The trials of digital data improvement continously recording by rotational seismometer

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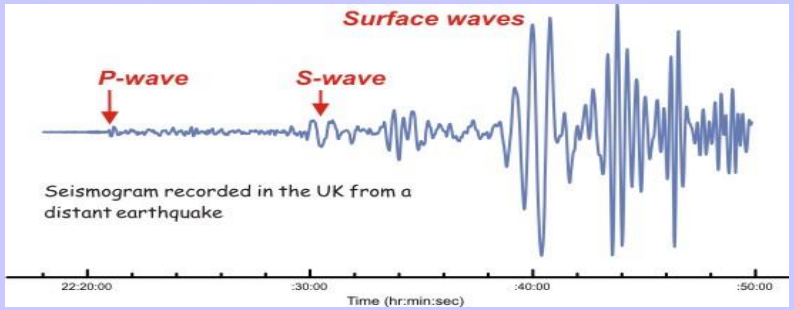
Integrated Optics – Sensors, Sensing Structures and Methods

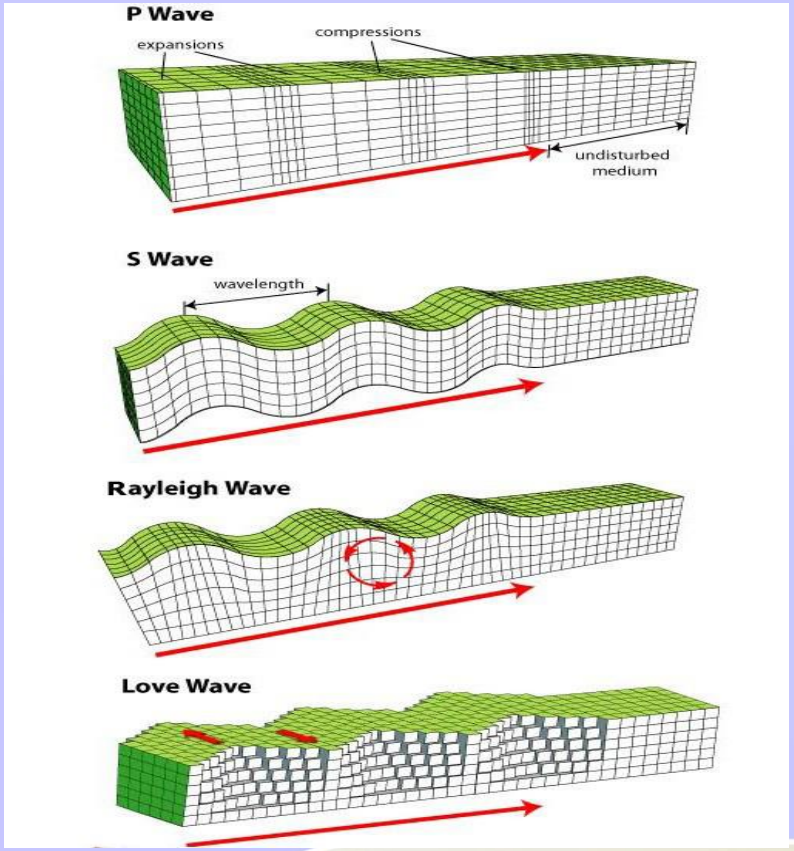
or

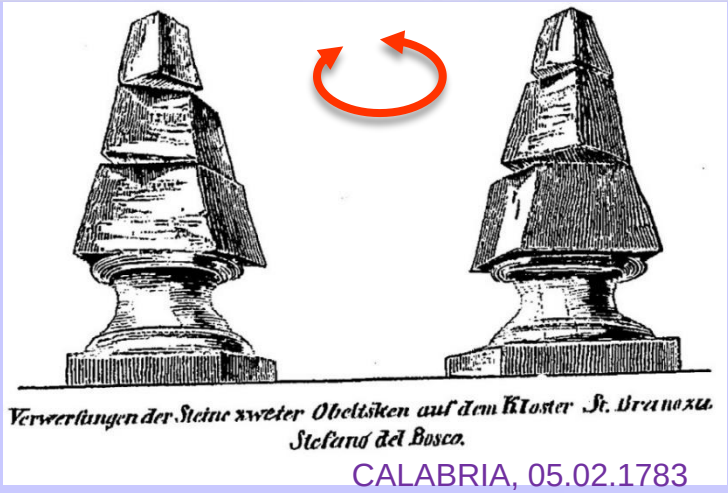
Winter School on Wave and Quantum Acoustics

50 Jubileuszowa Zimowa Szkoła Falowej i Kwantowej Akustyki

SEISMOLOGICAL INVESTIGATION OF ROTATION EFFECTS

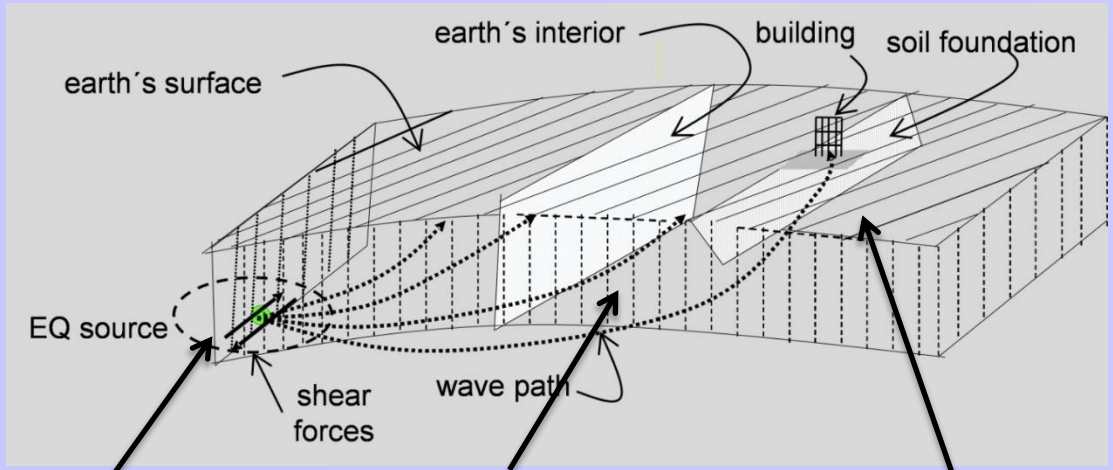






CALABRIA, 05.02.1783

[Gordon et al., *BSSA*, ***60***, 953-971, 1970]



Finite size as near field effects

(hypothetic) rotational wave (Teisseyre Roman) "anti-Richter"

reflection &interference „rotation of geological blocks"

