



HAL
open science

Enhancement of the low frequency performance of thin, film-faced layers of foam by surface segmentation

J. Stuart Bolton, Benoit Nennig, Nicolas Dauchez

► **To cite this version:**

J. Stuart Bolton, Benoit Nennig, Nicolas Dauchez. Enhancement of the low frequency performance of thin, film-faced layers of foam by surface segmentation. SAPEM, Dec 2014, Stockholm, Sweden. , 2014, SAPEM 2014. hal-01559071

HAL Id: hal-01559071

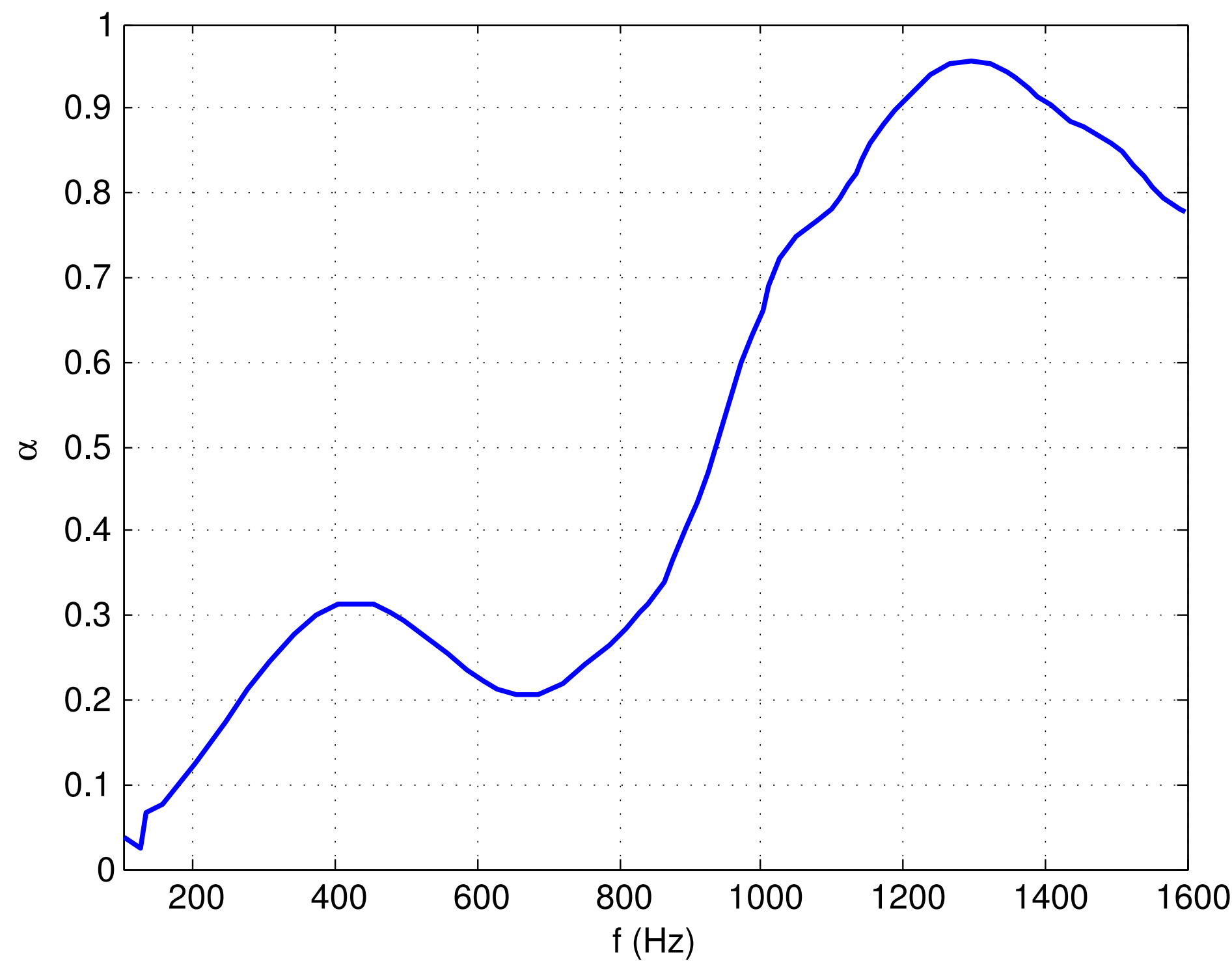
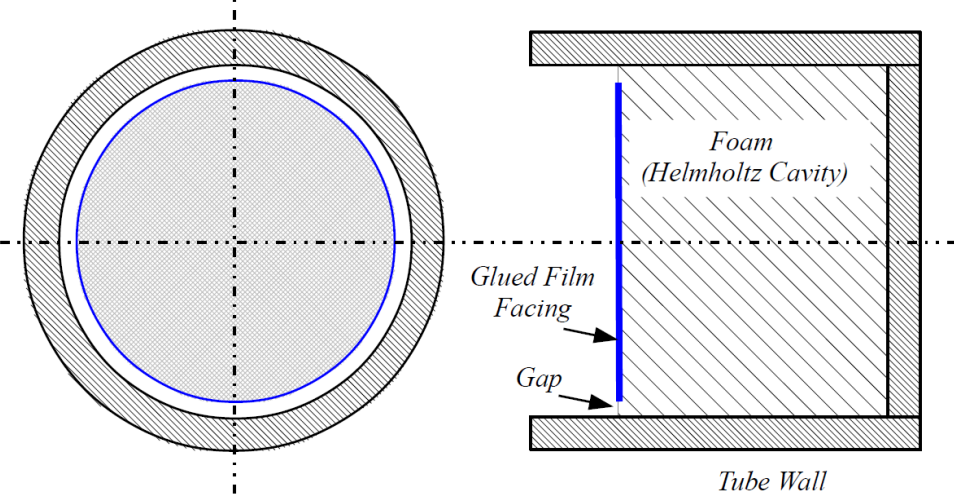
<https://hal.science/hal-01559071>

