Vibration measurements

Laboratories in Annecy working on Vibration Stabilization

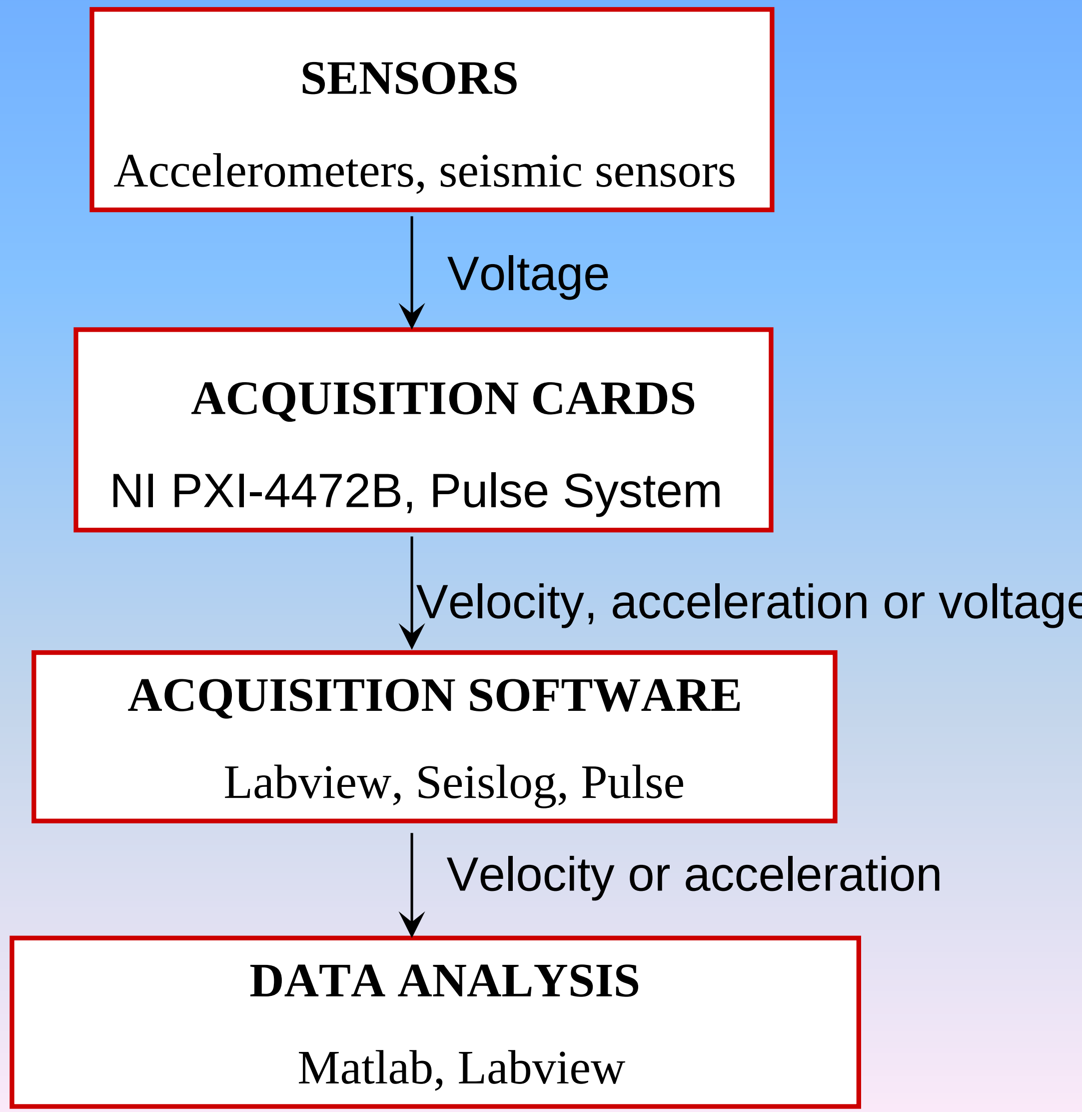
LAViSta

Catherine ADLOFF
Benoît BOLZON
Franck CADOUX
Yan BASTIAN
Andréa JEREMIE
Yannis KARYOTAKIS
Claude GIRARD
Nicolas GEFFROY

Outline

1. Setup and goals
2. Sensors
3. Data aquisition
4. Data analysis with Matlab
5. Measurements
6. Stabilization techniques at LAPP
7. Stabilization techniques at LISTIC

1. Setup and goals



Goals :

→Study sensors' resolution

→Study signal/noise ratio

→ Study of the ground displacement

2. Sensors

2 types of sensors :

→ **Seismic sensors :** Measurement of the ground velocity

→ **Accelerometers :** Measurement of the ground acceleration

Sensors	VE-13	Guralp CMG-40T	SP400U	GSV-320	ENDEVCO 86
Sensitivity	1V→1 mm/s	1V→0.625mm/s	1V→1 mm/s	1V→0.5 mm/s	1V→0.1g
Garanteed frequency range	1 - 315 Hz	0,033 - 50 Hz	0,1-50 Hz	1 - 315 Hz	1-100 Hz
Quantity	2	2	2	2	2

Non magnetic

3. Data acquisition

- **Home made DAQ based on PXI-4472B ADC from NI**
  - ✓ ADC designed for spectral analysis : includes anti-aliasing…
  - ✓ Labview software for data acquisition (our development)
  - ✓ VE13, Guralp, SP400, GSV320, ENDEVCO sensors

- **Bruel and Kjaer electronics**
  - ✓ ADC also designed for spectral analysis, especially for modal analysis
  - ✓ Pulse software for data acquisition (from the company)
  - ✓ VE13, Guralp, SP400, GSV320, ENDEVCO sensors
  - ✓ Less electronic noise and better resolution

→ Better results with accelerometers at low frequencies (same results with velocity sensors which have a bigger amplitude)

→ This system has been used to show the current results

4. Data analysis with Matlab

PSD and RMS
Coherence
Resolution

Raw data : velocity v (µm/s)

Temporal information

Power Spectral Density (PSD) at frequency **f (µm²/Hz)**

Information at a given frequency

Integrated displacement above frequency **f (µm)**

Information on frequency range

ACQUISITION

↓ **Sampling**

$v(i) = v(i\,\Delta t)$ avec $i=1..N$

↓ **Power Spectral Density**

$$\mathbf{PSD_{vel} = (T.F.[v(t)])^2 / \Delta f ; \qquad PSD_{displ} = \frac{1}{(2\pi \cdot f)^2} \cdot PSD_{vel}}$$

↓ **Root Mean Square**

$$RMS(f) = \sqrt{\sum_{f}^{f\,max} PSD_{displ}(f) \cdot df}$$

4. Data analysis with Matlab

Temporal information

Sensor 1 : $v_1(t)$ → Sensor 2 : $v_2(t)$

$$C(f) = \frac{|Re(<\tilde{v}_1(f)\tilde{v}_2^*(f)>|)}{\sqrt{|<\tilde{v}_1^2(f)><\tilde{v}_2^2(f)>|}}$$

Coherence between two sensors 1 et 2 at frequency **f**

Information at a given frequency

Example : two sensors very close to each other

C(f) very close to 1 : coherent measurements of the motion

C(f) is close to 0 : measurements are dominated by noise

4. Data analysis with Matlab

Principle : 2 identical sensors close to each other on the gro

Estimation of resolution with two approaches :

a) dV(t)=V_1(t)- V_2(t) —*Displacement PSD*→ $PSD_{displ}(V_1 - V_2)$ —*RMS*→ Integrated spectral difference

