Capacity for Rail

SP4 Advanced Monitoring

Dissemination, Brussels – 3rd November 2016

Gunnar Baumann
Gunnar.Baumann@deutschebahn.com

Noemi Jimenez Redondo, CEMOSA
Edd Stewart, Univ. of Birmingham
SP4 Members

SEVENTH FRAMEWORK PROGRAMME

C4R Capacity for Rail

Workpackages and content

SP 4 - Advanced Monitoring

WP 4.1

Monitoring Strategies and evaluation, Algorithms

Mechanical Analysis, Data handling, mathematics, „Customer needs“

WP 4.2

Monitoring Technologies & Sensor

Measurement technologies, overview and experiences in other industries

WP 4.3

Implementation in new structures

Civil engineering & monitoring technologies

WP 4.4

Migration of innovative tech-nologies to exist-ing structures

Infrastructure Knowledge and maintenance problems; meas-urement tech.

Demonstrators

Objectives of the last 36 months …

- Identify components and systems critical for operation/deterioration of the railway infrastructure that should be monitored
- Identify current and future monitoring possibilities. Process for technical and economical assessment
- Identify key operational parameters that govern deterioration of selected key components/systems
- Translation of measured data to deterioration predictions for these Collection strategies

Objectives of the last 36 months …

- Functional and technical requirements for railway monitoring and inspection
- Identifying and evaluating sensor and energy harvesting technologies
- Identifying and evaluating communications and data integration technologies
- Demonstration of innovative monitoring concepts in the laboratory

Objectives of the last 36 month ...

- Specific monitoring requirements and techniques for the new infrastructure elements incl. build-in technologies and plug&play
- Analysis of the interaction/interference between sensors and infrastructure elements
- Development of procedures for installation, maintenance and replacement of sensors. Recommendations.
- Demonstration of innovative monitoring concepts in new infrastructure

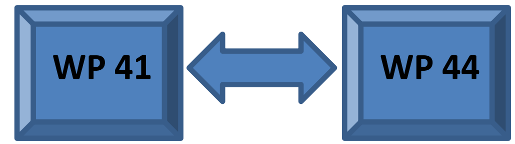
WP 44

Migration to existing structures

Capacity for Rail

Objectives of the last 36 months …

- Identify fault and cost drivers. Provide retrofit kits for existing railway infrastructure



- Application without existing power and data infrastructure in a plug and play method
- Integration into existing railway maintenance and operation systems. Standardised Open Interfaces
- Economic evaluation. Recommendations/Guidelines

Advanced Monitoring - Developments and Demonstrators - Analyses based on the available data

Capacity for Rail

Cost per damage	low	moderate	high
high	Root cause analysis	Early warning	**Act**
moderate	Monitoring	Root cause analysis	Early warning
low	Do nothing	Monitoring	Root cause analysis

Frequency of failure per time slice

The main objective is to reduce the number of technical disruptions and delay minutes as well as reducing the related life cycle costs of the switches.
In detail, the defined tasks to achieve the objectives are:

- Establishment of simple key performance indicators related to the availability for controlling substantial production means (performance measurement, analysis and monitoring system).
- Classification of all switches on availability criteria
- Definition of equipment standard for the complete system switch (which switch category gets e. g. a heating system or closure compartment cover) or **diagnostic** to fulfill performance requirements
- Development of a strategy for the preventive maintenance and implementation concept
- Target-actual comparison regarding the equipment standard sharply outlined on the switch

Important differences

Increasing Complexity & Costs

- Monitoring

  Measuring of direct or indirect values to identify unusual product behaviour. (Switches → measurement of the current)

- Diagnosis

  Automatic assessment of measured values. Repeatability ensured by statistic . Clear Knowledge about the behaviour of components or products.

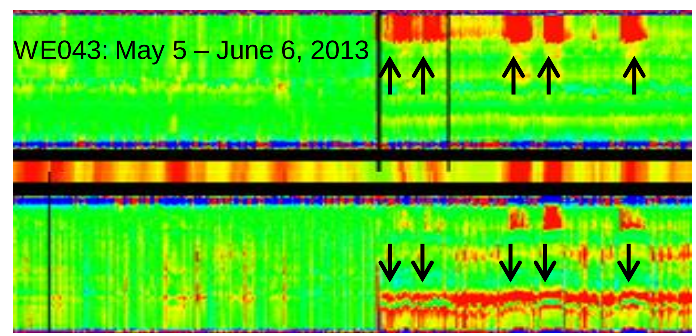
- Inspection (Self-inspection)

  Measurement or visual assessment of safety relevant behaviours. The measurement accuracy must be at least 10-times better than the value in the specification. (1,0 mm → 0,01 mm)

TRADITIONAL POINT DIAGNOSTICS

DIANA **LONG-TERM POINT MACHINE BEHAVIOUR**

Example: Point machine temperature-induced anomalies



Note: Proprietary point diagnostic system reports no error

Technologies to be used to develop integrated solutions for next generation railway monitoring and inspection

- Specification, identification and evaluation

Scope

- Sensing, energy harvesting, communications, processing and data integration

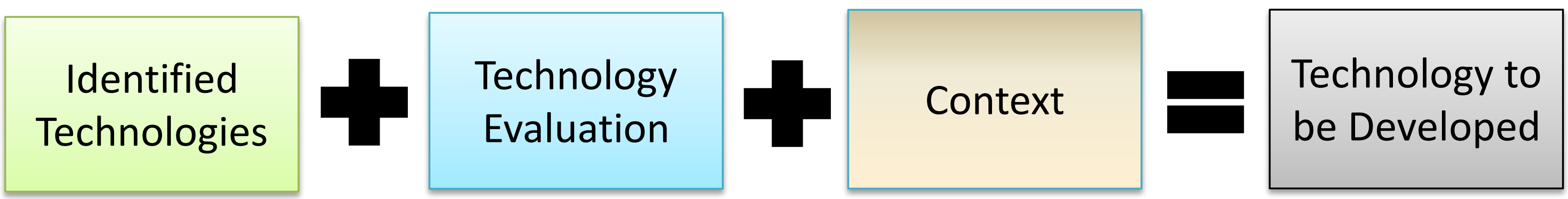
Expectations

- Low cost, robust, intelligent, and low power

Near-horizon technologies or technology transfer from other domains

- Not the development of entirely new approaches

Advanced Monitoring - Developments and Demonstrators - Technology Identification Framework



Advanced Monitoring - Developments and Demonstrators - Technology Identification Framework