[prof. Z. Zembaty lecture, *SMOiO KM PAS* 14.10.2016]

Rotational Seismology [Lee et al., *BSSA*, **99**, (2009), 945-957] a new, emerging field for the study of all aspects of rotational ground motion induced by earthquakes, explosions, and ambient vibrations

Seismological application:

- broadband seismology [Igel et al., *Geophys. J. Int.*, **168(1)**, (2006), 182–197],
- strong-motion seismology [Anderson, *The Intern. Handbook of Earthquake and Engineering Seismology*, 2003, Chap. 57, 937-965],
- earthquake physics [Teisseyre et al., Springer, 2006; Teisseyre et all, Springer, 2008],
- seismic hazards [McGuire, *Earthq. Eng. Struct. D.*, **37**, (2008), 329–338],
- seismotectonics [www.geophysik.uni-muenchen.de/~igel/Lectures /Sedi/sedi_tectonics.ppt],
- geodesy [Carey, *Expanding Earth Symposium*, (1983), 365-372],
- physicists using Earth-based observatories for detecting gravitational waves [Ju et al., *Rep. Prog. Phys.*, **63**, (2000), 1317–1427; Lantz et al., *BSSA*, **99**, (2009), 980-989]

Engineering application:

seismic behaviour of irregular and complex civil structures [Trifunac, *BSSA*, **99**, (2009), 968-97; Mustafa, InTech, 2015]

[Photo. Z. Zembaty]

ROTATIONAL INSTRUMENTATIONS

„Seismological" applications
[Bernauer et al., *J. Seism.*, **16**, (2012), 595-602]

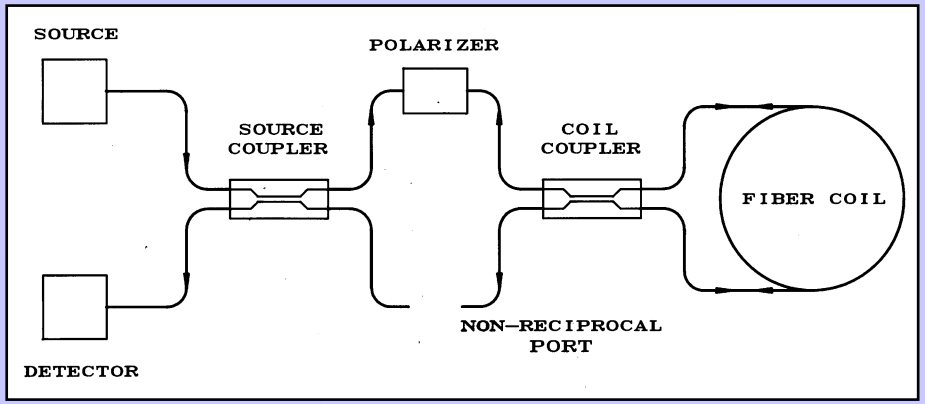
1. effectively insensitive to linear motion, or at any time, independent measurement of linear and rotational motions must be possible,
2. small (mobile) and stable with respect to ambient conditions, including changes of temperature,
3. the electrical power supply should be easily managed using batteries, at least combination with solar panels or fuel cells,
4. be able to measure amplitudes on the order of 10^{-8} rad/s at frequency range 0.01 Hz - 0.1 Hz.

„Engineering" applications
[Jaroszewicz et al., *Sensors*, **16**, (2016), 2161]

1. effectively insensitive to linear motion, or at any time, independent measurement of linear and rotational motions must be possible,
2. small (mobile) and stable with respect to ambient conditions, including changes of temperature,
3. the electrical power supply should be easily managed using batteries, at least in combination with solar panels or fuel cells,
4. be able to measure amplitudes up to a few rad/s at frequency range 0.01 Hz - 100 Hz.

Rotational sensor → ROTATIONAL SEISMOMETER (1-, 2- or 3- Axes)
field application → ROTATIONAL SEISMOGRAPH
network of **seismometers +** precise time source + recording device + network

Minimum FOG configuration → **FOS** optimization for **rotation rate** (**not angle**) detection

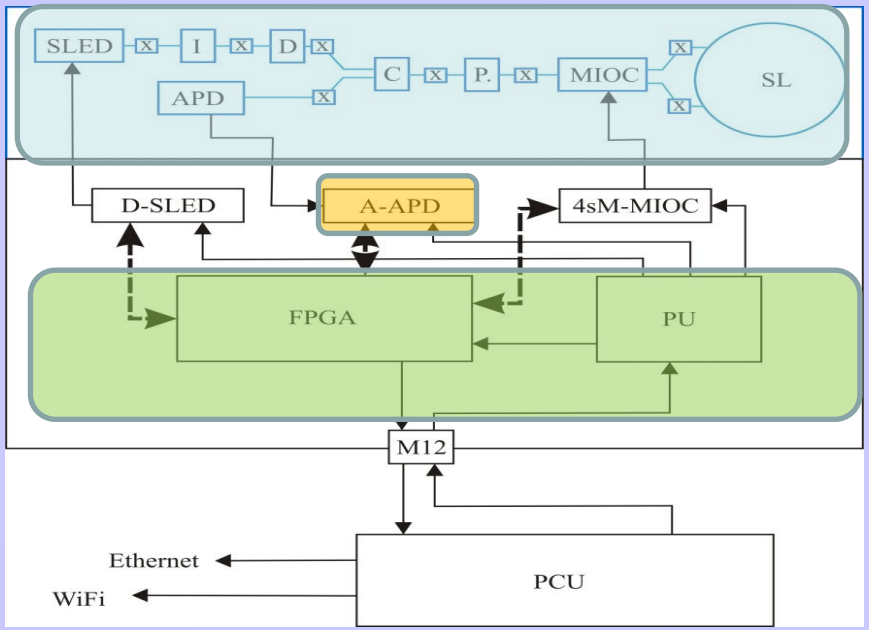


$$\Delta\phi = \frac{2\pi LD}{\lambda c}\Omega =$$

$$= \frac{6.28 \cdot 5000\,[m] \cdot 0.25[m]}{3 \cdot 10^8 \left[\frac{m}{s}\right] \cdot 1.55 \cdot 10^{-6}[m]} \cdot 10^{-8}\left[\frac{rad}{s}\right] = \frac{7850}{465} \cdot 10^{-8}[rad] \approx 0.2[\mu rad]$$

