

# LOCALISATION ET POMPAGE ENERGETIQUE DANS LES NONLINEAR ENERGY SINKS (NES)

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**Université de LYON**  
**FRANCE**

## Introduction

## I- LOCALISATION ET POMPAGE ENERGETIQUE

- 1) Principe
- 2) Modes normaux non linéaires
- 3) Mécanismes

## II- APPLICATIONS

## III- OPTIMISATION

## Conclusion

Sollicitation  
extérieure



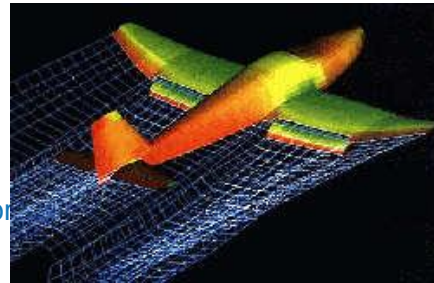
**Systeme Primaire (linéaire ou  
linéarisé: discrétisation,  
analyse modale... ou non  
linéaire)**



**Systeme Non Linéaire  
annexe**

**« absorbant » l'énergie par  
résonances des modes non  
linéaires**

**Contrôle Passif des  
vibrations**



## Introduction

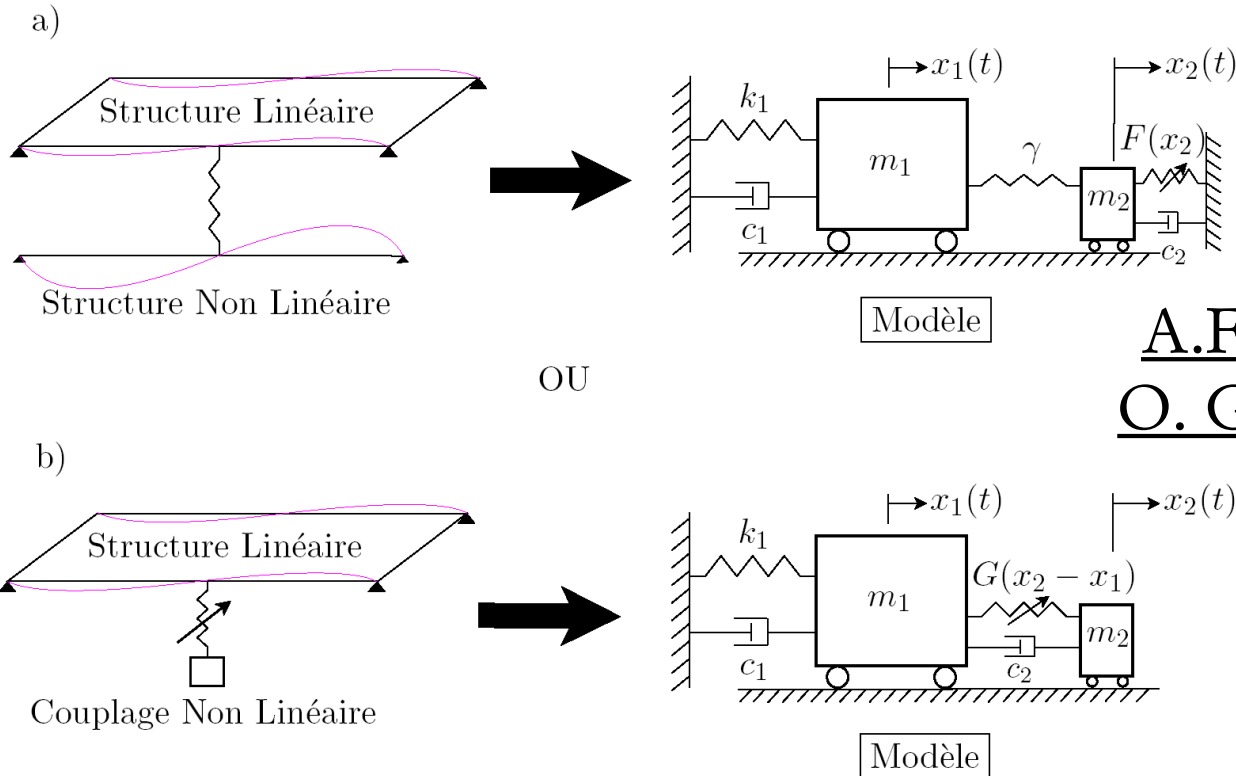
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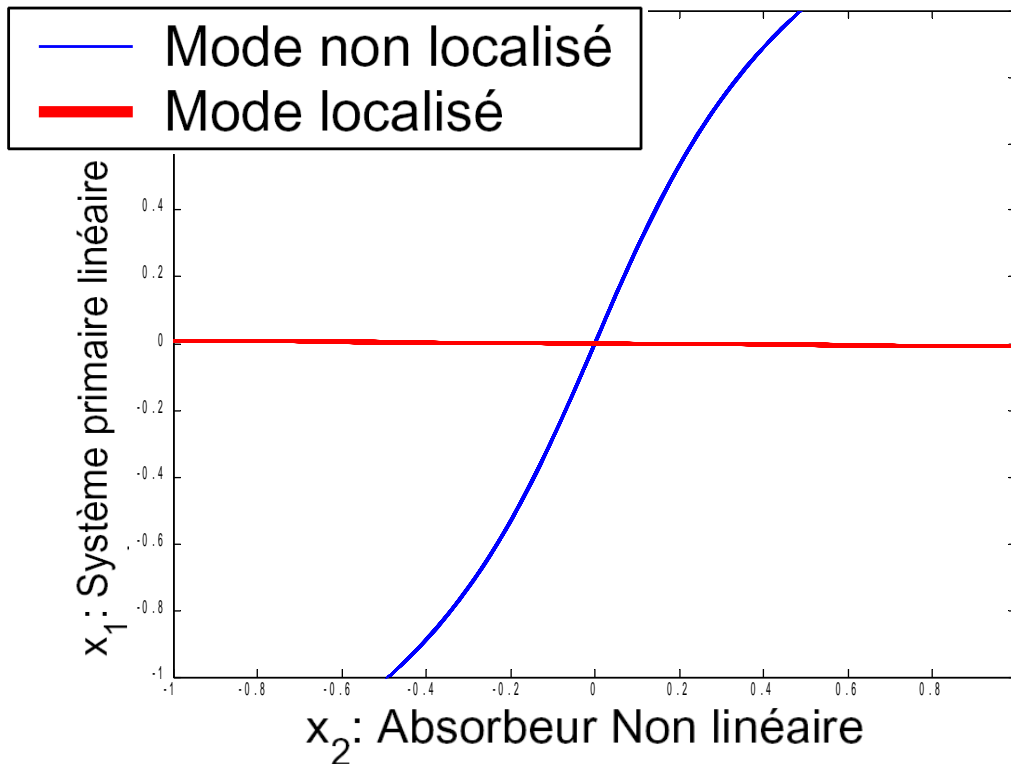
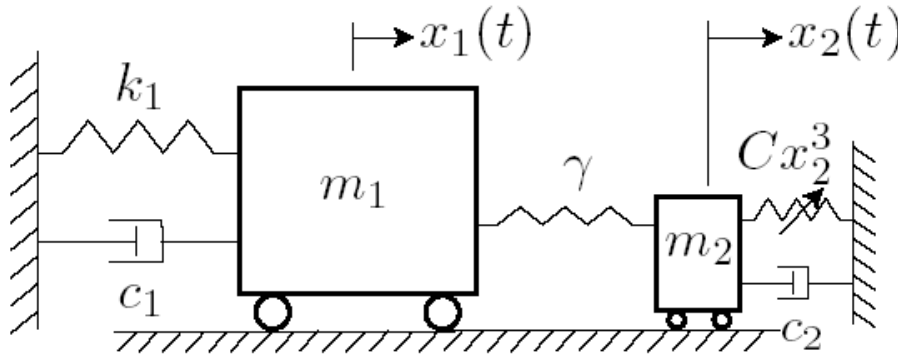
## Conclusion



A.F. Vakakis  
O. Gendelman

Problème:

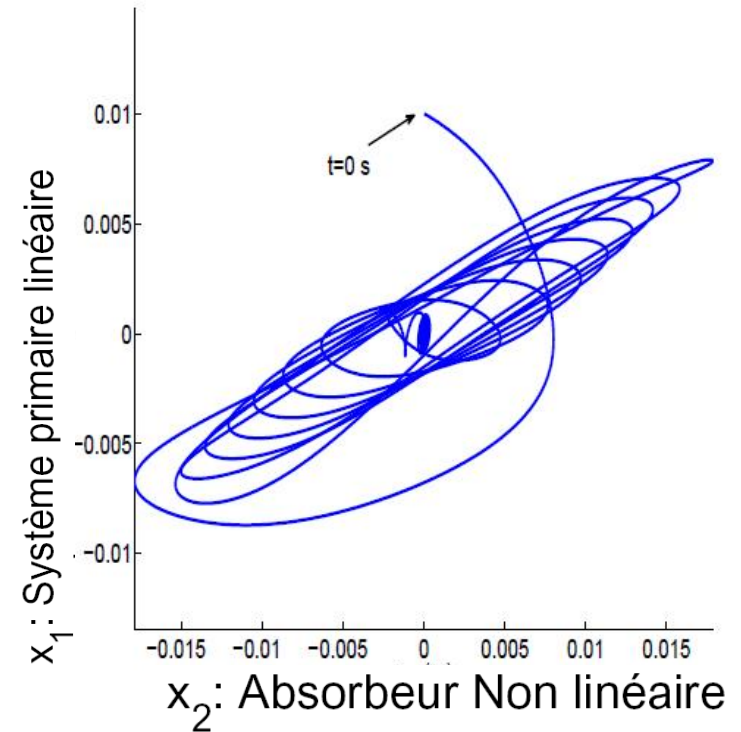
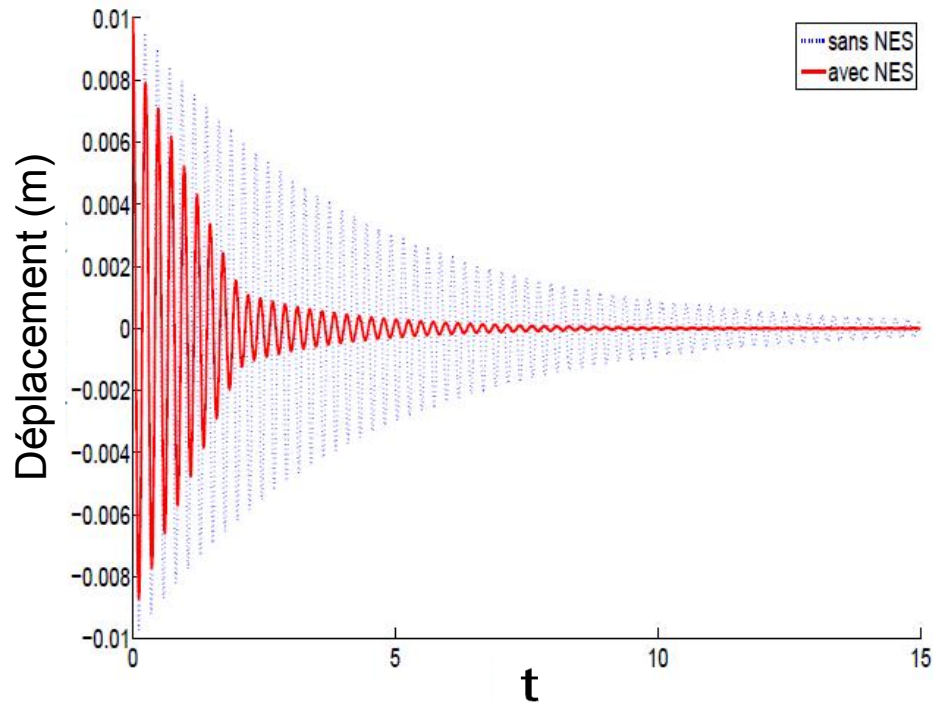
- Non modification des caractéristiques de la structure principale
- Création d'un mode non linéaire de vibrations résonant (pompage énergétique)



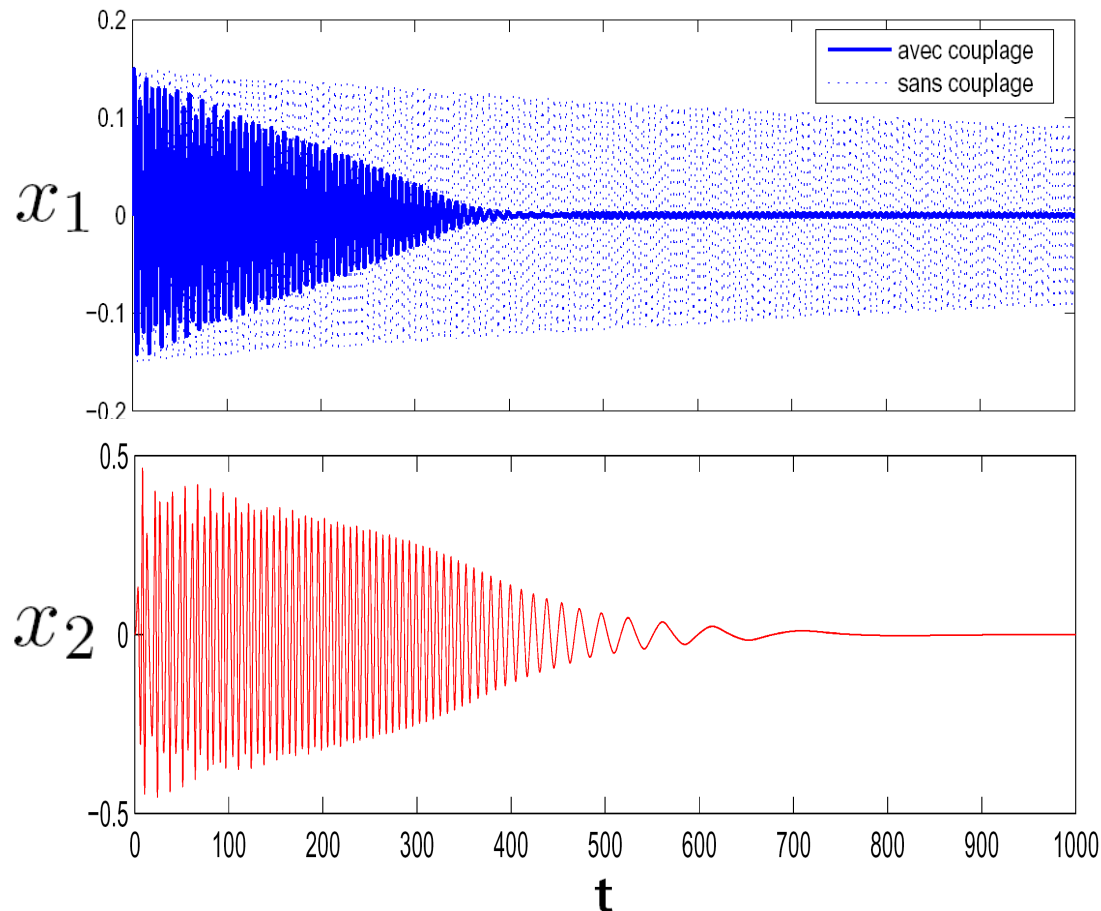
## Mode non linéaire:

« Free motions where all coordinates vary equi-periodically reaching their extremum values at the same instants of time. »

(Rosenberg)



- Pompage énergétique initié par un phénomène de battements non linéaires (excitation d'une orbite spéciale avec une fréquence principale supérieure à la fréquence naturelle de l'oscillateur linéaire)