Submitted on 10 Jul 2017

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Objectives: Understand the absorption of film-faced foam with circumferential air gap



Main results :

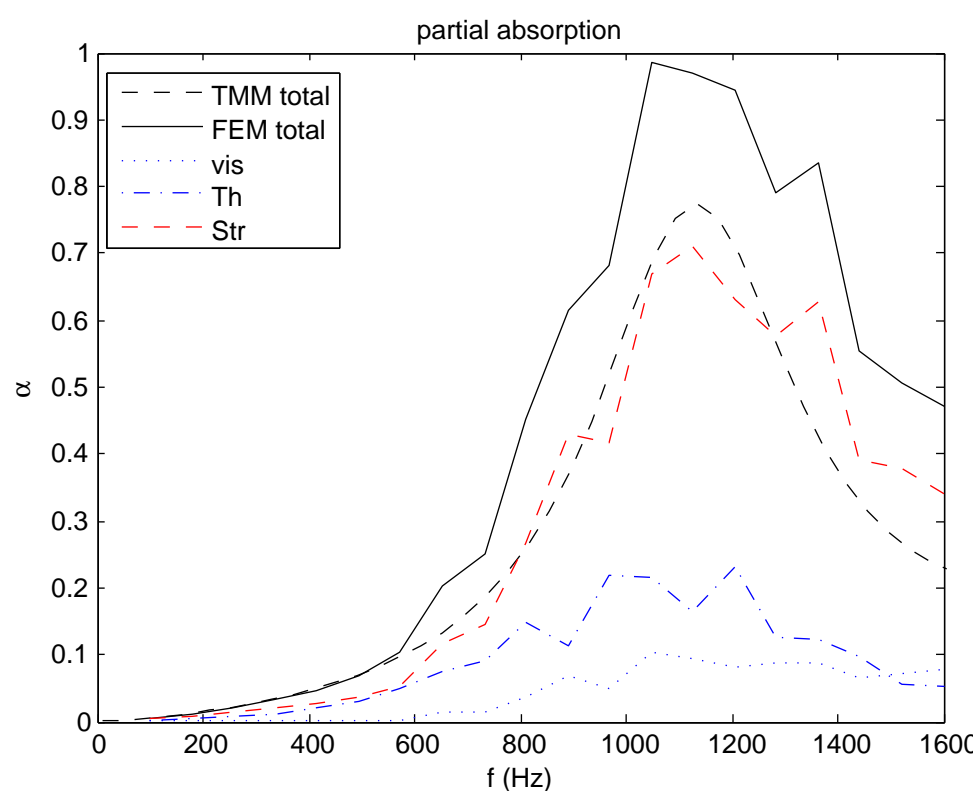
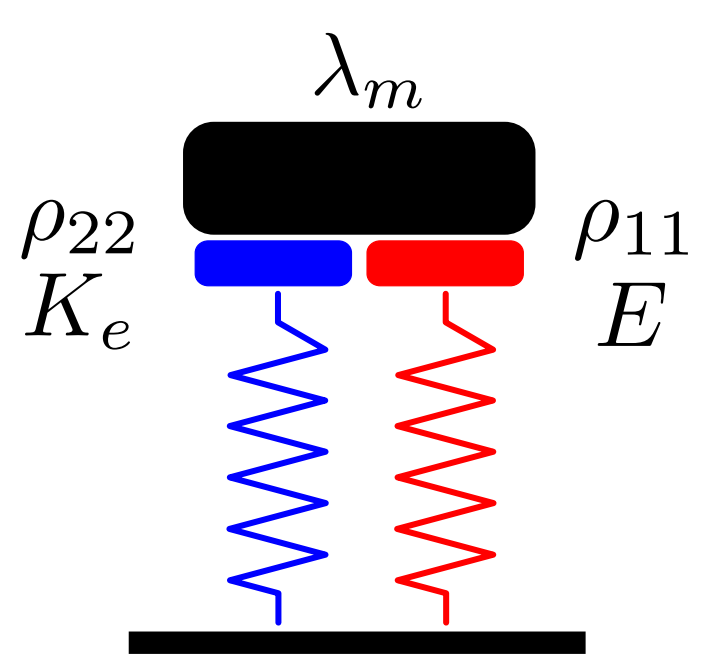
- New peak, at low frequency with viscous dissipation due to Diaphragm-Helmholtz resonator effect [1]
- Very low motion of the membrane around 400 Hz
- Membrane increases the structural dissipation
- Gap enhances also the absorption at higher frequencies when compared with airtight membrane
- Independently tunable membrane and air gap effects

Melamine foam : $E = 50(1 - 0.076i)$ kPa, $\nu = 0.4$, $\sigma = 9000$ Nm-4s, $\phi = 0.995$, $\alpha_\infty = 1.01$, $\Lambda = 64\mu\text{m}$, $\Lambda' = 143\mu\text{m}$. Sample : radius $r = 50$ mm, height $h = 25$ mm, air gap $b = 1$ mm. Membrane density $\lambda_m = 76$ g/m². Measurement B&K impedance tube

Simplified airtight membrane model

Assumptions :

- membrane of surface mass λ_m with no stiffness
- No air leak
- 1D Biot model



An approximation of the mass-spring resonance frequency, can be obtained with Ritz method

