O3.1-361

Infrasound uncertainty propagation: ensuring traceability from the laboratory to the field

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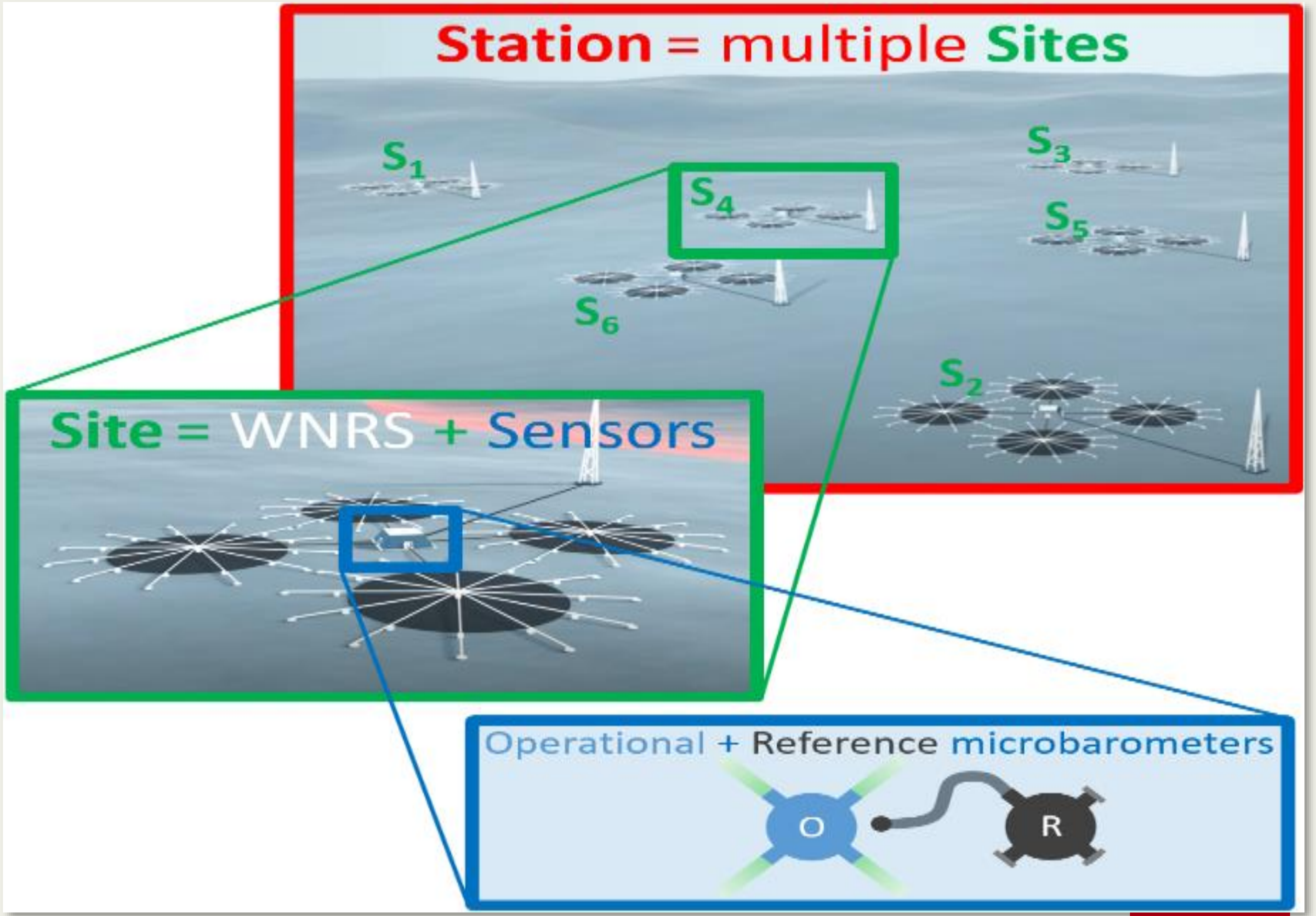
Outline

- Introduction
- On-site Dome Calibration
- Noise reduction (Dome vs Rosette)
- Wave parameter uncertainties
- Conclusions



