Continuous condition monitoring of pipelines and risers

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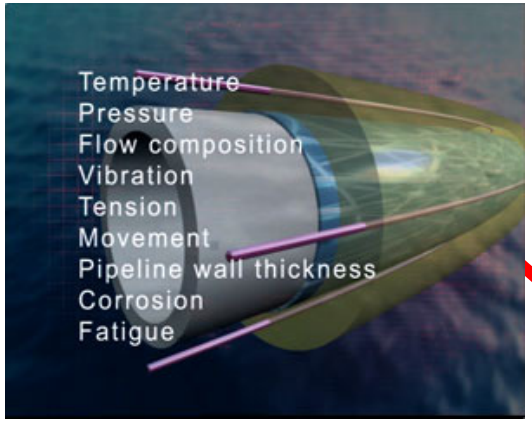
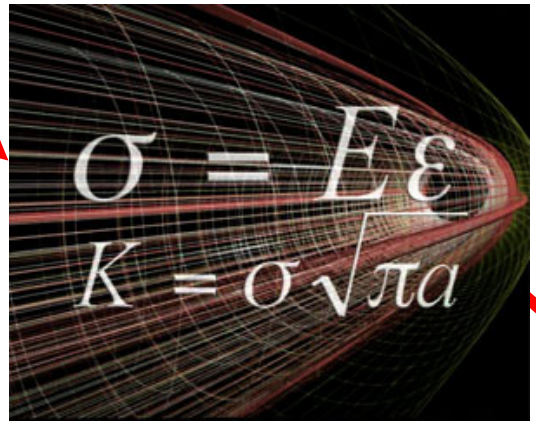
www.smartpipe.com

Data collection



- Sensors
- Communication
- Power

Data interpretation



- Materials degradation
- Analysis tools
- Database

Decision making

- Technical condition
- Warnings
- Simulations
- Visualisation

General system requirements

- No interference with laying operations
- Non intrusive sensors
- Low cost, simple, robust
- Lifetime >20 years
- Interfacing to existing sensor technology
- Low power consumption
- Local processing to reduce needed communication capacity

SmartPipe

Lithium batteries

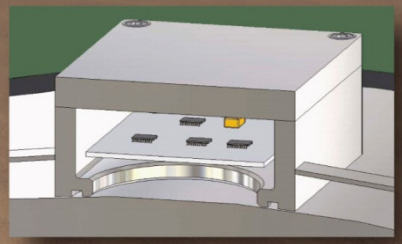
Thermo electric generator

Sensors:

- Wall thickness
- Stress/strain
- Vibrations
- Temperature
- Pressure
- Pipeline position

Electromagnetic communication in pipe

Sensor, power and communication packages



SmartPipe

Sensors

- Ultrasound wall thickness measurement
- Strain gauges for measuring deflection, vibration and internal pressure
- Thermistor for temperature measurements
- Accelerometer for measuring inclination

Communication

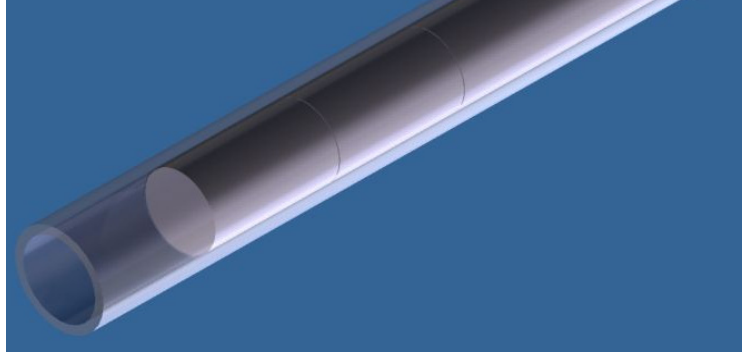
- Wireless electromagnetic signal in coating