Evaluation at multiple levels

<u>Technologies</u>

High level requirements

- Integration
- Standardisation

Mid level requirements

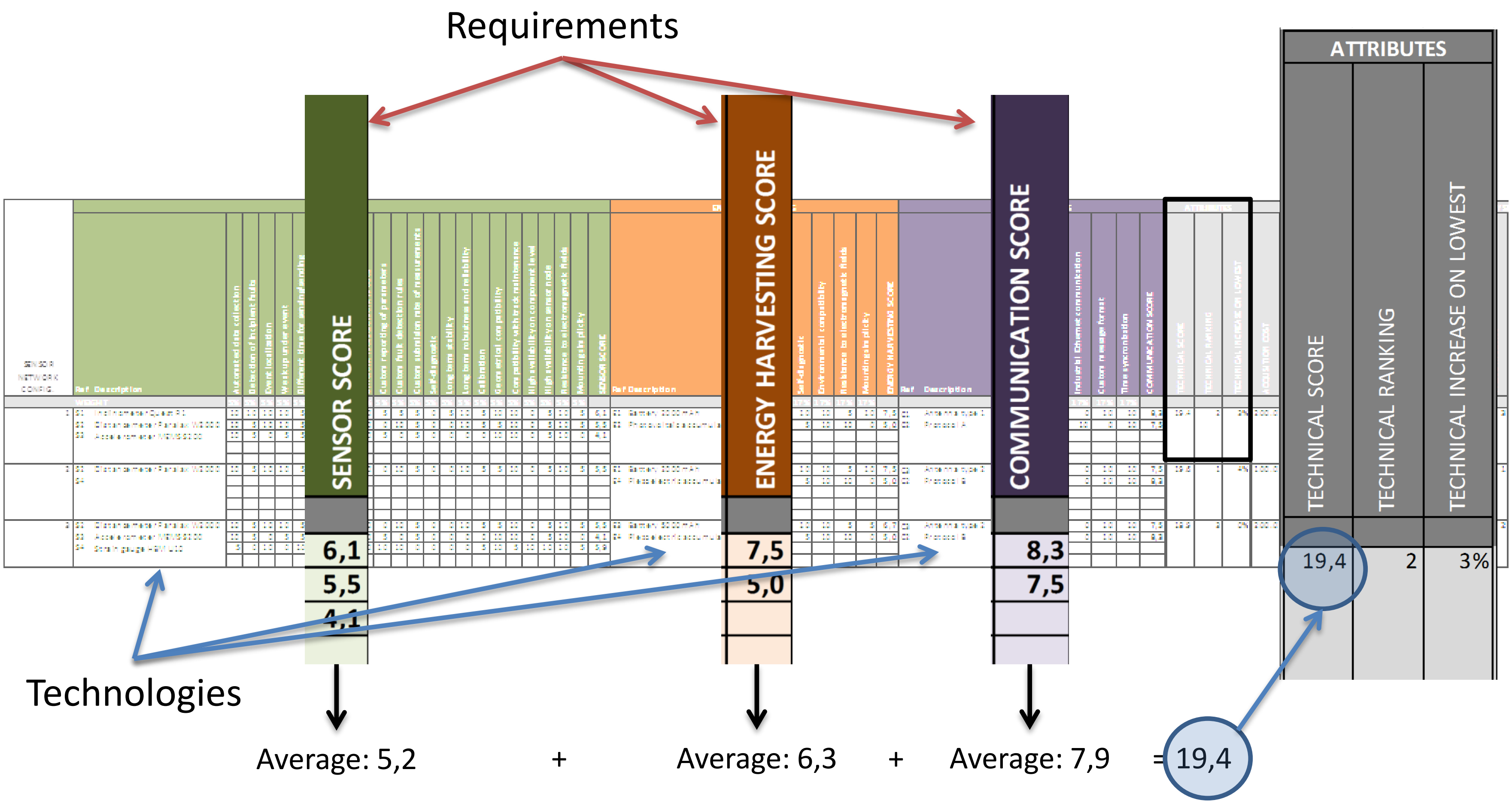
- Data aggregation, fusion and storage
- Fault detection (defect recognition)
- Diagnosis (evaluation algorithms)
- Prognosis (degradation algorithms)

Low level requirements

- Sensors (data acquisition)
- Energy harvesting (generation/storage)
- Communications

C4R
Capacity for Rail

Requirement types within a level are grouped

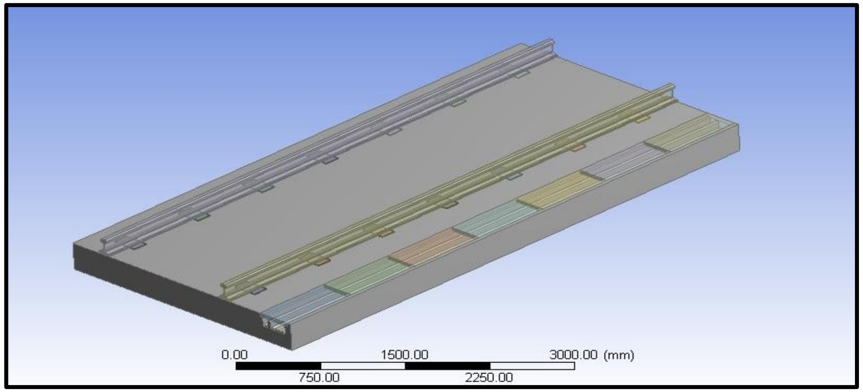


Scores in different requirement categories are collated

Capacity for Rail

Specific monitoring requirements and techniques

- **Identification of weak points in the new slab track system:**
  - High lateral forces in the stoppers
  - Possible movements in the gaps between consecutive slabs
  - Loss of tightening force in steel plates
  - Drainage of the blocks channels and the slab



- **These possible weak points cause failures in the track components**
  - New monitoring system should be designed in order to detect them

Objective: developing a new monitoring system which allow to detect the possible weak points in a remote way

Specific monitoring requirements and techniques

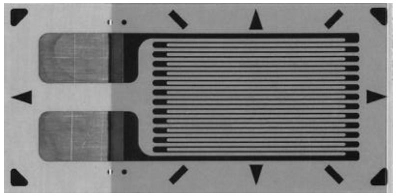
- **Requirements for the integrated monitoring system**
  - Sensor nodes shall be low-cost
  - Sensor nodes shall be energetically autonomous (battery-free or energy harvesting methods for self-recharging)
  - Sensor nodes shall be embedded in the infrastructure elements (i.e. below some centimetres of concrete)

Technology **RFID**

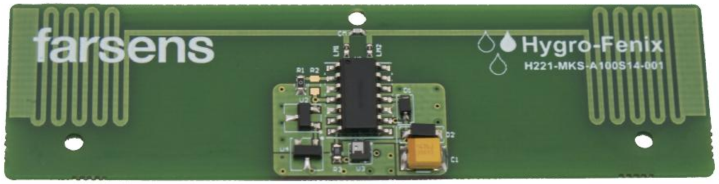
- **Low cost sensors**
- **No battery (passive RFID)**
- **Easy remote detection (contactless): hand reader or antenna reader**

Specific monitoring requirements and techniques

- **RFID sensors**
  - **Strain** measurement
    - ✓ Strain/deformation in the rebars of the concrete slab



  - **Temperature** measurement
    - ✓ Changes in concrete behaviour (sensor embedded in the concrete slab)

