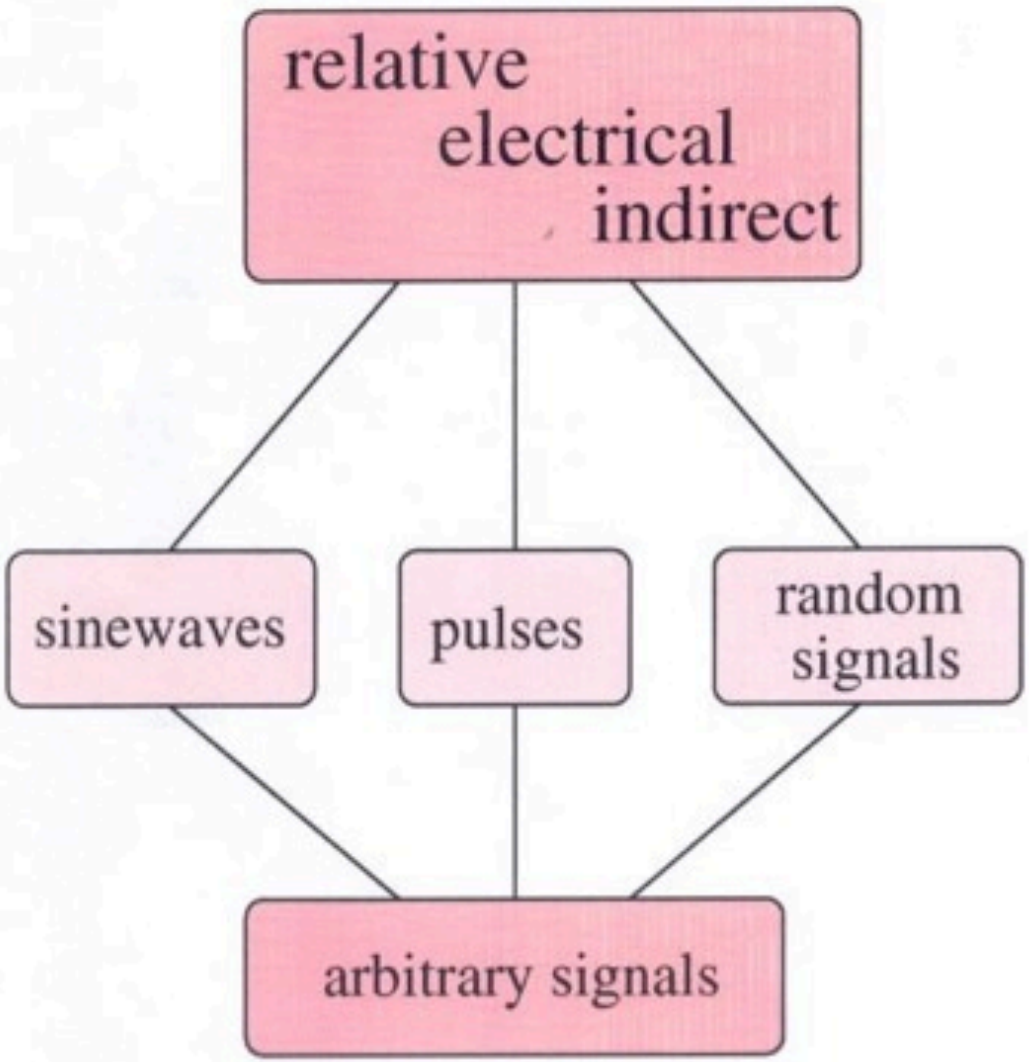
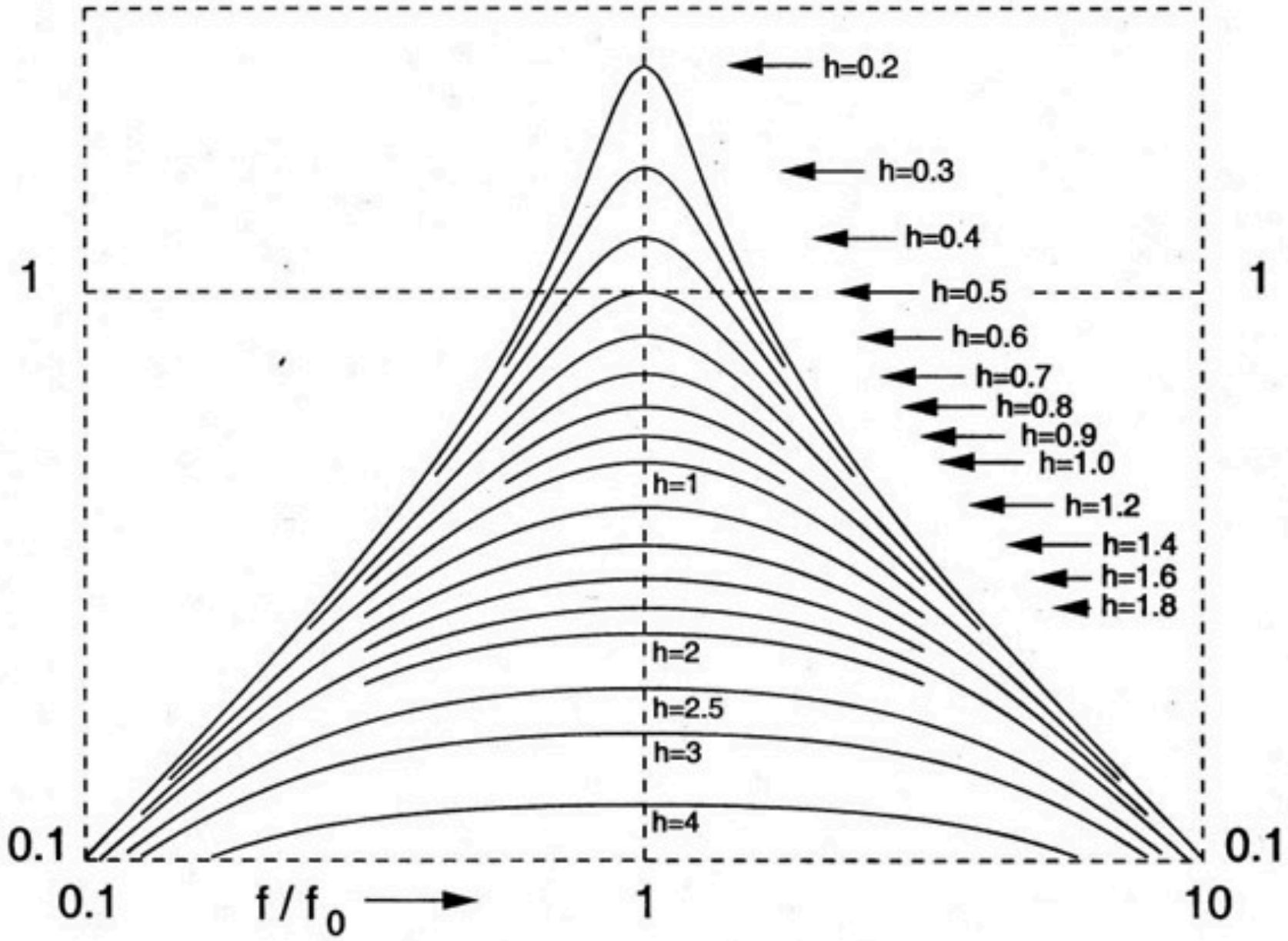
Modern Seismometers
Calibration

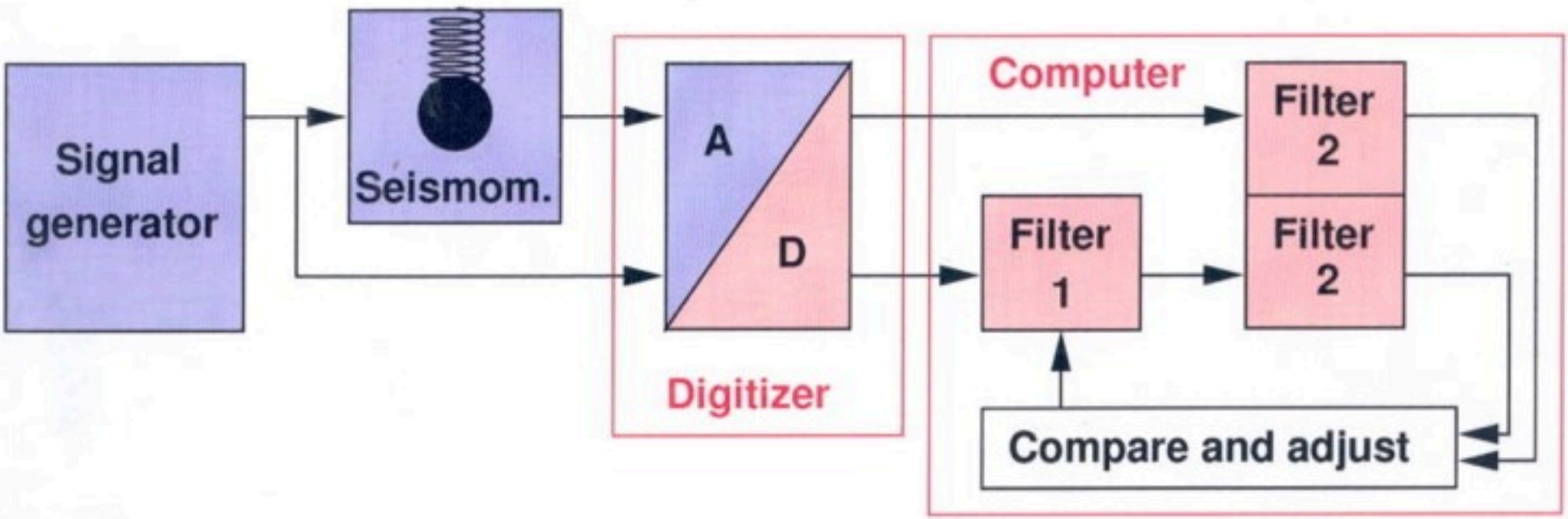
(Material of E. Wielandt)

Systematics of Seismometer calibration




h=0.2
h=0.3
h=0.4
h=0.5
h=0.6
h=0.7
h=0.8
h=0.9
h=1.0
h=1.2
h=1.4
h=1.6
h=1.8
h=1
h=2
h=2.5
h=3
h=4
1
1
0.1
0.1
0.1
f / f0
1
10