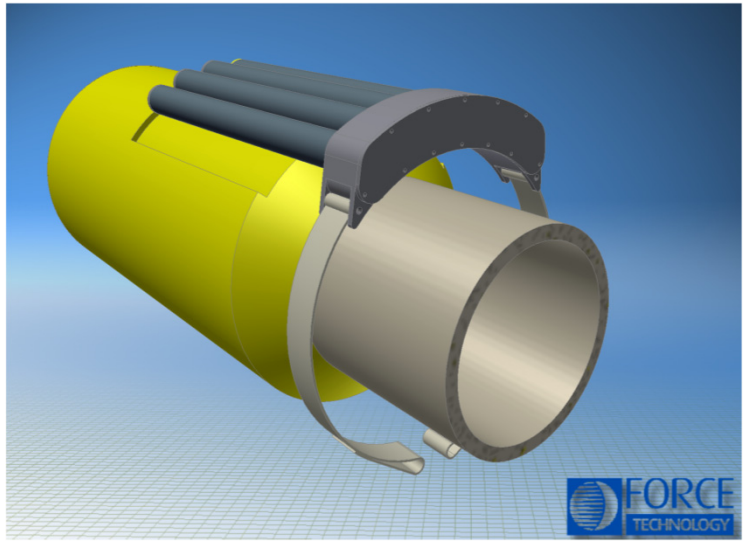
Power

- A package of conventional Lithium batteries
- Thermoelectric generator

Battery packing

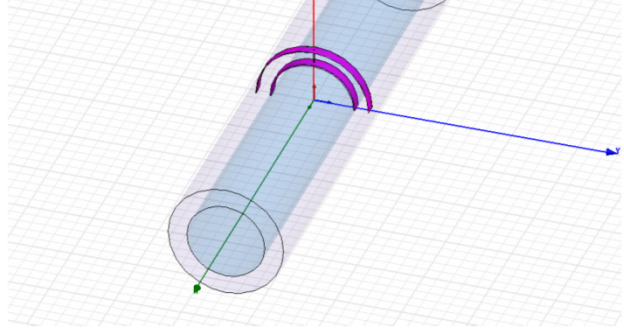
- Four cells in series inserted in steel tubes
  - 600 mm length
  - Space available for charge balancing electronics
  - Hermetically sealed to prevent water intrusion
- Ten 14.4 V battery packs encased in exterior bracelet
  - 40 cells in total (120% capacity)
  - Close contact to cold sea water beneficial for battery lifetime
- Exterior bracelet can be partially embedded in PP-insulation.





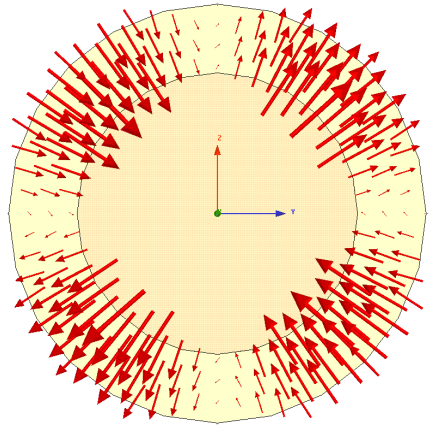
Communication

- Electromagnetic wave in the coating



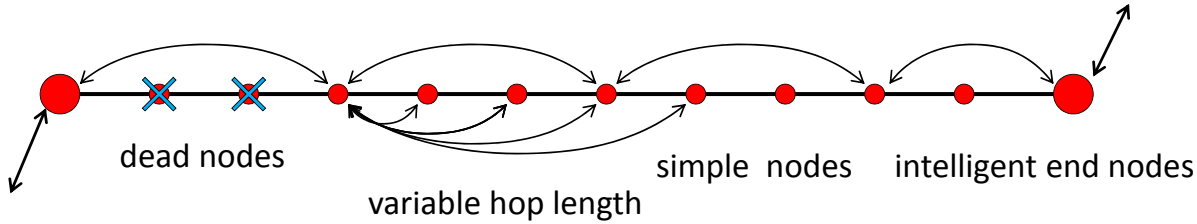
- Inter node distance: 24 m
- Redundancy distance: >200 m (8-10 nodes)
- Carrier frequency: 3.8 MHz
- Output power +14 dBm
- Band with: 150 kHz