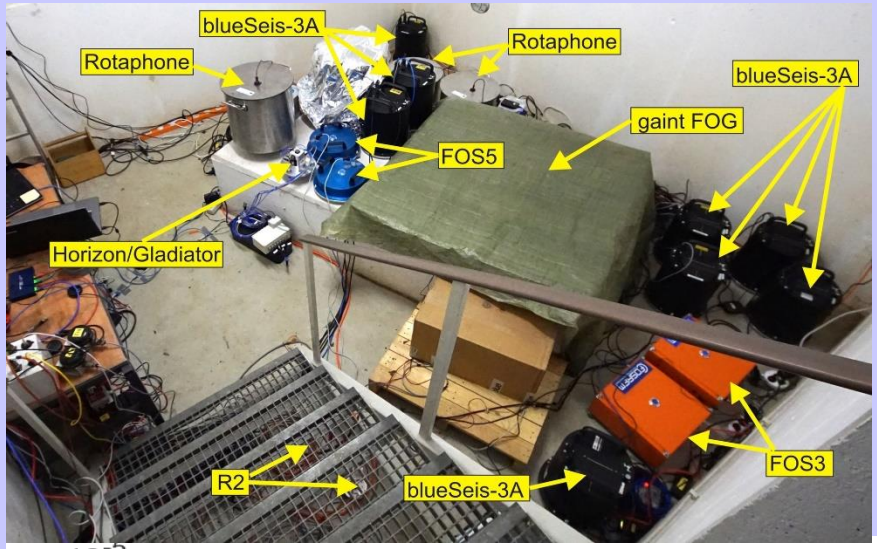
size of hydrogen nucleus

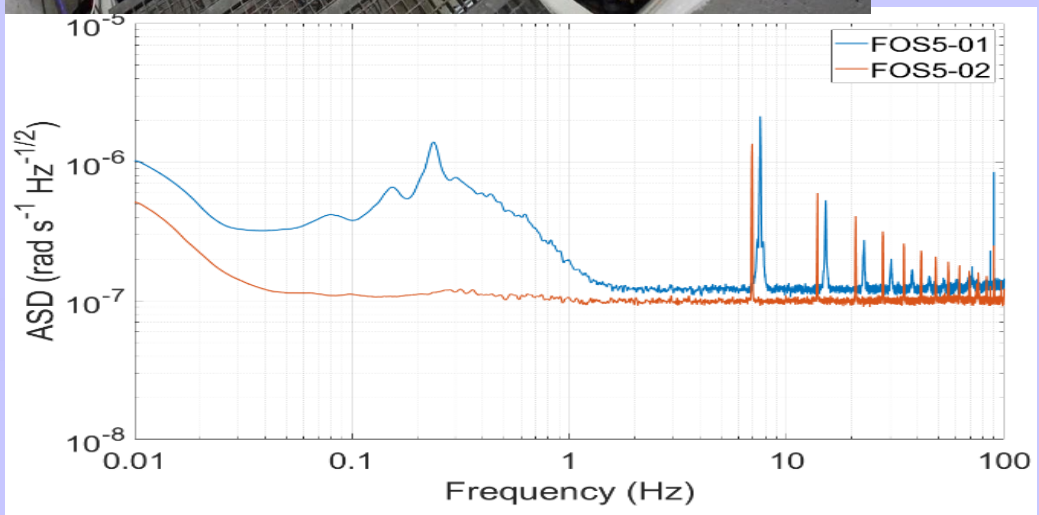
Ω_E=15 [deg/h]=7.3 10^{-5} [rad/s]



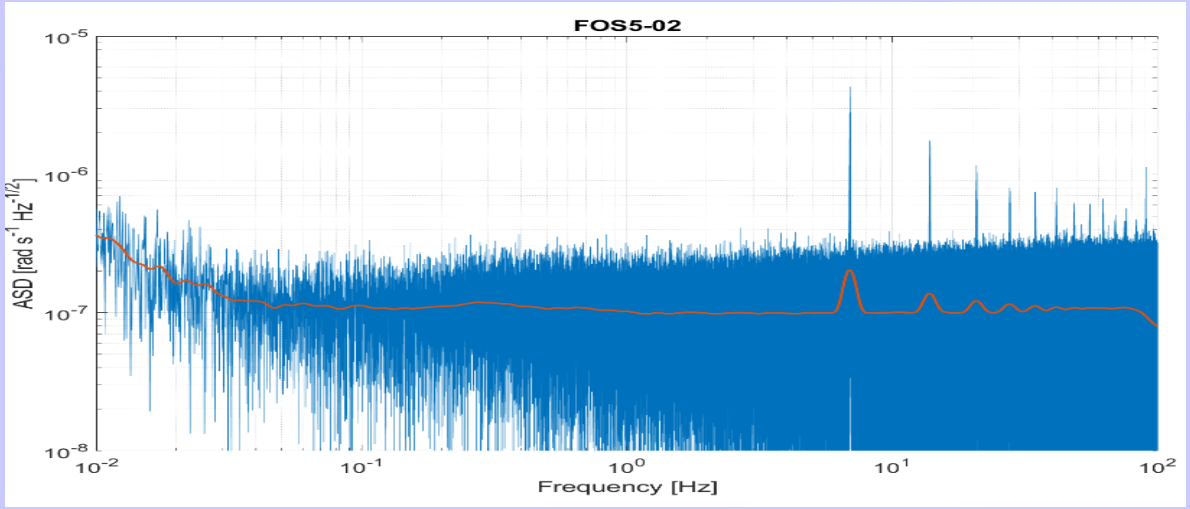
[A. Kurzych *et al.* „A historical perspective of the fibre-optic seismographs and their field application: the past, present and exciting future”] – poster sesion

OK – GO to the problems – I: deramping needs

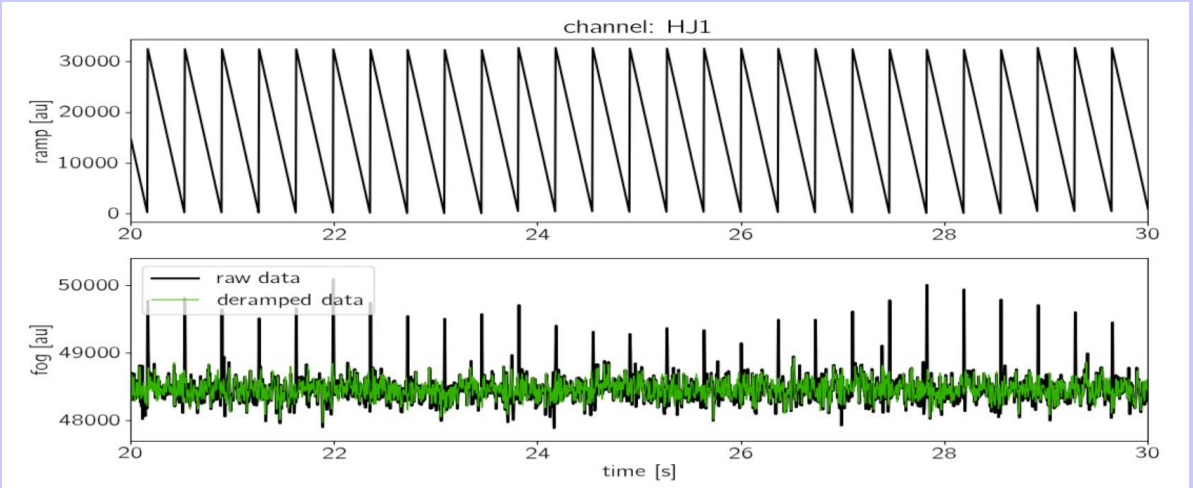




[A. T. Kurzych, *et al.* „Towards uniformity of rotational events recording…", *Opto-Electron. Rev.*, **29** (2021), 39]



