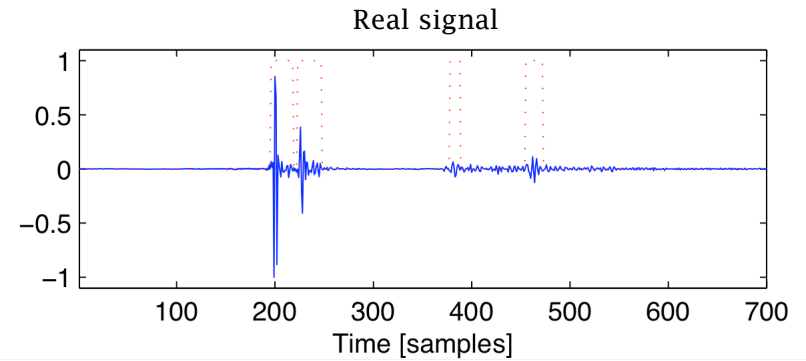
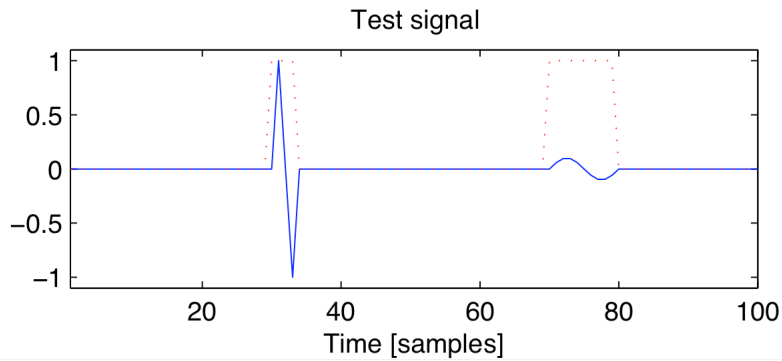


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Applications

Détection

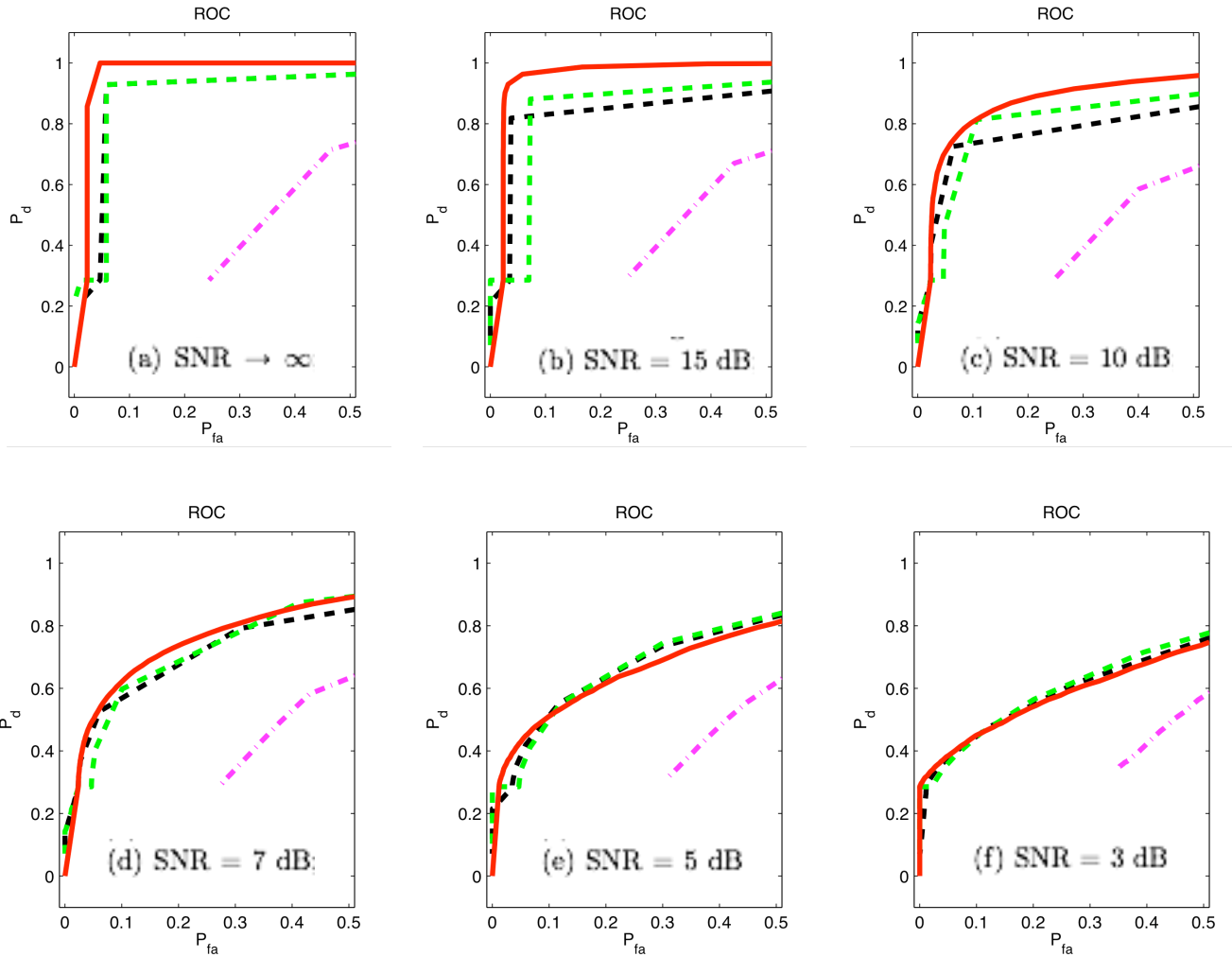


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Légende :

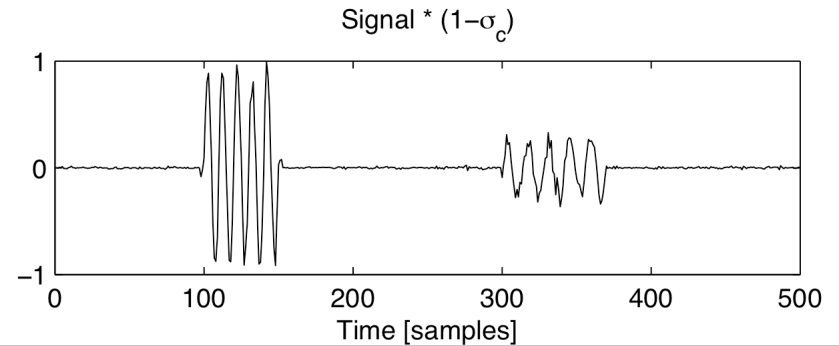
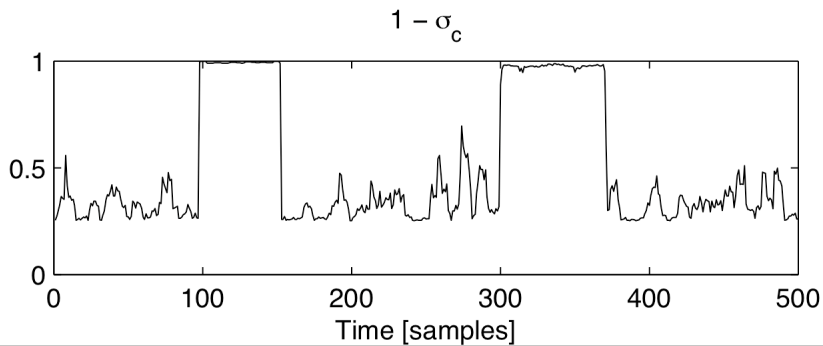
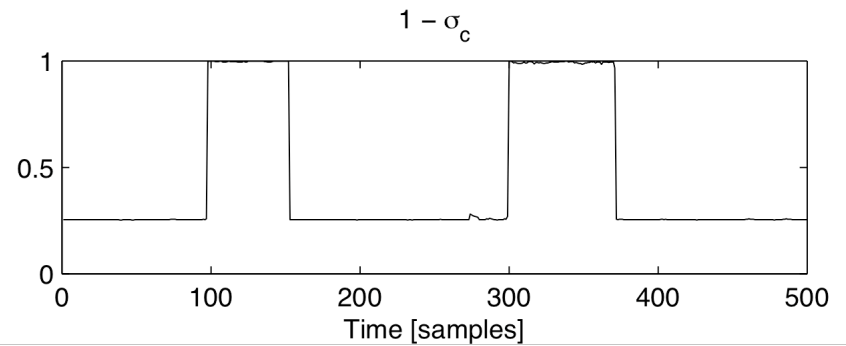
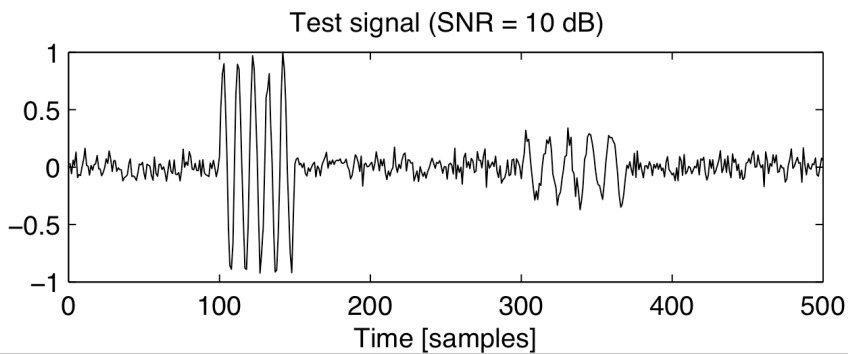
- RQA TDH
- - - VeSP E
- - - E
- · - · - WT + HOS

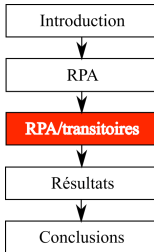
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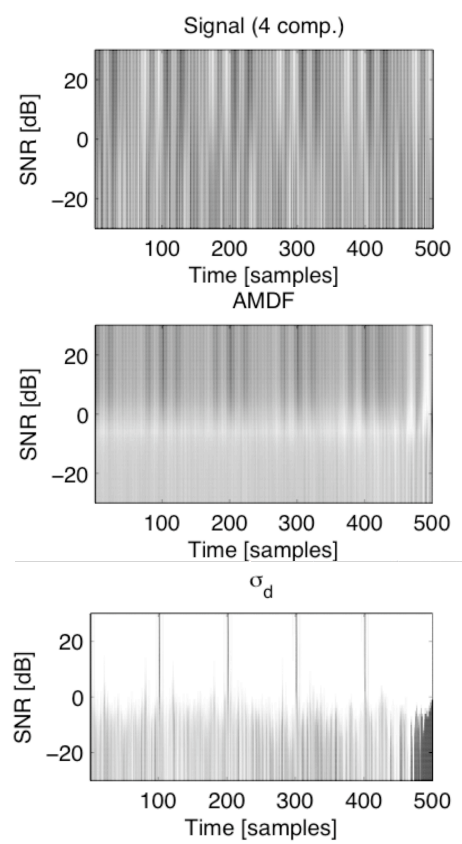
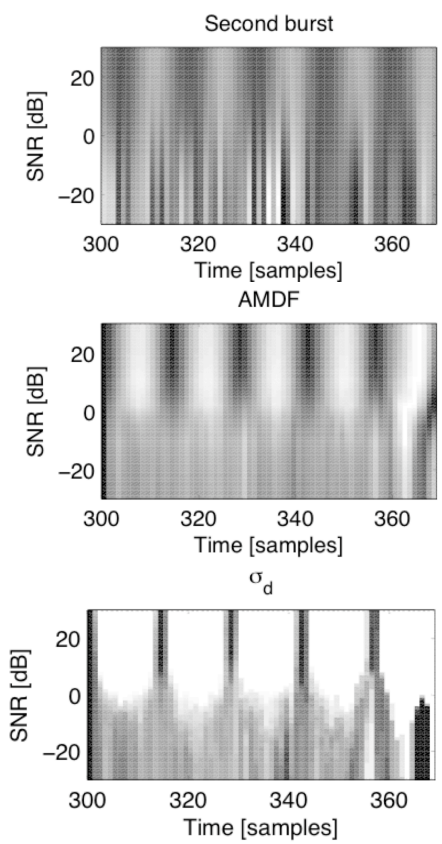
Réduction du bruit