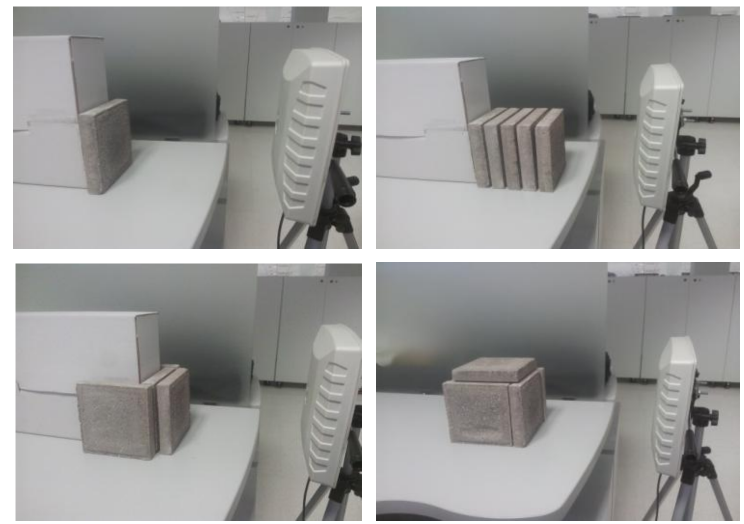


  - **Humidity** measurement
    - Detection of possible cracks or failures in the slab (embedded in concrete)

Need to perform interference assessment in reinforced concrete (RC) elements

Specific monitoring requirements and techniques

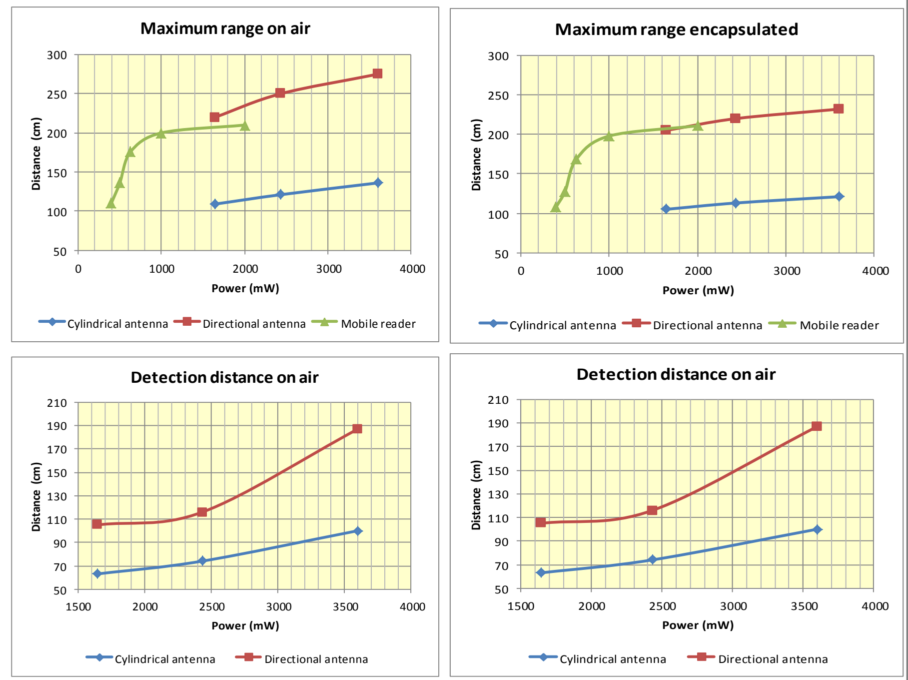
- **Interferences analysis**
  - Different concrete thickness
  - Possible steel interferences
  - PVC coating for RFID sensor



Specific monitoring requirements and techniques

❖ Results

- Good range of reading
- Max. 6 cm for concrete cover
- PVC coating do not affect to the signals

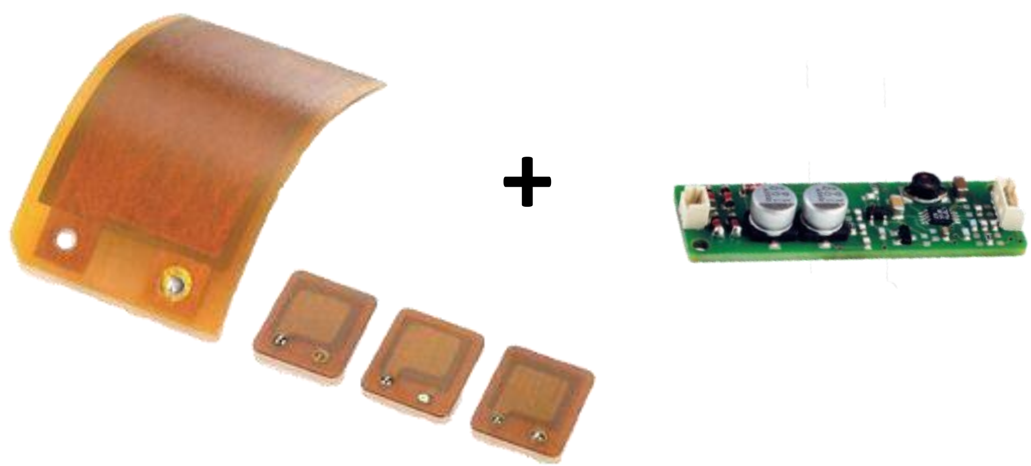


Next step:
Real scale validation in test box (CEDEX)

- Energy harvesting technologies
  - Identification
  - Evaluation
- Sensors
- Retro-fitting in existing railway
- Future plan

Vibration

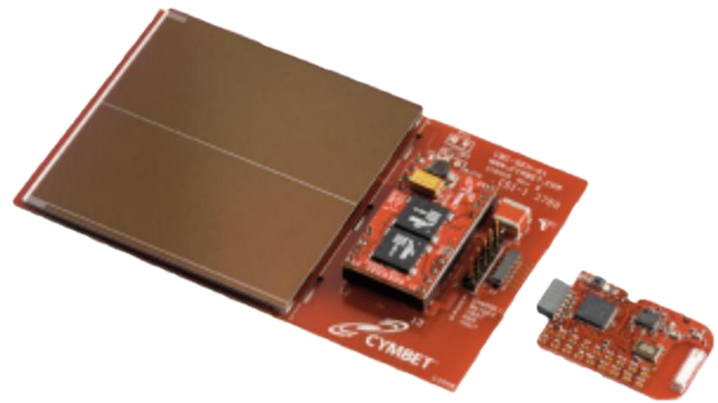
- PI Ceramic energy harvesting kit including:
  - 2 DuraAct Patch transducers
  - Electronic Module



PI Ceramic Energy Harvesting Kit

Advanced Monitoring - Developments and Demonstrators - Energy Harvesting Technologies

- Solar
- Texas Instruments
  - 400+ transmissions in dark
  - Inputs for external energy harvesters such as thermal, piezoelectric, 2nd solar panel, etc…
  - Ultra low power MCU with 16Mhz performance
  - Integrated temperature sensor
  - Integrated 2.4Ghz wireless transceiver

