Active control of multimodal tonal noise propagated in circular duct with axial subsonic mean flow up to M=0.3

M. Glesser, E. Friot, M. Winninger, C. Pinhède
A. Roure

LMA, CNRS UPR-7051, France
glesser@lma.cnrs-mrs.fr

Acoustics 2008,
Paris

Outline

Plan

1. **Motivations**
2. Materials and methods
3. Results and discussion
   - No flow, multimodal
   - In flow, planar mode
4. Conclusion

Motivations

Active noise control of aircraft engine noise: possible or not ?

- Multimodal tonal noise propagating in circular ducts in the presence of a mean flow

Motivations

Active noise control of aircraft engine noise: possible or not ?

- Multimodal tonal noise propagating in circular ducts in the presence of a mean flow

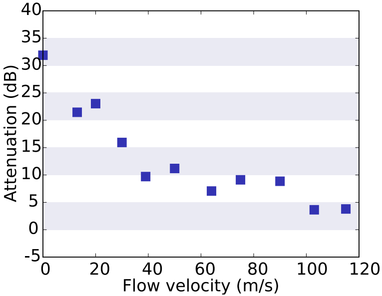


Figure: Tonal noise attenuation due to the control as a function of the flow velocity, for a 2450 Hz pure tone (6 modes).

Motivations

Active noise control of aircraft engine noise: possible or not ?

- Multimodal tonal noise propagating in circular ducts in the presence of a mean flow

Observation

6 modes, $M = 0.3 \Rightarrow$ control system inefficient

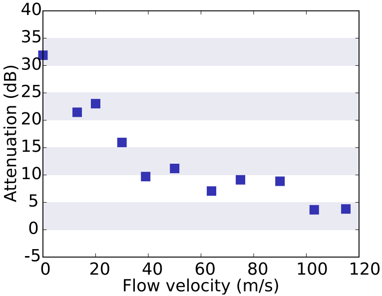


Figure: Tonal noise attenuation due to the control as a function of the flow velocity, for a 2450 Hz pure tone (6 modes).

Motivations
French research project CoMBE (Contrôle et Métrologie du Bruit en Ecoulement)

Laboratoire d'Etudes Aérodynamiques

LAUM

LEA, flow metrology (microphone array, LDA)

LAUM, flow metrology (microphone array)

Motivations

French research project CoMBE (Contrôle et Métrologie du Bruit en Ecoulement)

LEA, flow metrology (microphone array, LDA)

LAUM, flow metrology (microphone array)

LMFA, hybrid passive/active absorbers

ONERA, active control of the acoustic intensity

LMA, active control

Motivations

French research project CoMBE (Contrôle et Métrologie du Bruit en Ecoulement)

LEA, flow metrology (microphone array, LDA)

LAUM, flow metrology (microphone array)

LMFA, hybrid passive/active absorbers

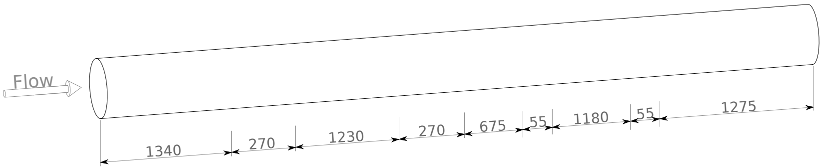
ONERA, active control of the acoustic intensity

