Informal Workshop

"Galileo Galilei (GG) and GGG lab prototype: state of the art and new possibilities"

10-12 February 2010, Pisa and San Piero a Grado

Capacitance sensing electronics: state of the art worldwide, current status in GGG and prospects for improvement

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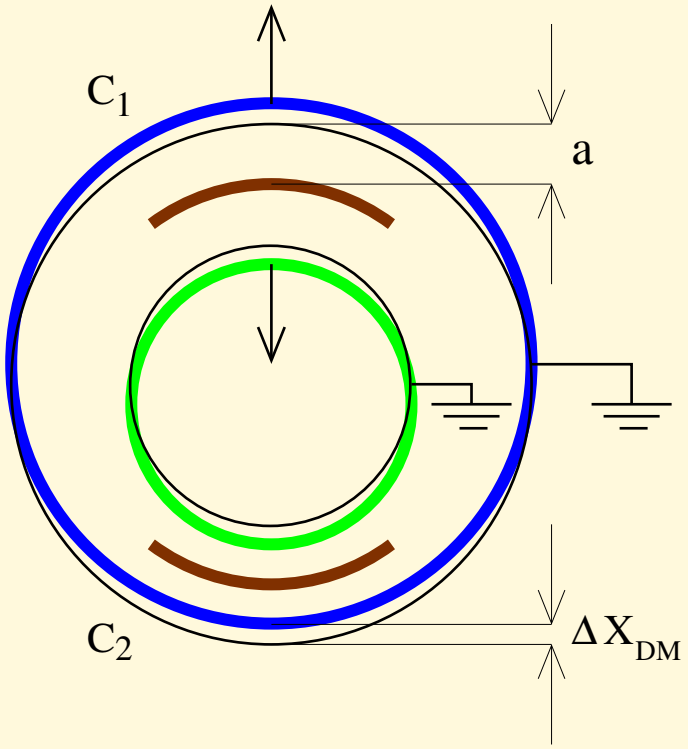
OUTLINE

- GGG (and GG) capacitive displacement sensor.
- The noise level of the GGG capacitance bridge
- The noise level of ONERA capacitance bridge.
- The noise level of the new GGG Capacitance bridge under developement.

The two capacitance sensor of the bridge of GGG.



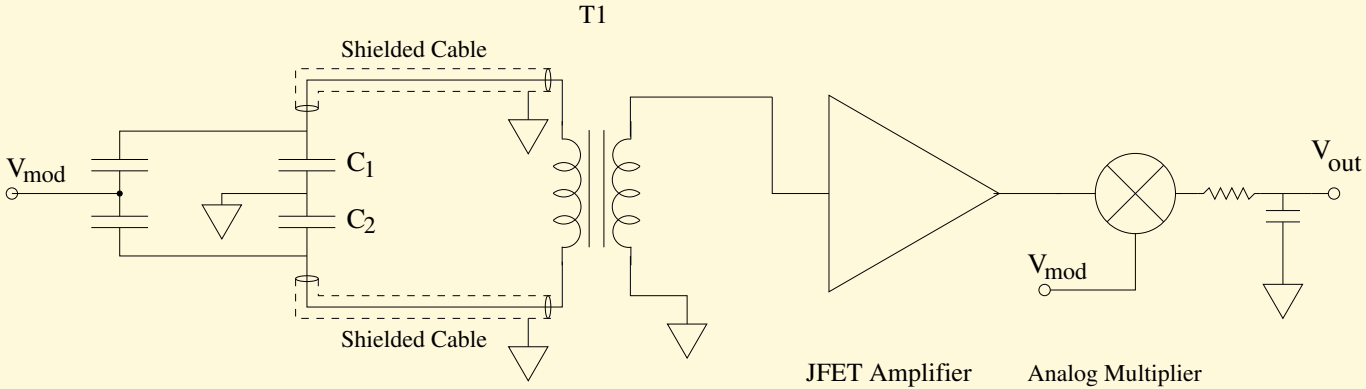
$$\frac{\Delta C}{2C_0} \simeq \frac{\Delta X_{DM}}{a}$$