Signal

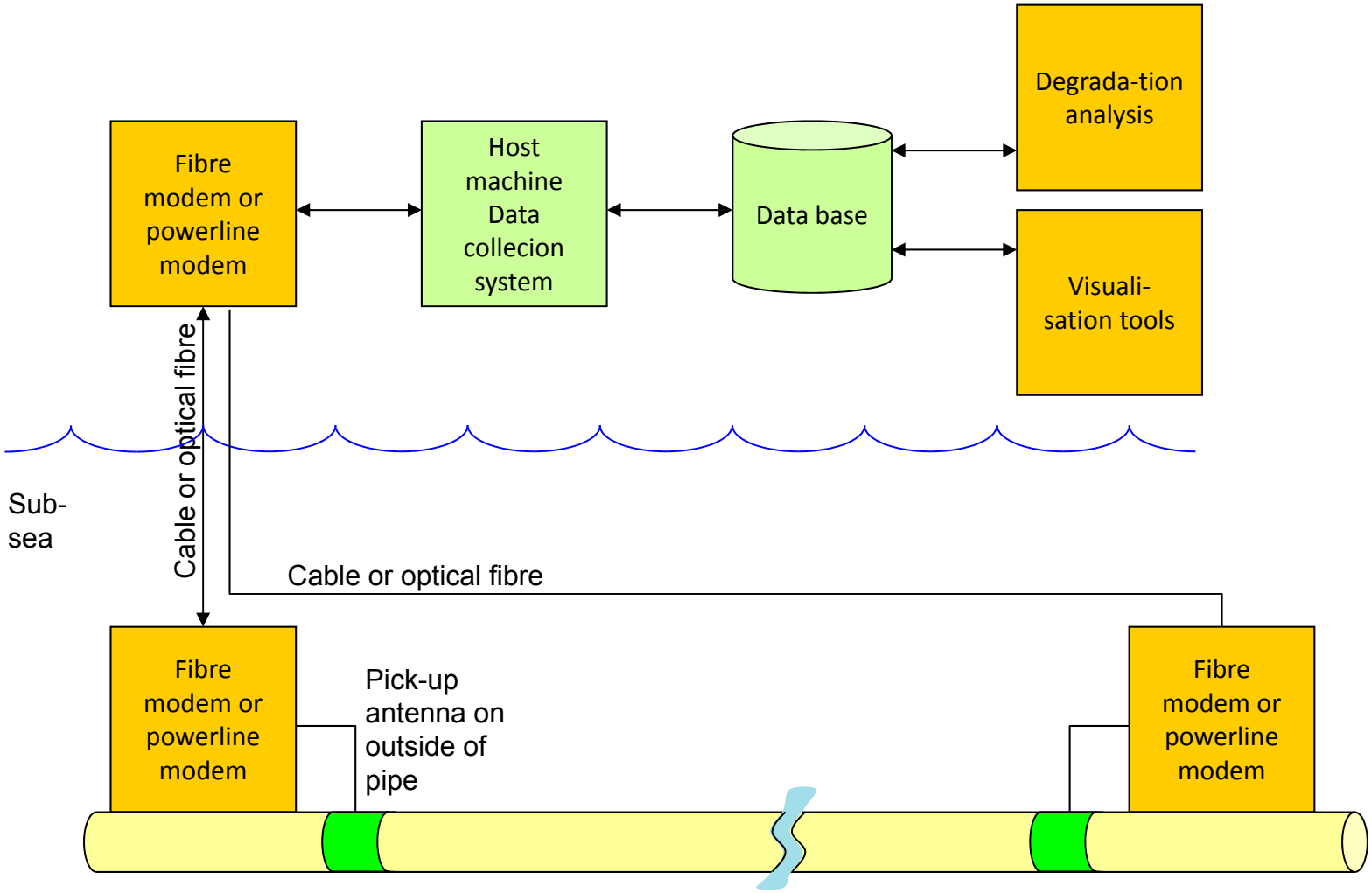


- Patented

Multihop topography



SmartPipe data management



SmartPipe Meso test

Test pipe:

- 216 m long
- 10" pipe
- 80 mm PP coating