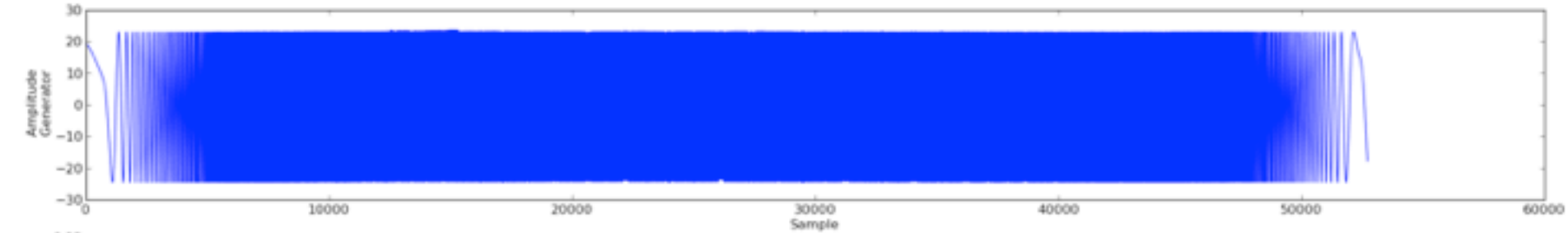
Calibration with arbitrary signals



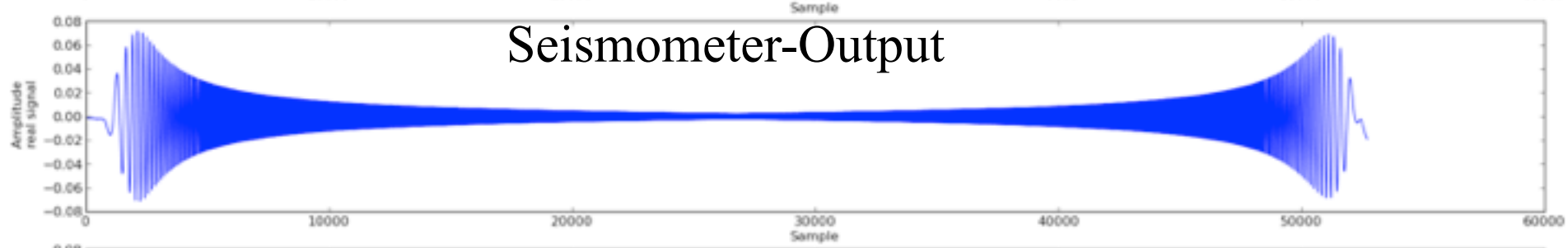
For a perfect fit, filter 1 must be an exact digital representation of the seismometer.
This is only possible when the passband is limited with the anti-alias-filter 2.