In GGG: $C_0 \simeq 100$ pF and a$\simeq 1$ mm

With $\Delta C_n \simeq 10^{-7}\text{pF}/\sqrt{(\text{Hz})}$

$\Delta X_{DM} \simeq 0.5 \cdot 10^{-12}\text{m}/\sqrt{(\text{Hz})}$

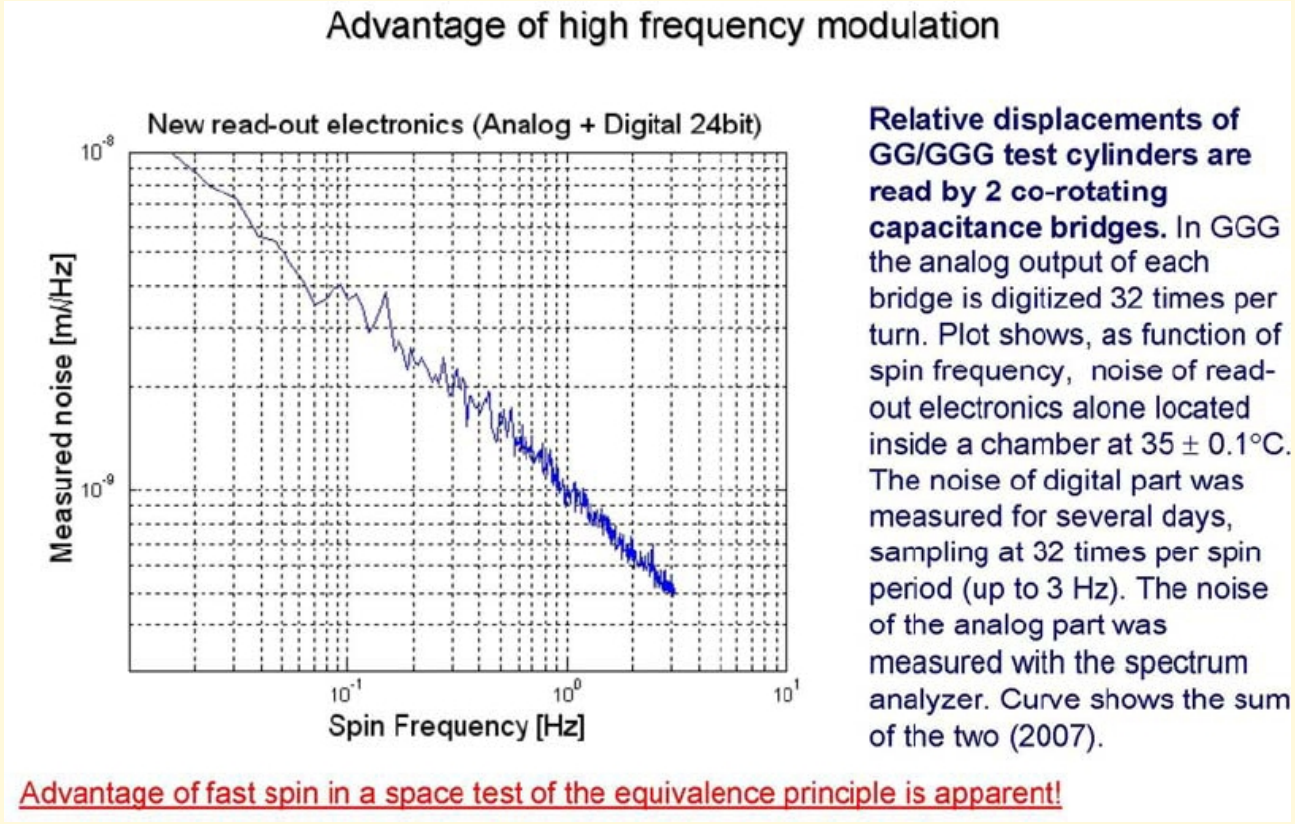
Simplified schematics of the GGG bridge



- The transformer acts as a balanced to unbalanced converter.
- The JFET amplifier is a voltage amplifier.
- The lock–in amplifier is based on an analog multiplier IC.

