Tunable mechanical monolithic sensors for large band low frequency monitoring and control

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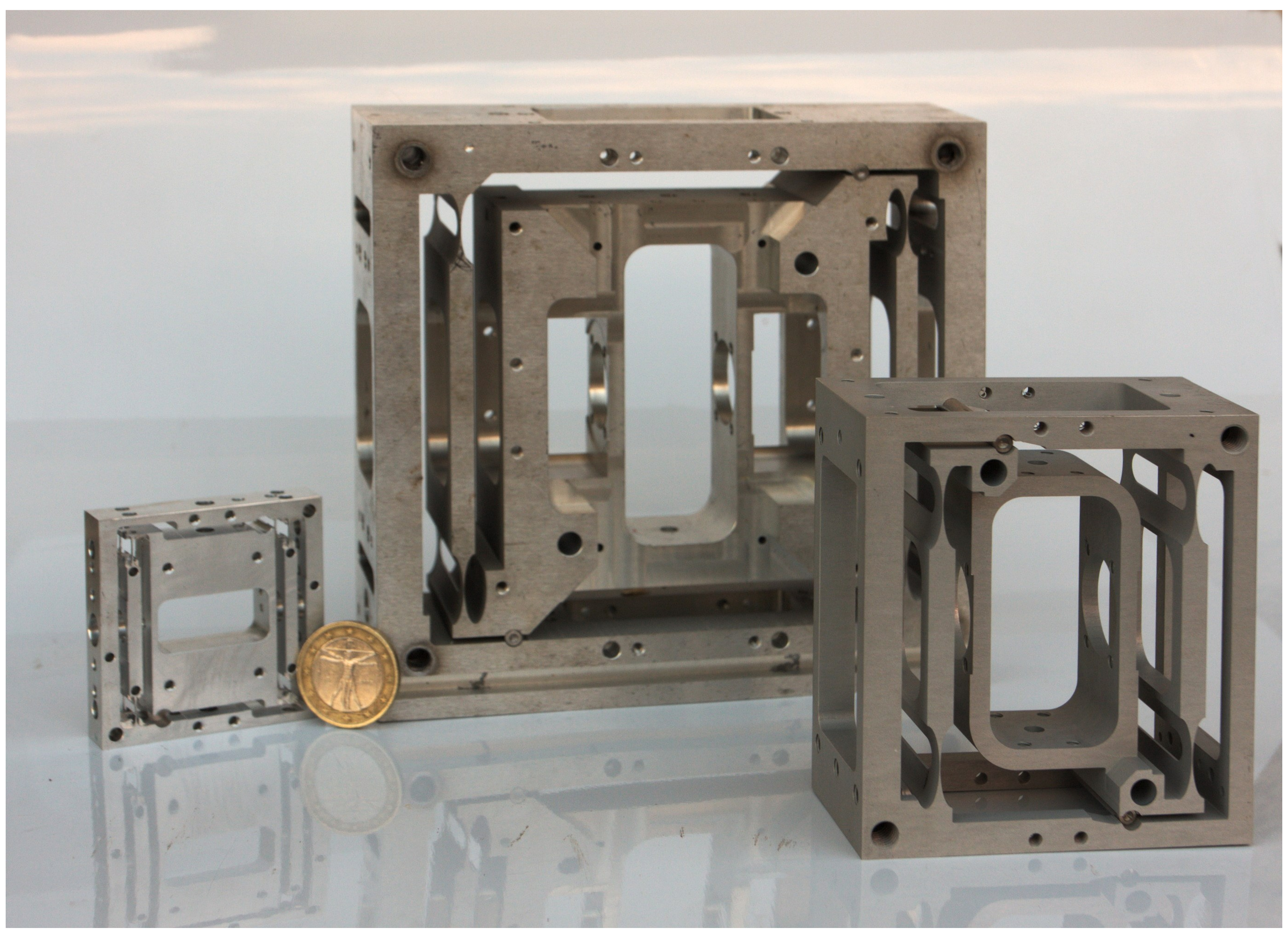
The GOAL: Implementation of compact, robust and light horizontal and vertical inertial sensors configurable as seismometers, velocimeters and/or accelerometers with sensitivity and band modularly configurable with suitable readouts.

The LIMITS: the limits of the mechanics of an inertial monolithic UNISA folded pendulum is its thermal noise, that for the most common applications is lower than the readout noise.