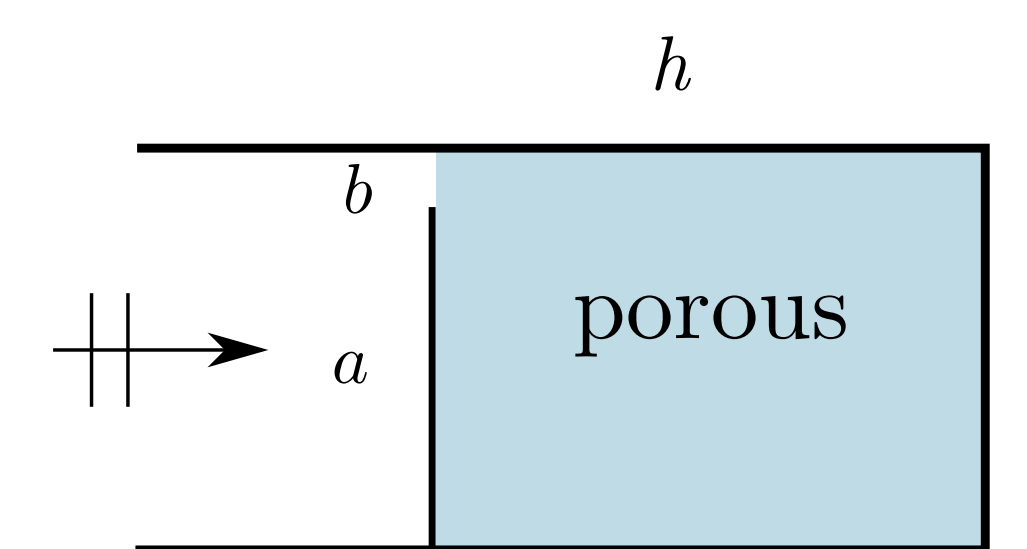
$$f_{mb} \sim \frac{1}{2\pi} \sqrt{\frac{K_{eff}/h}{(\rho_{11} + \rho_{22})h/3 + \lambda_m}} \quad (1)$$

where the effective compressibility of the material $K_{eff} = E + K_e$ is the sum of the stiffness of the fluid phase K_e and the stiffness of the solid phase E . Here, we get $f_{mb} = 930$ Hz.

Simplified Diaphragm model

Assumptions :

- Rigid frame porous material
- Diaphragm (motionless membrane)
- Plane wave regime



The inductance L of a slit of height b in a rectangular duct of height a and of cross section $a \times d$ is given by [2, p. 487]

$$\frac{Ld}{\rho} = -\frac{2}{\pi} \ln \sin \frac{\pi b}{2a}, \quad \text{if } b \ll a. \quad (2)$$

The impedance of the porous layer is $Z_p = -i\rho_p c_p \cot k_p h$ and the impedance of the diaphragm is $Z_d = -i\omega L S$. Assuming the best absorption arises when the imaginary part of $Z = Z_p + Z_d$ vanishes, we get

$$f_d \sim \frac{1}{2\pi} \sqrt{\frac{K_e}{VL}}, \quad (3)$$

where $V = Sh$ porous material layer volume. This stiffness is the same as for the Helmholtz resonator.