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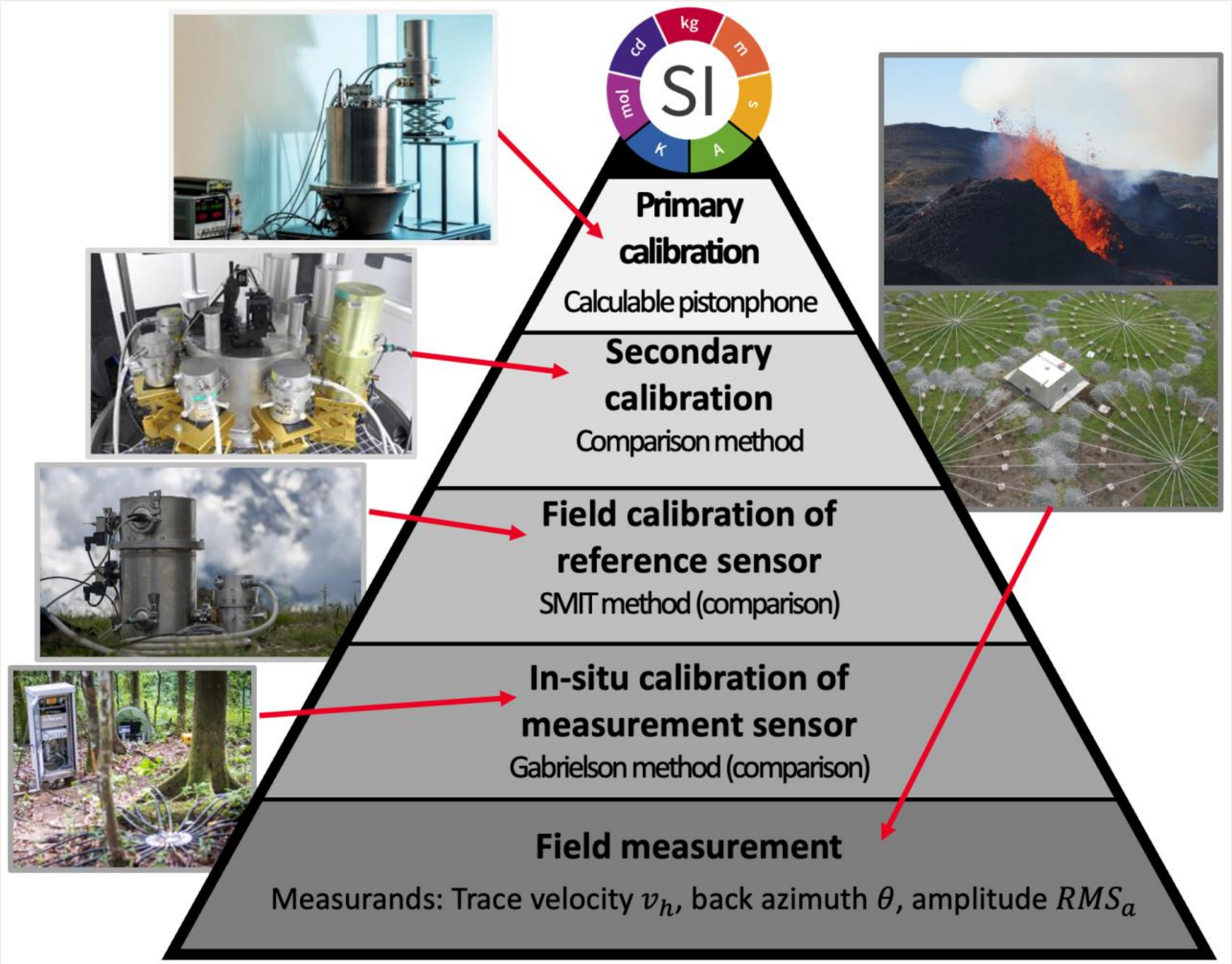
Metrological traceability – International System of units (SI)

Established using a **primary method** of measurement

The **Primary method** of measurement provides the essential first link in the chain of traceability from the definition of a unit of the International System of Units (SI)



Metrological traceability

Property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty.

Kristoffersen et *al.* (2025) https://doi.org/10.1121/10.0036380

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Wind Noise Reduction Systems (WNRS)

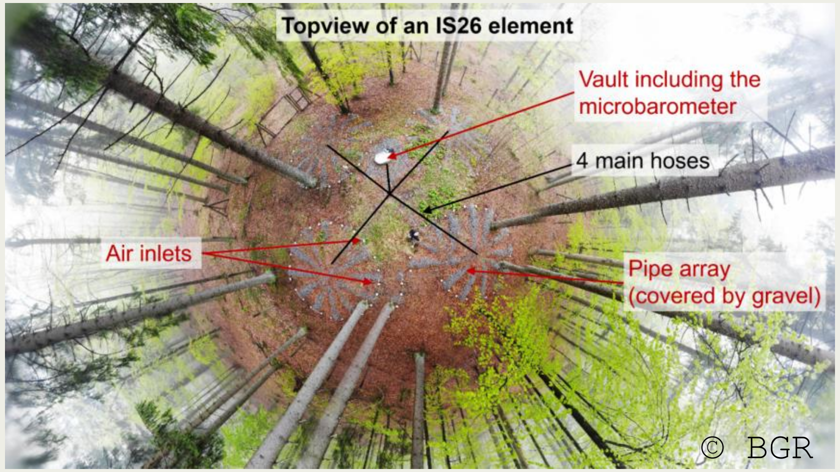
WNRS are used to improve SNR relative to wind generated noise.

