Transfer standard sensors for disseminating traceable calibrations to the field

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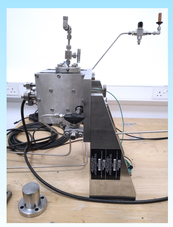
What is measurement traceability

- When making a measurement of a physical parameter like infrasound pressure or ground velocity, the result is expected to be physically meaningful.
- It should be linked to an authentic realisation of the parameter that is defined via base quantities such as mass, length, time and voltage.
- These base quantities are in turn linked to fundamental physical constants and quantum phenomena, providing a universally consistent basis for all measurements
- When a sensor calibration can be linked back to an absolute realisation of a sound pressure or velocity, it is said to be *traceable,* and the measurement is physically meaningful.

The Infra-AUV project has delivered several innovative developments in laboratory calibration of infrasound sensors, seismometers and hydrophones.



The next consideration is how to transfer measurement traceability to where it is needed…at monitoring stations in the field. This is achieved with so-called **transfer standard** sensors, which must be equally suited to use both in the laboratory and in the field.

For laboratory calibration they must be:
- Compatible with laboratory calibration techniques and apparatus
- Capable of high accuracy
- Stable

For field calibration they must be:
- Transportable
- Tolerant of a wide range of environmental conditions
- In widespread use with proven reliability
- Stable

Electro-mechanical/electroacoustic performance

While distinct types of sensor are used for infrasound, seismic and hydroacoustic monitoring, the general requirements for each type of transfer standard device are similar.

Operating frequency range: the frequency range where the sensor sensitivity is nominally constant. For International Monitoring System applications, the operating frequency range must be at least 0.02 Hz – 4 Hz for infrasound, 0.02 Hz – 16 Hz for seismometers and 1 Hz – 100 Hz for hydrophones.

Resonance frequency: an order of magnitude above the operating frequency range, to avoid onset influences

Sensitivity: the output voltage for a given velocity or acceleration for a seismometer, or a given sound pressure for an infrasound sensor or hydrophone. The sensitivity should be sufficiently high to suit the laboratory calibration stimuli and for those available in the field.

Dynamic Range: the amplitude range of effective operation. The lower limit is set by the **self-generated noise** of the sensor, which is required to be below the anticipated operational ambient noise level; and the upper limit is set by the onset of clipping or exceedance of **distortion** requirements.

Long-term stability: A typical periodicity for laboratory calibration is 1-2 years, but the transfer standard device should have sufficient stability over several calibration cycles to be trustworthy.

Environmental influences. While temperature, pressure and humidity can be controlled adequately in the laboratory, conditions in the field can be vastly different. The transfer standard sensor is therefore required to have a predictable behaviour under the range of environmental conditions experienced in the field.

For **hydrophones** in particular, deployment in the ocean requires high confidence in the impact of pressure (c.f. depth) and temperature on the performance of the transfer standard hydrophone.

Axis configuration (seismometers only): The seismometer may be a singe-axis or a three-axis device. Both configurations should be considered.

Transverse or cross-axis sensitivity (seismometers only): It is possible that a stimulus in one axis create an unwanted signal in the other axes. This behaviour should be constrained.

Vibration sensitivity: Infrasound sensors can also have an unwanted response to vibration through the same transduction mechanism. This behaviour should be controlled if possible.

Other aspects of performance

Aside from these performance parameters, the transfer standard sensors should be:

- Of a **size and weight** consistent with the capacity of the laboratory calibration facility and for straightforward installation at a monitoring station.
- **Portable** and sufficiently **rugged** to endure global transportation.
- **Compatible with laboratory calibration**; for example some infrasound calibration methods are sensitive to the air volume presented by the sensor, seismic calibration has load limitations and hydrophone calibration has constraints on the sensor size and form factor.
- **Commercially available** and generally familiar amongst users through widespread use.

The Infra-AUV project has selected the following transfer standard sensors, as having the optimum conformance with the varied and sometimes conflicting set of identified requirements

For infrasound
- MB2005
- HBK type 4193 microphone system


courtesy of HBK

For seismic
- Geotech GS13
- Nanometrics Trillium 360 GSN Vault
- Streckeisen STS2.5

For hydroacoustics
- Reson TC4033



These devices are being used as transfer standards in ongoing research in the Infra-AUV project.

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