Non-stationary signals: environmental disturbance and the NPL Watt balance

Ian M Smith, National Physical Laboratory

Jane Jiang, University of Huddersfield

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Outline

Background

Signal processing requirements

Initial data analyses

Wavelet analysis

A new way of realising the kilogram

The kilogram is the last remaining artefact standard in the SI and is defined as the mass of the prototype kilogram that is held at BIPM in Paris

NPL in-vacuum Watt balance, developed in the 1998-2001 Foundation Metrology Programme, measures mass in terms of the metre, the second and Planck's constant

Why is vibration a problem?

Balance compares the force generated by gravity acting on a mass, to the force generated by an electrical current passing through a coil in a magnetic field

Vibrations are a source of uncertainty in Watt balance measurements because vibration of the balance coil can lead to vibration-induced voltages

Measurement set-up

7 sensors in different locations

Each sensor records (250 Hz) for approx. 65 seconds

No overlap in time between sensors

20 minute data recording cycle

What do we want to do?

Identify non-stationary signals

Identify sources of vibration, their frequencies and amplitudes and how these change over time

De-noise the data

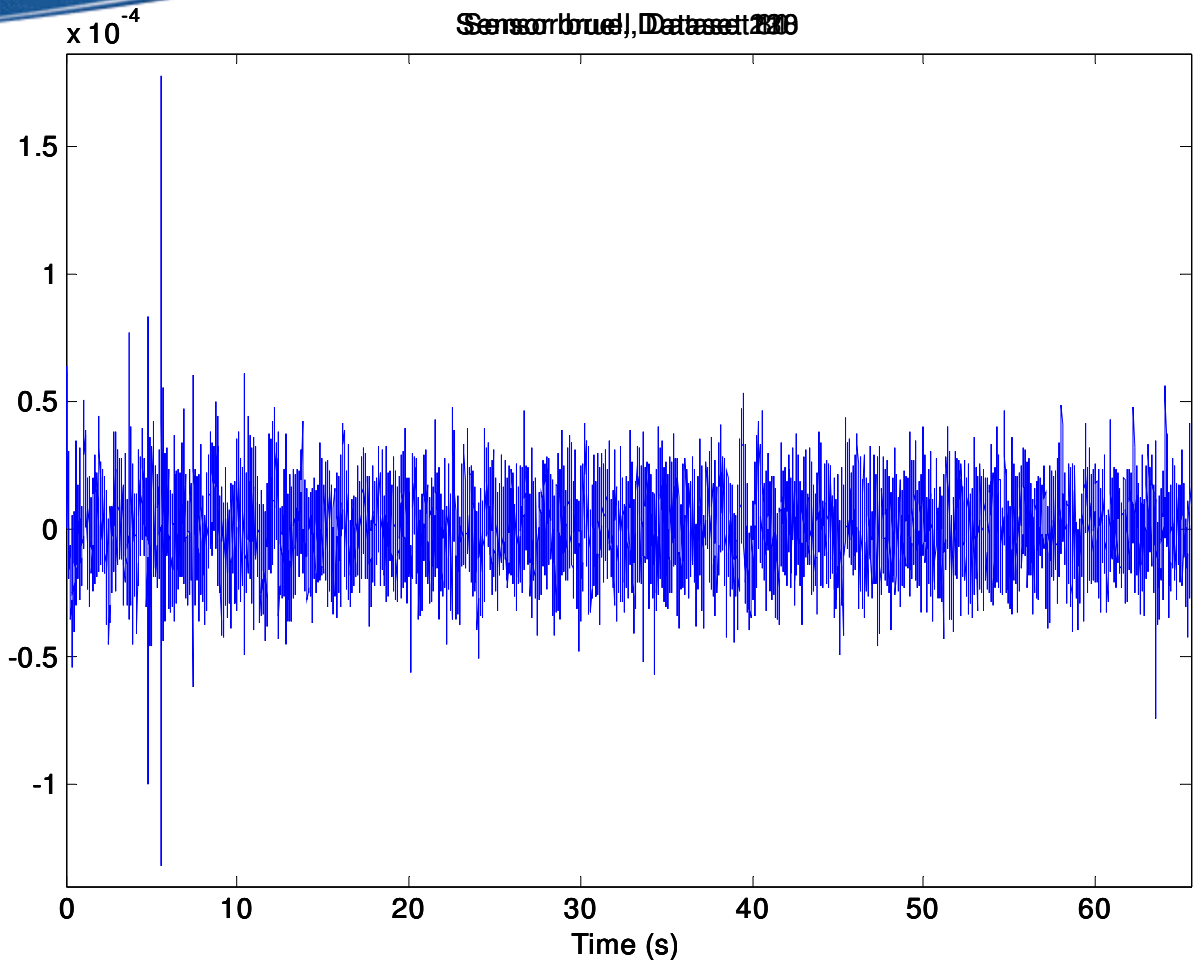
Reduce the amount of data that needs to be stored