Several different types of WNRS have been studied, such as rosette-style pipe arrays and domes.

The impact of these systems on acoustic wave parameters needs to be well understood.

Although the effects of pipe arrays has been studied, little research has been done to verify the effects of domes on infrasound signals.

Rosette-Style



2.4 m Metal Dome

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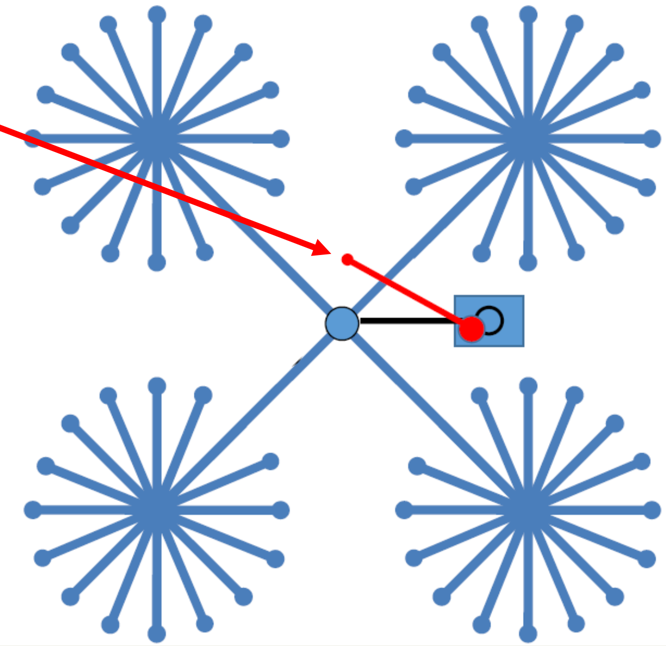
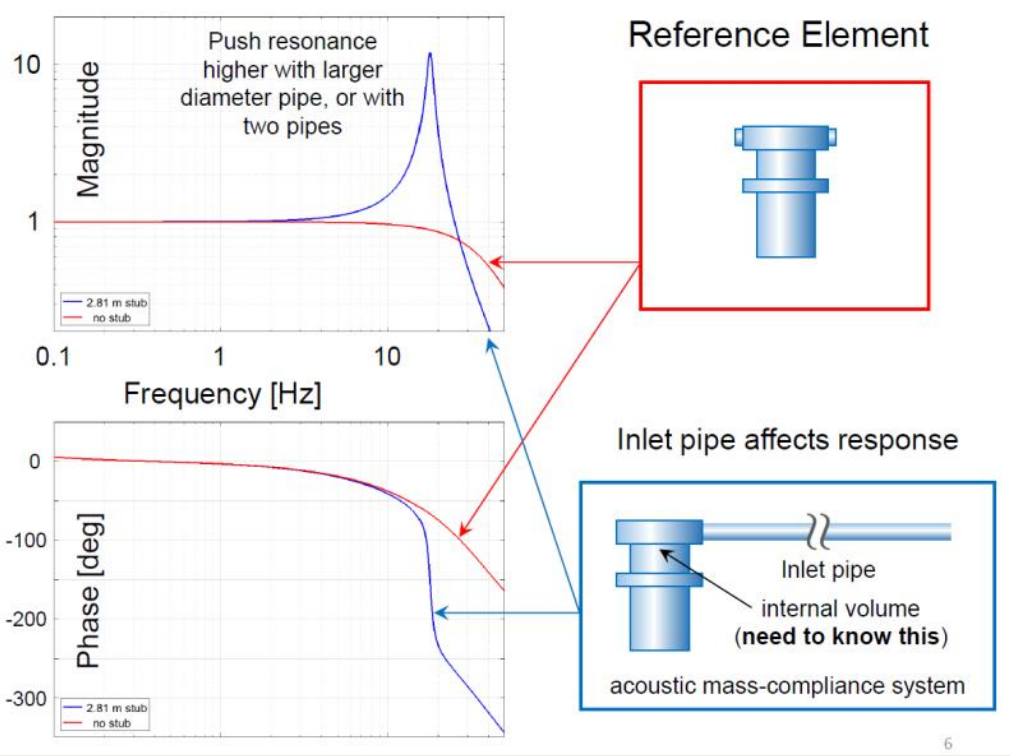
On-site calibration – Gabrielson method

Addition of inlet pipe affects frequency response of reference.