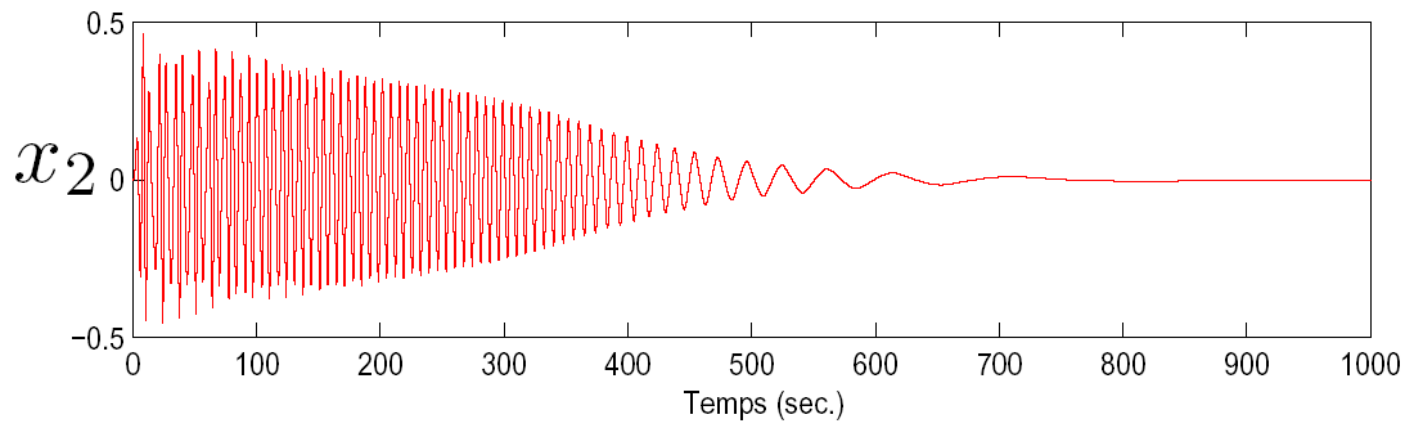
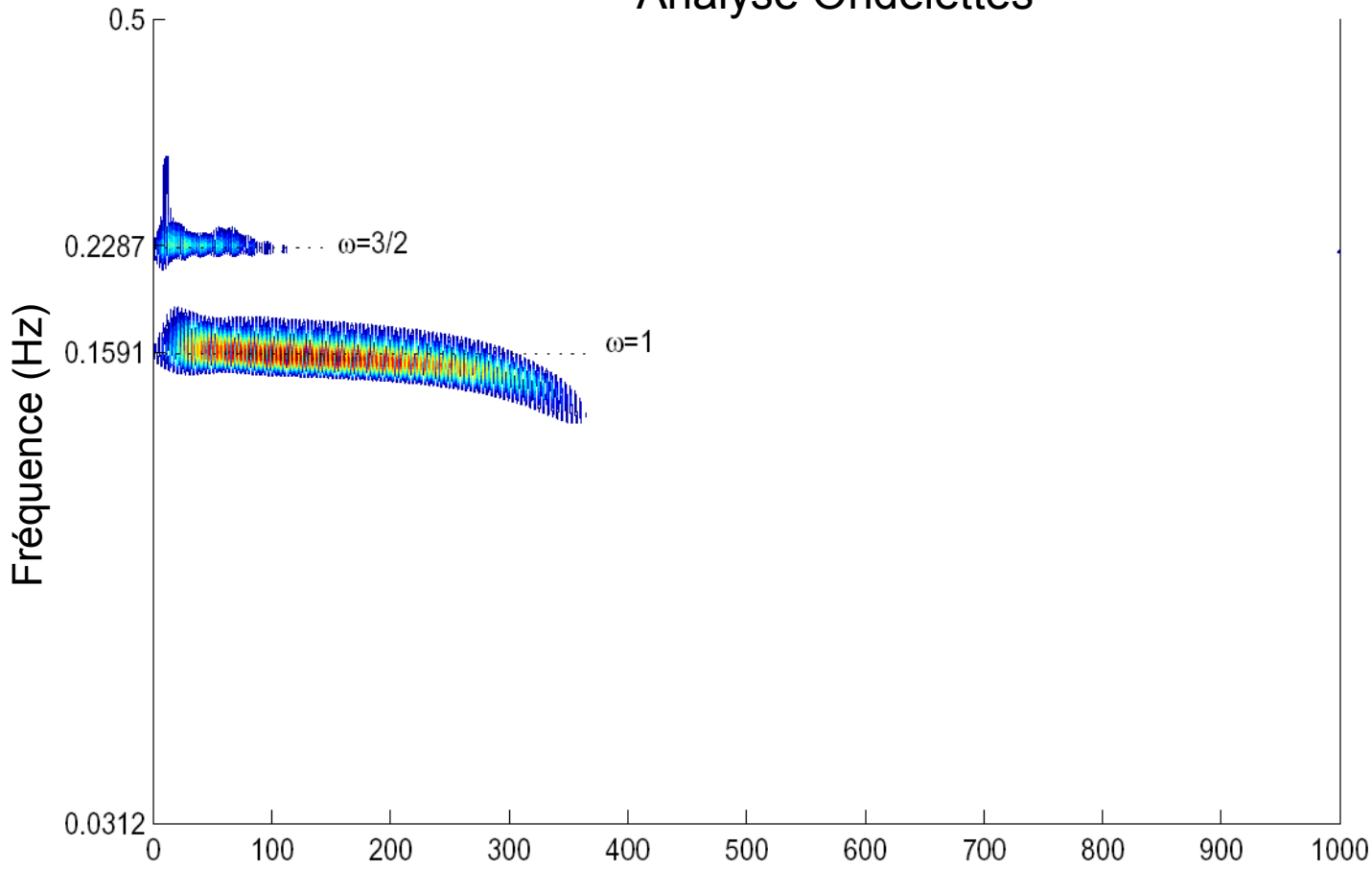


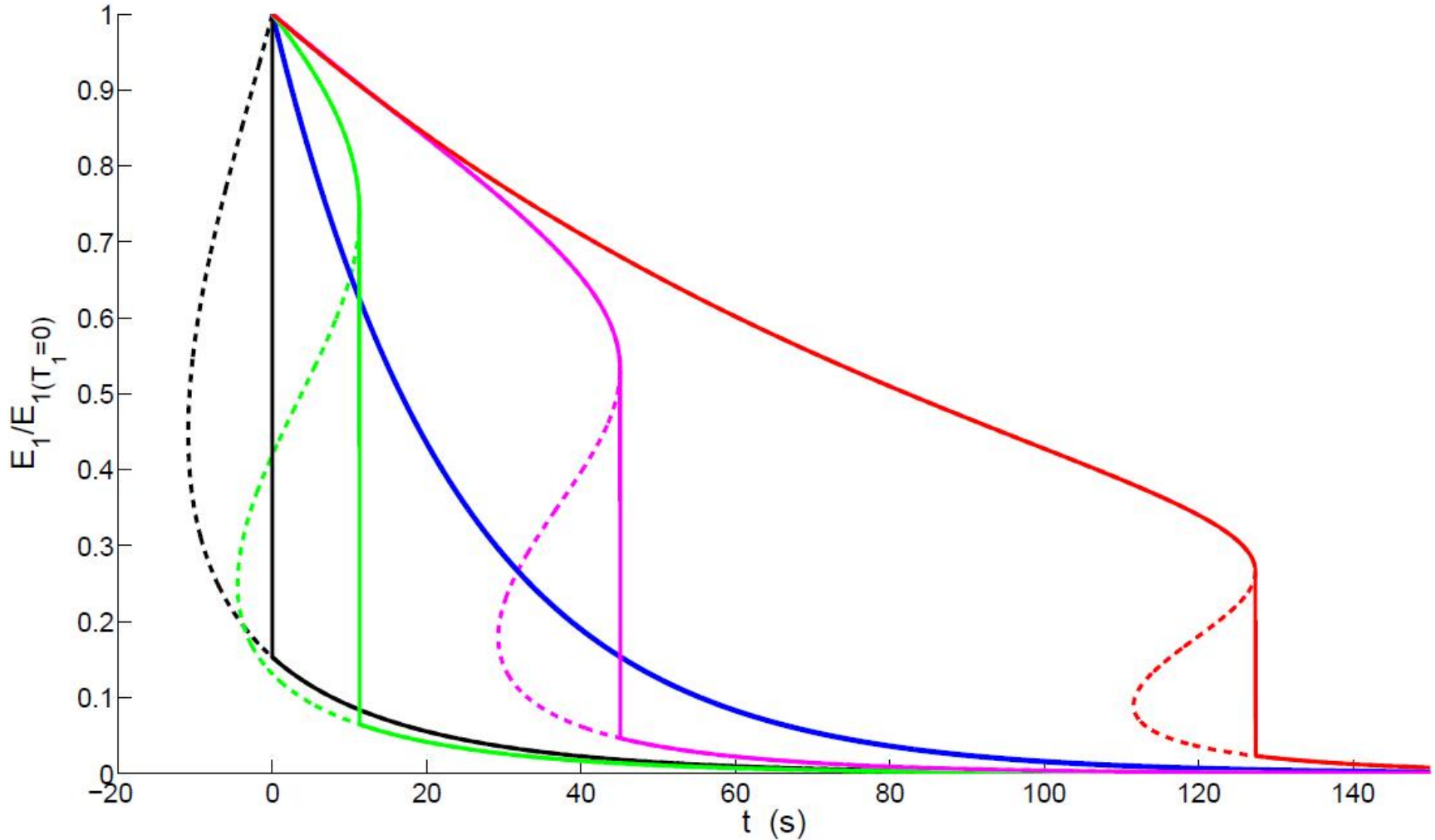


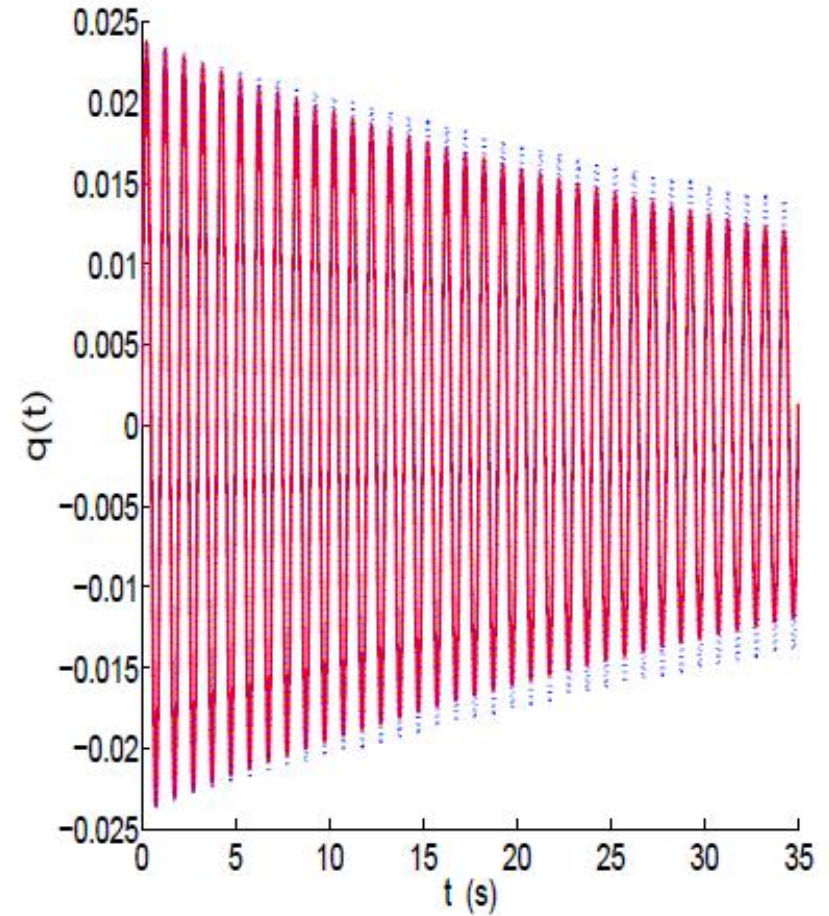
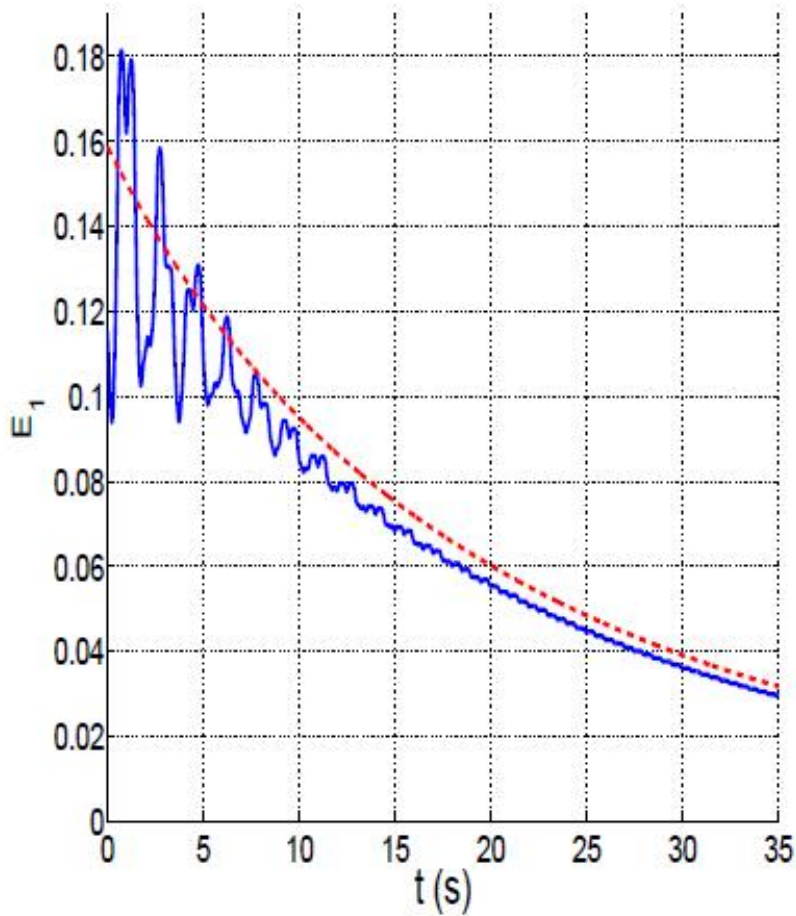
# Analyse Ondelettes

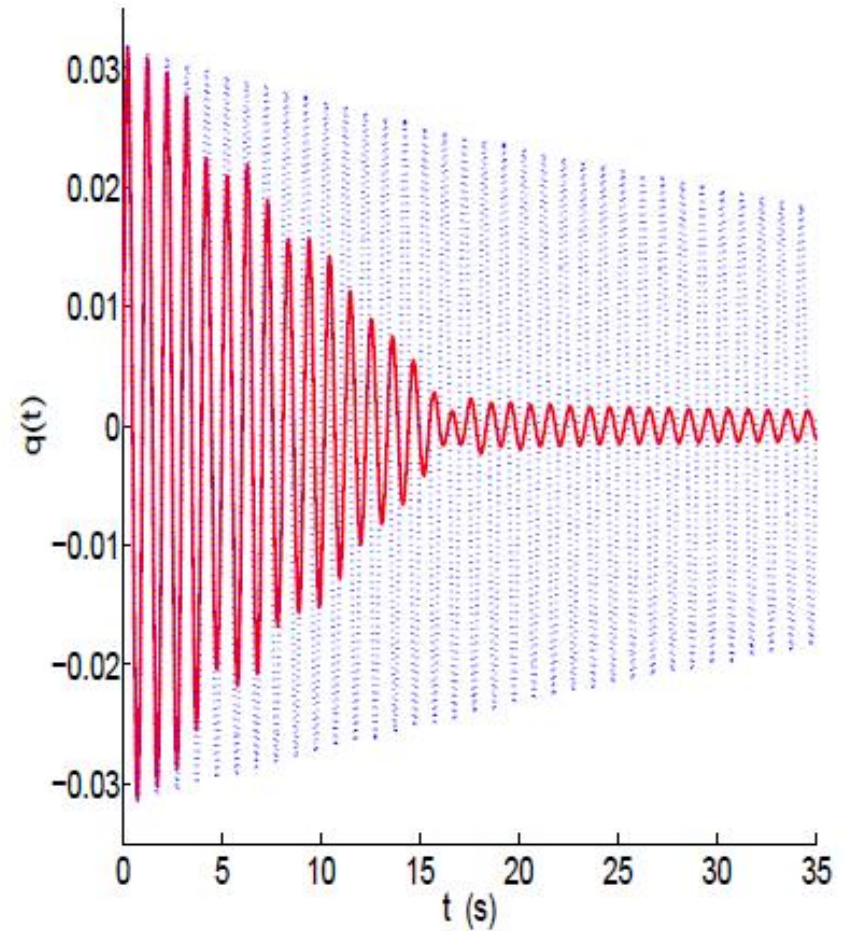
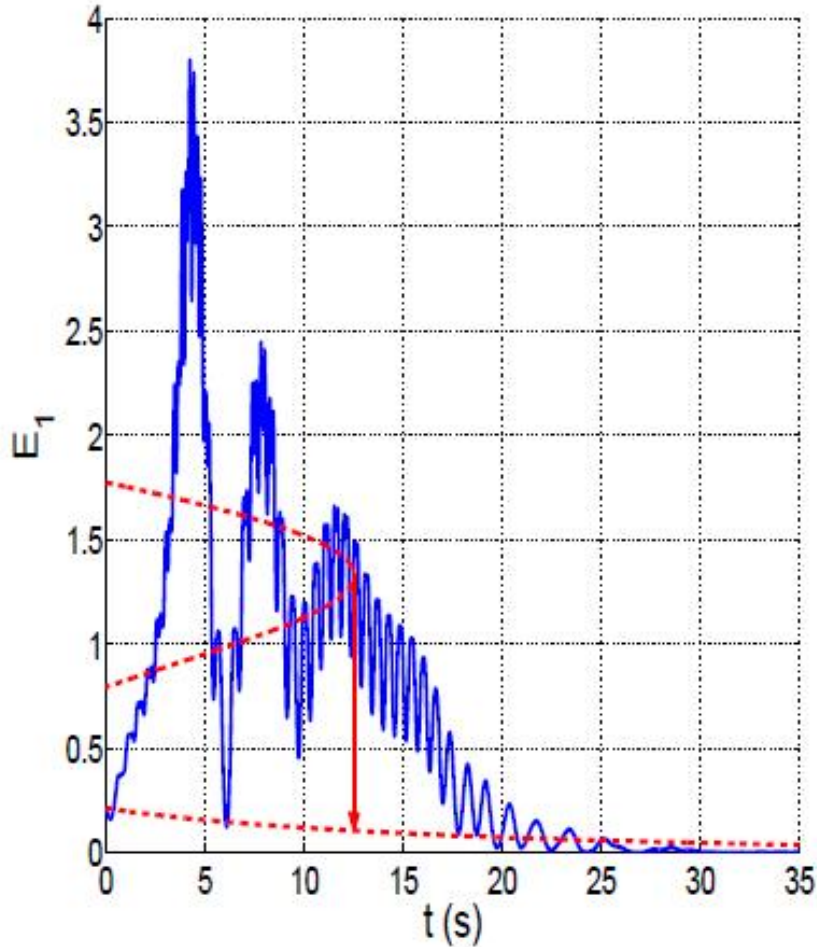


