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Study of an Electroacoustic Absorber

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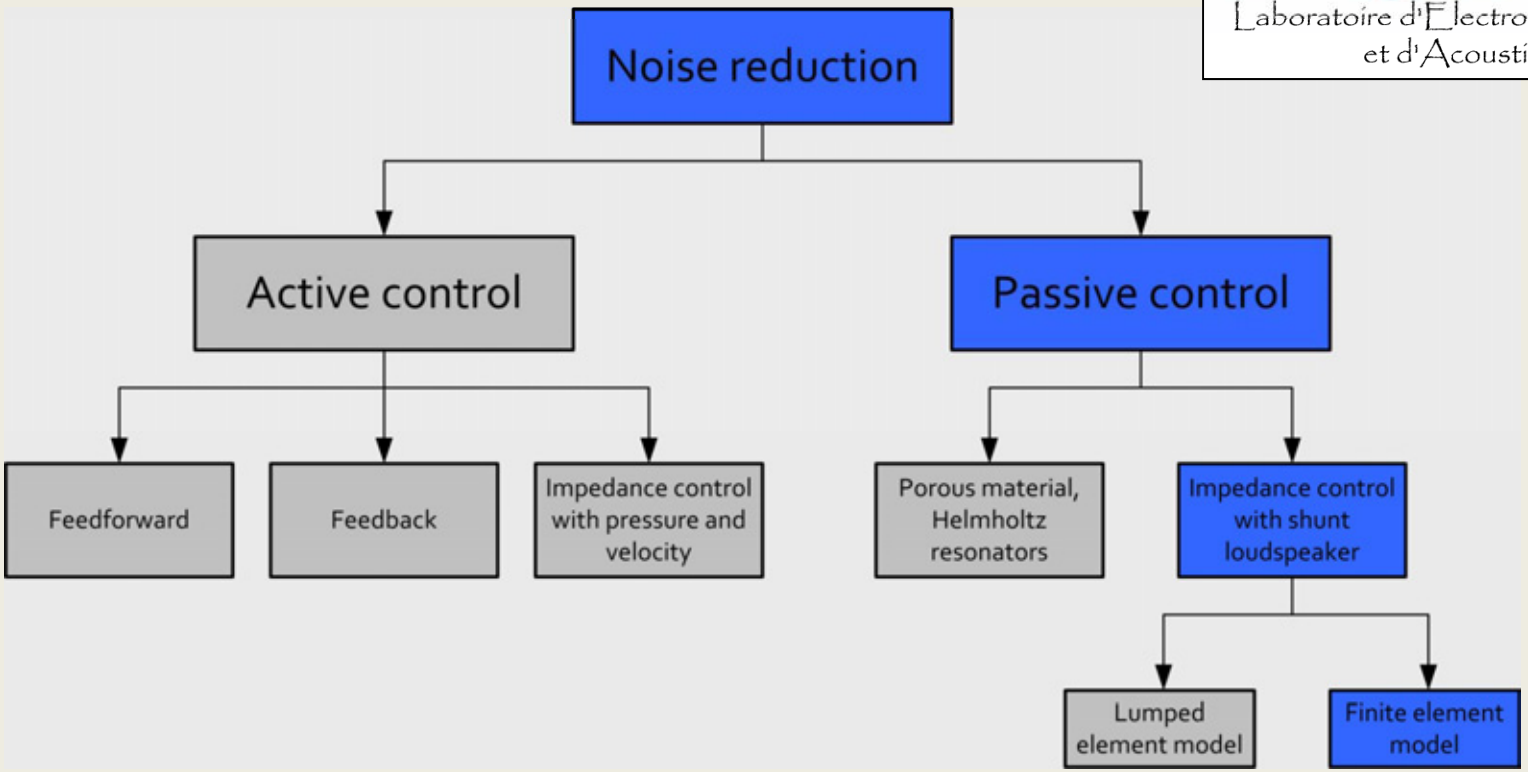
Introduction

Laboratory of Electromagnetism and Acoustics



Layout of the presentation

- System dynamics modeling
  - Electroacoustic absorber dynamics
  - Acoustic waveguide
- Numerical model
  - Loudspeaker structural properties
  - Acoustic performances assessment
- Results
  - Loudspeaker characteristics
  - Acoustic performances
- Conclusion