LMA, active control

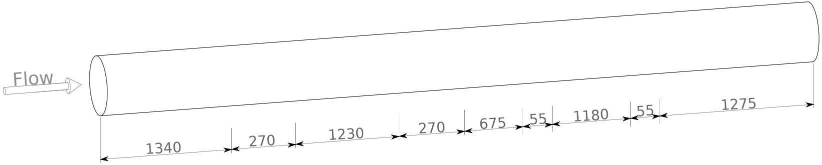
FNRAE, funding

Plan

Materials and methods
Setup

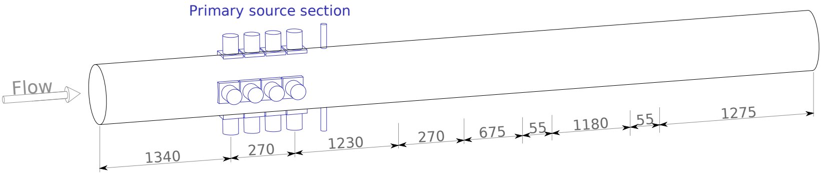


Materials and methods
Setup



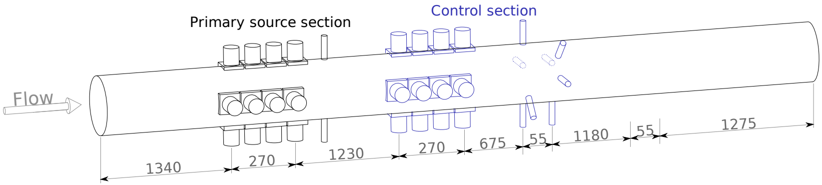
- $0 < u < 100$ m/s
- $0 < M < 0.3$
- Duct: 10 mm-thick, diameter of 176 mm

Materials and methods
Setup



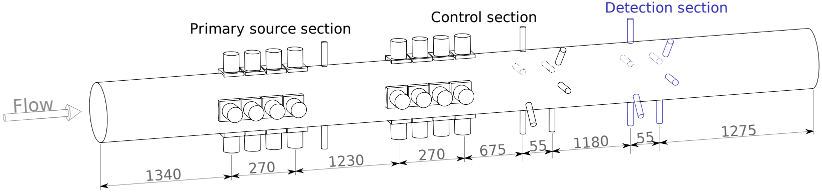
- $0 < u < 100$ m/s
- $0 < M < 0.3$
- Duct: 10 mm-thick, diameter of 176 mm

Materials and methods
Setup



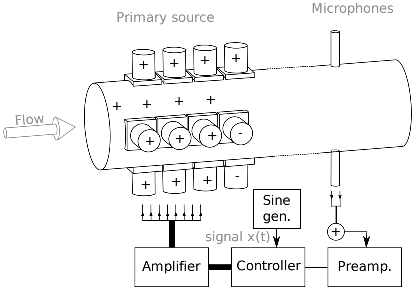
- $0 < u < 100$ m/s
- $0 < M < 0.3$
- Duct: 10 mm-thick, diameter of 176 mm

Materials and methods
Setup



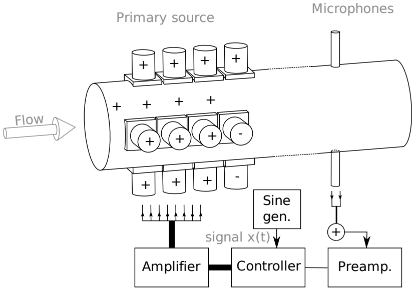
- $0 < u < 100$ m/s
- $0 < M < 0.3$
- Duct: 10 mm-thick, diameter of 176 mm

Materials and methods
Primary source



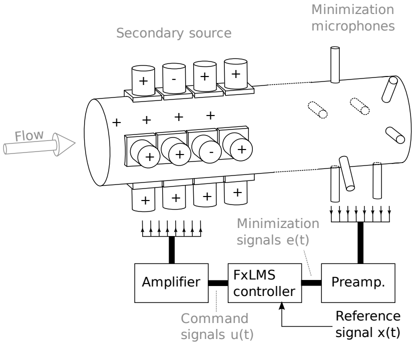
Materials and methods

Primary source

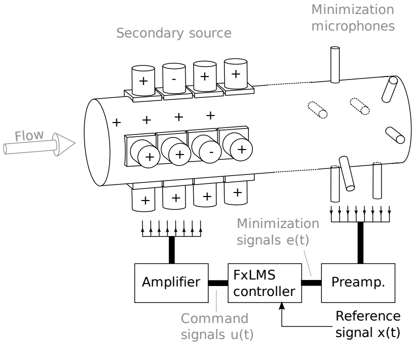


- 125 dB at 800 Hz
- 105 dB at 2450 Hz

Materials and methods
Control section



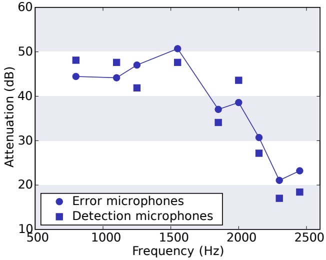
Materials and methods
Control section



- $\mathbf{W}(n+1) = \mathbf{W}(n) - \beta\,[\mathbf{H} * x(n)]^T\,\mathbf{e}(n)$