Département Génie Civil  
et Bâtiment

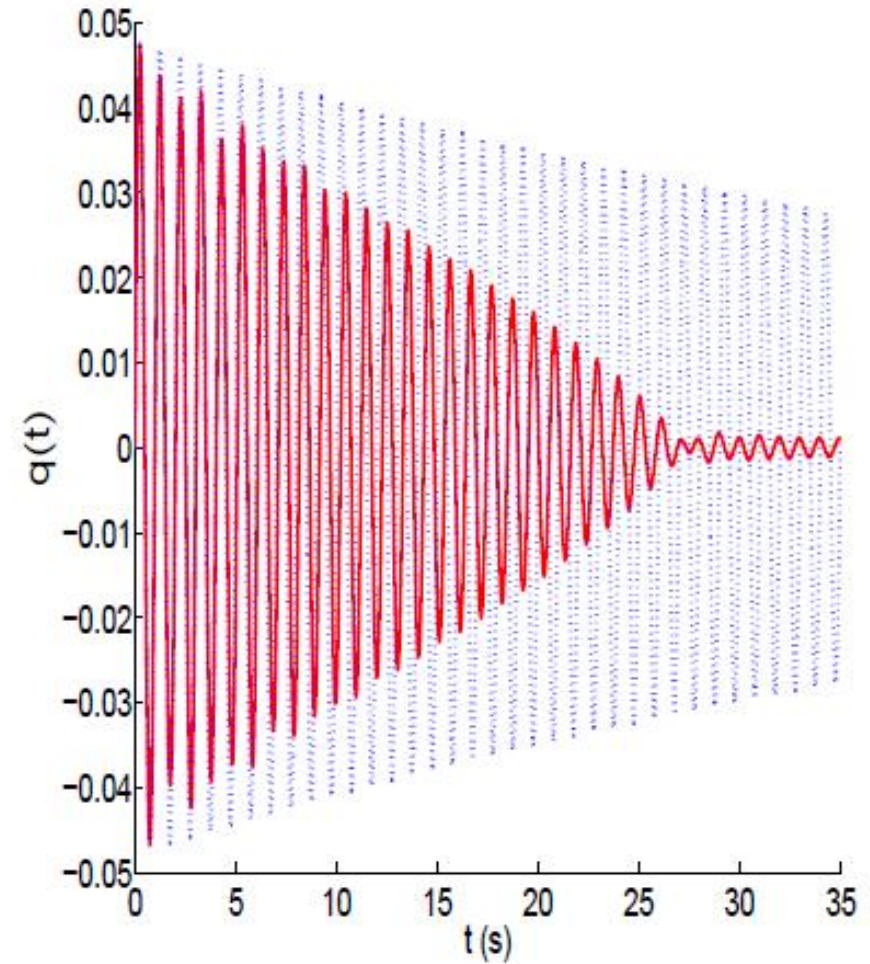
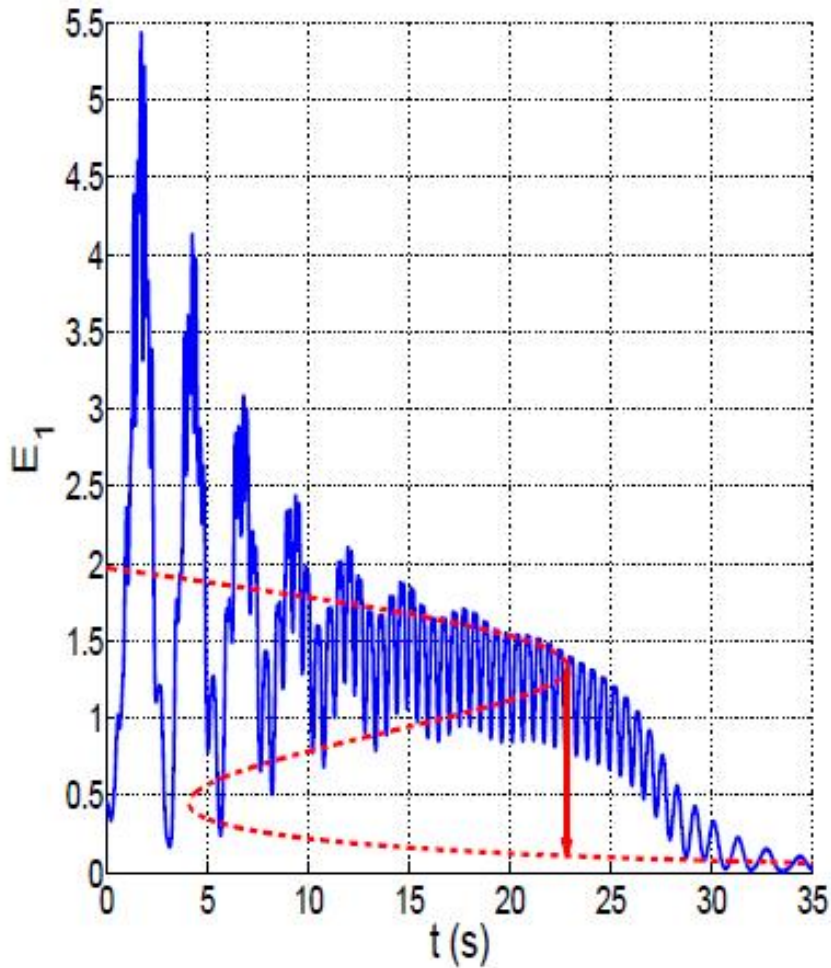












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- Génie Civil: réduction des vibrations de bâtiments, de ponts, de structures, de câbles... ■ ■
- Génie Mécanique (vibrations) ■
- Acoustique ■ ■
- Aéronautique (contrôle des vibrations d'ailes d'avion)
- Navale (stabilisation sous vagues)
- Electronique ■
- Nanotechnologie (couplage nonlinéaire).....

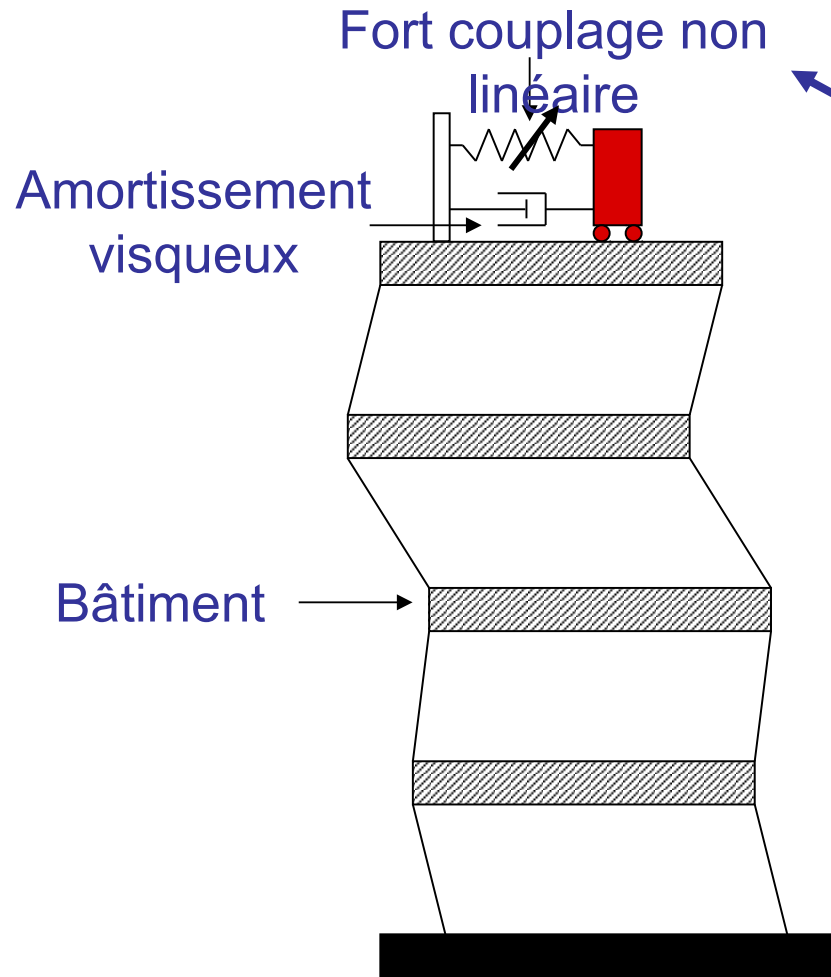
Survie de la structure  
ou  
Confort des usagers

## ■ Application en Génie Civil



Séisme : Annecy (15/07/1996)