System dynamics modeling

Electroacoustic absorber dynamics

- Electrical part
  - R_e (Ω), electrical resistance
  - L_e (H), electrical inductance

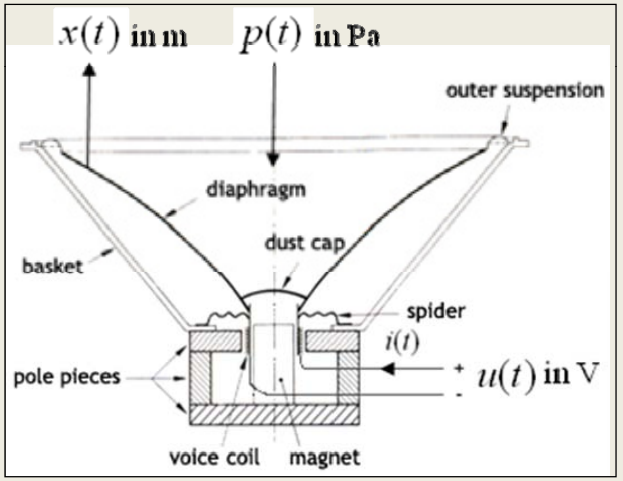
  } Z_e blocked electrical impedance
- Mechanical part
  - R_{ms} (N.s.m^{-1}), mechanical resistance
  - M_{ms} (kg), moving mass
  - C_{ms} (m.N^{-1}), mechanical compliance

  } Z_m free mechanical impedance
- Acoustic part
  - M_{ar} (kg.m^{-4}), acoustic mass of radiation
  - R_{ar} (Ω.m^{-4}), acoustic resistance

  } Z_{ar} acoustic impedance

- + Closed-box environment } Z_{ab} rear acoustic impedance
- + Shunt resistance } Z_{sh} shunt electrical impedance

- Coupling factors
  - S_d (m²), diaphragm area
  - Bl (N.A^{-1}), force factor



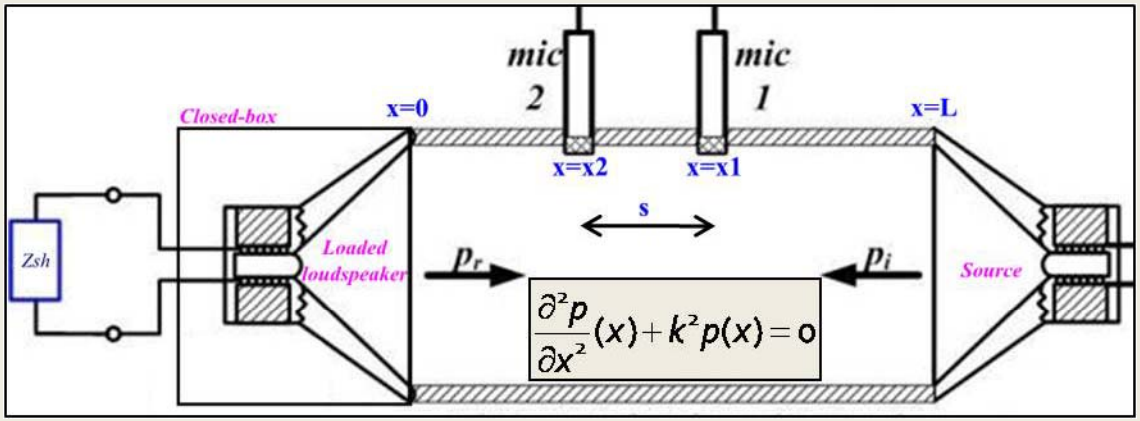
Absorber characteristic equations

$$\begin{cases} (Bl)\underline{I} - S_d \underline{p} = (\underline{Z}_m + S_d^2 \underline{Z}_{ab})\underline{v} \\ 0 = \underline{Z}_e \underline{I} + (Bl)\underline{v} + \underline{Z}_{sh}\underline{I} \end{cases}$$