CALEX - ObsPy Version

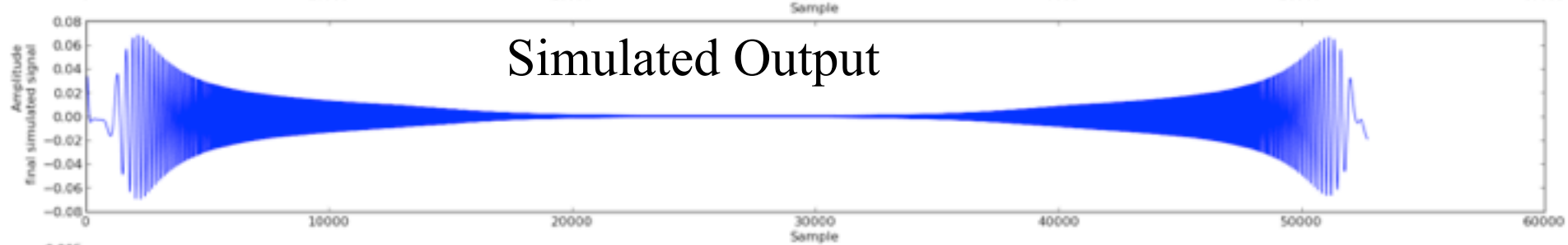
Generator-Input



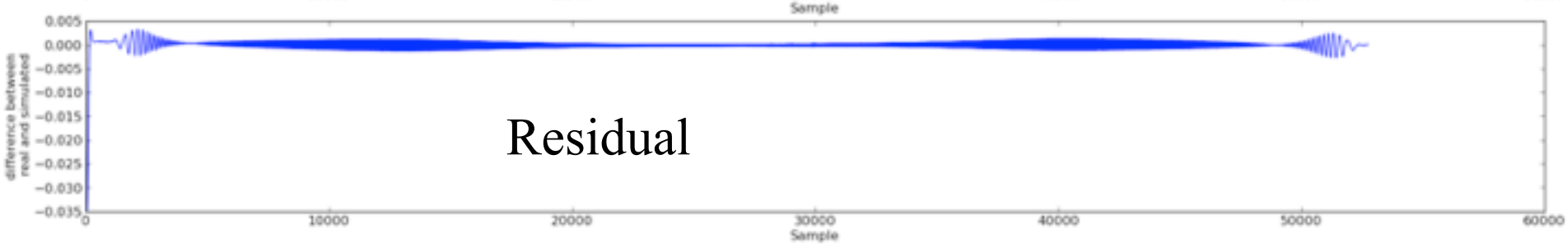
Seismometer-Output



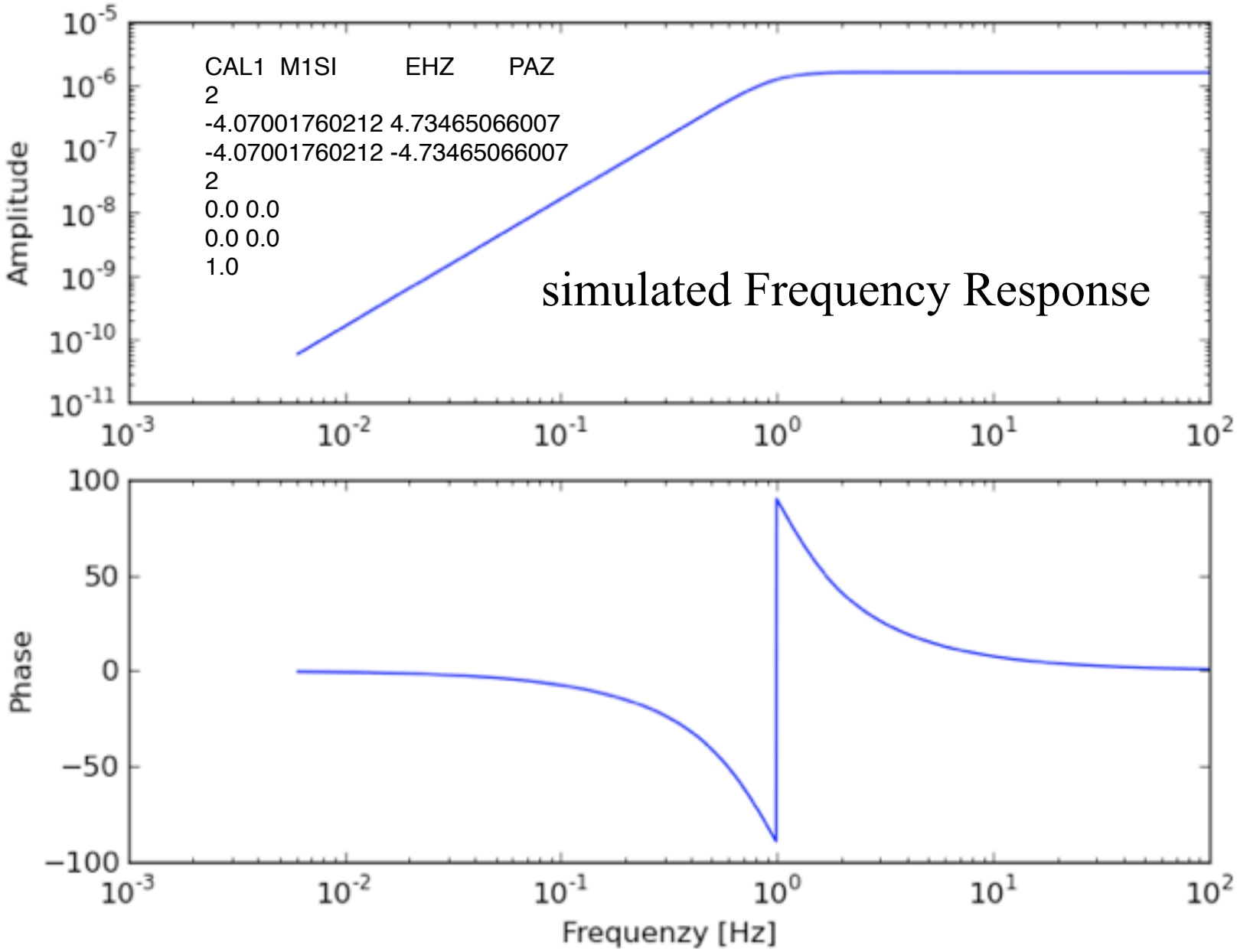
Simulated Output

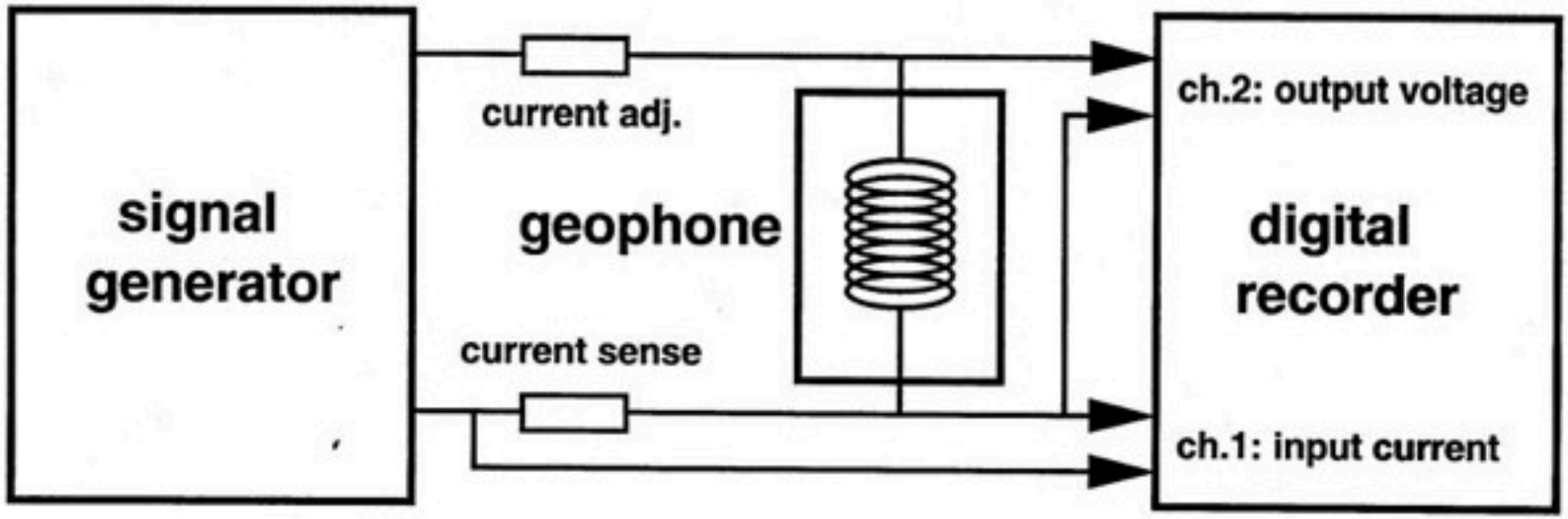


Residual



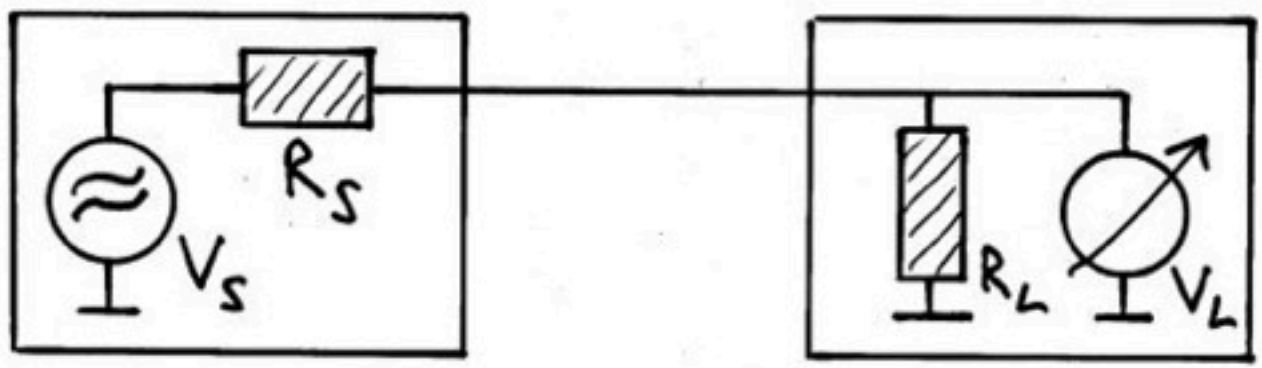
CALEX - ObsPy Version




signal
generator
current adj.
geophone
current sense
ch.2: output voltage
digital
recorder
ch.1: input current

What can easily go wrong without being obvious:

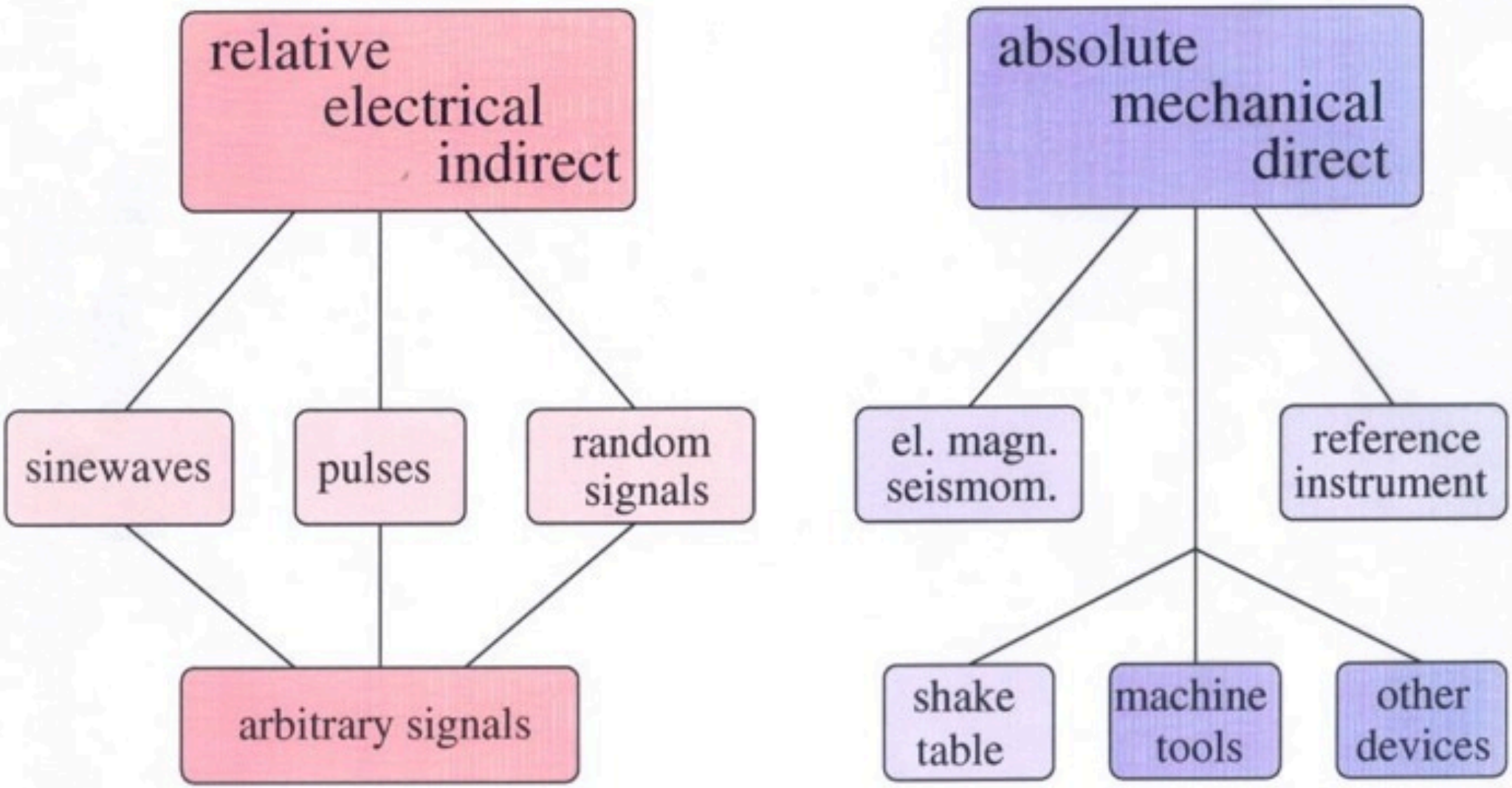
- Polarity reversed
- Only one out of two signal wires connected
- One wire shorted
- One wire interchanged between different channels
- Signal reduction by source / receiver impedance