Displacement PSD

b) $PSD_c(f) = 2(1 - C(f))\sqrt{PSD_1(f) PSD_2(f)}$

RMS

Integrated corrected difference

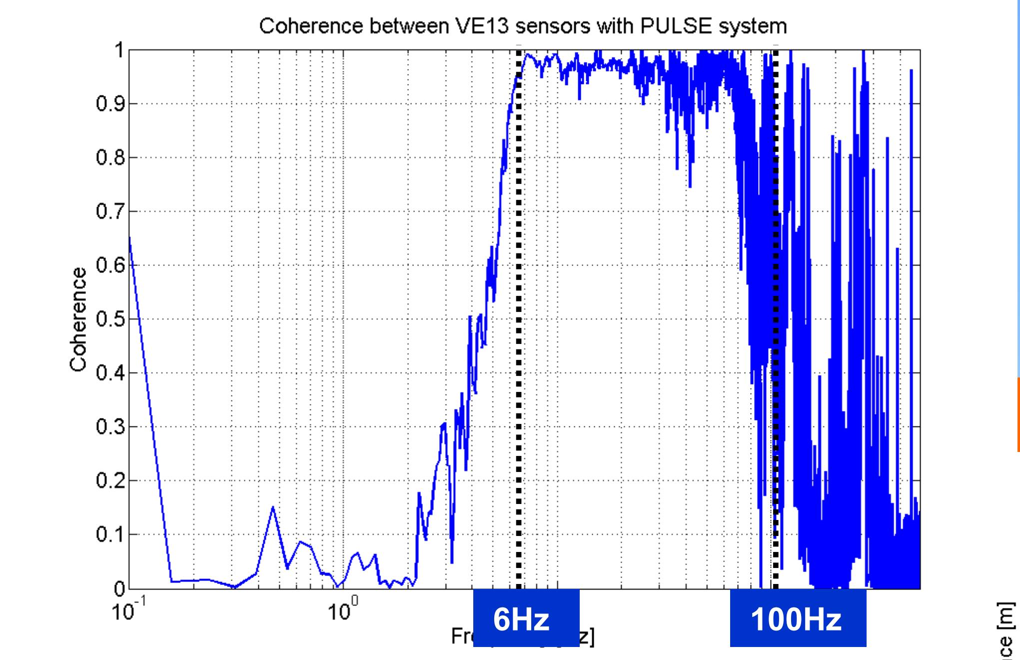
5. Measurements

Goal : Sensors study and ground motion study

- ✓ PSD
- ✓ Coherence
- ✓ Resolution
- ✓ RMS displacement
- ✓ Signal/Noise ratio

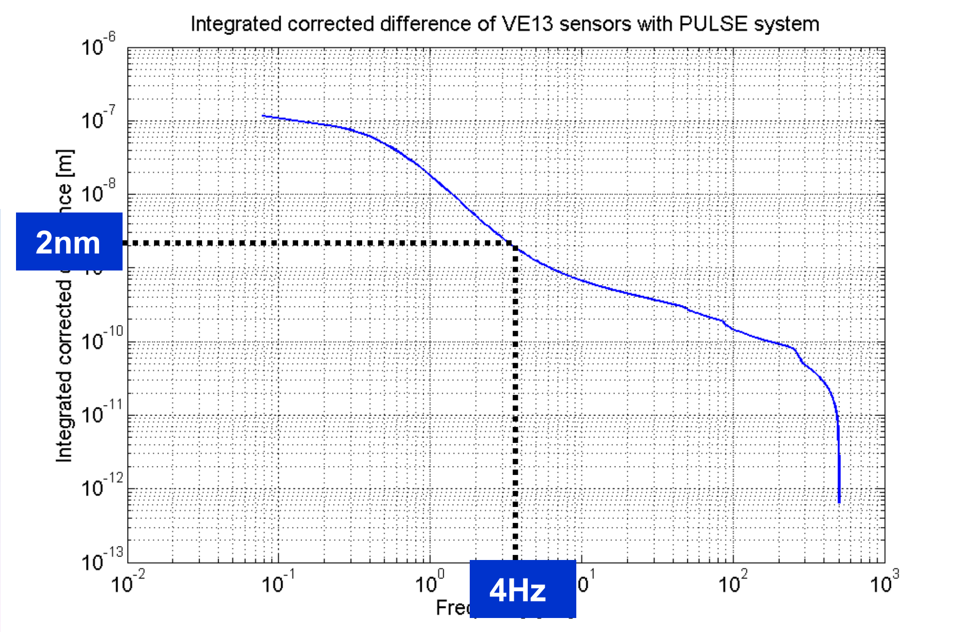
5. Measurements

Coherence



Frequency range : 1-315 Hz

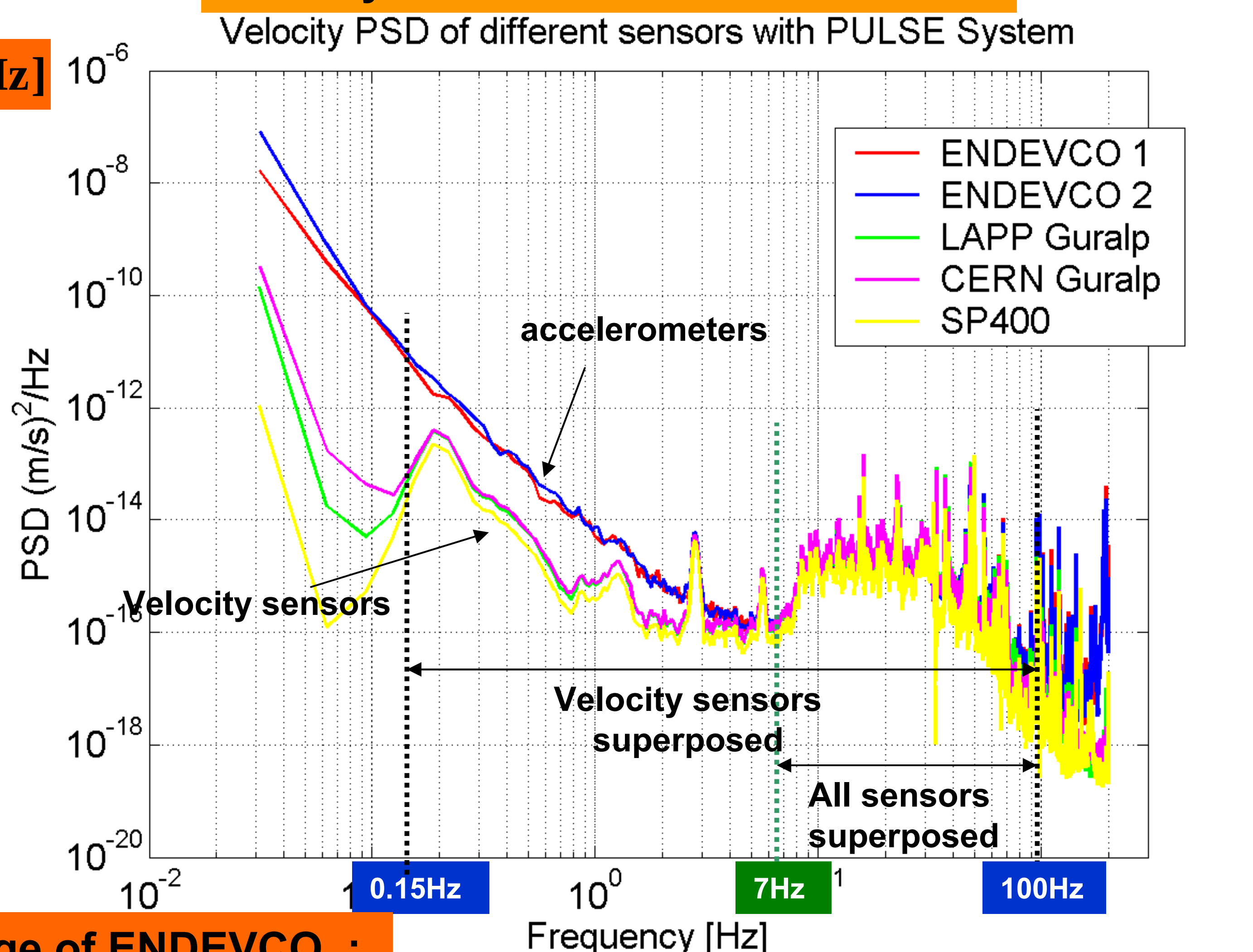
Resolution



5. Measurements

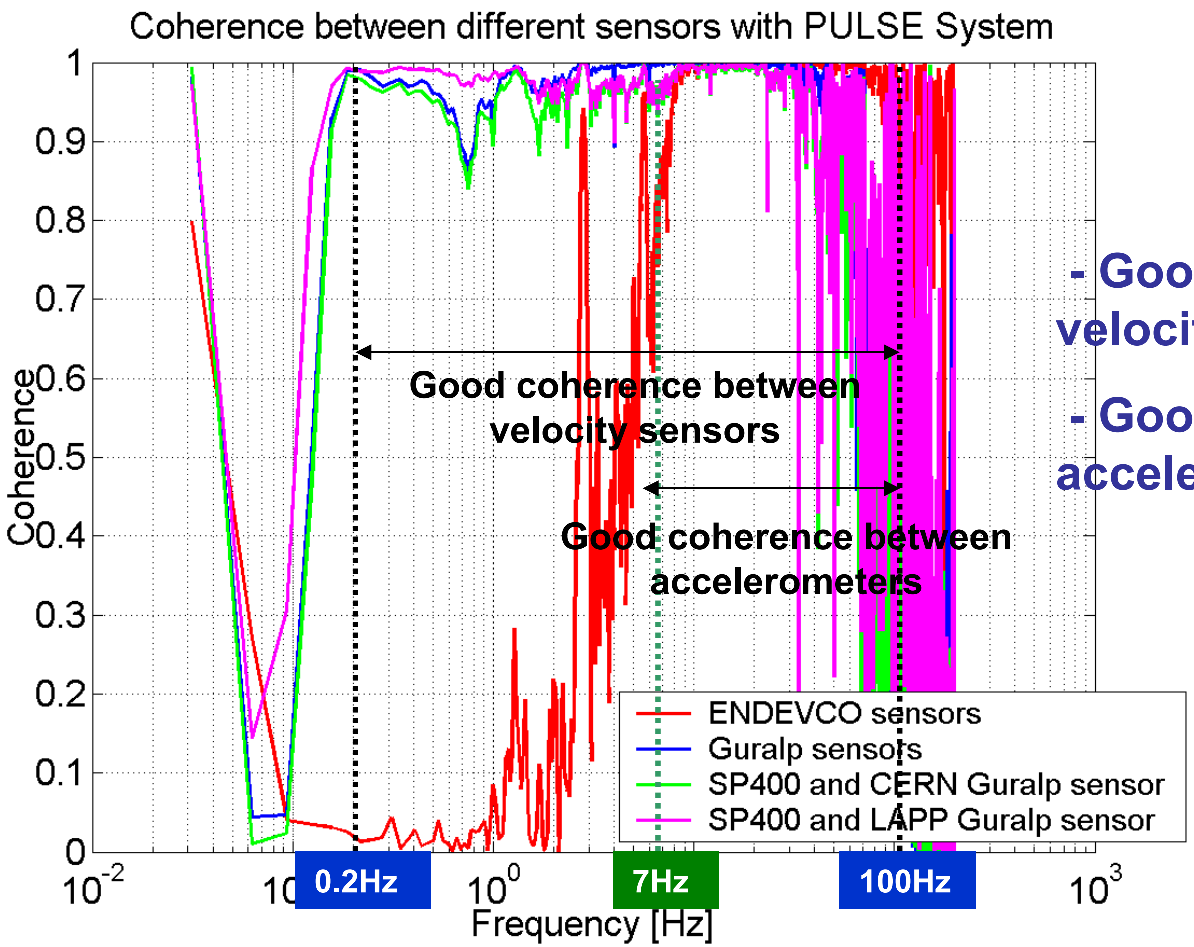
Velocity sensors VS accelerometers

$PSD[(m/s)^2/Hz]$



Frequency range of ENDEVCO : 0.01Hz-50Hz

5. Measurements



