



Publishable Summary for 15RPT02 UNAC-LOW Underwater Acoustic Calibration Standards for Frequencies Below 1 kHz

Overview

The goal of the project is to develop the European Metrological Capacity in underwater acoustic calibration for acoustic frequencies below 1 kHz by providing traceable measurement capabilities to meet the need for calibration of hydrophones and autonomous underwater acoustic noise recording systems. The project will develop the scientific and technical research capabilities in the field within Europe, and provide an improved metrology framework to underpin the absolute measurement of sound in the ocean in support of regulation and EU Directives (such as the Marine Strategy Framework Directive) for which traceability is currently lacking.

Need

There is an increased need for absolute measurements of sound in the ocean driven by ongoing concerns about the environmental impact of human activity, together with the emerging needs of industry and oceanographic science. In order to be meaningful, such absolute measurements require traceability to agreed standards, but traceability is not widely available for acoustic frequencies below 1 kHz. With regard to marine environmental protection, the expansion of offshore activities has led to concern about the environmental impact of man-made sound upon marine fauna. The effect on marine fauna of high amplitude sources may include physiological effects (e.g. damage to hearing) or behavioural effects (e.g. flight response or displacement from habitats). An increase in background noise level may also have chronic effects (e.g. masking of biologically produced sound vital for communication and foraging).

The anthropogenic sources of greatest environmental concern radiate most of their sound energy in the frequency range between 20 Hz and 1 kHz. However, in this frequency range there is a lack of availability of traceable measurement standards, with much of the historic demand being for testing of active systems at kilohertz frequencies. There is a direct and urgent need for traceable calibration of the hydrophone instrumentation used for measurements driven by the increased demand for measurement generated by regulation. However, there is also a technology push provided by the development and increasing commercial availability of new instrumentation, specifically autonomous recorders that combine hydrophones and acquisition and data storage capabilities.

Currently, no standards exist to calibrate these instruments, therefore there is an urgent need to develop traceable measurement capabilities for calibration of hydrophones and autonomous underwater acoustic noise recording systems at frequencies between 20 Hz and 1 kHz, including the 63 Hz and 125 Hz third-octave bands required by the EU MSFD. This must include research to develop new traceable calibration methods for autonomous noise recorders for which there are no established calibration methods. Underwater acoustics is a relatively immature field for metrology, and in addition to establishing a European calibration capability, a strategy must be developed for the long-term operation of the developed capabilities, contributing to a coherent metrology strategy for Europe within this field, providing significant improvement of the use of the available resources to better meet metrological needs and assure the traceability of national standards, and to develop a research capability within the metrology community.

Objectives

The overall objective of this project is to develop an absolute measurement technique for making the calibration of hydrophones and autonomous noise recorders at frequencies between 20 Hz and 1 kHz and the dissemination of the calibration capability in order to fulfil the related directive which is stated in the Marine Strategy Framework Directive (MSFD, Directive 2008/56/EC).

The project addresses the following scientific and technical objectives:

1. To develop traceable measurement capabilities to meet the need for calibration of hydrophones at frequencies between 20 Hz and 1 kHz, and covering the 63 Hz and 125 Hz third-octave bands, as required by the guidelines for monitoring undersea noise within the EU MSFD.
2. To develop calibration methods which provide traceable measurement capabilities to meet the need for calibration of autonomous noise recorders and systems used for long-term ocean acoustic monitoring at frequencies between 20 Hz and 1 kHz, including the 63 Hz and 125 Hz third-octave bands for NMIs and DIs seeking to establish a research capability in this field.
3. To develop an individual strategy for each participant for long-term operation of the developed measurement capabilities including regulatory support, research collaborations, quality schemes and accreditation, contributing to development of a coherent metrology strategy for Europe within this field (discussed and agreed within the EURAMET community via the EURAMET TC-AUV), and significantly increasing the research capacity in the field.

Progress beyond the state of the art

The project will develop and validate appropriate measurement methods for the calibration of hydrophones in the frequency range from 20 Hz to 1 kHz. At the conclusion of the project, at least two of the hydrophone calibration methods selected from those described in the scientific literature or the related international standards will be implemented into new calibration systems. These will be validated by comparison measurements between the project partners. Through this work, traceability for absolute measurement of sound in the ocean using hydrophones will be provided across the EU countries, with project partners offering calibration services from their established facilities to their neighbouring countries.

