Traceable Calibration of Seismometers

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Operation Conditions

Seismic Stations

- Seismic stations consist of many seismometers distributed over the site.
- Installed in vaults → Temperature and humidity can vary depending on location and season.
- Not supposed to be moved or transported for calibration

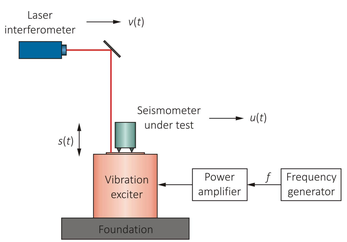
State of the Art

- Use of data sheet transfer functions
- 'Electrical calibration' using internal calibration coils

Typical Specifications

Frequency range: 0.01 Hz – 100 Hz
Sensitivity: ~ 1500 V/(m/s)
Mass: ~ 15 kg

Traceable Calibration



Why Calibrate?

- The 'electrical calibration' is not sufficient to detect sensor changes and to ensure reliable results.
- To obtain a realistic and independent measurement of the transfer function
- Seamless transfer if seismometers need to be replaced
- Improved comparability between different stations or seismometers
- Includes influences from coupling to the environment

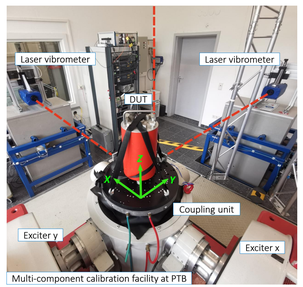
What is traceability?

- The results are traceable to the Système international d'unités (international system of units).
- The measurement uncertainty is specified as part of the measurement result.
- Measurement results of different countries or different laboratories are made comparable.
- Comparisons ensure quality.

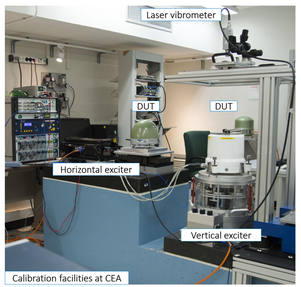
How is it done?

- Reference measurements by laser interferometry
- ➢ Movement of the exciter traceable to the wavelength of the laser and the time
- Output signal of the seismometer is compared to the reference
- Excitation using single frequency (better signal-to-noise ratio) or multiple frequency sinusoids (faster)
- Standard describing vibration calibrations: ISO 16063-11

Calibration Facilities in the Laboratory

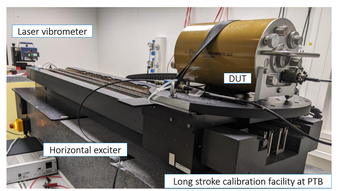


Multi-component calibration facility at PTB



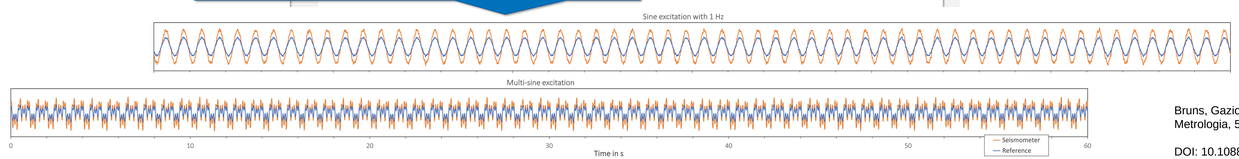
Calibration facilities at CEA

- Separate devices for vertical and horizontal excitation, or multi-component exciter
- Ideal: No disturbances due to non-linearities of the exciter, good isolation from ground motion
- Excitation levels about 1 mm/s
- Frequency range ~10 mHz – 20 Hz

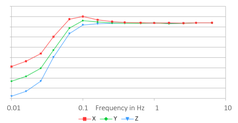


Long stroke calibration facility at PTB

These are real calibration signals generated by the multi-component exciter at PTB. The top shows a 1 Hz sine, the bottom a multi-sine with components of 1 Hz, 2 Hz, 4 Hz and 8 Hz.



Disturbing Influences and Issues



Tilting

- If the tilt angle varies during horizontal excitation, gravitational acceleration changes are superimposed to the nominal excitation.
- The influences can be significant, especially at low frequencies (large displacements, small acceleration levels).
- ➢ Solution: Measure tilt, compensate for influences

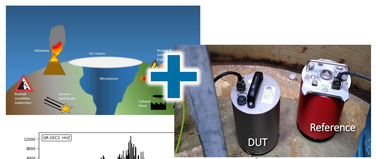
Temperature

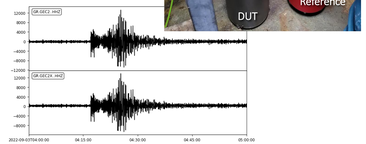
- Temperatures during calibration in the laboratory and in the field can differ significantly.
- Temperature sensitivity is device-dependent and unknown up to now.

Electromagnetic disturbances

- Some seismometers are sensitive to electromagnetic disturbances.
- Electrodynamic exciters can generate sufficiently high fields to induce errors.
- ➢ Solution: Shielding or compensation coils

On-site Calibration



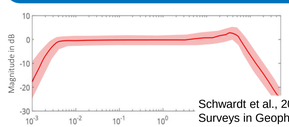


Procedure

- Comparison of a laboratory-calibrated reference and the device under test (DUT) are carried out on site using a gain ratio (procedure based on Gabrielson's method – known from infrasound)
- Excitation: natural or human-made seismic sources
- Requirements: sufficiently high excitation magnitude and good coherence of the signals
- After the transfer into the frequency domain (Fourier transform), the transfer functions of DUT and reference can be calculated.
- ➢ With the known transfer function of the reference (determined in laboratory), the transfer function of the DUT can be derived.

Open topics

- requirements for distances between reference and DUT, are natural sources sufficient
- Measurement uncertainties for this kind of calibration still need to be evaluated



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More details can be found in a dedicated poster: **Determination of the frequency response of seismic and infrasonic IMS stations...** - EGU23-11059