If inlet is offset from phase center of WNRS, both the magnitude and phase will be affected.

If vault is at WNRS center, it may not be practical to align the reference inlet if using a single pipe.





On-site calibration uses ambient signals for a calibration by comparison with the calibrated (primary & secondary) reference sensor.

Gabrielson, https://doi.org/10.1121/1.3613925
Green, https://doi.org/10.1093/gji/ggab155

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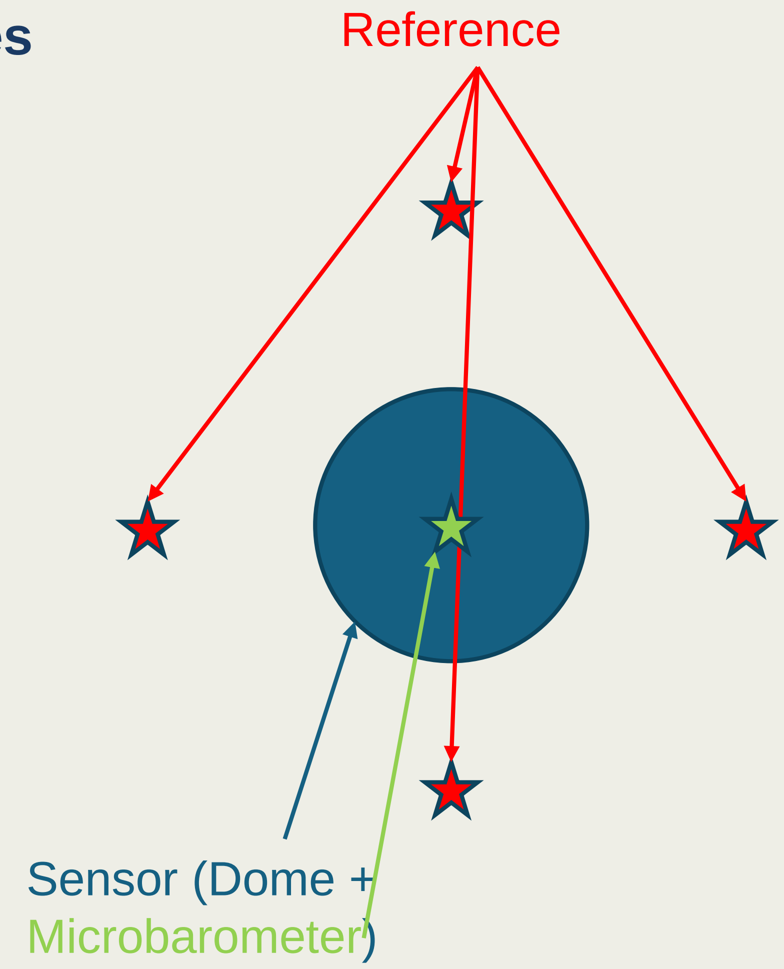
On-site calibration – adapted for domes

Due to the dome the reference sensor cannot be placed near the active sensor (under or too close to the dome) to minimize the impact of the dome on the reference sensor responses.

To accommodate these limitations, four reference sensors are placed symmetrically around the dome at a distance of ~2.4 m (the diameter of the dome) from the dome.

A virtual reference is then used to determine the phase shift.

The gain is determined using the average gain relative to the references. $|H| = \sum_{i=1}^{4} \left|H_i^{ref}\right|$



