Joint AES Swiss section / SSA meeting

Electroacoustic absorbers

low frequency absorption by hybrid sensor/shunt-based impedance control

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WARNING:
all sounds in this slideshow should be listened to with a subwoofer or (good) headphones.

Outline

- Context: room modes in the low-frequency range
- Presentation of the Electroacoustic Absorber prototype
- Design Methodology for room modal damping
- Experimental assessment: modal damping in rooms

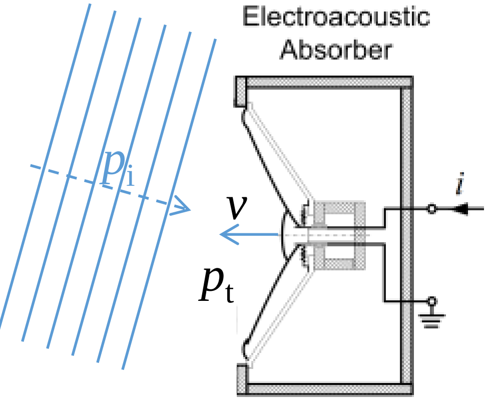
ELECTROACOUSTIC ABSORBERS PRESENTATION

Electroacoustic absorbers

- Development of an active sound absorption solution with α>0.83 along the range [20 - 200Hz]
- Based on actuated membranes (loudspeakers) used as a membrane absorbers
- Evaluation in reverberant conditions, focusing on low-frequency sound «equalization»

H. Lissek, R. Boulandet, and R. Fleury, "Electroacoustic absorbers: bridging the gap between shunt loudspeakers and active sound absorption", J. Acoust. Soc. Am., 129(5), 2968-2978, (2011).

Electroacoustic absorbers



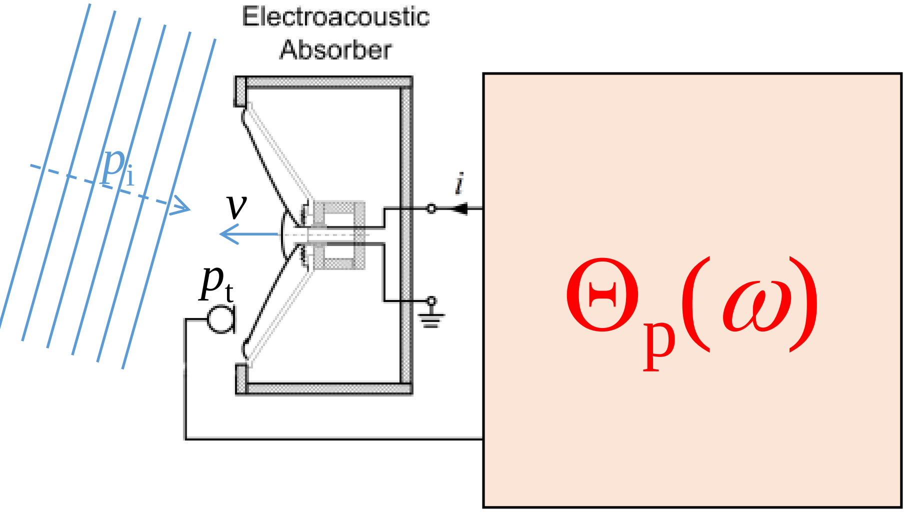
$$\begin{cases} S_d p_t = Z_m(\omega) v + Bl\,i \\ \text{with } Z_m(\omega) = R_{ms} + j\omega M_{ms} + \dfrac{1}{C_{ms}} + \dfrac{\rho c^2 S_d^2}{V_b} \end{cases}$$

Parameter	Description	Value	Unit
M_{ms}	Moving mass	14.7	g
R_{ms}	Mechanical resistance	1.31	$N.s.m^{-1}$
C_{ms}	Mechanical compliance	242.3	$mm.N^{-1}$
S_d	Membrane surface	151	cm^2
Bl	Force factor	6.85	$N.A^{-1}$
V_b	Cabinet volume	10	dm^3
ρ	Air mass density	1.2	kg/m^3
c	Sound celerity in air	344	$m.s^{-1}$

