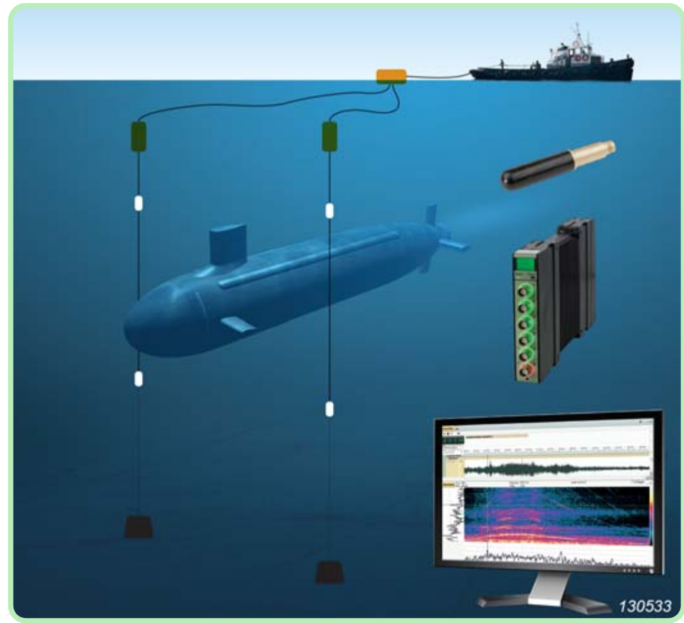
SYSTEM SUMMARY

Underwater Acoustic Ranging System



The Brüel & Kjær Underwater Acoustic Ranging System (UARS) is an integrated solution supporting navies with the task of managing and maintaining the acoustic stealth of their submarine and surface fleet.

Acoustic detection and identification techniques continuously become more advanced and sophisticated. As they evolve, so must acoustic stealth strategies. To maintain acoustic discretion all of a vessel's noise sources must be considered, including personnel, on-board equipment and cavitation, as well as the radiated noise signature of the vessel as a whole. In recent years there has also been a growing concern about underwater noise pollution, and thus the concept of 'green ships' is gaining in importance. This has resulted in a broader interest in the analysis of underwater (ship generated) noise, resulting in attempts to specify maximum limits for noise emission.

Static and dynamic acoustic ranging determines the underwater radiated noise from a submarine/surface vessel, measured over an extended frequency range. Acoustic ranging covers the full operational envelope of the vessel, including the identification of the different sources that contribute to the ships acoustic signature.The Brüel & Kjær acoustic ranging system is an integrated solution for both static and dynamic ranging. Systems can be configured for specific needs covering the complete measurement chain from sensor (hydrophone) to analysis (PULSE™).

System Overview

Brüel & Kjær's Underwater Acoustic Ranging System provides the following main functionality:

- Measure, record, analyse and listen to the various noise sources
- Determine the Closest Point of Approach (CPA)
- Perform corrections to 1m reference distance and other relevant corrections
- Determine the vessels acoustic signature at different operational conditions
- Provide tools for both broad- and narrow-band analysis
- Perform a comparison measurement either against historical data or a target
- Manage and report the measured data

Static and Dynamic Acoustic Ranging

Underwater acoustic ranging is divided into two applications: Static and Dynamic ranging.

In a Static ranging test, the submarine/ship is moored in a fixed position while all on-board equipment is turned on one at a time to go through the 100+ operational conditions. Static ranging provides a wealth of acoustic information, but must be complemented by operational tests at sea using so called dynamic ranging to capture flow and noise emitted under well-defined operating conditions.

In a Dynamic ranging test the submarine/ship follows a predefined path at predefined load conditions. Typically the noise signature is taken in a specific time window around CPA (Closest Point of Approach).

Dynamic ranging is used to determine the operational signature of the vessel. This is typically done with a new delivery to establish the vessels baseline, and then periodically and/or after maintenance to secure conformance with this baseline.

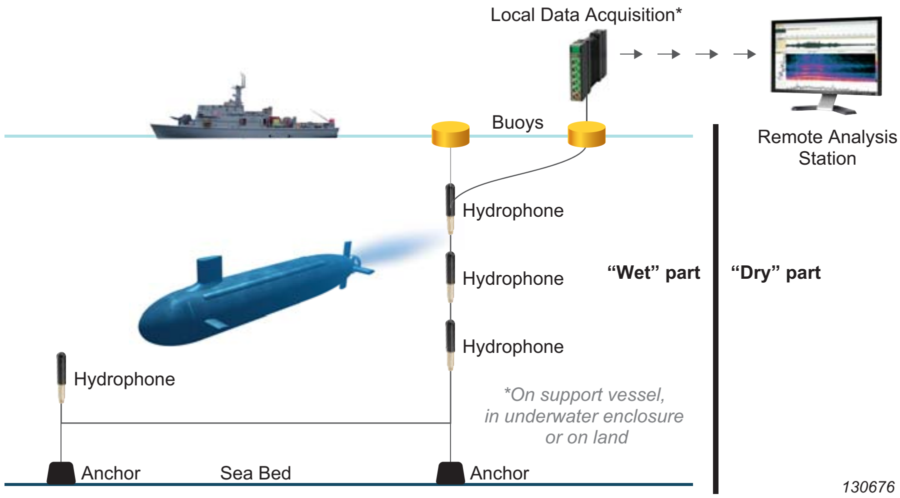


Fig. 1
Schematic layout of an acoustic range. The number of data acquisition units and hydrophones depends upon specific requirements. For Static Ranging the vessel is moored. For Dynamic Ranging the vessel is powered, and measurements made at the CPA

