Multimodal vibration damping through a periodic array of piezoelectric patches connected to a passive network

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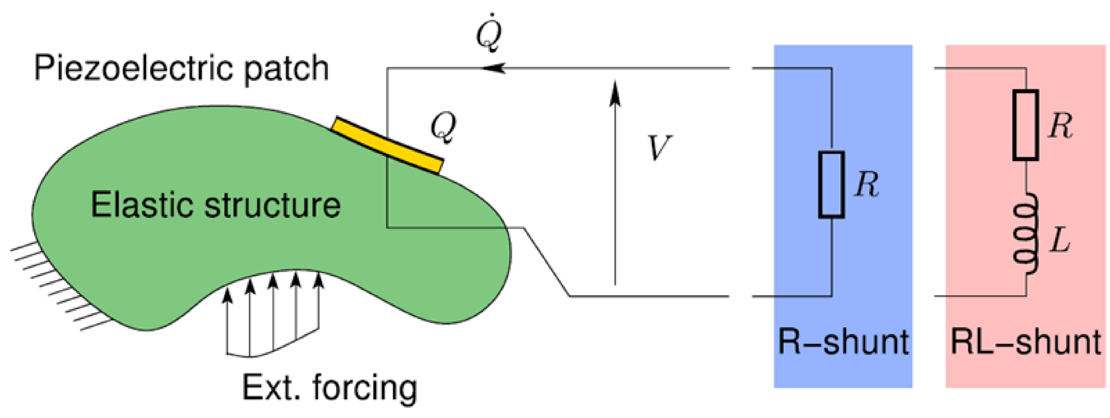
Context and motivations

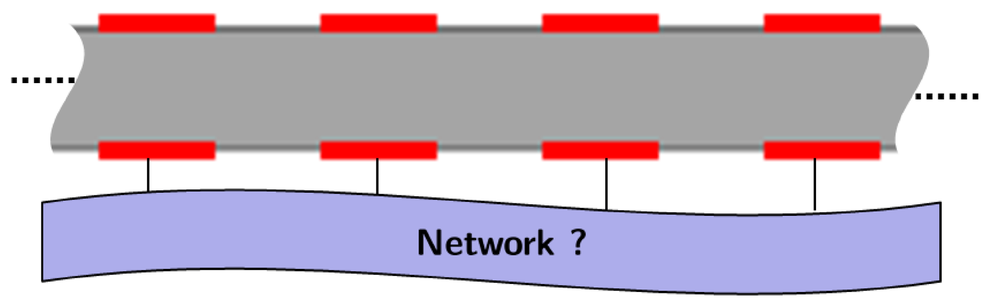
- **Vibration control with piezoelectric patches**
  - ▹ Deformation of a patch = Displacement of electric charges
  - ▹ Energy conversion followed by dissipation into resistors
  - ▹ Potentially light and passive control solution
  - ▹ Resonant shunt ≈ Tuned mass damper



- **Limits observed with the resonant shunts**
  - ▹ High inductance required = No practical passive solution
  - ▹ Sensitive and difficult tuning of multiresonant shunts
- **Goal of the present study**
  - ▹ Propose a passive and broadband control strategy

Mutimodal coupling

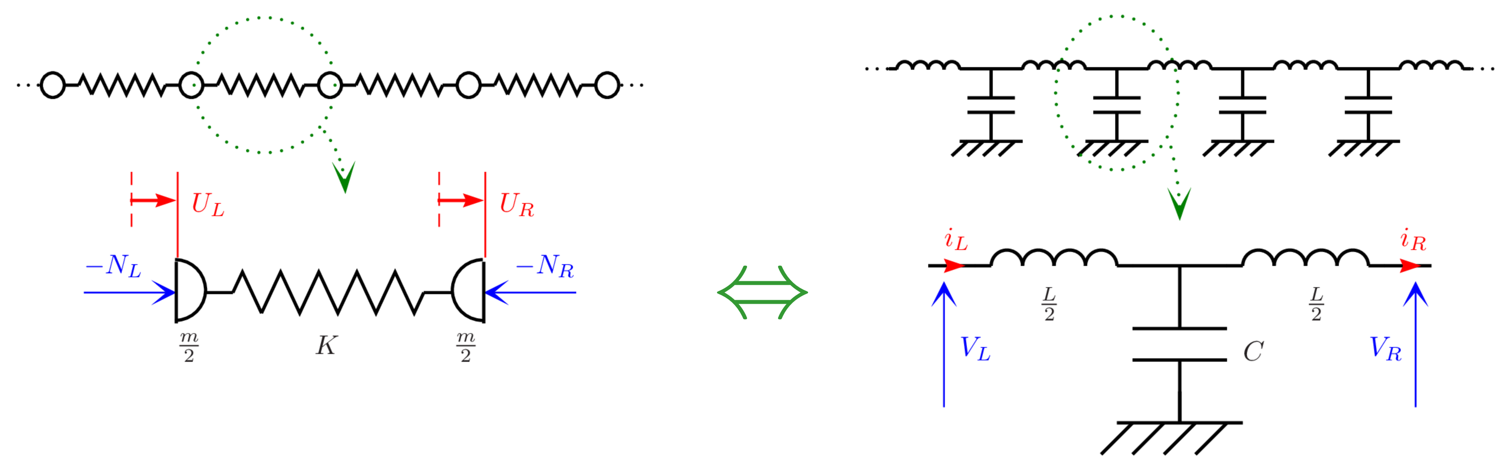
- **Modal coupling principle**
  - ▹ Two structures having the same modal properties
  - ▹ Similar boundary conditions and dispersion relations
  - ▹ Multimodal tuned mass damping effect