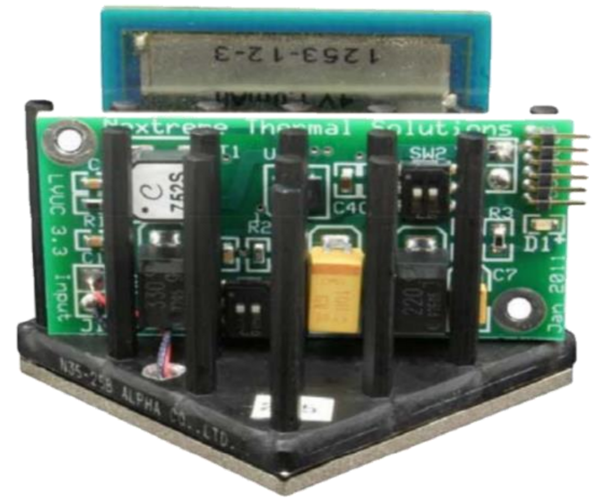


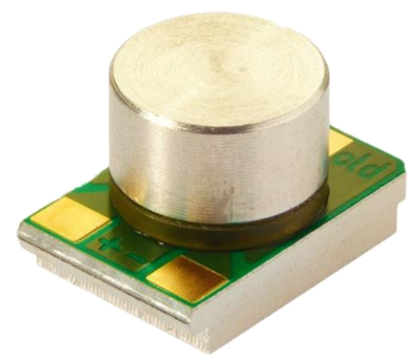
Advanced Monitoring - Developments and Demonstrators - Energy Harvesting Technologies

Capacity for Rail

- Thermoelectric
- Laird Thermal Power Module
  - Self-contained thin-film thermoelectric power generator with regulated output voltage
  - Up to 1.5 mW of usable output power stored in a micro power module
- MicroPelt – Peltier Thermogenerator
  - Packaged thermogenerator
  - Maintenance-free solid state operation;
  - High power density;
  - Low weight and thermal mass Output voltage of 60 mV/K
  - Dimensions: 15x10x9 mm.