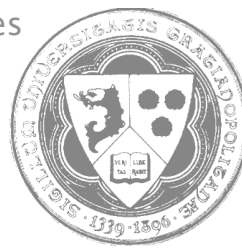


Applications

Estimation de la fréquence fondamentale

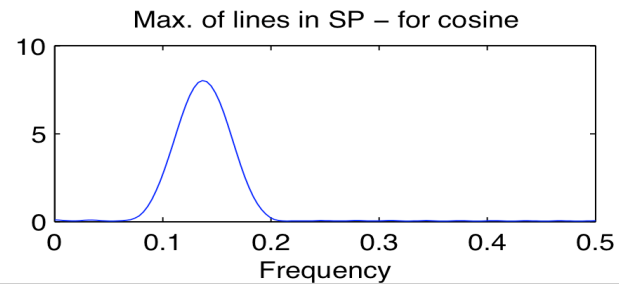
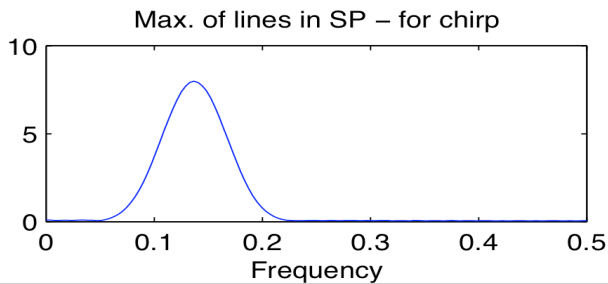
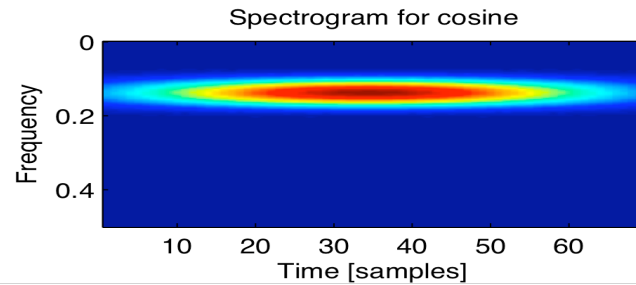
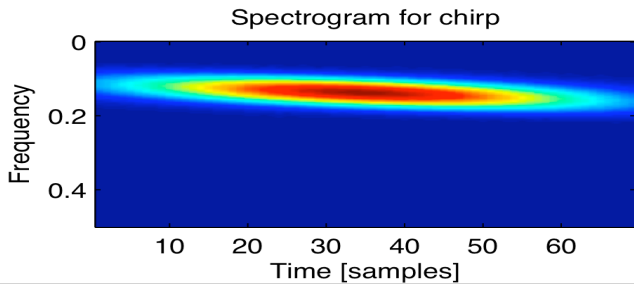
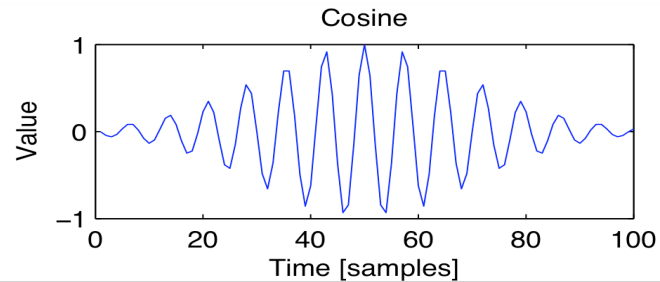
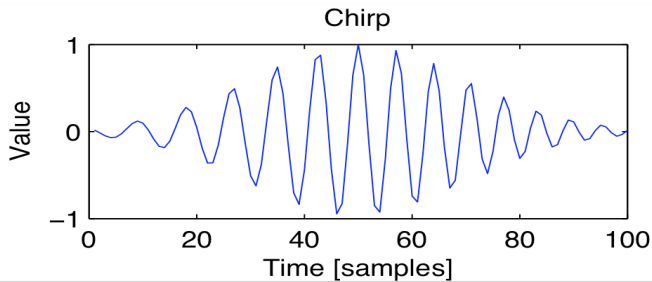


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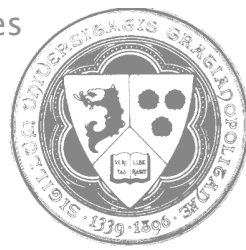


Applications

Identification des chirps

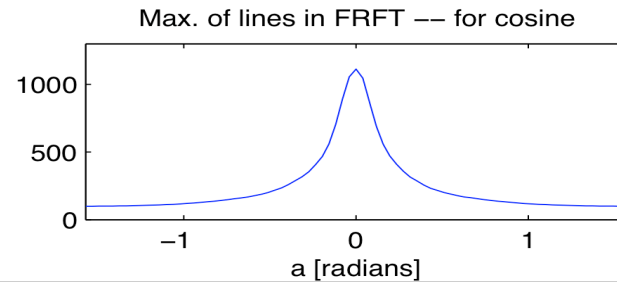
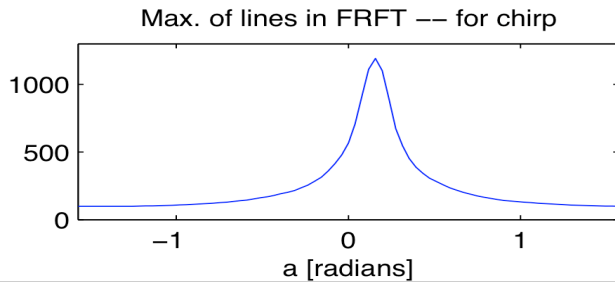
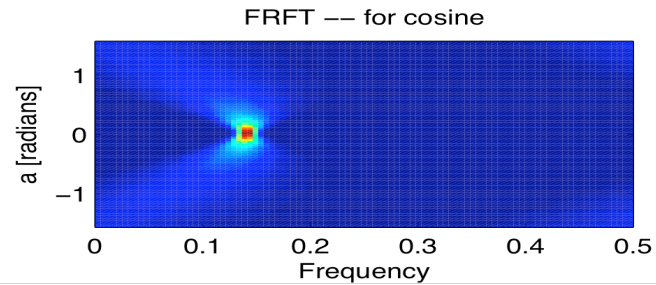
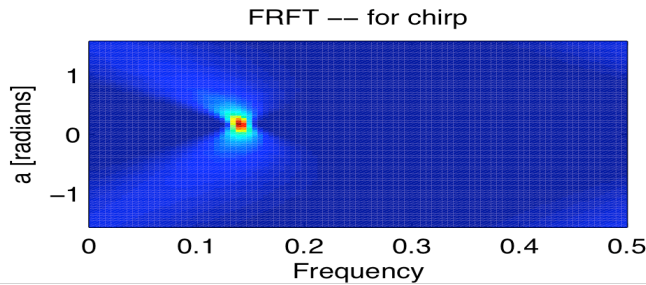
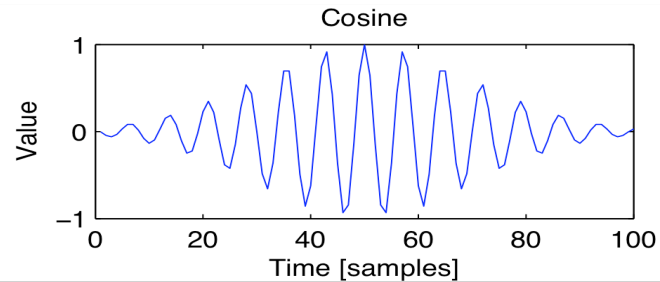
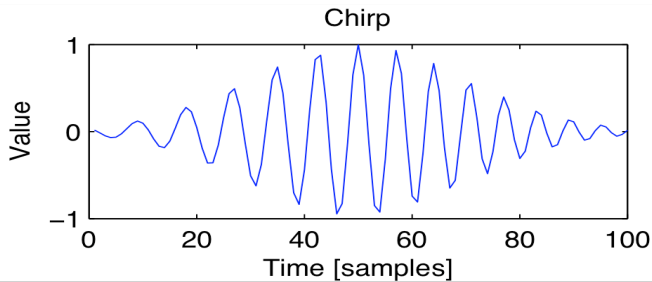


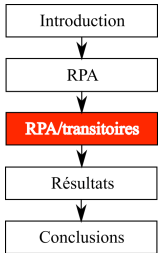
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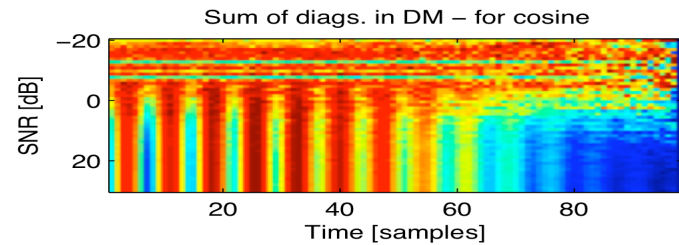
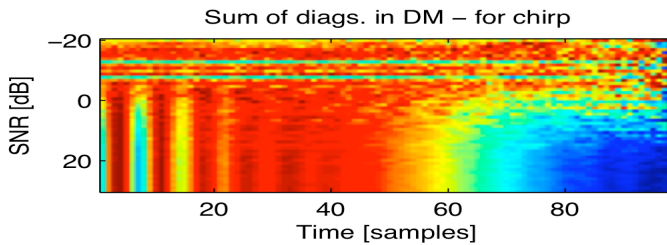
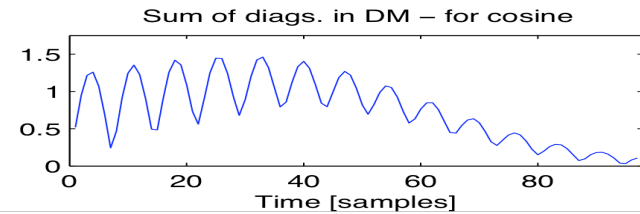
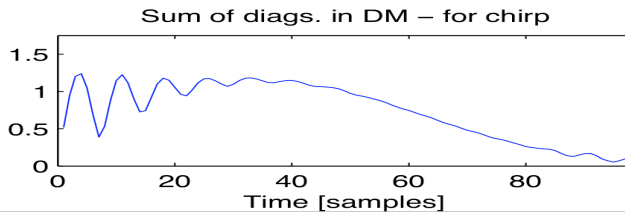
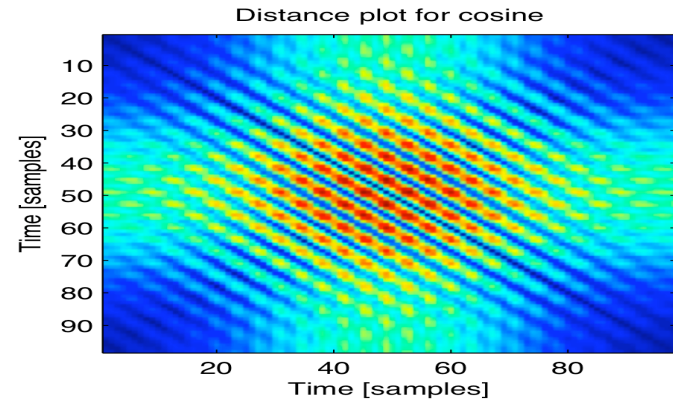
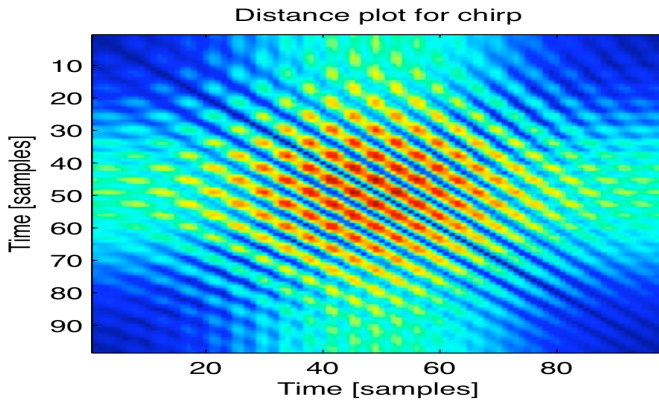
Identification des chirps