Exemple: ajout d'une raideur cubique

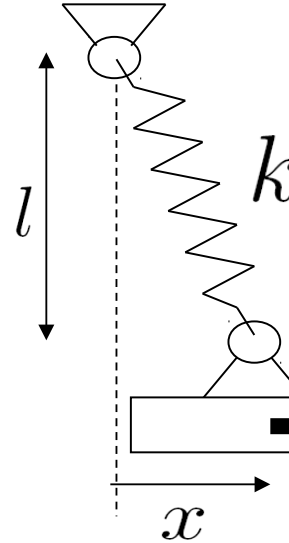
**+ excitation:**

- impulsion (oscillations libres)
- séismes

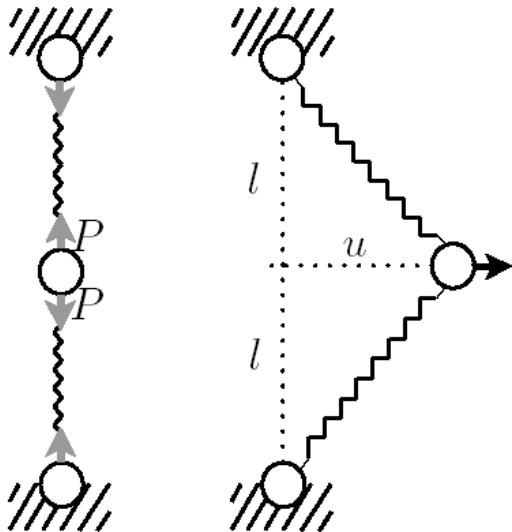
✓ Raideur: nonlinéarité cubique

## Système considéré

Nonlinéarité géométrique

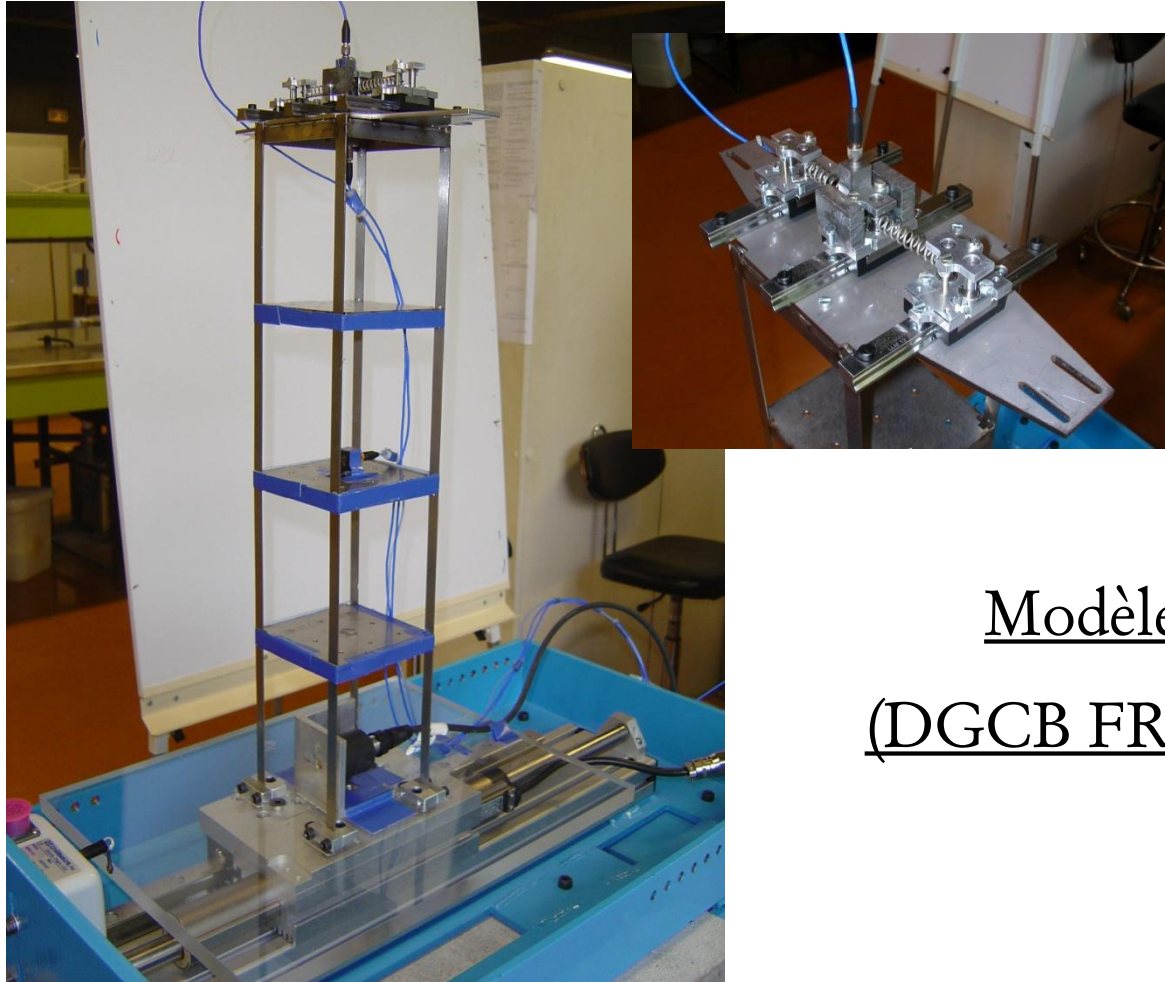


$$F_{tan} = \frac{k}{2l^2} x^3 \text{ if } \frac{x}{l} \ll 1$$

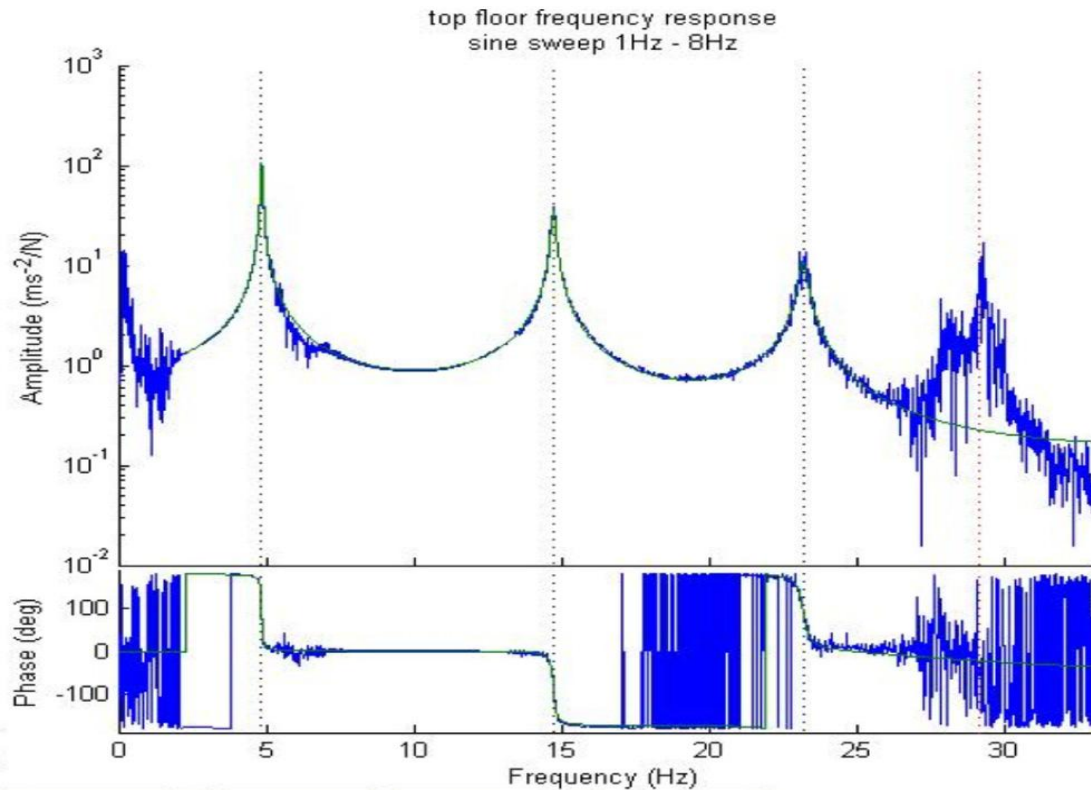


$$f = 2ku + \frac{2u(P - kl)}{\sqrt{l^2 + u^2}} \approx \frac{2P}{l}u + \frac{kl - P}{l^3}u^3 + O(u^5).$$

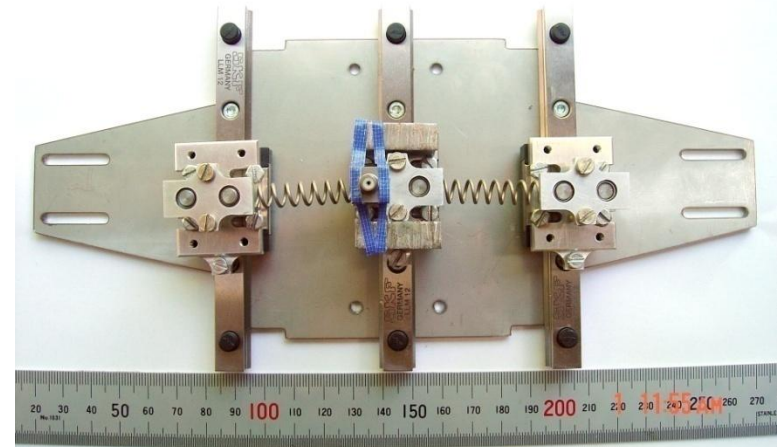
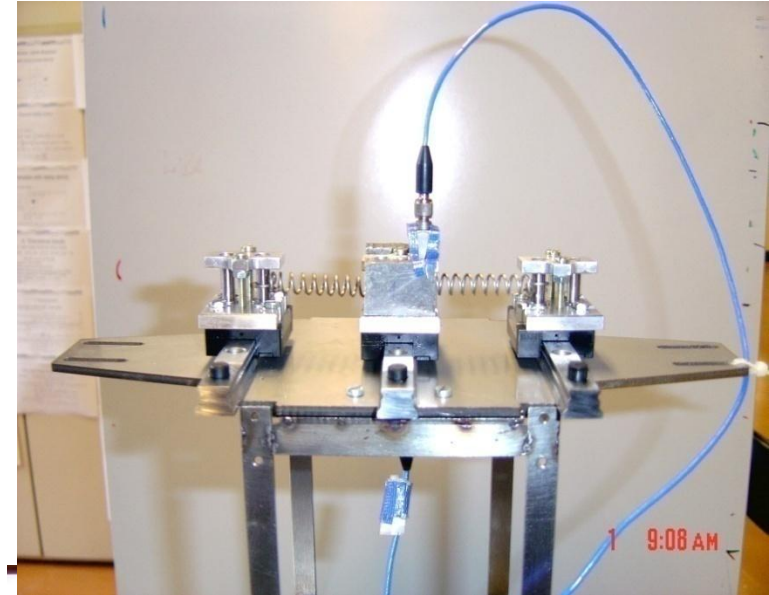
**Ou ressorts conique, membranes,  
 systèmes nonlinéaires...**

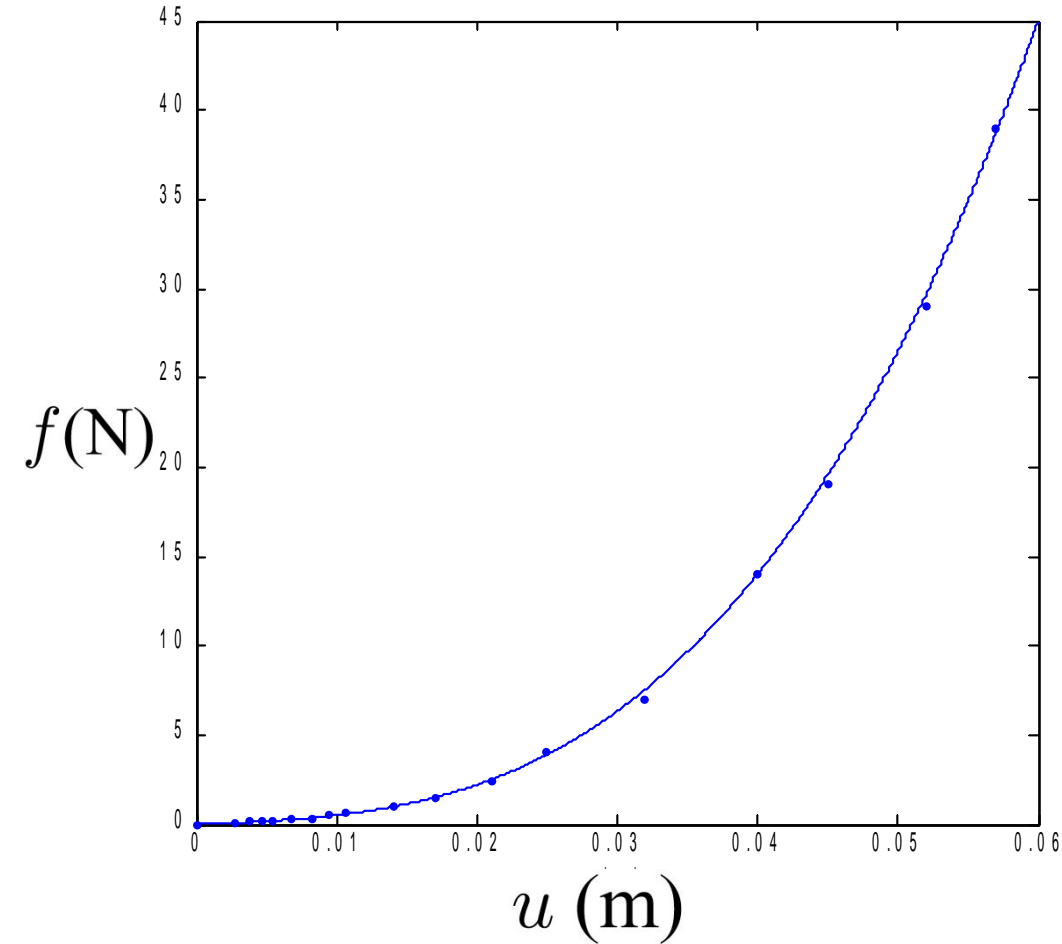


Modèle à 4 étages  
(DGCB FRE CNRS 3237)

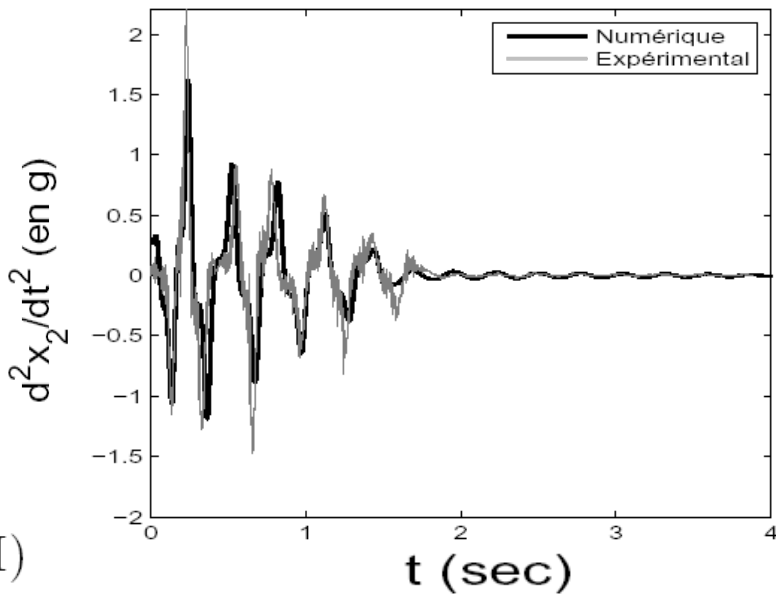
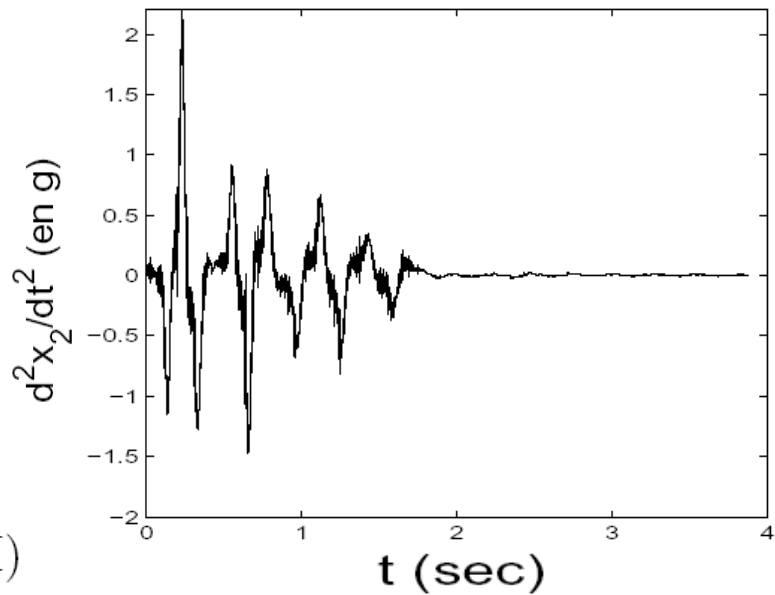
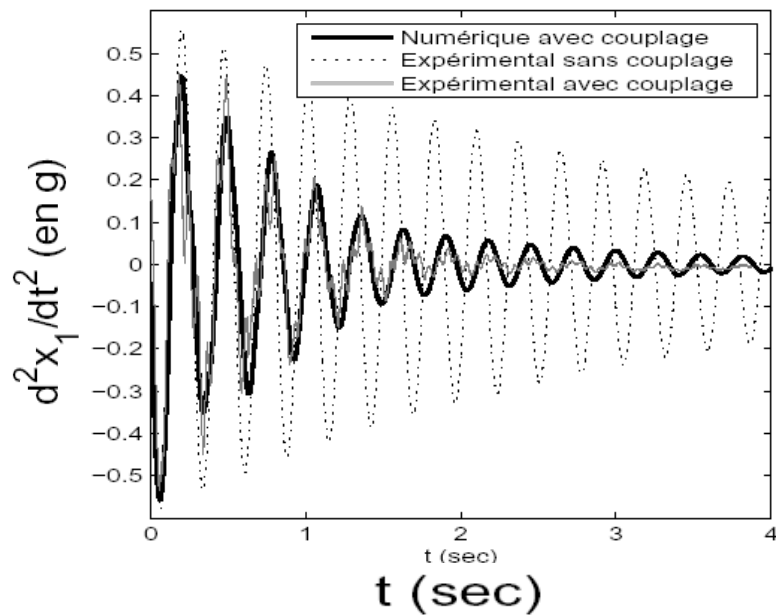
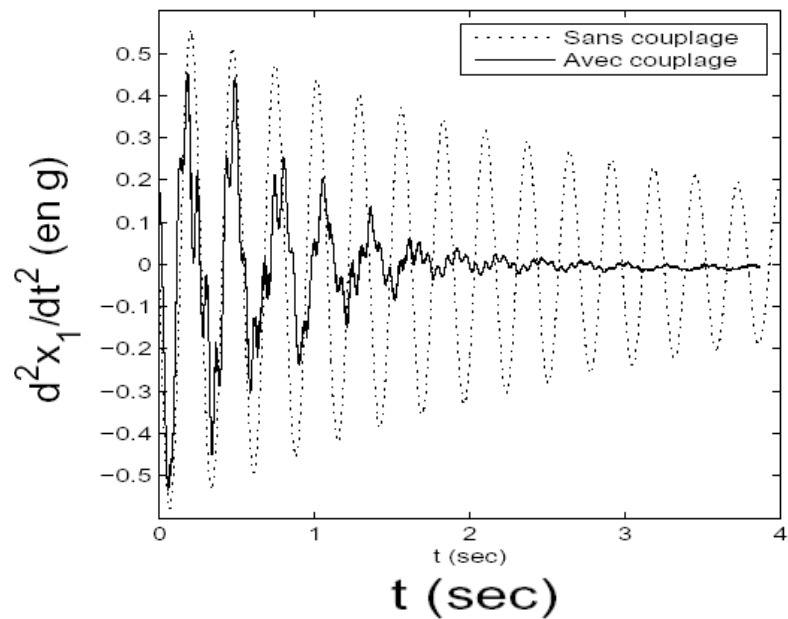