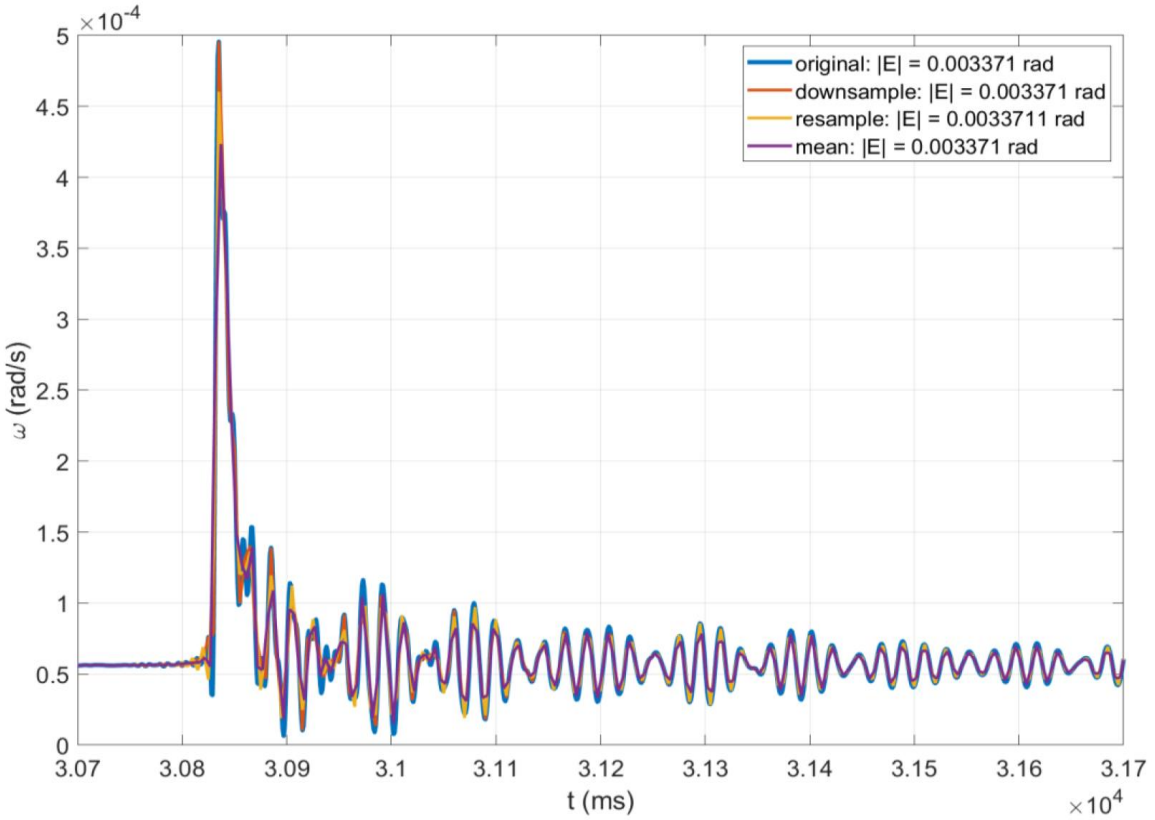
blue – raw data, red – Konno-Ohmachi filter with a smoothing coefficient 40.

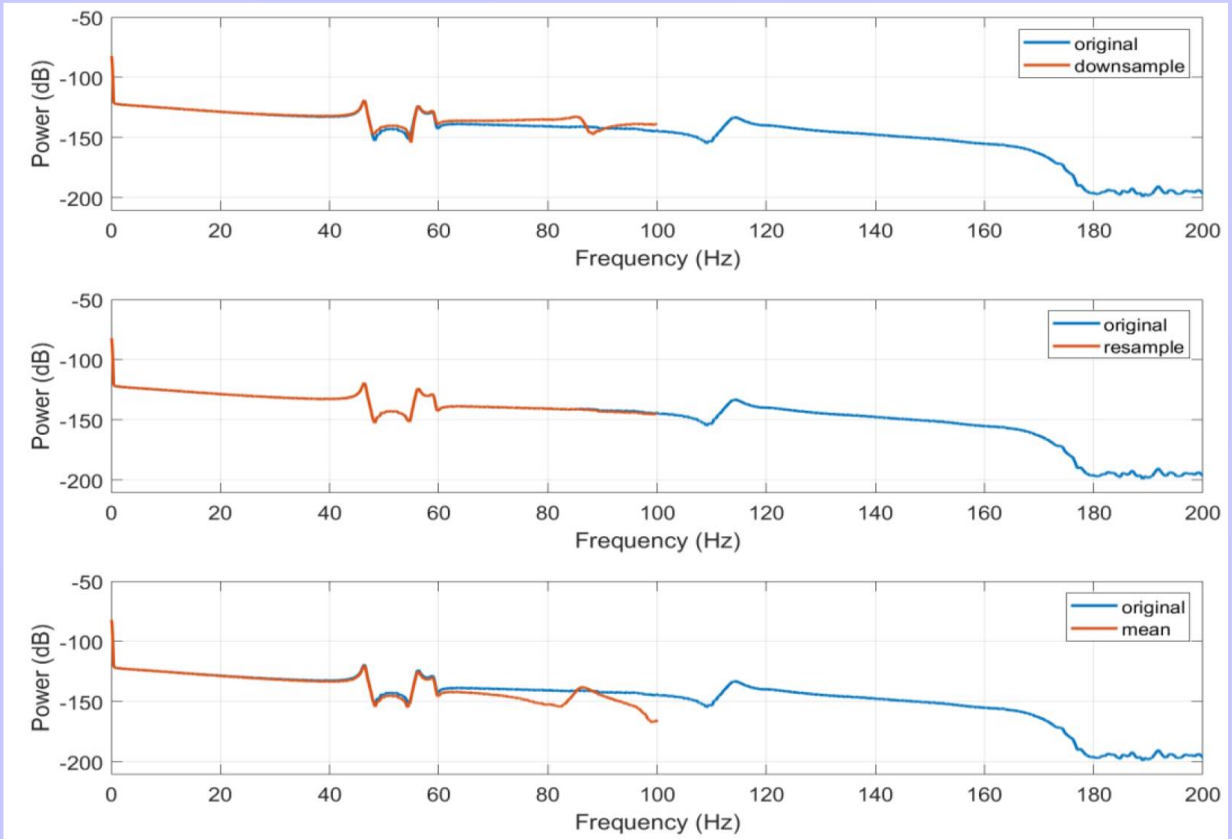


[https://github.com/fbernauer/blueseis_sandbox – thanks Felix Bernauer]