- 8 sensor and communication nodes

Testing communication range and sensors

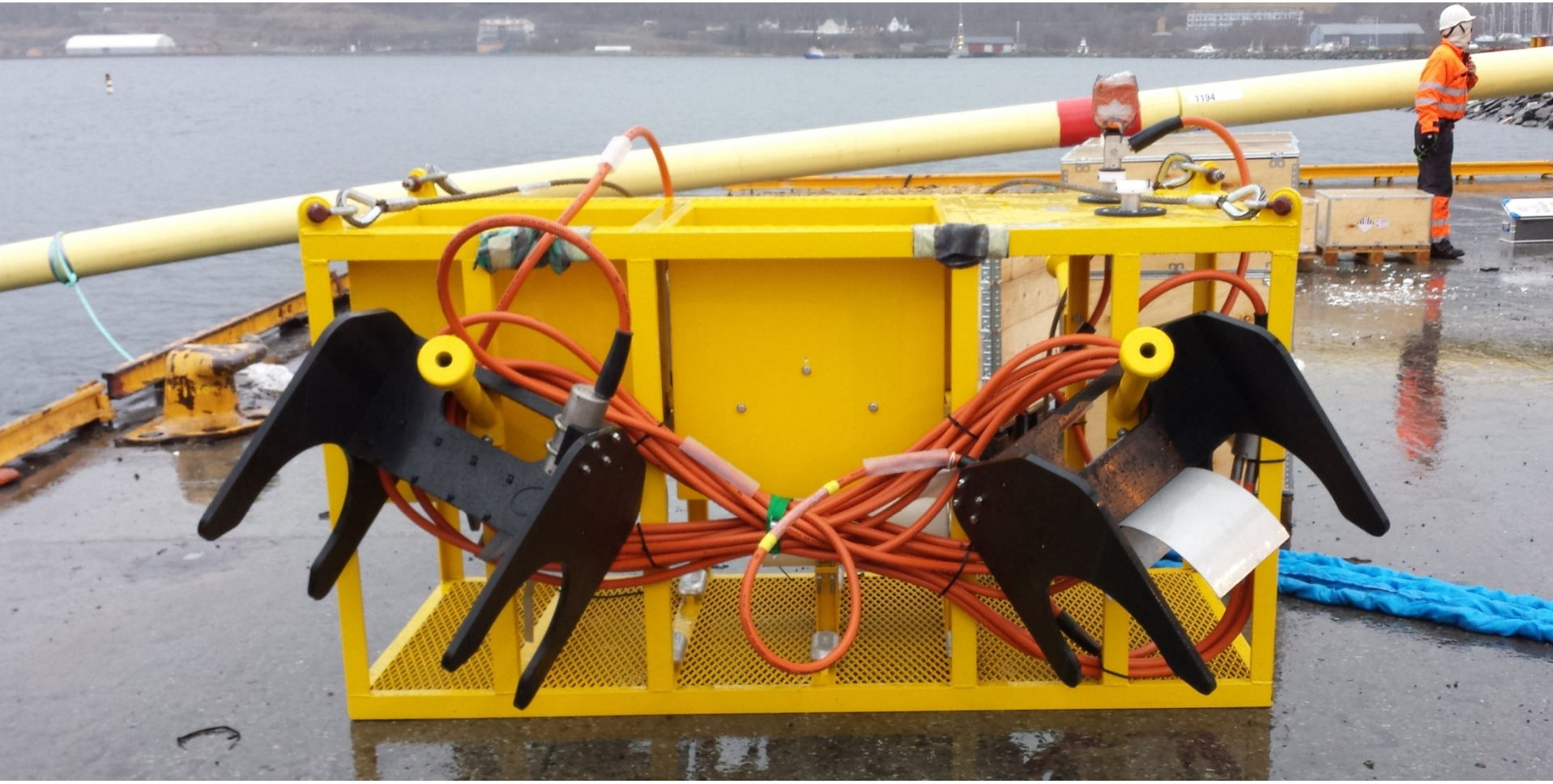
Installed November 18, 2013 in the Orkanger fjord on 10-15 m water depth

