Numerical modelling of piezoelectric vibration energy scavenging bimorphs

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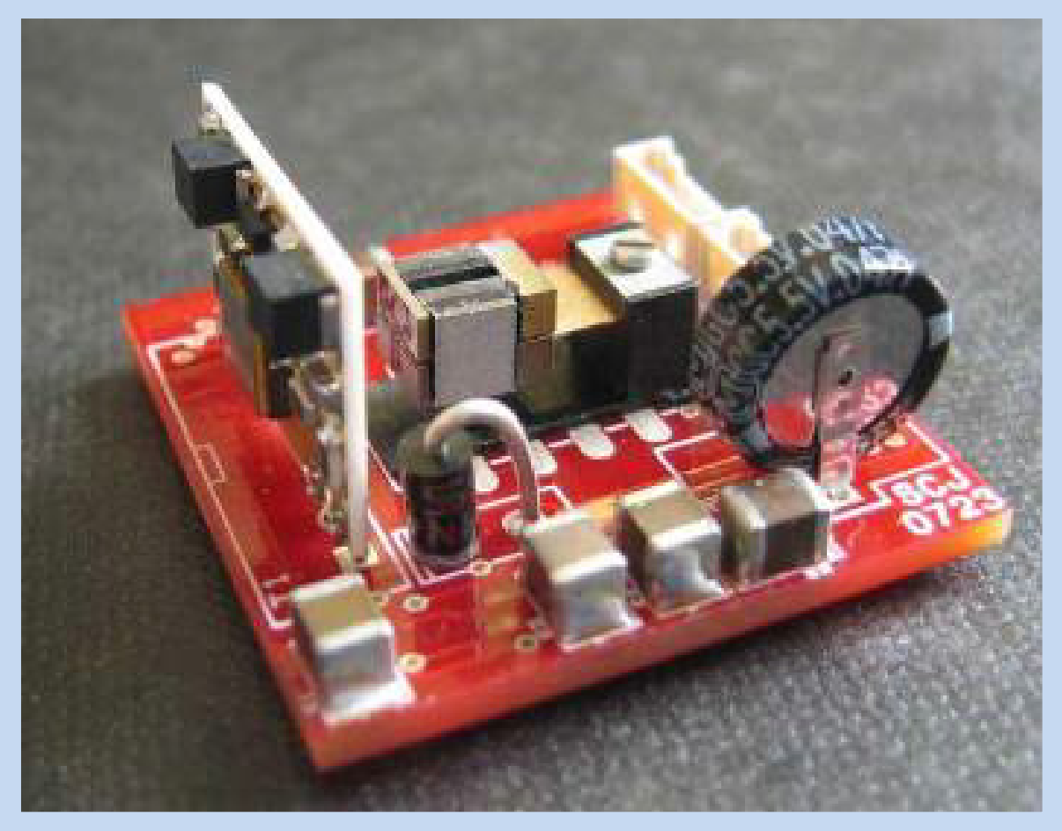
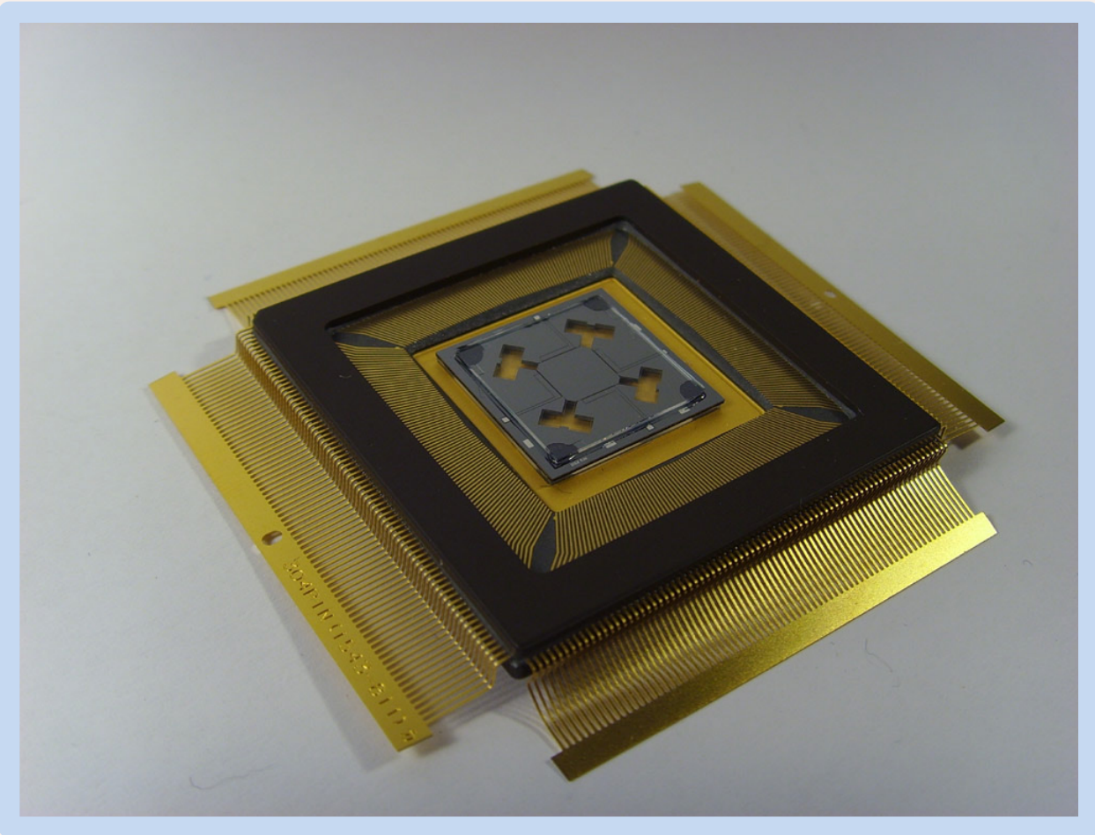