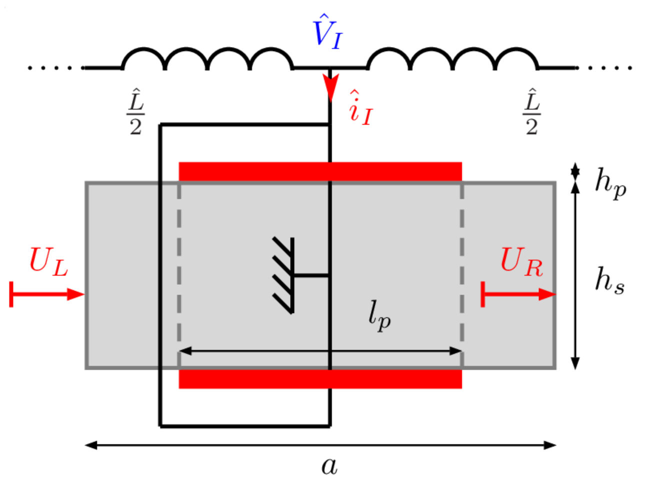
- **Application to the piezoelectric control**
  - ▹ Involve a multimodal electrical network
- **Questions**
  - ▹ Which electrical network ?
  - ▹ How to apply and model an electromechanical coupling ?

Control of longitudinal waves

- **Discrete model of a rod and its electrical analogue**



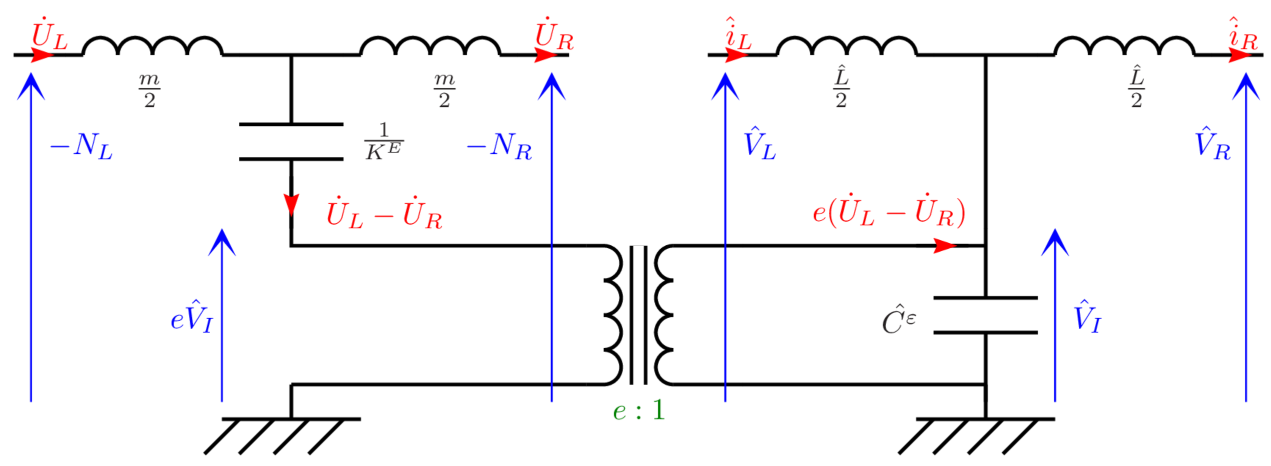
- **Unit cell of the coupled problem and its discrete electrical representation**