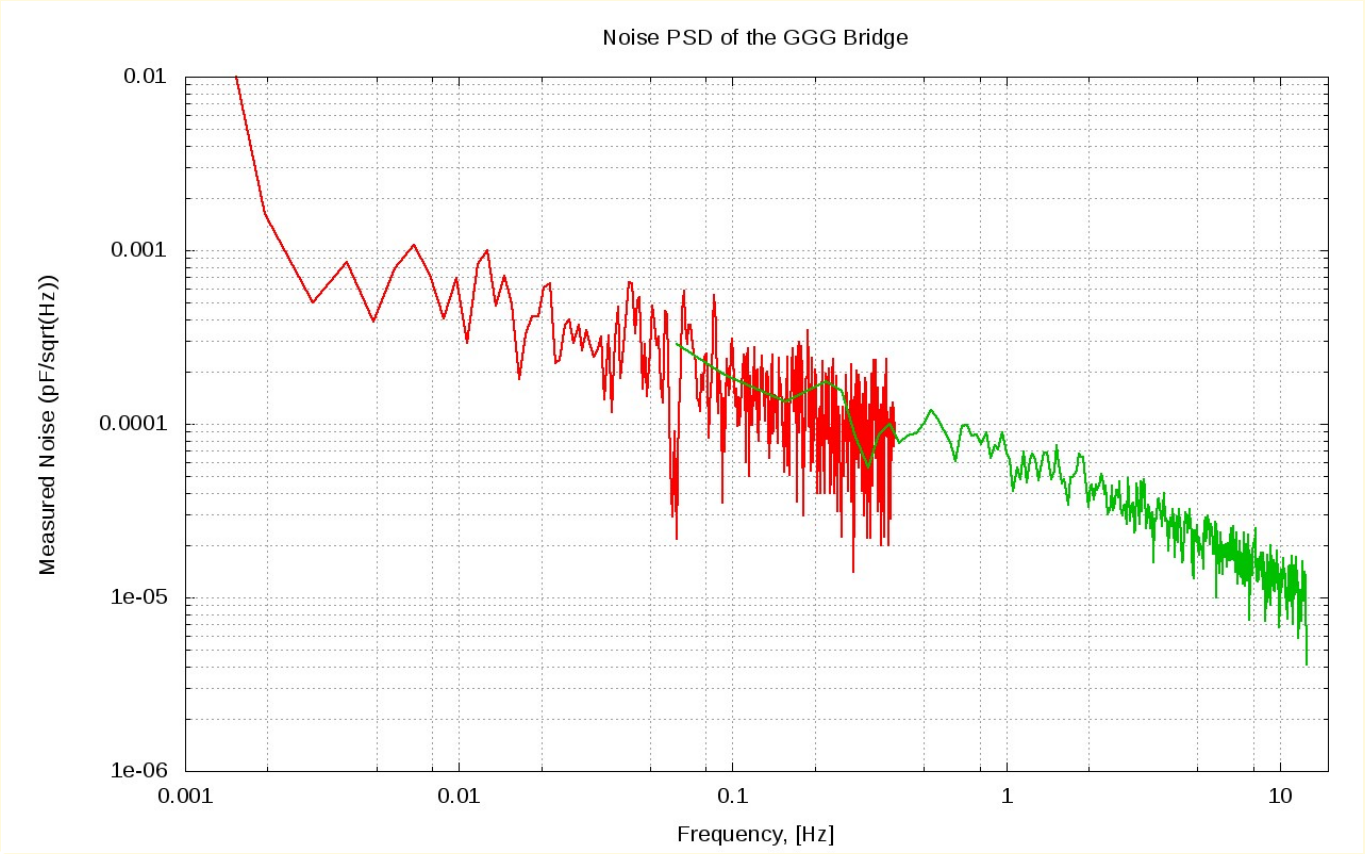
Measured noise of the GGG bridge.

$\sim 10^{-4} pF/\sqrt{Hz}$ at ~ 0.17 Hz, it does not limit the performance of GGG.