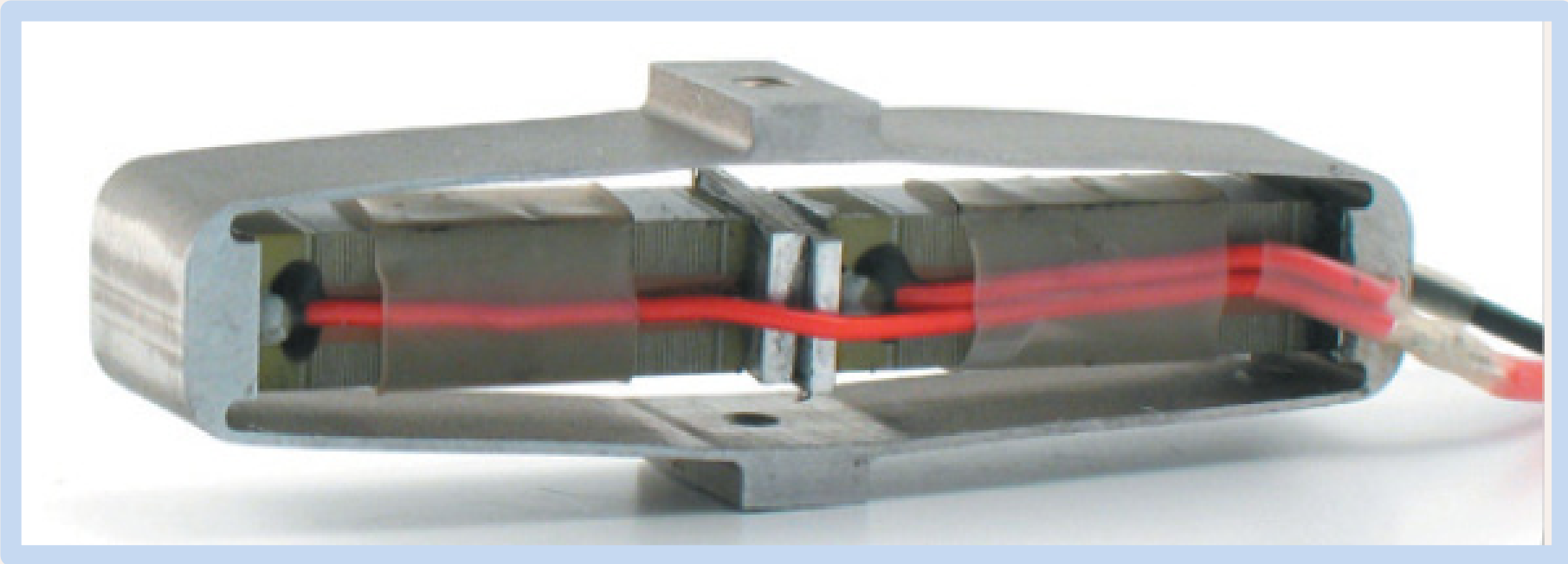
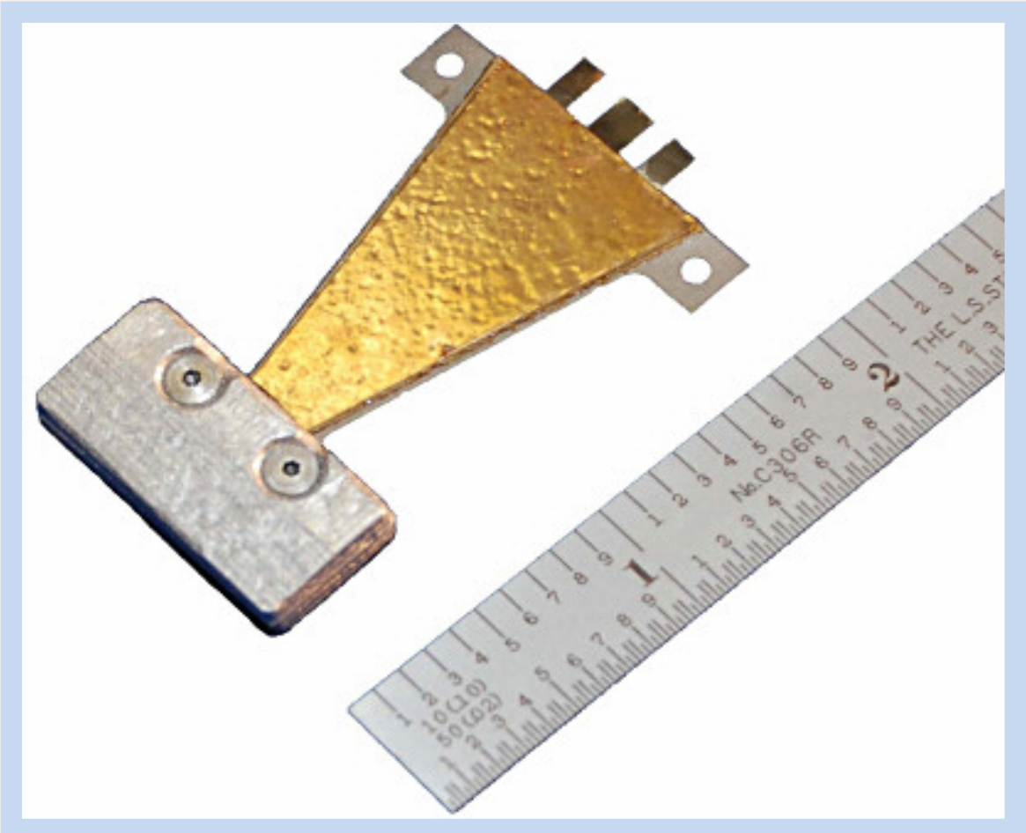
Kinetic vibration energy scavenging