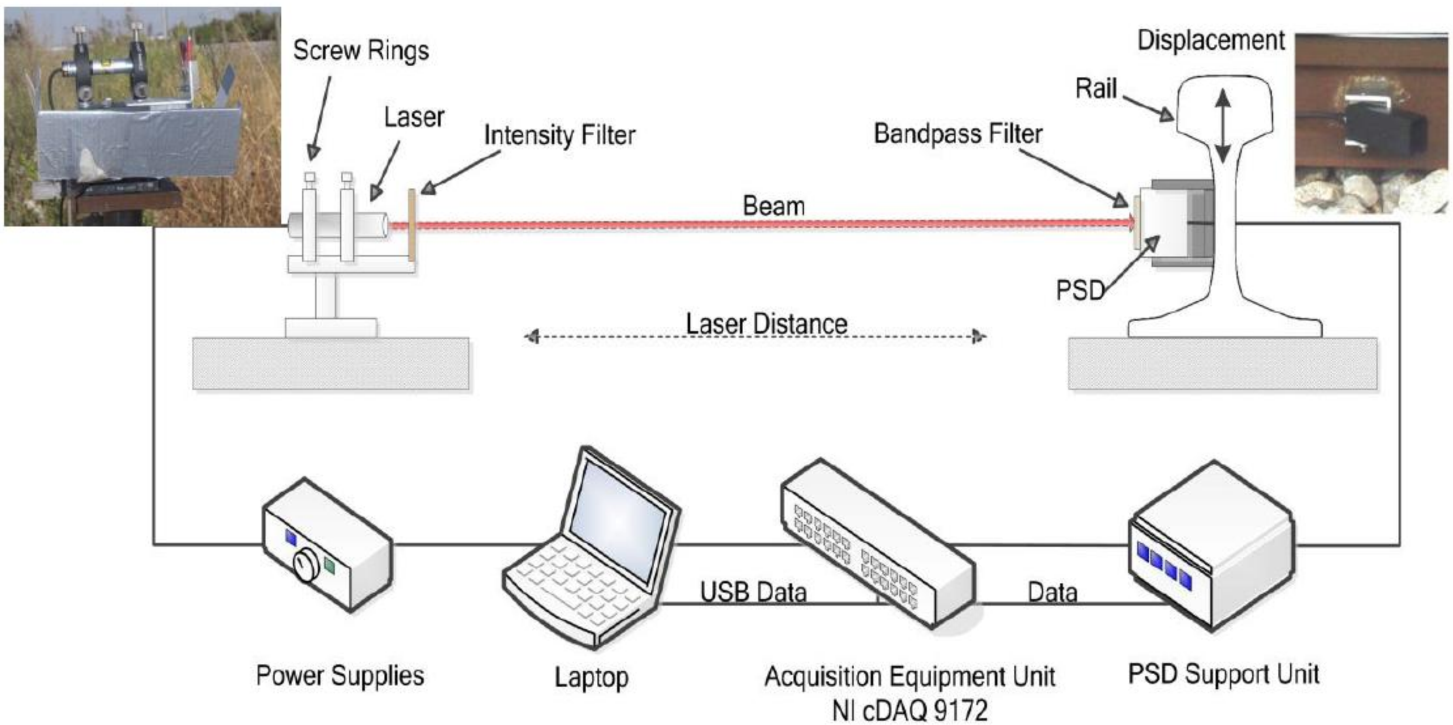
Thermobility WPG-1S



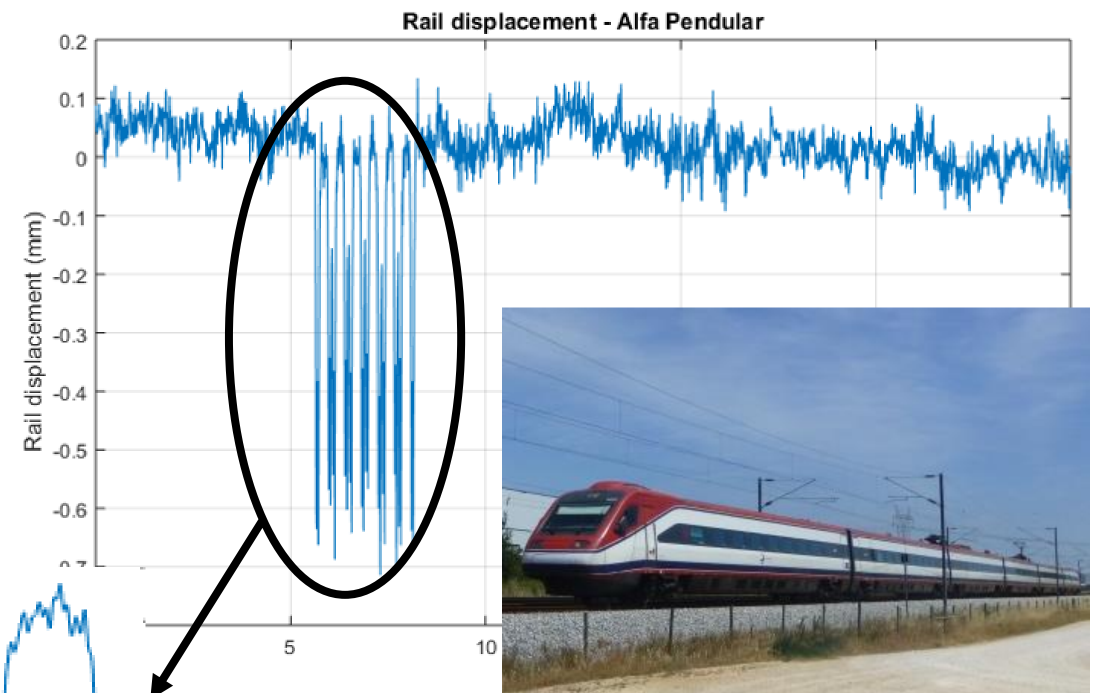


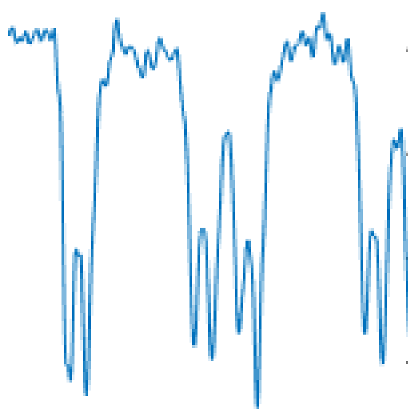
Micropelt TGP751

- Laser/PSD used to measure the vertical displacement of the rail



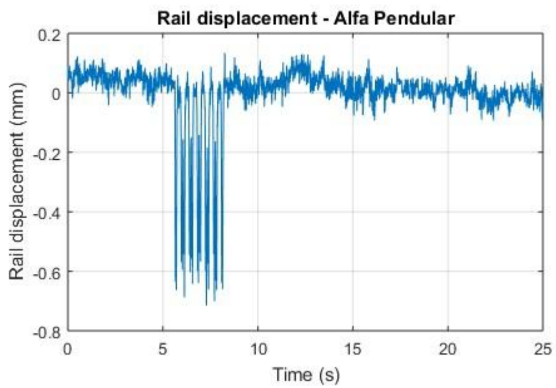
- Vibration generate by the passing train