Electroacoustic absorbers

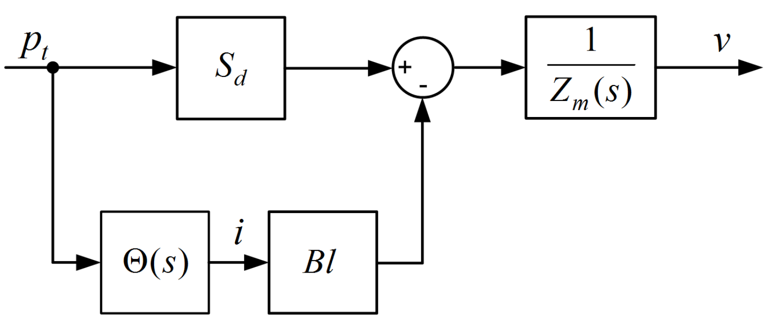
Objective:

force the membrane to behave as a given acoustic impedance $\mathbf{Z_{at}}$



$$\begin{cases} S_d\, p_t = Z_m(\omega) v + Bl\,\Theta_p(\omega)\, p_t \\ Z_a(\omega) = \dfrac{p_t}{v} = \dfrac{Z_m}{S_d - Bl\,\Theta_p(\omega)} \end{cases}$$

Effective acoustic impedance of the membrane



The desired acoustic impedance Z_{at} can be assigned by identifying the controller transfer function:

$$\Theta_p(\omega) = \frac{S_d Z_{at} - Z_m(\omega)}{Bl.Z_{at}}$$

EXPERIMENTAL VALIDATION OF ROOM MODES DAMPING

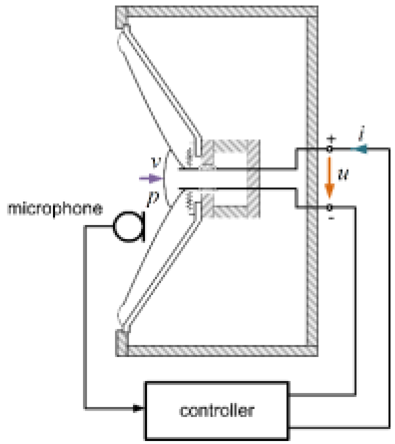
Experimental assessment

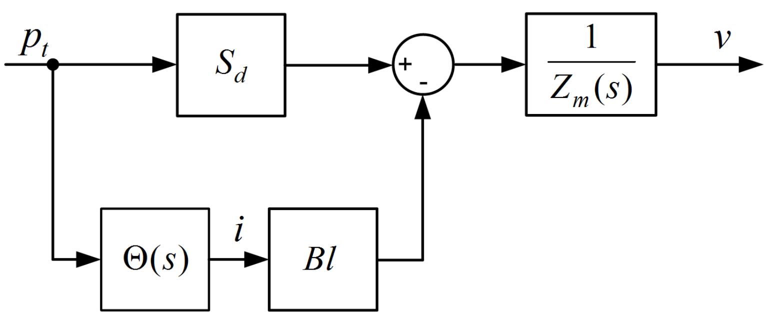
- 4x4 electroacoustic absorbers prototypes

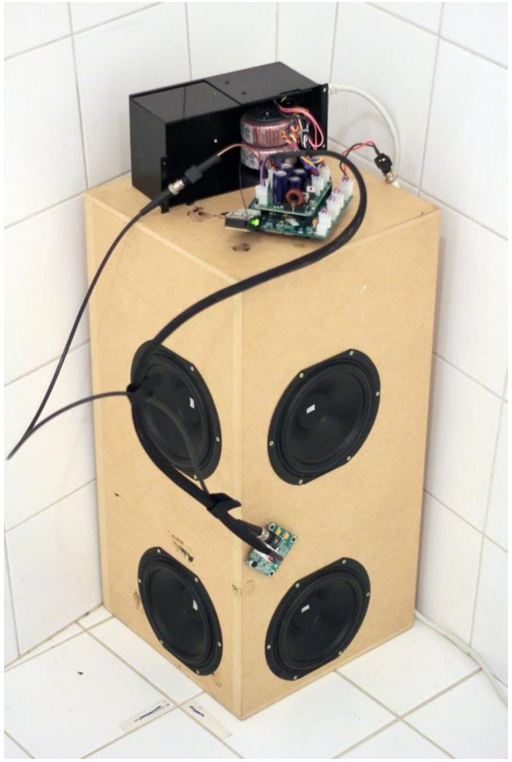
(total surface = 16x151 cm^2 = 0.24 m^2)

- In a reverberant chamber of 226.9 m^2

➔ evaluation of room modal damping







Experimental assessment

1. Frequency response without and with absorbers
   - → identify individual room modes
   - → assess damping performance on peaks and dips amplitudes