The SmartPipe

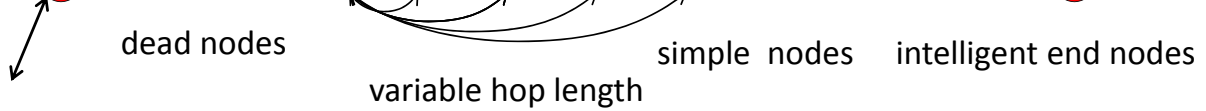
- Steel thickness = 9/16 i.e. 14.3mm
- OD = 10 3/4
- ID = 9 5/8


1147

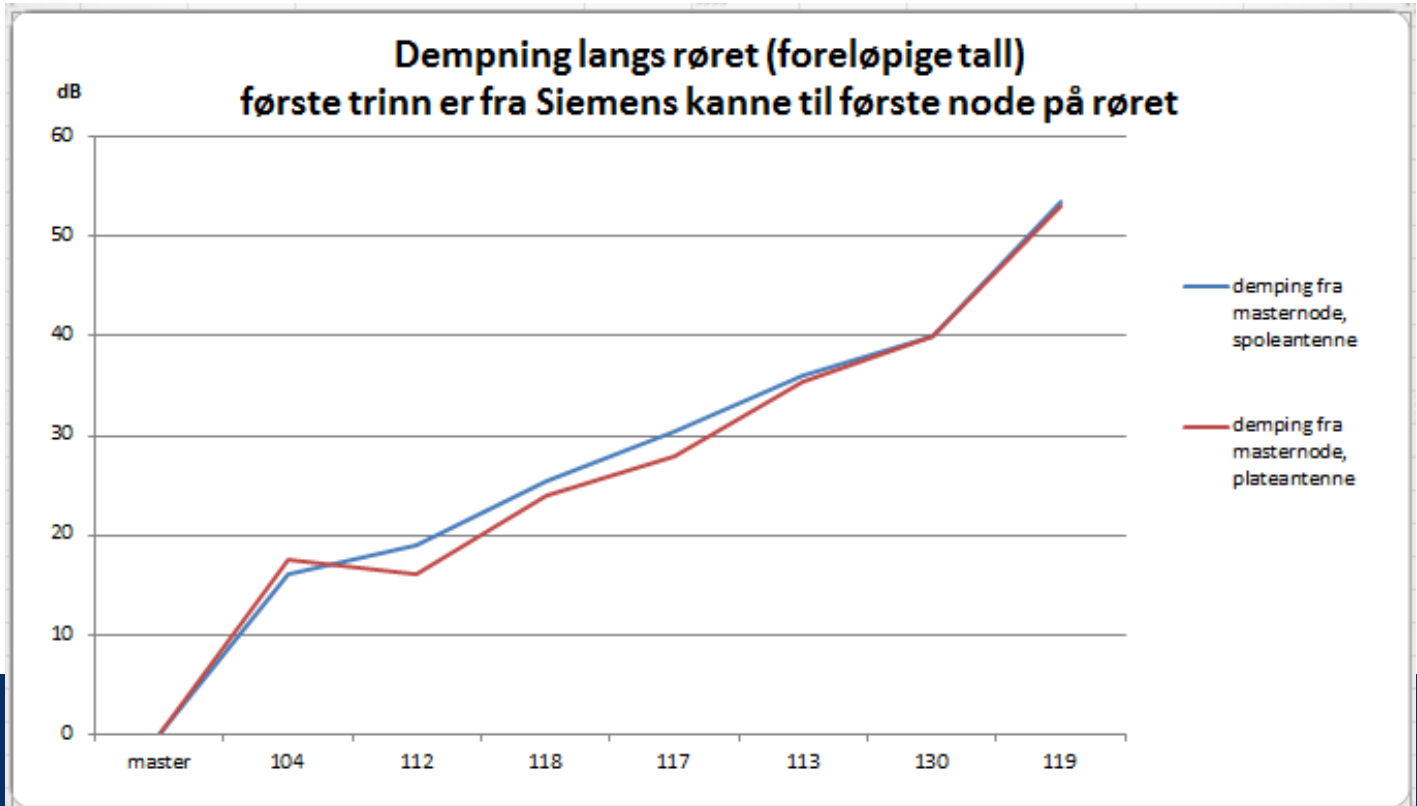
Antenna



Communication

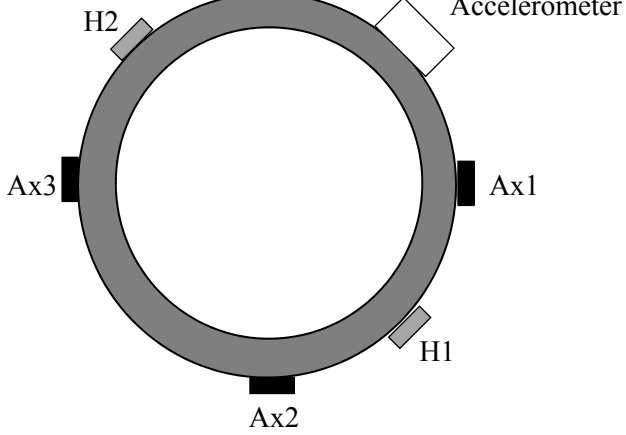


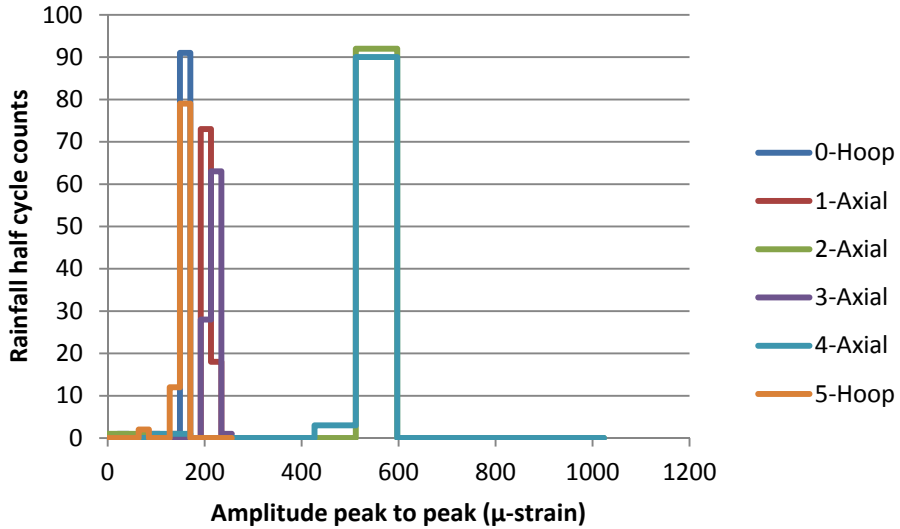
- Communication at least 200 m along the pipe
- Able to communicate with 8 nodes along the pipe
- Attenuation of the communication signal is as expected or better