The calibration methods developed in this project will provide the ability to determine the key acoustic performance characteristics of the recorders, including the self-noise of the hydrophone and system, the hydrophone and system sensitivities. The newly established methods to calibrate autonomous noise recorders will be implemented by the project partners and services offered to stakeholders in neighbouring countries, with recommendations given to technical standards committees including ISO TC43 SC3 (Underwater acoustics) and IEC TC87 (Ultrasonics) for preparation of related standards. This will be facilitated by members of the project consortium who are active in the standards committees (the consortium contains the Convenor of several key Working Groups). The manufacturers and end users of noise-monitoring systems will be informed of the developments so that the improvements can be incorporated into their own work.

Establishing traceable calibration facilities for the hydrophones and noise recorders by the project partners will sufficiently extend the capability of each related stakeholder. Also these calibration facilities shall be used for providing calibration services by NMIs/DIs and guides for end users working in the field on underwater acoustic measurement and monitoring including the design and production of corresponding systems.

Results

The project will facilitate significantly improved capability within Europe for marine acoustic metrology at frequencies below 1 kHz, providing much-needed traceability for absolute measurement of sound in the ocean, and underpinning acoustic measurements for the protection of the marine environment. In addition to the benefits for the metrology community itself, the improvements will also directly benefit the European marine acoustic community, with the main stakeholders being from:

- industry (manufacturers and suppliers of hydrophones and autonomous noise recorders),
- the end user community (scientific institutes and acoustic consultants undertaking in-situ measurements of sound in the ocean),

and the relevant regulatory bodies and licensing authorities (both national and international) that require acoustic measurements to be undertaken to satisfy the requirements of EU Directives such as MSFD, offshore licences and environmental impact assessment.

Calibration of hydrophones

As a result of this project, the improved traceability for hydrophone calibration will provide manufacturers and users with vital confidence in the measurement result. "Calibration of Hydrophones for the Frequency Range

Between 20 Hz and 1 kHz”, the existing methods covered by IEC 60565:2006 has been reviewed to select which methods for low frequency (20 Hz to 1 kHz) hydrophone calibration will be used. Comparison calibration in coupling chamber and standing wave tube methods were selected for further investigation.

A coupling chamber calibration setup has been designed and a technical drawing has been prepared for the manufacturing process at TÜBİTAK. According to the first design (Chamber 1) one set of coupling chamber has been manufactured and assembled. The coupling chamber was tested and characterized by calibrating a B&K Type 8104 hydrophone in the frequency band from 20 Hz up to 1.5 kHz in air and air-water regimes. Based on first test results, the chamber design was further developed to improve performance at frequencies over 400 Hz. A new designed chamber (Chamber 2) has been developed, manufactured and tested in the frequency band from 20 Hz up to 2.5 kHz. The calibration procedure was also developed.

For the verification of test results, a B&K 8104 type hydrophone has been circulated between TÜBİTAK, FOI and NPL. FOI calibrated the hydrophone in the frequency band between 20 Hz to 1 kHz by standing wave calibrator unit, NPL calibrated in the frequency band between 5 Hz to 400 Hz by coupling chamber method and TÜBİTAK calibrated in the frequency band from 20 Hz up to 2.5 kHz by coupling chamber method, in Chamber 2.

A draft uncertainty budget calculation table was prepared and used for evaluation of the uncertainties of the B&K Type 8104 hydrophone calibration.

The feasibility of extending the comparison pressure calibration methods down to frequencies lower than 20 Hz has been assessed at NPL, and successful calibration have been carried out down to as low as 5 Hz. Free-field calibrations have successfully been established for hydrophones in the frequency range from 250 Hz to 1 kHz using signal modelling methods to analyse the data. The uncertainties and limitation of all the methods are being assessed, and this will continued.

Calibration of autonomous underwater acoustic noise recording systems.