If possible, automate the above

Initial data analyses

- Visual inspection
- Matlab periodogram
- Matlab spectrogram
- Time-domain analysis

Visual inspection



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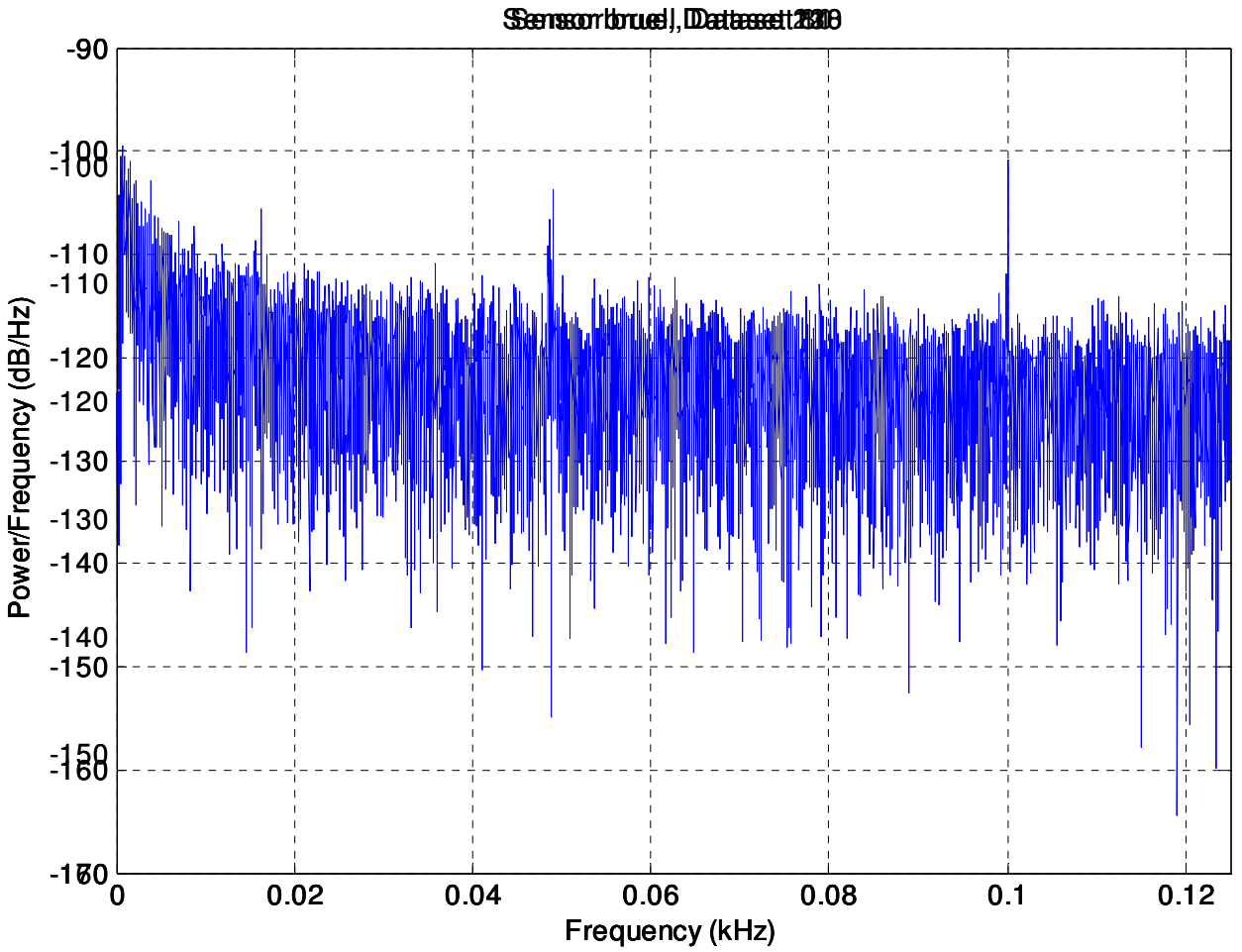
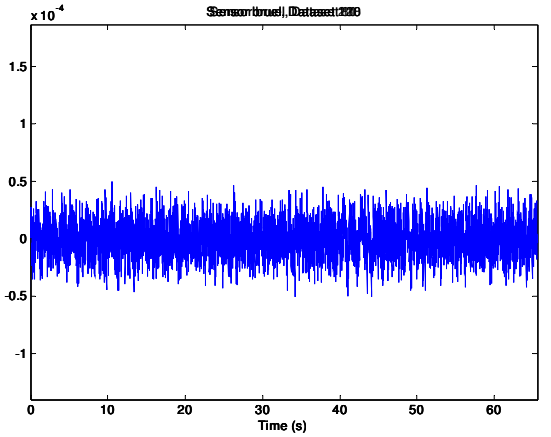
Matlab periodogram