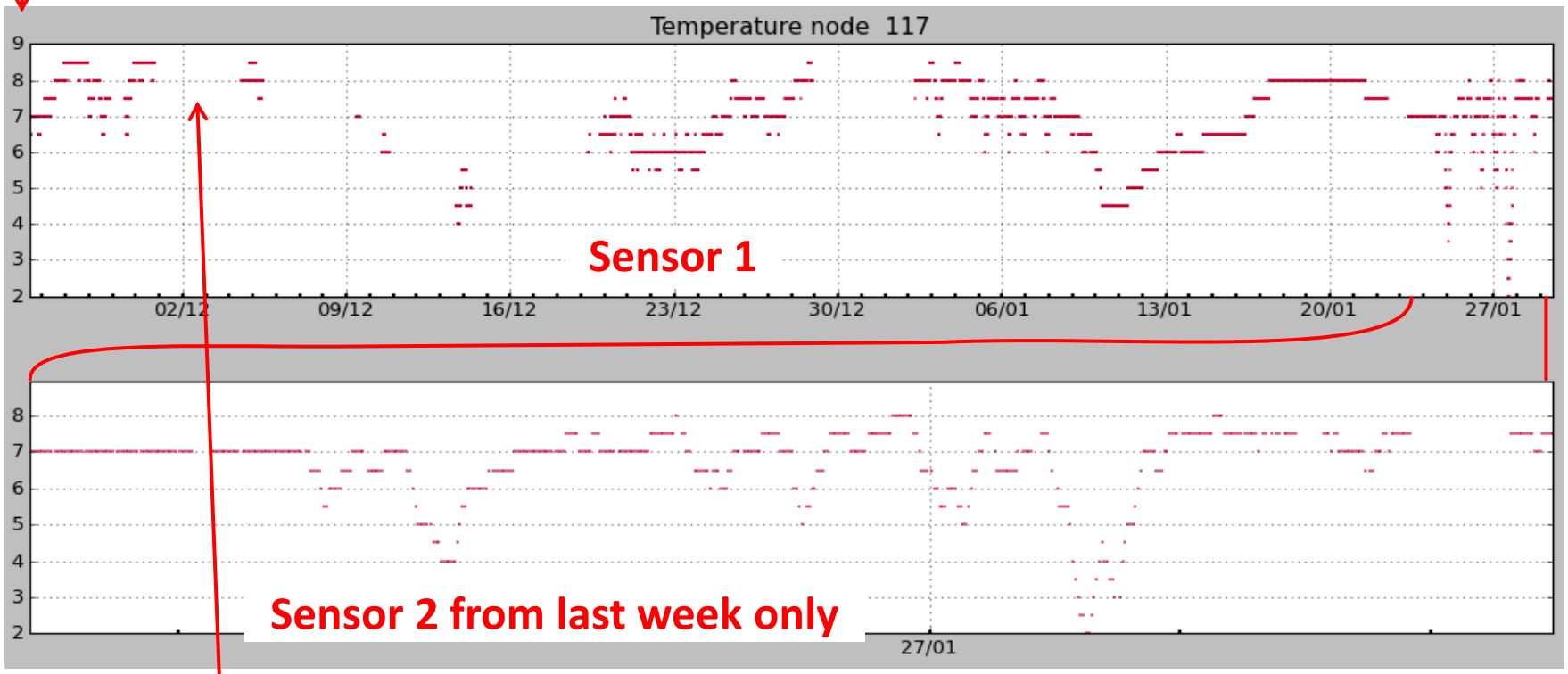
Fatigue monitoring test

- Pipe set in vibrational motion on land before the installation
- Counting vibration half cycles in different strain ranges
- Strain gauges mounted around the pipe as shown
- 93 half cycles
- Ax2 and Ax4 registered 92 and 93 half cycles





The figure shows data from two of the four sensors at node 117

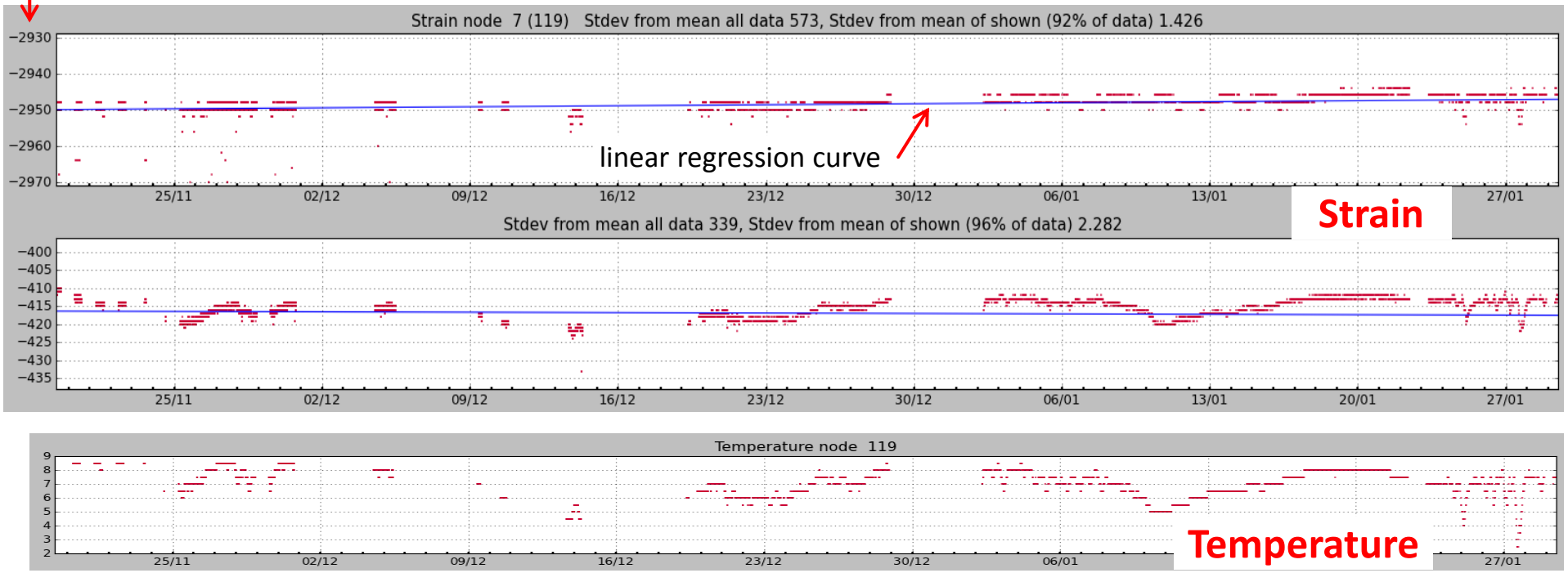


Holes in data logged at SINTEF are caused by faulty 3G router and PC outages, not by faults in the SmartPipe system.