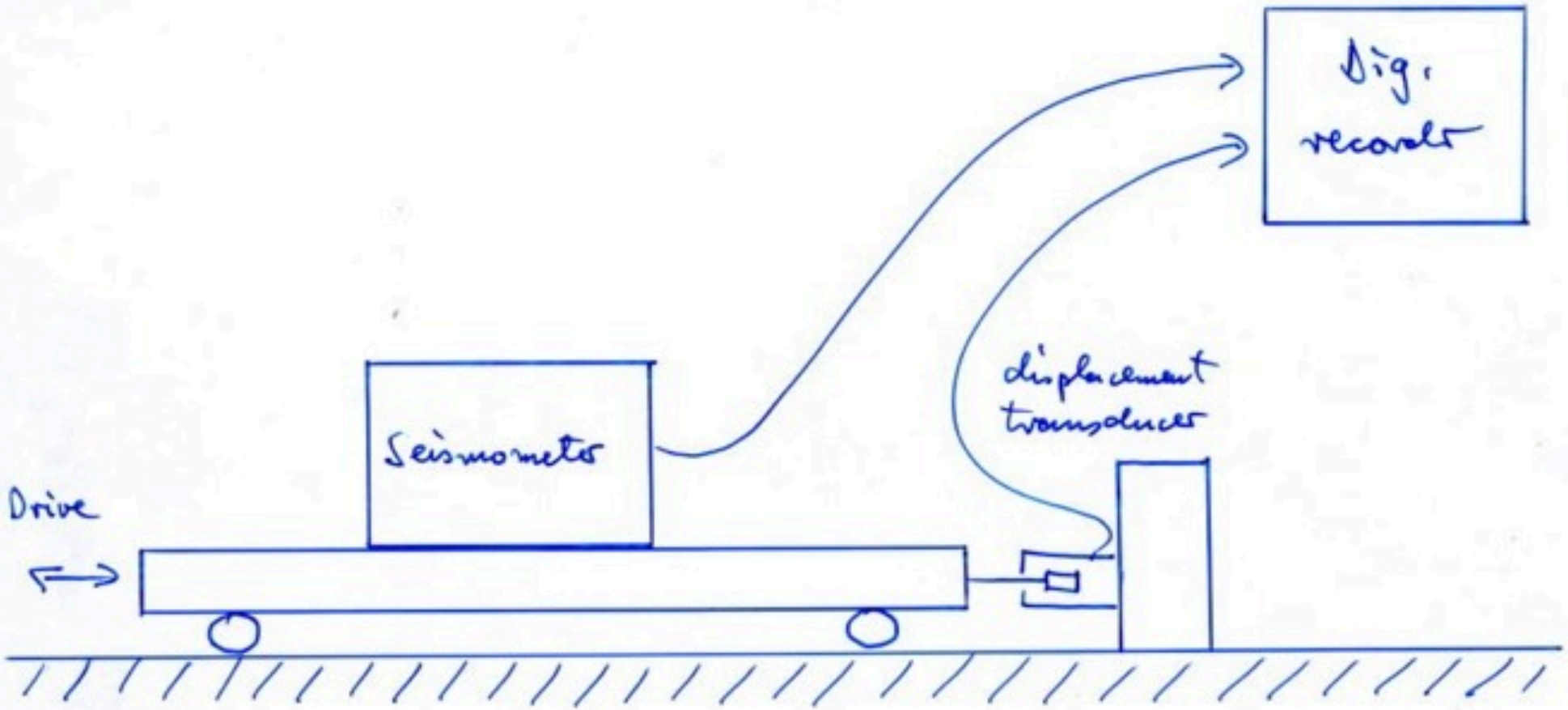


Seismometer Recorder

The measured voltage is $V_L = \frac{R_L}{R_L + R_S} V_S$

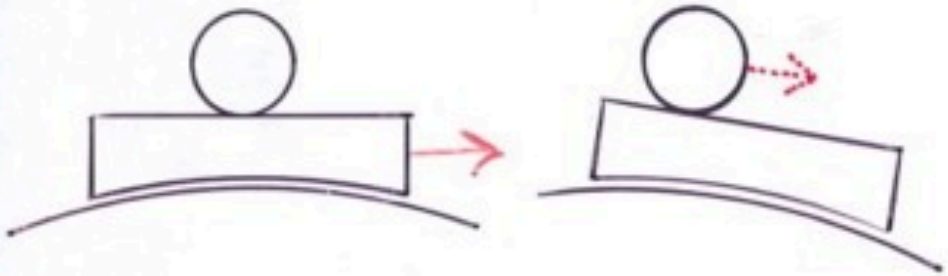
Systematics of Seismometer calibration



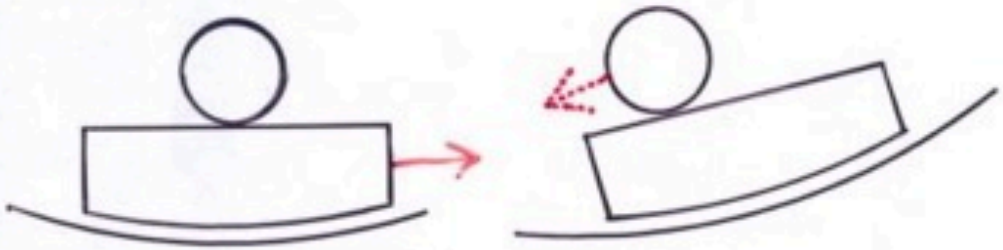


Shake table

stepwise motion

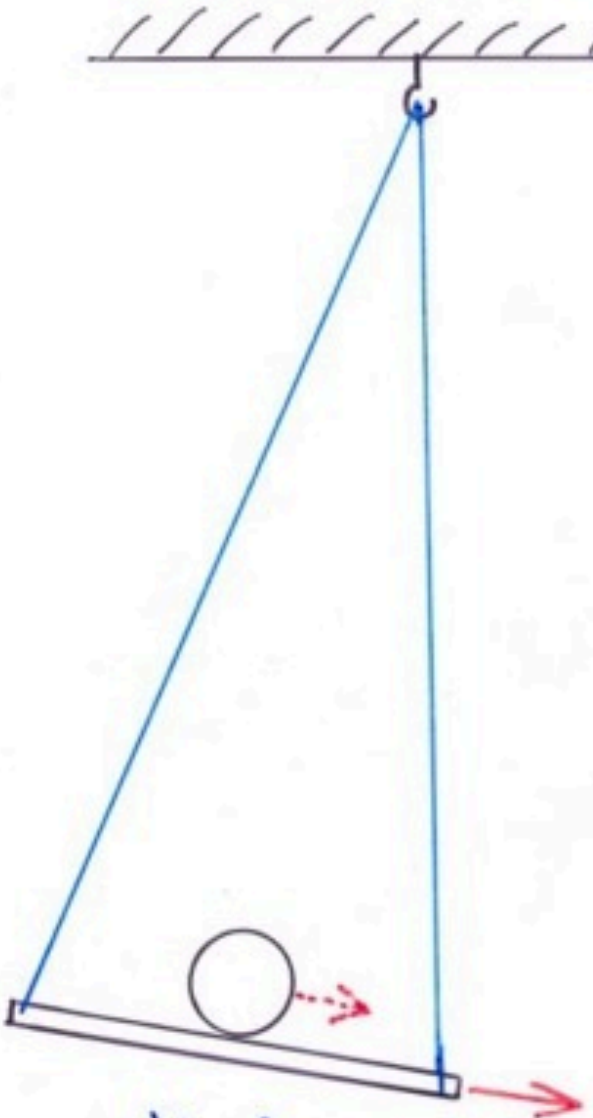


signal is too small



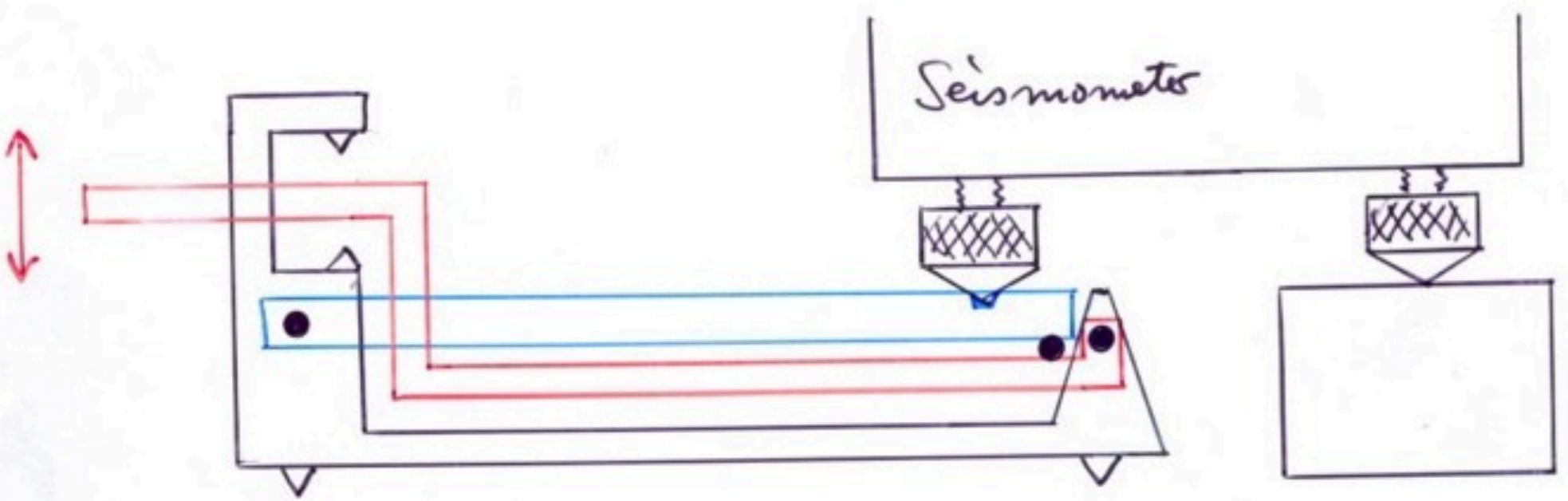
signal is too large

sinusoidal motion

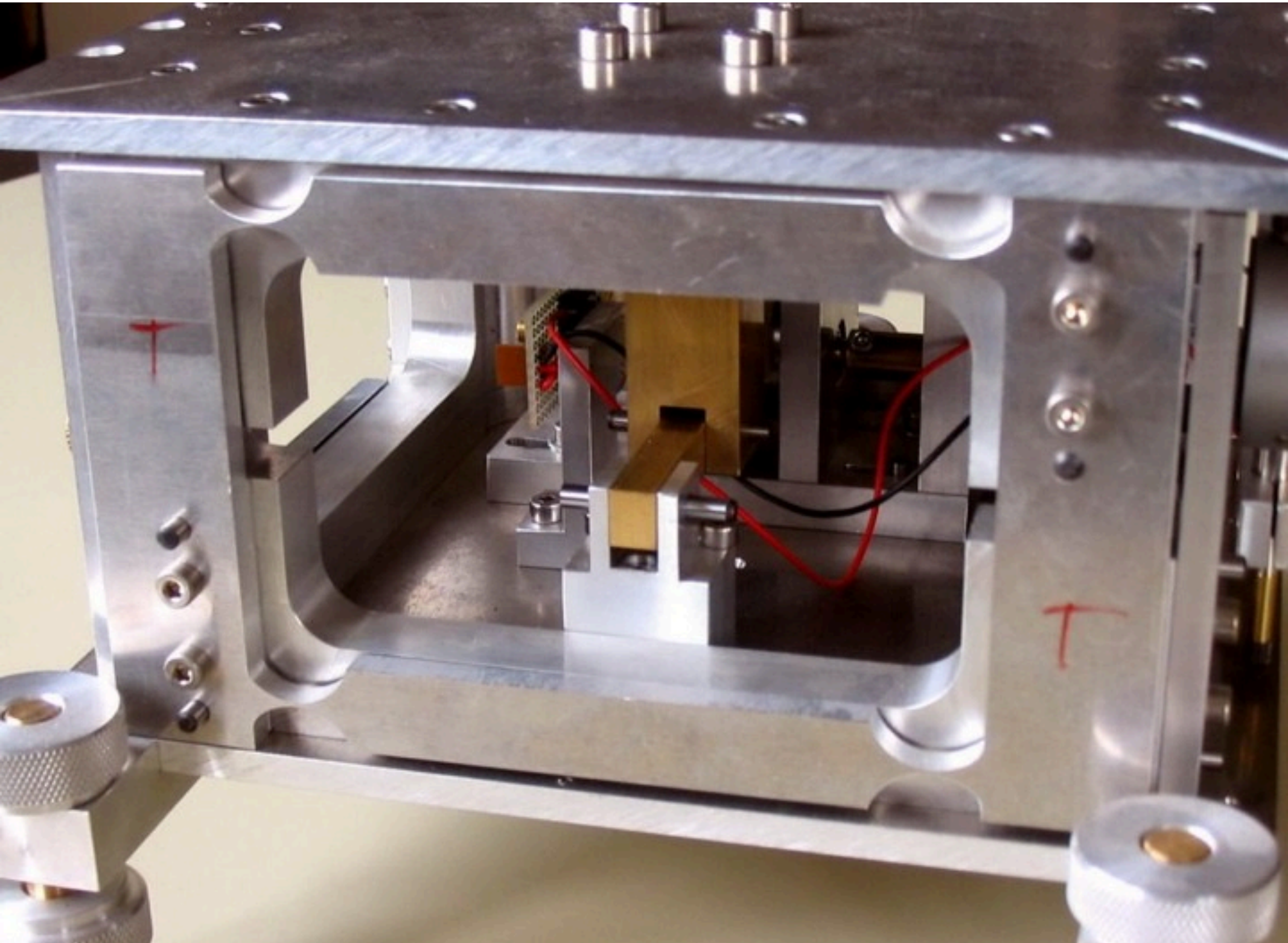


no signal at all!

