Technologies S.A.

Underwater Acoustic Sensing Platform

System Overview and Applications

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Contents

1 System Overview: Hardware and Solution

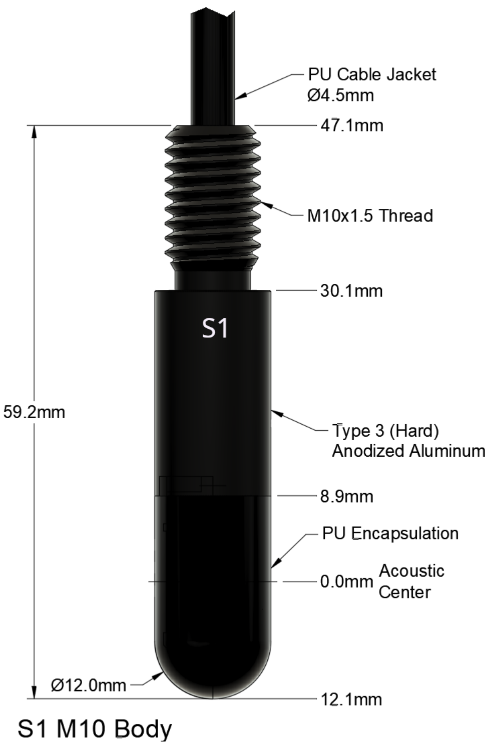
1.1 Underwater Acoustic Data Logging Apparatus Overview

INFILI develops and evaluates advanced sensing platforms for challenging environments, including underwater acoustic monitoring. As part of this effort, the company has designed a compact, high-fidelity data logging apparatus for long-duration acoustic capture and 3D characterization of underwater sound fields. The system integrates 10 Aquarian Audio S1 hydrophones for broadband pressure sensing and a Wilcoxon VS-301 Acoustic Vector Sensor for 3-axis particle velocity and omnidirectional pressure measurements. Combined with a high-throughput multi-channel acquisition and logging backbone, the apparatus supports scientific, industrial, and defense-oriented applications requiring reliable, synchronized, and scalable underwater acoustic capture.

1.2 Hardware Setup and Key Specifications

The hardware configuration of the system is presented below, covering the sensing components and the supporting acquisition infrastructure.

- **Hydrophone Array**



Characteristic	Specification
Linear range	1Hz to 100kHz ±2dB
Receiving sensitivity	−208 dBV re 1μPa (40μV / Pascal)
Transmitting sensitivity	140dB SPL re 1μPa, 1Vrms input at 1m, 90kHz
Maximum input voltage	30V p–p (continuous); 150V p–p (< 10% duty cycle, < 100kHz)
Horizontal directivity (20kHz)	±0.2 dB
Horizontal directivity (100kHz)	±1 dB
Vertical directivity (20kHz)	±1 dB
Vertical directivity (100kHz)	+6 dB to –11 dB
Operating depth	200m
Survival depth	350m
Operating temperature range	-10°C to +80°C
Nominal capacitance	5nF ±15% (plus cable @ 118pF/m)
Output connection	BNC (standard)

Figure 1.1: S1 hydrophone assembly and specifications.

- **AVS** – The VS-301 is a compact underwater acoustic vector sensor capable of measuring 3-axis particle velocity together with omnidirectional pressure, enabling full 3D characterization of the underwater acoustic field.

Characteristic	Specification
Output sensitivity	10 V/g
Full scale input range	0.5 g pk
Frequency response	3.0 Hz – 2.0 kHz
Transverse sensitivity, max	$< 5\%$
Temperature accuracy	$\pm 1\%$ °C
Pressure range	800 psi (operational, max)

Figure 1.2: Wilcoxon VS-301 acoustic vector sensor and accelerometer key specifications.

- **Data Acquisition System** – The acquisition subsystem is built around NI 24-bit synchronized analog input modules housed in a Gigabit-Ethernet CompactDAQ chassis, enabling high-resolution, multi-channel underwater acoustic capture.
  - 4 × NI-9232 C Series modules (3 channels each, 24-bit resolution, 102.4 kS/s)
  - Integrated in a CompactDAQ cDAQ-9185 chassis with Gigabit Ethernet connectivity for high-speed data streaming
  - Fully synchronized multi-channel sampling, enabling advanced spatial and temporal analysis
- **Data Logging Unit** – The data logging module is built around a Raspberry Pi 5 with NVMe storage, enabling long-duration, multi-channel, 24-bit captures in compact, field-deployable configurations.
  - Raspberry Pi 5 (8GB RAM) as the core logging controller
  - Equipped with NVMe SSD HAT and 512GB NVMe SSD
  - Records $>$ 47 hours of continuous 10-channel, 24-bit, 102.4 kS/s audio
  - Low-power operation and compact form factor

Figure 1.3: Data logging unit based on NI 9232 devices, with high sampling rate.

