



université
PARIS-SACLAY

SCHOOL
OF ENGINEERING
AND INFORMATION SCIENCE
TECHNOLOGIES, SEIST

Master of Mechanics

M2 Acoustical Engineering

Scientific coordinators : Benjamin Cotté (ENSTA ParisTech)
Xavier Boutillon (École polytechnique)

Administrative contact : Victoria Perez de Laborda
(ENSTA ParisTech)

Academic partners

- ENSTA ParisTech is the **reference university** for this program (timetables, grades, official documents, ...)





Organization of the year

- 1st semester : from September to the beginning of March
 - 30 ECTS to validate (10 courses of 3 ECTS in the Master of Mechanics)
in practice: 9 mandatory courses and at least 1 optional course
- 2nd semester : *research* internship of at least 5 months (30 ECTS)
 - Can be in a lab or a company, in France or abroad
- You need to fill an **agreement on the lecture program** with the courses you will follow
- Suggested online course to follow:
 - Mooc "Fundamentals of waves and vibrations" (E. de Langre, J.-F. Semblat, O. Doaré)
on Coursera platform



Mandatory courses

First period:

AE-06 General Acoustics : X. Boutillon (Polytechnique)

AE-01 Acoustic propagation in inhomogeneous moving media : B. Cotté (ENSTA) and O. Gainville (CEA)

AE-04 Acoustical Signal Processing : M. Kowalski (Univ. Paris-Sud)

AE-03 Numerical techniques in acoustics : M. Aussal (Polytechnique)

Second period:

AE-08 Psychoacoustics : X. Boutillon (Polytechnique) and M. Rébillat (ENSAM)

AE-09 Structural acoustics (shared with M2 (MS)2SC) : B. Cotté (ENSTA) and A. Talbot (MSC - FFT)

AE-10 Non destructive testing : A.-S. Bonnet Ben Dhia (ENSTA), A. Lhémery (CEA) and M. Rébillat (ENSAM)

AE-02 Aeroacoustics : L. Lesshaft (Polytechnique) and X. Gloerfelt (ENSAM)

AE-05 Experimental techniques in acoustics : to be determined – in research labs

**For ENSTA students involved in the *Simulation and Modelisation program*,
course AE-05 is optional**

AE-06 General acoustics

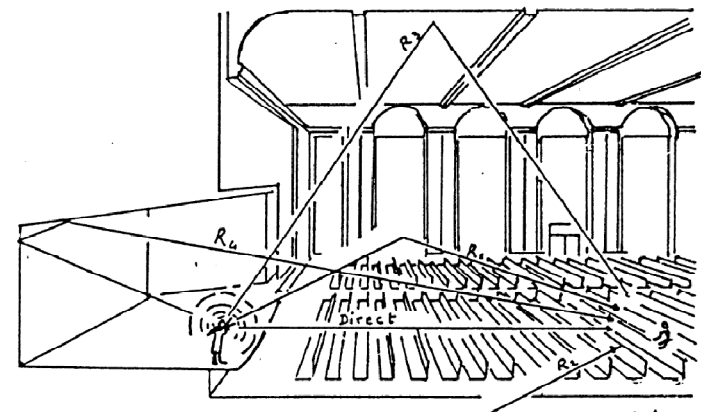
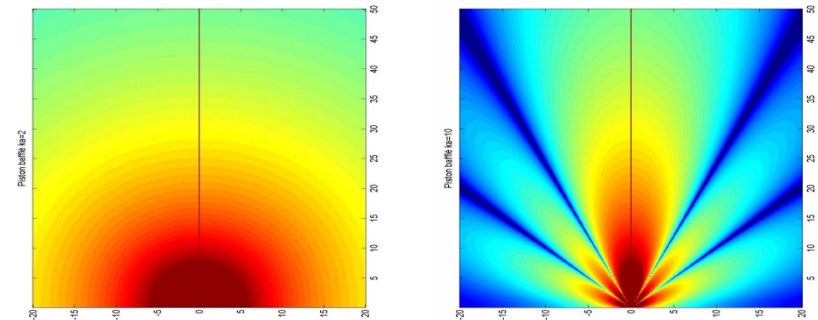
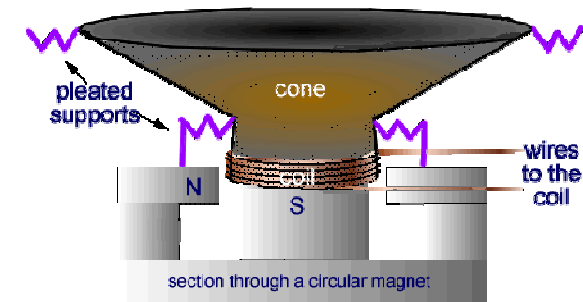
Teacher: X. Boutillon (CNRS & École polytechnique)

Objectives: introduce some theories of linear acoustics

- Equations of acoustics, approximations, linearization.
- Lumped-element models, electroacoustics.
- Wave-guides and cavities – Room acoustics
- Acoustical radiation of simple sources – Parametrization of the acoustical field.
- Reciprocity
- Deviation to simple isentropic approximation
- ...

Course organization:

- Lectures
- Analysis of articles in acoustics, including problem solving.



