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Challenges of Low Frequency Seismometer Calibrations

Leonard Klaus[1], Franck Larsonnier[2], Jacob H. Winther[3], Thomas Bruns[1]
[1]Physikalisch-Technische Bundesanstalt (PTB), [2]CEA DIM, [3]DPLA

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INTRODUCTION

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 a calibration is necessary.

METHODS/DATA

How to calibrate?

While exciting sinusoidal excitations with an electrodynamic shaker, the output of a seismometer under test is compared with a well-known reference.

Laser interferometers are used as the reference. Their output is traceable to the length (unit: m) and to the time (unit: s).

START

RESULTS

Disturbances:

Disturbances from different sources influence the measurement results.

Those may be: tilting, temperature, electromagnetic disturbances

CONCLUSION

Compensation:

The magnitude of the disturbances need to be determined in order to be accounted for in the measurement uncertainty estimation of for correction

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Why Calibrate?

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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.
- Seismometers are not supposed to be moved or transported for calibration

Typical Specifications

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

State of the Art

- Use of data sheet transfer functions to assess the behaviour
- ‘Electrical calibration’ using internal calibration coils after the sensors are deployed in the field
- Limited comparability after replacing sensors, as only the some properties can be determined with the internal calibration

What is traceability?

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

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How to calibrate?

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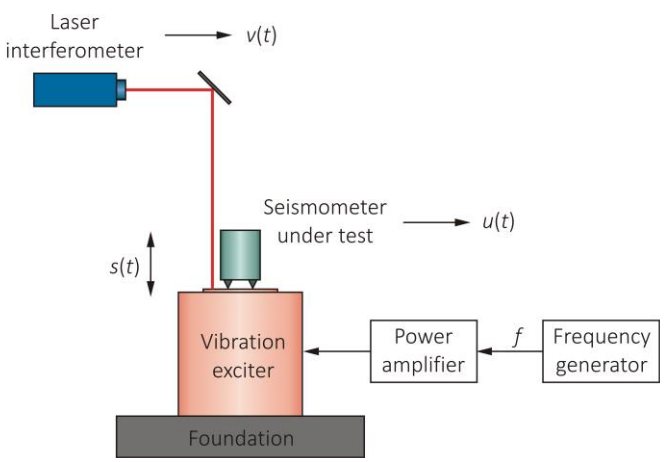
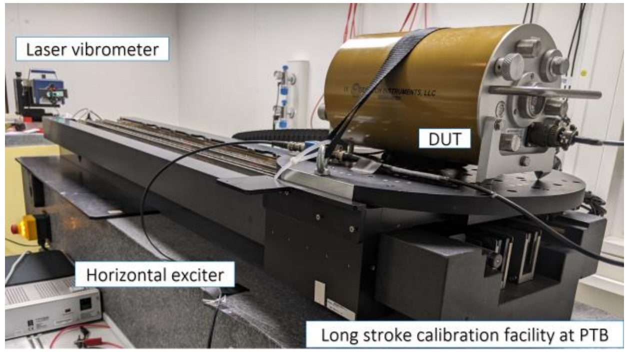
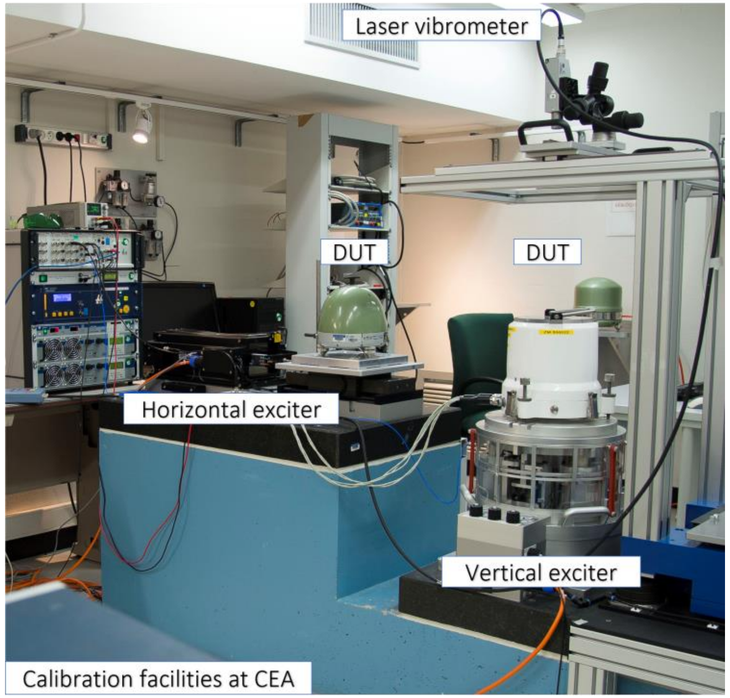
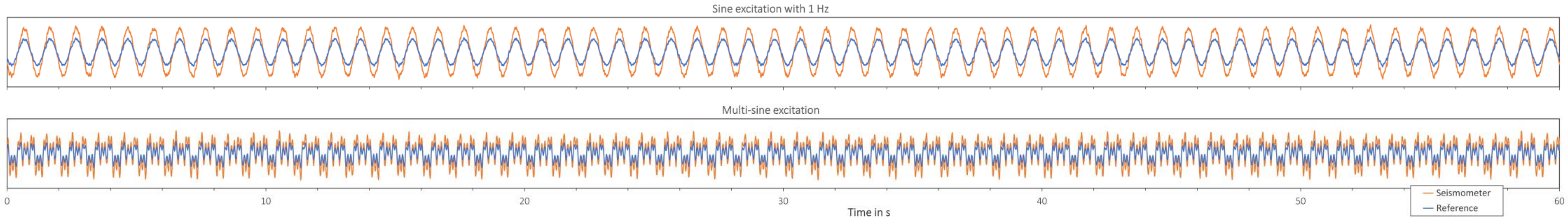