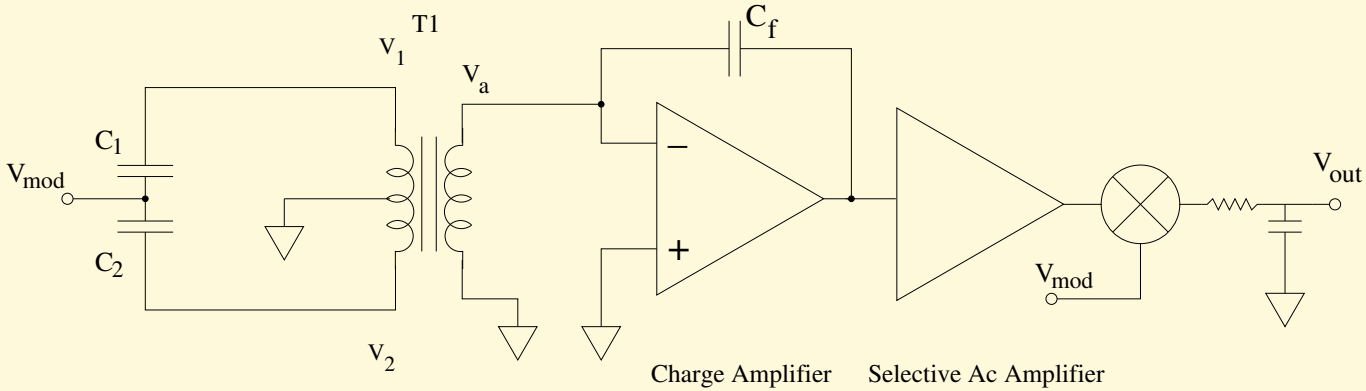
Measured noise of the GGG bridge.

Modified version, the performance is the same.
$\sim 10^{-4} pF/\sqrt{Hz}$ at ~ 0.17 Hz, it does not limit the performance of GGG.



Simplified schematics of the ONERA bridge

V. Josselin et al. Sensors and Actuators **78** (1999) 92–98.



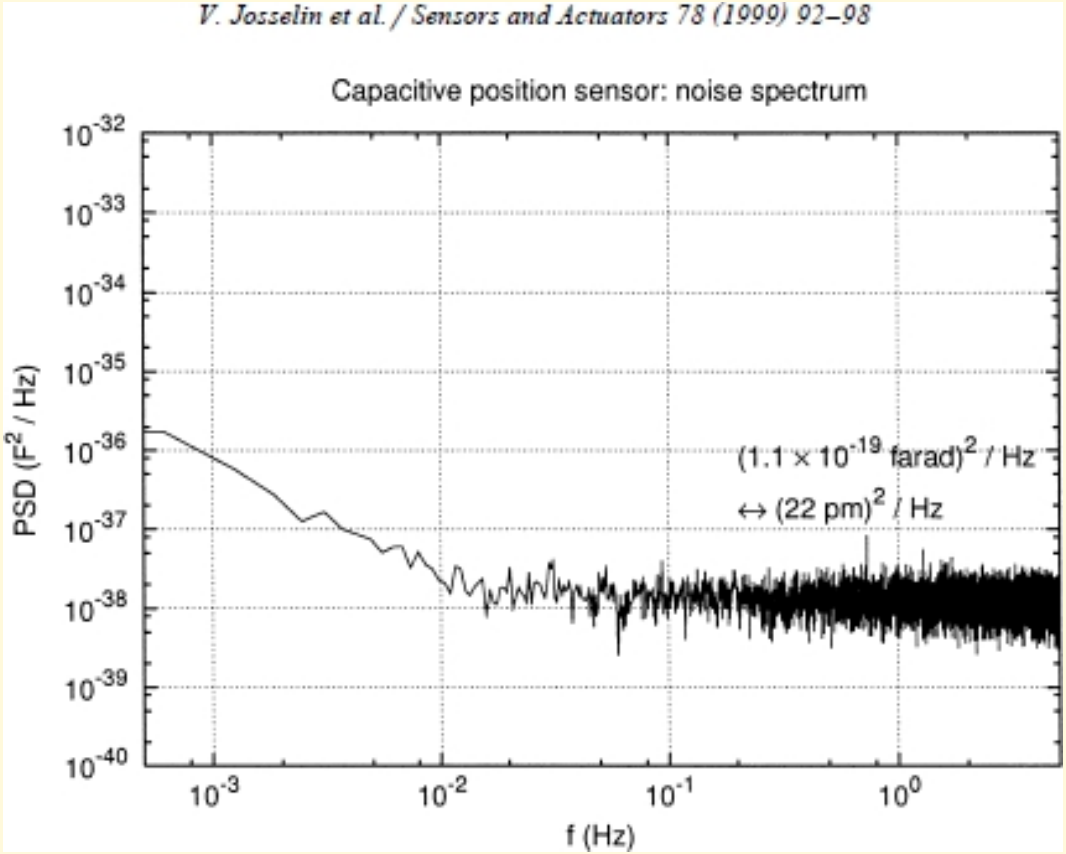
- The test mass is connected to the modulating signal.
- The primary of the transformer is connected to ground.
- The transformer is part of the bridge.
- The charge amplifier is a current amplifier.