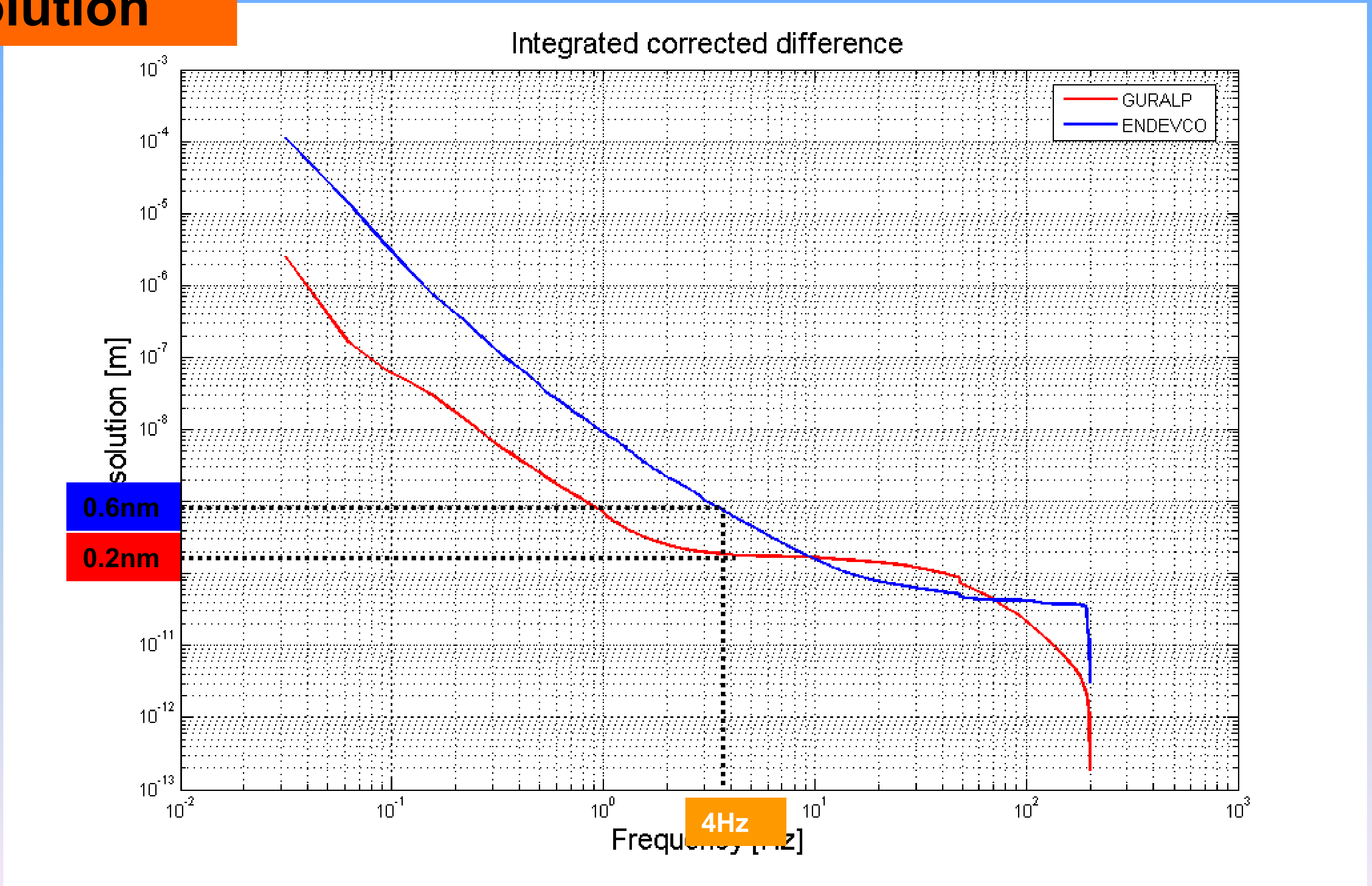
- **Good coherence between the 3 velocity sensors above 0.2Hz**
- **Good coherence between the 2 accelerometers only above 7Hz**

The accelerometers have the same amplitude as the velocity sensors and also a good coherence from 7Hz. Why not below?

Frequency range of ENDEVCO : 0.01Hz-50Hz

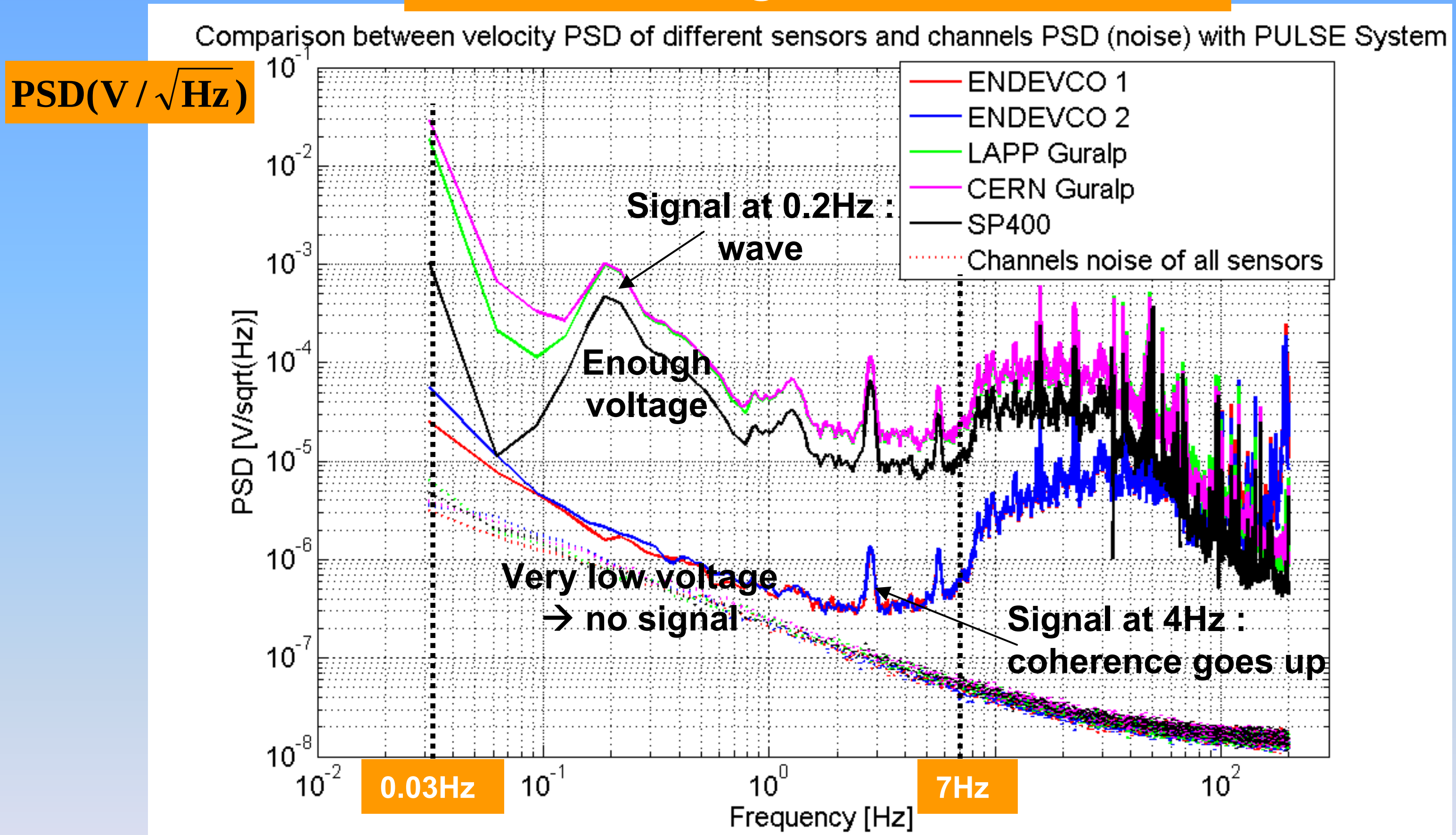
5. Measurements

Resolution



5. Measurements

Problem of Signal/Noise ratio

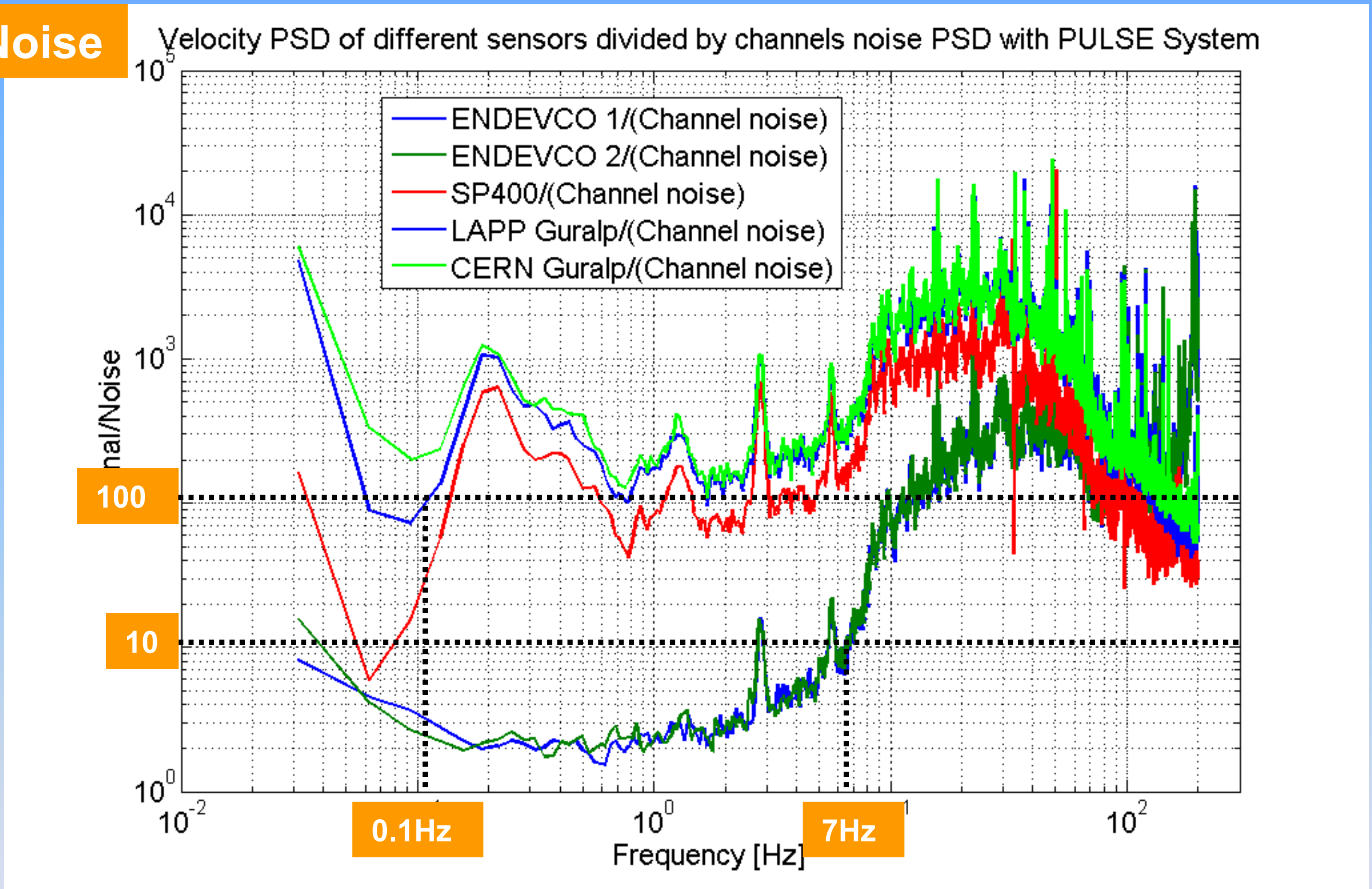


-Acceleration amplitude is very low and very close to ADC noise below 7 Hz : almost only noise is being measured