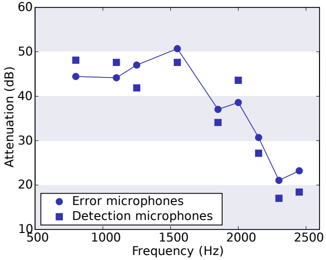
Plan

No flow, multimodal



⟵ Control under no-flow conditions at various primary source excitation frequencies

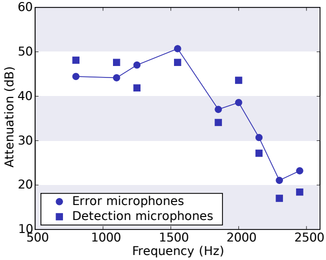
No flow, multimodal



⟵ Control under no-flow conditions at various primary source excitation frequencies

- Up to $f = 1500 Hz$: optimal performances

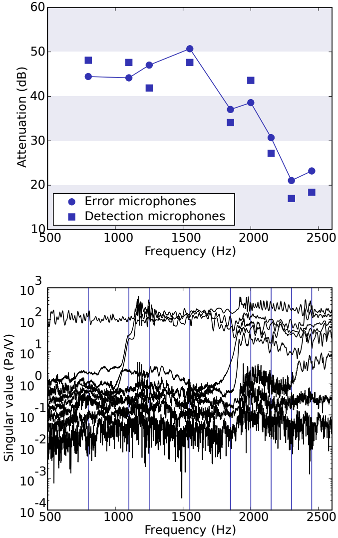
No flow, multimodal



$\longleftarrow$ Control under no-flow conditions at various primary source excitation frequencies

- Up to $f = 1500Hz$: optimal performances
- From $f = 1500Hz$: decrease of the performances

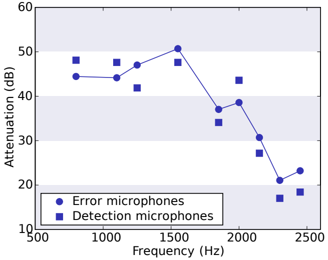
No flow, multimodal

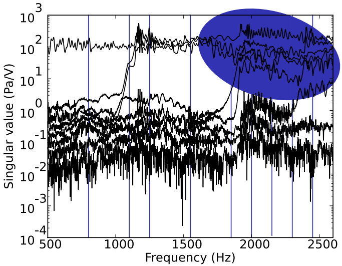


⟵ Control under no-flow conditions at various primary source excitation frequencies

- Up to $f = 1500Hz$: optimal performances
- From $f = 1500Hz$: decrease of the performances

No flow, multimodal





$\longleftarrow$ Control under no-flow conditions at various primary source excitation frequencies

- Up to $f = 1500Hz$: optimal performances
- From $f = 1500Hz$: decrease of the performances

Limiting factor

The poor conditioning of the secondary transfer matrix is responsible for the decrease in the ANC performances