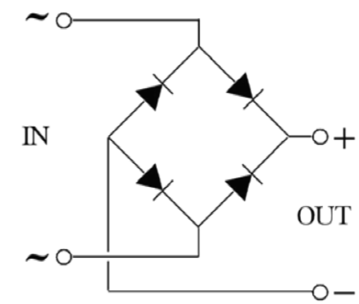


Axle passing the sensor

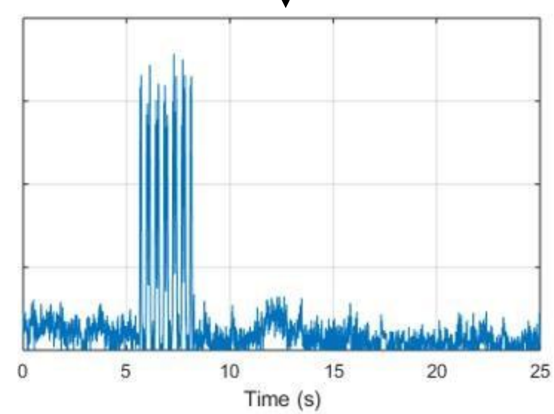
Capacity for Rail



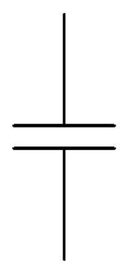
PI DuraAct Transducer



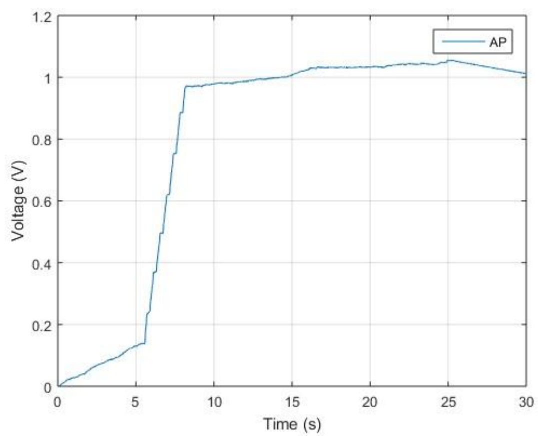
Bridge rectifier



Rectified voltage



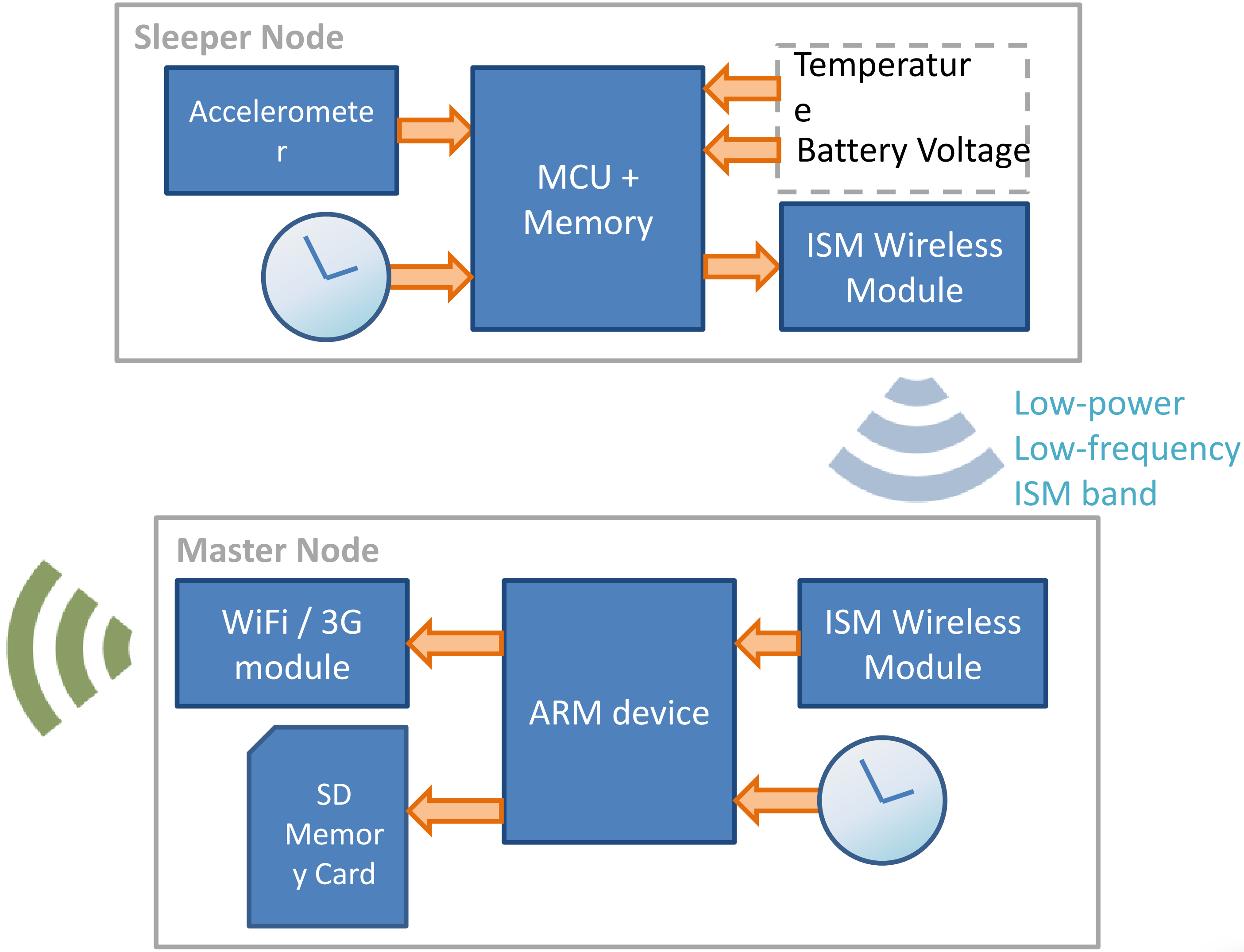
200µF capacitor

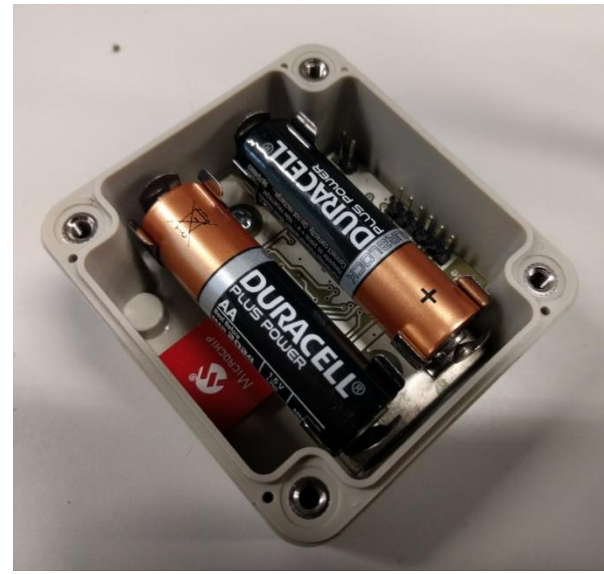


Voltage across the capacitor

Total energy = E = ½ *C*Vcap^2

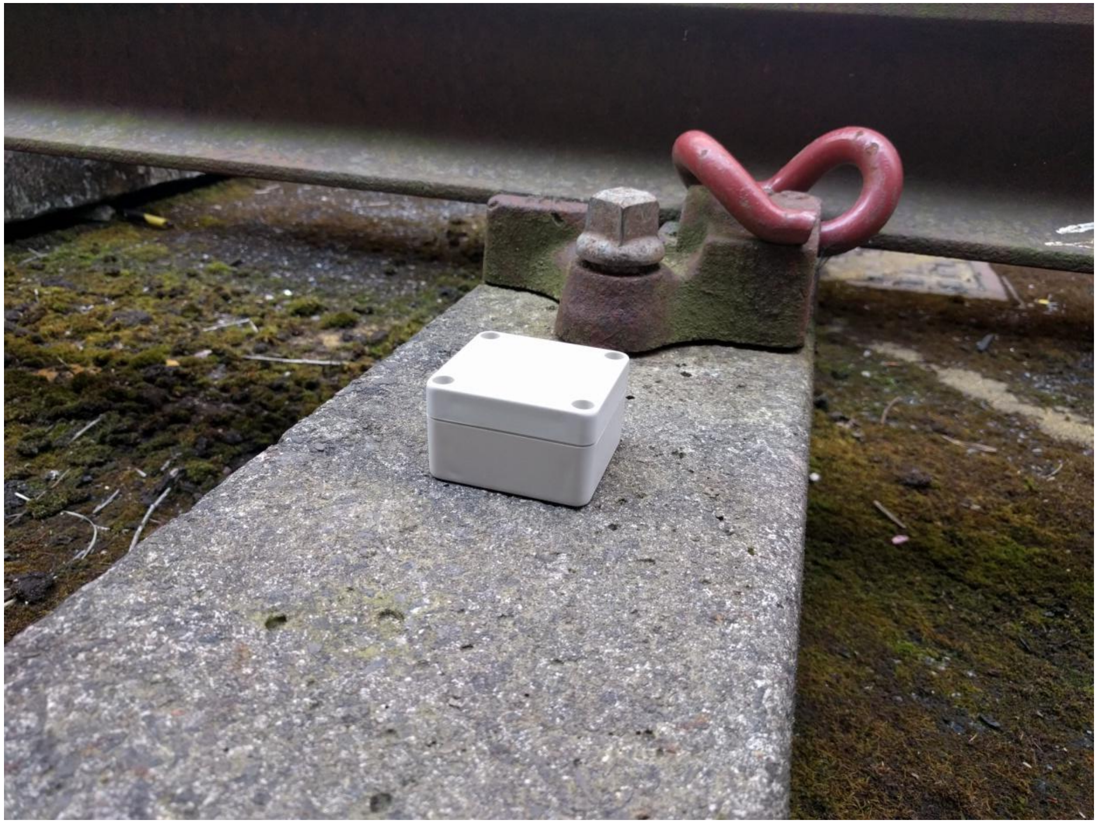
Advanced Monitoring - Developments and Demonstrators - UoB Wireless Node System Overview



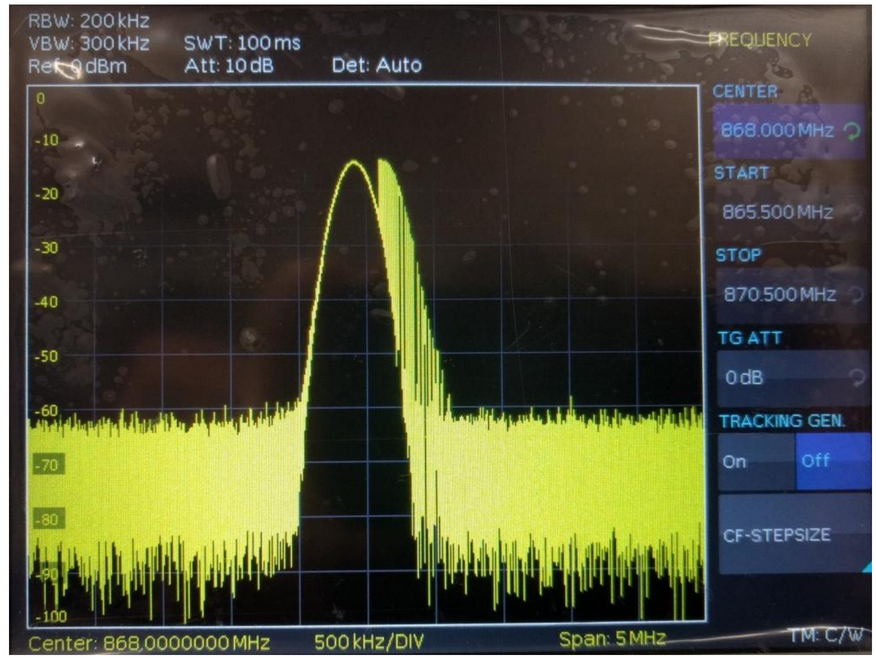


- Internal accelerometer
- ‘Sleeps’ until a train is detected
- Samples at 1600 Ss^{-1}
- Downsampled to 800 Ss^{-1}
- Stored in memory (16KB)
- Transmitted to master node after train has passed
- Battery powered – designed to last ~5 years