2. Modal decay times without and with absorbers
   - → assess damping performance in the time domain

3. Recording of music rendering, without and with absorbers
   - → listen to the effect on music rendering

4. Recording of kick drum, without and with absorbers
   - → listen to the effect on acoustic music playing

Experimental setup

Hardware

- **Recorders/analyzers**
  - B&K Pulse (frequency responses)
    - frequency resolution: 31.5 mHz
  - M-Audio M-Track 8 soundcard (recordings)
- **Microphones**

PCB 130D20
(frequency responses)

Beyerdynamic M101 N
(recordings)

- **Sources** Subwoofer

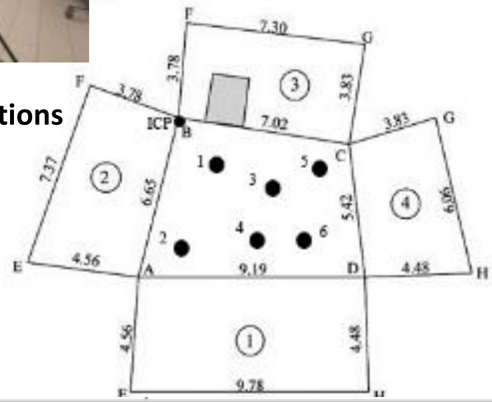
Kick drum
(Pearl Export)

Facility (reverberant chamber, V=215.6 m^3, S=226.9 m^2)

4 electroacoustic absorbers at the 4 room corners

Supplementary panel absorber

7 microphone positions

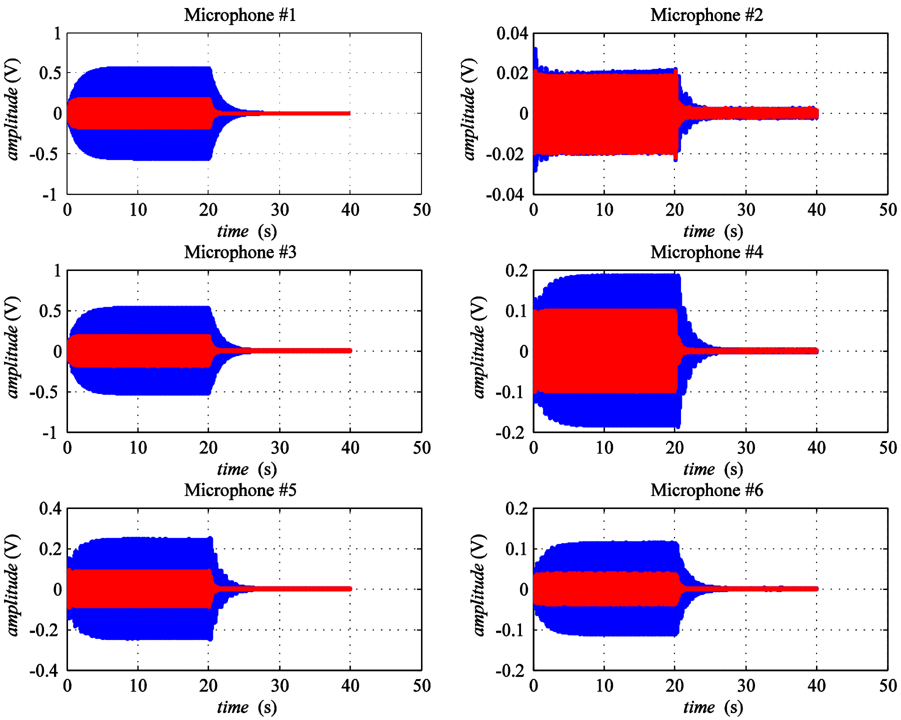


Id	height m	Distance to corner A m	Distance to corner B m	Distance to corner C m	Distance to corner D m
ICP	0.83	-	0	-	-
Micro 1	1.83	4.89	3.35	-	-
Micro 2	2.79	2.07	5.55	-	-
Micro 3	1.81	6.40	4.90	-	-
Micro 4	2.20	-	4.17	3.31	-
Micro 5	1.22	-	-	1.62	5.00
Micro 6	1.49	-	-	4.00	2.84