- Velocity amplitude is much higher than acceleration amplitude and than ADC noise below 7Hz : signal is being measured

5. Measurements

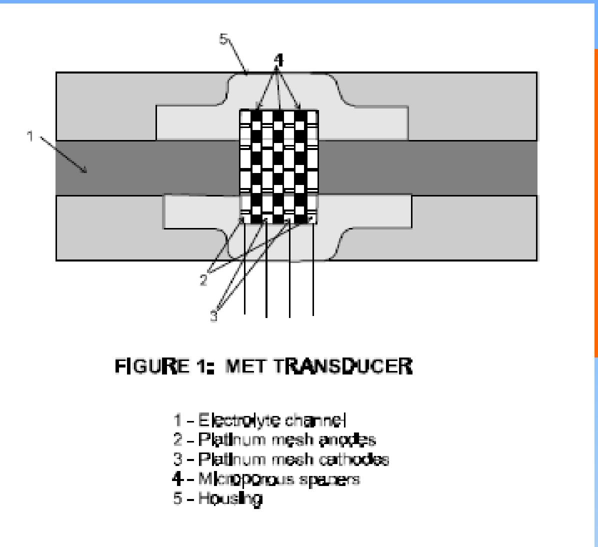
Signal/Noise



- For accelerometers, signal/(ADC noise) ratio is less than 10 below 7Hz : too low

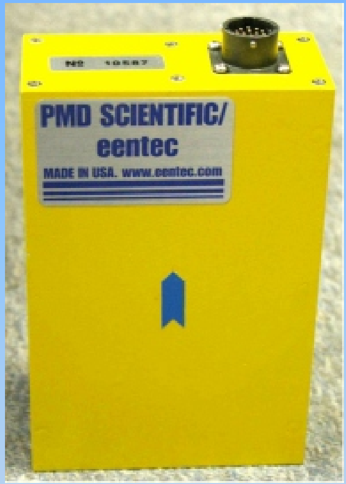
- For velocity sensors, this ratio is above 100 from 0.1Hz : quite high

5. Measurements



- 0.0167 to 75 Hz
- Non magnetic
- 20KV/(m/s)→very sensitive!!

SP500 sensors from EENTEC



Electrochemical motion sensor

- Special electrolytic solution
- Four platinum mesh electrodes (2 anodes and 2 cathodes)
- An external acceleration creates a differential pressure across the channel and forces the liquid to move with velocity V. Ions move to the electrodes .

1 Tesla testing

5. Measurements

Measurements with SP500 sensors done at SLAC by A. Seryi

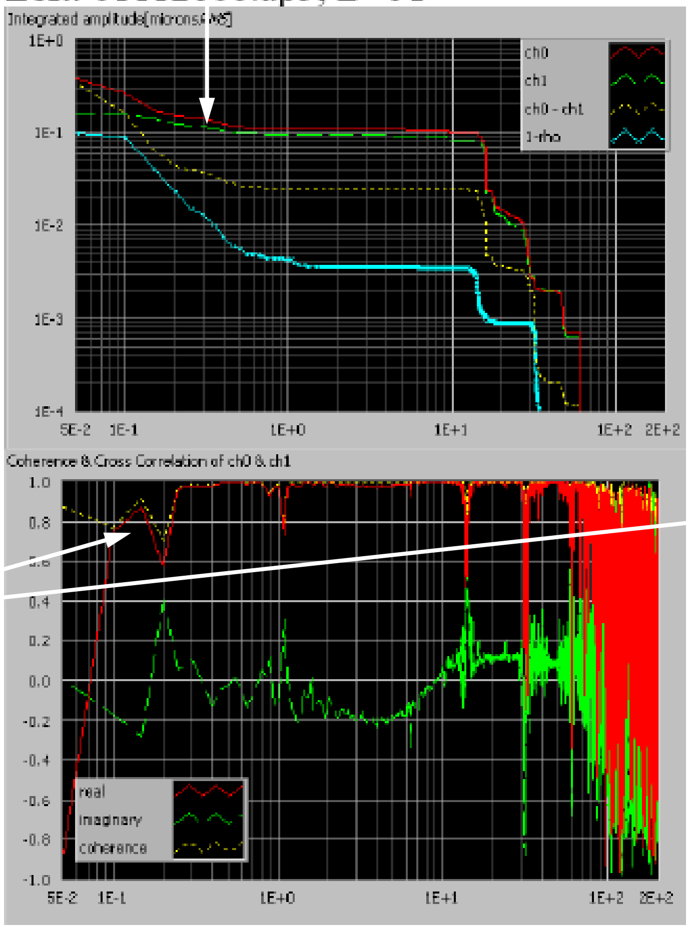
Both sensors in vertical direction

Same amplitude for the 2 sensors with B=0

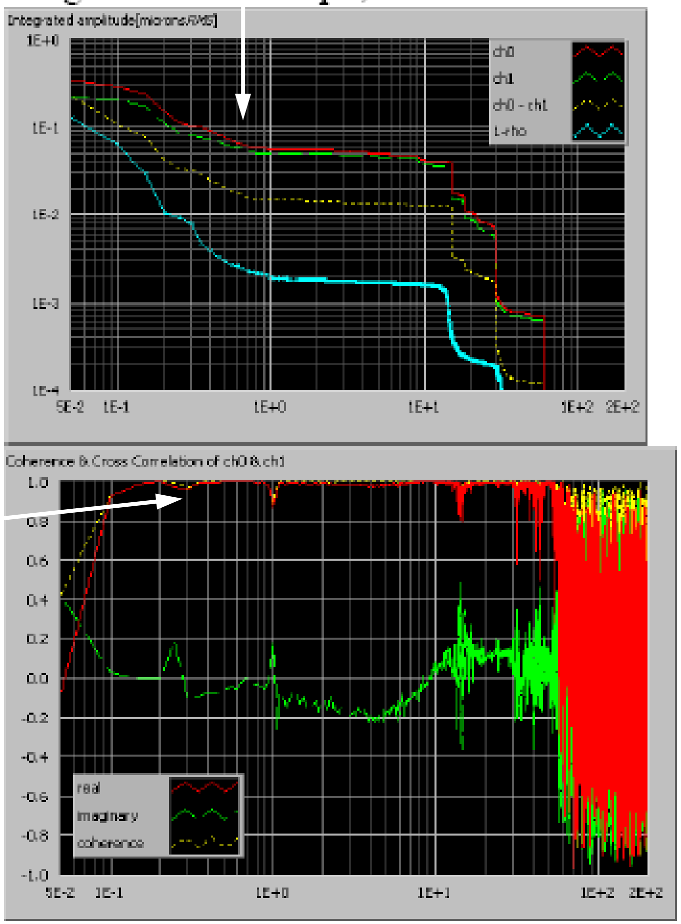
Same amplitude for the 2 sensors with B≠0

Same coherence with or without magnetic filed

Left: 01112600.ap5, B=0T

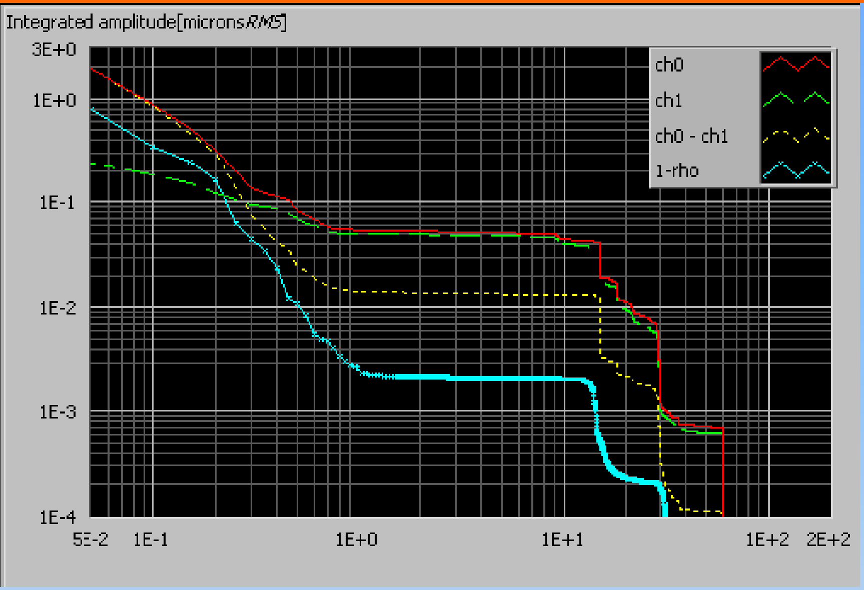


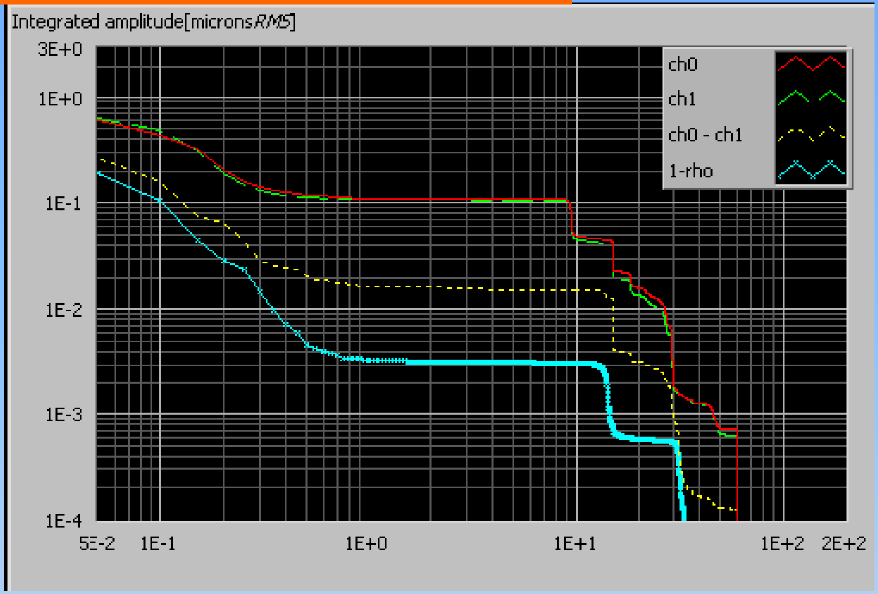
Right: 01115400.ap5, B= -0.995T



5. Measurements

Measurements with SP500 sensors done at SLAC by A. Seryi





Variations of condition in the building is demonstrated above with B=0 , where 2 consecutive measurements are shown. Variation of conditions is noticeable and explains difference of spectra measured with and without magnetic field.