- Small size, to be mounted on sleeper end



- Low frequency ISM band
- 868 MHz FSK
- Very low power
- Each node transmits at specified time slot
- Real-time clocks are periodically synchronised by the master



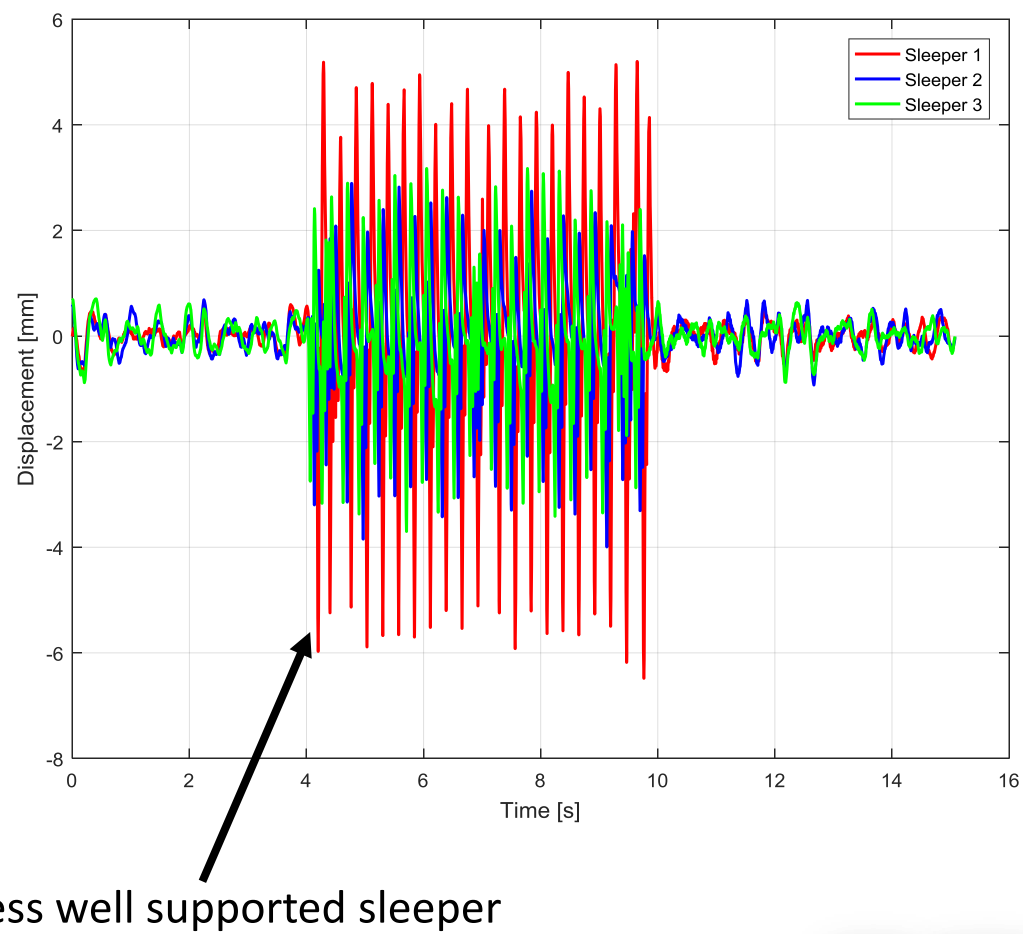
- Monitoring sleepers at UK high-speed 1 using low power accelerometer and embedded system
  - Eurostars
  - Javelines
  - Freight trains
- Monitoring the noise signature pre/post grinding
  - Use of lower power microphone and embedded system

- 3x accelerometer installed in Kent UK – High speed line

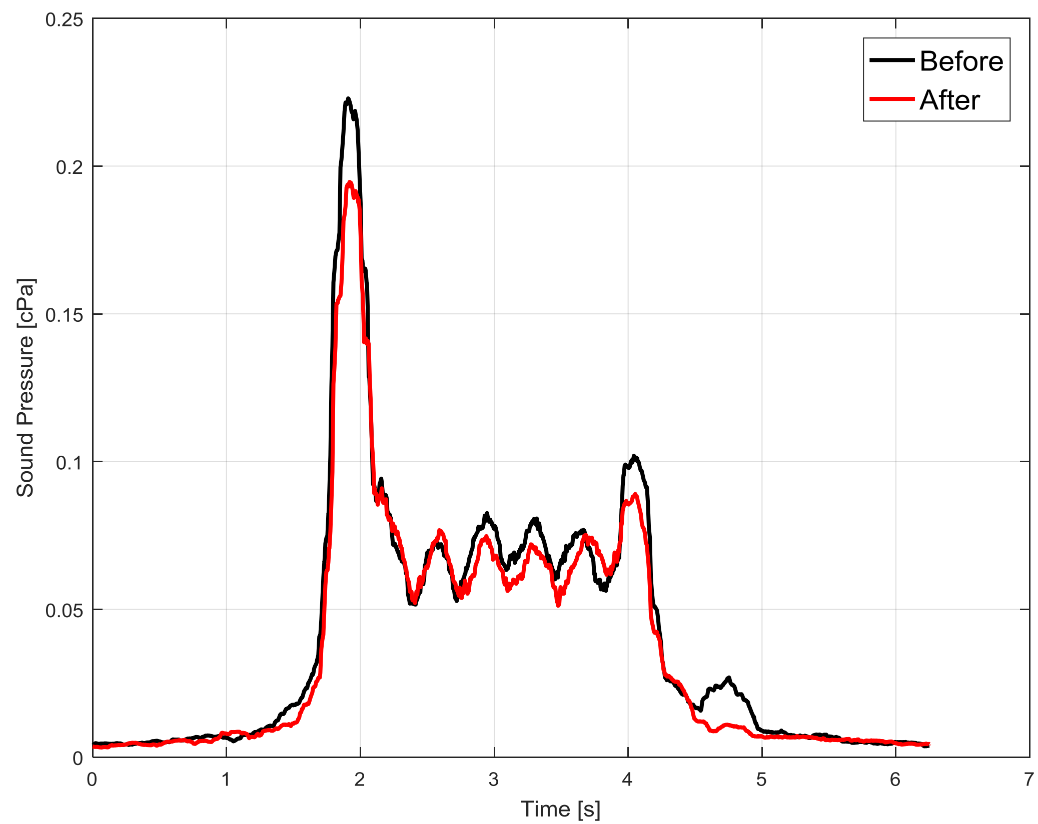
- Around 1400 measurement were taken in 2 weeks
    - Line speed