2. Modal decay time

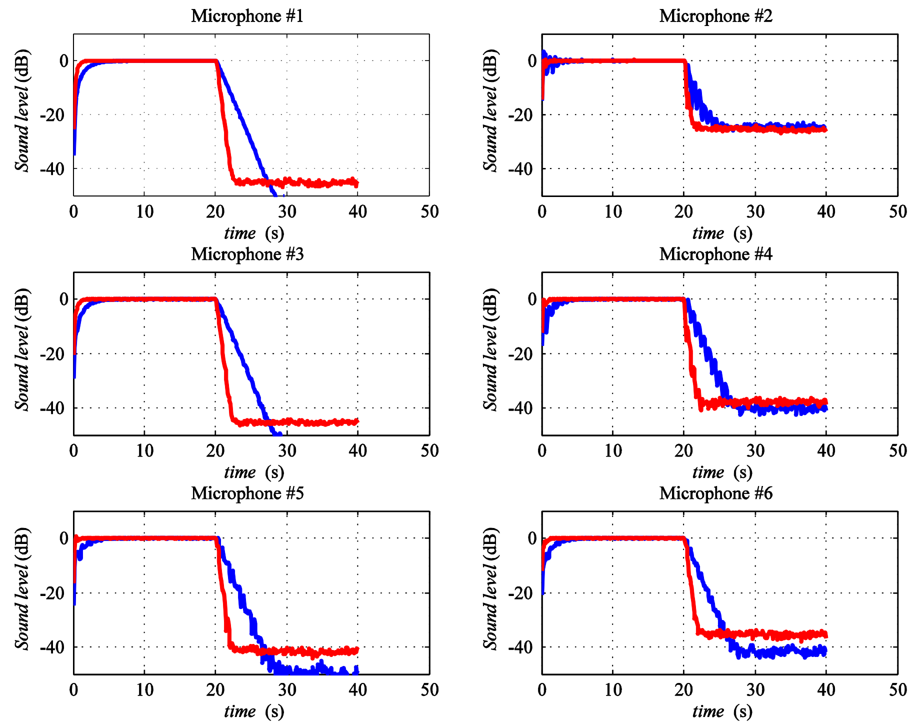
Mode 8 – waveforms

(hardwalls : 52.78 Hz - absorbers : 52.72 Hz)