Acoustic waveguide

Absorber

$$\frac{\partial p}{\partial x}(0) + j\beta_0 kp(0) = 0$$



Source

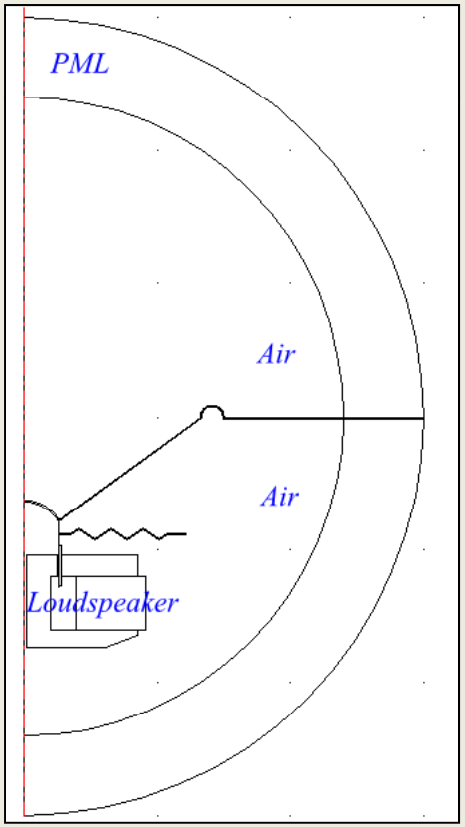
$$p(L) = p_L$$

$$p(x) = p_L \frac{(\beta_0 + 1)e^{-jkx} - (\beta_0 - 1)e^{jkx}}{(\beta_0 + 1)e^{-jkL} - (\beta_0 - 1)e^{jkL}} \qquad x \in]0, L[$$

- Positions of the microphones : s and x_1 → $\Delta f_{measure}$ = [38 Hz; 343 Hz]
- Hypothesis :
  - Plane wave if f < 1326 Hz
  - Negligible attenuation because α = 0.0075 at 400 Hz *(ISO 10534-2 standard)*

Numerical model

- Loudspeaker structural properties



- Geometric parameters
  - a (m) diaphragm's radius

  → $S_d = \pi a^2$ mechano-acoustic coupling factor
- Electromagnetic parameters
  - B_o (T) remanent flux density in magnet
  - N number of turns in coil
  - R_e (Ω) electrical resistance

  → $Bl = N B_o 2\pi r_{coil}$ electro-mechanical coupling factor
- Mechanical parameters
  - E (Pa) Young's modulus
  - ν Poisson's ratio
  - ρ (kg.m^{-3}) density
  - ζ damping

  → $|Z_{hp}(\omega)|$ (Ω) and f_s (Hz)

Acoustic performances assessment

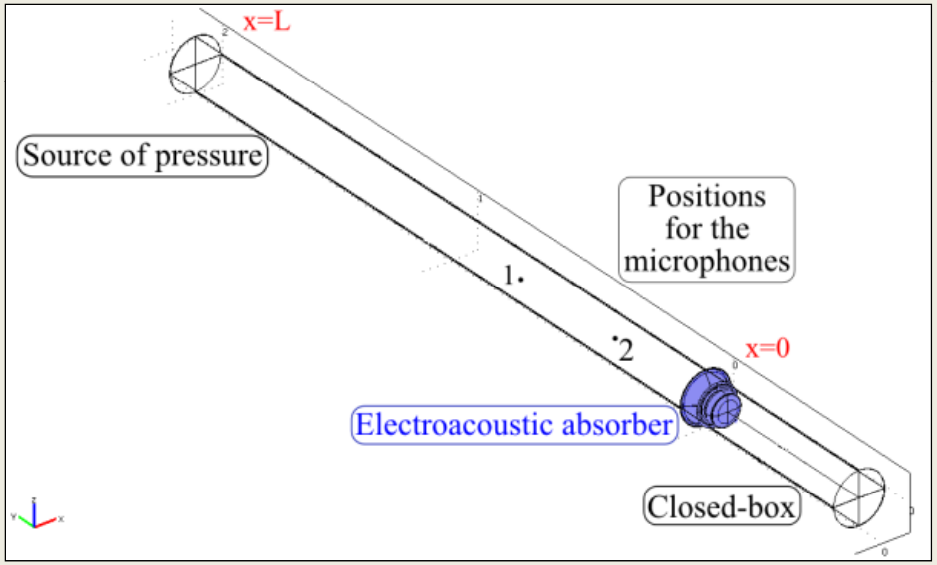
- Electroacoustic absorber

$$\begin{cases} I = \dfrac{V_{sh} - Blv}{Z_e} \\ V_{sh} = \dfrac{R_{sh}}{R_{sh} + Z_e} Blv \end{cases}$$