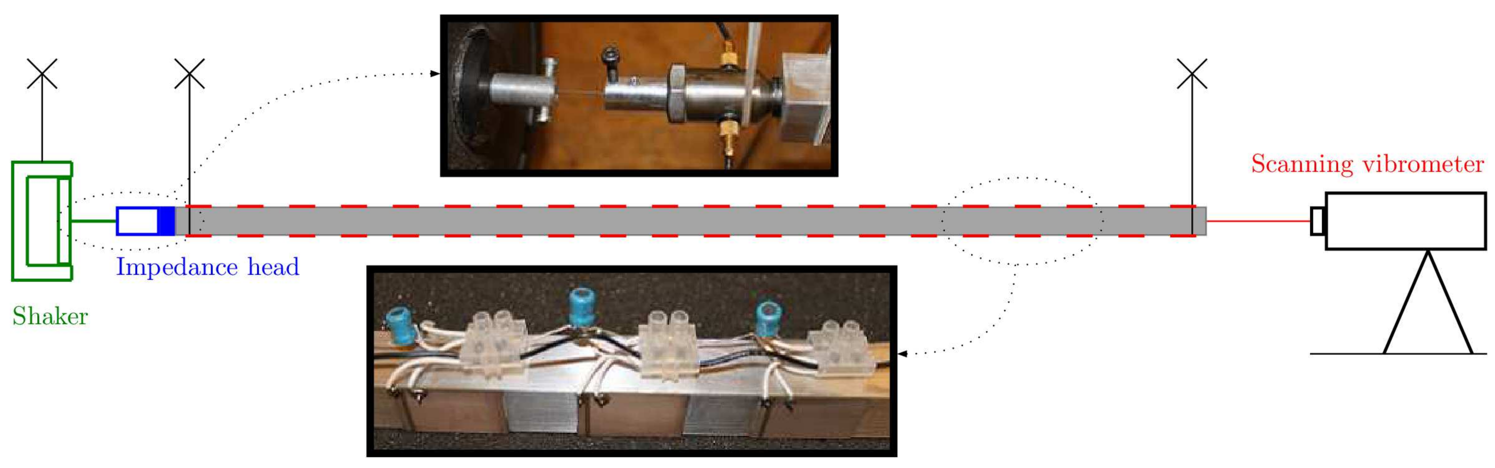
▹ Transfer matrix formulation :

$$\begin{bmatrix} U_R \\ \hat{i}_R \\ N_R \\ \hat{V}_R \end{bmatrix} = \boldsymbol{T} \begin{bmatrix} U_L \\ \hat{i}_L \\ N_L \\ \hat{V}_L \end{bmatrix}$$

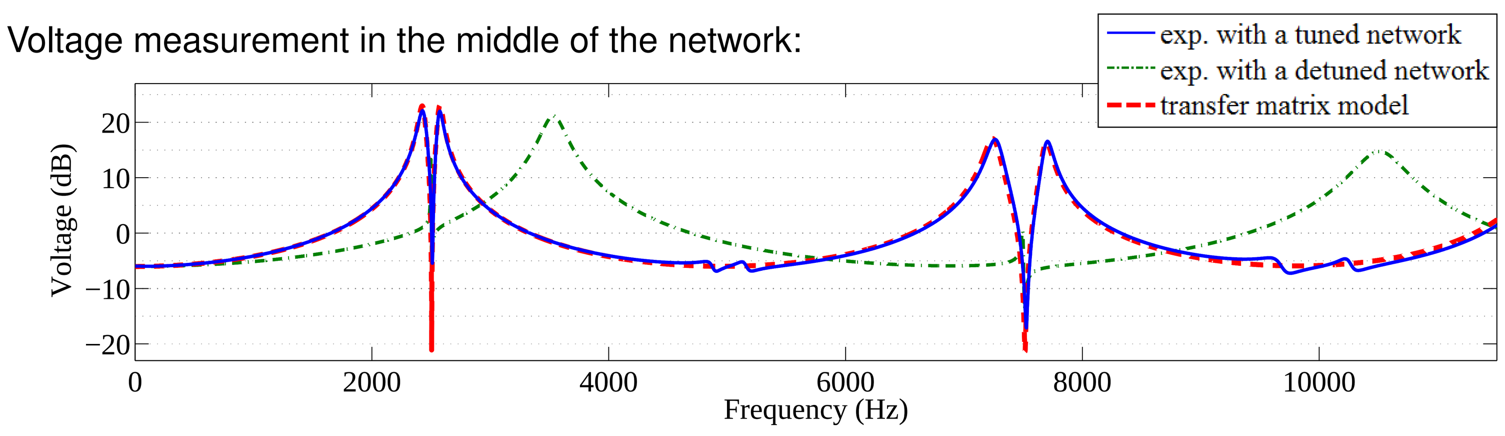
▹ Modal coupling condition : $\frac{1}{\hat{L}\hat{C}^{\varepsilon}} = \frac{K}{m}$