All functional nodes and sensors show practically the same temperature with variation in the least significant bit only. This is as expected.

Variation in temperature is probably cased by changes in water temperature due to tides, and weather conditions.

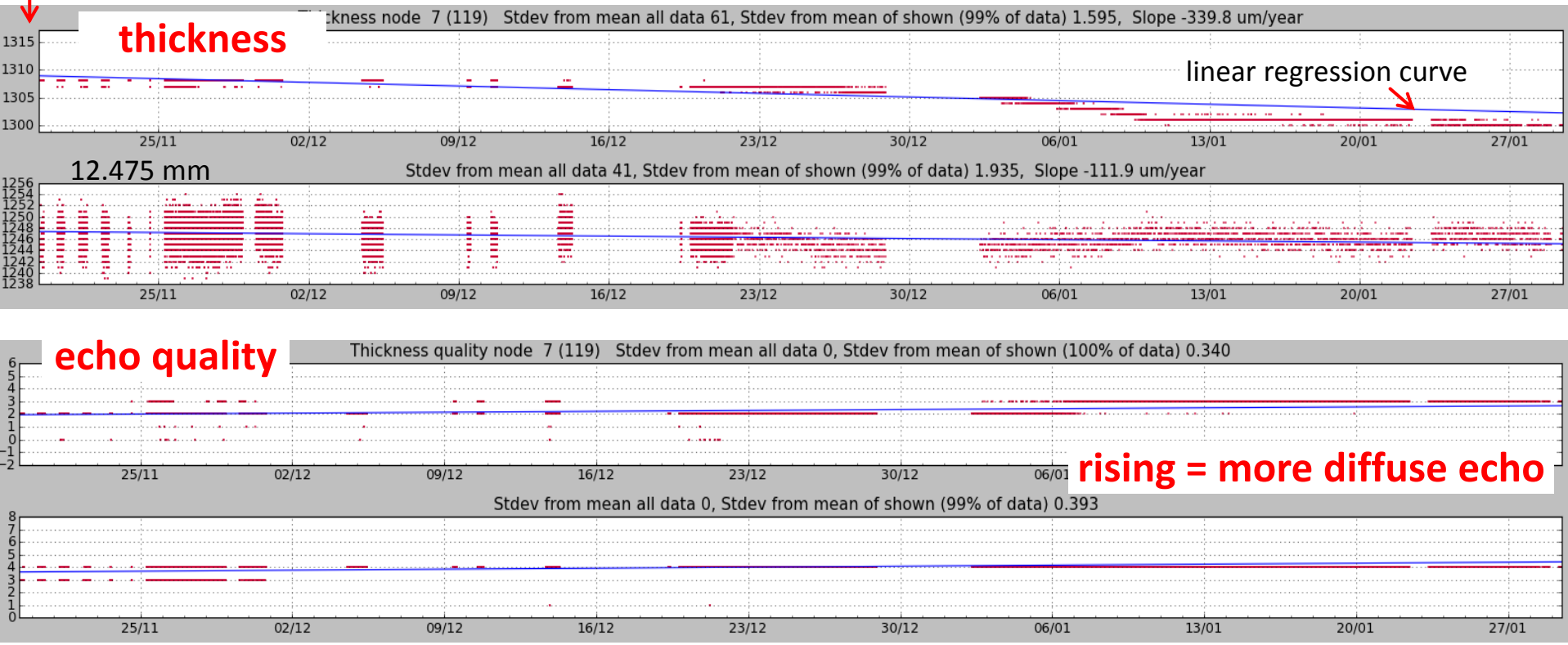
The figure shows two of the six sensors at node 119



- The strain values correlate with the temperature. This is as expected.
- As expected the strain values do not change much over time (just a few µS)
- The static strain value on each sensor element is more or less random and assumed to be caused by the mounting procedure (stretching of belt etc)
- Some sensors show some outliers that have been removed from these plots.