The effect of tilt in a calibration experiment

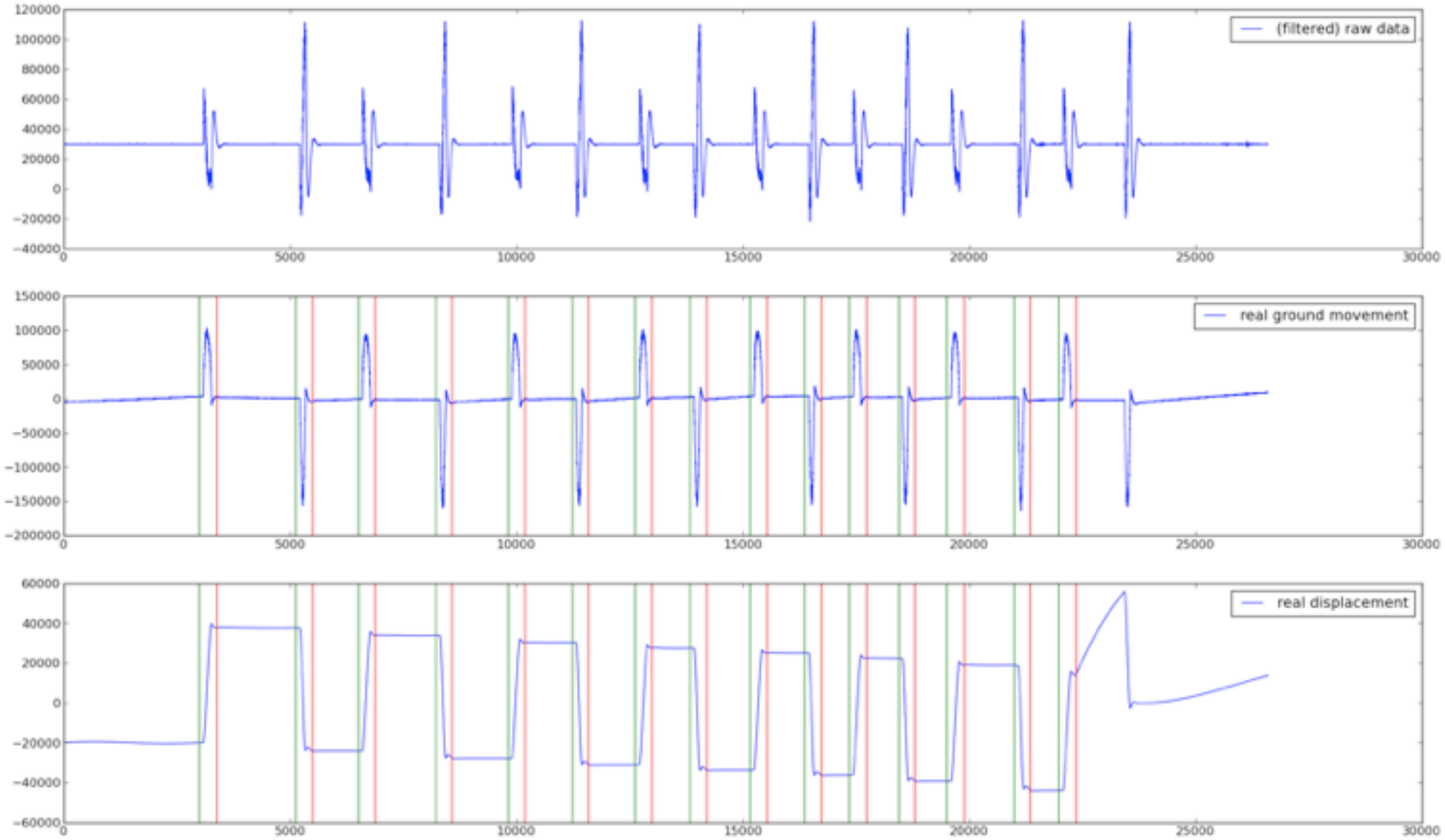


Tilt calibrator

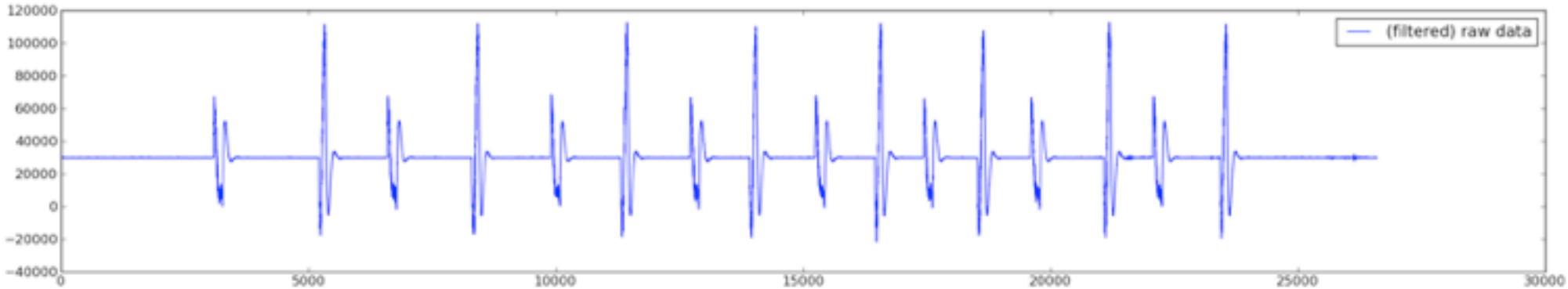


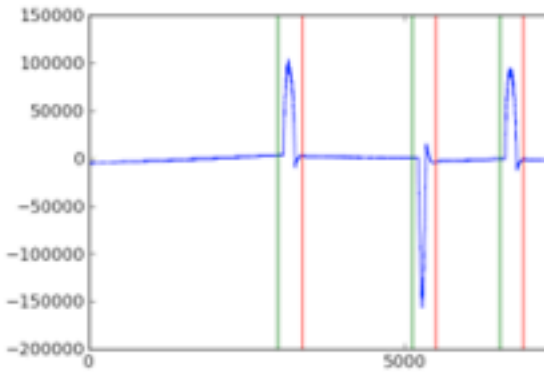

HAHN&KOLB
STOSSGESCHÜTZT
X 0,1 mm
0,001 mm

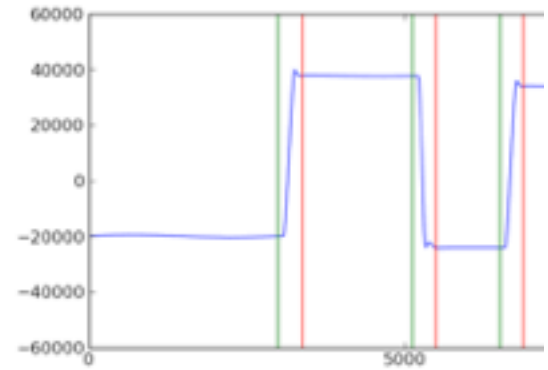
DISPCAL - ObsPy Version



DISPCAL - ObsPy Version

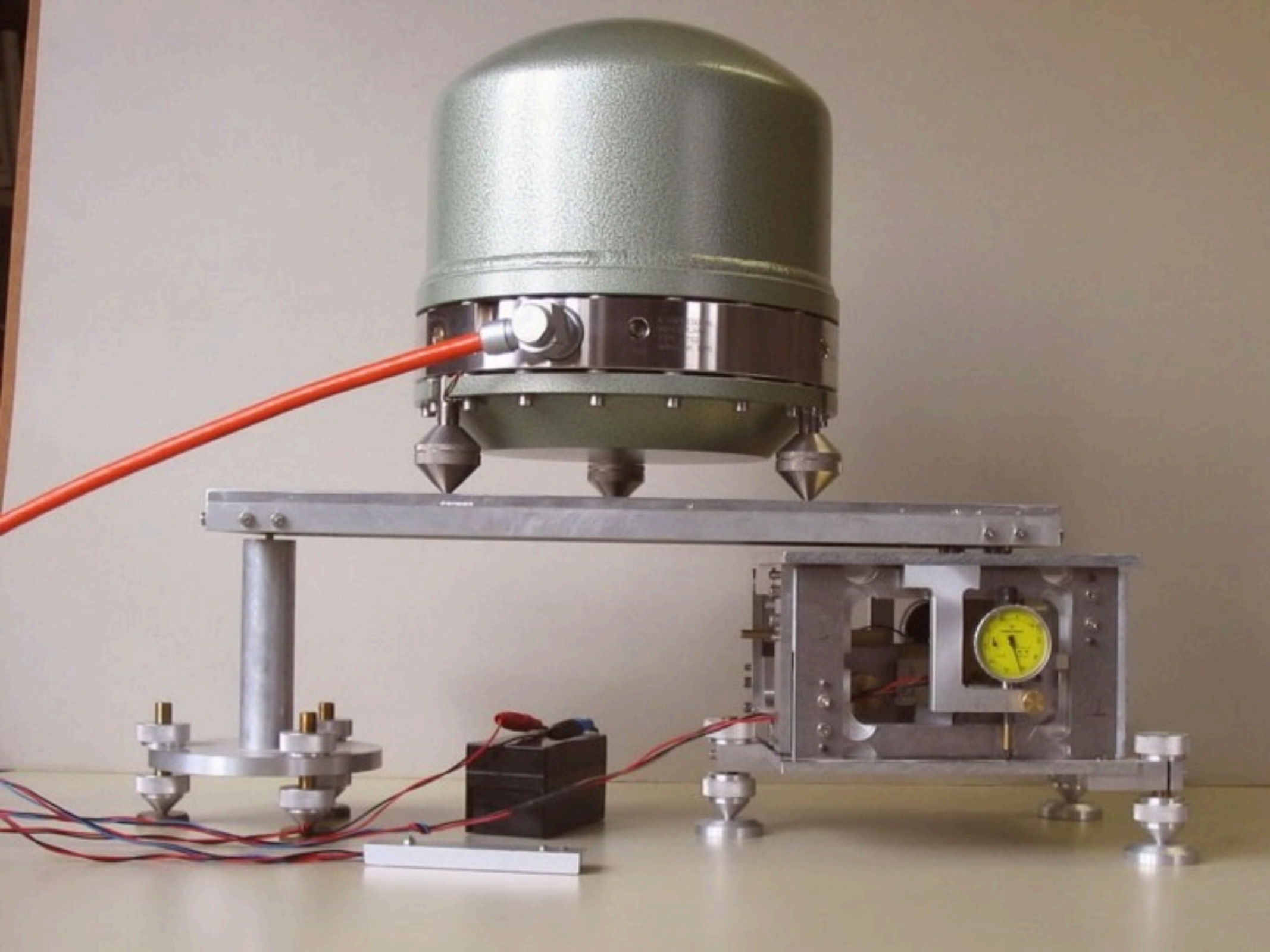




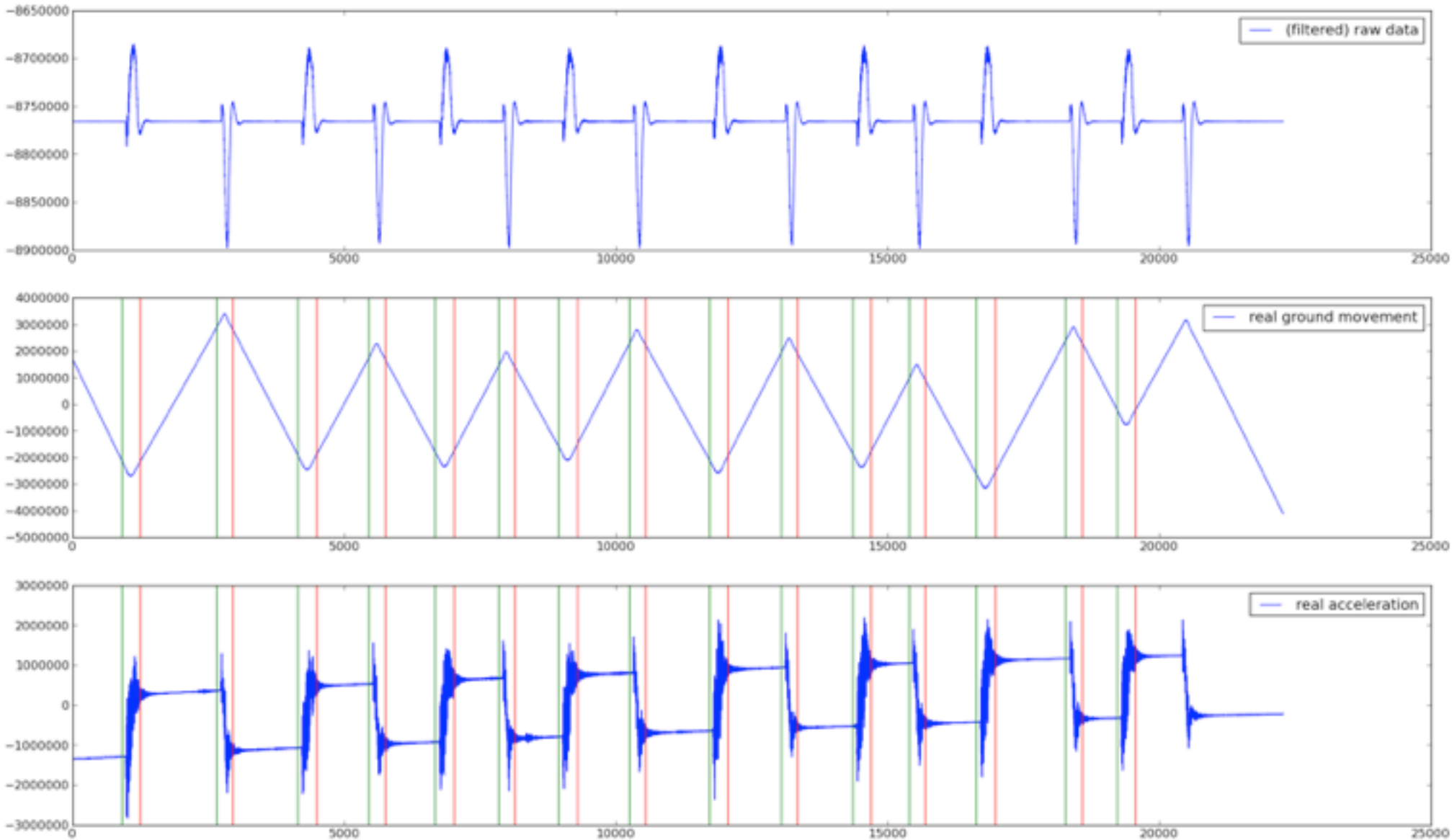


Raw average step: 59575.268 +/- 1745.928
Raw generator constant: 94.382 +/- 2.766Vs/m

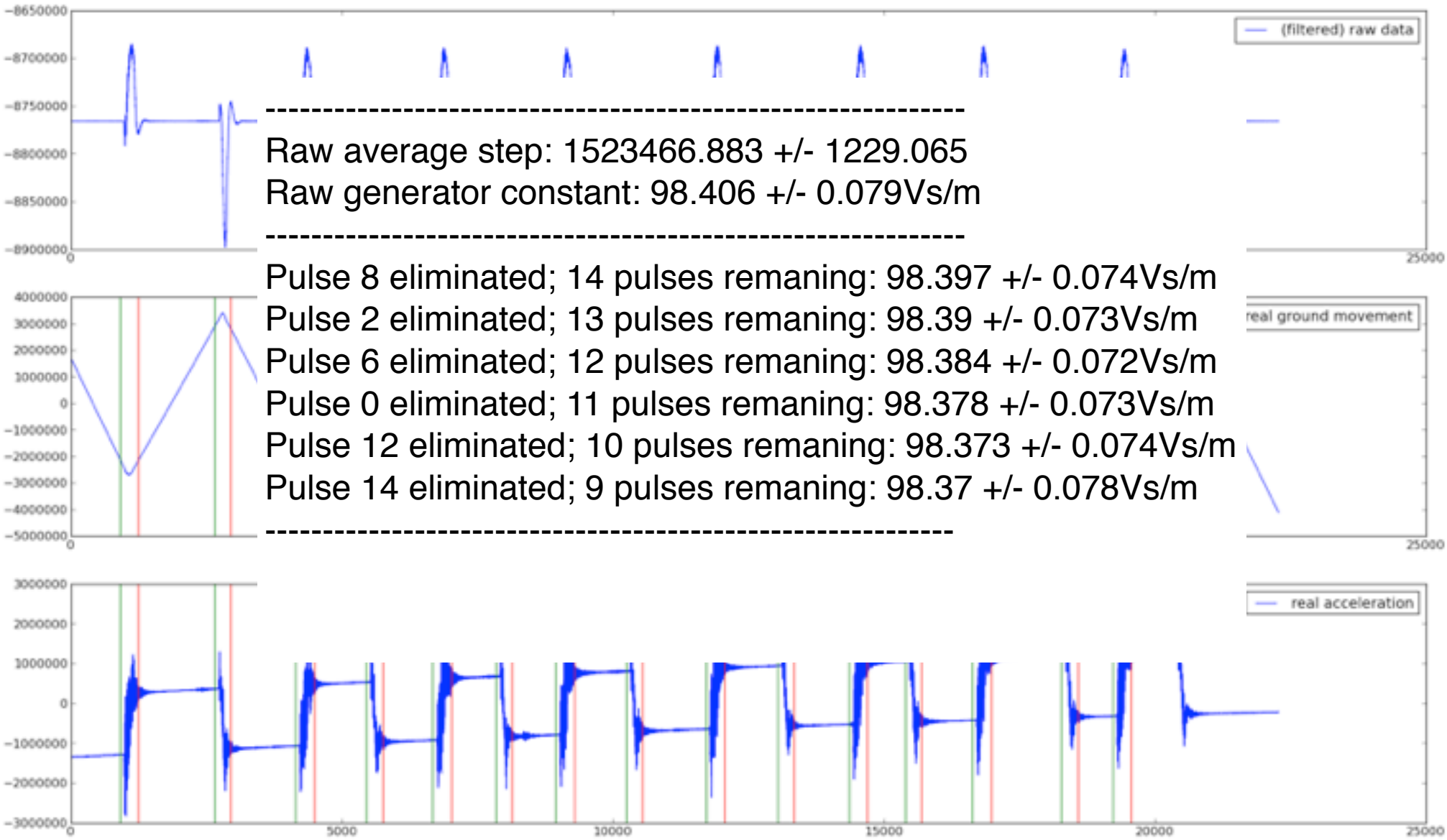
Pulse 6 eliminated; 14 pulses remaning: 94.517 +/- 2.815Vs/m
Pulse 4 eliminated; 13 pulses remaning: 94.685 +/- 2.853Vs/m
Pulse 10 eliminated; 12 pulses remaning: 94.902 +/- 2.865Vs/m
Pulse 8 eliminated; 11 pulses remaning: 95.178 +/- 2.835Vs/m