The new methods for calibration of autonomous recorders will provide manufacturers with important feedback on key performance metrics for the first time, leading to the development of improved system performance and validated calibration methods and better uncertainties. The new calibration guidance developed by the project will also be directly used by calibration laboratories, which will assure traceability of measurements performed by end users of recorder systems. This will enable results of in-situ measurements of ocean noise to be reported with a more robust associated uncertainty (1 dB for hydrophones and 1 to 1.5 dB for autonomous sound recorders), which will enable a transparent comparison of measurement results made in different environments and by different users. Moreover, a comparison of the performance of autonomous noise recorders will be possible either individually as a function of time to assess stability, or between differing designs of recorders. This will provide increased reliability and confidence in the performance of instruments for the end-user community. A summary report entitled “Calibration of Autonomous Noise Recorders for the Frequency Range Between 20 Hz and 1 kHz” provides a review of the existing literature and research work, and a description of the methods proposed for the calibration and characterisation of marine autonomous acoustic recorders used for long-term ocean acoustic monitoring. The proposed methods include pressure calibration, free-field calibration and diffuse field calibration. The report describes proposed calibration solutions, and summarises a number of the issues regarding the characterisation of the performance of such devices.

Methods for low frequency pressure calibration of autonomous recorders have been developed at NPL using calibration by comparison to microphones in a closed air-filled chamber. Successful calibrations have been carried out in the frequency range from 5 Hz to 315 Hz. New adaptors have been developed to enable couplers to accept various hydrophone models of autonomous recorders, and adjustable support carriages have been designed for use in support of recorder body during measurements. The newly-developed automated software extracts signal levels from the recorder files. Experimental and theoretical investigations have been conducted to determine the effect of non-uniform sound pressure in the chamber. Modelling has been compared to actual measurements at different locations inside the chamber. The effect of uncertainty contributions at (very) low frequencies has been examined.

Initial free-field calibrations have been undertaken by NPL to investigate the effect on the response of resonances in recorder bodies, and these have been compared with finite element modelling. Further free-field measurements (using a dummy recorder) are planned to investigate the effect of resonances in the recorder body.

Trial measurements have also been undertaken by FOI using their standing wave tube facility.

The setup and procedure for deployment, mooring, retrieval of the recorder and for data extraction and processing has been defined by CNR and ISPRA. Two periods of 15 days in either site, adding up to one month total deployment time, have been planned, to be completed tentatively by end of 2018.

Individual strategy for long-term operation of the developed measurement capabilities

NPL launched a new measurement service for autonomous recorders in 2017. Initially, this provides only pressure calibrations at frequencies from 25 Hz to 315 Hz by use of comparison in a closed chamber. Before launching the service, NPL surveyed potential customers in the UK and adjacent EU states to obtain feedback on their calibration requirements. The feedback was highly positive, and the service was launched at the Ocean Business exhibition. It has already had a total of more than 30 calibrations undertaken for UK regulators, Government institutes, users and manufacturers. The new service was selected by EURAMET MSU as a Good News Story and the relevant article is available at:

https://www.euramet.org/index.php?id=40&tx_news_pi1%5Bnews%5D=622&tx_news_pi1%5Bcontroller%5D=News&tx_news_pi1%5Baction%5D=detail

Impact

The project and its results have been presented at the following conferences:

- IEEE Oceans in Aberdeen UK in April (NPL)
- European Underwater Acoustic Conference UACE2017 in Greece in September (NPL)
- IMEKO TC19 Workshop on Metrology for the Sea in Naples in October (CNR)
- Participation of TÜBİTAK MAM to International Metrology Congress CIM-2017 in Paris/France on 19-21 September 2017 by fair booth
- Presentation by TÜBİTAK MAM at 8th Naval System Seminar in Ankara/Turkey on 16-17 October 2017.

Furthermore, NPL exhibited the work carried out in this project at the UK Ocean Business exhibition hosted at the UK National Oceanography Centre (NOC) in Southampton in April 2017.

A journal paper on the characterisation of autonomous recorders, and a paper on signal modelling techniques for low frequency hydrophone calibration are in preparation.

Impact on industrial and other user communities

The UNAC-LOW stakeholder group now has more than 20 contacts, exceeding the original expectation of 15. The stakeholders include key contacts from manufacturers and suppliers, such as Wildlife Acoustics, RTSys, RSAqua, Ocean Instruments, Ocean Sonics and Teledyne-Reson. Also included are representatives of the user community such as Quiet Oceans, University of Catalunya, Institut für technische und angewandte Physik GmbH, Baker Consultants, CO.L.MAR, and Loughborough University. In addition, there are influential members of the regulatory authorities in both Europe (e.g. Marine Scotland) and the USA (e.g. NOAA). The group also includes metrology institutes (e.g. NIST, VNIIFTRI) and standards bodies (ISO TC43 SC3, IEC TC87 WG15). The stakeholder group reflects a truly worldwide interest in the project outputs, not just a European interest, with countries such as the UK, France, Spain, Germany, Italy, USA, Canada and New Zealand.