Conclusion : - No visible influence of high magnetic field on the MET sensors

- Very small size and high sensitivity : 20KV/(m/s)→Signal/Noise ratio : high → we hope that they can measure below 0.1 Hz

- Can be the sensors used for our prototype

5. Measurements

Conclusion

With accelerometers, we are not able to measure ground signals less than 7 Hz even if the frequency range begins at 0.01 Hz :

- Ground acceleration is too small at low frequencies

- ADC noise is high at low frequencies

→Signal/Noise ratio too small at low frequencies

→**Solution :** an acquisition system with less noise at low frequencies or a sensor with a bigger sensitivity (more than 10V for 1g), but that is difficult to find on the market

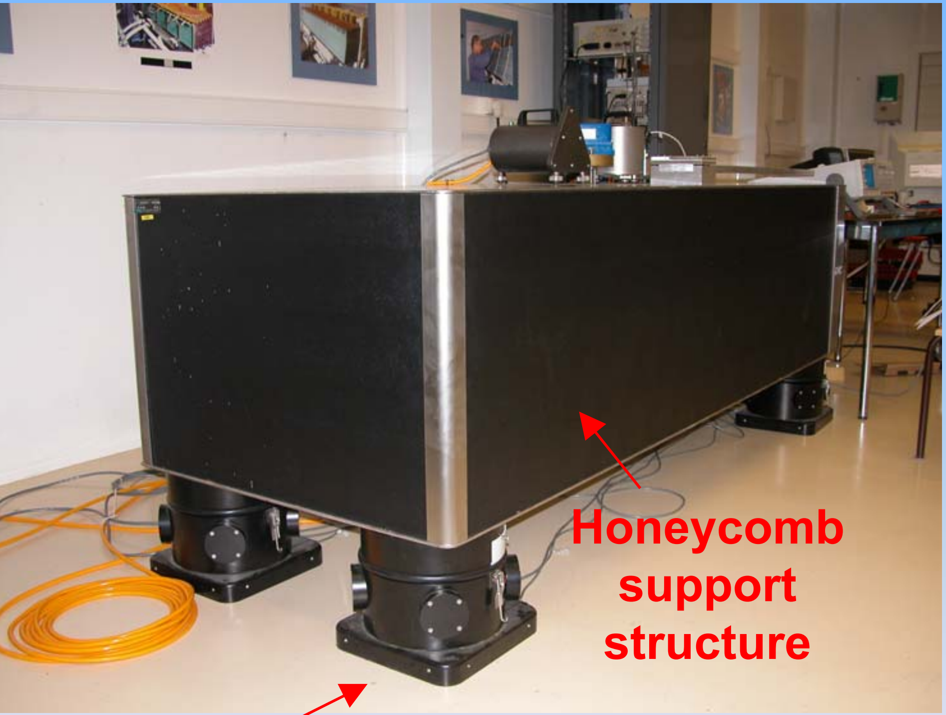
With velocity sensors, we are able to measure ground signals above 0.2 Hz :

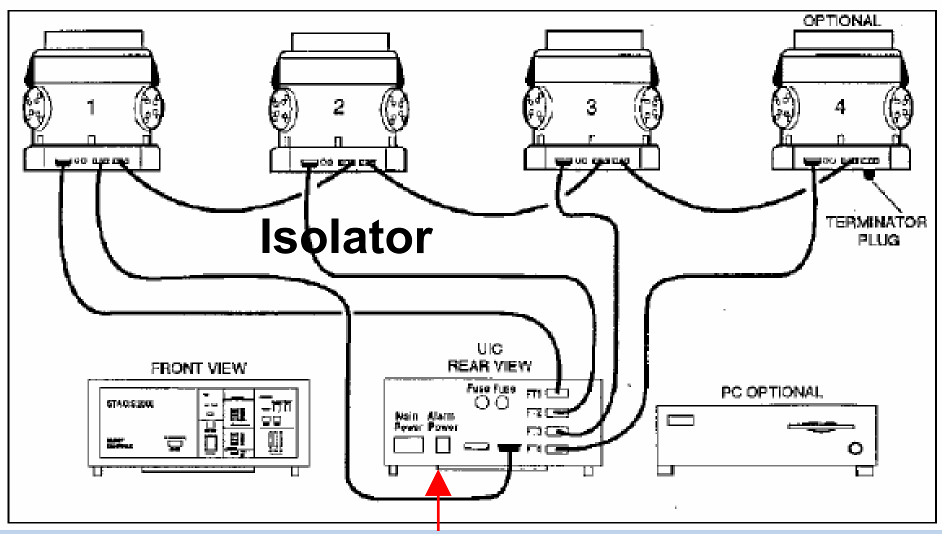
- Ground velocity is much higher than ADC noise and than ground acceleration at low frequencies

→ Signal/Noise ratio big at low frequencies

6. Stabilization techniques @ LAPP

Stabilization of the ground motion with the STACIS 2000 Stable Active Control Isolation System



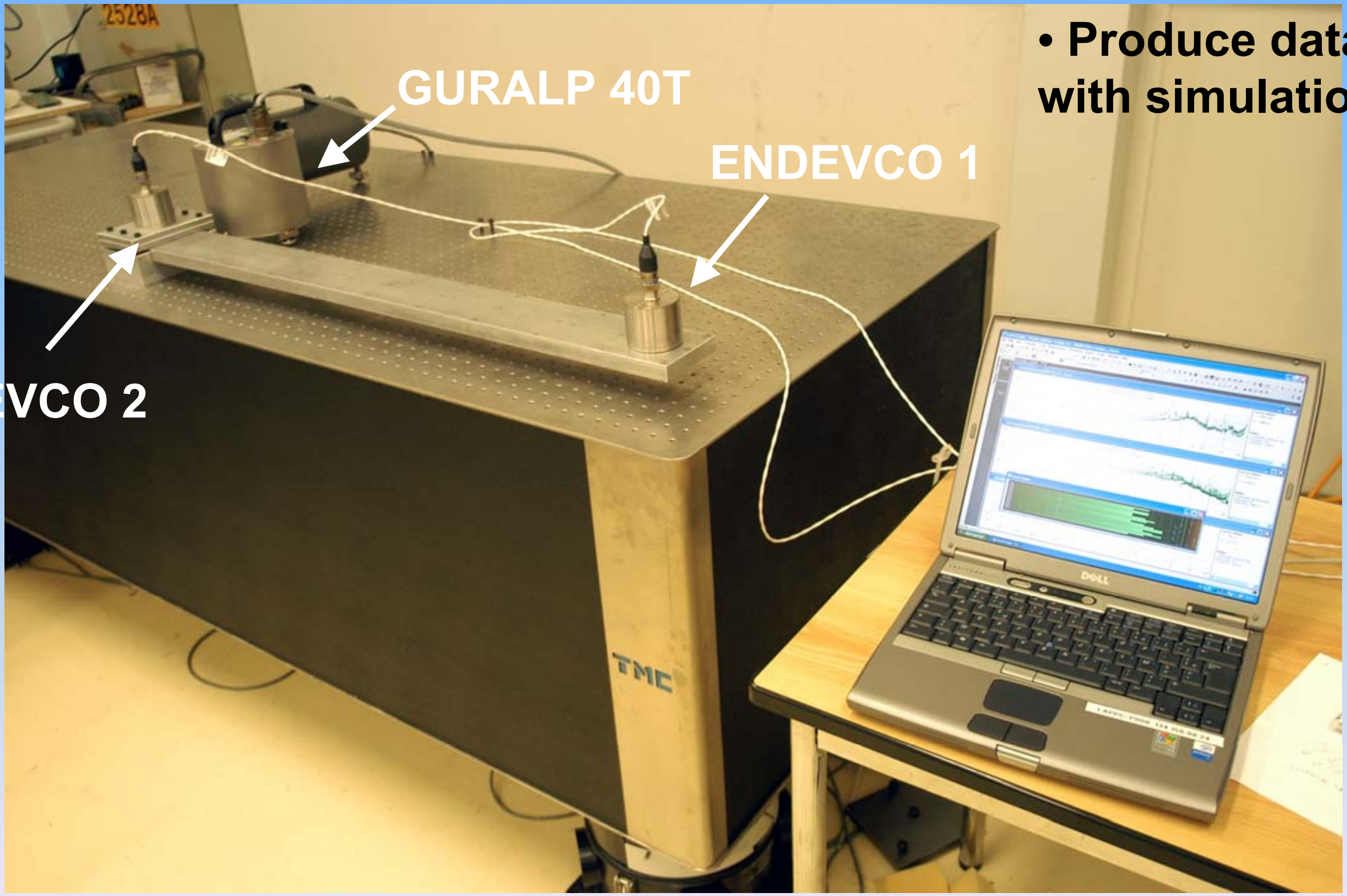


User Interface Controller : to provide communications with and diagnostics of the STACIS 2000 system

Isolators : contain all the necessary electronics, vibration detection and correction devices, along with passive Isolators. For each isolator, a geophone measures vibration until a piezoelectric actuator makes correction.