Pulse 12 eliminated; 10 pulses remaning: 95.52 +/- 2.748Vs/m
Pulse 0 eliminated; 9 pulses remaning: 95.97 +/- 2.523Vs/m



TILTCAL - ObsPy Version



TILTCAL - ObsPy Version



Raw average step: 1523466.883 +/- 1229.065

Raw generator constant: 98.406 +/- 0.079Vs/m

Pulse 8 eliminated; 14 pulses remaning: 98.397 +/- 0.074Vs/m

Pulse 2 eliminated; 13 pulses remaning: 98.39 +/- 0.073Vs/m

Pulse 6 eliminated; 12 pulses remaning: 98.384 +/- 0.072Vs/m

Pulse 0 eliminated; 11 pulses remaning: 98.378 +/- 0.073Vs/m

Pulse 12 eliminated; 10 pulses remaning: 98.373 +/- 0.074Vs/m

Pulse 14 eliminated; 9 pulses remaning: 98.37 +/- 0.078Vs/m

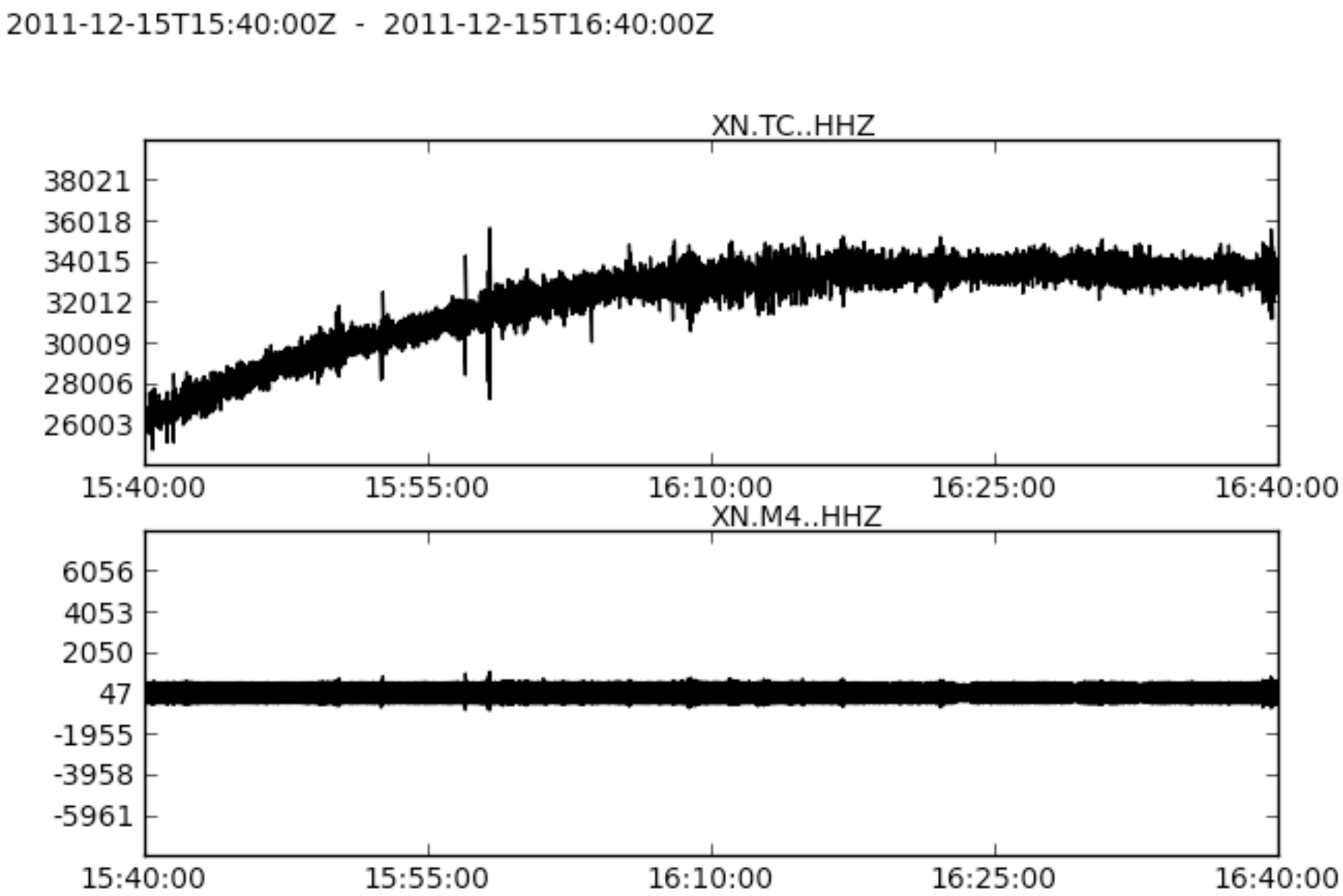
Absolute calibration of seismic sensors by displacement and tilt