AE-01 Acoustic propagation in inhomogeneous moving media

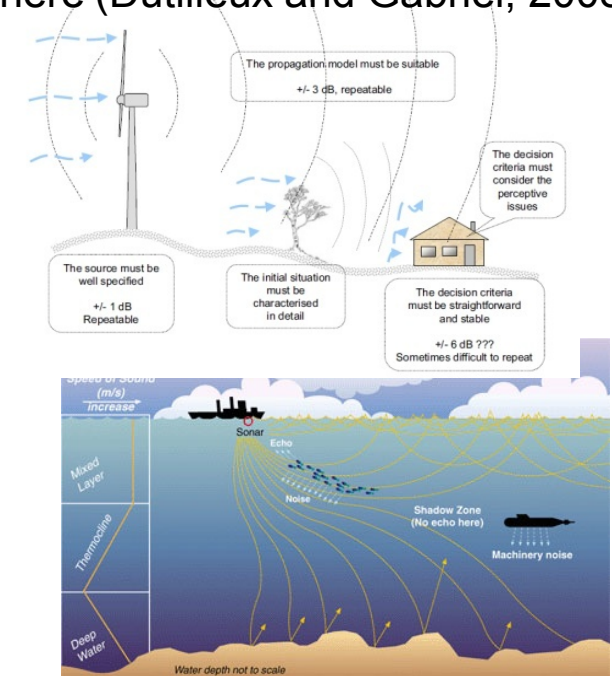
Teaching team: B. Cotté (ENSTA) and O. Gainville (CEA) Wind turbine noise propagation in the atmosphere (Dutilleux and Gabriel, 2008)

Objectives:

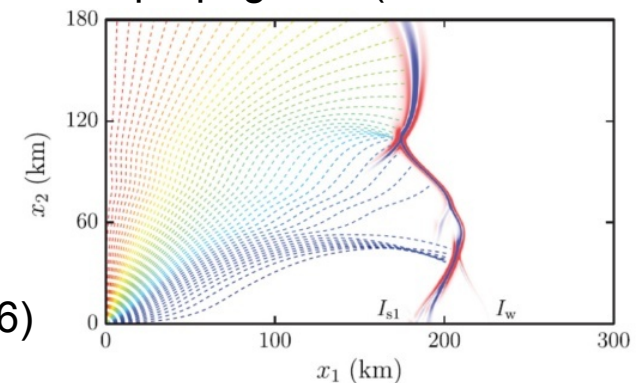
- describe the physical phenomena involved in acoustic propagation: ground reflection, refraction effects, diffraction by obstacles, scattering by turbulent fluctuations, ...
- propose models to account for these phenomena
- apply relevant numerical method to solve an acoustic propagation problem in a specific situation

Course organization:

- Practical session exercises
- 1 midterm exam and 1 numerical mini-project with defense and report



Underwater sound propagation (www.dosits.org)



Infrasound propagation (Sabatini *et al.*, 2016)

AE-04 Acoustical signal processing

Teaching team: Matthieu Kowalski
(Univ. Paris Sud)

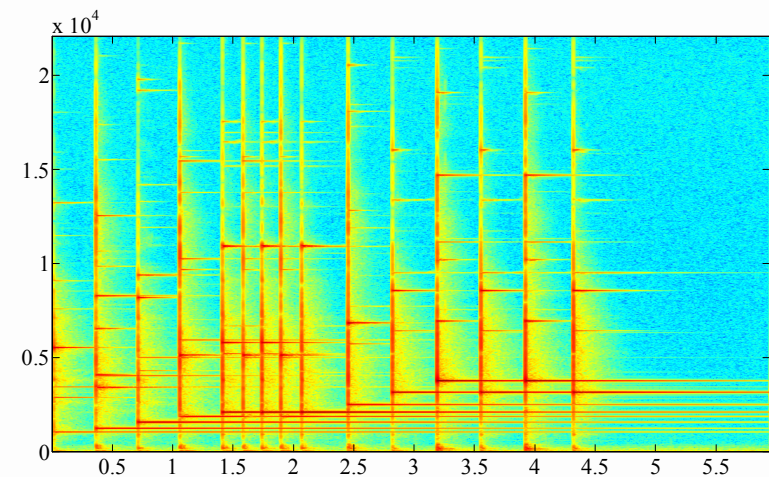
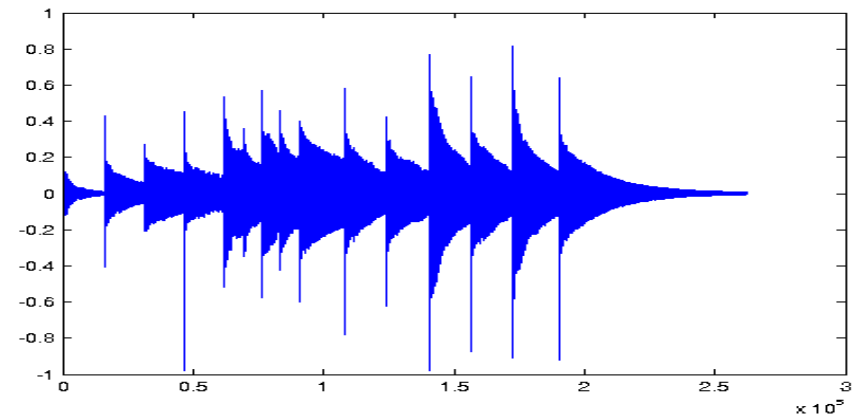
Objectives:

- Basic techniques of signal processing: spectrum analysis, filtering
- Advanced techniques: Time-frequency, wavelets

Organization:

- Alternate between courses and practical sessions with Matlab
- Examples: chord song synthesis, audio denoising

Evaluation: 1 final exam



AE-03 Numerical techniques in Acoustics

Teaching team : Matthieu Aussal (Ecole Polytechnique)