A total of 5 training courses have been run by NPL since the start of the project, each of which covered the scope of the UNAC-LOW project. The application sectors of the customers are varied and include a marine environmental regulator in the UK, a Government metrology institute from South Africa, an oceanographic institute from Japan, and a defence agency from Canada. A training workshop was also held for a mixed UK audience from industry on Ocean Acoustic Measurement. During the courses, low frequency calibration of hydrophones and autonomous recorders was covered (among other topics).

TUBITAK has also delivered a one day theoretical and practical training course for Turkish Naval Force Staff. Consideration has been given to the organisation of the stakeholder workshop, with the aim to hold it centrally in Europe (Italy is the tentative proposal). However, it has been decided to delay the timing so as to coincide with another international meeting to maximise stakeholder attendance with minimal extra expense. In addition, there will be more project outputs to discuss with stakeholders.

Impact on relevant standards

Outputs of the project are now feeding into international standards activity. Significant input has been provided by (NPL) to the revision of IEC 60565-2 CD: Calibration of hydrophones: Procedures for low frequency pressure calibration, where the June 2017 meeting of IEC TC87 WG15 in Vienna was chaired by NPL. This standard is of direct relevance to UNAC-LOW, and will shortly be balloted as a Committee Draft for Vote (CDV) and should be published before the end of the UNAC-LOW project. NPL also made significant contributions to the recently published IEC 60500:2017 (Properties of hydrophones). For ISO TC43 SC3 standards, ISO 18405:2017 (Terminology) and ISO 18406:2017 (Measurement of marine pile driving noise) were published in 2017, and the drafting of ISO 17208-3 (Measurement of ship noise) is in progress. Although less directly relevant to the outputs of UNAC-LOW, key input was provided on hydrophone and instrument calibration requirements for measurements of low frequency sound sources in the ocean, underpinning the traceability of such measurements. At the October 2017 plenary meeting of ISO TC43 SC3 in Woods Hole, USA, a New Work Item Proposal for development of standards for recorder calibration was agreed. This is likely to be a joint exercise with IEC TC87, will have input from UNAC-LOW partners, and will provide a direct output for the work of UNAC-LOW.

In addition, a UNAC-LOW plays a leading role on the Standards and Calibration sub-committee of the Science Committee of the prestigious International Quiet Oceans Experiment (IQOE). This positions the project partners to directly realise the benefit of the project outputs and promote uptake of the traceable services offered within any subsequent acoustic monitoring project generated under the auspices of IQOE.

Impact on the metrology and scientific communities

Partners will continue to working on their individual strategies for the long-term development of the operational capabilities. Discussions on a coherent European metrology strategy for the field were initiated within EURAMET TC-AUV and will be on the agenda for the next TC-AUV meeting in May 2018.

Further efforts have been expended on building in the requirement for the metrology outputs provided by UNAC-LOW into other research projects and initiatives to their direct benefit. This has been done for the EU INTERREG ocean ambient noise monitoring project for the North Sea titled JOMOPANS, which addresses the noise monitoring required by the EU Marine Strategy Framework Directive. This project will use and benefit directly from the calibration and traceability provided by UNAC-LOW, and has two common partners (NPL and FOI). The JOMOPANS project started in January 2018, overlapping in time with the UNAC-LOW so that direct liaison may be made between the two extant projects.

The exploitation plan is reviewed at each project meeting.

List of publications

No peer-reviewed papers have been published thus far.

Project start date and duration:	01 May 2016, 36 Months	
Coordinator:	Alper Biber, Dr., TÜBİTAK, Tel: +90 262 677 31 59 E-mail: alper.biber@tubitak.gov.tr	
Project website address:	http://empir-unaclow.com/	
Internal Funded Partners:	External Funded Partners:	Unfunded Partners:
Partner 1 TÜBİTAK, Turkey	Partner 4 CNR, Italy	
Partner 2 DFM, Denmark	Partner 5 FOI, Sweden	
Partner 3 NPL, United Kingdom	Partner 6 ISPRA, Italy	