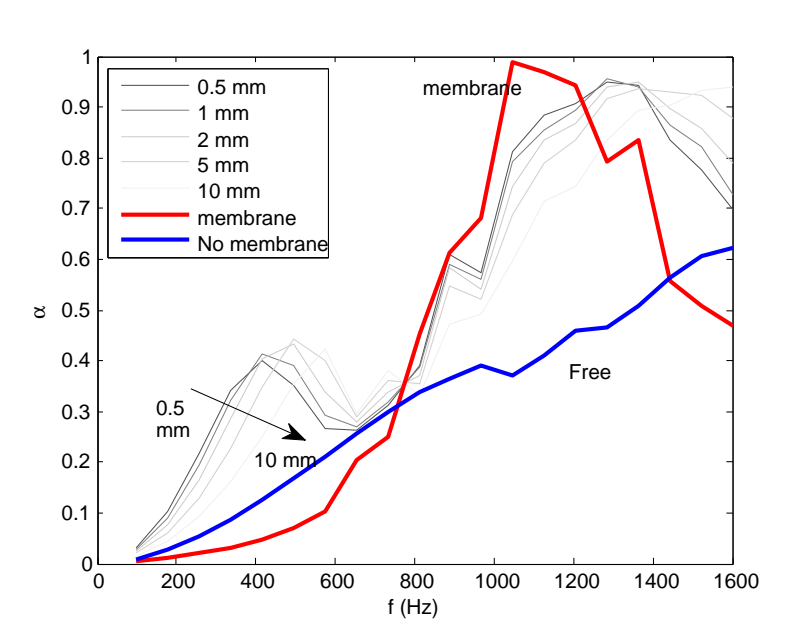
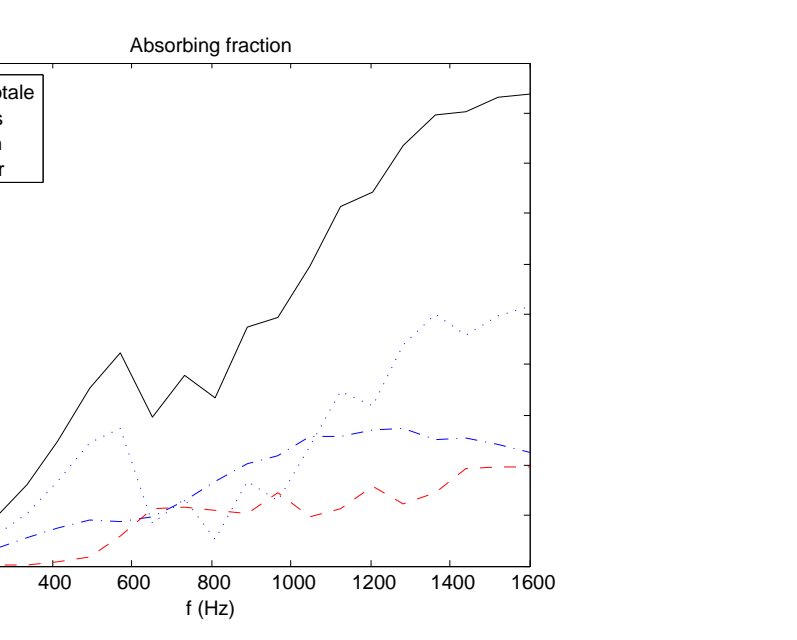
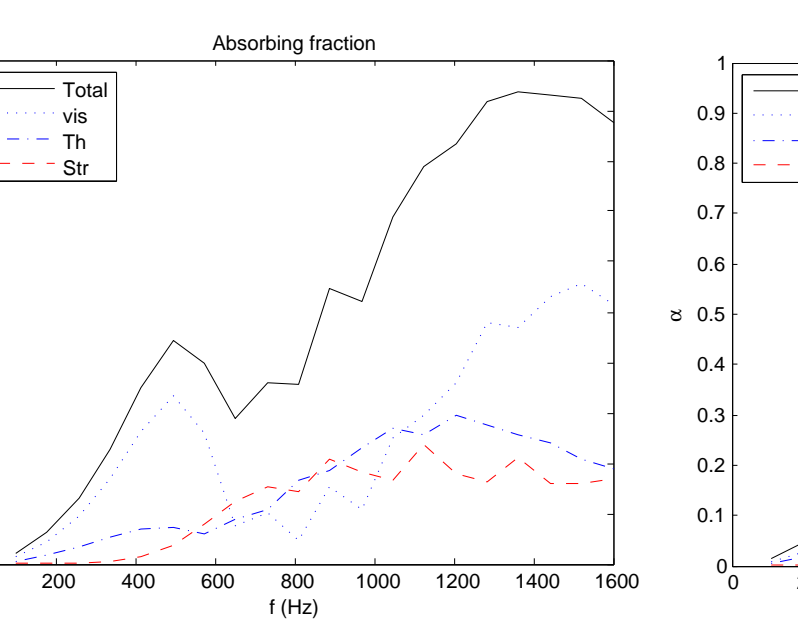