Modèle à 4 étages



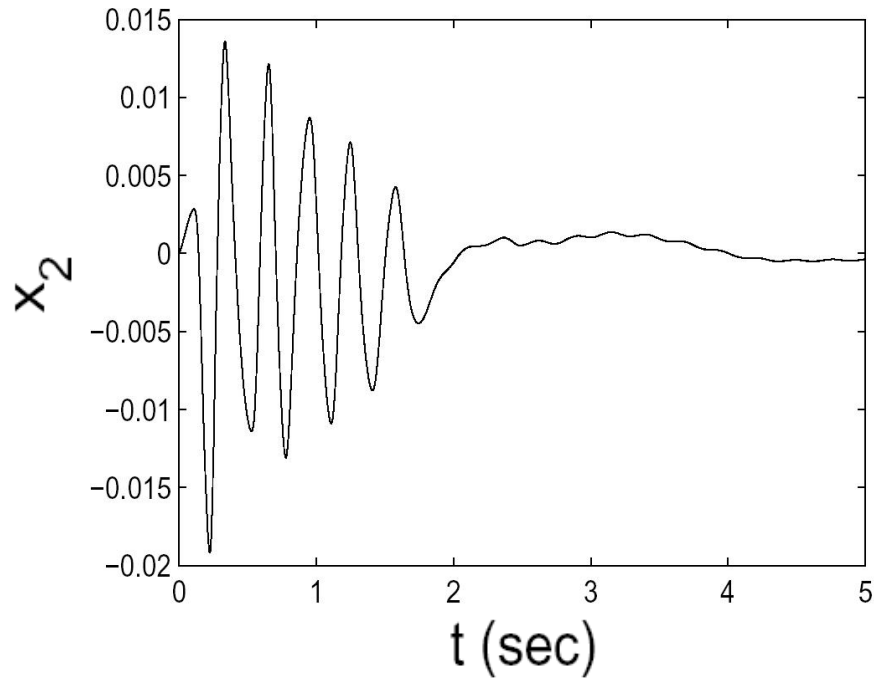


$$f = 2.10^5 u^3 + 30u$$

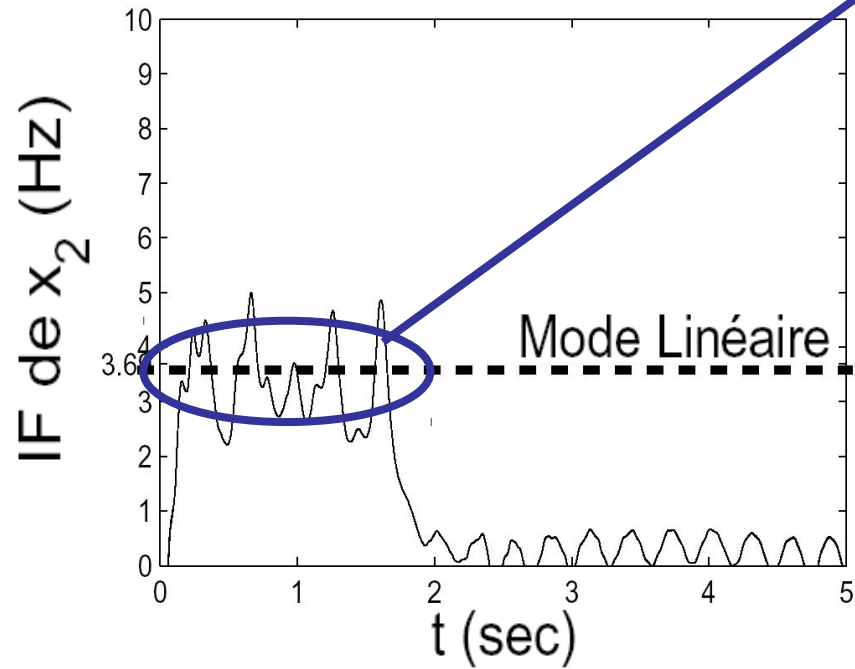


I)

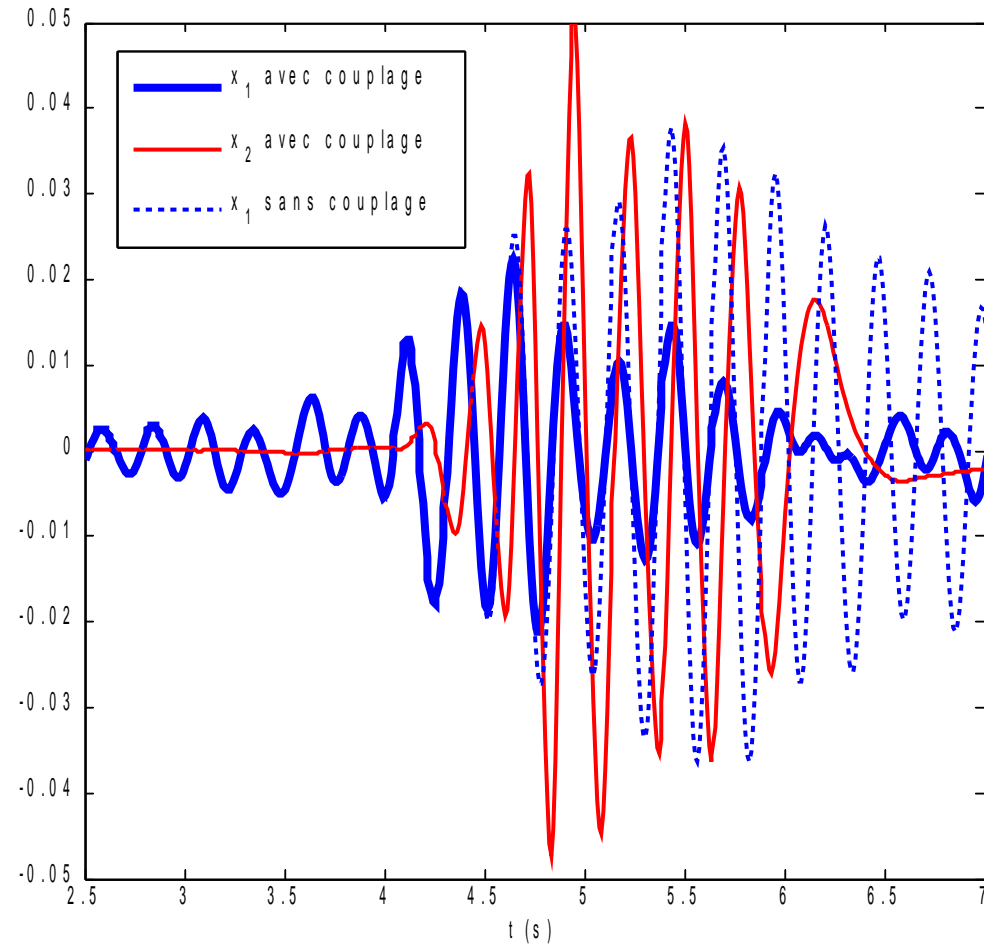
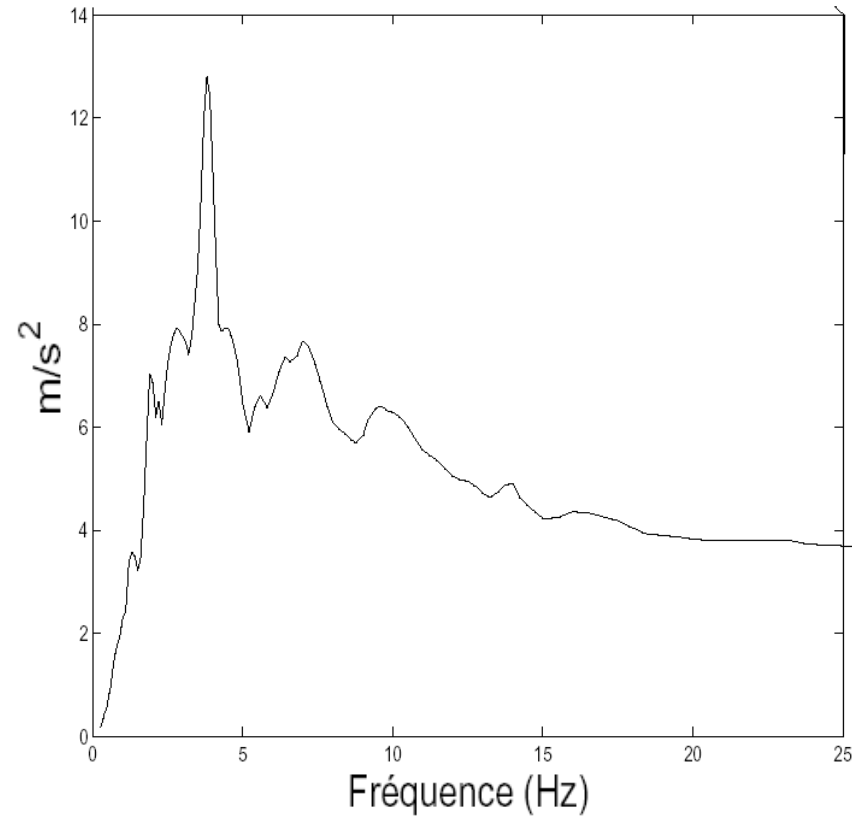
II)



Capture de résonance



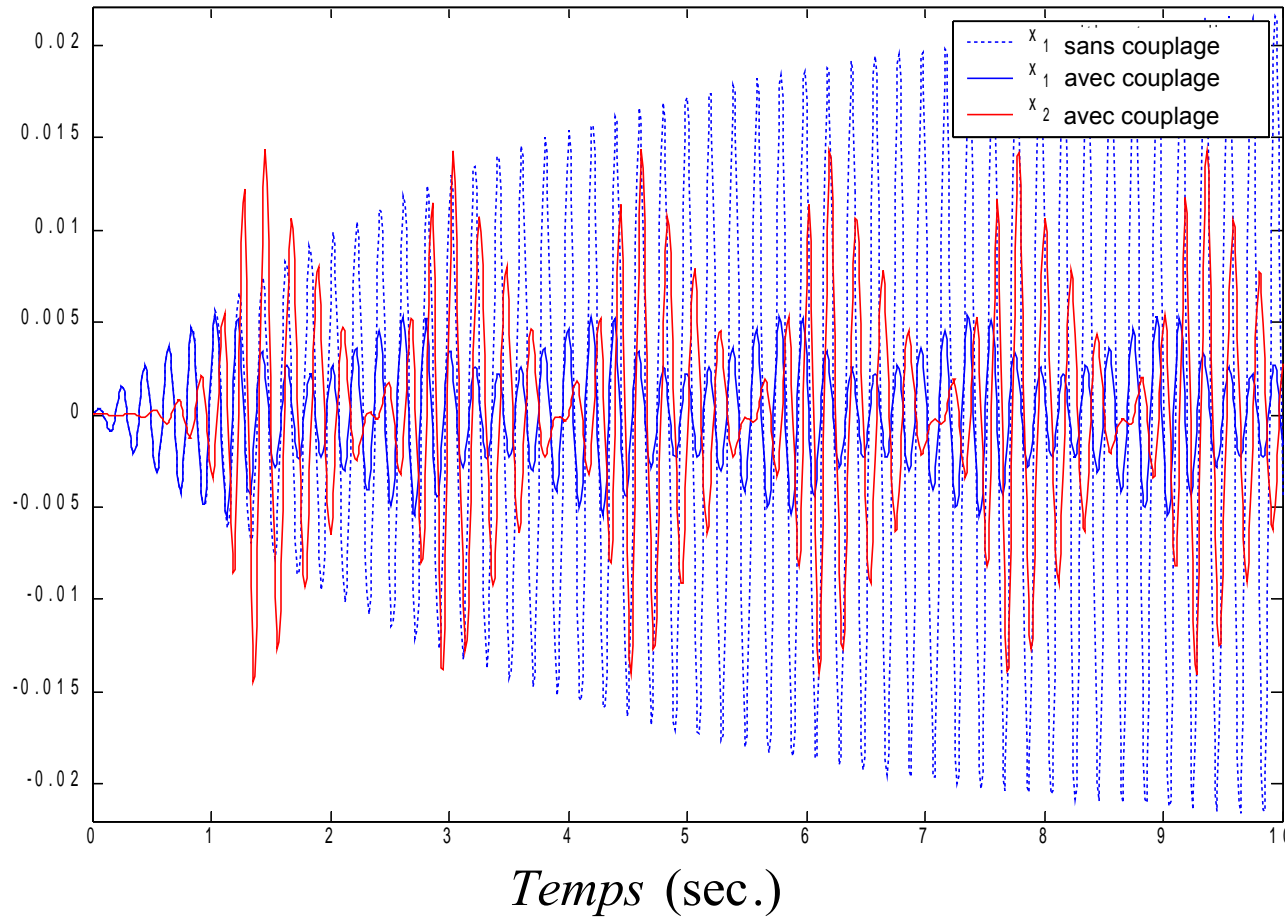
Spectre d'un séisme réel (Friule)



