A study of defects on infrasound pipe array Wind-Noise-Reduction Systems (WNRS) using in-situ calibration

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Infra-AUV Project

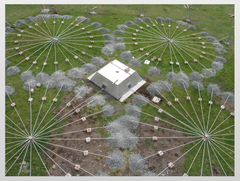
- Development of primary low-frequency calibration methods for sound in air, underwater acoustics and vibration metrology
- Dissemination of primary standards: Secondary calibration and test methods for environmental measurement infrastructure
- Traceability for global seismic and acoustic environmental sensor networks by novel on-site calibration and improved knowledge of operational sensor behaviour
- Improvements in current environmental measurement station deployment strategies gained by traceable calibration, known measurement uncertainties and improved knowledge of operational sensor behaviour

Objectives

- In-situ calibration of the Wind-Noise-Reduction System (WNRS)
- Comparison with an electro-acoustic model of the WNRS
- Test the effects of pipe blockages on the WNRS – both modelled and experimental

Wind Noise Reduction System

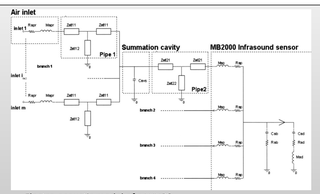
- WNRS reduces the wind generated noise amplitude without greatly affecting the infrasound in the band of interest (0.01 to 4 Hz)
- Correlation analysis between sensor elements is used to calculate the speed and back azimuth, therefore results are very sensitive to errors in the phase.
- Models of the WNRS provide theoretical estimate of the system response.
- Passive on-site calibration techniques measure the system response.



Arrays of infrasound station IS49, Tristan da Cunha, United Kingdom. https://www.ctbto.org/verification-regime/monitoring-technologies-how-they-work/infrasound-monitoring/

Electro-acoustic model of WNRS

- Fluids can be treated in a similar fashion to electric currents, with each element having an associated complex impedance
- Disconnected elements and blocked elements can be simulated by setting element admittances to 0 (impedances to infinity)

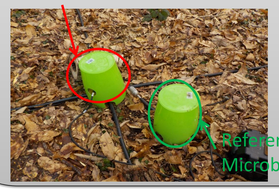


Electro-acoustic model of a WNRS
Benoit Alcoverro and Alexis Le Pichon, "Design and optimization of a noise reduction system for infrasonic measurements using elements with low acoustic impedance", The Journal of the Acoustical Society of America 117, 1717-1727 (2005) https://doi.org/10.1121/1.1804966

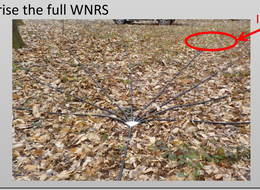
In-Situ Calibration

- Based on the approach first used by Gabrielson (https://doi.org/10.1121/1.3613925).
- A reference sensor (shown in green) is placed near the centre of the WNRS array providing a known calibrated signal.
- Frequency response of the sensor is determined from time intervals with high (>0.98) coherence between the reference and the sensor under test.
- The amplitude of the WNRS is then determined relative to the reference sensor
- An 18 m WNRS was installed – 4 primary pipes and 8 secondary pipes (32 total inlets)

WNRS Microbarometer



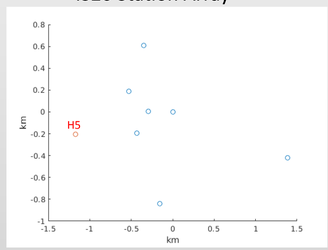
Single rosette with 8 inlets. 4 similar rosettes comprise the full WNRS



Experiment at IS26

- Across-array coherence (Green et al. 2021)
  - Across-array coherence and PMCC detections using this larger array will be used to remove the effects of the partial coherence of the wind-noise
- Quantificaiton of errors in PMCC outputs (back azimuth and trace velocity)
  - Using ground-truth values determined from co-located IS26 element, errors in the azimuth and trace velocity will be quantified for defective WNRS
  - Defective WNRS will be corrected using calibration, and results compared with IS26-H5