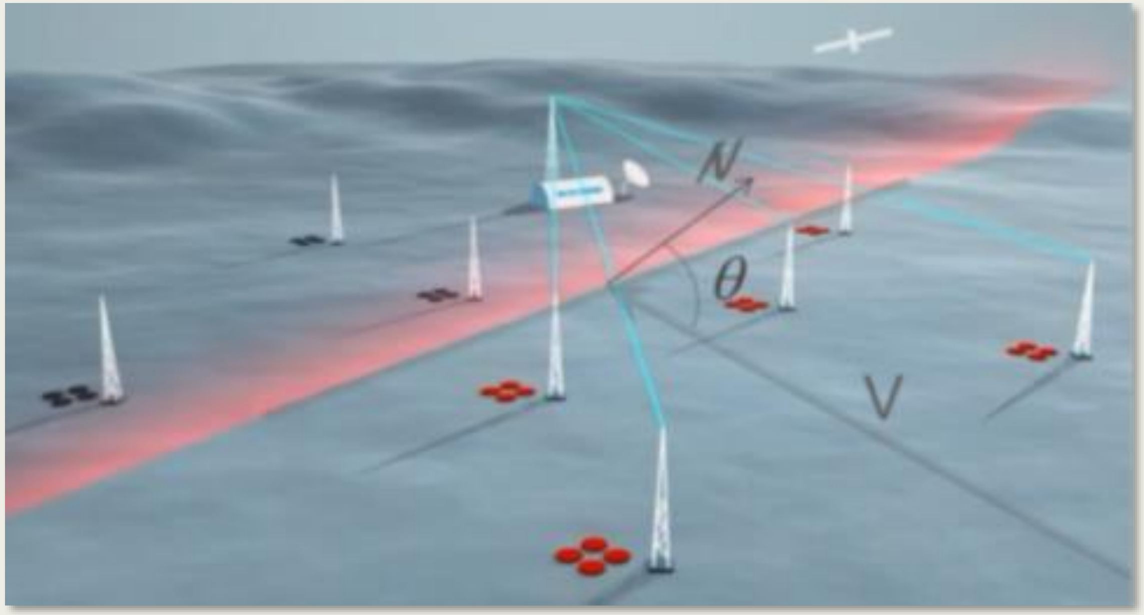
Wave parameter estimation

Principle of Progressive Multi-Channel Correlation (PMCC) is to determine the time-delay of arrival (TDOA) at each detector.

Operational analysis method used at IDC.

From the TDOA's, back azimuth and trace velocity of the source wave-vector is determined.

PMCC relies on the relative arrival times, errors in sensor phase will result in errors in direction of the source.



https://www.ctbto.org/our-work/monitoring-technologies/infrasound-monitoring

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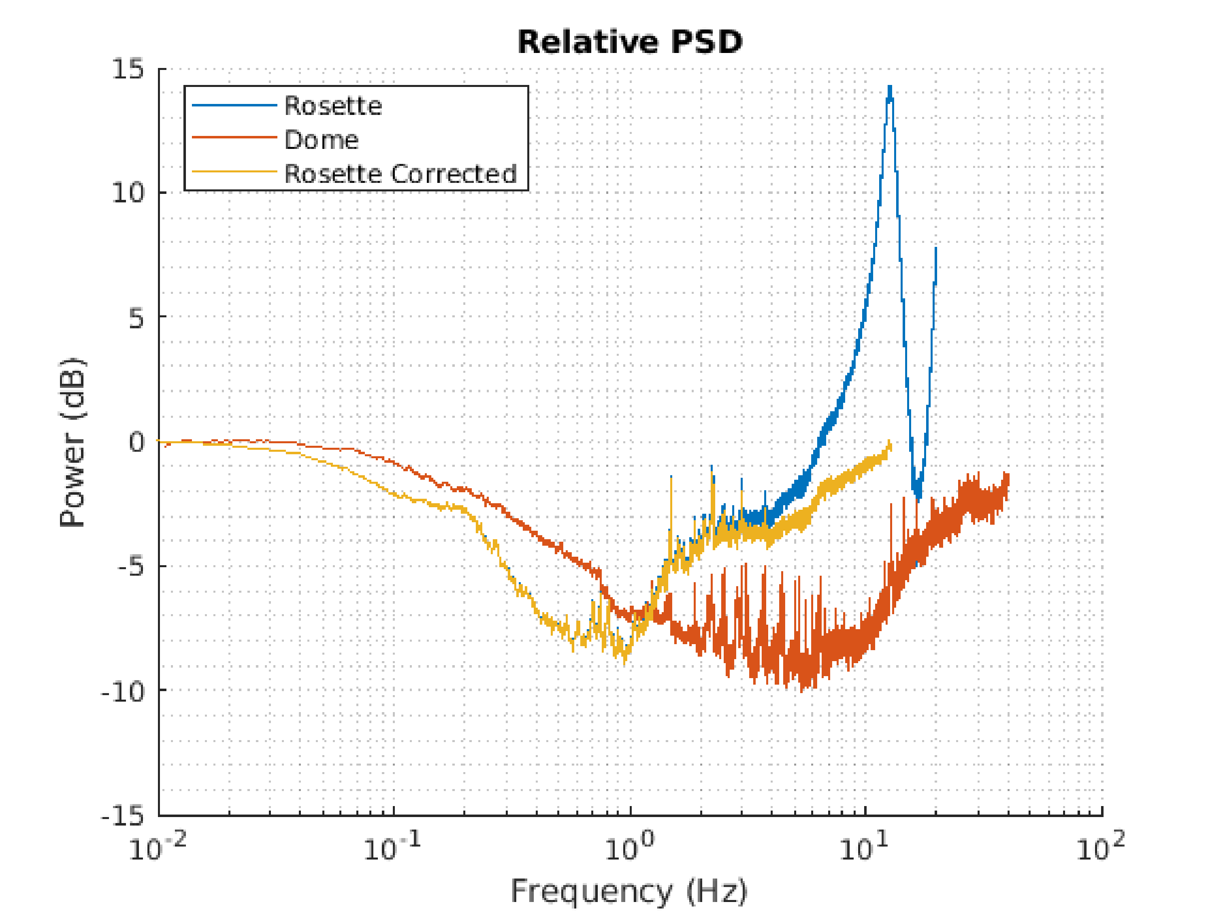
Comparison of relative noise reduction – Rosette vs Dome