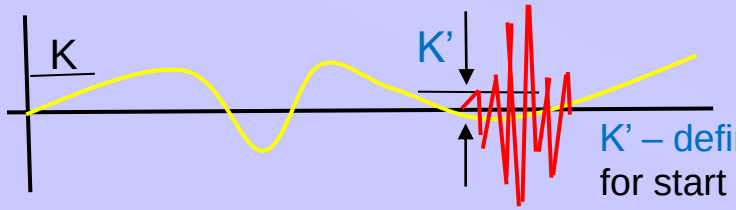
… – II: resampling needs

1000 Hz -> miniSEED about 115 MB/h/channel => 24h miniSEED ~ 8.2 GB
☹☹☹ SeisGram2K needs to 80-100 MB – resampling to 200 Hz.
Downsample: < data(m)=rawdata(5*n+1), n = [0, 1, 2, .., N-1] >
Resample: < trend elimin. -> FIR -> downsample -> delay compensate >
Means: < data=1/5 $*\sum_{i=1}^{5}$ rawdata(5*n+i), n=[0, 1, 2, …, n-1] >

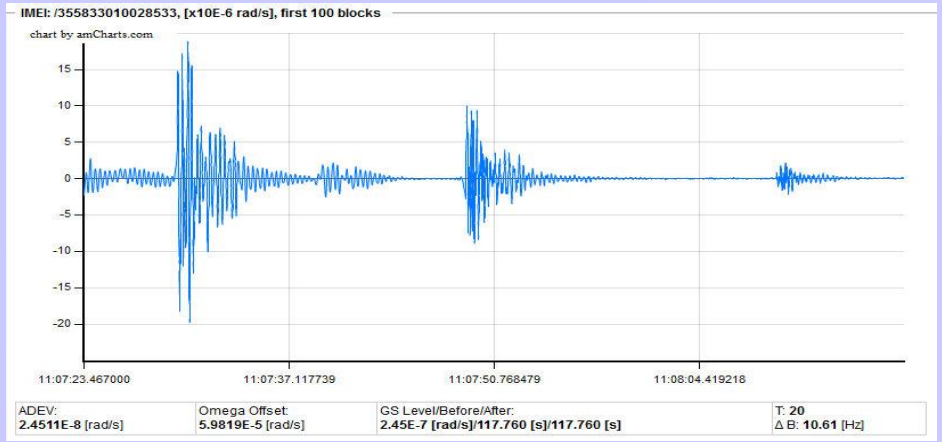




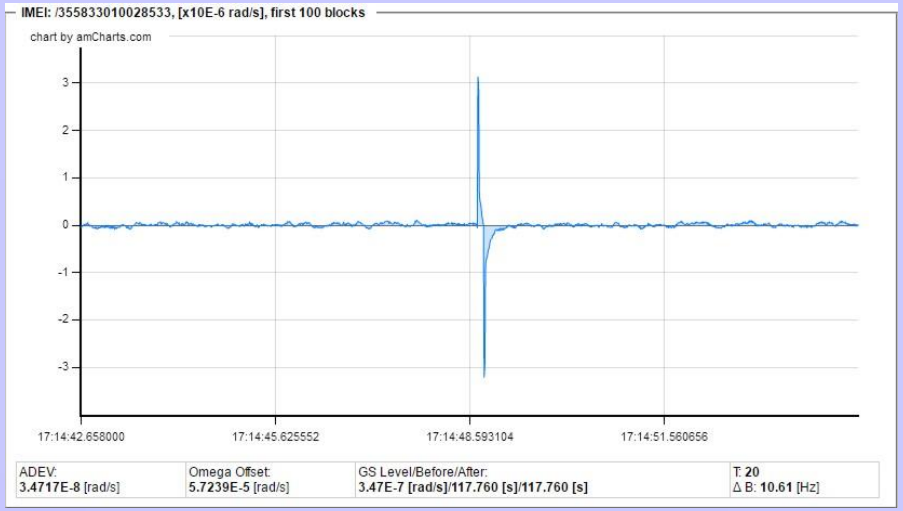
… – III: artifacts elimination

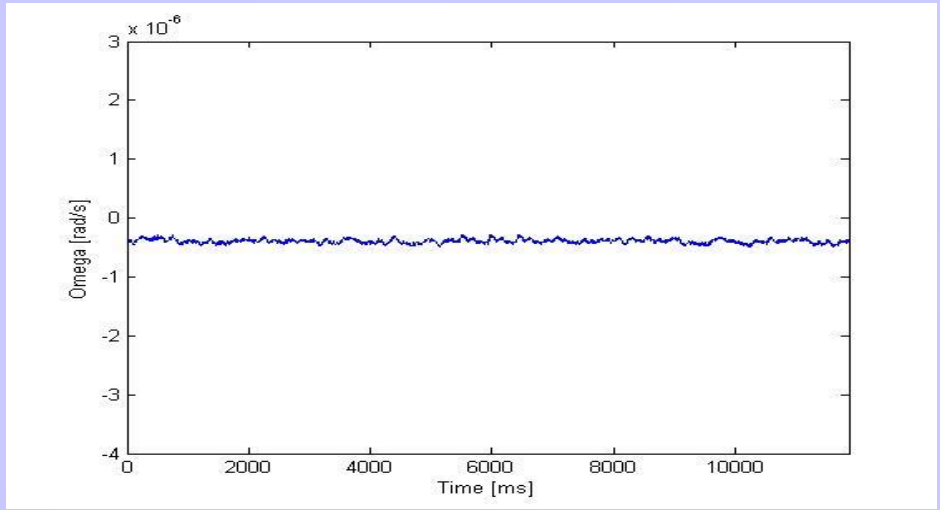


K' – definied local Ω level
for start to recording data



Real situation `drifting signal` (bias exist)





$$\left|\Omega_{av}(x_l)-\Omega_{x_l}\right| > \Delta\Omega_{av}(x_l)k_L \quad l=1,2,3,$$