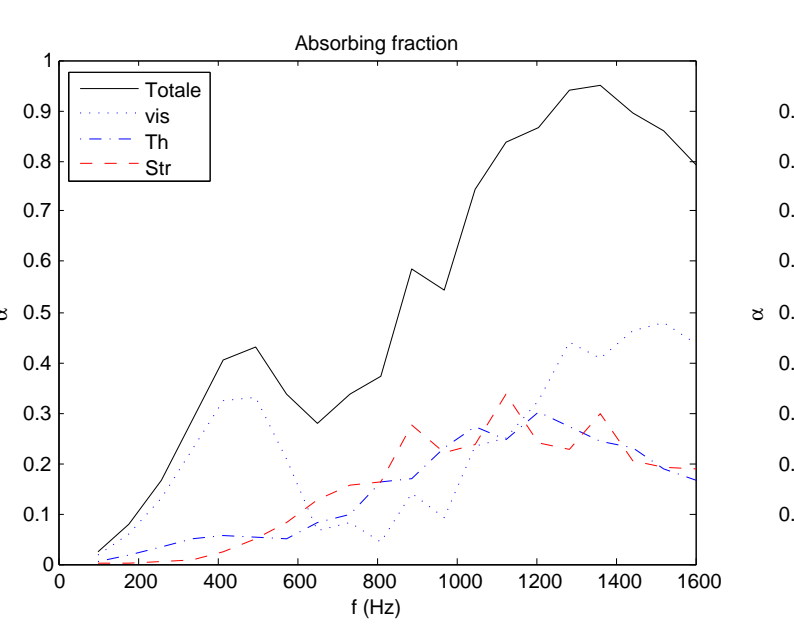
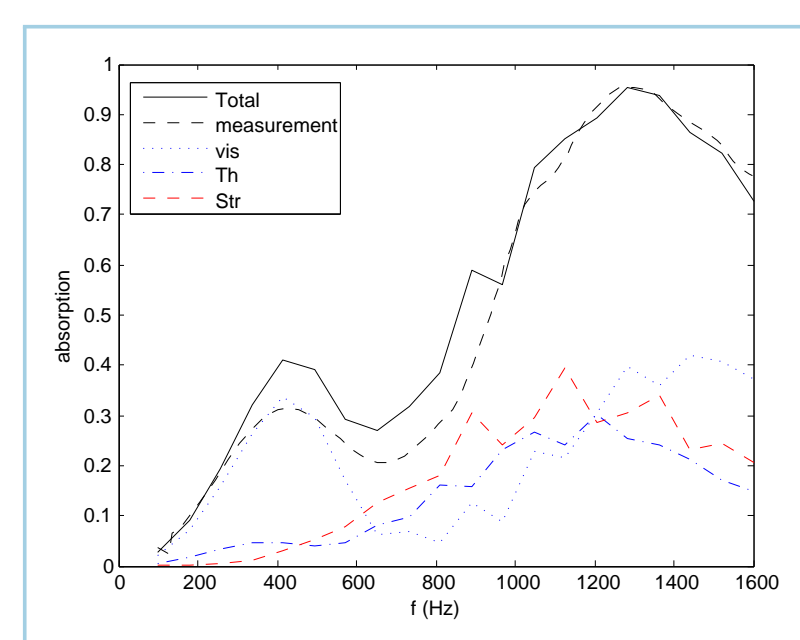
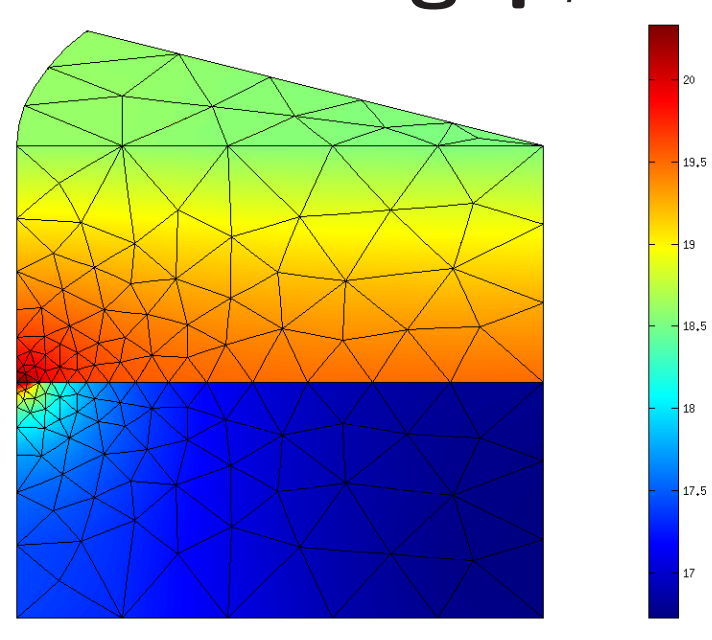
Putting $\rho \approx \rho_{22}$ yields $f_d \approx 600$ Hz with is closed to the frequency of the 1st experimental peak.