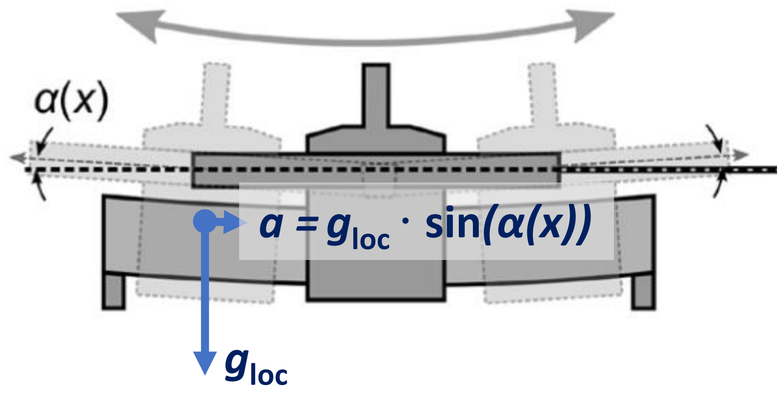


How is it done?

- Reference measurements by laser interferometry
- ➢ Movement of the exciter traceable to the wavelength of the laser and 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



Disturbances



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).

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.

Compensation

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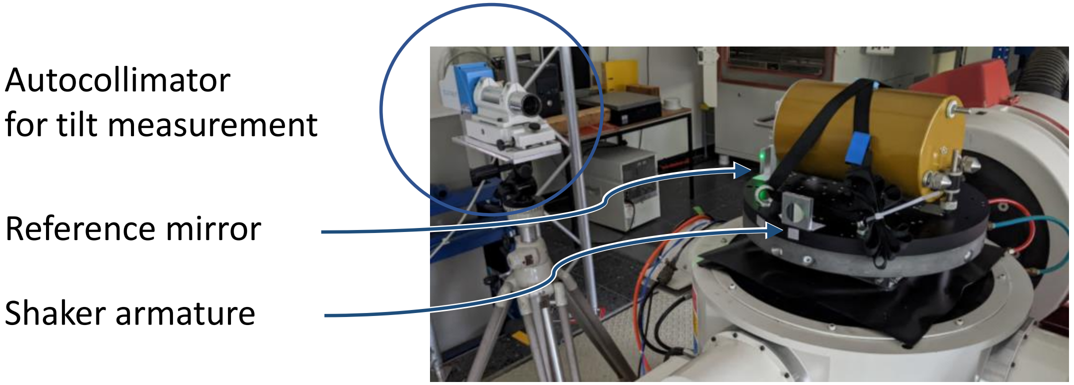
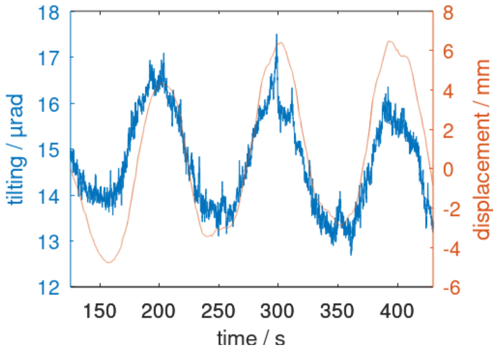
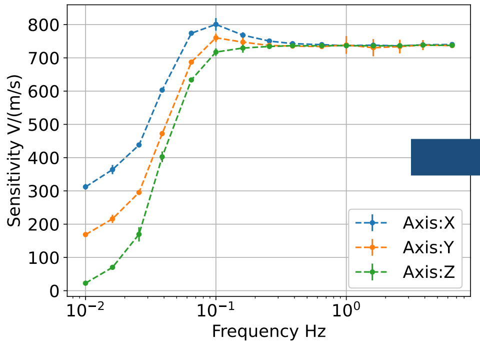
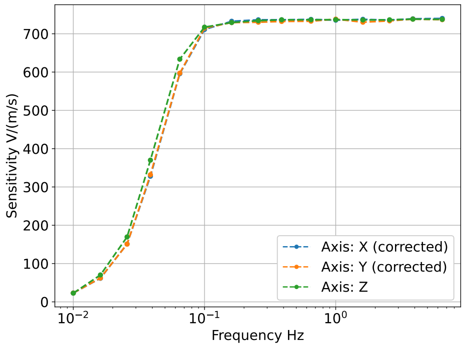


Resulting measurement results:

Strong correlation between tilt angle and shaker displacement







Tilting

- The curvature of the shaker's motion can be measured
- Tilt measurements can be carried out with autocollimators, inclinometers or static accelerometers measuring the change in the gravitational excitation
- If the curvature can be described by a circular motion, it can be compensated without measuring the tilt angle during the calibration measurement

➢ Uncertainty of the angle measurement still influences the uncertainty of the seismometer calibration

Electromagnetic disturbances

- The electromagnetic exciters can be equipped with compensation coils to reduce the generated electromagnetic disturbances
- Some seismometers can be ordered with internal shielding to reduce the sensitivity
- Seismometers can be shielded when placed on he shaker (and in the vault)

Conclusions and Outlook

Conclusions:

- State of the art: Seismometers are not calibrated with traceability to the international system of units (SI)
- Traceable calibrations have many advantages:
  - the behaviour can be assessed independently, if seismometers are replaced
  - calibration results assure comparability of old and new data
- In-laboratory calibrations are carried out using electrodynamic exciters and with laser interferometers as the reference
- Disturbances influence the measurements

How to bring the calibration to the field: On-site calibration:

- In parallel to the development of in-laboratory calibrations, research is carried out to use such calibrated seismometers in the field by carrying out on-site calibrations
- More information in dedicated presentation in session O3.1: Michaela Schwardt, "Determination of the Frequency Response of Seismic and Infrasonic International Monitoring System Station Sensors Using an On-Site Calibration Approach"

A panel discussion on Metrology will focus on the importance of traceability for the IMS on Tuesday, June 20th from 16.00 to 17.30

A dedicated workshop on Metrology will be offered on Wednesday, June 21st and on Thursday, June 22nd

References / Acknowledgement

ISO 16063-11, "Methods for the calibration of vibration and shock transducers — Part 11:Primary vibration calibration by laser interferometry", International Standardization Organiszation, 1999, [*https://www.iso.org/standard/24951.html*](https://www.iso.org/standard/24951.html)

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Infra AUV

EMPIR EURAMET
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