Noise PSD calculated from ~7 days of data, with the curve representing the median of 2500 s windows.

Rosette-style pipe array and dome provide different relative noise reduction.

2.4-m dome provides higher frequency noise reduction than 18-m rosette, once the rosette transfer function is removed.

Noise reduction is shifted relative to the apertures of the WNRS.



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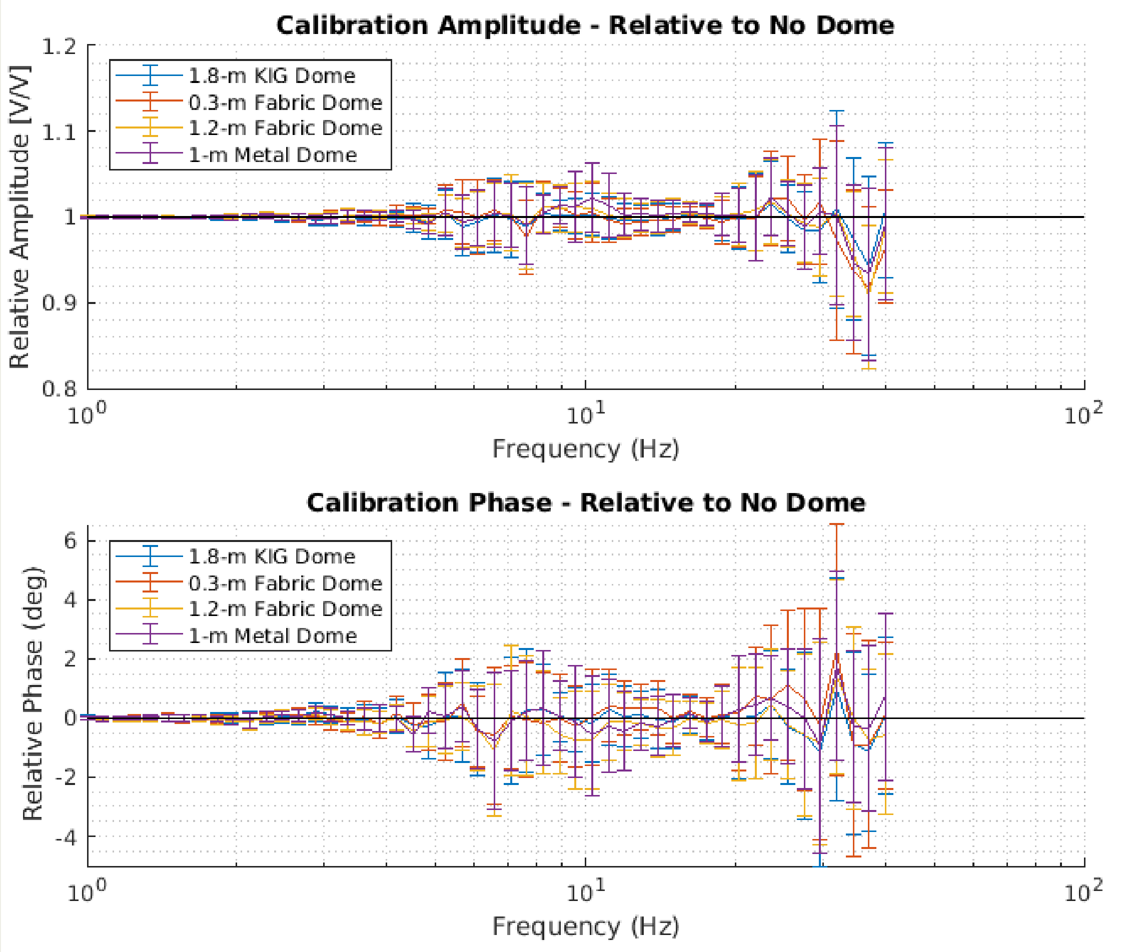
Dome Calibration – Loud Speaker Source

Calibration of several domes using loud speaker source.