The ADVANTAGES: effective as horizontal and/or vertical sensor, its monolithic mechanics and the large typology of material used for its construction allow its use also in critical environmental like ultra high vacuum (UHV), cryogenic temperatures, underground, marine and space environments.

UNISA Monolithic Folded Pendulums GE15, GF15 and GI16



Band
1μHz ÷ 1 kHz

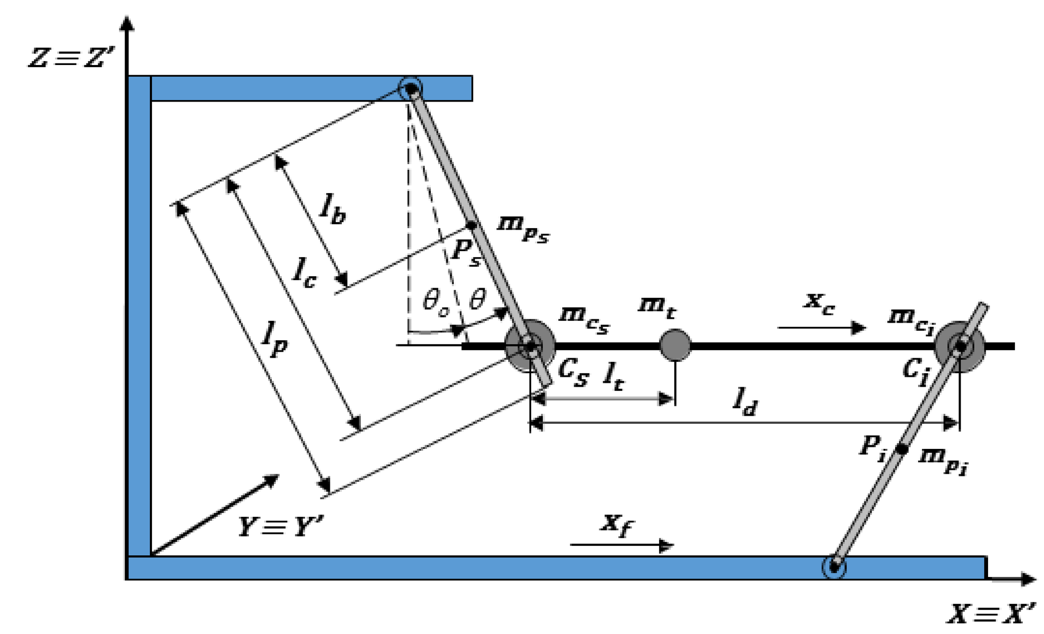
Resonance Frequency
60 mHz ÷ 10 Hz

Readout
LVDT, capacitive sensor, optical lever, optical fibre bundle, interferometer

Readout Noise
$10^{-14} \div 10^{-6}$ m/Hz$^{1/2}$

Quality Factor
Q > 16000 in UHV
Q > 2000 in air

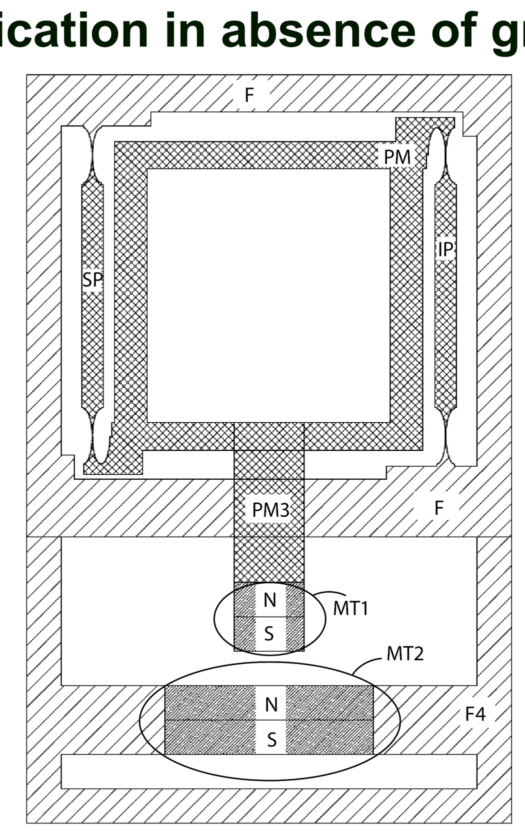
Folded Pendulum Basic Scheme



$$f_o = \frac{1}{2\pi}\sqrt{\frac{K_{eq}}{M_{eq}}} = \frac{1}{2\pi}\sqrt{\frac{K_{g_{eq}} + K_{e_{eq}}}{M_{eq}}} =$$