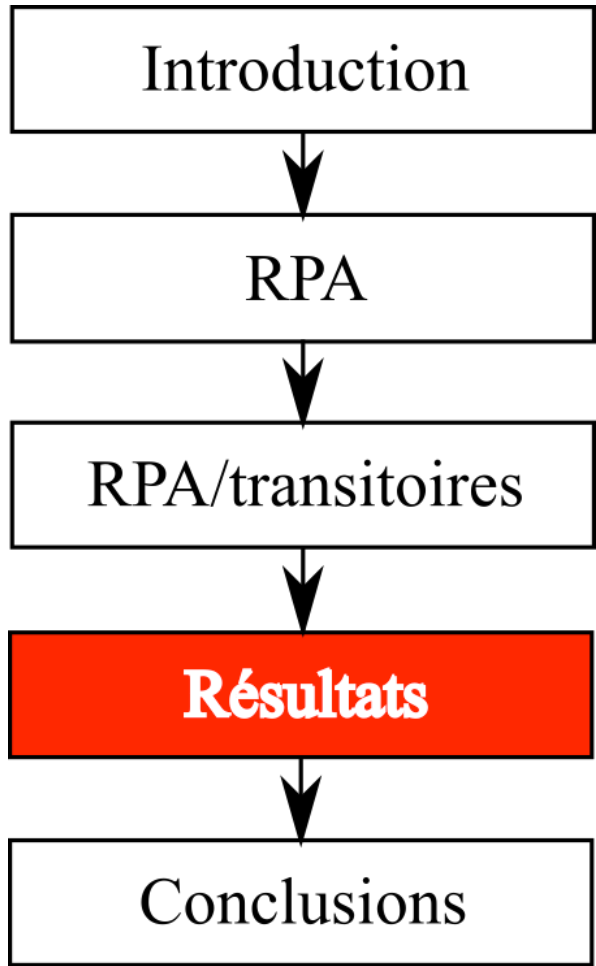
Applications

Identification des chirps

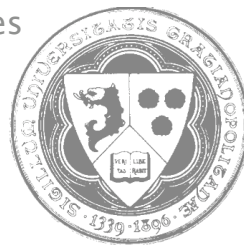




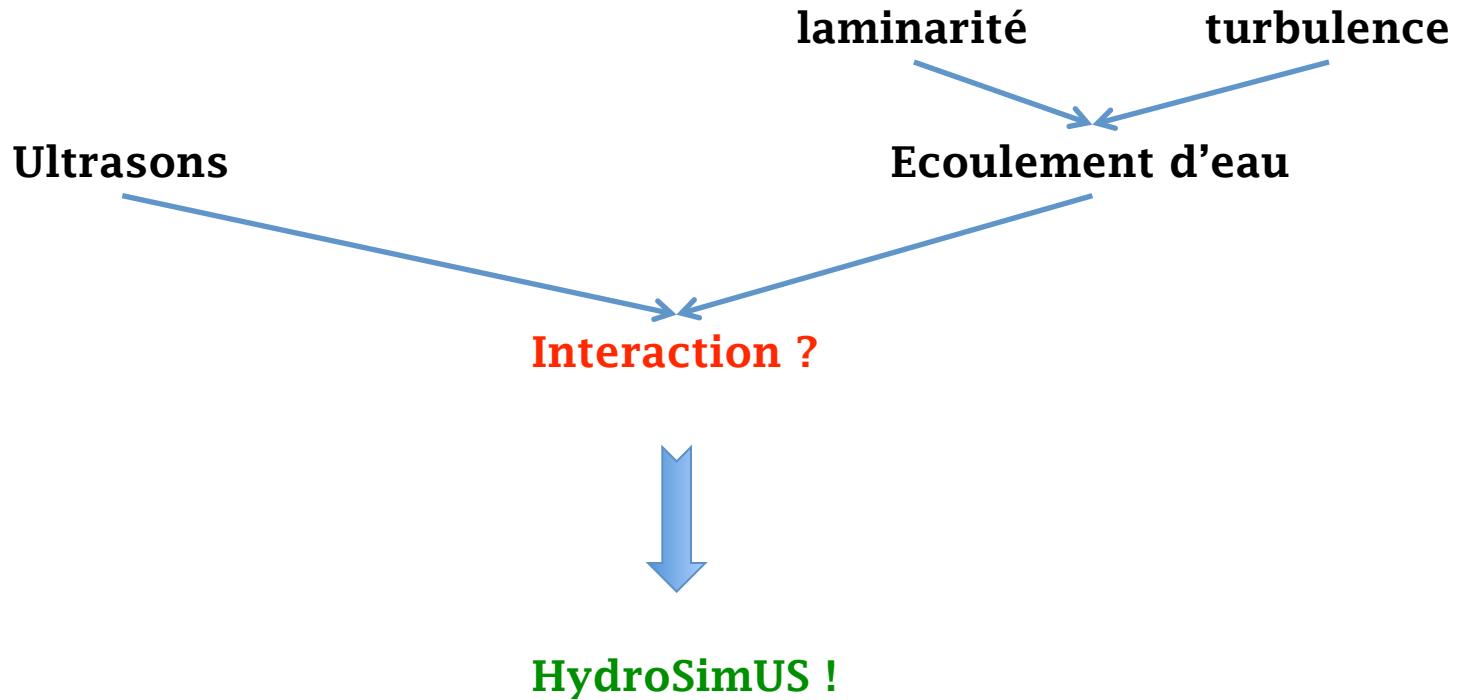
Plan



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 - Propagation ultrasonore dans des écoulements
 - Expériences simulés
 - Signaux synthétiques
 - Estimation du temps de propagation
6. Conclusions



Propagation ultrasonore dans des écoulements

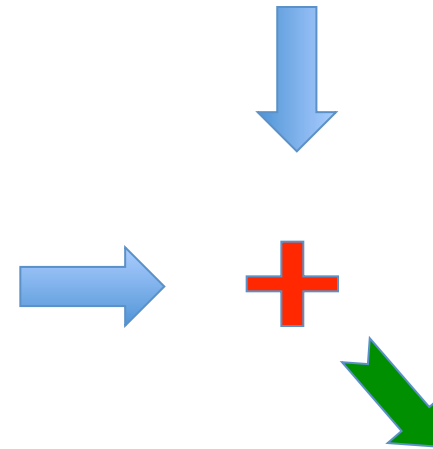
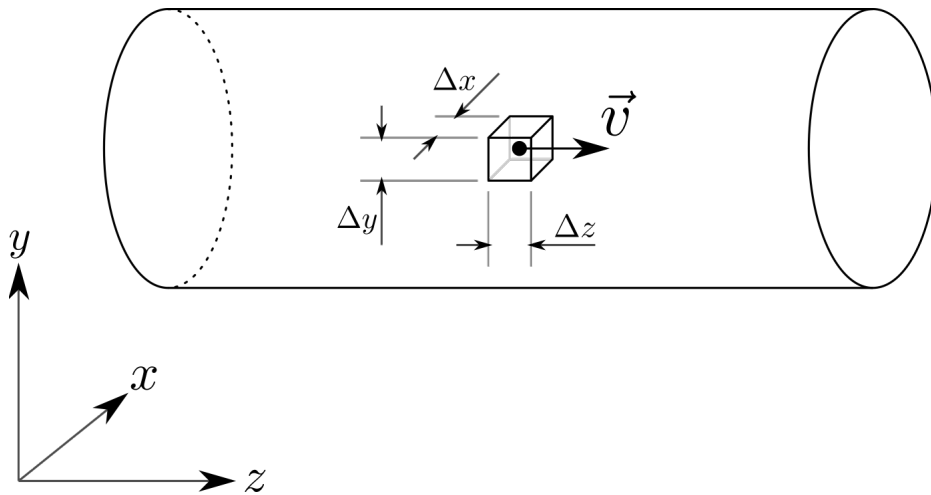


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- ↓
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Propagation ultrasonore dans des écoulements

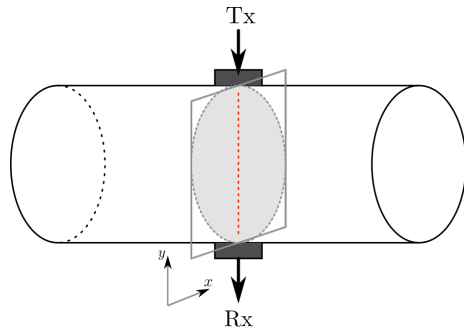
$$\nabla^2 p - c^{-2} \cdot \left(\frac{\partial}{\partial t} + \vec{v} \cdot \nabla \right)^2 p = 0$$



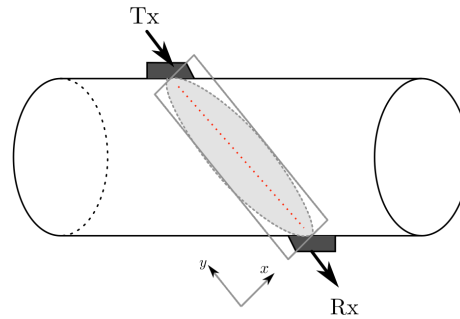
HydroSimUS !



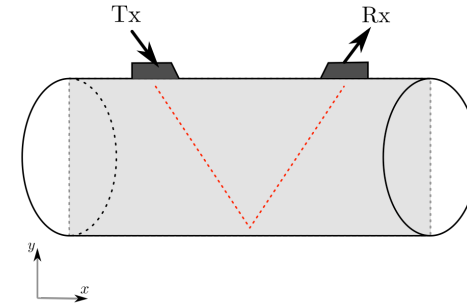
Propagation ultrasonore dans des écoulements



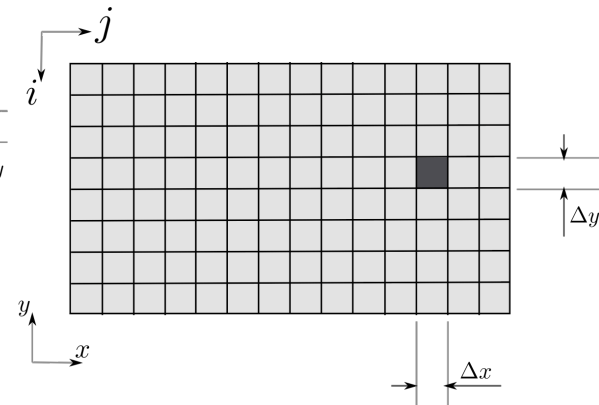
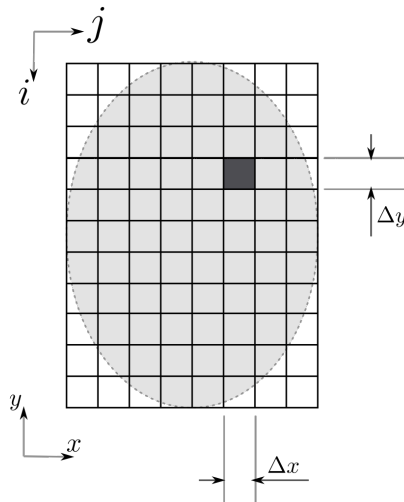
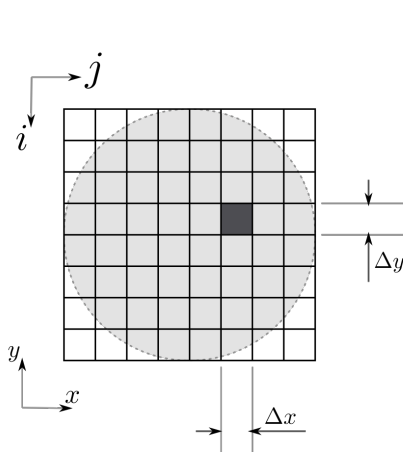
Transversal section



Oblique section



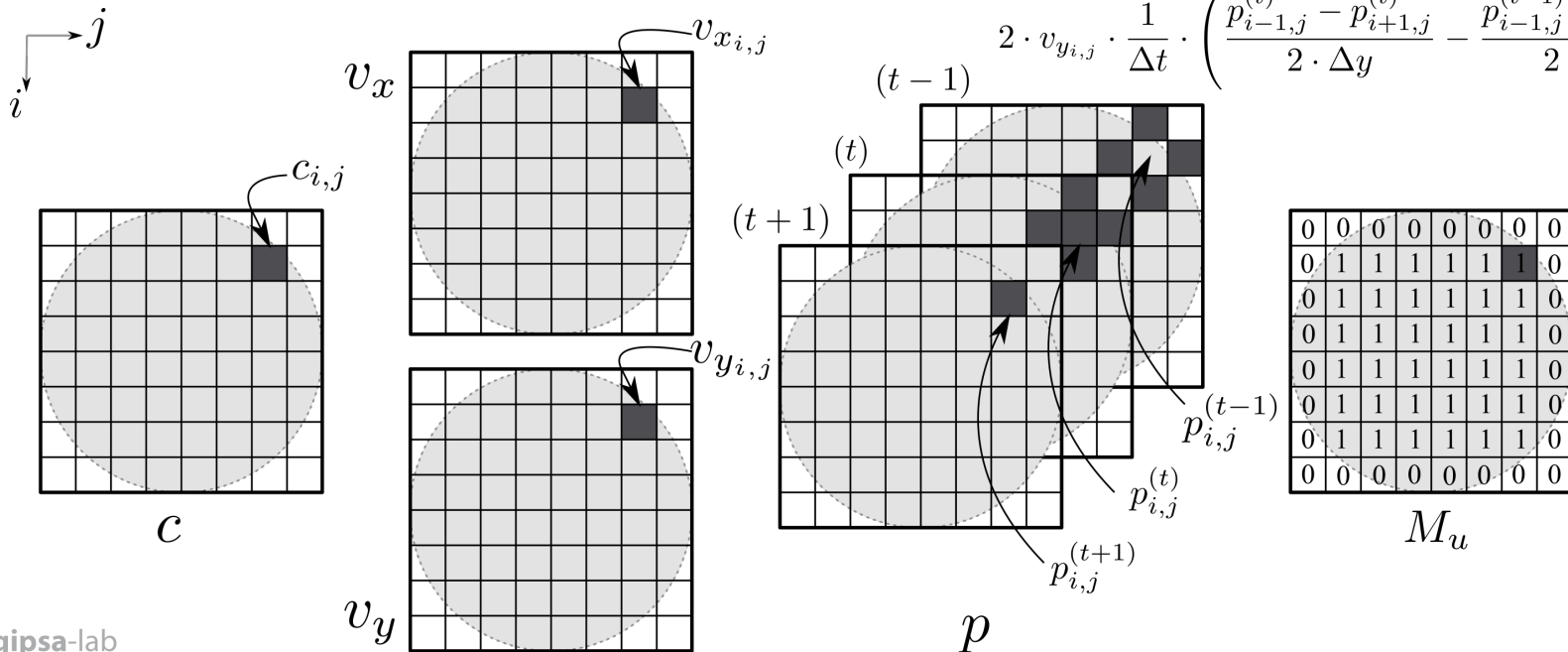
Longitudinal section





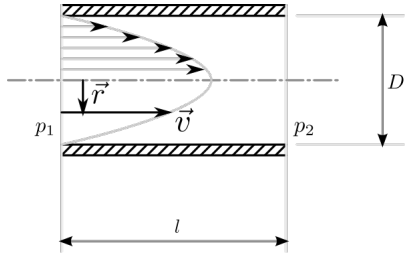
Propagation ultrasonore dans des écoulements