Sensor type \	milling machine	balance	tilt lever
Streckeisen STS2 # 99113	X: 1484 +-3 Y: 1490 +-4 Z: 1502 +-6	 Z: 1503 +-4	X: 1481 +-3 Y: 1480 +-4 Z: 1481 +-6
Sensonics Mk3A	H: 499 +-4		
SM4 geophone 10 Hz		Z: 28.5 +-0.1	

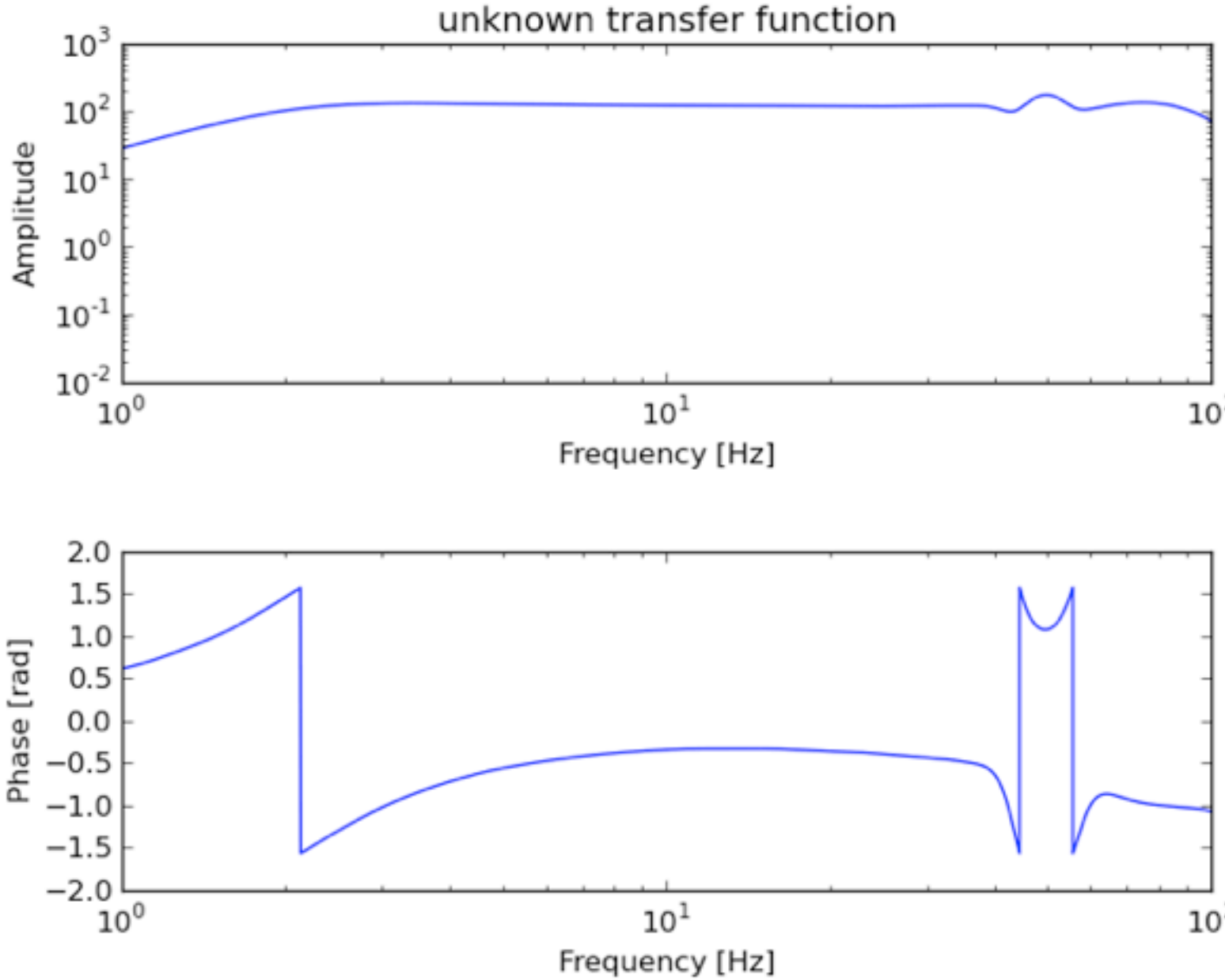
Specs were: STS2 1500 Vs/m Mk3A 500 Vs/m SM4 28.8Vs/m


Trillium

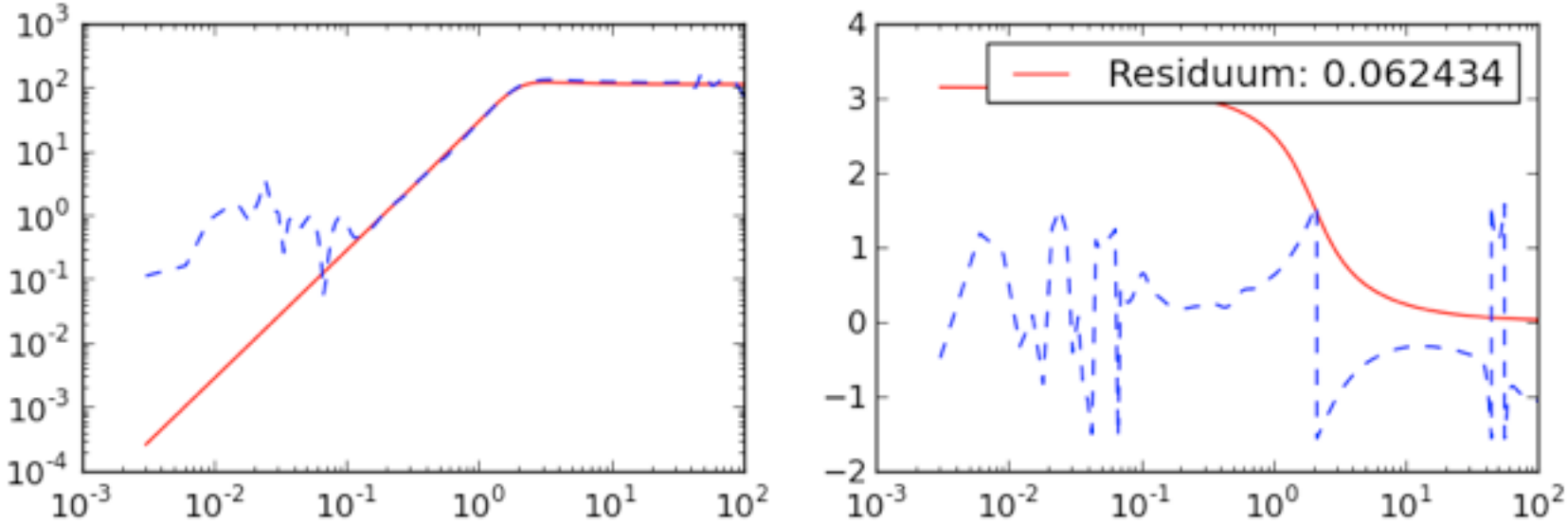
NoiseCalib - ObsPy Version (RELCALSTACK)



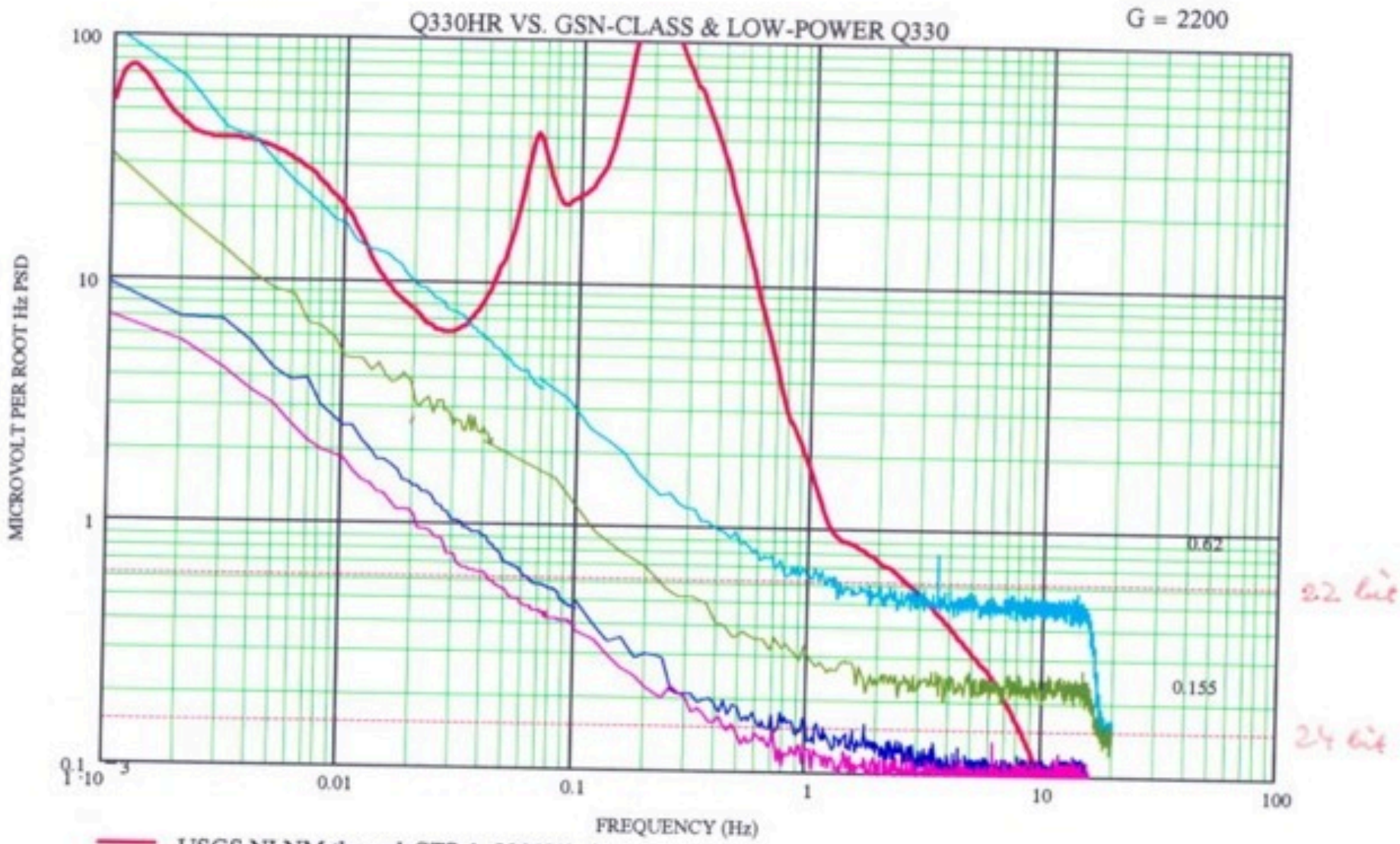
NoiseCalib - ObsPy Version (RELCALSTACK)