IS26 Station Array



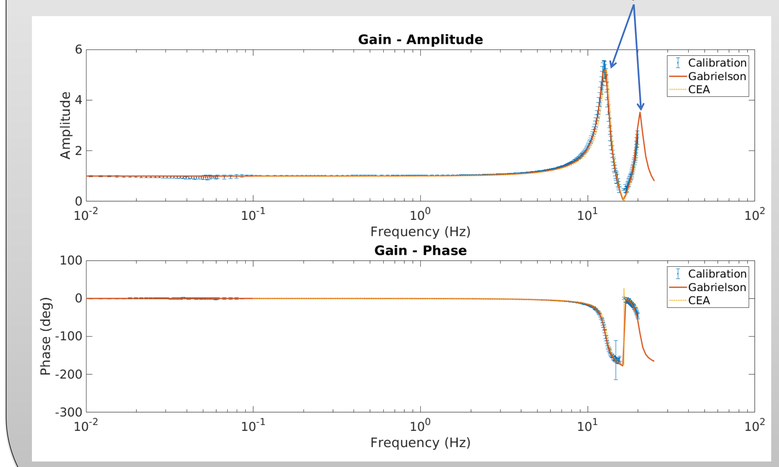
WNRS Microbarometer

Reference Microbarometer

Calibration Results

- Amplitude and phase are close to 1 and 0 degrees for the IMS band of interest (0.01-4 Hz).
- Resonances peaks are observed in coincidence in both the model and the calibration curves.
- Partially coherenct wind-noise at low frequency causes

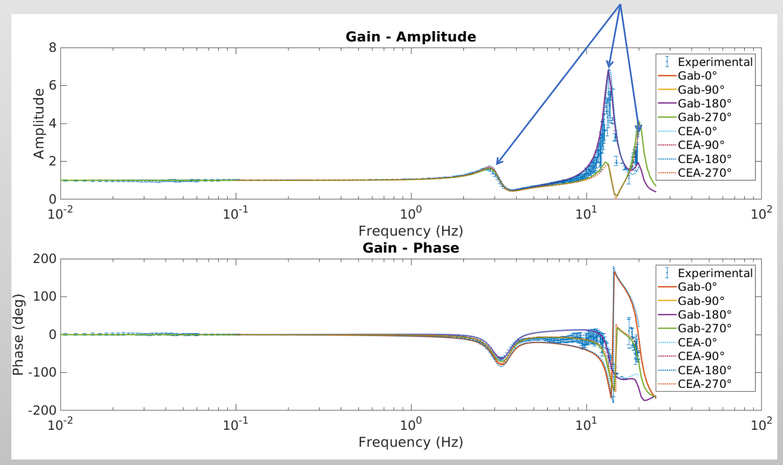
Resonance peaks



8 Blocked Inlets

- 8 inlets (1 rosette) were blocked with rubber stoppers.
- Gain is well reproduced in the model, with small deviation after first resonance peak due to anisotropy caused by the blockages.
- Larger uncertainties are observed at frequencies greater than 3 Hz.

Resonance peaks



Summary

- On-site calibration experiment is ongoing at IS26 array and preliminary experiments were completed at the CEA
  - Simulation tool has been consolidated to predict the full frequency response of WNRS
  - Analysis demonstrates synergy between model and calibration data, such as the blocked inlet scenario
  - WNRS response curves (with uncertainties) have been measured and introduced into an uncertainty analysis
- Ongoing/Future Work
  - Temporary WNRS has been installed at IS26 (Germany) to provide cross-array coherence measurements.
  - Us of the co-located IS26 detector to provide 'ground-truth' measurements will allow for a quantification of the errors introduced by the defectiv e systems to the PMCC results.

References

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Acknowledgements

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