Energy scavenging/harvesting is the process of collecting low level ambient energy and its conversion into electric power.







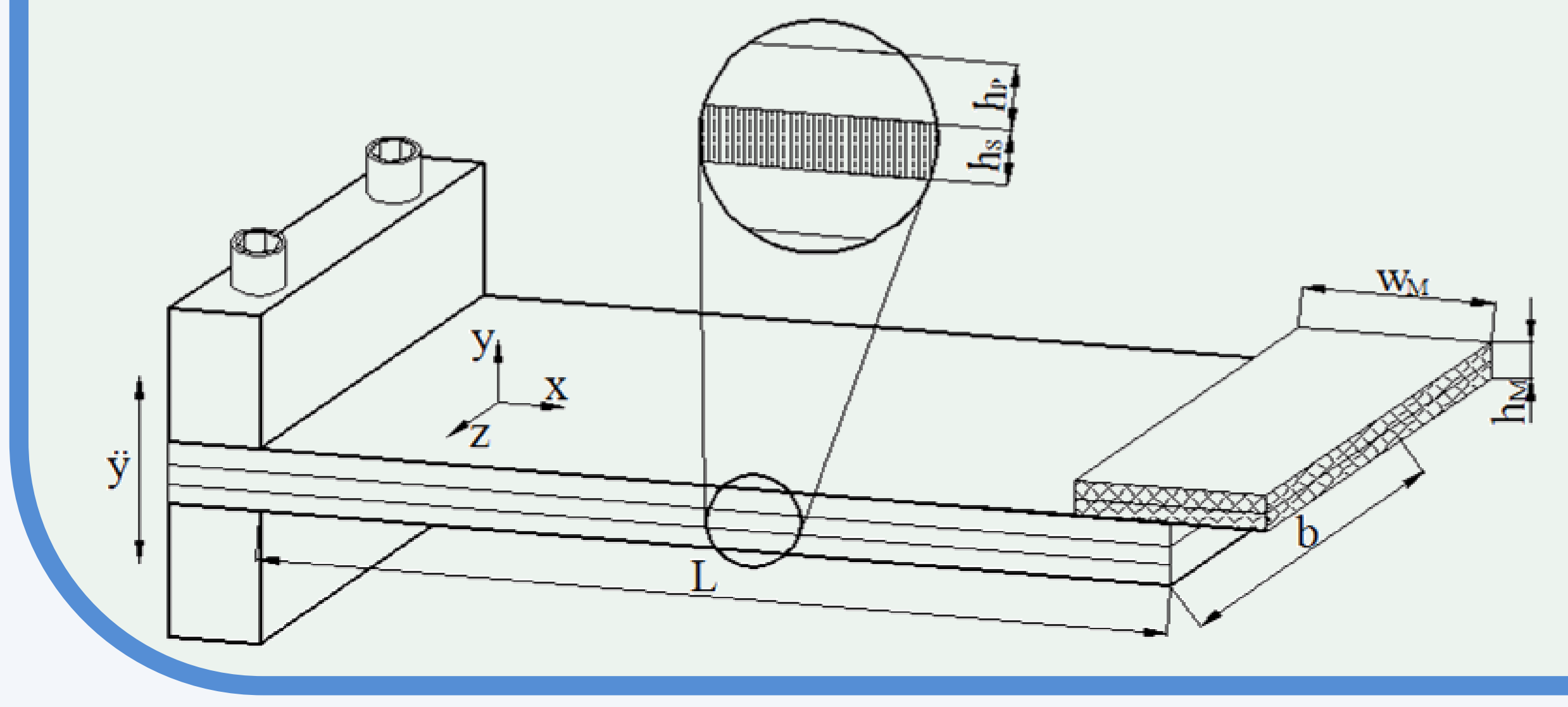


There are different concepts of *kinetic vibration energy harvesting*, some of the most prominent being: a) **electromagnetic** scavenging (Beeby et al. 2007), b) **electrostatic** scavenging (Nimo et al. 2011), c) **piezoelectric stack** scavenging (Cedrat Group, 2008) & d) **piezoelectric bender scavenging** (AdaptivEnergy, 2009) - considered in this work.