Sensors

Brüel & Kjær hydrophones are individually calibrated waterborne-sound transducers which have a flat frequency response and are omnidirectional over a wide frequency range. Their construction is such that they are absolutely waterproof and have high corrosion resistance.

Due to the nature of ranging measurements most applications call for a low noise hydrophone, for example a hydrophone with built in pre-amplifier.

Fig. 2
Type 8106 Hydrophone

A preamplifier very close to the sensing element in the hydrophone brings benefits such as:

- No signal attenuation/degradation due to the cable
- Better S/N ratio
- Higher sensitivity

Type 8106 (see Fig. 2) is a high-sensitivity hydrophone with an upper frequency limit >80 kHz, and an equivalent noise level well below sea-state zero.

Type 8106 has a built-in preamplifier with provision for insert-voltage calibration, and the capability to drive long cables without loss of sensitivity, or signal degradation. High quality underwater extension cabling is available.

LAN-XI Data Acquisition

Fig. 3
LAN-XI data acquisition hardware

The LAN-XI data acquisition hardware is a versatile system of modular units that can be combined in frames, setup as distributed or used as a stand-alone data acquisition system.

Several configurations are possible for underwater acoustic ranging. Systems range from permanent installed solutions to mobile ranges. The LAN-XI modules can be located in suitable enclosures, on a support vessel, on-land or underwater – the number of channels (and hydrophones) depending upon system requirements.

The modules are robust, extremely compact units well suited for mounting in confined spaces. The LAN-XI modules provide all data acquisition, powering and conditioning functionality:

- Acquire condition, filter and amplify the hydrophone signals
- Perform analogue to digital conversion on signals, with suitable anti-alias filtering
- Transmit signals to the Remote Acquisition and Analysis Station via a LAN

High Dynamic Range

The LAN-XI data acquisition units provide 24-bit A/D conversion and a very high dynamic input range. Brüel & Kjær's 160 dB DYN-X input technology ensures that the input ranging of the units is always optimal – avoiding high-level overloads at the same time as utilising the extreme low noise floor.

Wide Frequency Range

The family of LAN-XI hardware comprises a number of module types, optimised for different applications. Modules are available that can measure up to 25.6, 51.2, 102.4 and 204.8 kHz (with a corresponding sampling frequency of 65.5, 132, 264 and 528 kHz, respectively).

Local Area Network (LAN)

Interfacing between the data acquisition hardware and acquisition workstation is via standard TCP/IP technology. This offers the flexibility of using standard copper/fibre transmission, providing high-speed, redundant networks.

Powering the Modules via POE

Power over Ethernet (POE) provides a means to power each input module over the LAN cables rather than by separate power cables. This minimises the number of cables required, resulting in lower cost, faster setup, easier maintenance, and greater installation flexibility. LAN-XI modules can, of course, also be powered via external DC supplies and purpose-built Battery Modules (Type 2831).

Synchronising the Modules via PTP

IEEE standardised LAN network protocol is used to synchronize the different modules in the system with sub-microsecond accuracy. This can be used with any LAN-XI module, either as stand-alone, in a frame, or in a distributed system. All modules in the system can be synchronized using the same LAN cabling as the signal and module power.

Remote Acquisition and Analysis Station

The Remote Acquisition and Analysis Station is the main workstation running the UARS software applications. This is based on a suite of PULSE application software, where the complete operation is controlled by a workflow driven application, which covers everything from system setup, data acquisition, real-time audio, data management, detailed analysis, reporting and archiving. For test documentation purposes, a full set of test meta data can be stored together with test data.

Audio Monitoring

An audio monitor function provides operators with the ability to listen to any signal from any hydrophone.

Noise Signature Analysis

Using contemporary FFT (Fast Fourier Transform) techniques a vessel's underwater noise signal can be split into its different frequency components to produce the complete acoustic signature.
The Brüel & Kjær ranging software provides a number of different spectrum plotting possibilities:

- Traditional FFT spectra
- Narrow-band FFT spectra
- Contour/Waterfall plots
- LOFAR Low Frequency Recording (also called A-scans)
- DEMON analysis (Detection of Envelope Modulation on Noise)
- CPB (Constant Percentage Bandwidth), n^{th} octave plots