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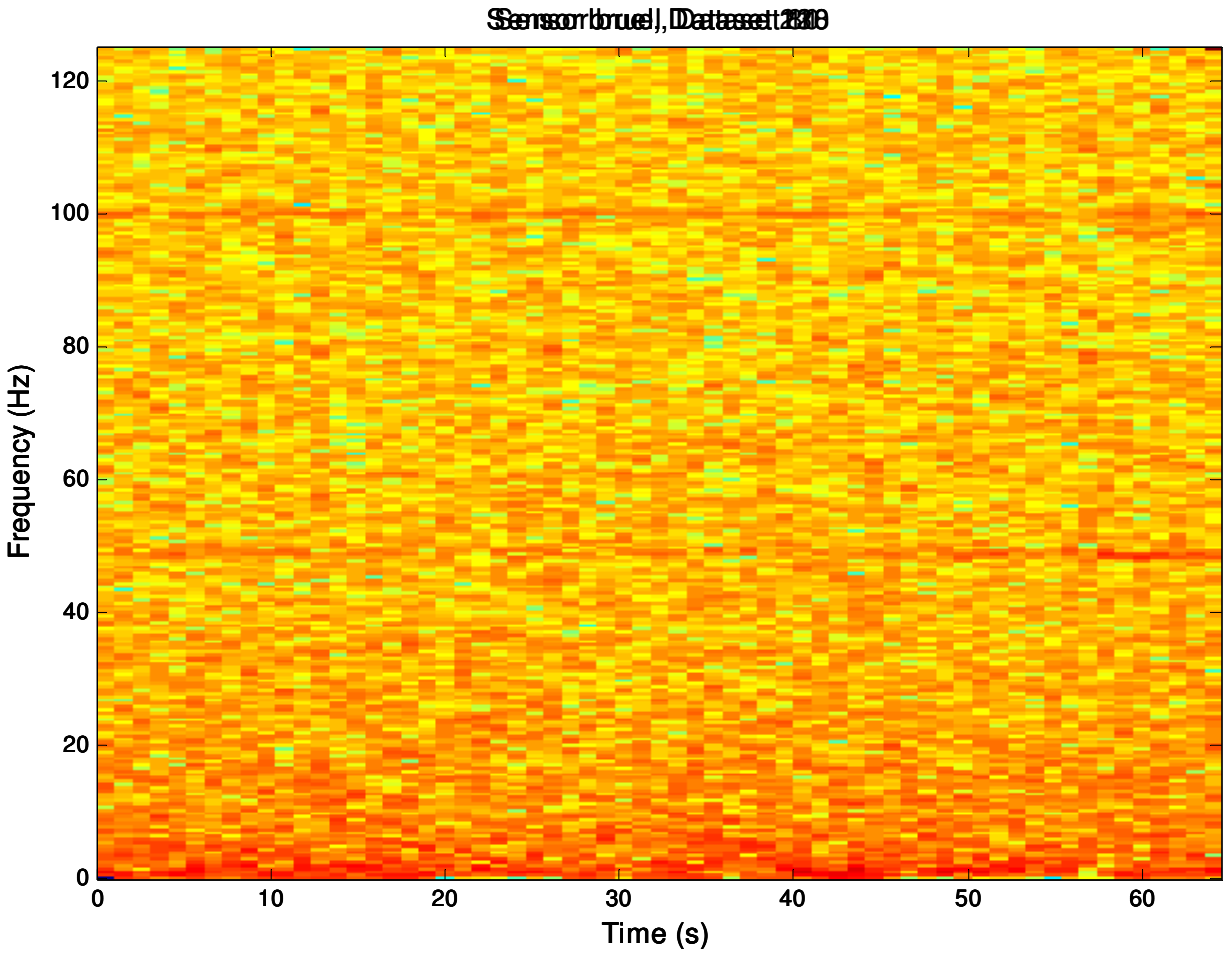
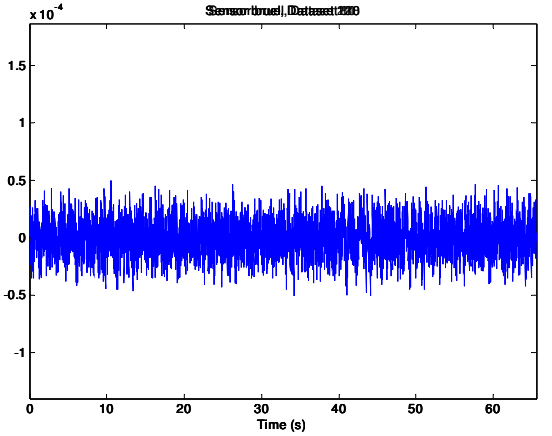
Matlab spectrogram