Piezoelectric bimorph in bending mode

This technique is particularly advantageous due to:

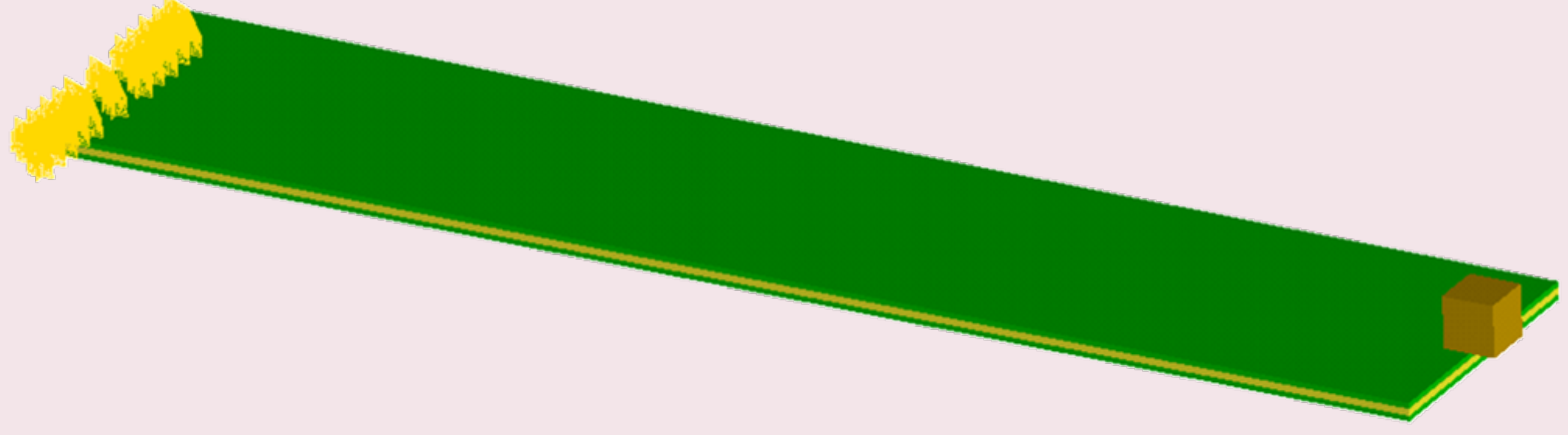
- design simplicity,
- linear electromechanical response,
- miniaturization potential,
- high energy and power densities.



In a previous work, a coupled modal electromechanical frequency response (FRF) analysis was performed and validated experimentally thus showing:

- a nonlinear hardening effect of the applied electrical loads,
- an intricate dependence of obtainable power on applied loads.