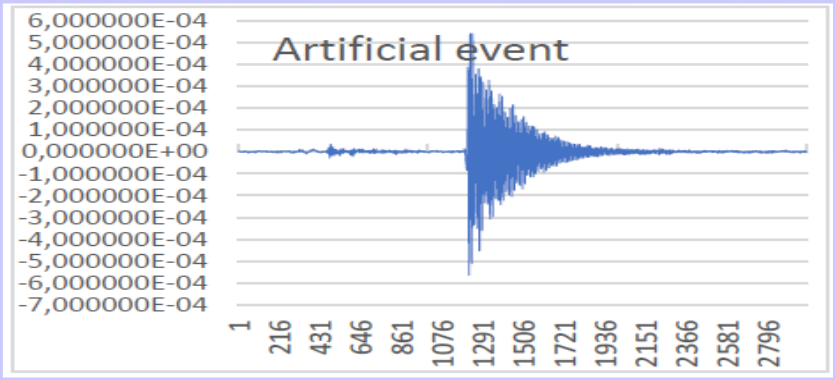
$$\Omega(x_1)\Omega(x_2)<0; \quad \Omega(x_2)\Omega(x_3)<0,$$

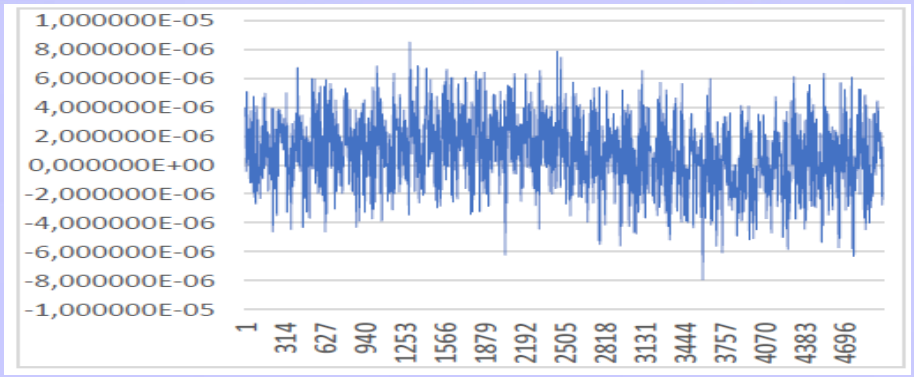
$$0<x_2-x_1<t_L; \quad 0<x_3-x_2<t_L,$$

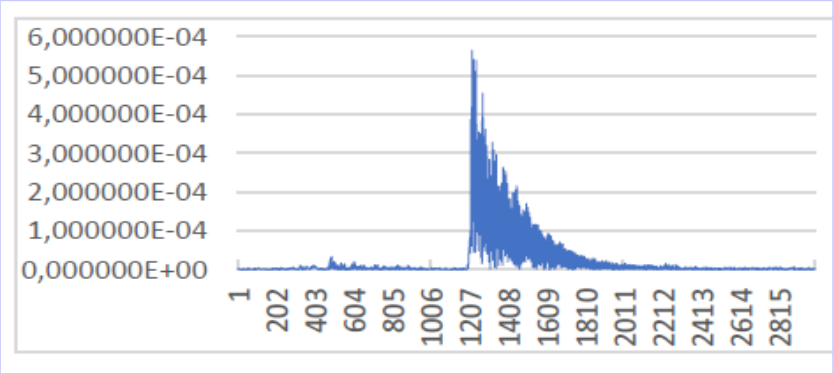
k_L – detection threshold, t_L – time of detection chosen experimentaly

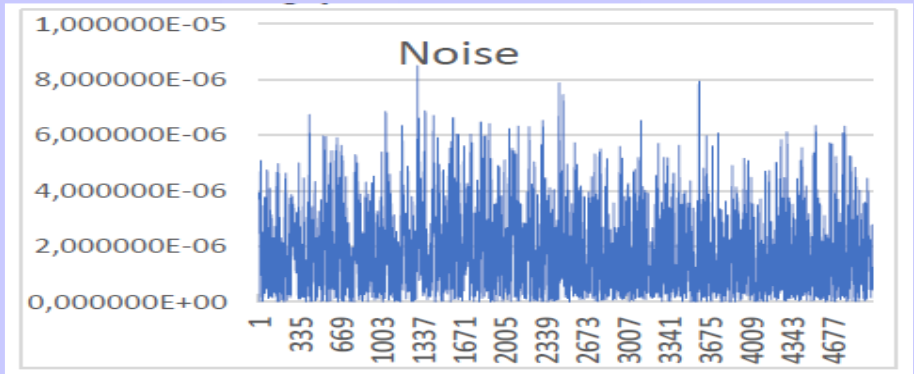
[A. Kurzych *et al.*, „The laboratorey investigation of the innovative sesnors for torsional effects in engineering structures' monitoring", *Opto-Electron. Rev.*, **24** (2016), 134]