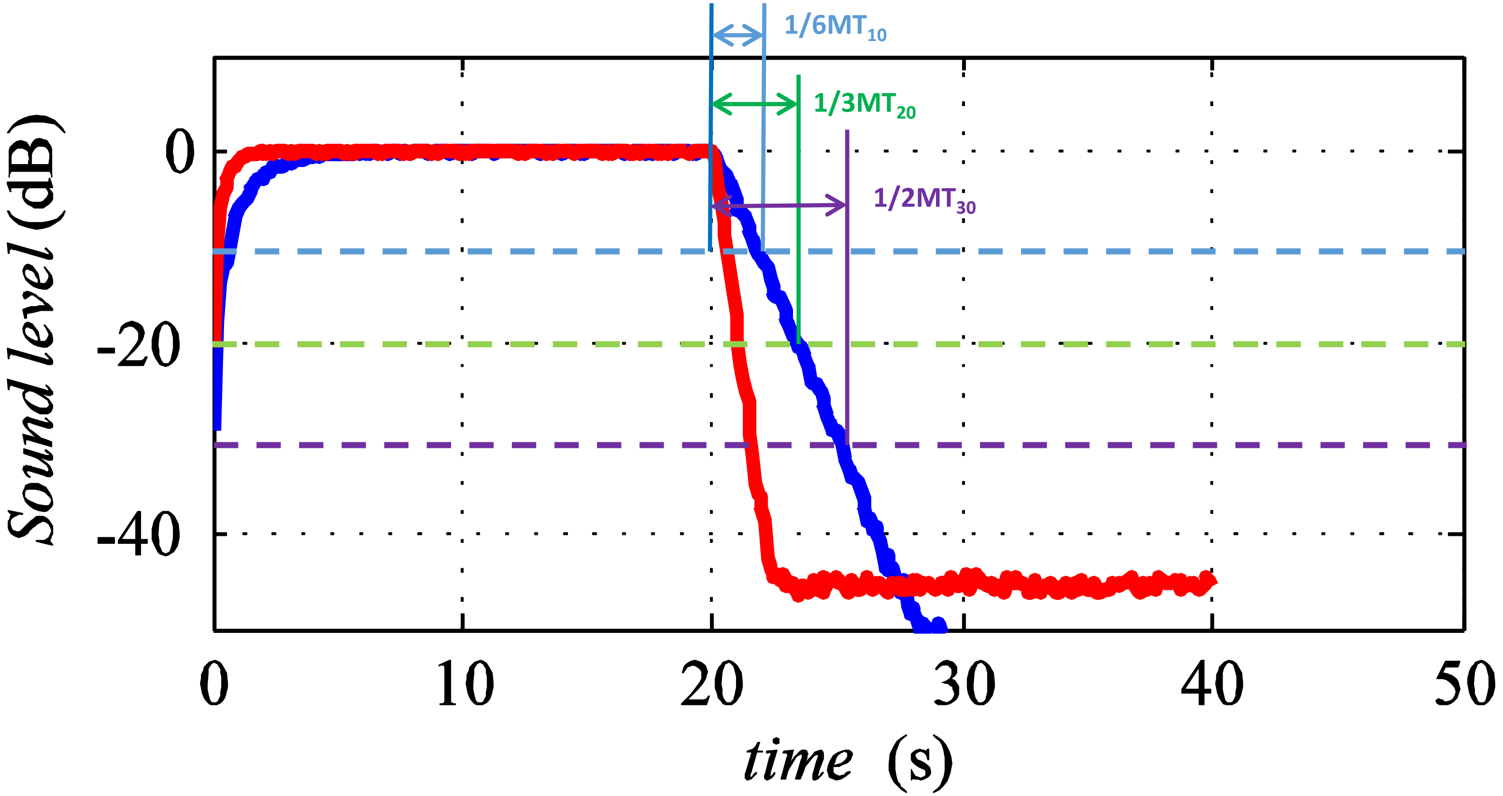


Mode 8 - echograms

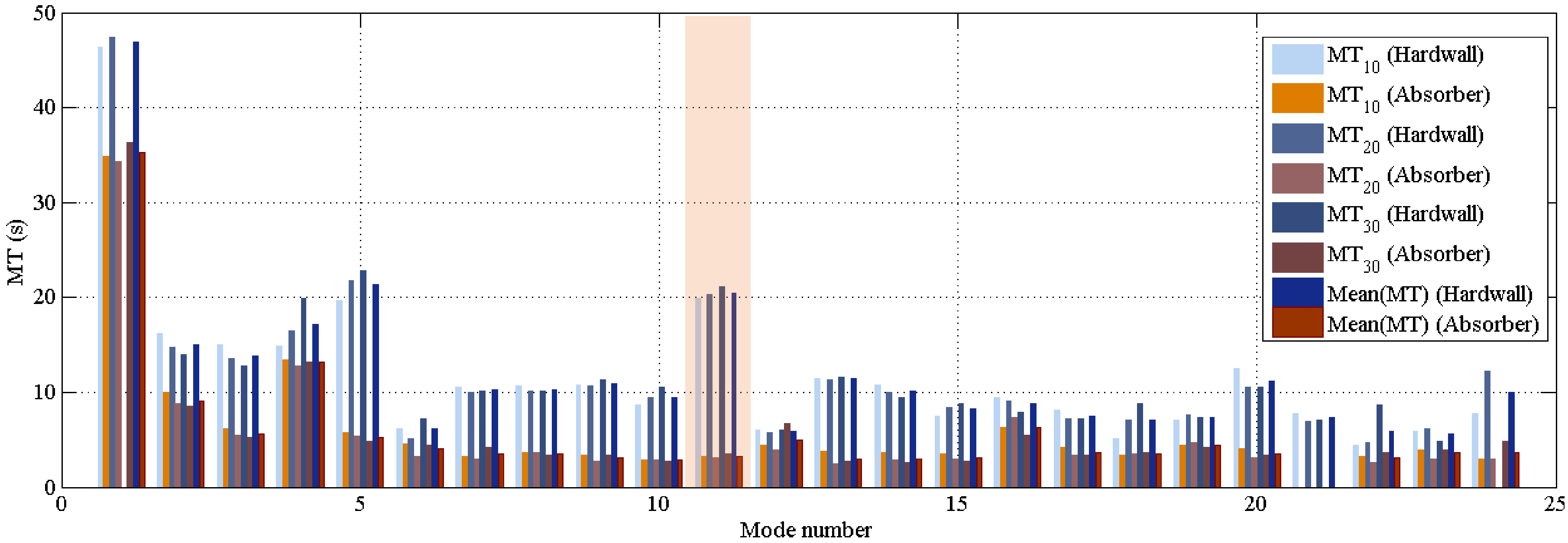
(hardwalls : 52.78 Hz - absorbers : 52.72 Hz)



2. Modal decay time



2. Modal decay time



Conclusions

- 4 electroacoustic absorbers prototypes achieve efficient room mode damping in the reverberant chamber
  - Max damping: 12.2 dB @ 58 Hz,
  - Global damping: 8 dB over [20 – 100 Hz],
  - Max modal decay time reduction: 85% @ 58 Hz
    (from 20 s down to 3 s),

for a total absorber surface representing only 0.1% of the whole room walls surface

Conclusions

Most recent results (August 2015)