- Source of pressure

  $p_L = 1\ Pa$

- Impedance tube and closed-box
  - Sound hard walls
  - Filled with air ($\rho_o = 1.25\ kg.m^{-3}$ and $c_o = 343\ m.s^{-1}$)



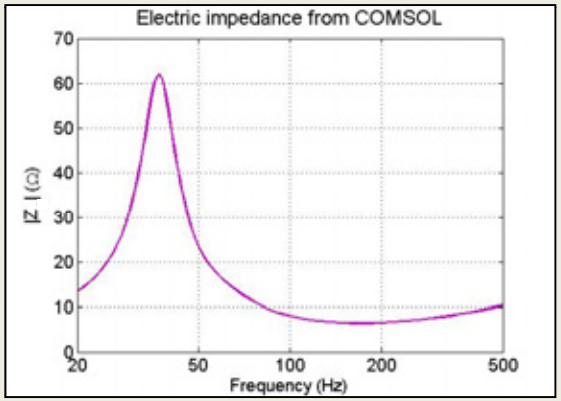
- ISO 10534-2 standard :

  Pressure of microphones 1 and 2 → H_{12} → $r = \dfrac{H_{12} - e^{-iks}}{e^{iks} - H_{12}} e^{2ikx_1}$ → $\begin{cases} \alpha = 1 - |r|^2 \\ Z_s \end{cases}$