Loud speaker covered frequencies between 2 and 25 Hz.

No dome scenario was used as reference to remove ambient environment effects (reflections etc.).

Unity gain and zero phase shift were observed for all domes tested up to 25 Hz.



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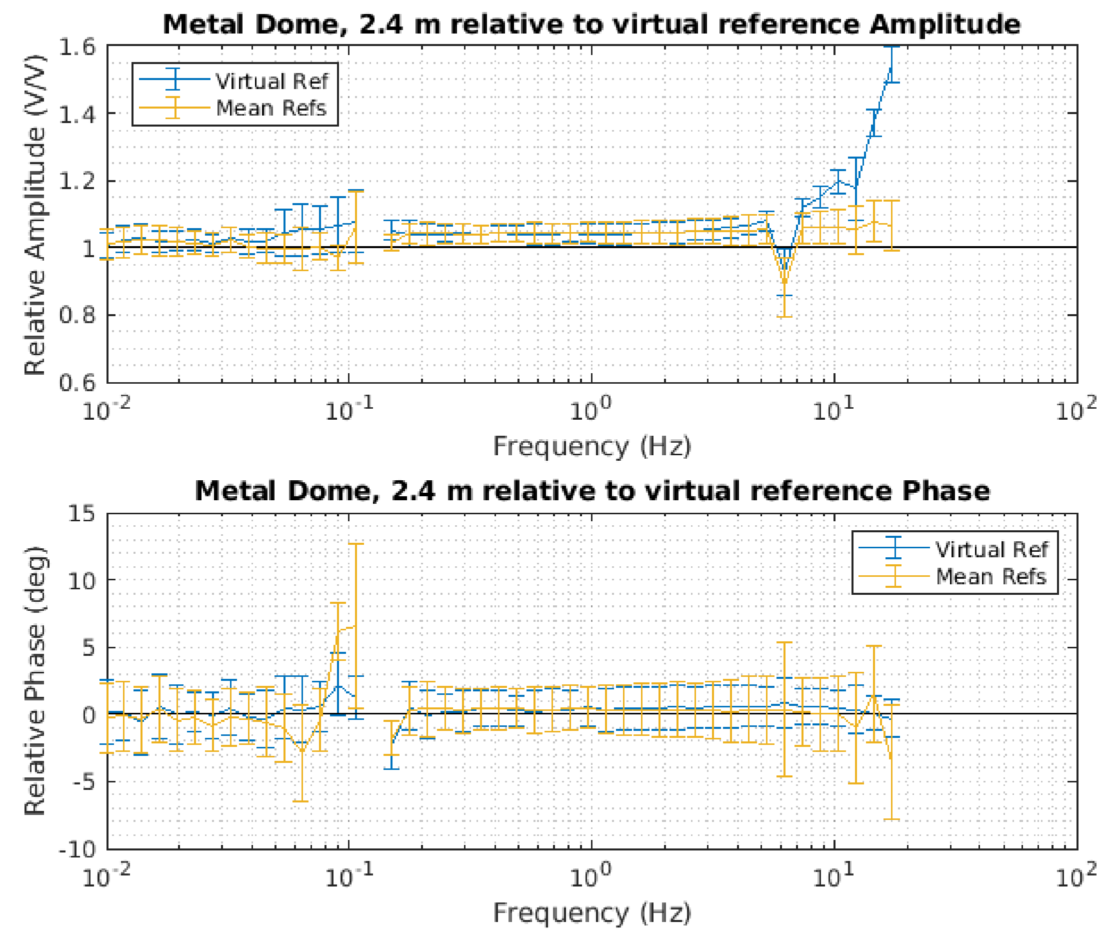
Dome Acoustic Calibration - Results

Virtual reference (average of the 4 reference sensors) shows no phase shift up to 20 Hz, but gain of the virtual reference biases calibration of the dome.

Slight bias in gain relative to mean of the references. This may be due to an underestimation of uncertainties (reference uncertainties are not taken into account).

This demonstrates that the 2.4-m dome does not have a quantifiable impact on the acoustic signal in the infrasound band of interest (0.02 – 4Hz).