No flow, multimodal

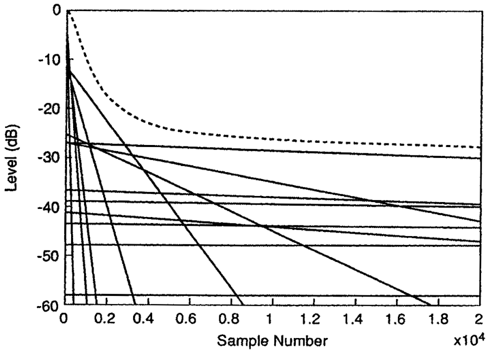
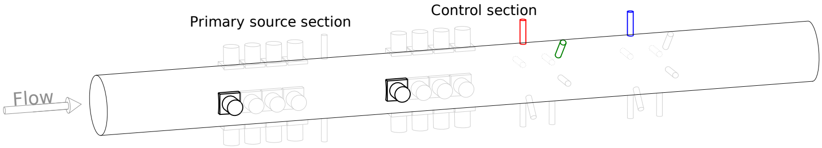
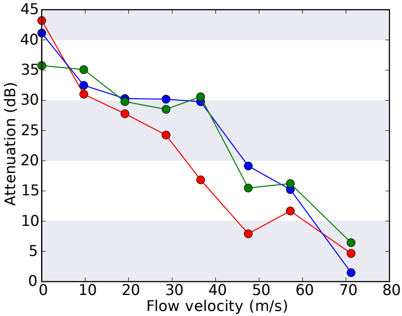


Figure: The convergence of the sum of squared error signals, normalised by the sum of squared primary disturbances, together with the individual 'modes' of convergence, for a steepest descent control system operating with 16 loudspeakers and 32 microphones in a small enclosure (after Elliott et al. 1992)

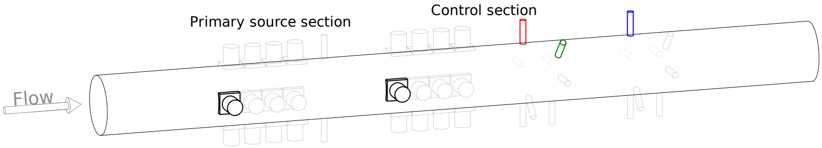
In flow, planar mode

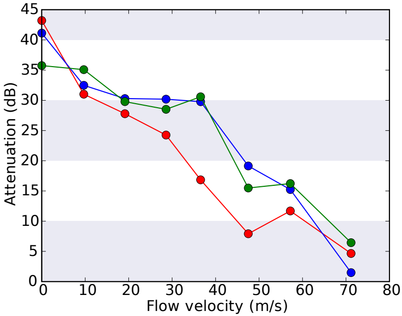




⟵ Single-channel control of 800 Hz tonal disturbances

In flow, planar mode

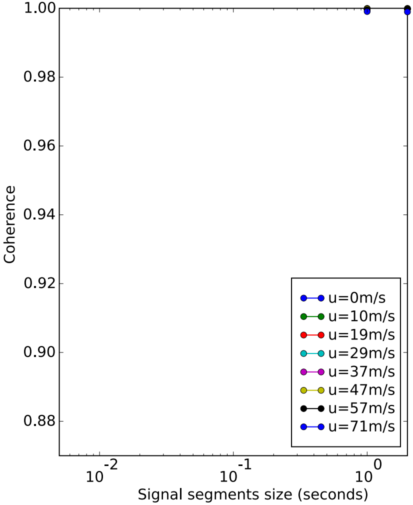




⟵ Single-channel control of 800 Hz tonal disturbances

- Decrease of the control performances in presence of flow

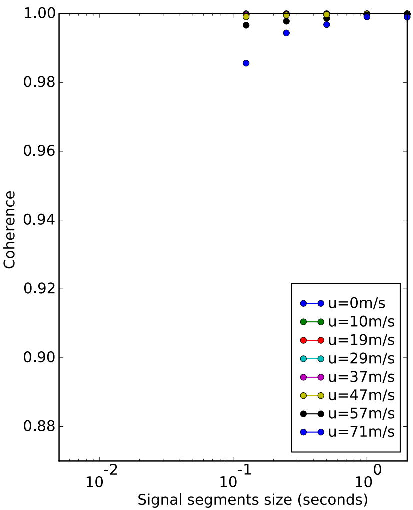
In flow, planar mode



$\longleftarrow$ Coherence between the reference signal and the signal detected by an error sensor

$$\gamma_{ex}(\omega_0) = \frac{\left| \left\{ \overline{E_m(\omega_0)} X_m(\omega_0) \right\}_m \right|^2}{\left\{ |E_m(\omega_0)|^2 \right\}_m \cdot \left\{ |X_m(\omega_0)|^2 \right\}_m}$$