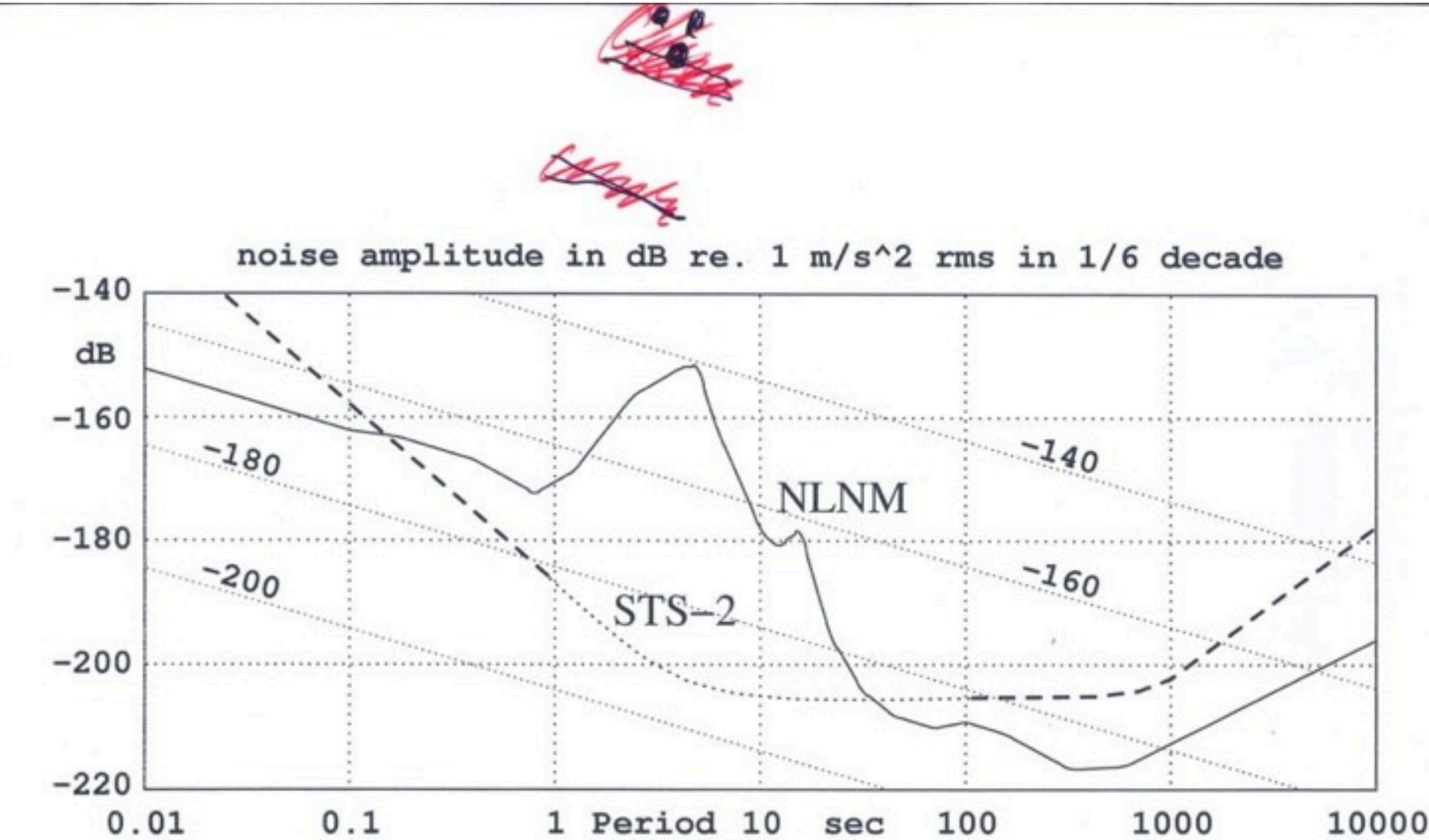


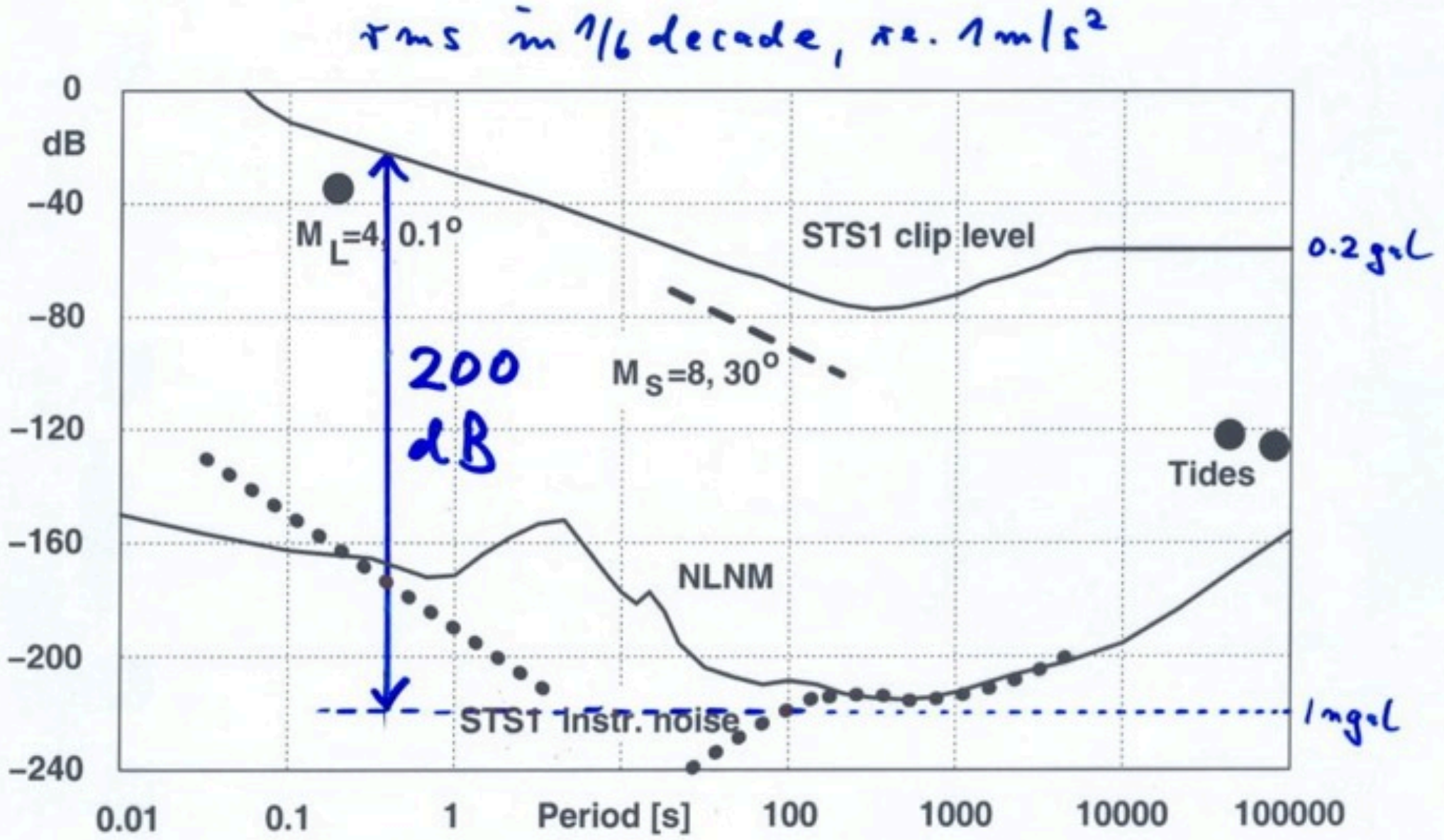
NoiseCalib - ObsPy Version (PyQt_FitResp)



f_0=2.0 Hz, h = 0.56, G=110V/m/s


Q330HR VS. GSN-CLASS & LOW-POWER Q330
G = 2200
MICROVOLT PER ROOT Hz PSD
100
10
1
0.1
1·10^-3
0.01
0.1
1
10
100
FREQUENCY (Hz)
0.62
0.155
USGS NLNM through STS-1. 2200V/m/s
MAX-model Q330HR
MIN-model Q330HR
Standard Ultra Low Power Q330
Q730B GSN-Class digitizer


noise amplitude in dB re. 1 m/s^2 rms in 1/6 decade
-140
dB
-160
-180
-200
-220
-180
-200
-140
-160
NLNM
STS-2
0.01
0.1
1 Period 10 sec
100
1000
10000


rms in 1/6 decade, re. 1 m/s²
0
dB
-40
-80
-120
-160
-200
-240
M L=4, 0.1°
STS1 clip level
0.2 g.l
200
dB
M S=8, 30°
Tides
NLNM
STS1 instr. noise
1 ng.l
0.01
0.1
1
Period [s]
100
1000
10000
100000