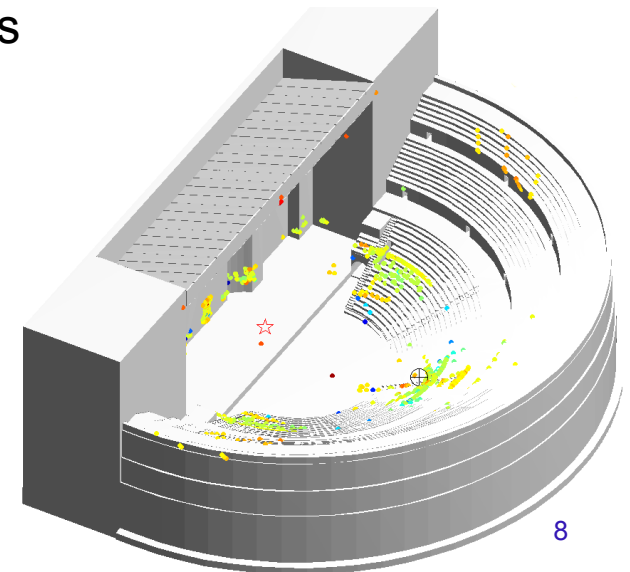
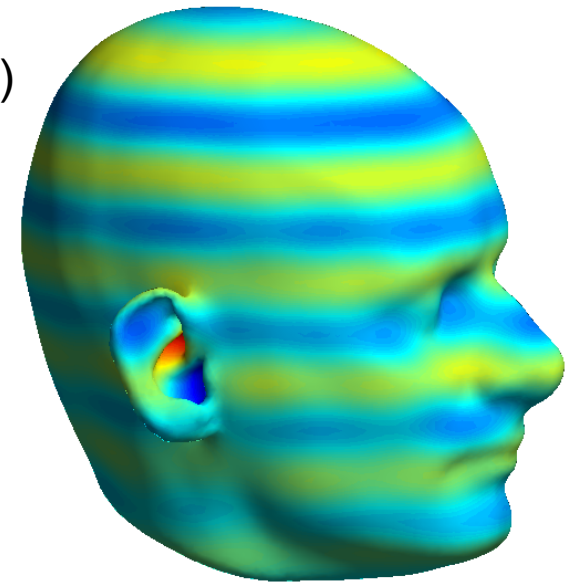
Purpose : Discover, develop and use numerical methods for acoustic simulation

Objectives :

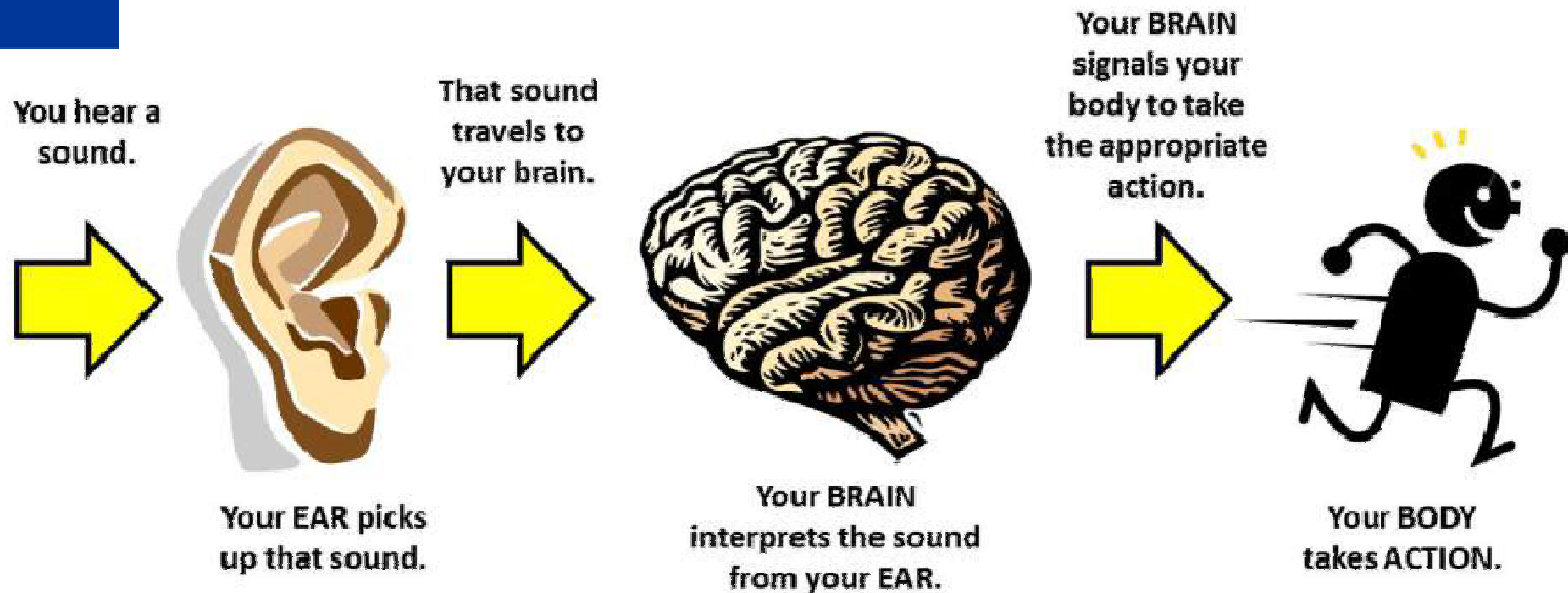
- **Model** acoustical phenomena using classical schemes from applied mathematics (FDTD, FEM, FVM, Ray-tracing, etc.).
- **Program** various solvers from scratch.
- **Analyze** results and limitations of numerical tools developed.