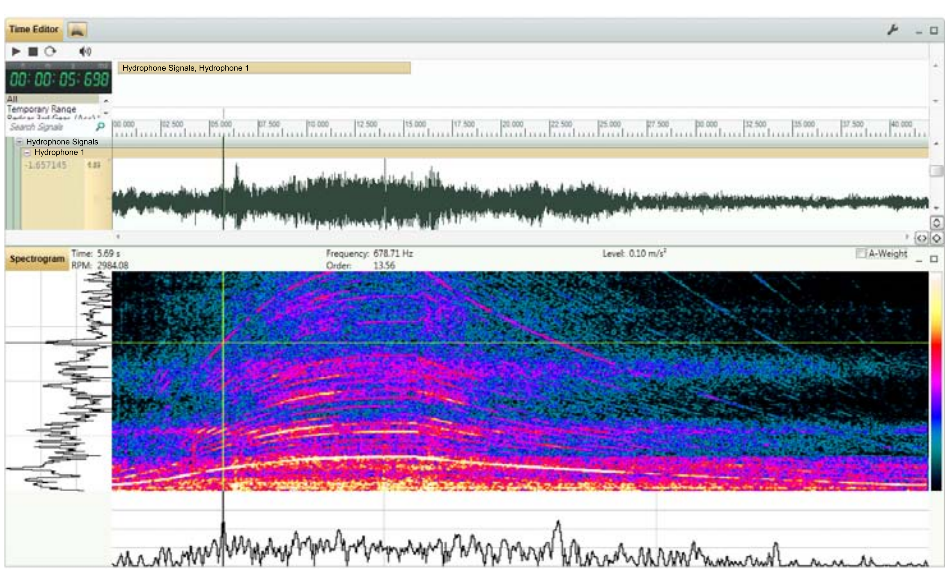


Fig. 4
Detailed signal analysis functions are available. In this example, cursors in the time and spectrogram displays are synchronized during audio playback to give instant feedback on frequency and amplitude. 2D graphs, projected to the left and bottom of the spectrogram show the instantaneous spectrum and frequency slice

Closest Point of Approach (CPA)

For dynamic ranging the noise from the vessel is analyzed as it passes a specific point on the track, referred to as the Closest Point of Approach (CPA).

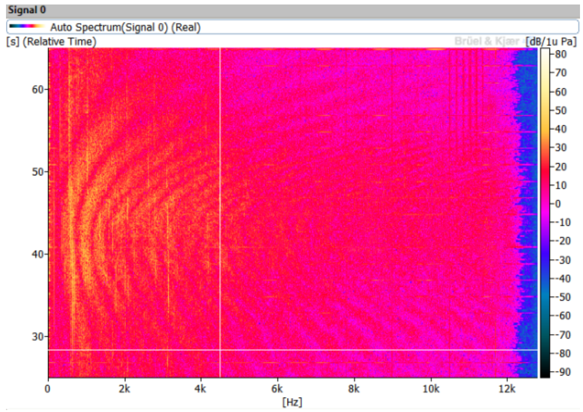


Fig. 5
Typical example of the Lloyds Mirror technique. Interference fringes are used to determine the CPA

The CPA can be determined in a number of ways:

- By synchronizing user-provided time-aligned vessel position data with the measured noise data (based on a common time-reference). Coordinated data from a tracking/navigation system can be interfaced to the UARS measurement system in a number of formats
- Using the Lloyds Mirror technique (see Fig. 5). The benefit of this technique is that it is simple and doesn't require any track data from the vessel under test (unless the actual range to CPA is required)

Normalised Data

The radiated noise data acquired is normalized to 1 meter according to the sound propagation loss in the water, and the vessel navigational data received from the tracking navigation subsystem. The normalization algorithm can also take into account parameters such as water temperature, salinity, pressure and currents if suitable measured data is made available to the UARS.

Data Management and Report Generation

Recorded time data and post-analyzed spectra are stored along with test meta data that identifies measurement object and test conditions. The system can generate test and measurement reports that are fully in accordance with STANAG requirements, and the report generator is suitably flexible to allow the customer to create their own reports.

System Engineering

The measurement, recording and analysis part of the UARS is provided by standard off-the-shelf products. A typical underwater range, however, requires a significant amount of system engineering and ancillary equipment in the form of buoys, watertight enclosures, hydrophone suspension, cable winch systems and anchor releases, etc. Brüel & Kjær can provide engineering services on a project basis, or sub-contract to suitable agencies.

Adhering to Standards

In order to generate the full set of data in a standardised format, the UARS application follows the measurement requirements and procedures set forth in:

- NATO STANAG 1136 – Standards for Use When Measuring and Reporting Radiated Noise Characteristics of Surface Ships, Submarines, Helicopters, etc., in Relation to Sonar Detection and Torpedo Acquisition Risk
- ANSI S 12.64:2009 - Quantities and Procedures for Description and Measurement of Underwater Sound from Ships - Part 1: General Requirements

Acoustic Ranging Case Study

Case Study BO-0487 'The Royal Norwegian Navy - Underwater Acoustic Noise Measurement of Vessels' is available from Brüel & Kjær. It describes the acoustic range at Heggernes, near Bergen, Norway, which is used for measuring noise from all types of NATO naval vessels. The range is run as a cooperation between Norway, the Netherlands and Germany.

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