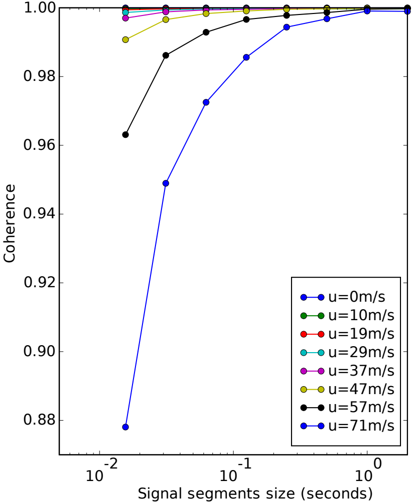
In flow, planar mode



$\longleftarrow$ Coherence between the reference signal and the signal detected by an error sensor

$$\gamma_{ex}(\omega_0) = \frac{\left|\left\{\overline{E_m(\omega_0)}X_m(\omega_0)\right\}_m\right|^2}{\left\{|E_m(\omega_0)|^2\right\}_m \cdot \left\{|X_m(\omega_0)|^2\right\}_m}$$

In flow, planar mode

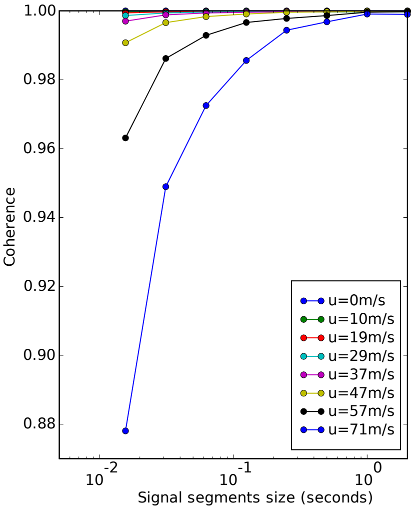


$\longleftarrow$ Coherence between the reference signal and the signal detected by an error sensor

$$\gamma_{ex}(\omega_0) = \frac{\left|\left\{\overline{E_m(\omega_0)}X_m(\omega_0)\right\}_m\right|^2}{\left\{|E_m(\omega_0)|^2\right\}_m \cdot \left\{|X_m(\omega_0)|^2\right\}_m}$$

- Short time scales: decrease of the coherence

In flow, planar mode



⟵ Coherence between the reference signal and the signal detected by an error sensor

$$\gamma_{ex}(\omega_0) = \frac{\left|\left\{\overline{E_m(\omega_0)}X_m(\omega_0)\right\}_m\right|^2}{\left\{|E_m(\omega_0)|^2\right\}_m \cdot \left\{|X_m(\omega_0)|^2\right\}_m}$$

- Short time scales: decrease of the coherence

Limiting factor

Short term instabilities reduce the control efficiency

Plan

Conclusion

- Before the study: disappointing control results obtained in reduced scale turbine

Conclusion

- Before the study: disappointing control results obtained in reduced scale turbine
- After the study: two limiting factors are identified
  - Secondary transfer matrix conditioning
  - Short term instabilities due to the turbulence

Conclusion

- Before the study: disappointing control results obtained in reduced scale turbine
- After the study: two limiting factors are identified
  - Secondary transfer matrix conditioning
  - Short term instabilities due to the turbulence

Future work

- Resolve conditioning problems by using diagonalized control algorithm
- Combine flow metrology with simple noise control models in order to reach a better understanding of the performances limitations due to the flow

Active control of multimodal tonal noise propagated in circular duct with axial subsonic mean flow up to M=0.3

M. Glesser, E. Friot, M. Winninger, C. Pinhède
A. Roure

LMA, CNRS UPR-7051, France
glesser@lma.cnrs-mrs.fr

Acoustics 2008,
Paris