Published noise of the ONERA bridge.

V. Josselin et al. Sensors and Actuators **78** (1999) 92–98.

$\sim 10^{-7} pF/\sqrt{Hz}$ down to $\sim 10^{-2}$ Hz corresponding to $\sim 22 \cdot 10^{-12} m/\sqrt{Hz}$.

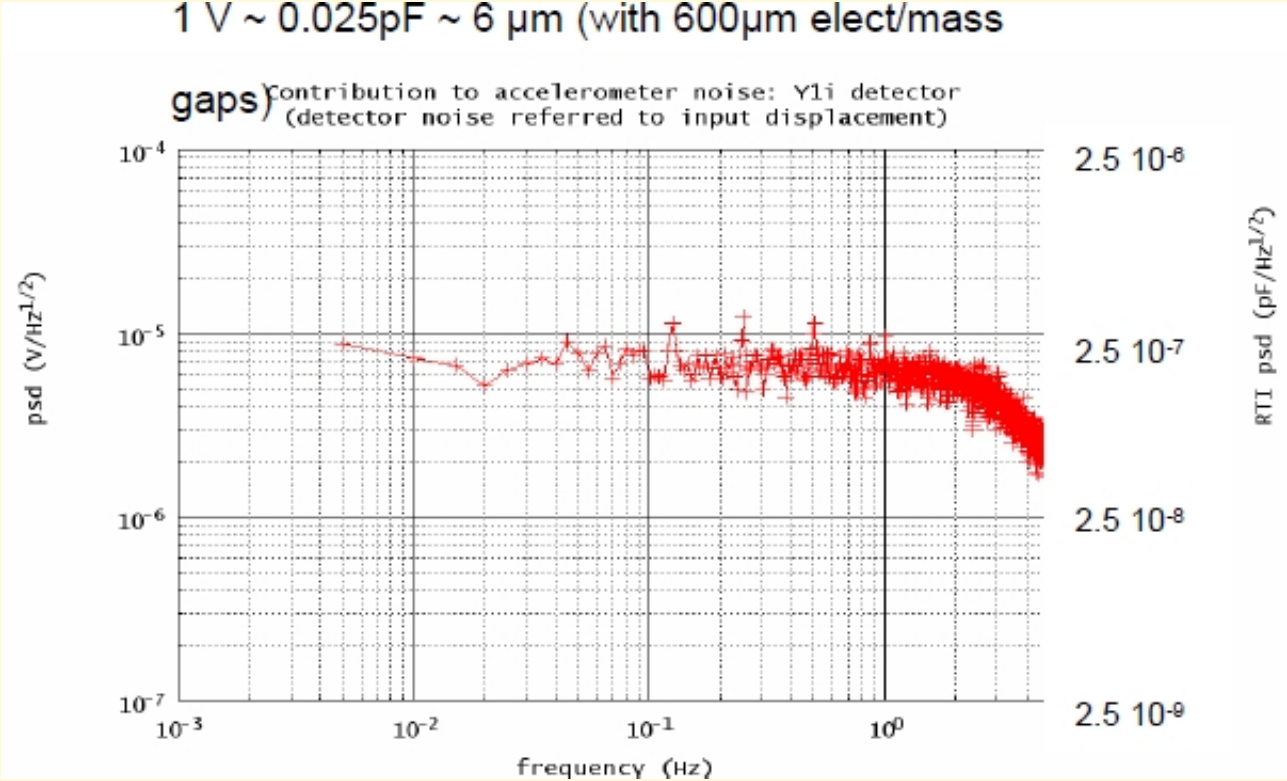
LISA noise is $\sim 2 \cdot 10^{-9} m/\sqrt{Hz}$ down to $\sim 10^{-4}$ Hz.