Seabed Deployment Setup and Hydrophone Array Geometries

Figure 1.4: Seabed deployment frame for the hydrophone array during coastal field trials.

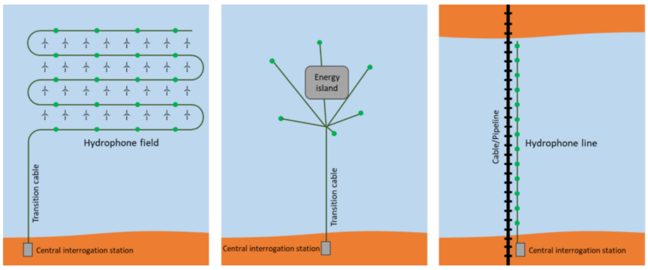


Figure 1.5: Examples of possible hydrophone deployment geometries: (left) hydrophone field around an offshore installation; (center) star-shaped array around an energy island; (right) linear hydrophone line following a subsea cable or pipeline.

INFILI's field engineering team conducts dedicated underwater acoustic deployments to characterize real-world sensor behaviour and validate the complete acquisition and logging chain. Field tests are performed from both floating platforms and coastal infrastructure, where S1 hydrophones and the VS-301 acoustic vector sensor are mounted on custom test frames and deployed on the seabed. The apparatus operates continuously using National Instruments hardware and custom-built logging modules, demonstrating stable and robust performance under realistic marine conditions.

The datasets collected through these deployments are of exceptional value: there are currently no publicly available datasets from acoustic vector sensors or multi-hydrophone arrays. This scarcity creates significant barriers to advancing AI in underwater acoustics. INFILI addresses this gap by designing and operating its own specialized measurement systems, enabling the collection of high-quality, real-world data. These datasets power the development and training of advanced AI models for underwater target detection, classification, identification, trajectory anomaly detection, and sound-emission analysis.

Figure 1.6: INFILI field engineering activities during open-water testing, showing the full acquisition stack deployed on a floating platform alongside vector-sensor and hydrophone evaluation setups.

INFILI provides the full processing chain from sensing to machine-learning-ready features. The underwater sound picked up by the hydrophones is first digitised by the NI 9232 module in the cDAQ-9185 chassis and streamed to the on-board Raspberry Pi 5, which acts as the main processor and data-logging unit of the system. Using INFILI's signal-processing software, a Sound Signal Processing (SSP) chain cleans the sound by reducing background noise and extracting low-frequency time–frequency features (lofargrams). These processed representations suppress broadband background noise and emphasise the spectral patterns of interest, making them suitable inputs for classical detectors as well as modern machine-learning models for detection, classification and tracking. INFILI develops, trains and evaluates such machine-learning models on top of its own datasets, enabling end-to-end pipelines from raw recordings to higher-level analytics and decision support.

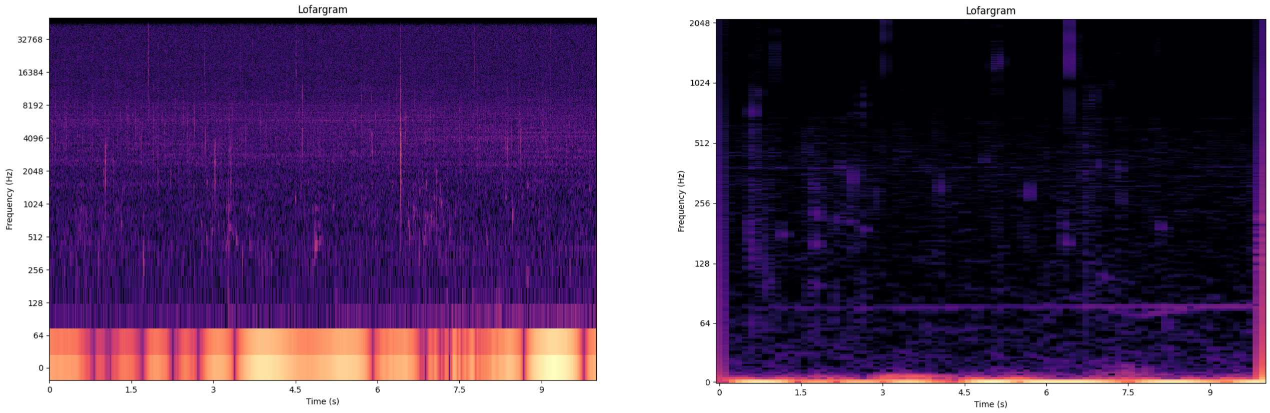


Figure 1.7: Example of a 10-second recording from a single hydrophone. Left: raw lofargram with strong broadband noise. Right: processed lofargram after the SSP chain, where low-frequency targets are enhanced and background noise is reduced.