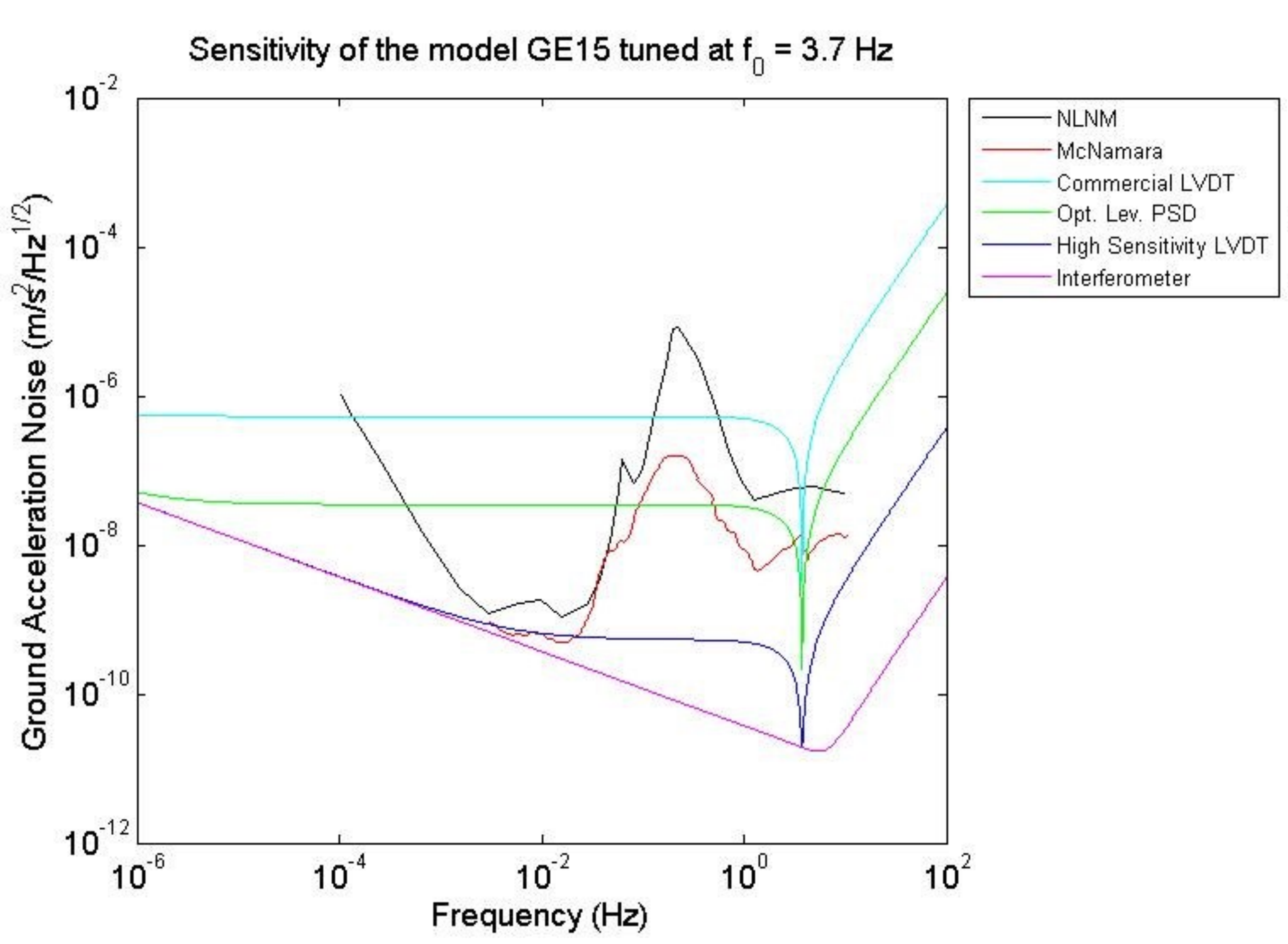
$$= \frac{1}{2\pi}\sqrt{\frac{\left[\left(m_{p_s} - m_{p_i}\right)\frac{l_p}{2l_c} + \left(m_{c_s} - m_{c_i}\right)\right]\frac{g_{eq}}{l_c} + \frac{k_\theta}{l_c^2}}{\left(m_{p_s} + m_{p_i}\right)\frac{l_p^2}{3l_c^2} + \left(m_{c_s} + m_{c_i}\right)}}$$