$$\frac{p_{i,j}^{(t+1)} - 2p_{i,j}^{(t)} + p_{i,j}^{(t-1)}}{(\Delta t)^2} = (c_{x,i,j}^2 - v_{x,i,j}^2) \cdot \frac{p_{i,j+1}^{(t)} - 2p_{i,j}^{(t)} + p_{i,j-1}^{(t)}}{(\Delta x)^2} + (c_{y,i,j}^2 - v_{y,i,j}^2) \cdot \frac{p_{i-1,j}^{(t)} - 2p_{i,j}^{(t)} + p_{i+1,j}^{(t)}}{(\Delta y)^2} - 2 \cdot v_{x,i,j} \cdot \frac{1}{\Delta t} \cdot \left(\frac{p_{i,j+1}^{(t)} - p_{i,j-1}^{(t)}}{2 \cdot \Delta x} - \frac{p_{i,j+1}^{(t-1)} - p_{i,j-1}^{(t-1)}}{2 \cdot \Delta x} \right) - 2 \cdot v_{y,i,j} \cdot \frac{1}{\Delta t} \cdot \left(\frac{p_{i-1,j}^{(t)} - p_{i+1,j}^{(t)}}{2 \cdot \Delta y} - \frac{p_{i-1,j}^{(t-1)} - p_{i+1,j}^{(t-1)}}{2 \cdot \Delta y} \right)$$



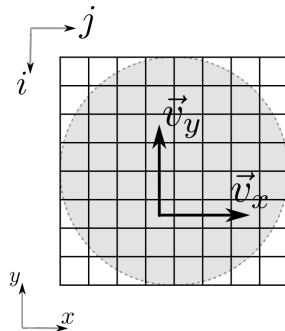
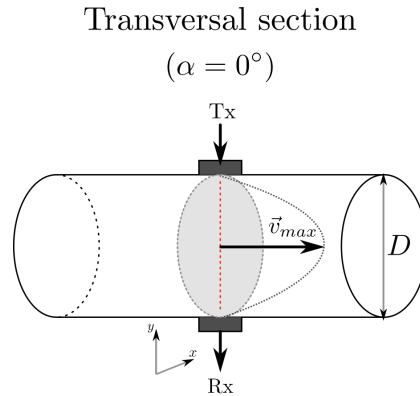


Profil de vitesse Poiseuille

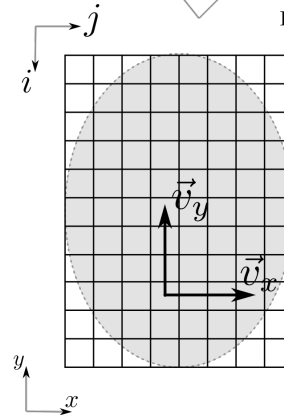
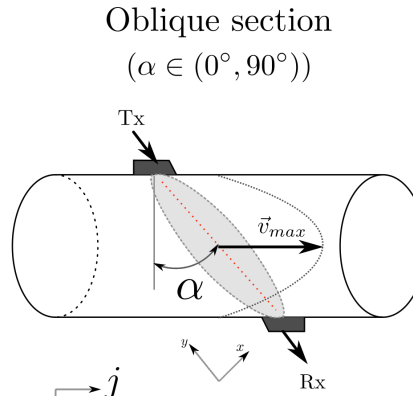


$$v = \frac{G}{4\mu} \cdot \left(\frac{D^2}{4} - r^2 \right)$$

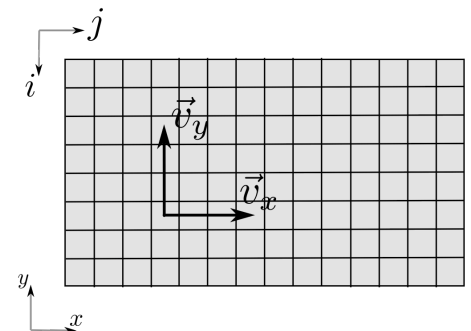
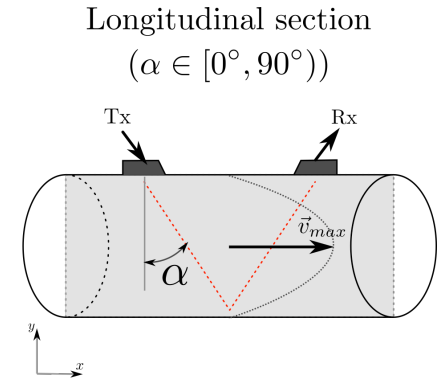
$$v_{max} = \frac{G \cdot D^2}{16 \cdot \mu}$$



$$\begin{cases} v_x = 0 \\ v_y = 0 \end{cases}$$



$$\begin{cases} v_x = 0 \\ v_y = v \cdot \sin \alpha \end{cases}$$

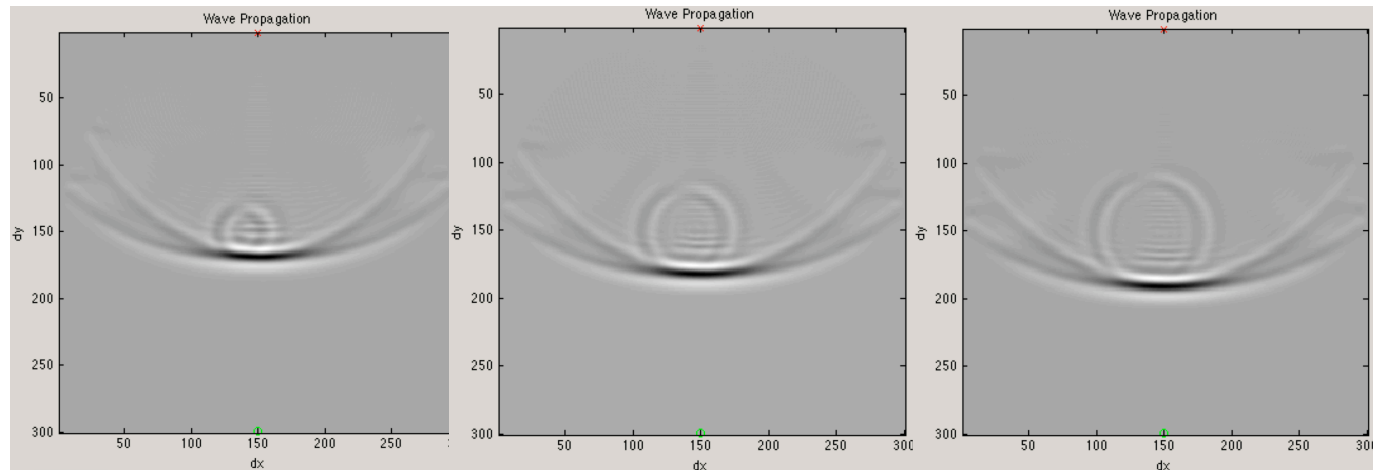
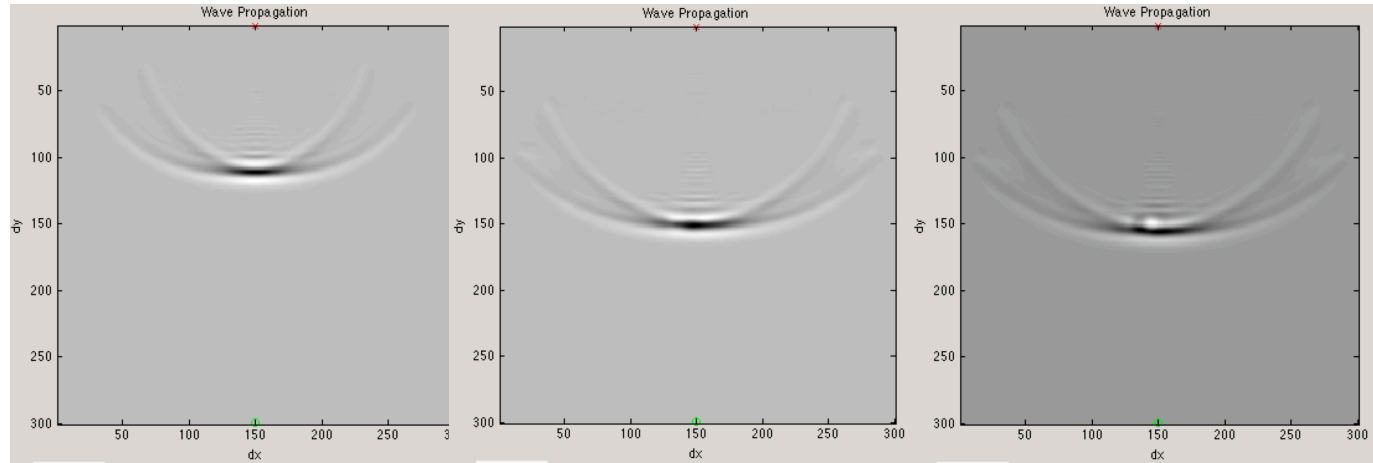
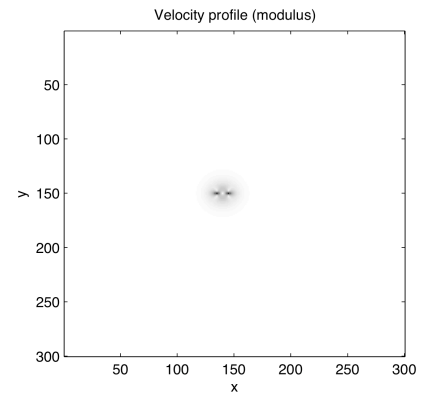
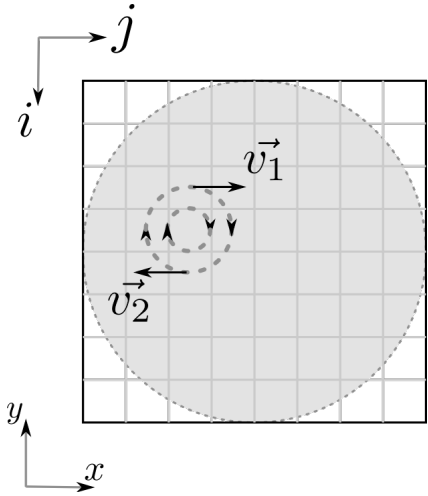