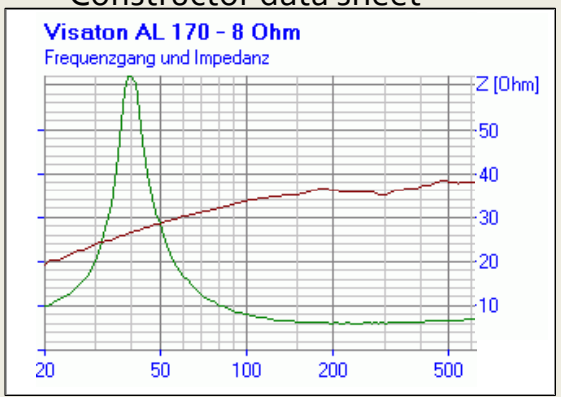
Results

Loudspeaker characteristics

- Electrical impedance $|Z_{hp}|$
  - From Comsol Multiphysics®



  - Constructor data sheet

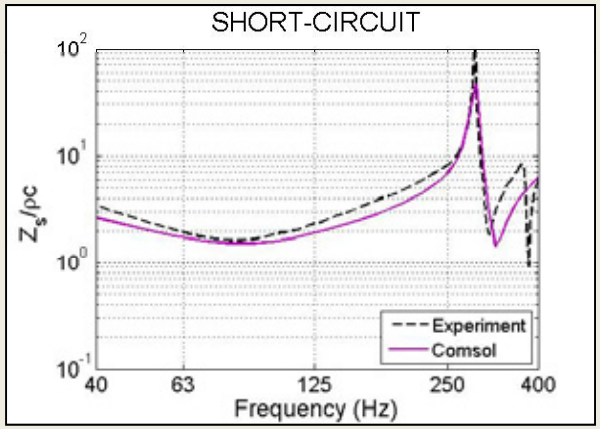


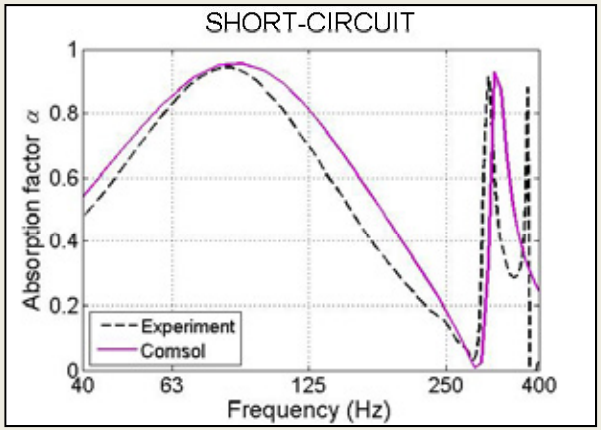
- Thiele and Small parameters

Symbol	Data sheet	Model	Error (%)
a (cm)	7.4	7.5	1
S_d (cm²)	133	137	3
Bl (Tm)	6.9	6.7	3
f_s (Hz)	38	37	3
R_e (W)	5.6	5.6	0
L_e (mH)	0.9	3.2	72
R_{ms} (Ns.m^{-1})	0.8	0.78	3
M_{ms} (kg)	13	12.1	7
C_{ms} (mm.N^{-1})	1.35	1.4	4
V_{as} (L)	34	39	13
Q_{ms}	3.88	3.9	1
Q_{es}	0.43	0.38	13
Q_{ts}	0.39	0.35	11

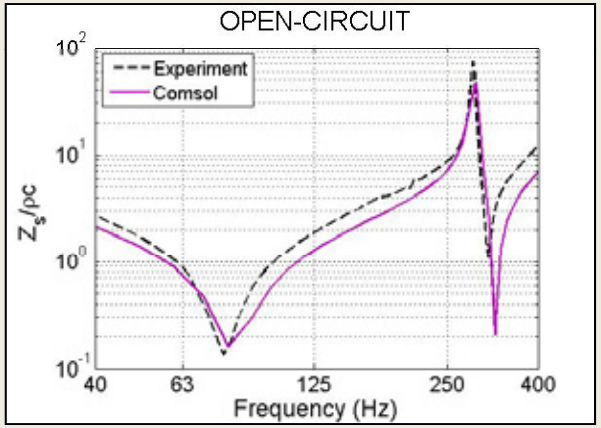
- Acoustic performances (Measurement vs. Comsol)

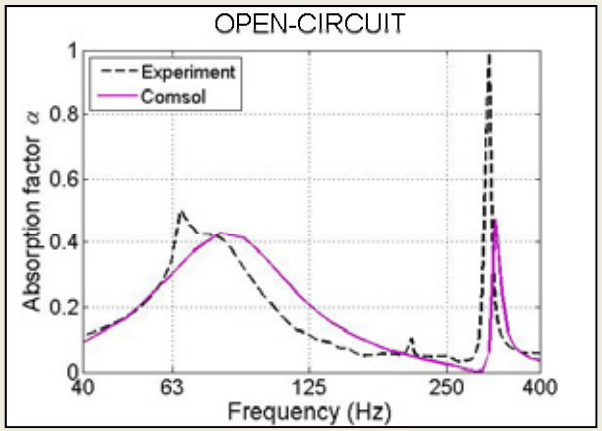
R = o



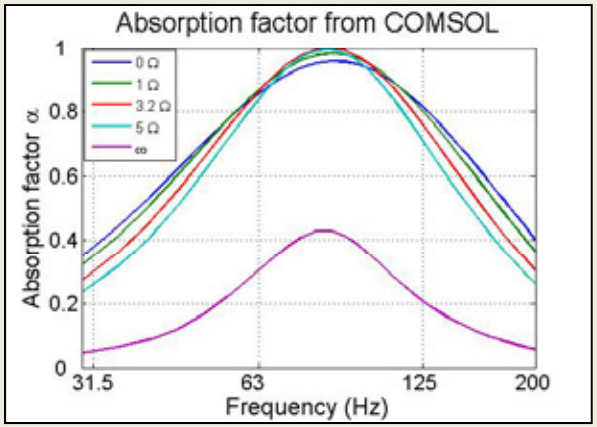


R = ∞





$$R_{sh,opt} = \frac{(Bl)^2}{(\rho c S_d - R_{ms})} - R_e = 3.2\Omega$$



Conclusion

- Enhancement prospect
  - Fittings of some parameters → Cancelation of the shift in frequency
  - Optimization of the parameterization of the software
    - Perfectly Matched Layers
    - Mesh

    } → Improvement of the calculation time
- Good agreement between numerical results and experiments
  - Validation of the finite element model
- Use for improving the design of electroacoustic absorber

Thank you for your attention

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