Course organization :

- First period in guided courses/TP
- Second period in autonomous projects
- Evaluation with projet report and oral defense
- (Pairs work allowed)



AE-08 Psychoacoustics



Teaching team: X. Boutillon(X)
M. Rébillat (ENSAM)

Objectives:

- Understanding all the perceptual chain between sounds and their perception
- Applying methodological tools to design experimental protocols for psychoacoustics

Course organization:

- Lectures with exercises and examples
- Project (2 students) with two intermediate presentations (bibliographical, preliminary protocol) and one final defense.

AE-09 Structural Acoustics

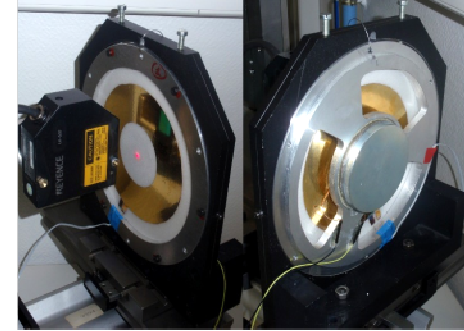
Loudspeaker radiation (Doaré *et al.*, 2013)

Teaching team: B. Cotté (ENSTA) and A. Talbot (MSC-FFT)

Objectives:

Give the principles and calculation methods of acoustic fields radiated by vibrating structures:

- Model elementary and extended sound sources
- Describe the physics of elasto-acoustic coupling (fluid-structure interaction)
- Predict the noise radiated by vibrating structures of increasing complexity using modal methods and Statistical Energy Analysis



Lightweight and electrical vehicle noise
(Renault Twizy)

Course organization:

- Practical session exercises and sessions using the Actran software
- 1 final exam and 1 report on Actran project

vibro-acoustic study of a ski cabin (2018 Actran project)



AE-10 Non destructive testing (NDT)

Teaching team: A.-S. Bonnet-BenDhia (ENSTA), A. Lhémy (CEA),
M. Rébillat (ENSAM)

Objectives:

After a presentation of the industrial significance of NDT and needs for its development, notably for methods relying on elastic waves, lectures on:

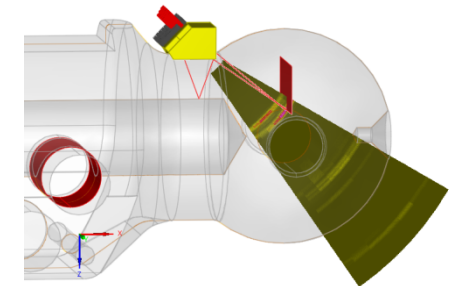
- Theory of bulk and guided elastic wave propagation in solids
- Radiation, scattering and reception of elastic waves
- How this physics is used to examine materials, to find/characterize defects (defectology), to monitor structures (structure health monitoring)
 - Defectology using ultrasonic bulk or guided waves
 - SHM using guided waves

Course organization:

- Lectures + practical work sessions
(CIVA simulation, SHM experiment / simulation)
- 1 final exam and 1 mini-project



Ultrasonic testing in aircraft industry



Ultrasonic testing of a complex component with a phased-array (CIVA simulation)

AE-02 Aeroacoustics

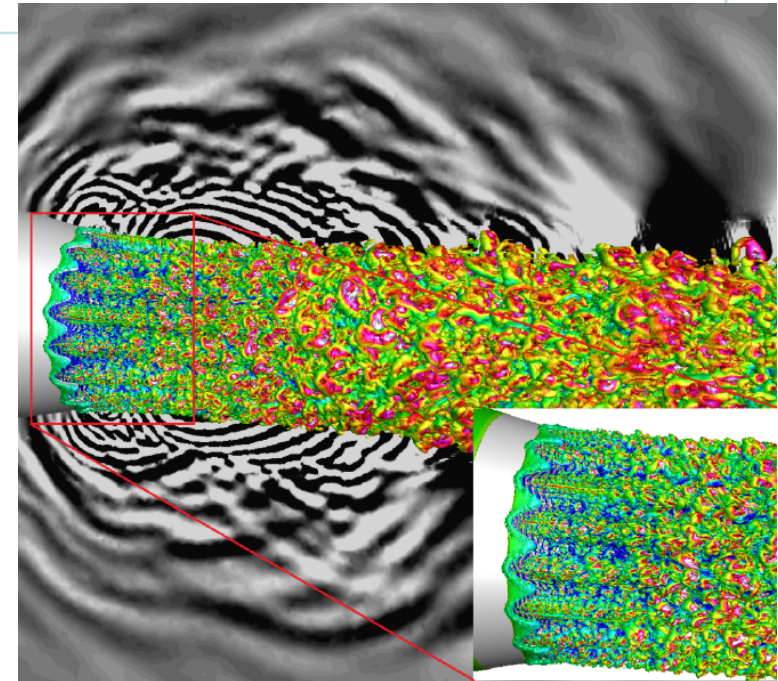
Teaching team: L. Lesshafft (Polytechnique) and X. Gloerfelt (ENSAM)

Objectives:

- provide a physical understanding of the various ways that fluid flow generates sound;
- present main aeroacoustic theories;
- understand noise generation mechanisms by a free turbulent flow (jet noise of aircraft engines) and in presence of solid surfaces (whistling of flow past a cavity, airfoil noise for fans, wind turbines, ...)
- apply acoustic analogy theory on a simple case (aeolian noise)

Course organization:

- Lectures & Practical session exercises
- 1 final exam and 1 mini-project on acoustic analogy



Numerical simulation of jet noise



New concept of silent aircraft (ONERA)