Finite Element Model of the piezoelectric bimorph

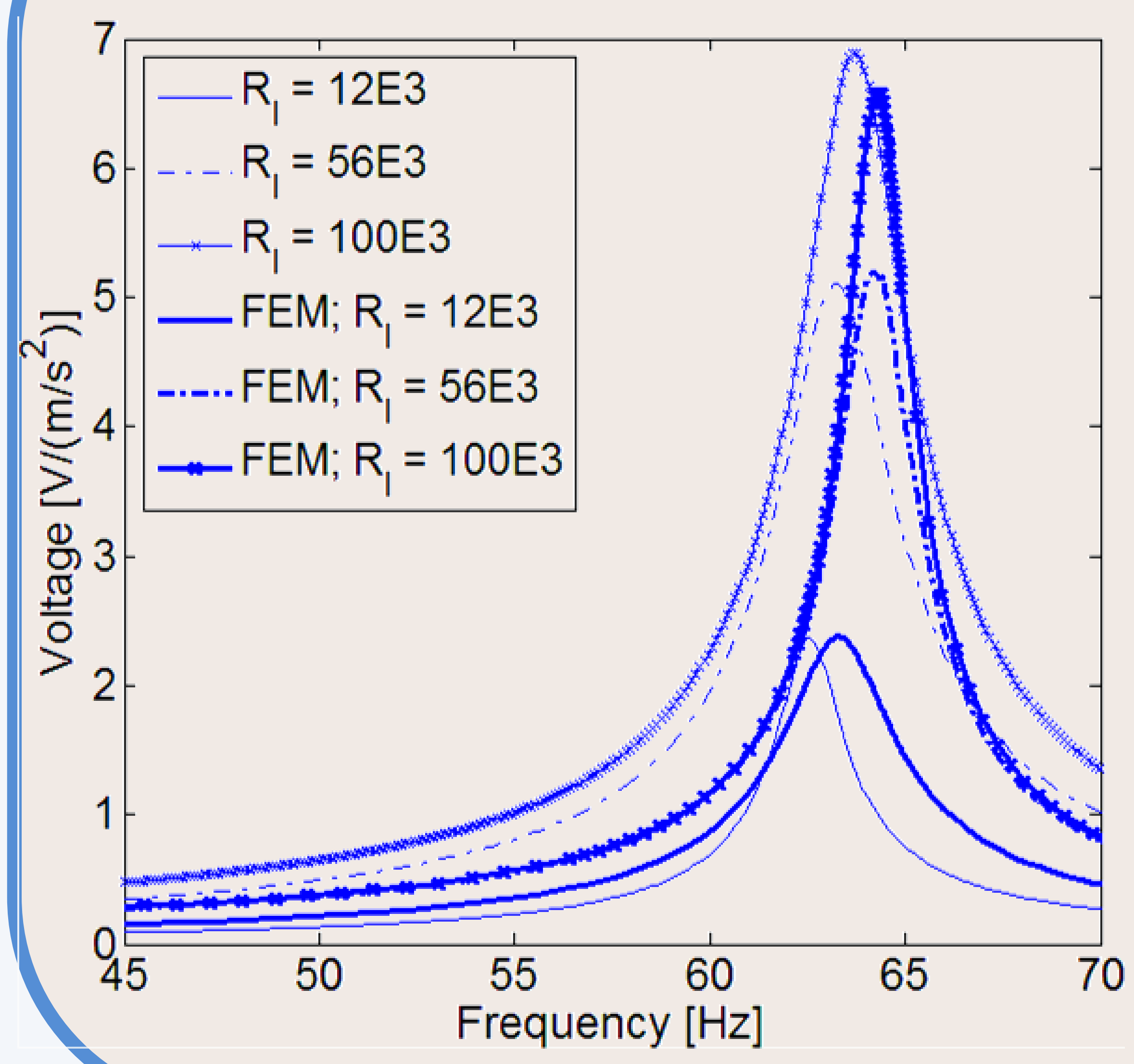


ANSYS™ Finite Elements employed:

- **Piezo** - brick SOLID226 / tetrahedral SOLID227
- **Other** - brick SOLID186 / tetrahedral SOLID187
- **Load** - CIRCU94

Although the structure and the modelling procedure are quite simple, special attention is to be dedicated to electrical coupling of the piezoelectric layers.