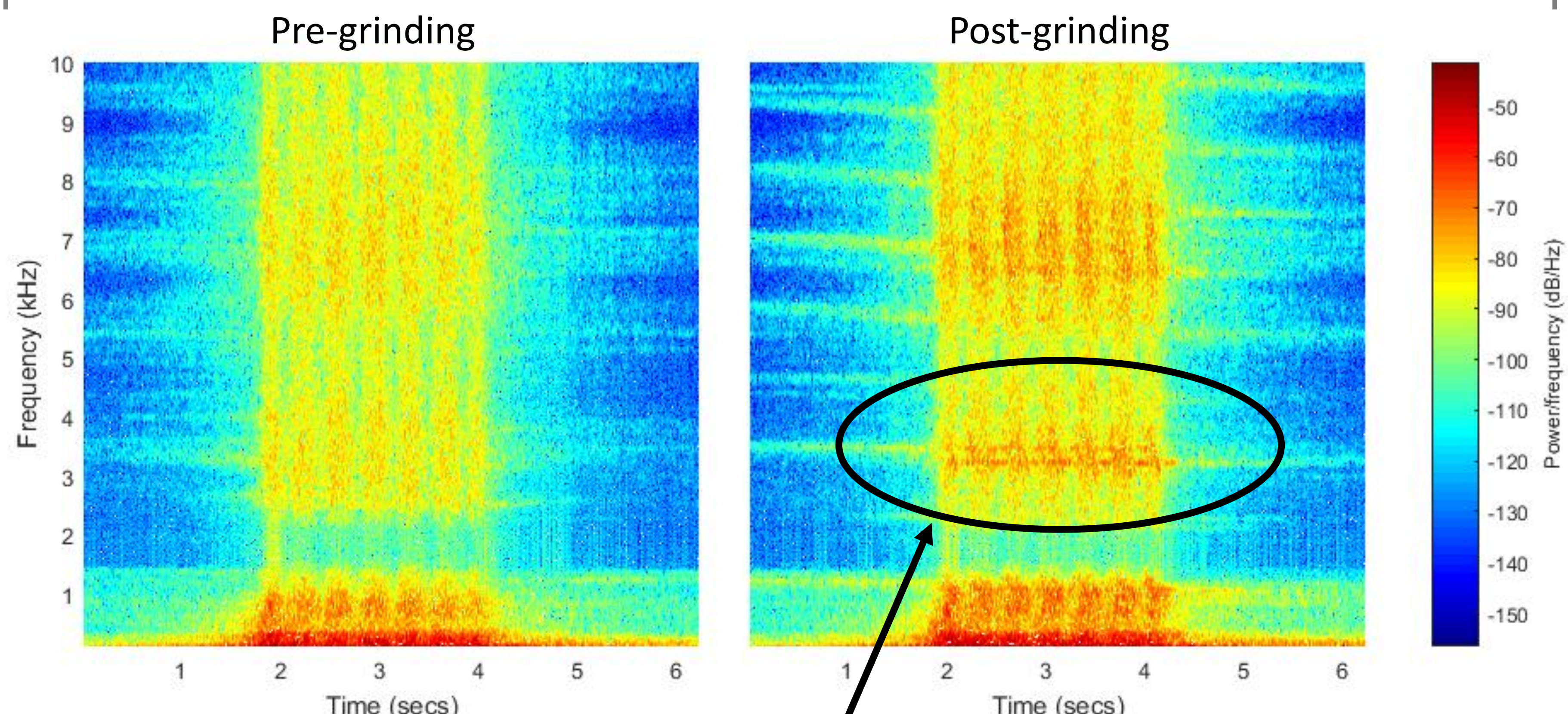
      220 kph to 300 kph

- Displacement curve for the three accelerometer
- One seems to be slightly different to the other two



- Lower RMS values in the sound pressure level after grinding





Post-grinding wheel/rail interface harmonics

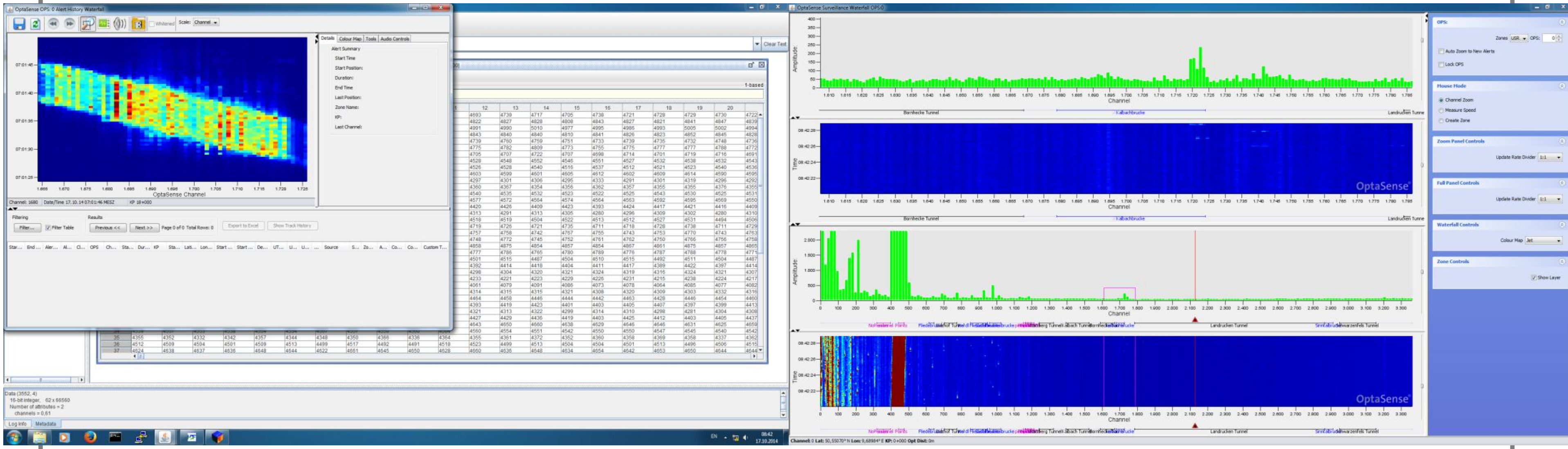
- # Transition zone monitoring

New Sado river crossing

- Transition zone site – Rio Sado

Advanced Monitoring - Developments and Demonstrators - Implementation in new structures

- A first evaluation of an –Optasence-fingerprint of a high-speed line was done and should be analysed by track specialists within the department (DB).



Switch type W874 & W873, km 321,2:
EWR 60-1200-1:.. , concrete sleeper, movable frog,
V_max = 250 km/h, typ. 230 km/h

Test site advantages:

- Track geometry by wayside monitoring (tilt- sensors)
- Sleeper voids by accelerometer
- Measurements by regular inspection by measurement train all 3 month
- Weekly monitoring by equiped ICE-2 train
- Acoustic monitoring of the switch (class-1 standard)

…any questions?

Capacity for Rail

Thank you for your attention !

- Mani Entezami , Edd Stewart, Graeme Yeo , - University of Birmingham
- Rui Calçada, Joaquim Gabriel, Rodolfo Martins , – University of Porto
- Franscisco Ganhão – Infraestruturas de Portugal
- Noemi Jimenez-Redondo - CEMOSA
- Gunnar Baumann - DB Netz AG

SEVENTH FRAMEWORK PROGRAMME