AE-05 Experimental techniques in acoustics

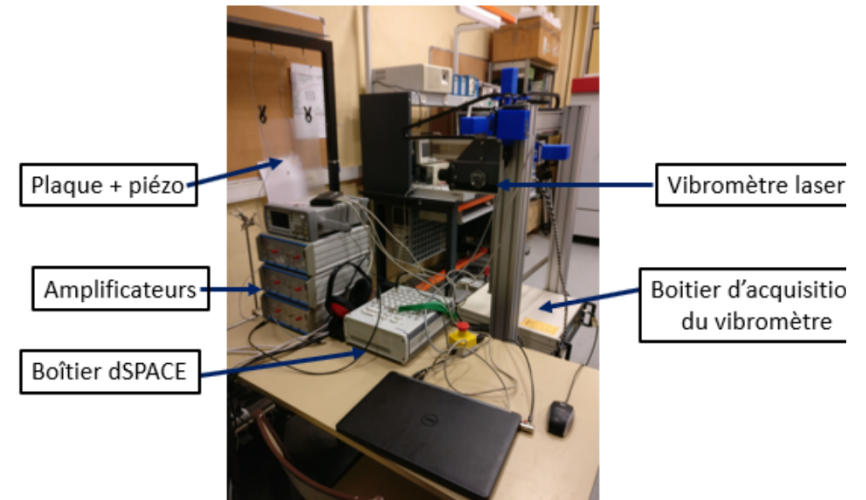
Teaching team: O. Doaré (ENSTA), Emil Garnell (Polytechnique), M. Rébillat (ENSAM), ...

Objectives:

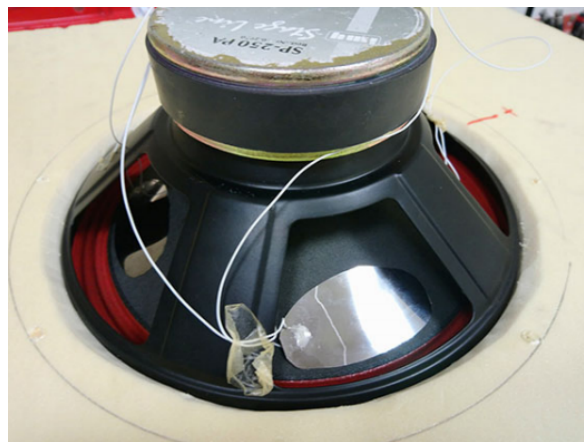
- Perform an experimental project in acoustics (team work)
- Initiation to sensors, data acquisition and signal analysis issues
- Define how to reach a given scientific objective

Course organization:

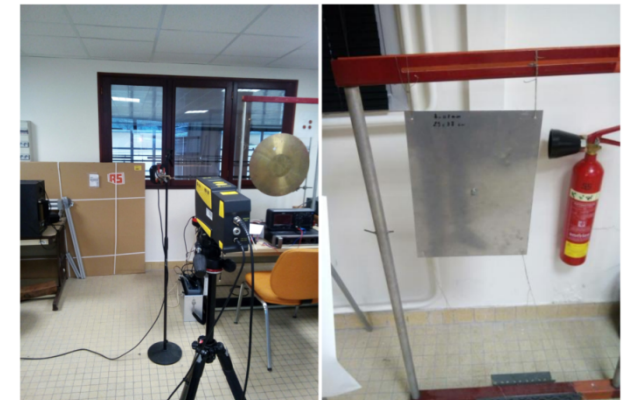
- Experimental project
- Written and oral reports



Piezoelectric control of plates



Improvement of a loudspeaker with piezoelectric patches



Listening through a plate or window



Suggested optional courses

Courses of the M2 Acoustical Engineering:

AE-15 Matériaux pour l'isolation acoustique
in French, M2 AE, shared with Supmeca curriculum
S. Job and B. Nenning (Supmeca) – takes place at Supmeca

AE-11 Interactions fluides-structures
in French, M2 AE, shared with M2 (MS)2SC and ENSTA curriculum
O. Doaré (ENSTA) - takes place at ENSTA

AE-07=AMS307 Propagation et diffraction dans les guides d'onde
in French, M2 AE, shared with AMS
A.-S. Bonnet Ben Dhia et E. Luneville (ENSTA) - takes place at ENSTA

More information can be found on our website :

<https://acoustics-saclay.ensta-paristech.fr>



Suggested optional courses

Courses from other M2 programs

Vibrations non linéaires

in French, M2 (MS)2SC

C. Touzé (ENSTA), J.-L. Dion (SupMéca) - takes place at ENSTA

Turbulence dynamics

in English, M2 Fluid Mechanics

L. Jacquin (ONERA), C. Muller (LMD) - takes place at Polytechnique

Other courses from M2 Biomechanical Eng. (in English), (MS)2SC (in French), M4S (in English), etc.

More information can be found on our website :

<https://acoustics-saclay.ensta-paristech.fr>

AE-15 Matériaux pour l'isolation acoustique (in French)

Équipe enseignante: S. Job and B. Nennig (Supméca)