Modal and full transient analysis – results and discussion

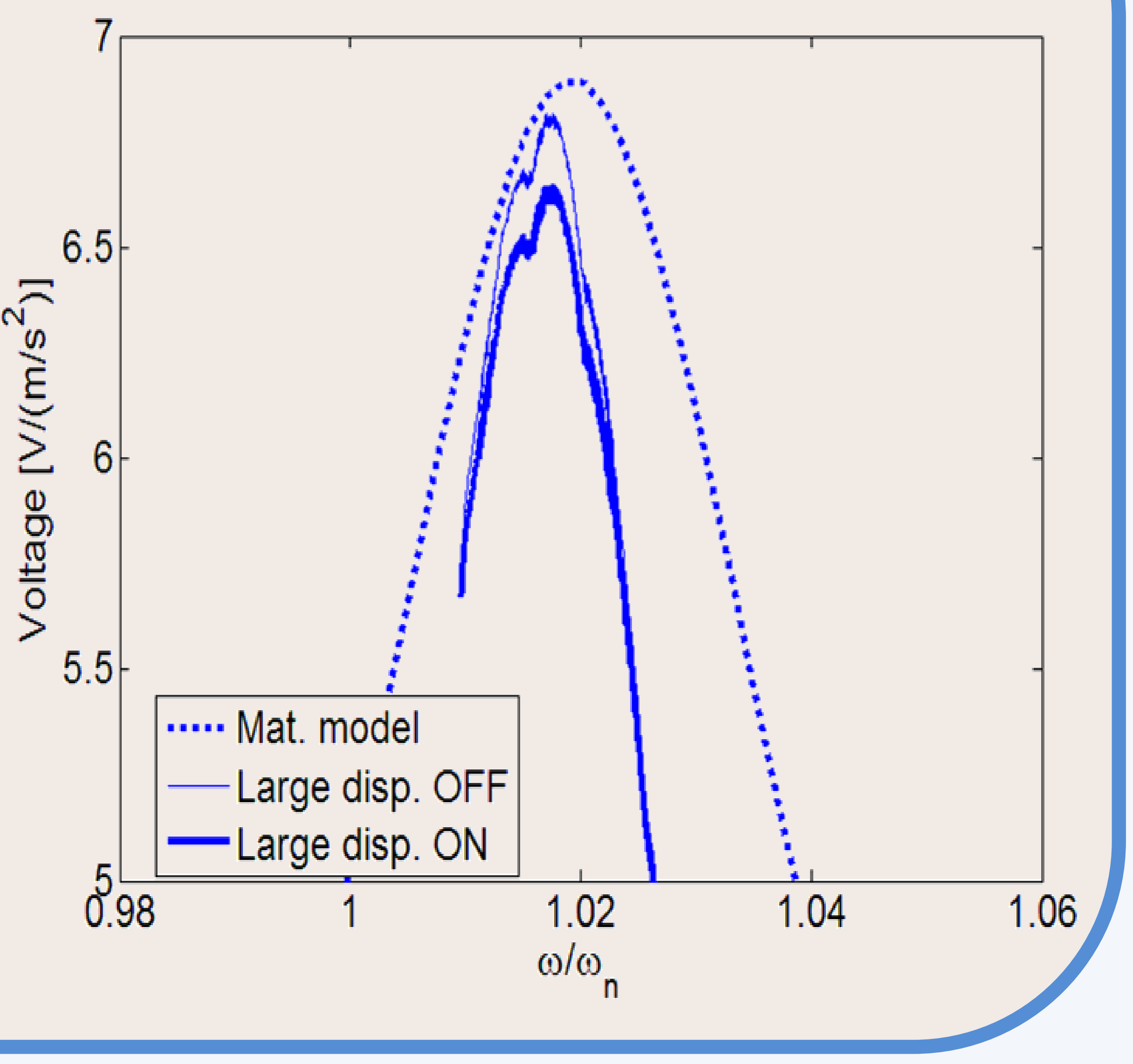


After preliminary modal analysis, a coupled harmonic and transient analysis are performed in ANSYS and validated via the analytical model [Erturk 2009.].

Harmonic analysis results display an offset in terms of frequencies and voltage levels, limited to 4% with respect to the analytics.

Transient analysis is better in terms of accuracies of frequencies (err. < 0.015%) and output voltages (err. < 1%).

With geometric nonlinearities included, a decrease of voltage amplitudes is observed. This can be attributed to large deflections (small cross section rotations)



Conclusions and outlook

A finite element model built in ANSYS is used for modal, harmonic and nonlinear transient analysis. The results are compared with a linear analytical model and good correspondence is achieved allowing an excellent estimation of maximum obtainable powers. In a future work, the authors will explore different harvester geometries as well as further the influence of mechanical nonlinearities on the bimorph behaviour.

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