1.3 Distributed Acoustic Sensing Overview

A Distributed Acoustic Sensing (DAS) system uses an optical fiber, often a standard subsea telecom fiber, as a long, continuous sensor that can detect sound, vibration, and strain along its entire length. This system is highly effective in subsea environments, making it an ideal solution for monitoring and sensing applications in underwater conditions.

1.3.1 How DAS Works Underwater

A Distributed Acoustic Sensing (DAS) system uses an optical fiber, often a standard subsea telecom fiber, as a long, continuous sensor that can detect sound, vibration, and strain along its entire length.

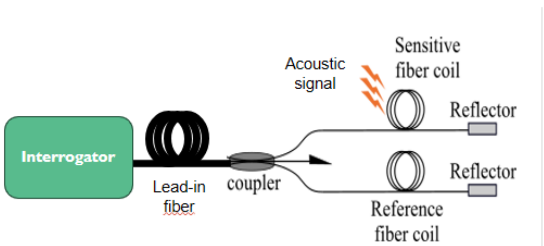


Figure 1.8: Diagram of the Distributed Acoustic Sensing (DAS) system.

- **Laser pulses injected into the fiber:** A DAS interrogator unit sends rapid pulses of laser light down the optical fiber.
- **Fiber acts as thousands of sensors:** Tiny imperfections naturally present in the fiber cause a small portion of the light to scatter back toward the interrogator.
- **Interrogator analyzes backscatter changes:** The DAS unit measures time and phase changes in the returning light.
- **Real-time acoustic and vibration detection:** The system reconstructs these changes into acoustic and vibration signals along the entire fiber path.

1.3.2 Principle of Operation: Split Lasing and FM Detection

The DAS system relies on the principle of split lasing to measure the coupling coefficient along the fiber. When an acoustic wave perturbs the fiber, it alters this coupling coefficient. As a result, the system's oscillation frequency is modulated, generating frequency-modulated (FM) signals that can be detected and reconstructed by the interrogator.

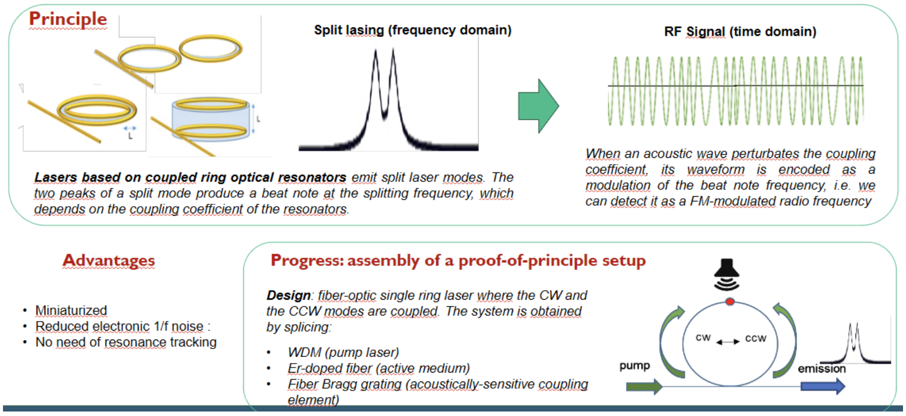


Figure 1.9: Principle of split lasing. An acoustic perturbation modifies the coupling coefficient in the fiber, and the resulting waveform is encoded as a modulation of the beat-note frequency, observed as an FM-modulated radio frequency signal.

2 Applications and Use Case Domains

Underwater acoustic sensing systems, such as DAS (Distributed Acoustic Sensing) combined with hydrophones and other sensors, provide a robust and scalable solution for a wide range of scientific, industrial, and security-driven missions. The ability to monitor and analyze acoustic events in real-time or post-processed time has made these technologies essential for numerous applications, particularly in subsea environments. Below are the primary domains where this system excels:

- **Underwater Acoustic Environment Monitoring**
- **Passive Acoustic Monitoring (PAM) of Marine Life**
- **Vessel and Submarine Detection**
- **Oceanographic Research and Geoacoustic Studies**
- **Sensor Calibration and Beamforming Algorithm Development**

This setup offers high-resolution data acquisition, enabling efficient signal processing and detection of a variety of underwater phenomena. Additionally, DAS and hydrophone systems are instrumental in enabling:

- **Pipeline Monitoring** (leaks, impacts, pig tracking)
- **Seismic and Microseismic Sensing**
- **Cable Tampering Detection**
- **Marine Mammal Tracking** (in some configurations)