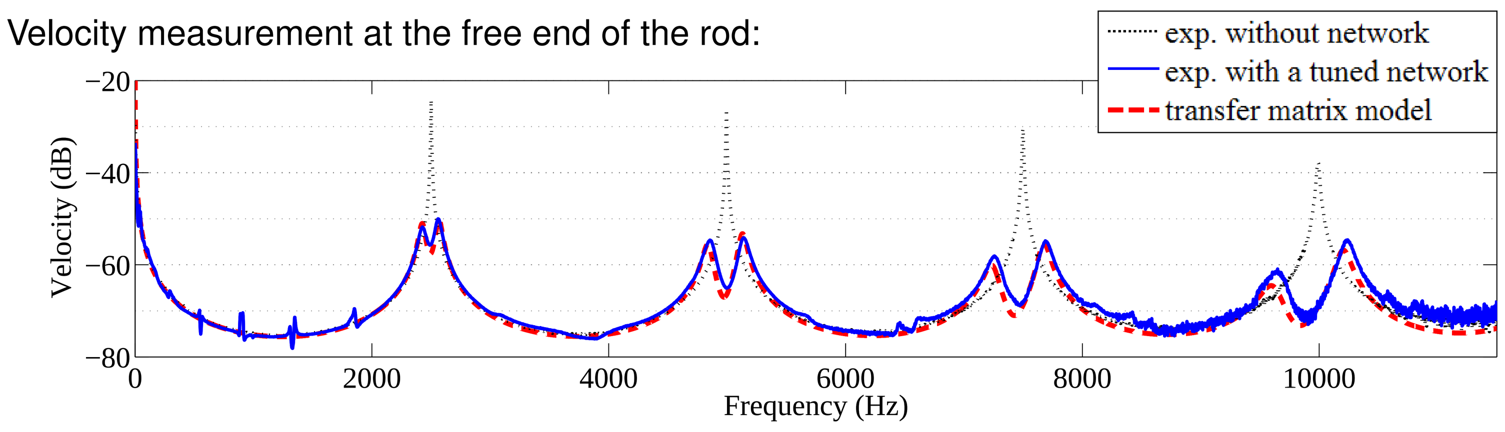
- **Experiments on a rod covered with 20 pairs of piezoelectric patches**
  - ▹ Experimental setup:



▹ Voltage measurement in the middle of the network:



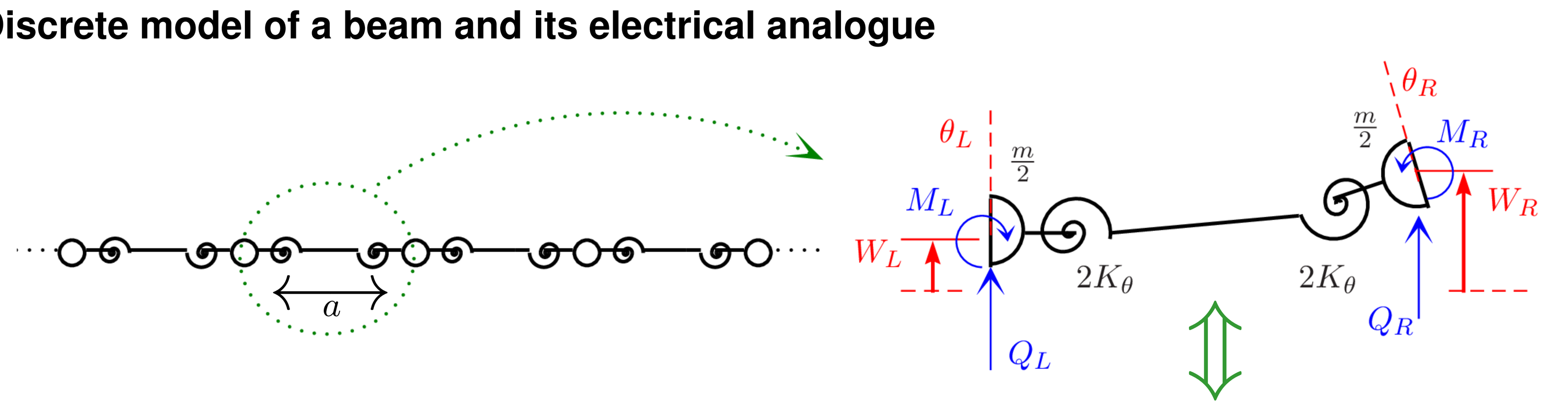
▹ Velocity measurement at the free end of the rod:



