EMPIR JOINT RESEARCH PROJECT

March 2023

INFRAAUV News

NEWSLETTER NUMBER 3

CONTENTS

WELCOME

With this document you hold the third newsletter of our Infra-AUV project in your hands. Again, we have tried to give you a brief glimpse into the various aspects of the joint research and development work.

And "various" it is! Going through the pages, you will find interesting contributions from our three branches "sound in air", "vibration" and "underwater acoustics" as well as from different environments from the lab to the woods! There are articles that should find interest in different targeted audiences, like metrology, geoscience and legal metrology for the public.

This newsletter carries information about several new primary methods in acoustic calibration in the infra-sound region, provided by the French LNE and the Danish DPLA. The colleagues from PTB put a spotlight on the consequences of our work on the testing and use of sound-level meters for infrasound measurements for the public. And CEA introduces a new system for the field calibration of infrasound sensors, which has been called for for many years and has now been realised, representing a significant progress for the operation of monitoring stations.

One of our biggest challenges currently concerning seismic measurements is called "tilt". You will understand why after reading the subsequent brief news and learn about its impact when the LNE tells you about the extension to 0.1 Hz in their calibration capabilities. However, I fear the solution must wait until the next Newsletter. Nevertheless, the highlight about the running seismometer field experiment demonstrates that our work so far was not in vain.

The implementation of on-site calibration for underwater acoustics will be supported from our project by feasibility studies, our partners from NPL introduce you to the developed concepts and first modelling results.

Again, we hope you find the news as exciting as we found the research. As always you can find out more via our web-site or by direct contact to our Team

- *Thomas Bruns, project co-ordinator*

THE CONSORTIUM

This consortium brings together a wide range of expertise and leading skills found within the partner organisations and comprises national metrology institutes (NMIs) and designated institutes (DIs) who are complemented by a number of research institutes and IMS station operators representing the expertise needed from the stakeholders.

PTB, Germany
HBK, Denmark
CNAM, France
DFM, Denmark
LNE, France
NPL, United Kingdom
TUBITAK, Turkey
BGR, Germany
CEA, France
ASN, United Kingdom

NEWS IN BRIEF

INFRA-AUV AT CTBTO WORKSHOPS

Project developments in hydroacoustic sensor calibration were featured in a poster presentation at the International Hydroacoustics Workshop organised by CTBTO in September 2022. The workshop was an excellent opportunity for specialists from this field to discuss latest developments and members of the project team from NPL seize this opportunity to discuss the implementation of on-site calibration in the ocean. Then in January 2023, the CTBTO Infrasound Technology Workshop took place in São Miguel Island in the volcanic Azores, Portugal. The Infra-AUV project was heavily featured in the session on *Measurement Systems*, opening with a presentation of the objectives and a series of highlights from across the project. This was followed by more detailed presentations on infrasound calibration by laser pistonphone and carousel methods developed in the project, and finally a round-up of all the infrasound calibration methods currently under consideration in Infra-AUV and their relative merits. As the session progressed, the focus shifted towards field calibration, with further presentations from the project on natural and anthropogenic calibration stimuli, novel field-calibration devices, and on using calibration to correct for the influence of defects in wind-noise reduction components of the system. Overall, the measurement systems topic featured heavily in the ITW2022 programme indicating the growing importance attributed to metrology in the CTBTO monitoring activities.

DEVELOPMENTS IN SEISMIC CALIBRATION

One of the tasks of the Infra-AUV project is to establish a traceable calibration capability for seismometers from 0.1 Hz to 20 Hz for CEA, with traceability linked to LNE. CEA oversees the maintenance and calibration of seismometers deployed around the world within the International Monitoring System. At LNE both hardware and software have been under development to extend operations below the long-established 0.5 Hz limit.

A significant challenge was the characterisation of the tilt induced by the bending of the shaker's horizontal bar to correctly assess the displacement of the device under test, and to correct for this effect. The processing of data also had to be optimised for the lower frequency range.

Validation was made with assistance from another project partner, PTB, using reference devices with a long calibration history, retained at LNE. Finally, with the uncertainty budget prepared the calibration capability has been established down to 0.1 Hz. While further work is in progress, the facility is ready to provide high-accuracy calibrations to users.

LOW-FREQUENCY RECIPROCITY CALIBRATION

For many years, reciprocity calibration of microphones has been the internationally agreed method for establishing primary measurement standards for sound pressure. Until now, the method has been limited to frequencies above 2 Hz. HBK-DPLA has successfully extended the method to frequencies below 40 mHz, providing a single calibration solution all the way to the 10 kHz limit of one-inch laboratory standard microphones. Preliminary analysis of measurements down to 25 mHz show a reproducibility of around 0.06 dB and better than 0.03 dB at 80 mHz.

A major practical challenge at low frequencies is the equalization of the static pressure in the coupling cavity and the surrounding air. If the cavity is fully sealed, even small temperature variations deteriorate the measurements. If the equalization mechanism is too open, it becomes difficult to determine and compensate for its influence. However, a consistent equalization system and a method to determine the time constant for compensation have been developed.

TILT INFLUENCE IN SEISMIC CALIBRATION

During the calibration of seismometers with an excitation in horizontal direction, it was found that an exactly rectilinear movement is crucial. If the trajectory of the excitation changes direction, varying/changing components of the gravitational acceleration are superimposed on the applied acceleration stimulus, causing unwanted disturbance. If the curvature of the movement is (approximately) circular, these disturbances will be of the same frequency and in phase with the excitation, so cannot be distinguished from rectilinear excitation.