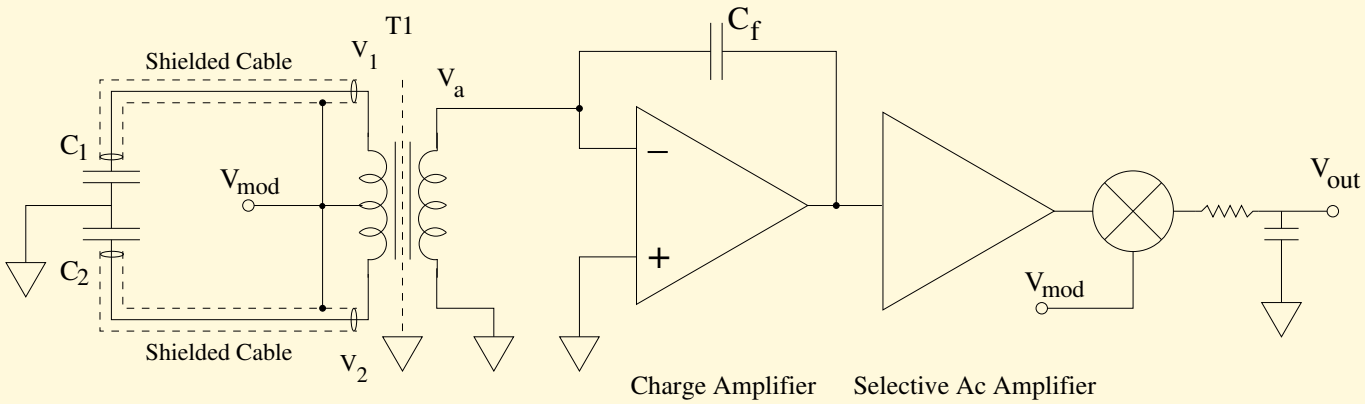
MICROSCOPE bridge noise.

From a recent talk given in Les Houches, October 20—22, 2009 by Manuel Rodrigues. Based on the same ideas as the ONERA bridge.

$$\sim 2.5 \cdot 10^{-7} pF/\sqrt{Hz} \text{ down to } \sim 5 \cdot 10^{-3} \text{ Hz.}$$



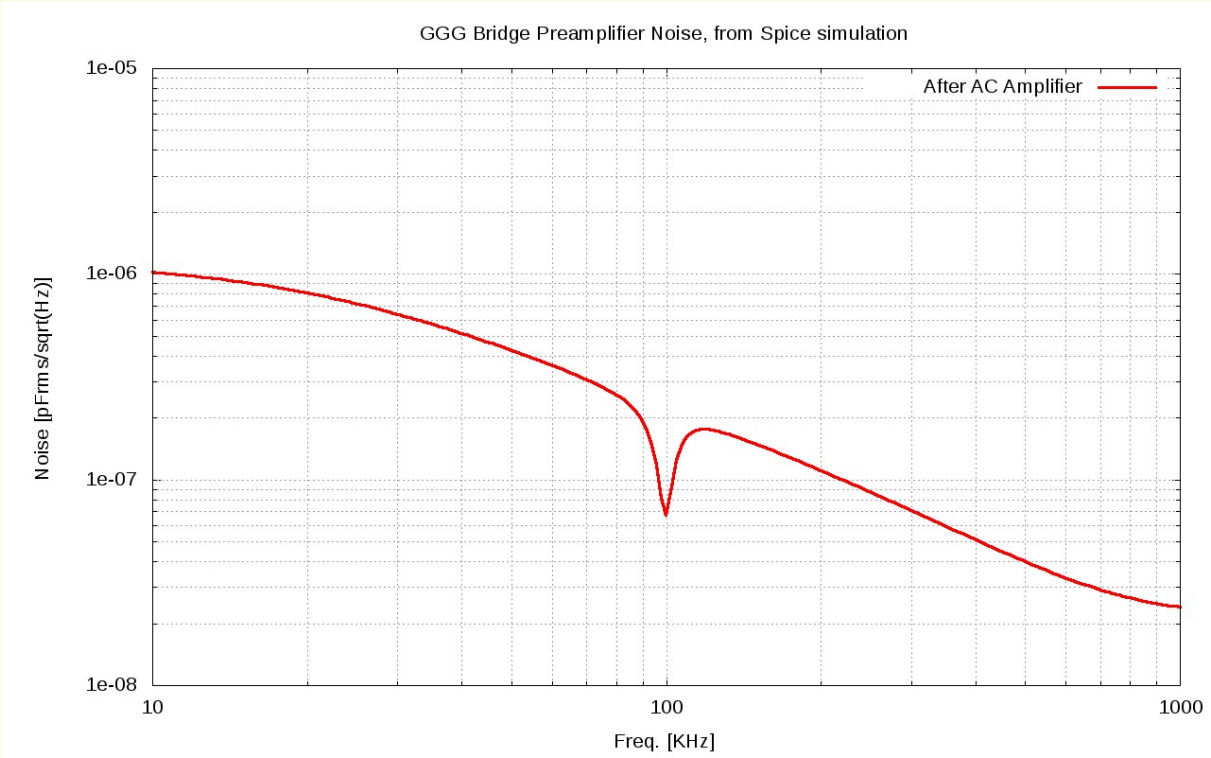
Simplified schematics of the new GGG bridge