$$\begin{cases} v_x = v \\ v_y = 0 \end{cases}$$

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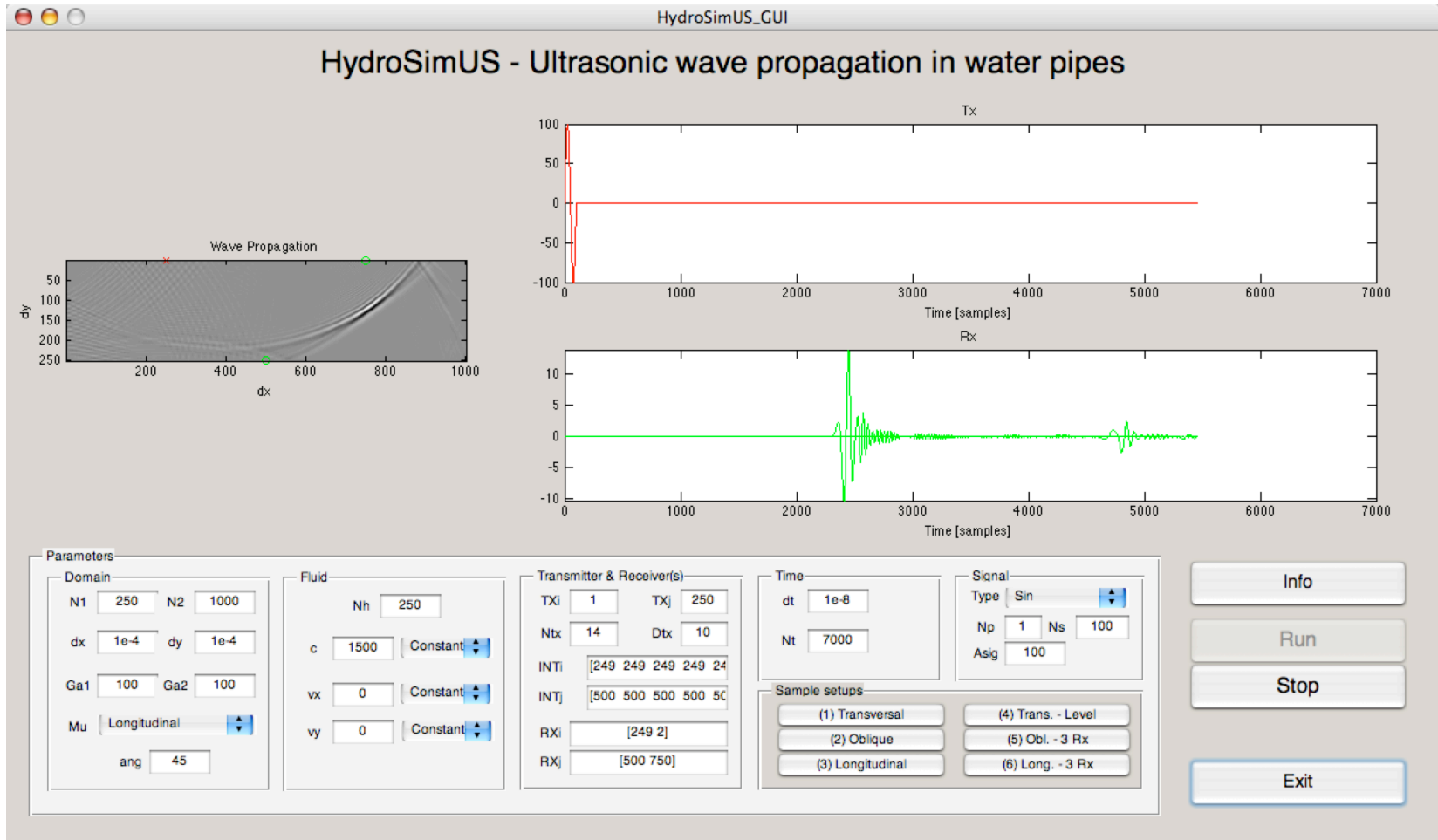


Modélisation des tourbillons

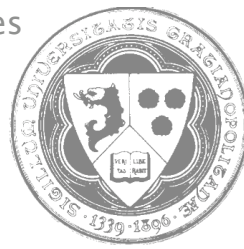




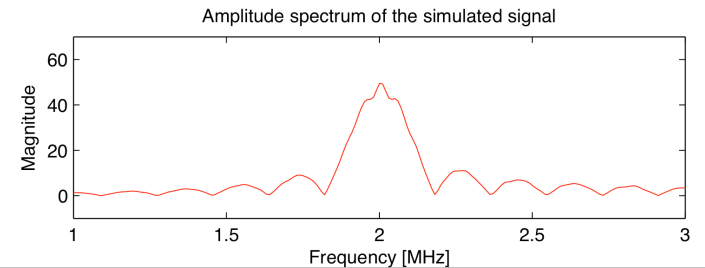
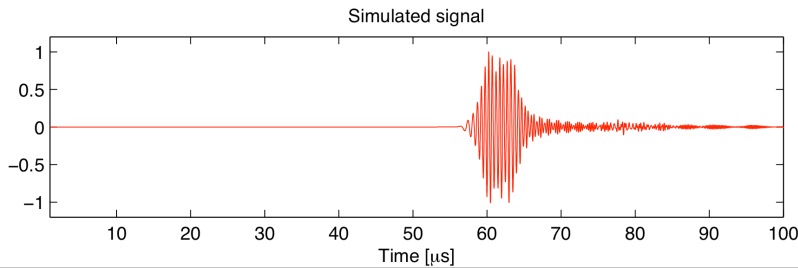
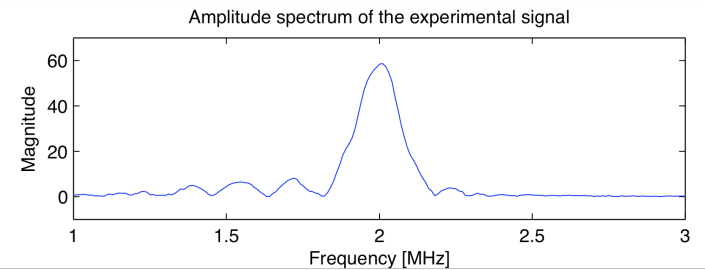
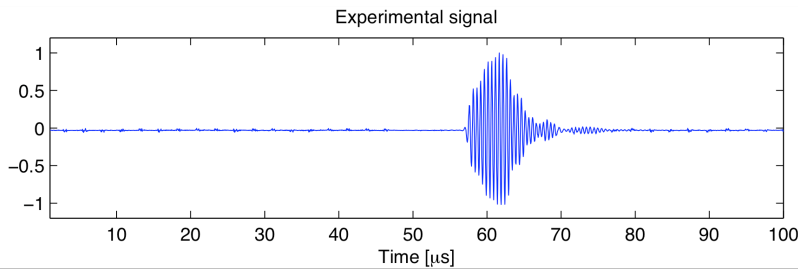
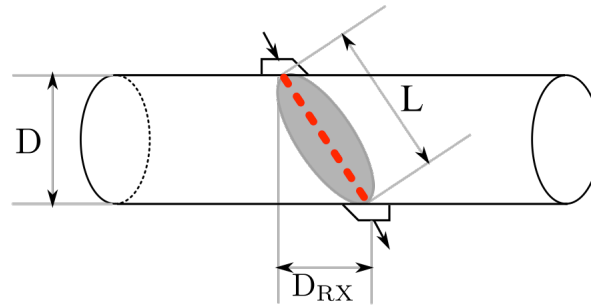
Interface graphique

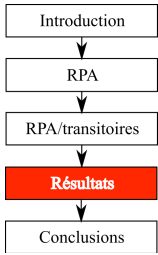


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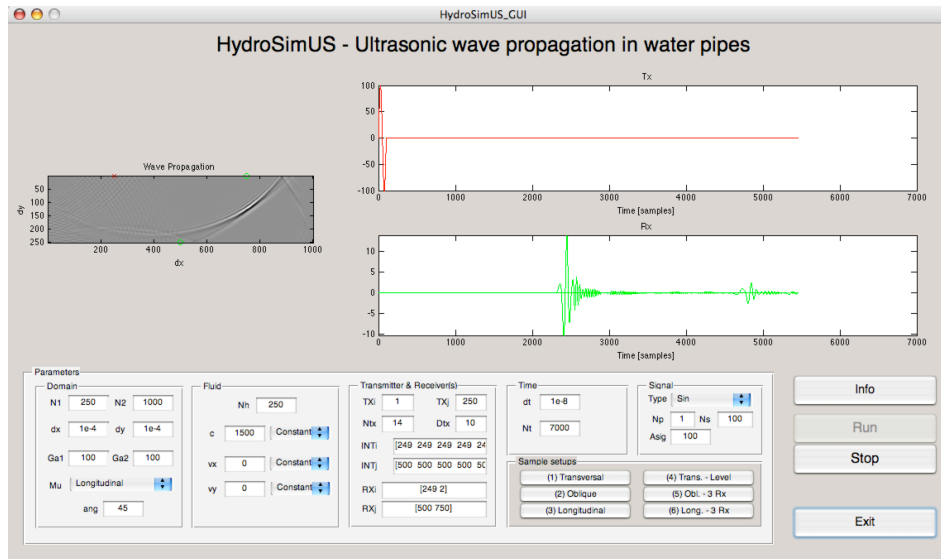
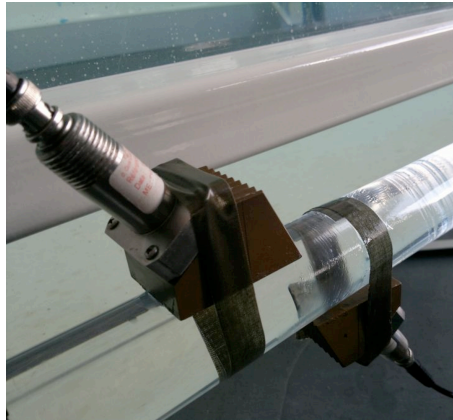


Exemple





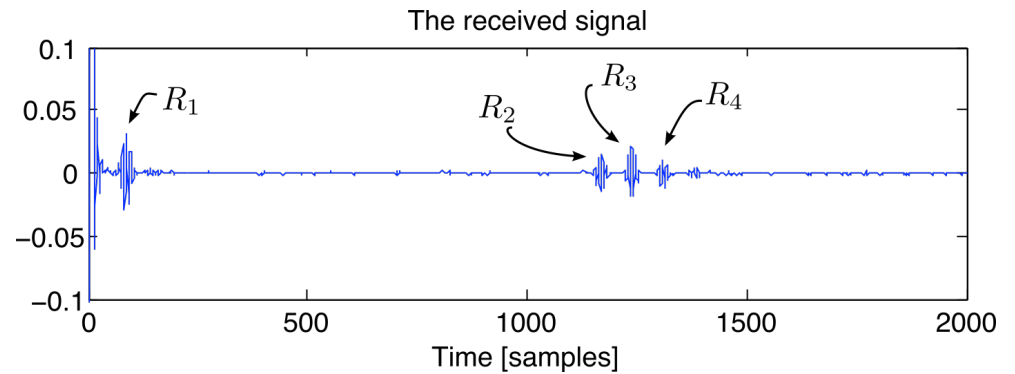
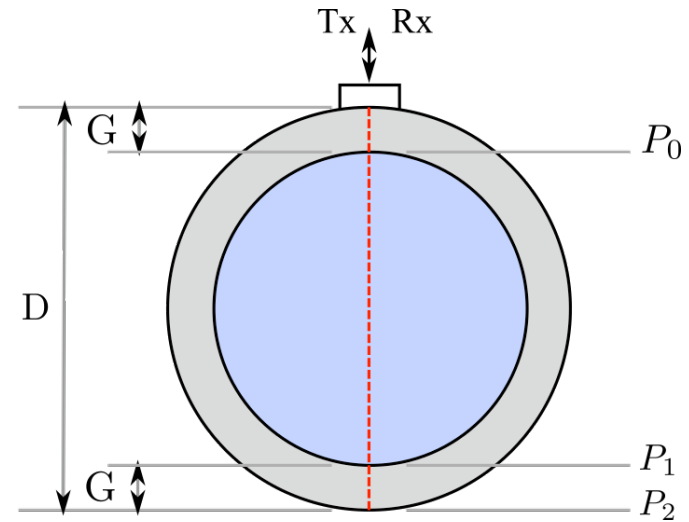
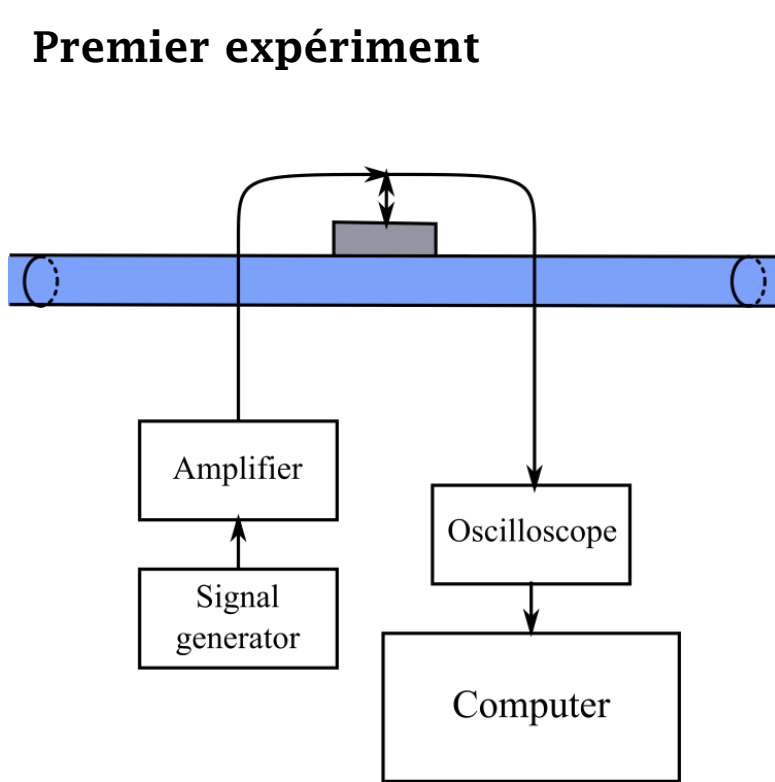
Expériences et simulations