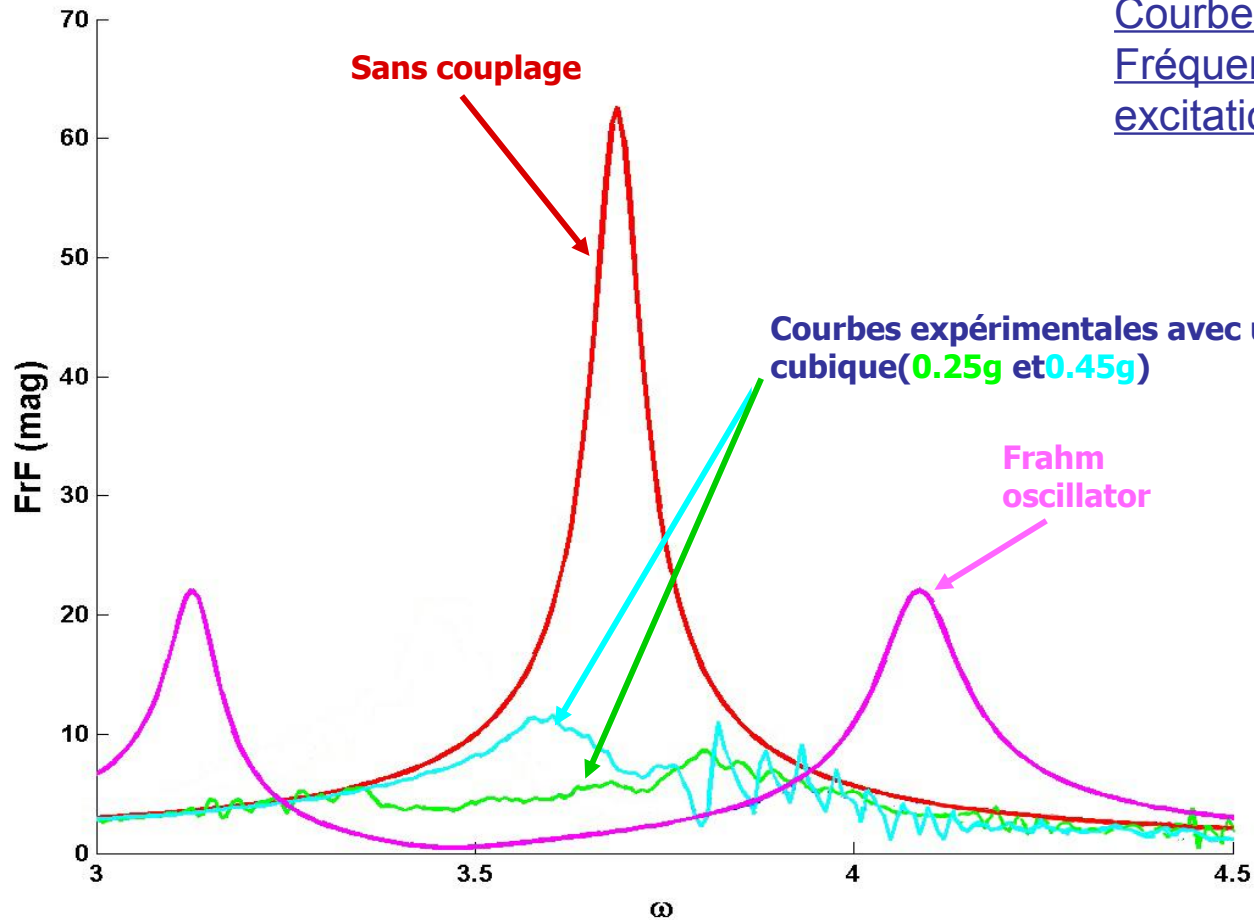


## Excitation périodique

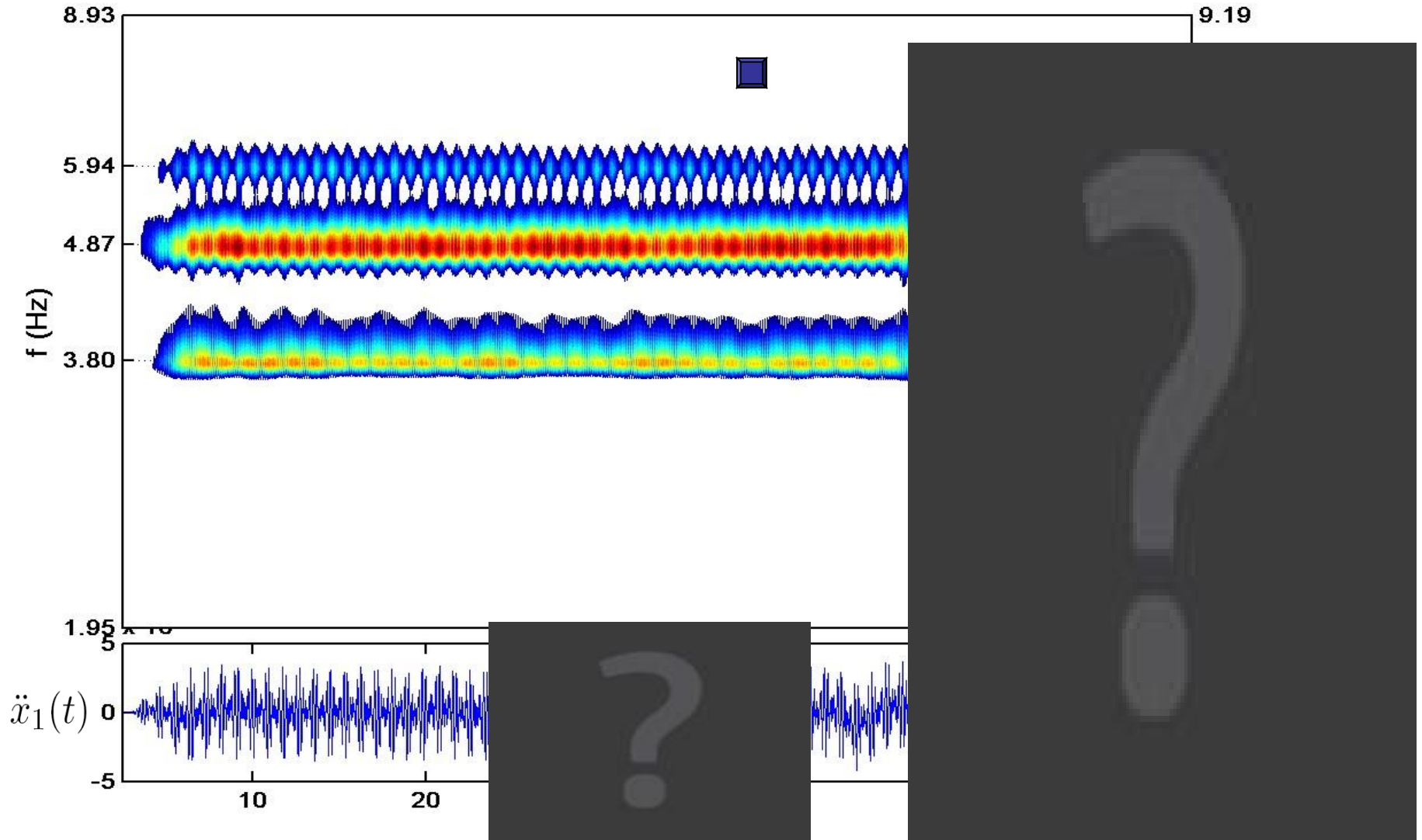
Oscillations  
 des 2  
 structures



NL  
 L

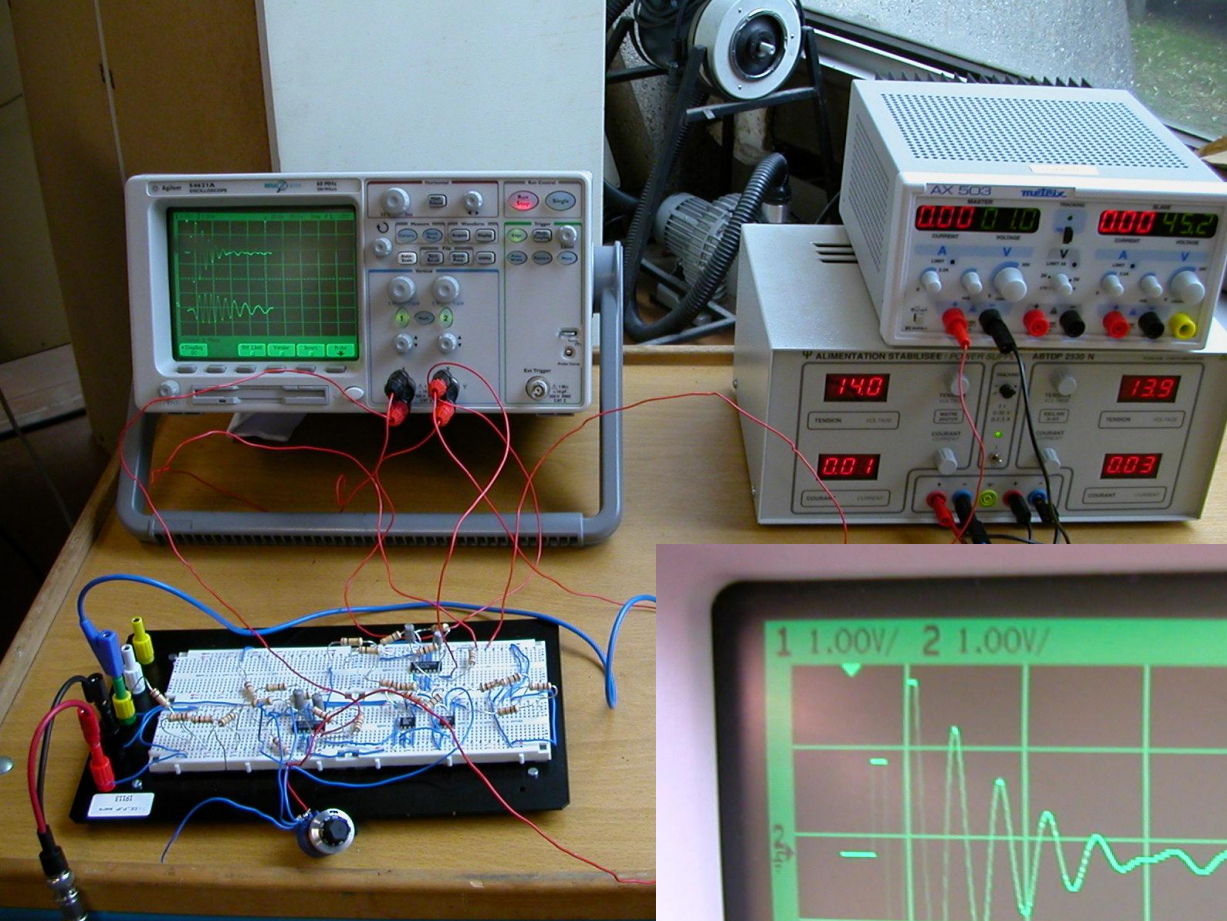


Courbes Amplitudes-Fréquences avec une excitation périodique

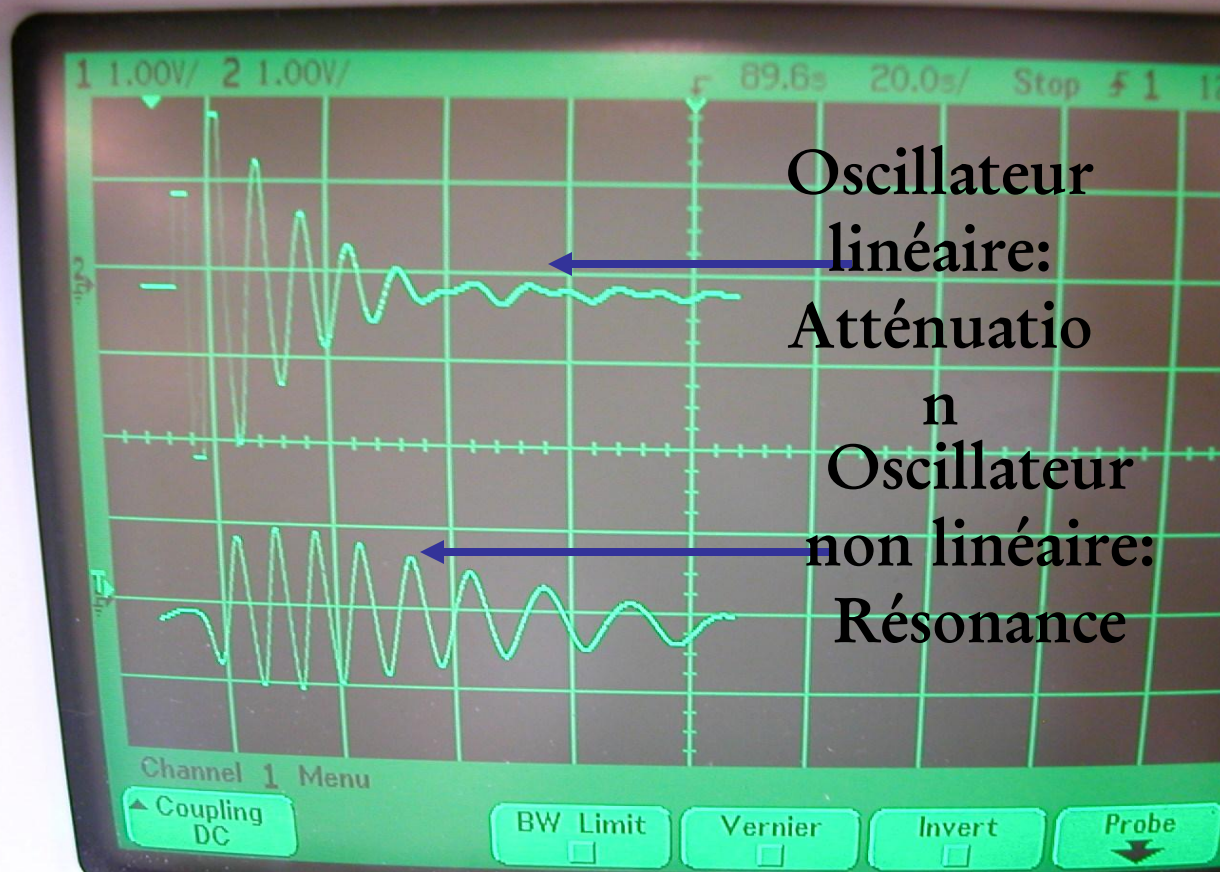




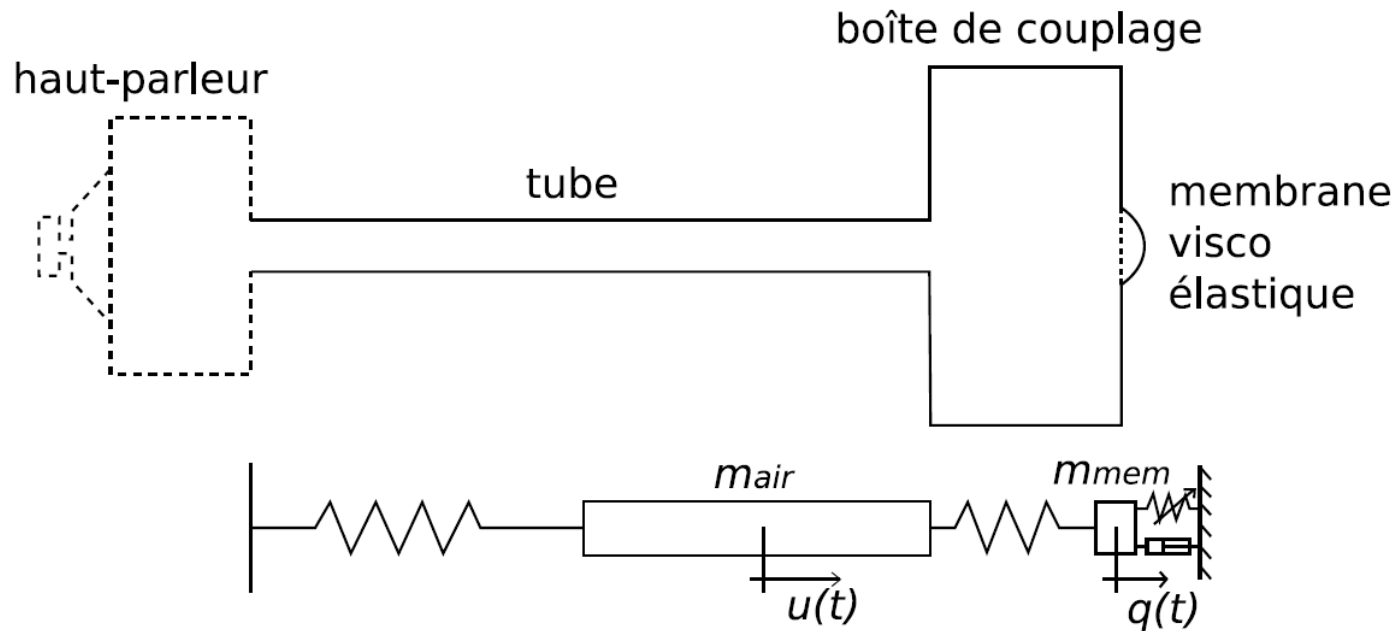
## Application électronique



Le Pompage  
énergétique se  
produit



## ■ Application Acoustique



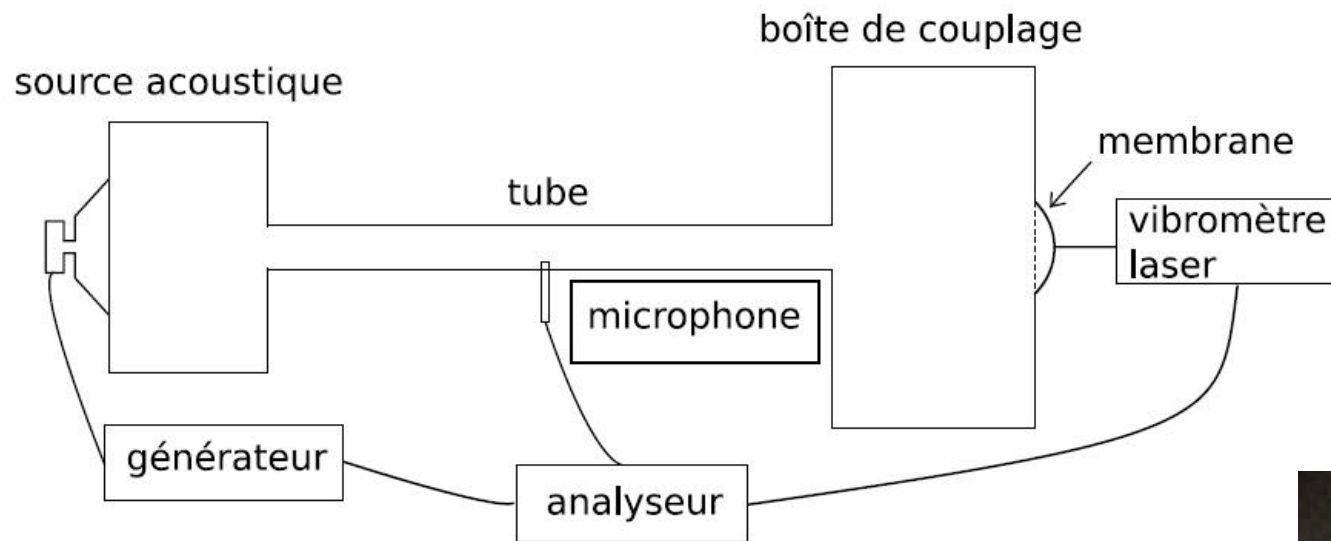
**R. Bellet, B. Cochelin, P. Herzog, P.-O. Mattei**