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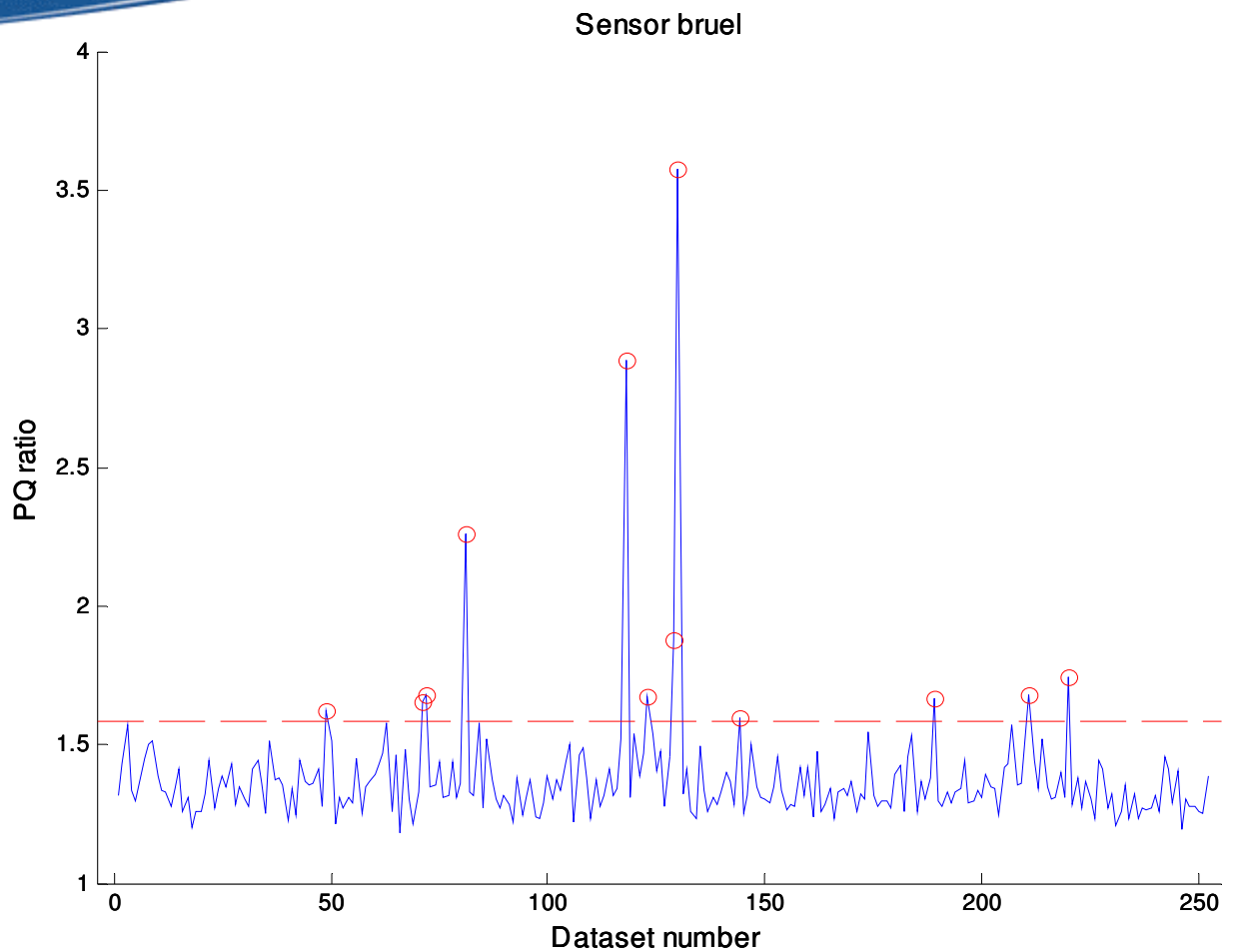
Time-domain analysis

For each signal i

- **Divide signal into N portions of length m**
- **For each portion j, evaluate** $p_q(i,j) = \sqrt{\frac{1}{m}\sum_{k=1}^{m} s_k^2}$
- **Calculate PQ ratio** $r_{p_q}(i) = \frac{\max_j p_q(i,j)}{\min_j p_q(i,j)}$

Assign sensor threshold value and identify possible signals of interest

Time-domain analysis



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Initial data analyses

Visual inspection of signal

- Time consuming
- Subjective

Matlab periodogram

- Frequency information only

Matlab spectrogram

- Time and frequency information

Time-domain analysis

- Identifies possible non-stationary signals
- Automation not trivial