Expériences et simulations

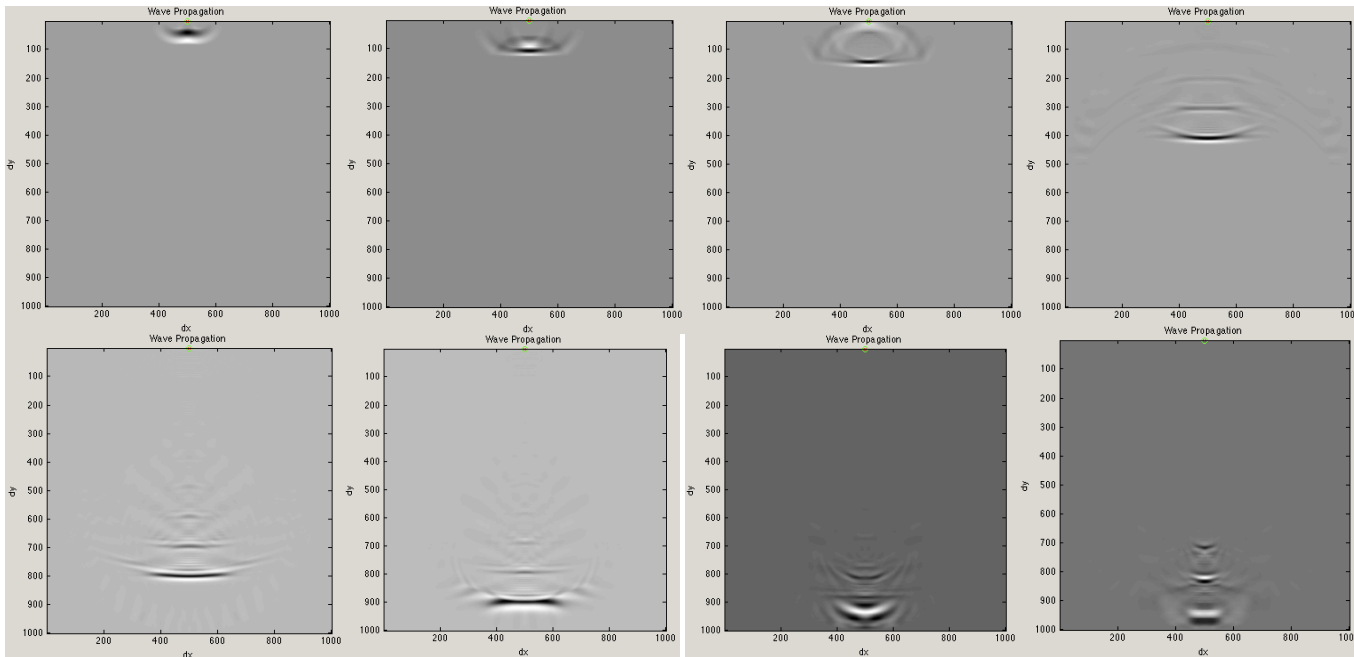
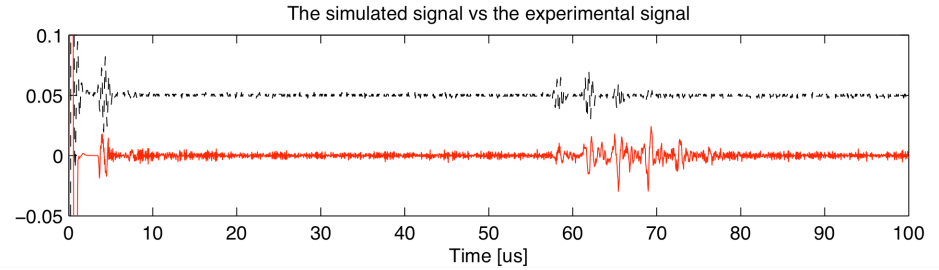
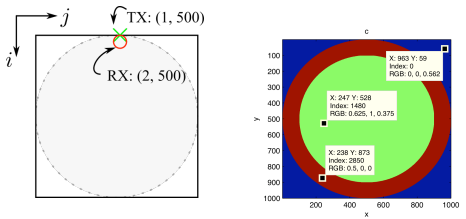
Premier expérience





Expériences et simulations

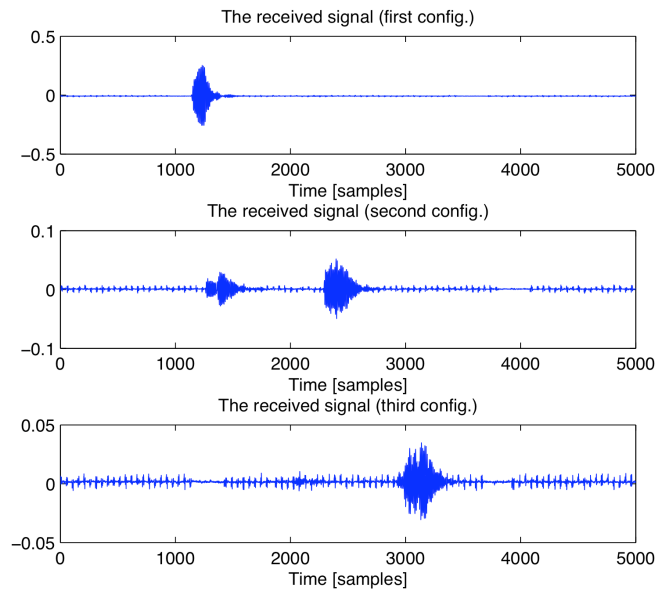
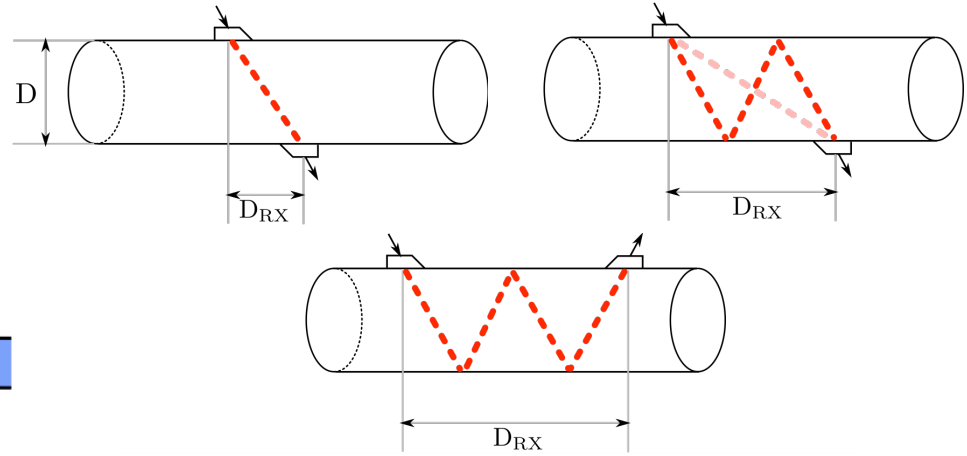
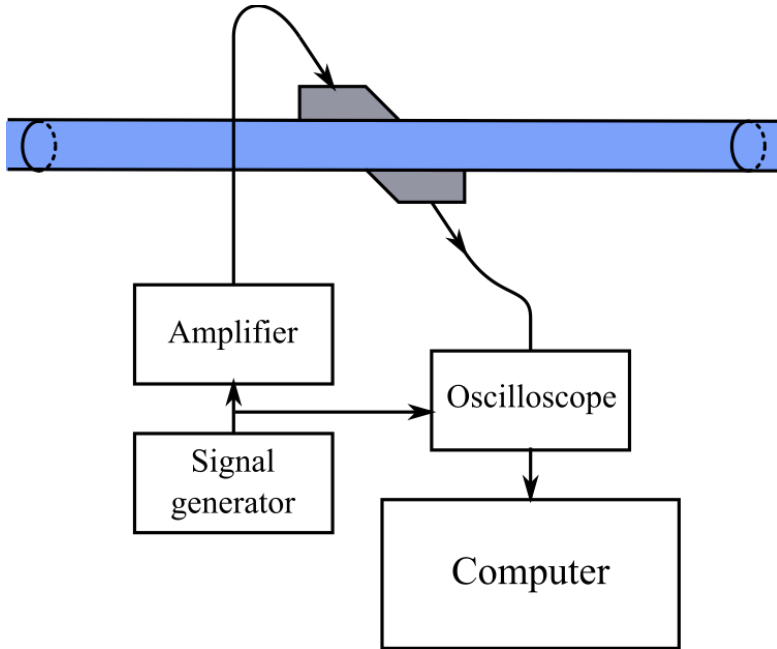
Premier expérience (simulation)





Expériences et simulations

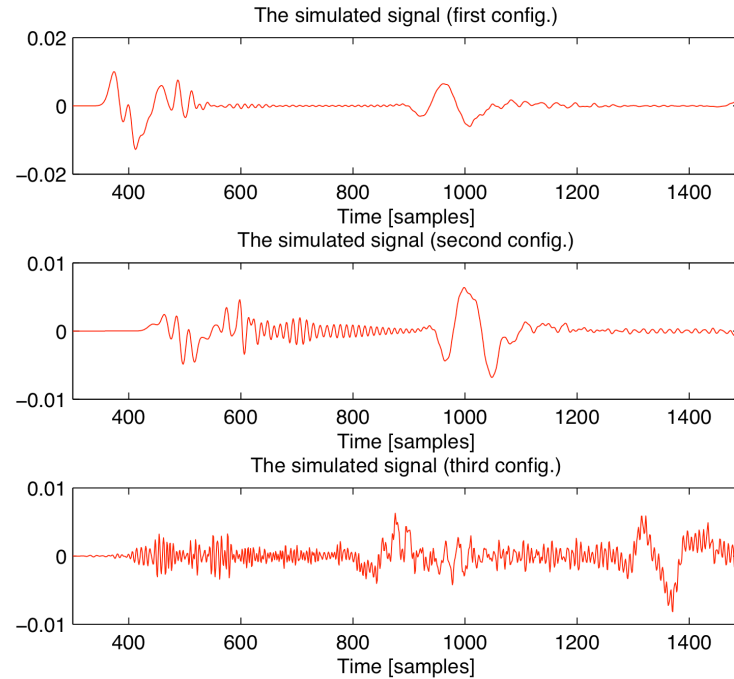
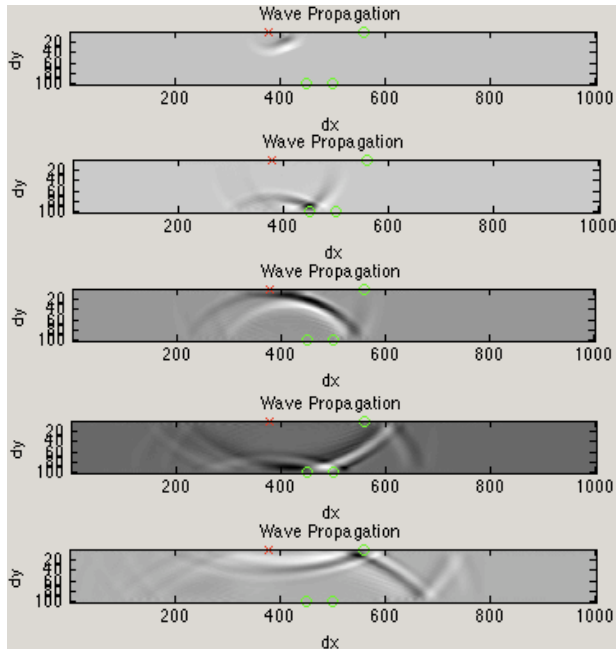
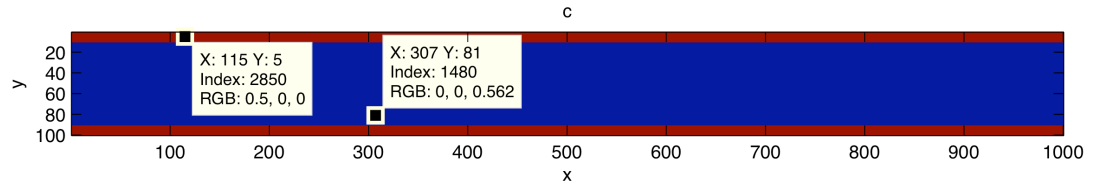
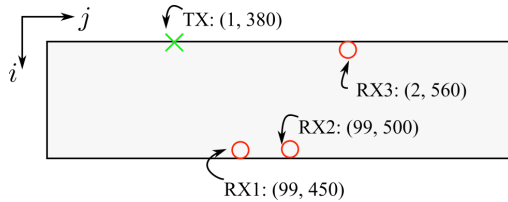
Deuxième expérience





Expériences et simulations

Deuxième expérience (simulation)