13.080 mm

The figure shows two of the eight sensors at node 119



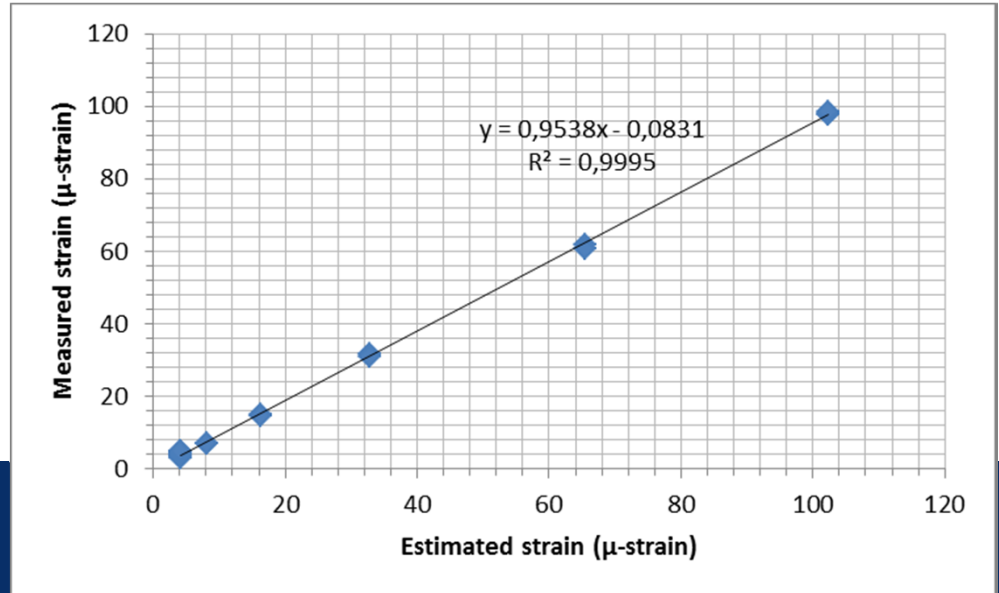
- For most sensors the data shows a falling thickness and falling echo quality (rising quality number).
- The mean change of thickness corresponds to 100um/year which is within expected range (steel in ocean water).
- The echo quality is expected to fall as the steel surface corrodes.
- Some sensors are more noisy than others but the averaged value seems to be correct.
- Some sensors show outliers that have been removed from these plots.

Laboratory testing of sensor resolution

- Strain gauges
- Ultrasound

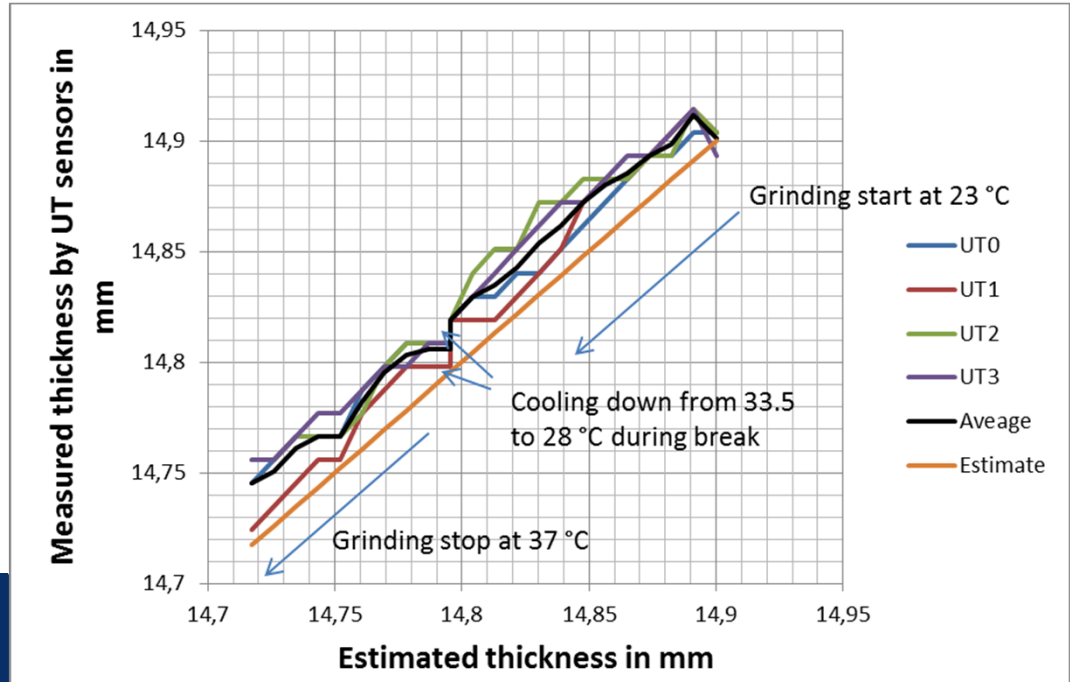
Strain test

- Tensile testing machine
- Compressive mode
- 10 to 250 kN
- Calculated strain plotted vs measured strain
  - 5% scaling deviation
  - Resolution better than 10 µ-strain



Wall thickness

- Sensor belt mounted on steel panel
- Grinded on the backside in ca 10 µm steps
- Sensor measurement vs µm screw gauge
- 180 µm grinded away
- Average of 4 measurements has a resolution better than 10 µm



The consortium