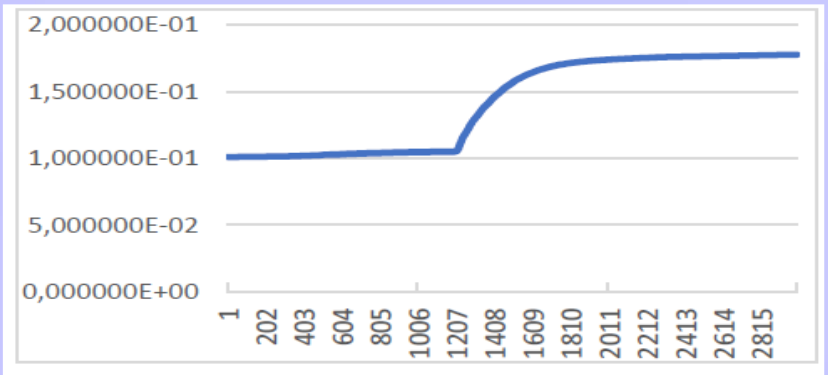
… – III: artifacts elimination

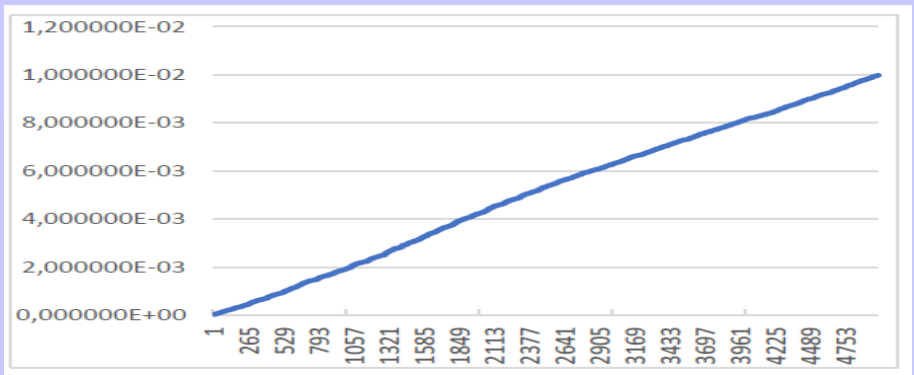




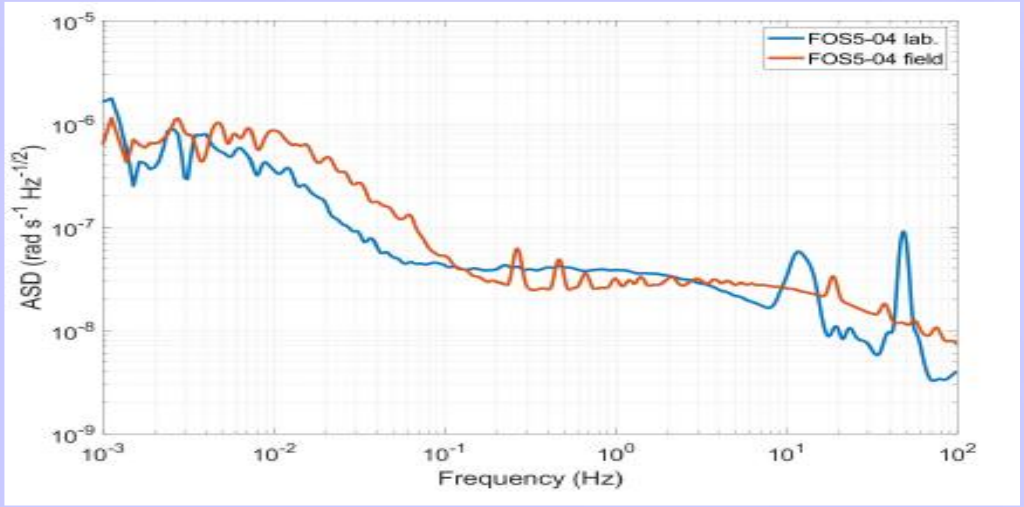


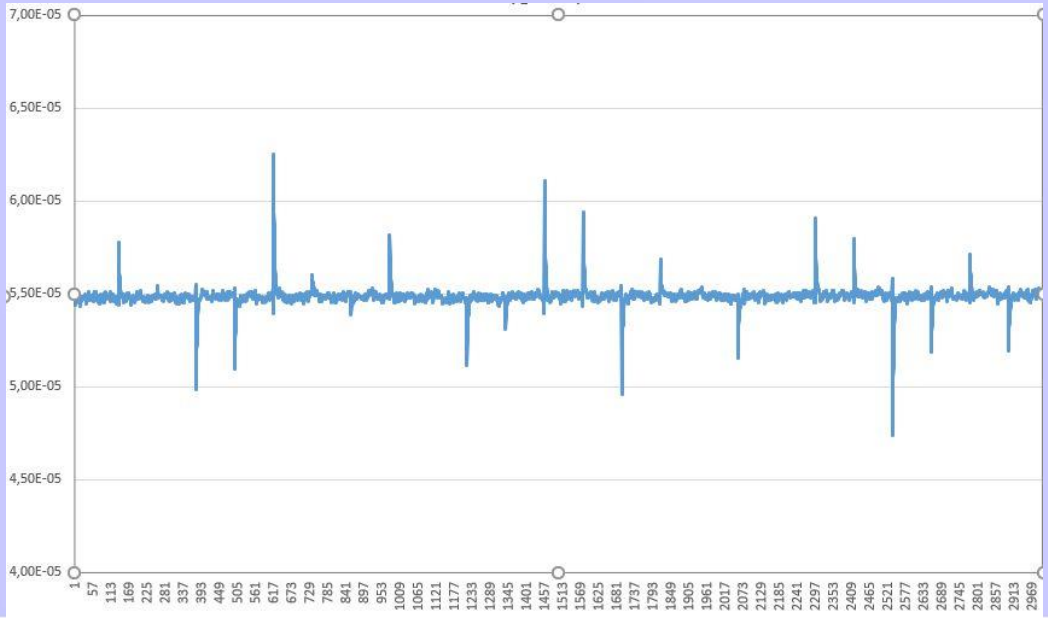




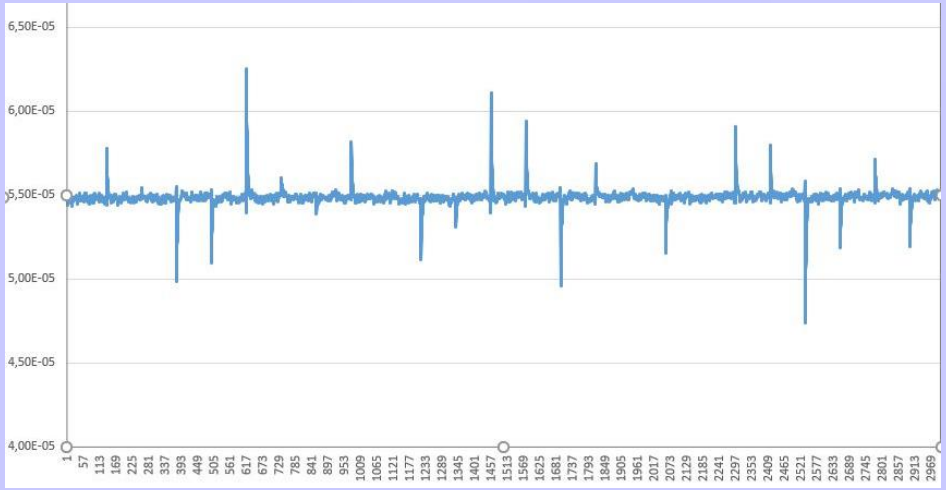


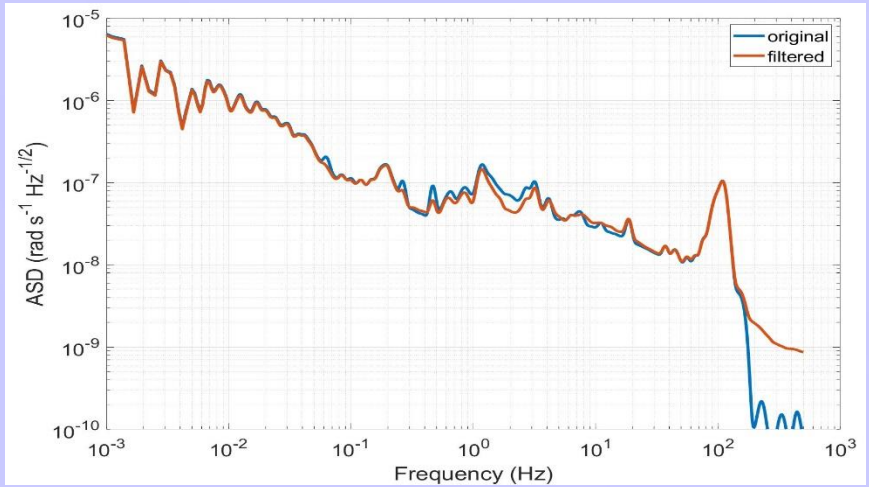
FOS5-04 – field exploatation at Książ PAS laboratory