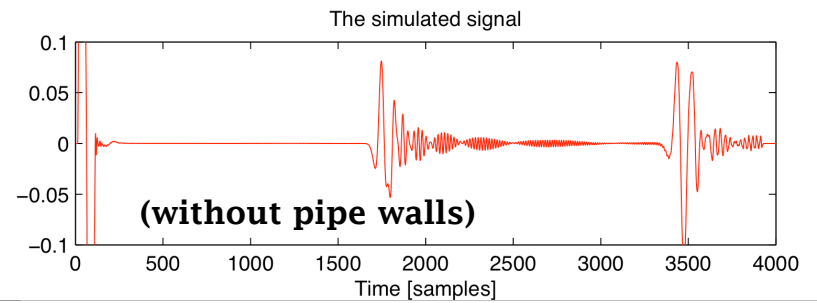
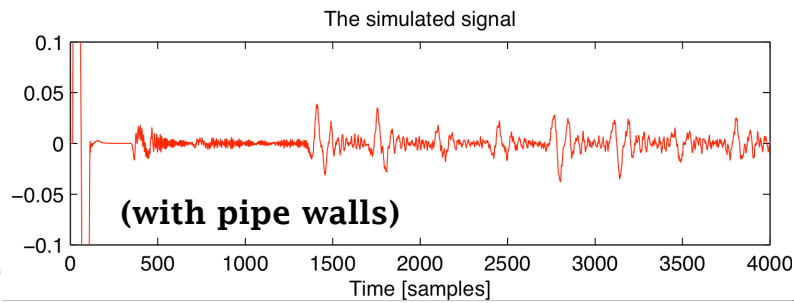
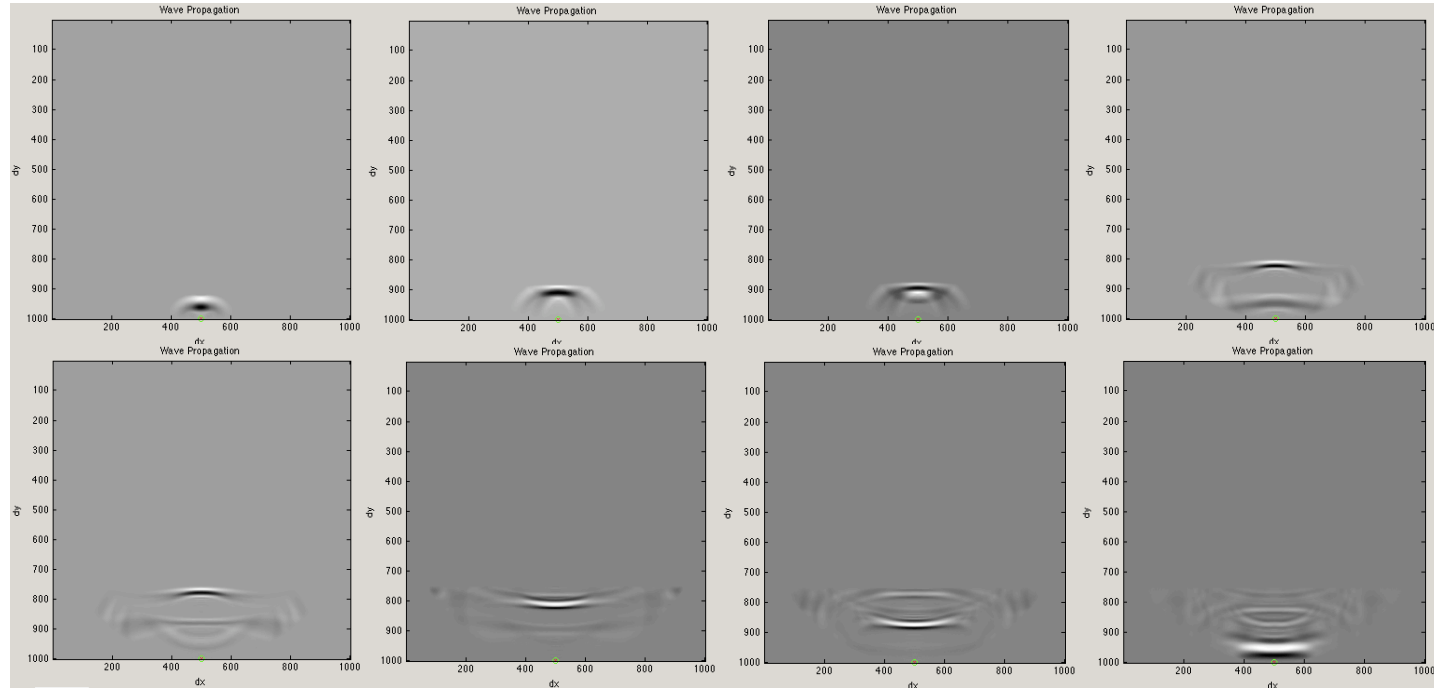
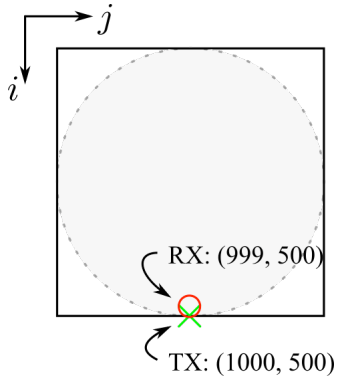


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Signaux synthétiques

Niveau de l'eau

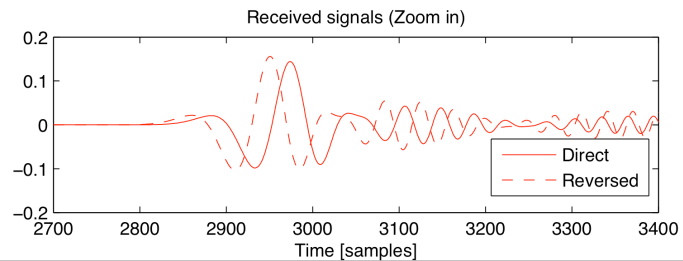
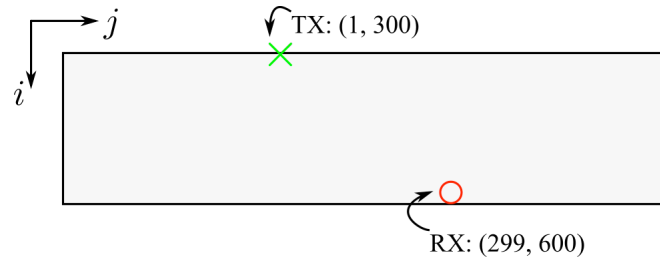
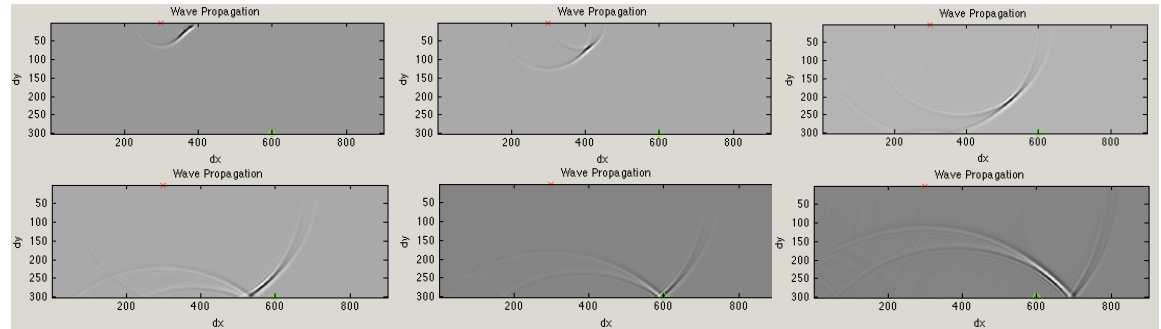
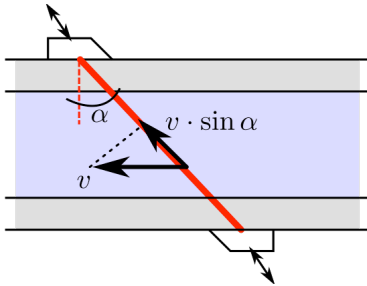


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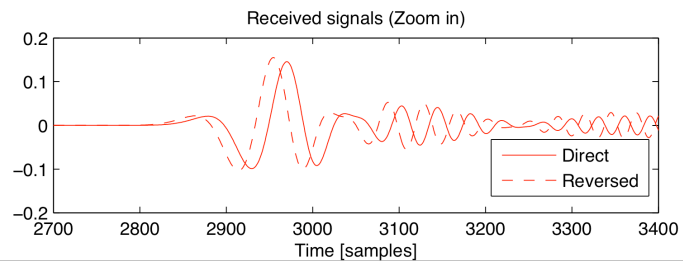


Signaux synthétiques

Vitesse de l'eau



Profil constant



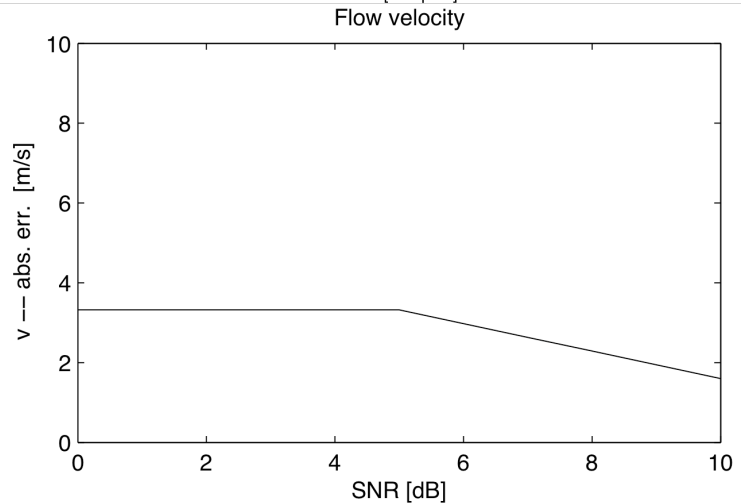
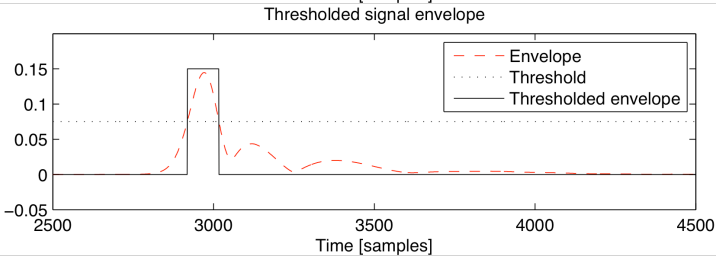
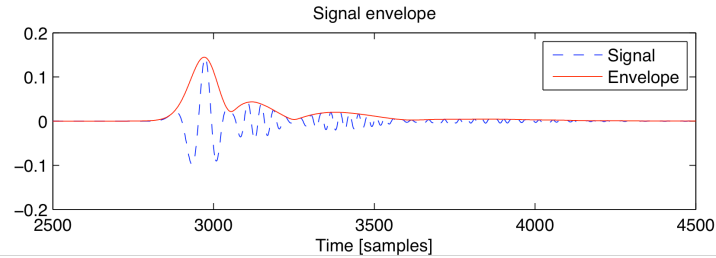
Profil Poiseuille

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Estimation du temps de propagation

Méthode classique

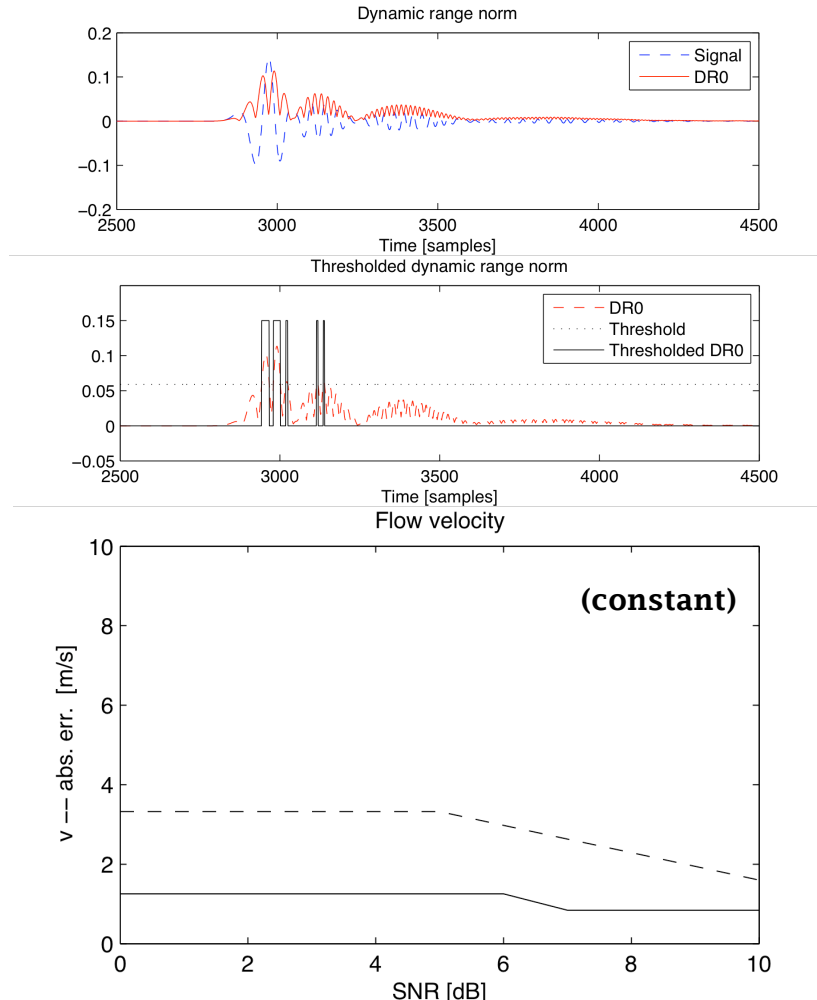


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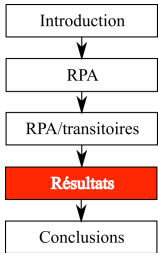
Estimation du temps de propagation