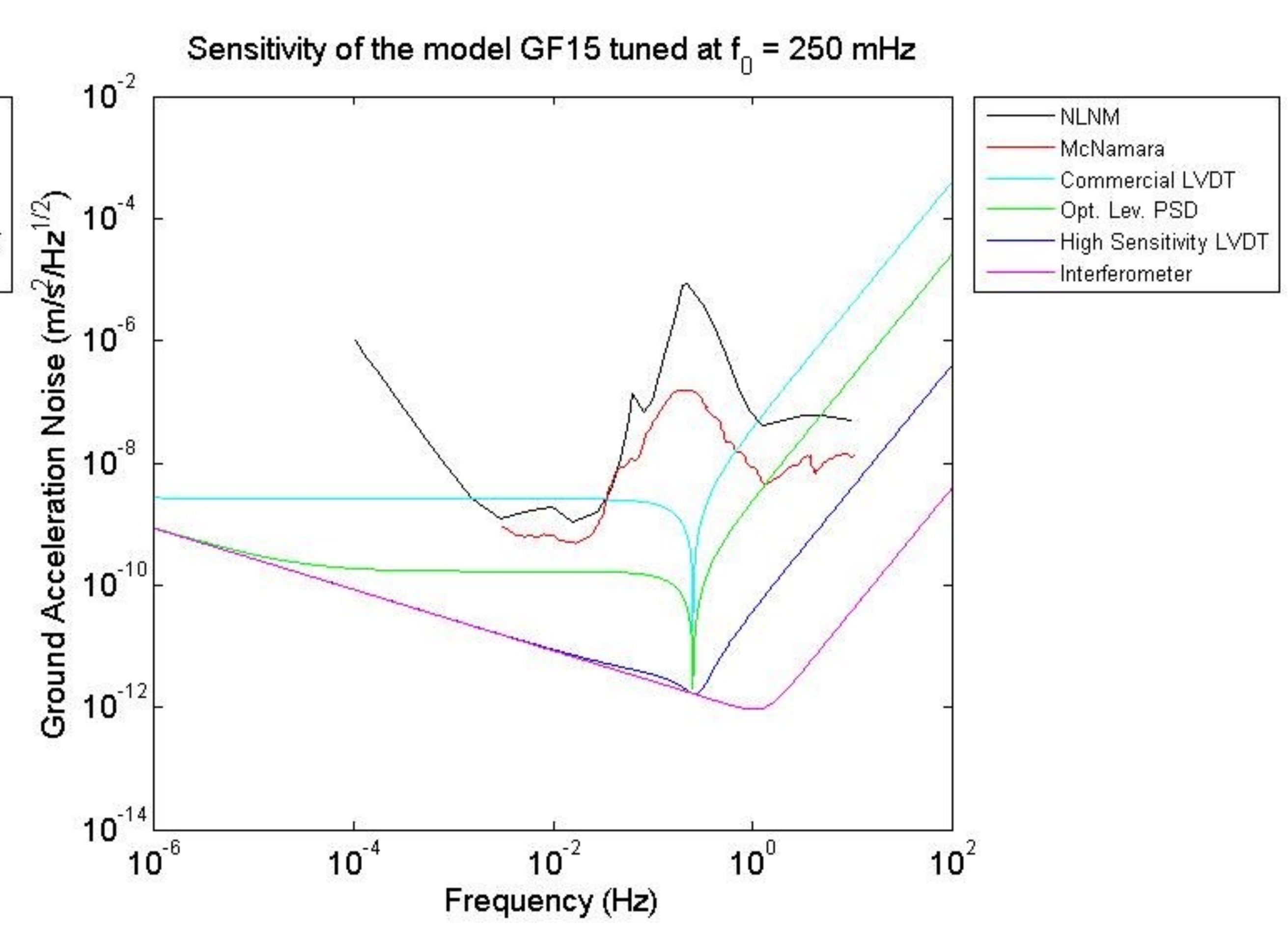
Application in absence of gravity



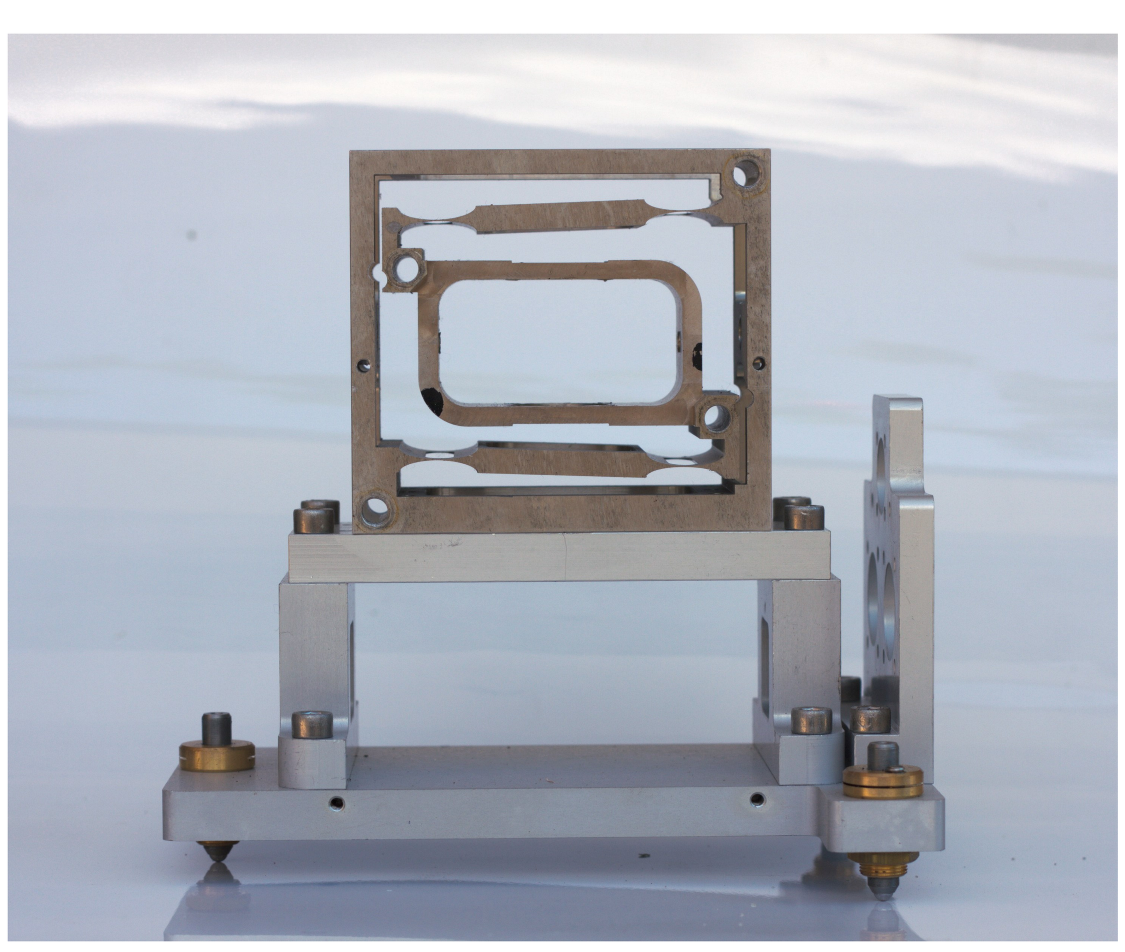
The couple of magnets MT1-MT2 generates an equivalent gravitational acceleration

Folded Pendulum Sensitivities





UNISA Monolithic Folded Pendulum GD14 in vertical configuration with LVDT readout



CONCLUSIONS

- The UNISA folded Pendulum architecture has been demonstrated to be fully scalable, both theoretically and experimentally, according to test performed on many models, like the ones presented (GE15, GF15, GI16).
- At room temperature the global sensitivity of an UNISA Folded Pendulum is determined by its thermal noise and by the typology and quality of its readout.
- The UNISA Folded Pendulum architecture allows the implementation of horizontal and vertical seismometers, velocimeters and accelerometers,
- Due to their mechanical characteristics, UNISA folded pendulums are very effective in air, in ultra-high vacuum (UHV) and in cryogenic conditions.
- UNISA folded pendulums have been tested in monitoring and control in different fields.

Acknowledgments

The authors acknowledge Beneforti Donatella & C. S.n.c. for the technical support and the implementation of the mechanics of the monolithic folded pendulum sensors.

Amaldi12

12th Edoardo Amaldi Conference on Gravitational Waves
July 9-14, 2017, Hilton Hotel, Pasadena, CA, USA