**LMA Marseille**

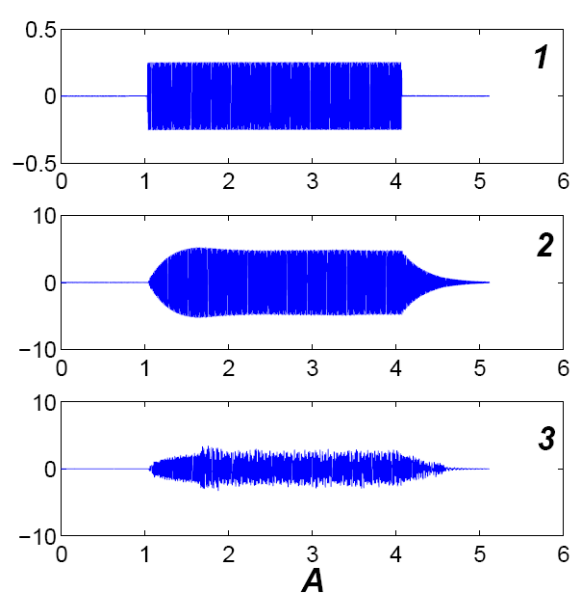
$$\ddot{u} + u + \beta(u - q) = 0$$

$$\gamma \ddot{q} + \alpha_3(2\eta\omega q^2 \dot{q} + q^3) + \beta(q - u) = 0$$

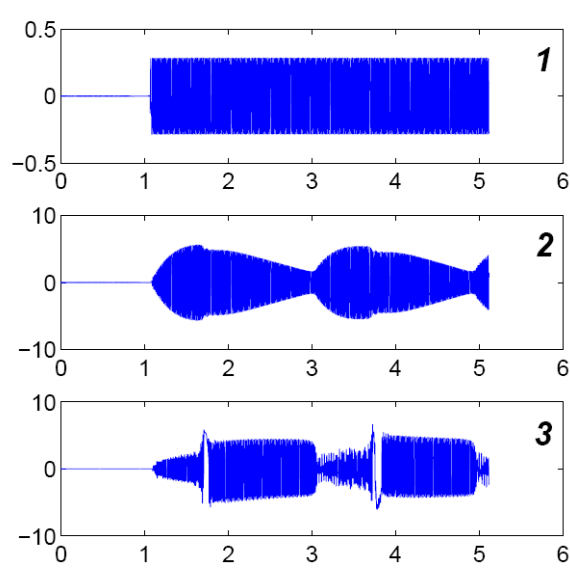
## ■ Application Acoustique



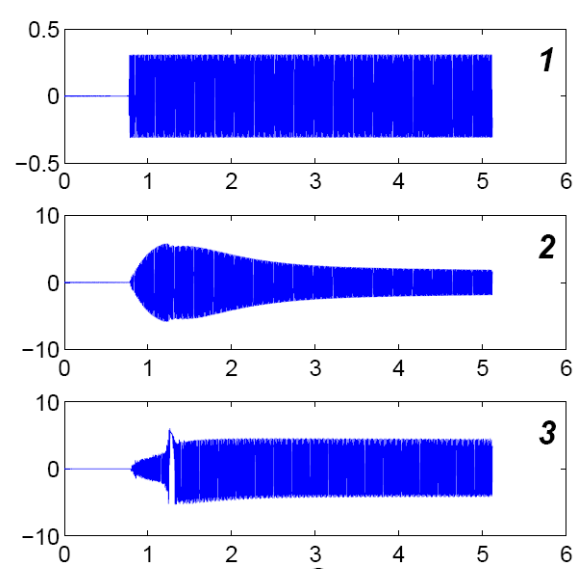
**R. Bellet, B. Cochelin, P. Herzog, P.-O. Mattei**  
**LMA Marseille**



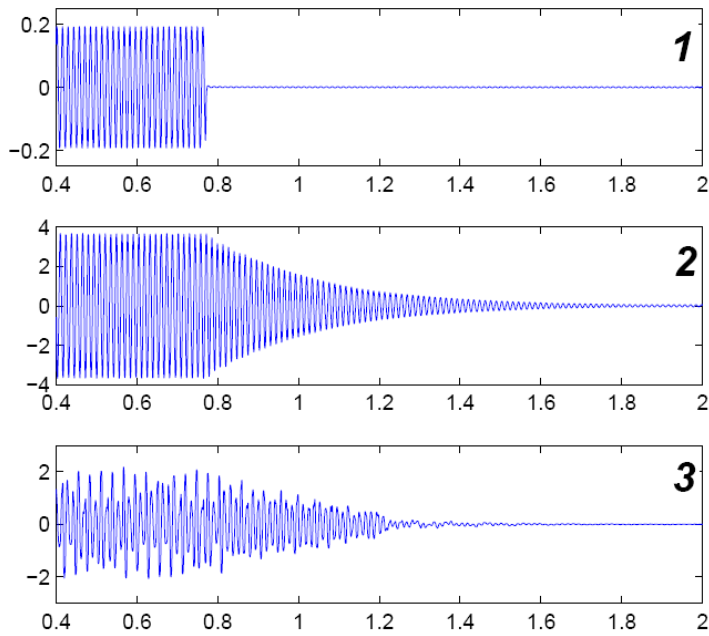
**A**



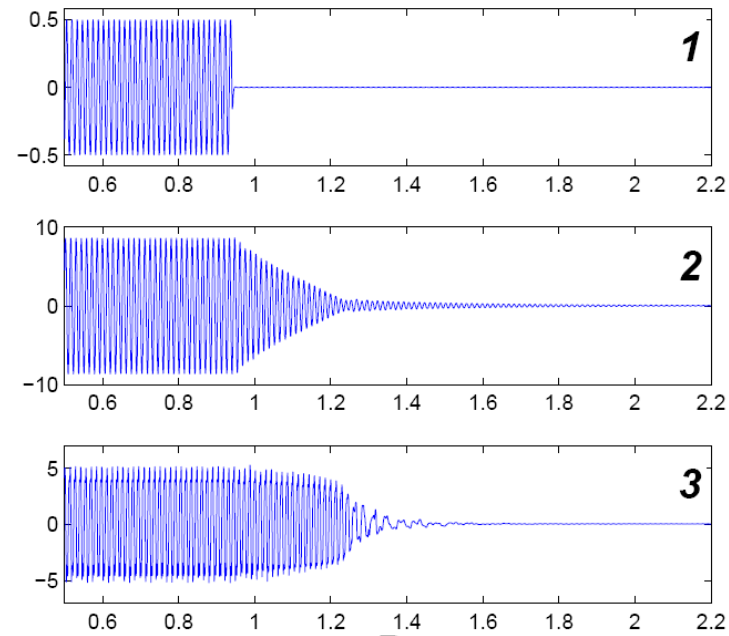
**B**



**C**



**A**



**B**

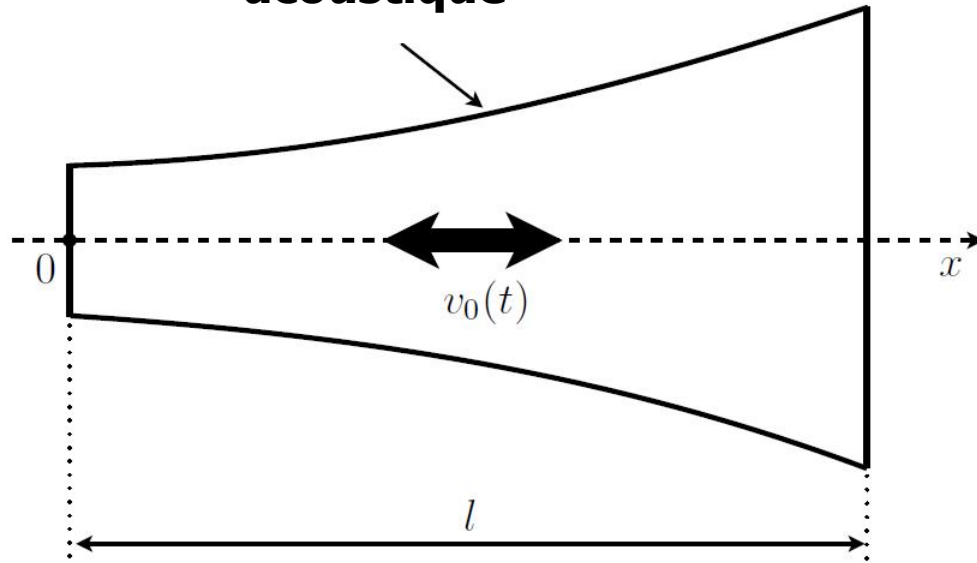


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***LMA Marseille***



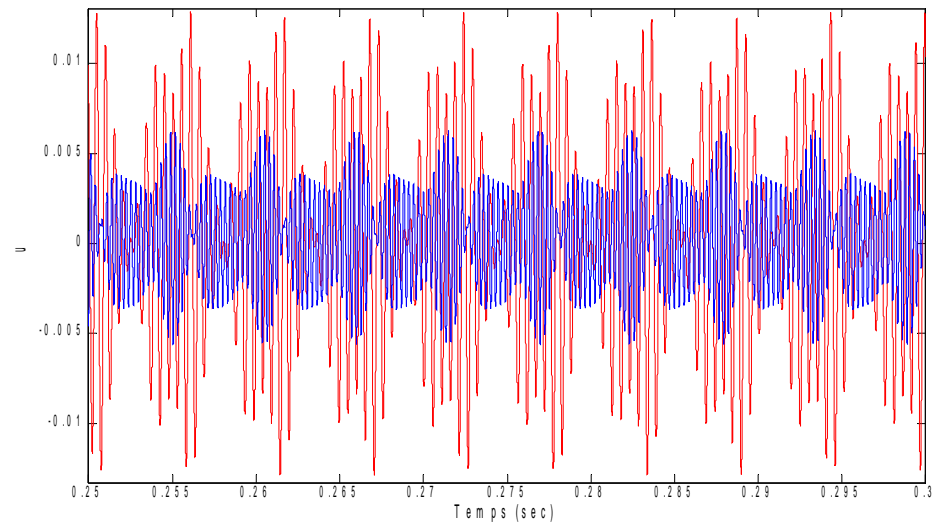
## Résonateur non linéaire acoustique



## ■ Application Acoustique

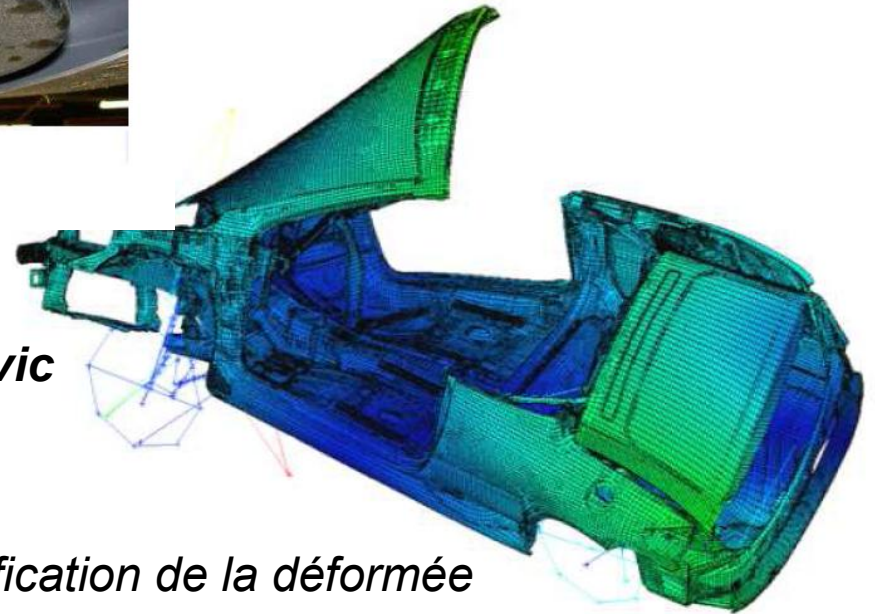
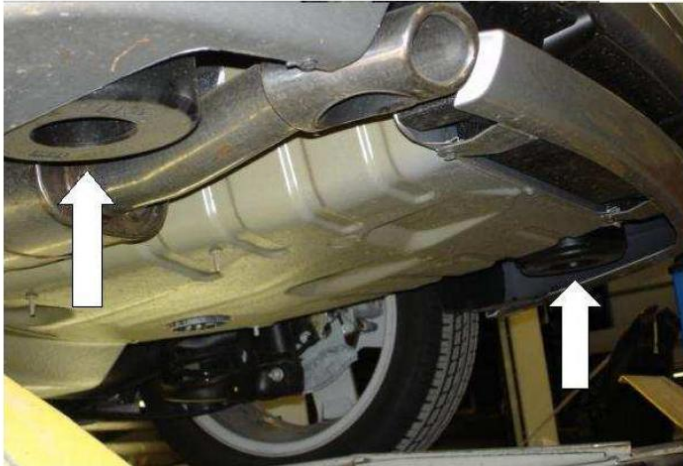


Localisation



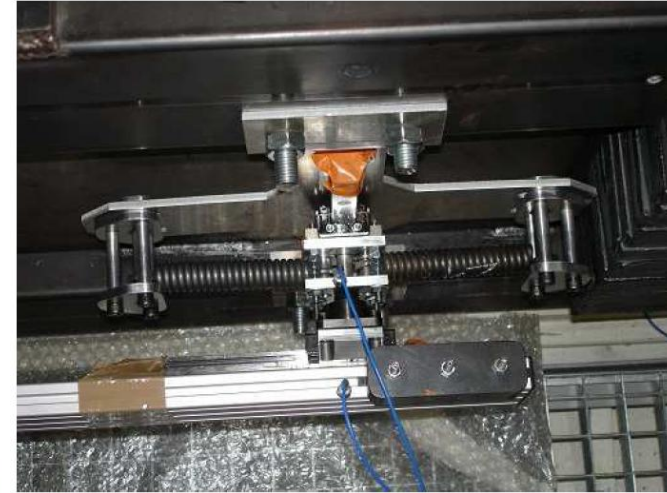
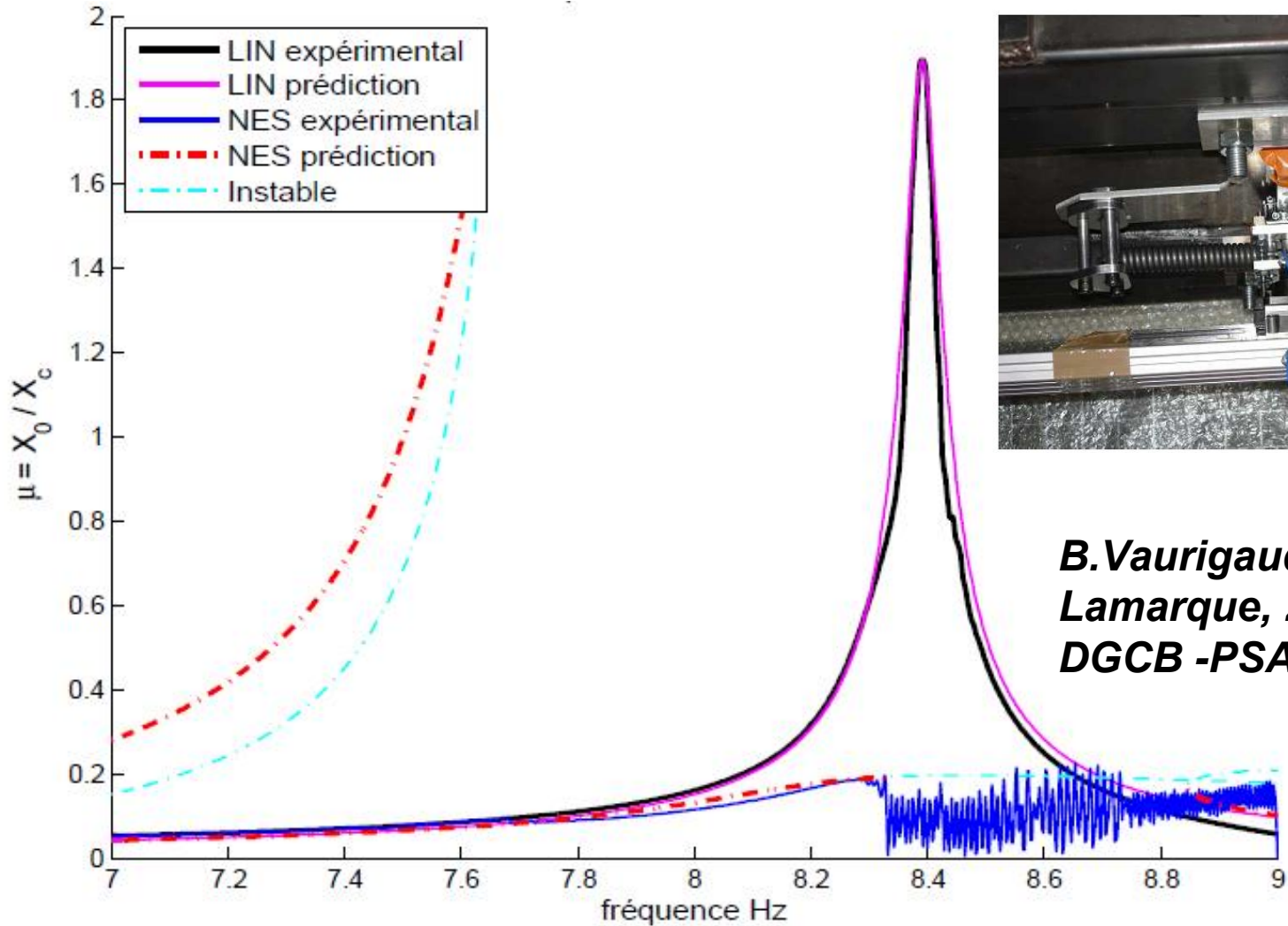