- We have modified the ONERA circuit.
- The two GGG test masses are connected to the electrical ground.
- The primary of the transformer is connected to the Mod. signal.
- Redesign of the transformer.
- We are now using a commercial lock–in amplifier.

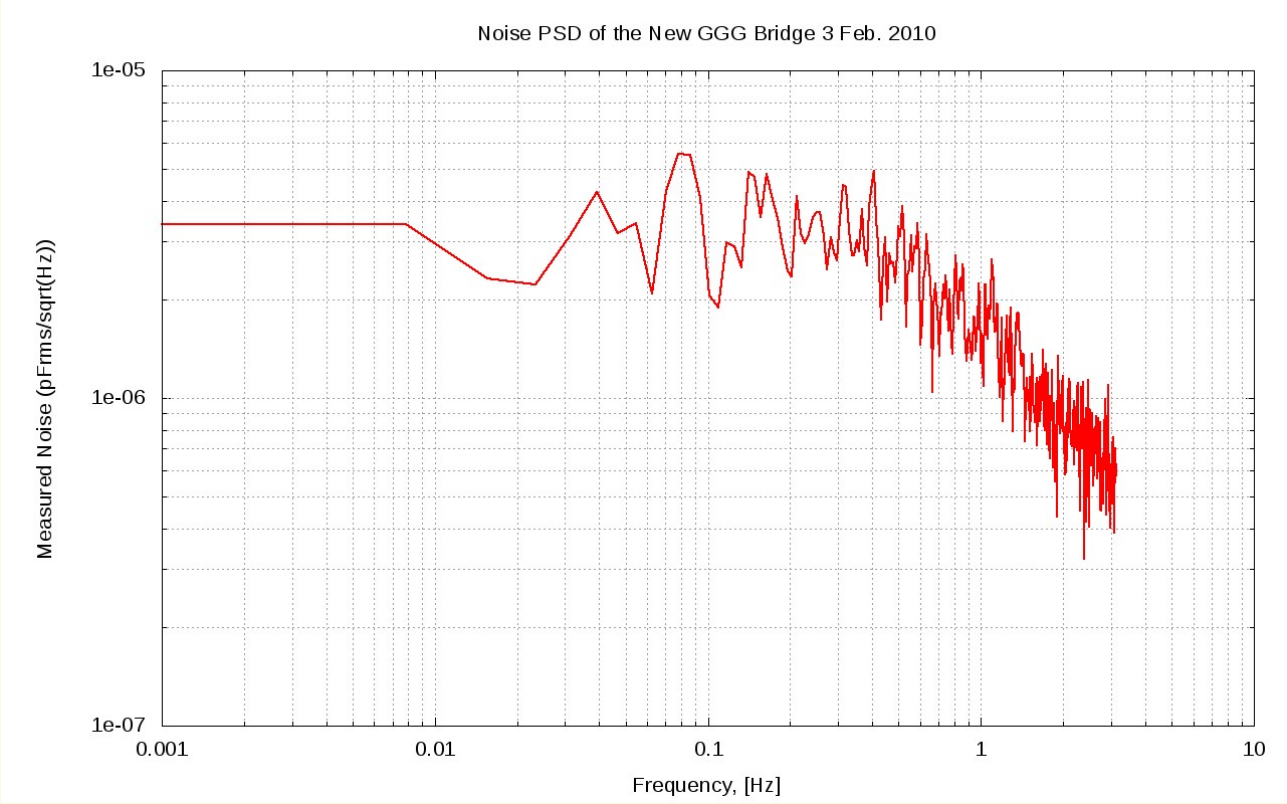
Results of Spice simulation of the new GGG bridge.