Numerical simulations

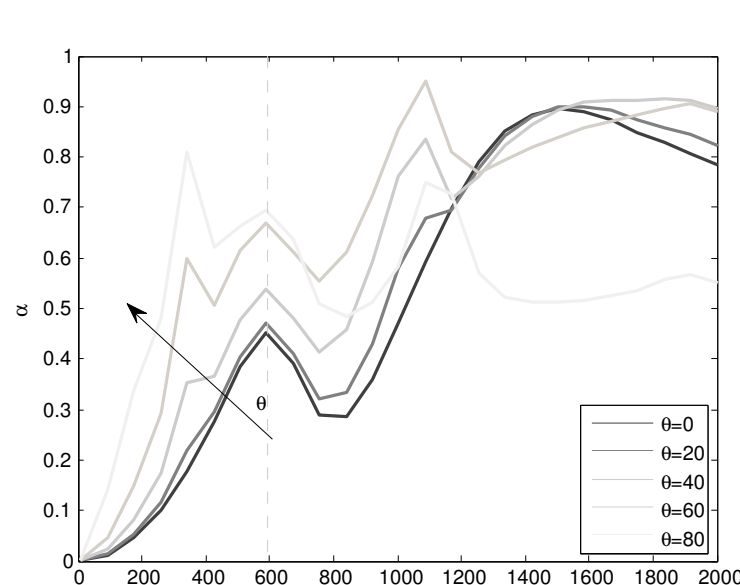
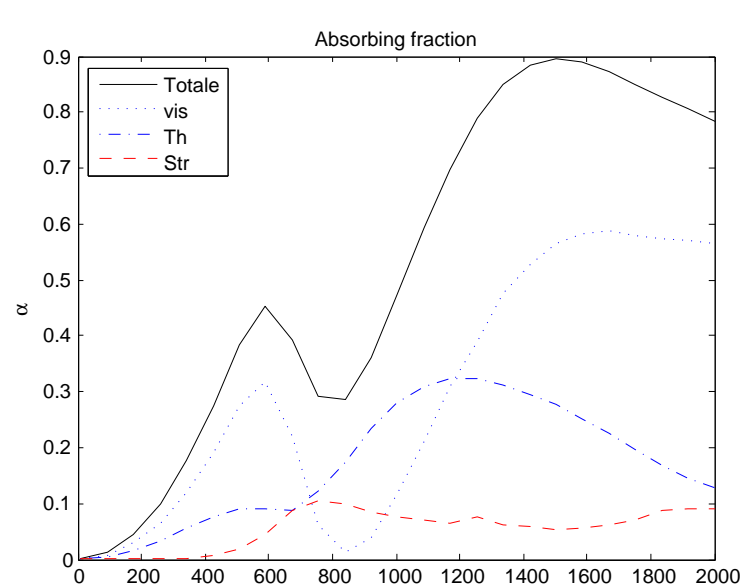
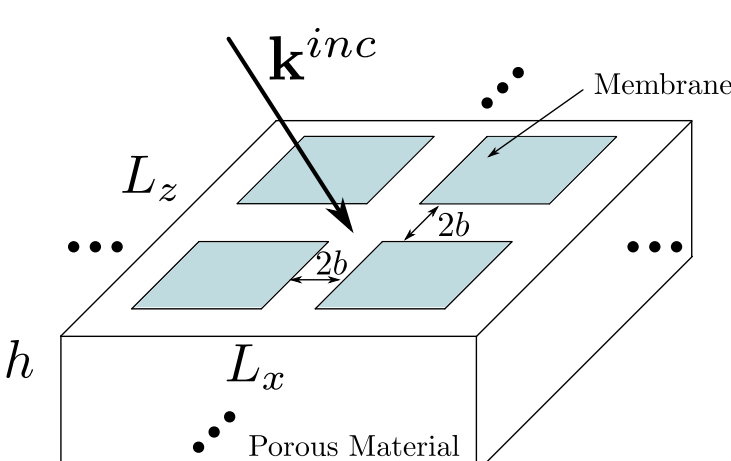
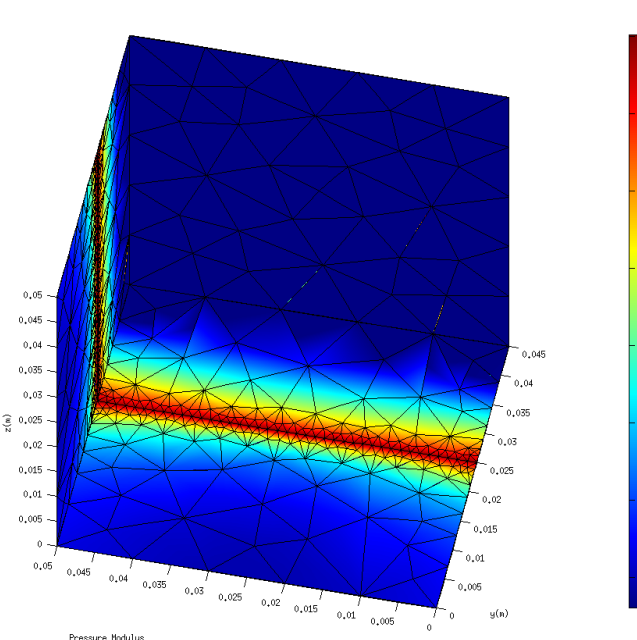
Assumptions :