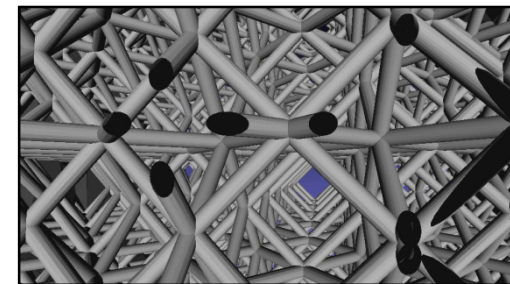
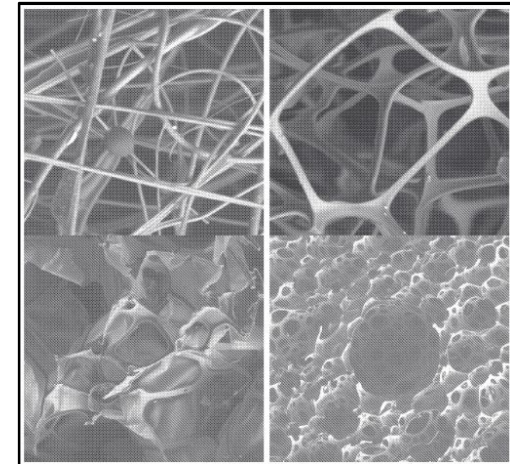
Objectifs:

Acquérir les principes généraux, les fondements théoriques et les compétence pratiques de l'Acoustique en fluides dissipatifs et dans les matériaux poreux.

- Propagation acoustique en fluides dissipatifs
- Propagation d'ondes dans des guides capillaires
- Les modèles et les paramètres des milieux poreux
- Méthodes de caractérisations expérimentales
- Techniques de simulations numériques
- Mise en œuvre pratique en cas réel

Organisation du module:

- 5 cours/TD (20h) + 3 TP exp/sim (12h)
- Évaluation QCM (25%) + présentation/rapport TP (75%)



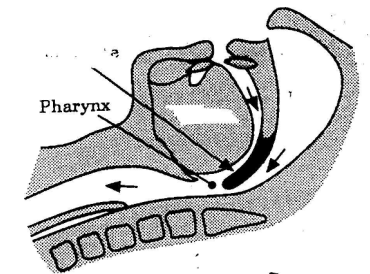
AE-11 Interactions fluides-structures (in French)

Equipe enseignante: O. Doaré (ENSTA)

Thèmes :

- Notions de base en dynamique des structures (modes propres, fréquences propres, base modale, méthodes numériques en analyse modale)
- Effet de la présence d'un fluide environnant au repos sur la dynamique des systèmes mécaniques
- Aéroélasticité, instabilités de flambage et de flottement de structures interagissant avec un fluide en écoulement
- Forçage des écoulements instationnaires sur les structures vibrantes (turbulence, sillages tourbillonnaires)

**Cours/TD théoriques, TD en salle info sous Matlab
Contrôle + projet Matlab**



AE-07=AMS307 Propagation et diffraction dans les guides d'onde (in French)

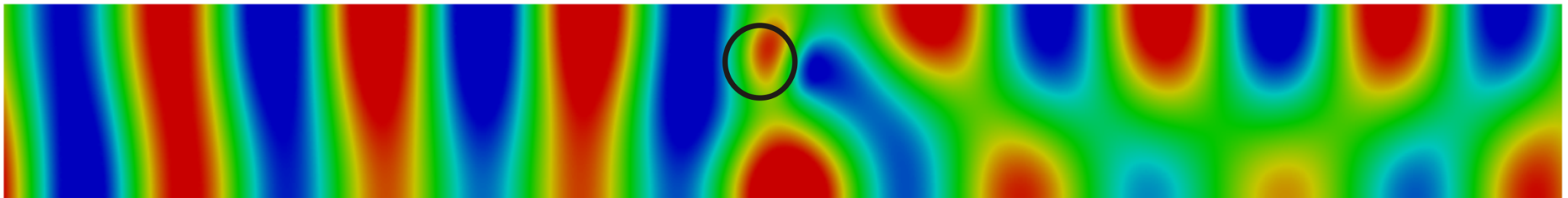
Equipe pédagogique: Anne-Sophie Bonnet
Ben Dhia et Eric Luneville (ENSTA ParisTech)

Course organization:

- Cours et TD
- Mini-projet (lecture d'article ou projet numérique) suivi du rendu d'une synthèse écrite et d'une soutenance orale.

Objectifs:

- modéliser la propagation acoustique dans les guides d'ondes
- concevoir et analyser des méthodes numériques efficaces adaptées à la physique des guides d'onde (exemple: « Perfectly Matched Layers »)



Champ acoustique total dans un guide (2D) contenant une perturbation :
le cours va présenter des méthodes numériques pour calculer ce type de champ, en utilisant des éléments finis au voisinage du défaut et en exploitant les décompositions modales à l'infini.

Vibrations Non-Linéaires (in French)

Teaching team: Cyril Touzé (ENSTA ParisTech)
and Jean-Luc Dion (SupMéca)

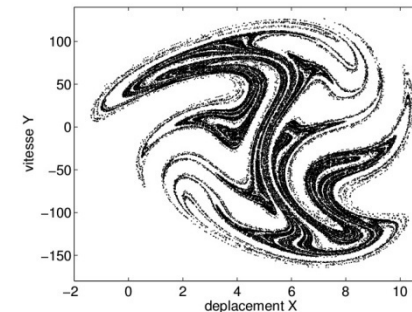
Objectives:

- give an overview and a classification of the nonlinear phenomena in mechanics
- provide the students with analytical and numerical tools in order to understand and predict nonlinear phenomena
- use dynamical system theory in order to understand bifurcations and chaotic vibrations
- use adapted signal processing techniques in order to analyze nonlinear phenomena