Noise of the modulated signal after the preamplifier.
At the modulation freq. of 100 KHz the simulated noise is $\sim 10^{-7} pF/\sqrt{Hz}$



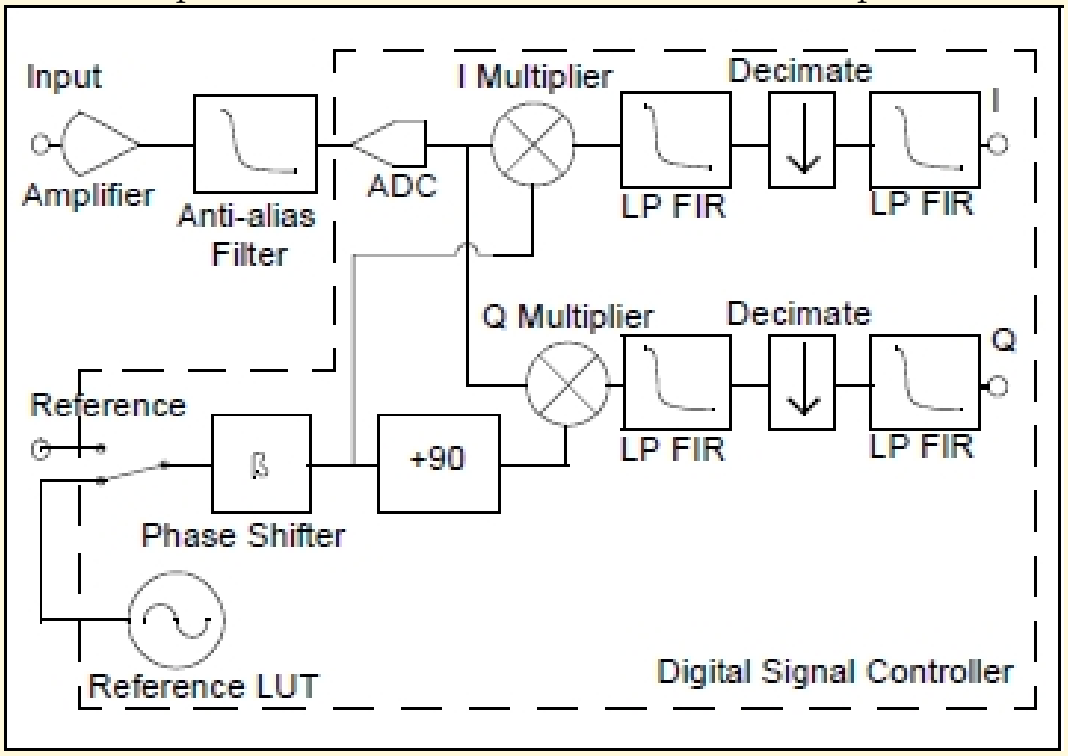
Measured noise of the new GGG bridge prototype

Noise of the demodulated signal. Integration time is 3 sec. that is $f_c \simeq 0.33$ Hz
Obtained a few days ago, $\sim 5 \cdot 10^{-6} pF/\sqrt{Hz}$ at ~ 0.17 Hz, to be improved.



We need a digital lock–in amplifier.

Analog mixers ICs are limited in terms of dinamic range and noise. A digital lock–in amplifier will provide the requested performance. Digitisation of the modulated ($\simeq$100 KHz) preamplifier signal at 2Ms/sec, 24 bits.
DSP implemented in an FPGA or in a microprocessor.



Present status and Next steps

Present status:

- These are preliminar results.
- Only the "front–end" part of the bridge has been tested, we have used a commercial lock–in amplifier.

Next steps:

- Improve the noise performance and stablity of the circuit.
- Design the Digital lock–in amplifier circuit block.