- FEM simulations with Quadratic elements [3]
- Dissipated energy computed with [4]
- Clamped boundary condition, DtN map for radiation

Effect of the air gap, ranging from 0.5, 1, 2, 5, 10 mm and radius $r = 50$ mm



Periodic patch and oblique incidence effect : $L_x = 50$ mm, $L_z = 50$ mm, $b = 1$ mm, $h = 25$ mm



Prospects :

- Combination with double porosity material [5]
- Combination with Cuboid [6]

References

[1] R. A. Schultz, *Effect of solid phase properties on the acoustical performance of poroelastic materials*, MSME thesis, Purdue University (2012).
 [2] P. Morse and K. Ingard, *Theoretical Acoustics*, International series in pure and applied physics (McGraw-Hill, 1968).
 [3] N. Atalla, M. A. Hamdi, and R. Panneton, *J. Acoust. Soc. Am.* **109**, 3065 (2001).
 [4] O. Dazel, F. Sgard, F.-X. Becot, and N. Atalla, *J. Acoust. Soc. Am.* **123**, 2054 (2008).
 [5] F. C. Sgard, X. Olny, N. Atalla, and F. Castel, *Appl. Acoust.* **66**, 625 (2005).
 [6] N. Dauchez and B. Nennig, in *Internoise* (August 2012, New York city, USA).