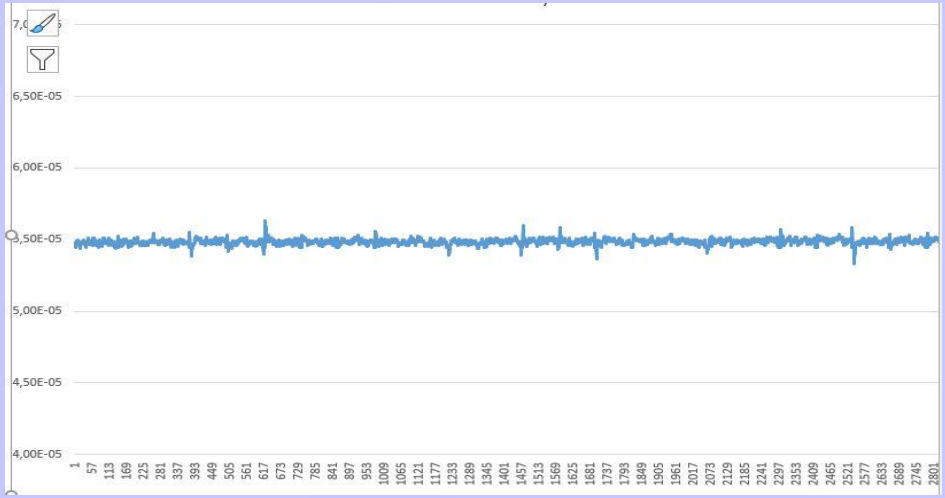


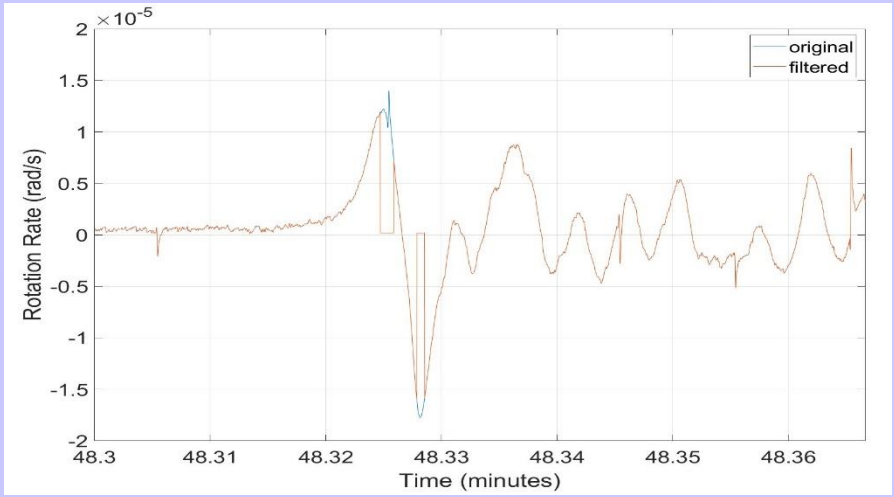
… – III: artifacts elimination





Step 1: artifacts detection (1. local extreme with a value exceeding a specified number of times the average value of the original signal's modulus, 2. in their vicinity, selected samples have the same sign, 3. in the immediate vicinity of the sample there is no similar one but in the opposite sign). Step 2: artifacts eliminating consists in subtracting the model form of the disturbing impulse so as to recreate the measurement signal as much as possible.





The general know joke

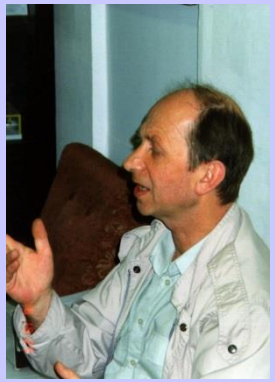
is

If you don’t know how solve the problem – give it on exam for student. They have no knowlege about it and can solve them

so

No thank you for your attention but….

ACKNOWLEGEMENTS



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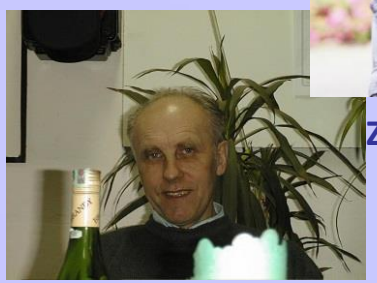
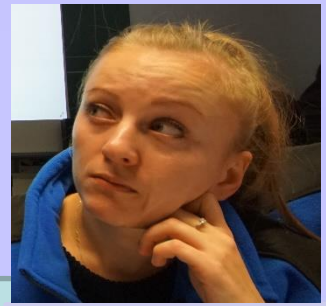


Ryszard
Janiszewski

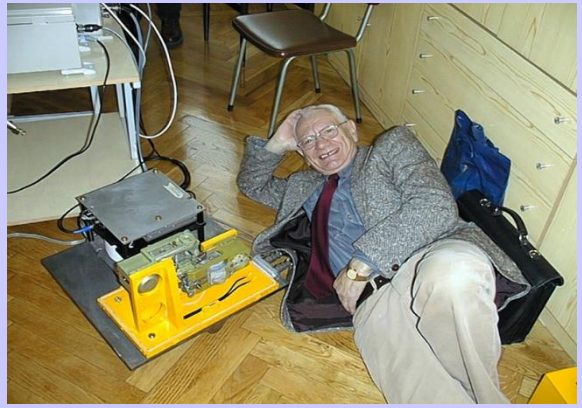


Anna Kurzych
Dr Eng.,

GBMON/13-995/2018/WAT, Ministry of the National Defence Republic of Poland

as well as

NCBR project POIR.01.01.01-001553/20-00



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