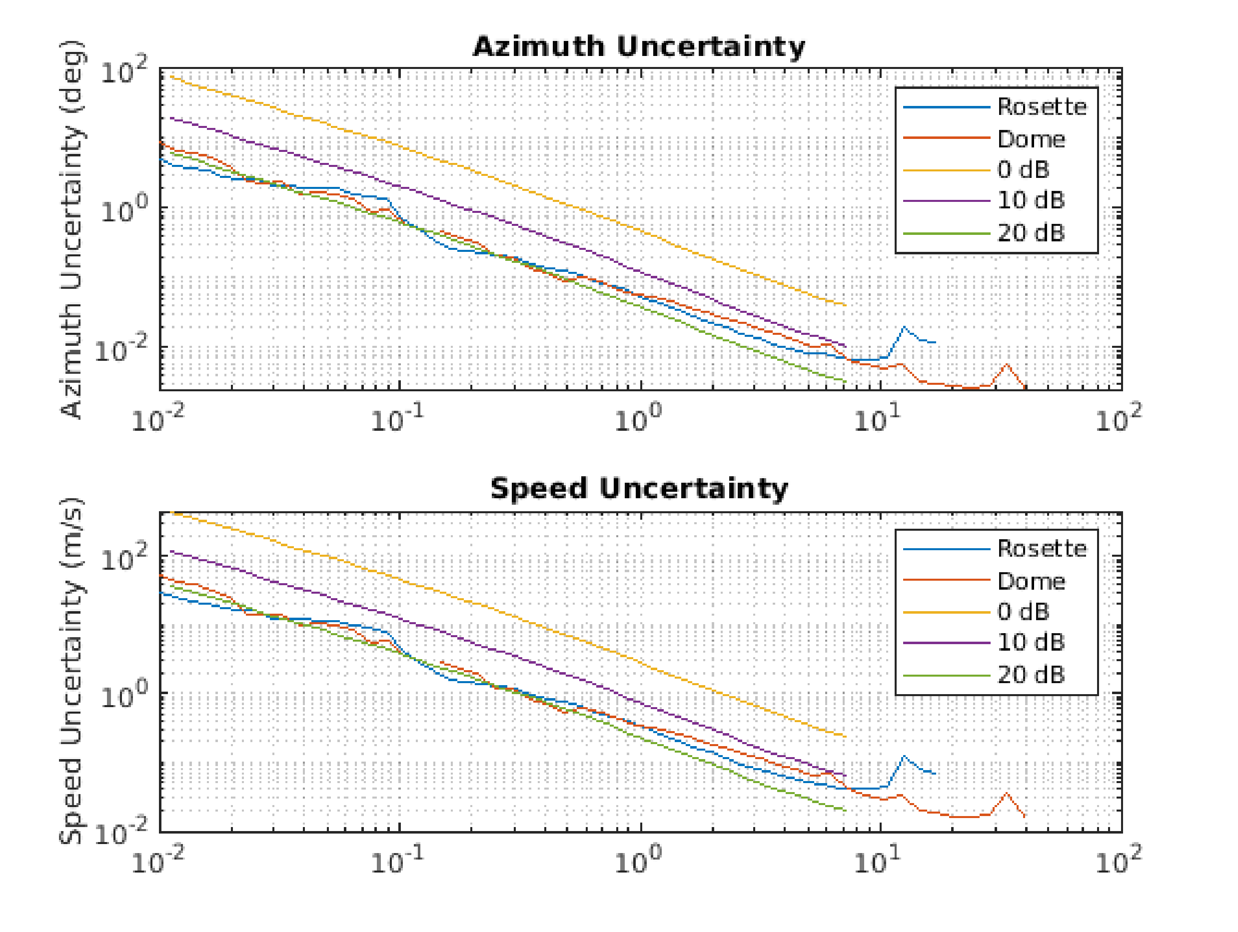


Azimuth and trace velocity uncertainties

On-site calibration phase uncertainties were applied to the IMS infrasound station IS26 (Germany). This station is comprised of 8 sensors with an aperture of ~2 km.

Rosette and dome calibration related uncertainties are similar.

Calibration related uncertainties are roughly equivalent to the uncertainty associated with an SNR between 10 and 20 dB.



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Conclusion

The effects of domes on infrasound amplitudes have been well-studied, but few calibrations of the dome phase response have been done.

We have demonstrated that, for a 2.4-m metal dome, the phase shift remains negligible relative to the corresponding calibration uncertainties.

Dome phase calibration results in uncertainties that are similar to that of an 18-m rosette, and SNR of between 10 and 20 dB within the IMS band of interest (0.02-4 Hz).

Further calibrations should be performed using different sizes and styles (e.g. different porosities, materials etc.) of dome.

Overall, domes provide good noise reduction capabilities, especially at higher frequencies (>2 Hz).

Thank you for your attention

Metrology side event - The role of metrology in seismic, hydroacoustic, and infrasound (SHI) monitoring activities.

Wednesday Sept. 10, 9:00 am
Prinz Eugen Saal