6. Stabilization techniques @ LAPP

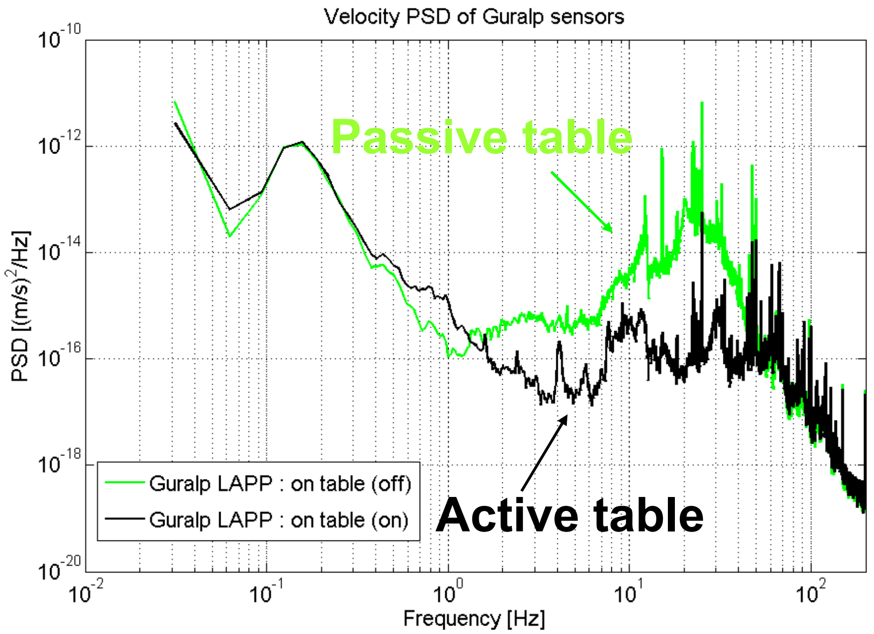
- Evaluate table action
- Produce data to compare with simulation