## ■ Application Automobile



***B.Vaurigaud, C.H. Lamarque, Z. Dimitrijevic  
DGCB -PSA***

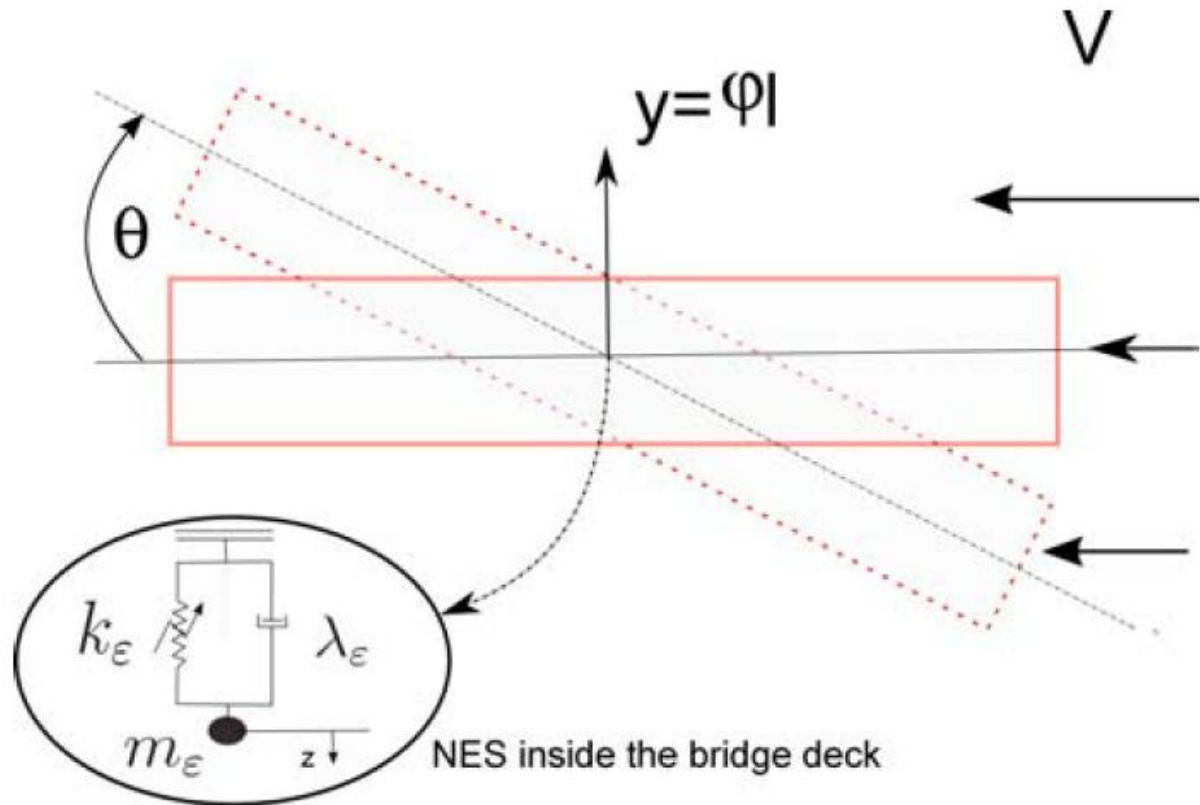
*Véhicule PSA avec amplification de la déformée  
du mode de torsion*



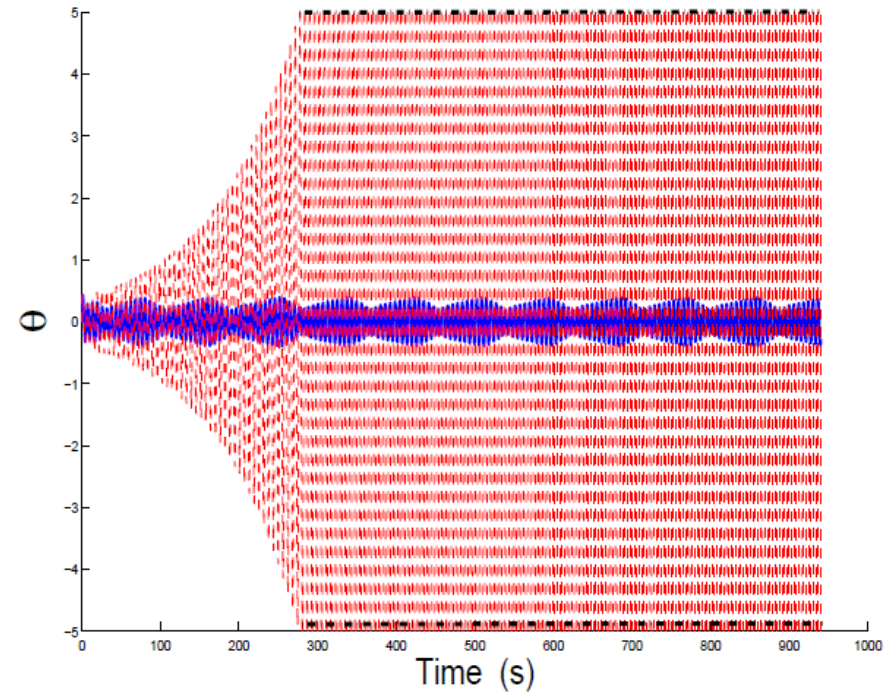
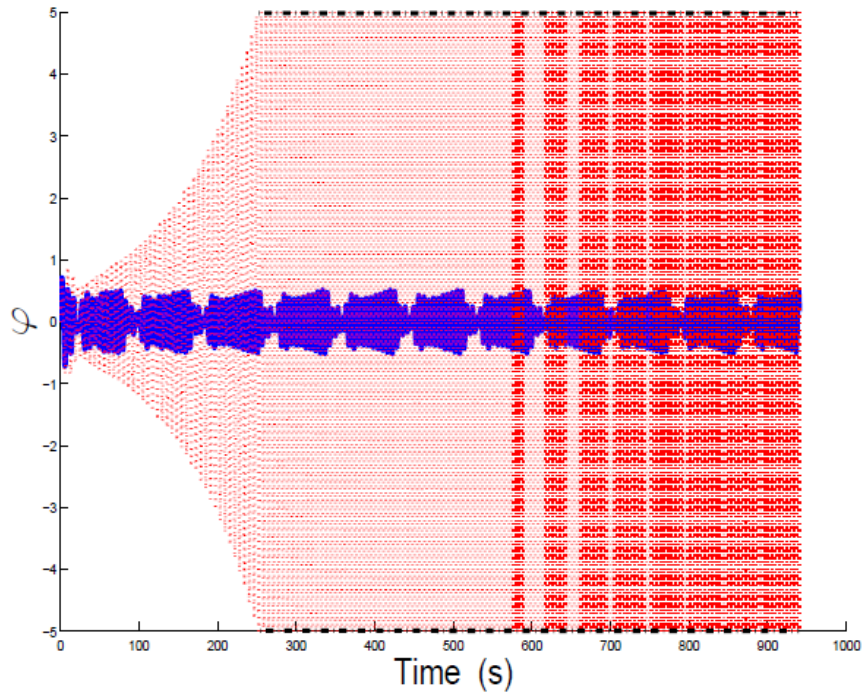
**B. Vaurigaud, C.H. Lamarque, Z. Dimitrijevic  
 DGCB -PSA**

*Modèle de tablier à 2 ddl couplé dans la direction de flexion uniquement avec un NES à 1 ddl.*

## ■ Instabilité aéroélastique



**B.Vaurigaud, C.H. Lamarque  
 DGCB**



**B.Vaurigaud, C.H. Lamarque**  
**DGCB**

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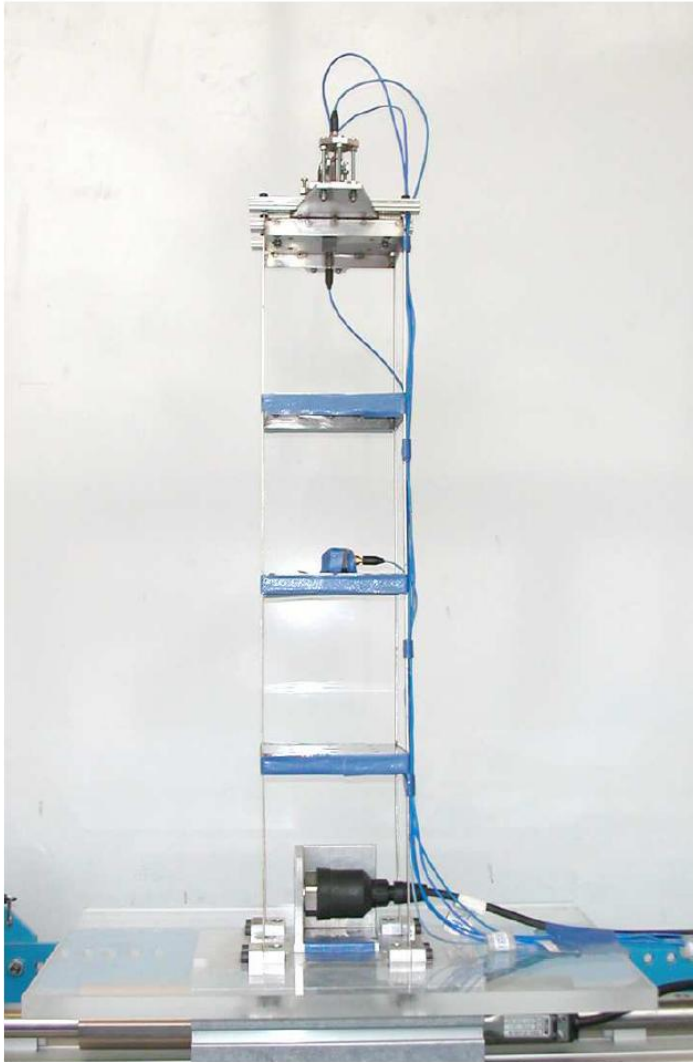
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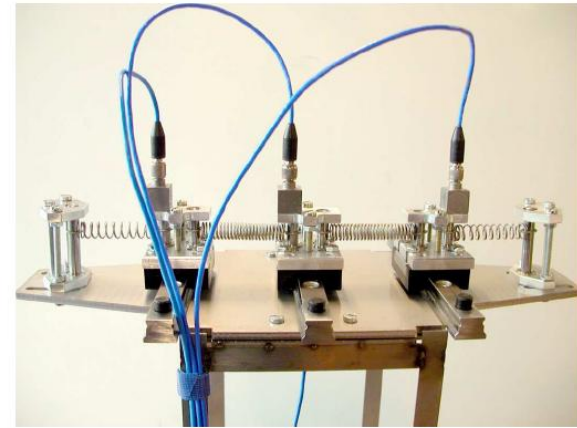
## III- OPTIMISATION

## Conclusion

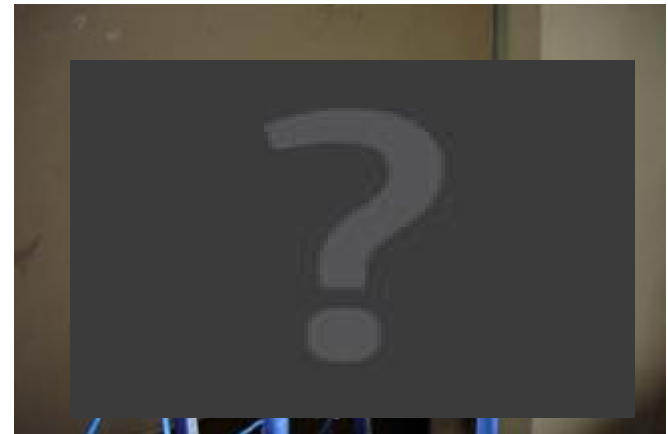




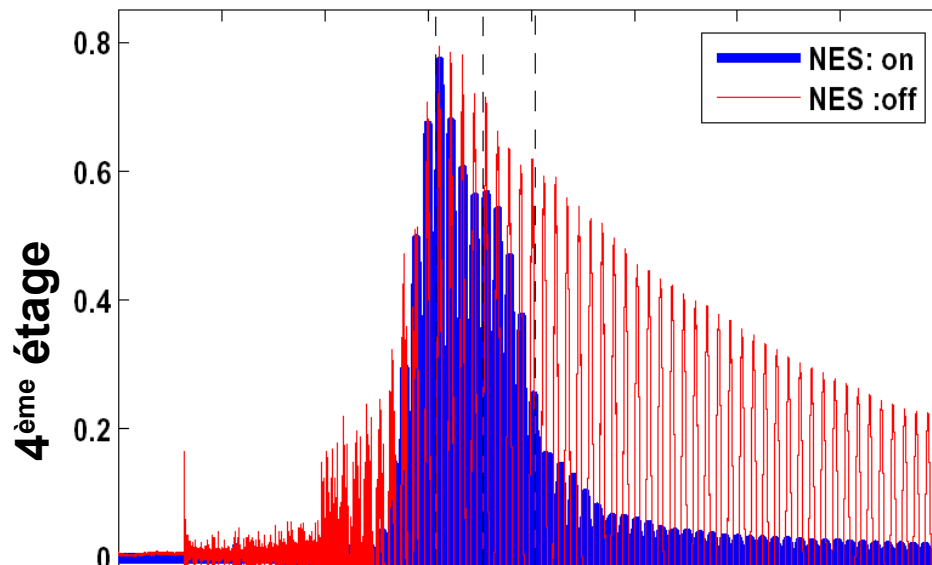
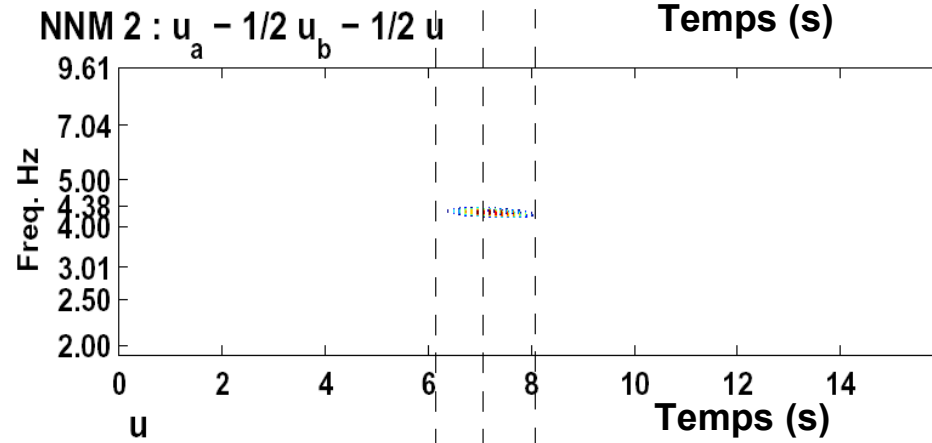
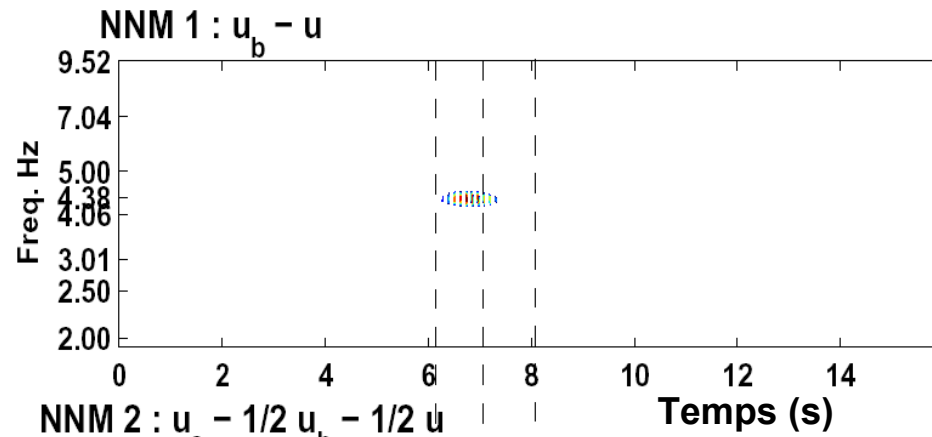
a)



b)



c)



- Plusieurs modes, interactions , design couplé
- Réduction de modèles et design du NES
- Prise en compte de la gravité
- Systèmes primaire et annexe non linéaire régulier, et non régulier...
- Transferts applicatifs (câbles, confort véhicule, roulis, cinétique chimique)
- Contrôle semi-passif...

Liens avec  
GDR DYNOLIN



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