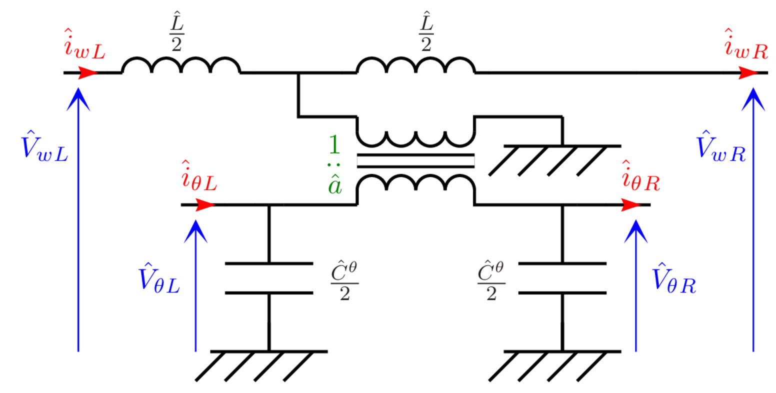
▹ Conclusion = Validation of the multimodal damping strategy and the transfer matrix model

Control of transverse waves

- **Discrete model of a beam and its electrical analogue**

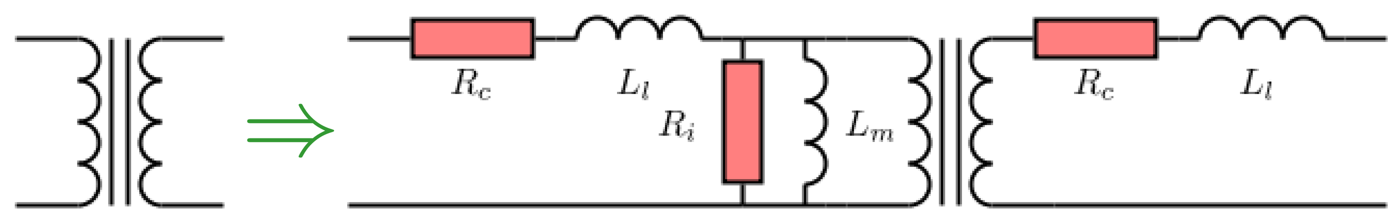


- ▹ Discretization and electromechanical analogy
- ▹ Coupled problem = 8×8 transfer matrix
- ▹ Network involving ideal transformers
- ▹ Modal coupling condition : $\frac{1}{\hat{L}\hat{C}^{\theta}}\hat{a}^2 = \frac{K_\theta}{m}a^2$



- **Models for standard passive components (under consideration)**
  - ▹ Inductor:

▹ Transformer:



- ▹ Parasitic effects: copper and iron losses (R_c & R_i), leakage and magnetizing inductances (L_l & L_m)
- ▹ Difficulties when selecting standard electrical components

Future work

Short-term	Medium-term	Long-term
Experimental validation of the multimodal damping for bending	Extension of the strategy to the control of plates with a 2D network	General formulation for the control of any mechanical structure

References

[1] O. Thomas, J. Ducarne, J-F Deü, *Performance of piezoelectric shunts for vibration reduction*, Smart Materials and Structures, Vol. 21, No. 1, IOPscience (2012), p. 015008.
[2] C. Maurini, F. dell'Isola, D. Del Vescovo, *Comparison of piezoelectronic networks acting as distributed vibration absorbers*, Mechanical Systems and Signal Processing, Vol. 18, No. 5, Elsevier (2004), pp. 1243-1271.
[3] B. Lossouarn, J.-F. Deü, M. Aucejo, *Wave propagation in coupled periodic lattices and application to vibration attenuation through a piezoelectric network*, ISMA 2014 Proceedings, pp. 3369-3394.