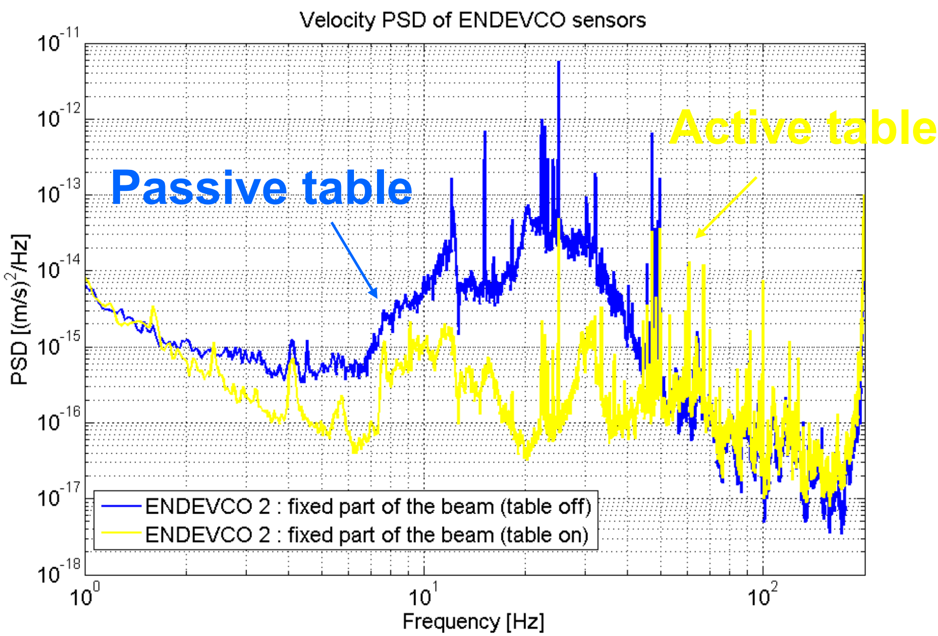
6. Stabilization techniques @ LAPP

Guralp sensor

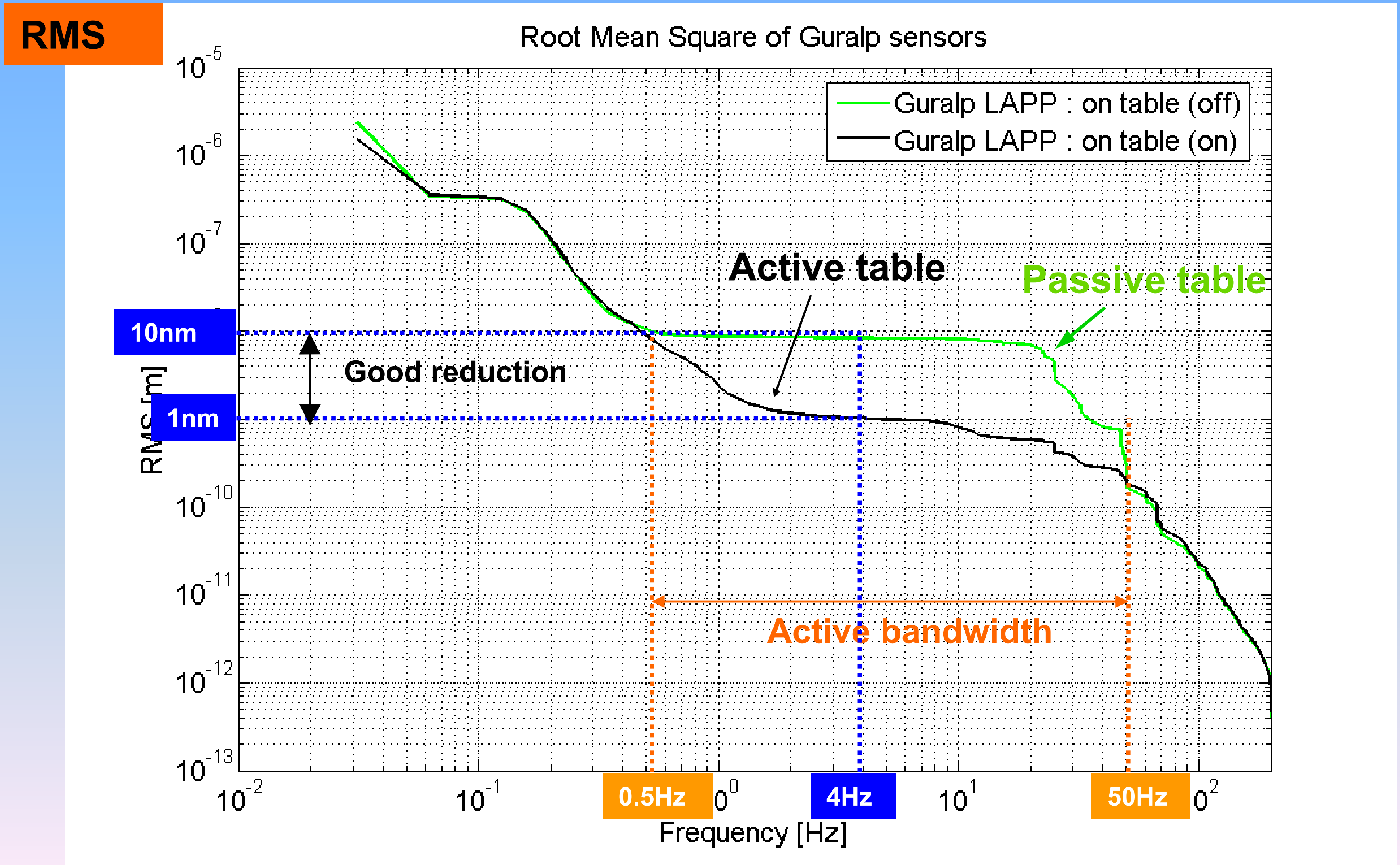
Velocity PSD



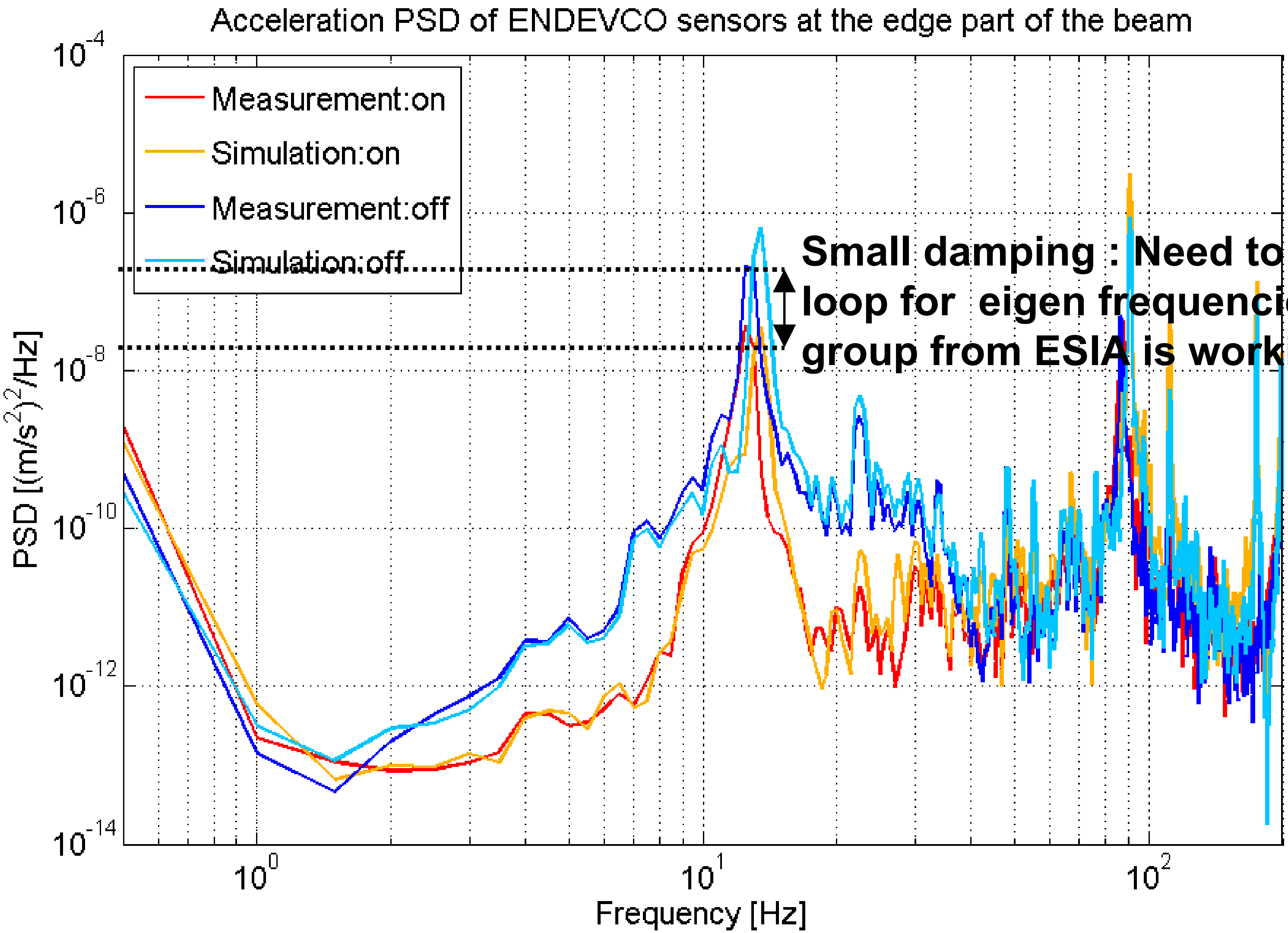
Accelerometers



6. Stabilization techniques @ LAPP

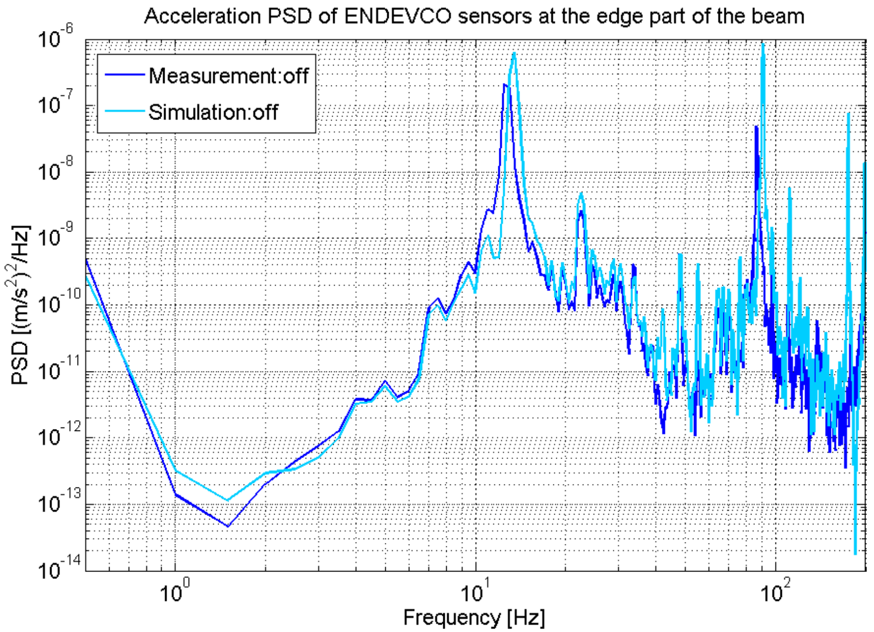


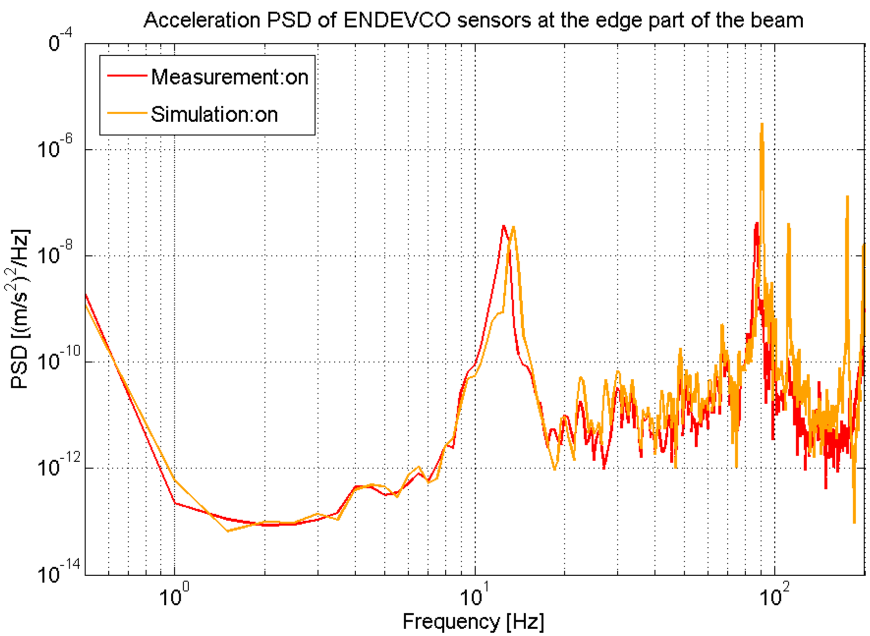
6. Stabilization techniques @ LAPP



Small damping : Need to use a special loop for eigen frequencies (LISTIC group from ESIA is working on that)