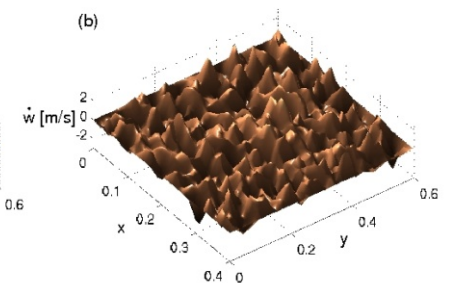
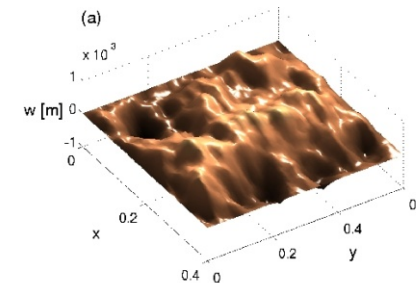
Course organization:

- Lectures and practical sessions in computer room
- evaluation : bibliographic work on a research article + oral defense

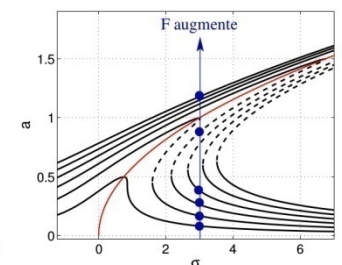
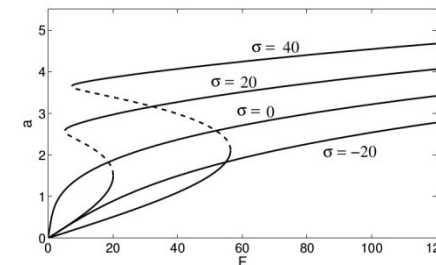
Nonlinear phenomena occurs in a number of mechanical problems, ranging from geometric to material nonlinearity, including contacts and friction.



Strange attractor



Nonlinear plate vibrations (wave turbulence)



Duffing oscillator



Turbulence Dynamics

Teaching team: Laurent Jacquin (ONERA), Caroline Muller (LMD, ENS)

Objectives:

Present recent advances in the field of turbulence research:

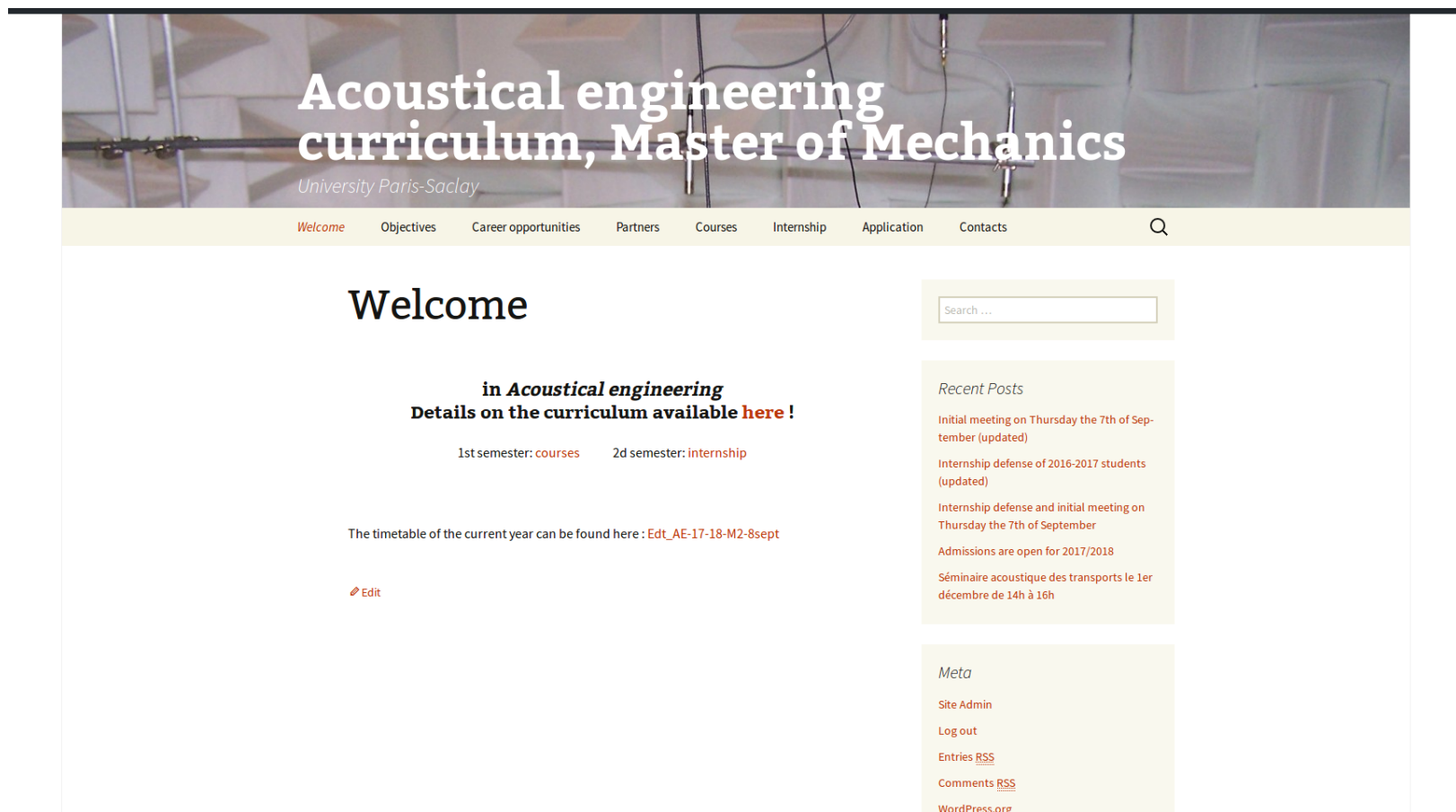
- Statistical description of turbulence
- Concept of turbulence model
- Concept of coherent events, definition of a vortex
- Dynamics of isotropic turbulence: kinetic energy cascade, triadic interactions, Waleffe's hypothesis; modelling: k-epsilon, EDQNM.
- Dynamics of anisotropic homogeneous flows: shear, strain and rotation, introduction to Rapid Distortion Theory, modelling: k-epsilon.
- Turbulent boundary layer: dynamics, mean flow description, role of vortices/coherent structures, concept of Self-Sustained Process in turbulent shear flows; modelling: k-epsilon