Méthode VeSP DR0



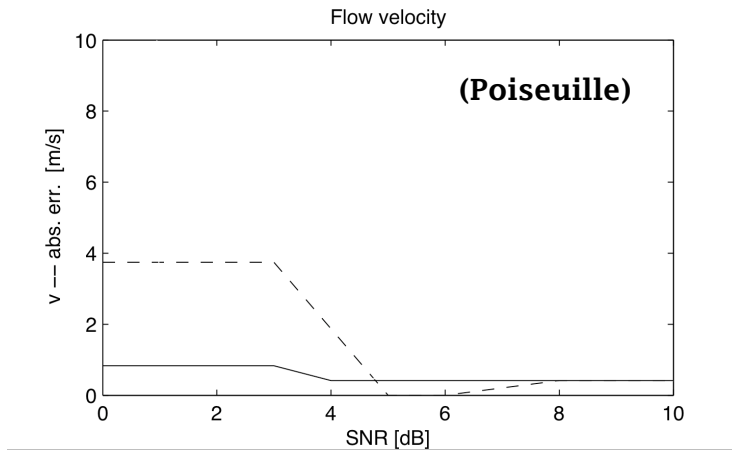
Légende :

- **DR0** ($w=12$)
- - - **Envelope** (Hilbert)

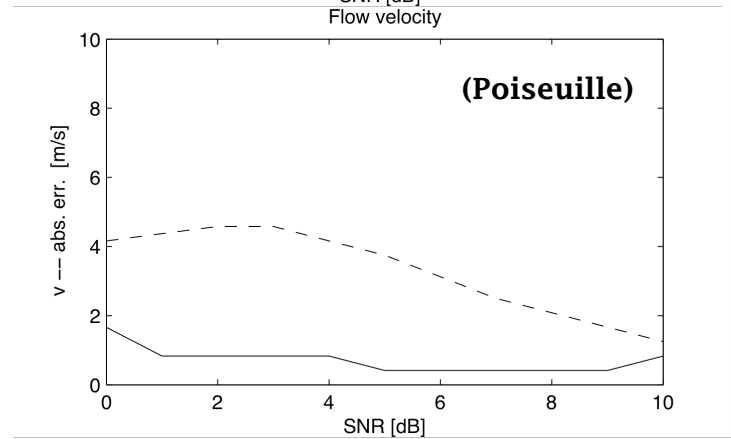
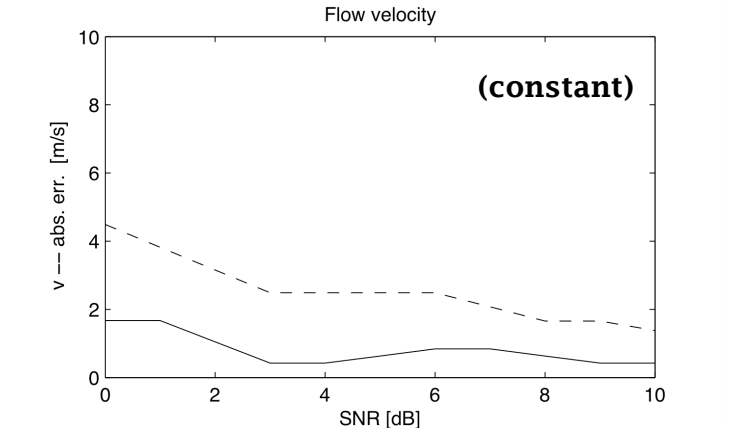


Estimation du temps de propagation

Résultats comparatifs



Bruit blanc



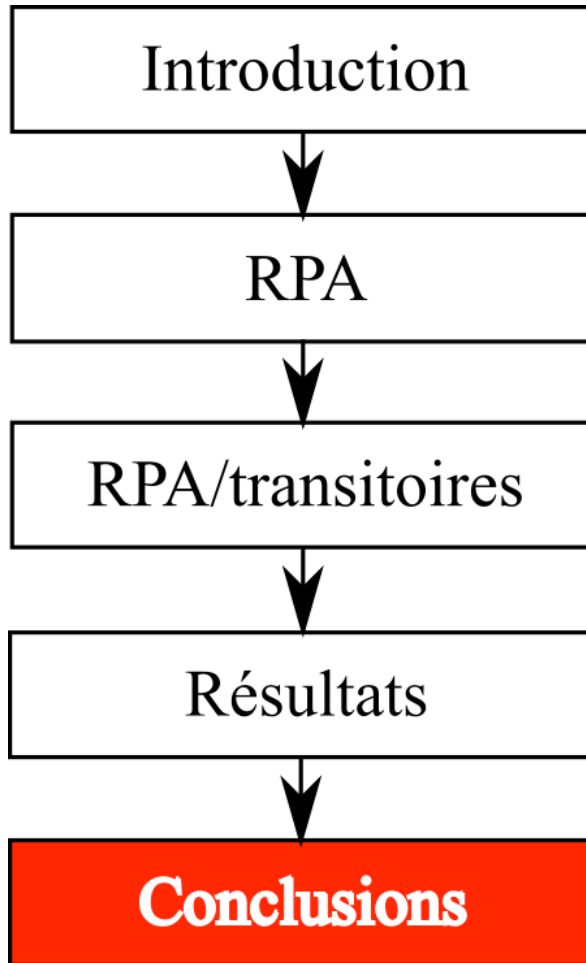
Bruit coloré

Légende :

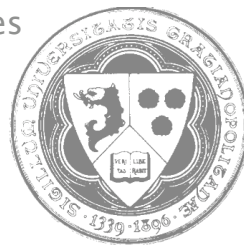
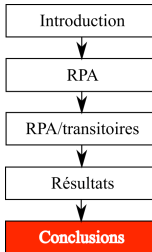
- DRO ($w=12$)
- - - Enveloppe (Hilbert)



Plan

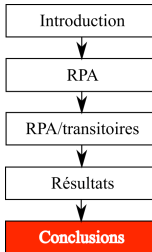


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 - Contributions
 - Perspectives



Contributions

- > RPA => **échantillons vectoriels** (VeSP), **réurrences** (RQA)
- > **nouvelles distances** : angulaire, gamme dynamique, produit scalaire, ...
- > **rayon de récurrence** adaptatif
- > généralisation des outils de traitement du signal => nouvelles représentations (**temps - rayon de récurrence**)
- > **applications** dans le traitement des transitoires
- > boîtes à outils : **HydroSimUS**, **VeSP**



Perspectives

Théorique :

- > Nouveaux **outils VeSP/RQA**
- > Analyse **temps-réccurrence multi-échelle**
($w > 1 \Rightarrow$ extensions)

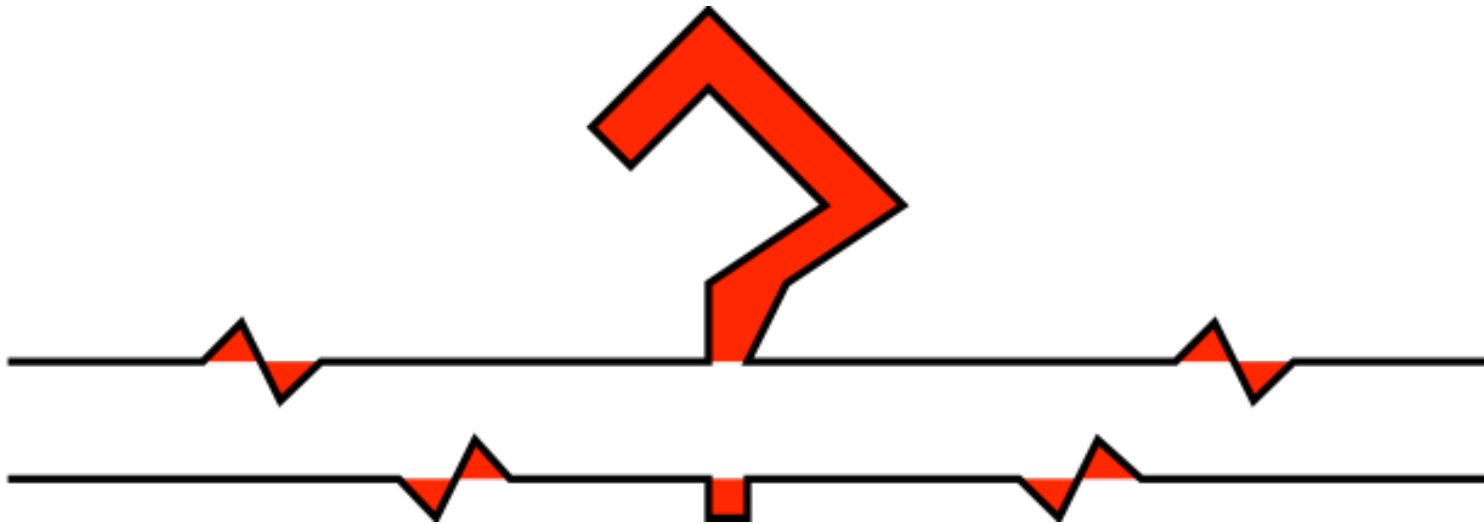
Applicatif :

- > **Détection des fissures** dans les conduites d'eau
- > **Réseaux distribués de capteurs**

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Questions...



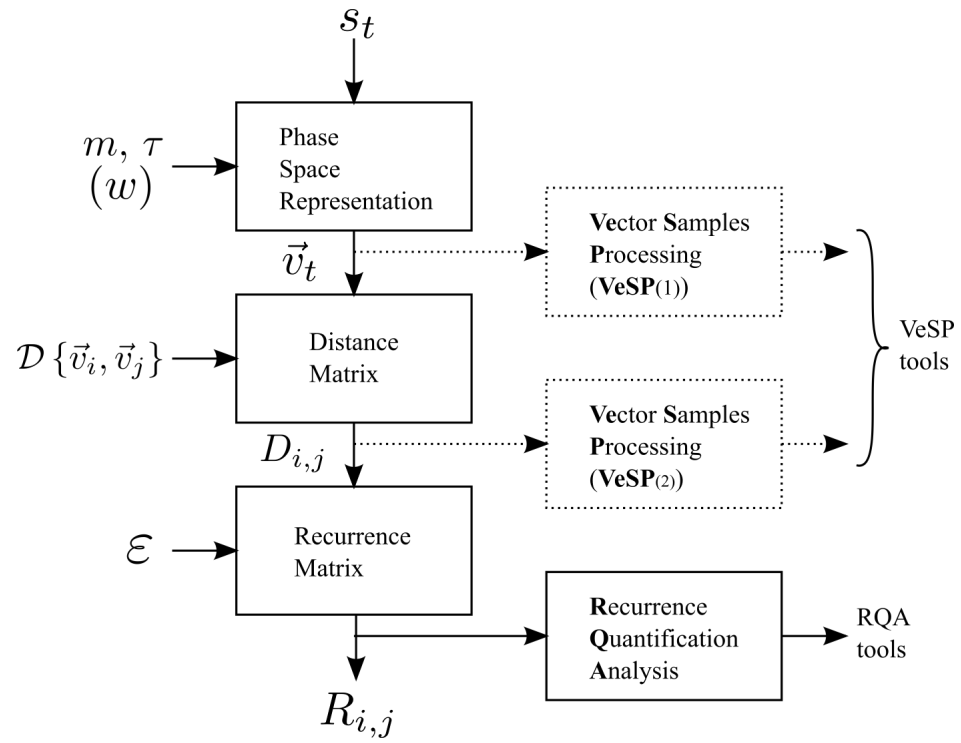
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Description de la méthode RPA

Recurrence Plot Analysis

- 1) time-delay embedding
- 2) recurrence plot
- 3) recurrence quantification analysis



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L'émetteur