6. Stabilization techniques @ LAPP

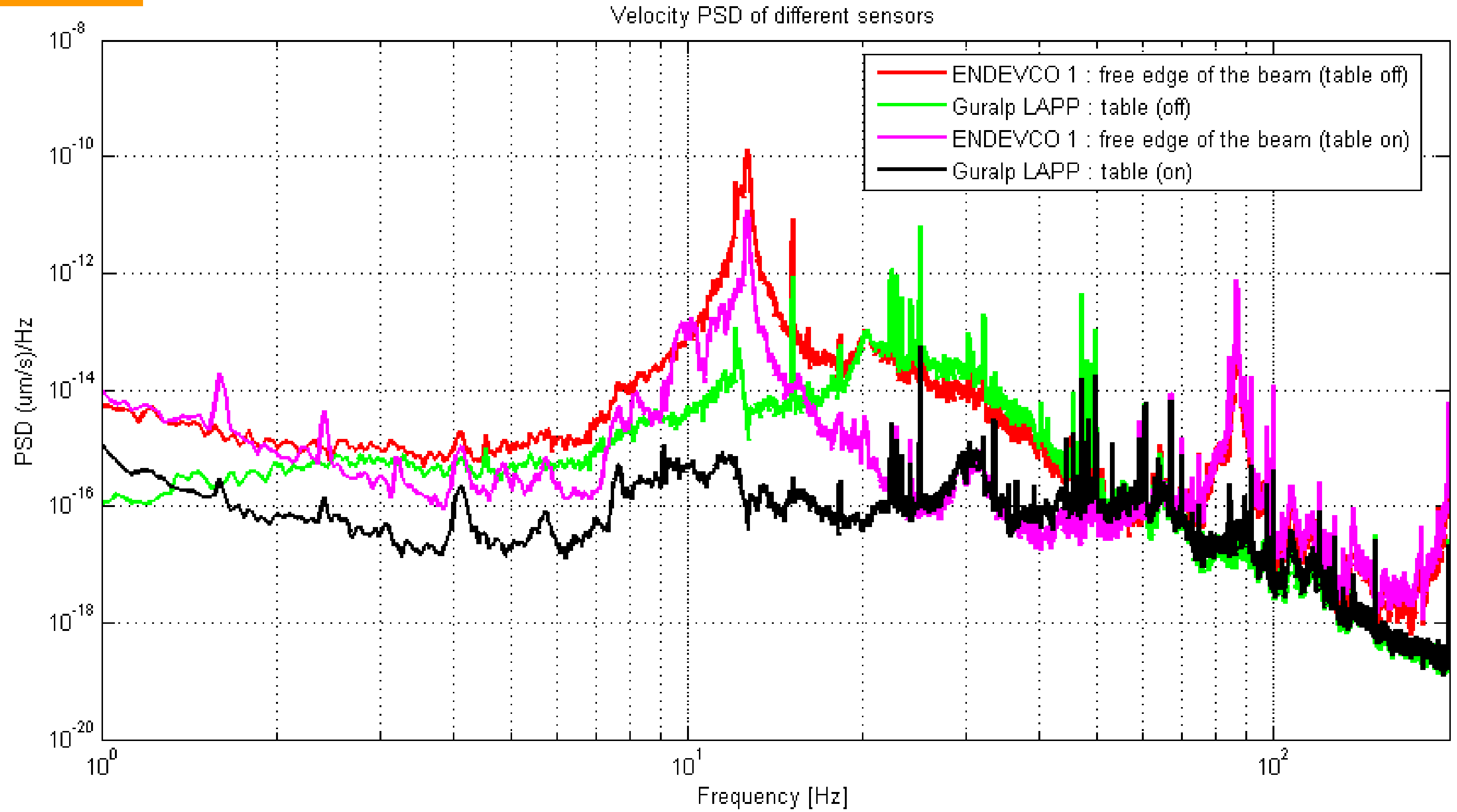




Benoit BOLZON

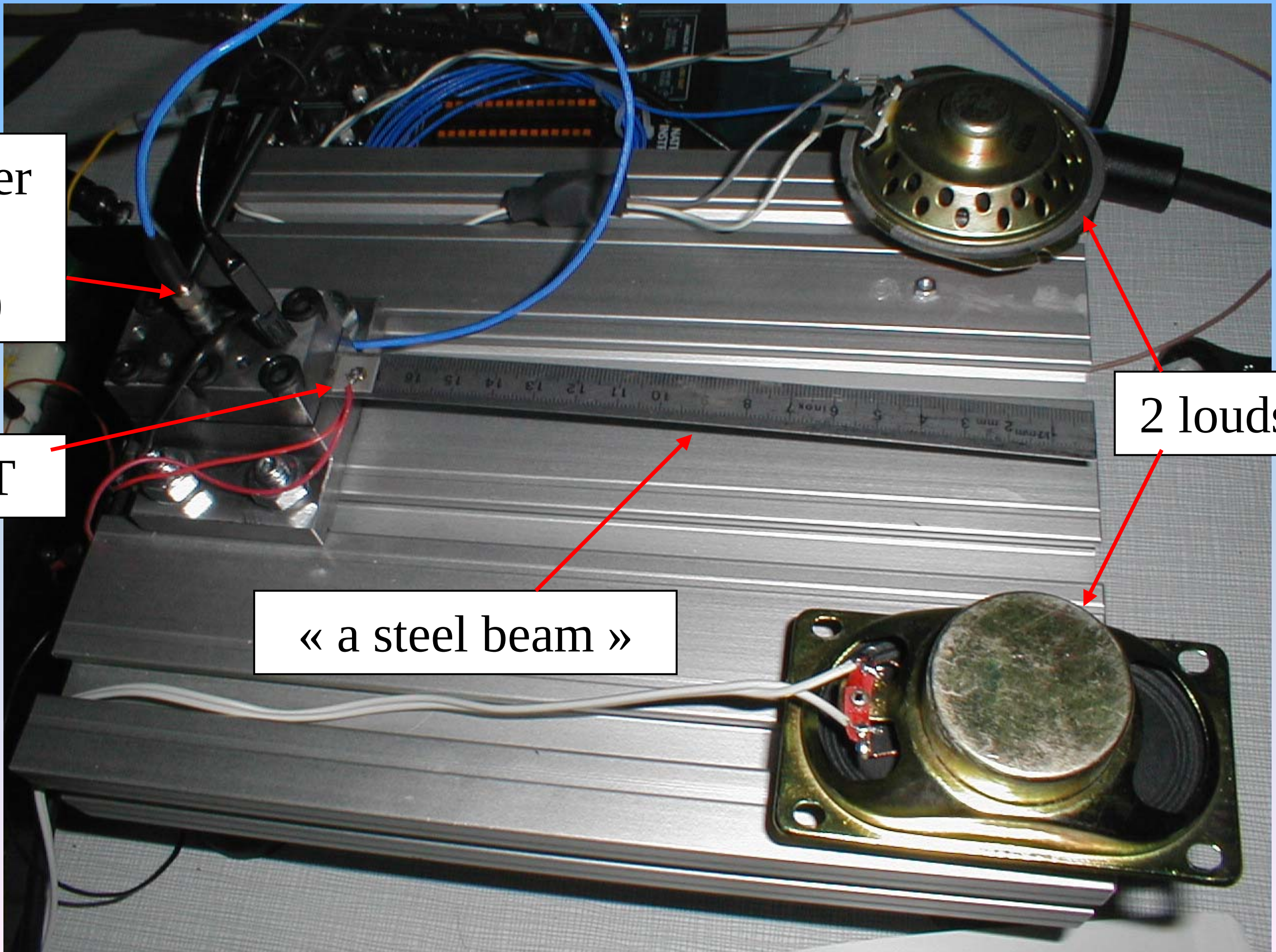
6. Stabilization techniques @ LAPP

Summary



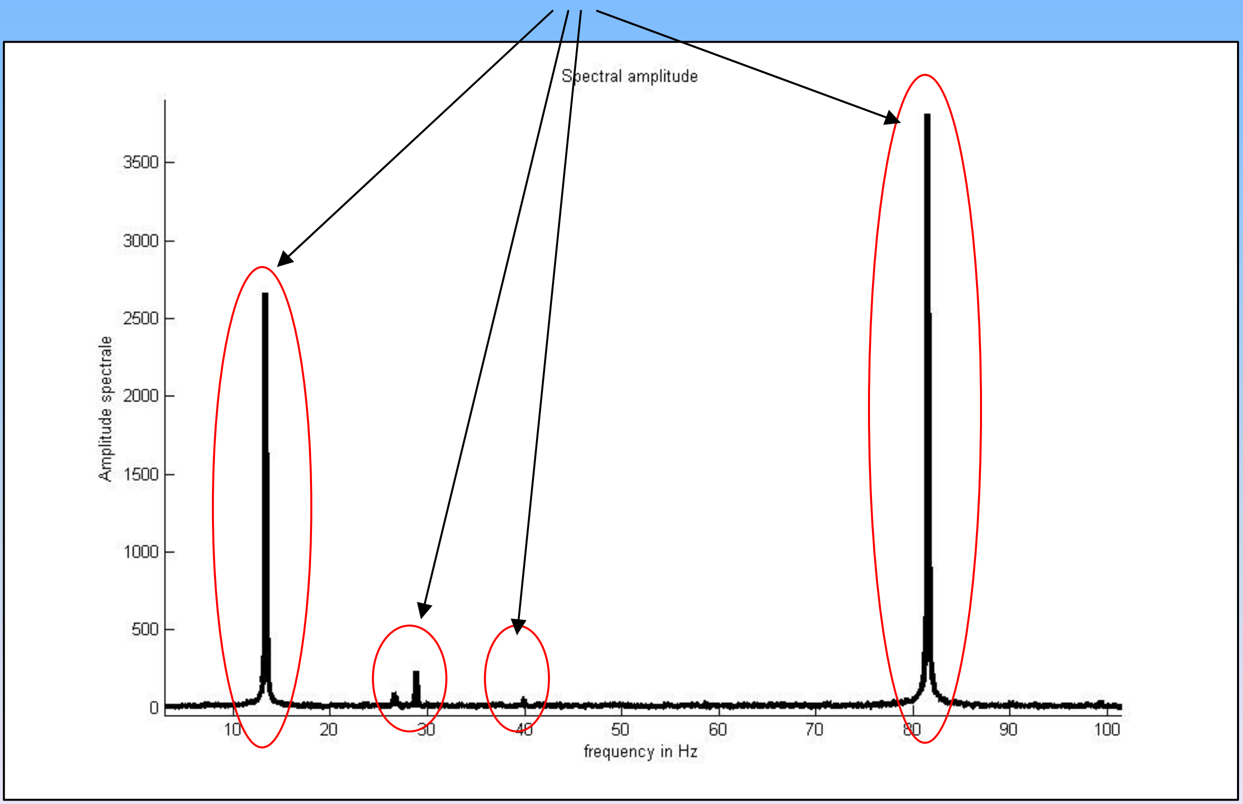
7. Stabilization techniques @ LISTIC

Experiments



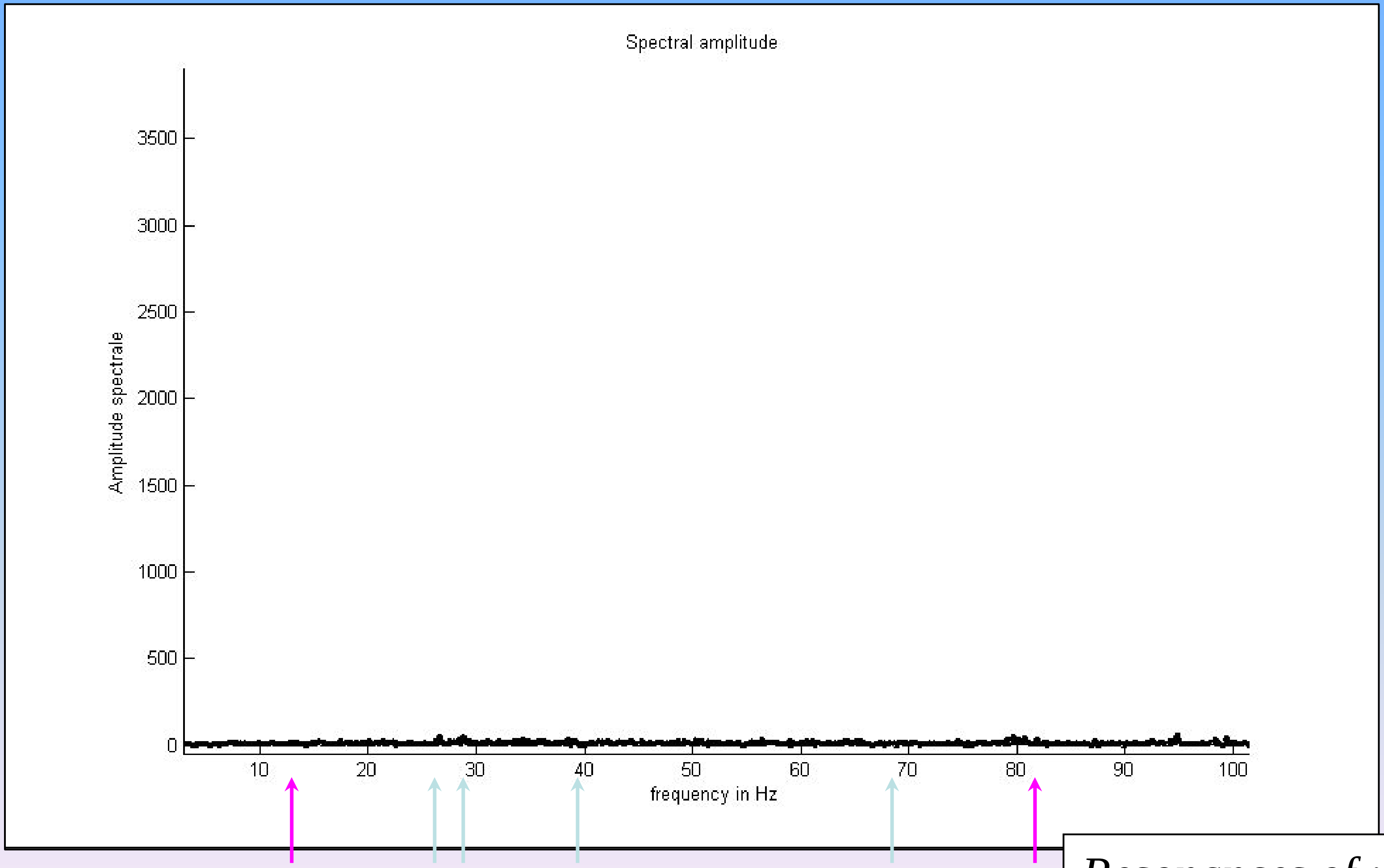
7. Stabilization techniques @ LISTIC

Current objectives: Independently reduce the main resonances



For example, an identification of one mock-up…

Rejection of 6 resonances : (without and with rejection)



Resonances of : *-beam* *-support*

CONCLUSION AND FUTURE

→ Future measurements

- **Smaller SP400 sensors are available at SLAC : should be the sensor used for the prototype because of its non-magnetic properties**
- **B field measurement at CERN**
- **Better understanding of the STACIS table : perhaps buy the next generation of our User Interface Controller for its adjustable parameters**