Course organization:

- Lectures and practical sessions
- Written exam

Timetable

The last version of the timetable can be found on the welcome page of the website of the program : <https://acoustics-saclay.ensta-paristech.fr>



The screenshot shows the homepage of the 'Acoustical engineering curriculum, Master of Mechanics' website. The header features a banner with the title and 'University Paris-Saclay'. Below the banner is a navigation menu with links: Welcome, Objectives, Career opportunities, Partners, Courses, Internship, Application, and Contacts. The main content area has a 'Welcome' heading, followed by a search bar and a section titled 'in Acoustical engineering' with the text 'Details on the curriculum available here!'. Below this, it lists '1st semester: courses' and '2d semester: internship'. A note states 'The timetable of the current year can be found here : Edt_AE-17-18-M2-8sept' with an 'Edit' link. On the right sidebar, there are sections for 'Recent Posts' (listing several updates) and 'Meta' (listing Site Admin, Log out, Entries RSS, Comments RSS, and WordPress.org).

Acoustical engineering curriculum, Master of Mechanics
University Paris-Saclay

[Welcome](#) [Objectives](#) [Career opportunities](#) [Partners](#) [Courses](#) [Internship](#) [Application](#) [Contacts](#)

Welcome

in Acoustical engineering
Details on the curriculum available [here](#) !

1st semester: [courses](#) 2d semester: [internship](#)

The timetable of the current year can be found here : [Edt_AE-17-18-M2-8sept](#)

[Edit](#)

Recent Posts

- [Initial meeting on Thursday the 7th of September \(updated\)](#)
- [Internship defense of 2016-2017 students \(updated\)](#)
- [Internship defense and initial meeting on Thursday the 7th of September](#)
- [Admissions are open for 2017/2018](#)
- [Séminaire acoustique des transports le 1er décembre de 14h à 16h](#)

Meta

- [Site Admin](#)
- [Log out](#)
- [Entries \[RSS\]\(#\)](#)
- [Comments \[RSS\]\(#\)](#)
- [WordPress.org](#)



Research labs and themes

- **Institute of Mechanical Sciences and Industrial Applications (IMSIA, ENSTA):** Structural Acoustics, Aeroacoustics and atmospheric propagation, Musical Acoustics (B. Cotté, C. Touzé, O. Doaré)
- **Laboratory of Mechanics of Solids (LMS, X):** Structural Vibrations, Sound Scattering by Loudspeakers, Musical Acoustics (X. Boutillon)
- **Wave propagation : Mathematical Studies and Simulation (POEMS, Ensta):** Non Destructive Testing, aeroacoustics, musical instruments (A.-S. Bonnet-Ben Dhia, J.-F. Mercier, P. Joly, M. Bonnet)
- **Laboratory of Hydrodynamics (LADHYX, X):** Aeroacoustics (L. Lesshafft)
- **Signals and Systems Laboratory (L2S, Univ. Paris Sud):** Signal Processing (M. Kowalski)
- **Smart digital systems (LIST/DISC, CEA):** Non destructive testing (A. Lhémercy)



Research labs and themes

- **Process and Engineering in Mechanics and Materials laboratory (PIMM, ENSAM):** Nondestructive Sensing, Psychoacoustics, Structural Vibrations (M. Rébillat)
- **Fluid Dynamics Laboratory (DynFluid, ENSAM):** Aeroacoustics (X. Gloerfelt)
- **Information Treatment and Communication Laboratory (LTCl, Telecom-ParisTech):** Processing of musical signals (B. David, G. Richard)
- **Defense and security department (DAM/DIF, CEA):** infrasound monitoring (O. Gainville and A. Le Pichon)
- **Laboratoire QUARTZ (Supméca):** Acoustic wave propagation in poro-granular metamaterials (B. Nennig and S. Job)

Industrial partners

Main application sectors:

- Transportation noise (ground, air and maritime)
- Acoustical signal processing (sonars, virtual reality)
- Industrial and building acoustics
- Structural monitoring and imaging
- Acoustical modeling and simulation



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Passion for life





Seminars and lab visit

- Internship defense of 2017-2018 students (if not confidential)
 - Sept. 13th, 9am, at Polytechnique (PC 104)
 - Sep. 20th, 9am, at Polytechnique (PC 05)
- Visits of research labs / experimental facilities scheduled during the year
- You are strongly encouraged to go to the Forum Trium (www.forum-trium.com/) the 7th of November
 - Meet recruiters from companies / Find an internship
 - Review your resume (CV) with recruiters



Seminars and lab visit

- Seminars or roundtables will be organized on several topics of interest for a large audience of students:
 - Ground transportation noise
 - Applications of aero- and hydro-acoustics in aerospace / underwater Acoustics
 - Audio engineering
 - Other topics you might be interested in ?



Student life at University Paris Saclay - ENSTA ParisTech

- Many events organized: see the BDE (*Bureau des élèves*), BDA (*Bureau des Arts*), BDS (*Bureau des Sports*), ...

<https://www.ensta-paristech.fr/fr/decouvrir-ecole/vie-etudiante/bureau-des-eleves-bde>

- A forum of associations is organized on the 4th of October