This issue is particularly pertinent with seismometer calibrations. These instruments are very sensitive (and therefore require only small excitation) and measure down to very low frequencies. Disturbances from gravitational excitation remain constant, and therefore become relatively larger at the small excitation levels and the larger displacement amplitudes used in the calibration. At excitation levels of 1 mm/s, a small tilt of 1 µrad (about 0.00006 degrees) will lead to a relative error 1.6% at 0.1 Hz and as much as 16% for 0.01 Hz!

To overcome this problem, the curvature can be measured. The calibration results can then be corrected for the influences due to the gravitational acceleration. In this project, tilt measurements were carried out by means of laser interferometry and autocollimators. If the curvature of the movement is circular and stable (and not of some arbitrary trajectory) it can be measured once and corrected afterwards. Otherwise, the tilt angle would have to be measured as part of the seismometer calibration.

NEWS IN BRIEF

INFRASOUND CALIBRATION ACHIEVEMENTS

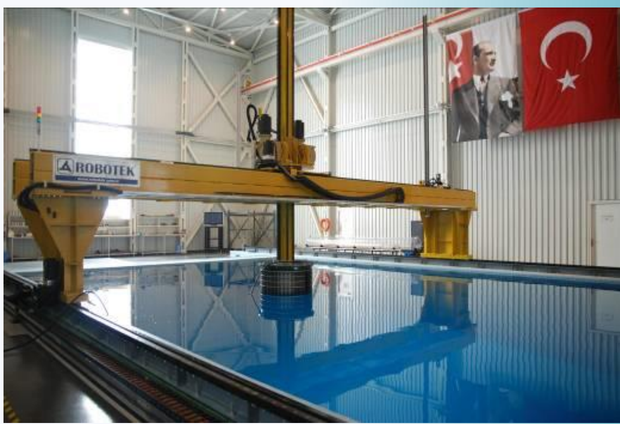
Primary standards for infrasound have developed rapidly as a result of the Infra-AUV project, with three viable calibration capabilities now available. LNE has developed a laser pistonphone operating in the frequency range 10 mHz – 20 Hz. Special attention was given to the validation of the method by demonstrating equivalence with other independent and recognized methods, leading to the work being published in *Metrologia* (the foremost scientific journal specialising in metrology). Moreover, the general calibration principle has been recognised by the International Electrotechnical Commission (IEC) in IEC/TR 61094-10.

PTB has developed another form of absolute calibration referred to as the “Carousel method” operating in the frequency range 0.1 Hz – 10 Hz. The basic element of the setup consists of a vertically oriented rotating disk on which the sensor to be calibrated is mounted. The dependency of ambient pressure on elevation produces a calculable pseudo-sound-pressure that serves as the calibration stimulus. Finally, HBK-DPLA upgraded their existing facilities for pressure reciprocity calibration of microphones to extend their capabilities down to 40 mHz. An interlaboratory comparison across these three very different systems is in progress.

RESEARCH HIGHLIGHTS

HYDROPHONE CALIBRATION BY COUPLER RECIPROCITY

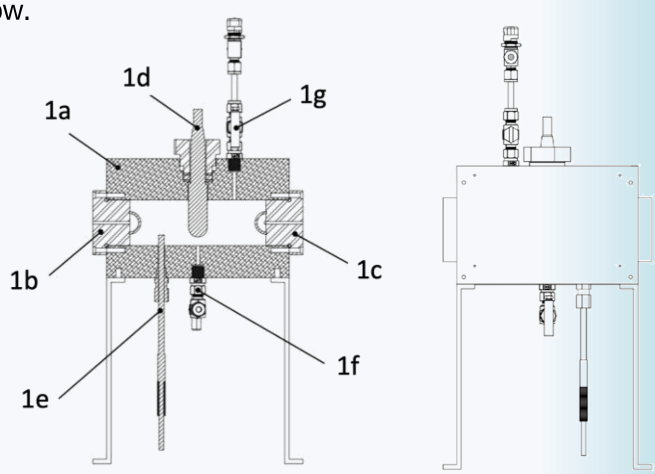
Measurement standards for hydroacoustics are typically realised through free-field reciprocity calibration of hydrophones, conducted in open water or in a large tank. Size constraints then lead to a low frequency limit of around 250 Hz for a large open-water facility or 1 kHz in a tank.



Calibration at lower frequencies is possible by coupler reciprocity implemented in a small, closed cavity, which also offers greater control of the temperature and static pressure and an opportunity to calibrate at simulated ocean conditions. TÜBİTAK are one of the first to develop facilities for calibration at frequencies as low as 1 Hz as a function of temperature and static pressure (or simulated water depth), a key requirement for deep-ocean applications.

TÜBİTAK has designed a completely new system and proceeded with the manufacture, installation and development of the setup. The geometrical design is constrained by the upper frequency limit and size of the hydrophone elements, including both the in-built reference hydrophones and the device under test. The configuration of the coupler is shown below.

1.a. Body of chamber
1.b. Projector Element
1.c. Transducer Element
1.d. Hydrophone Element
1.e. Pt100 Thermocouple
1.f. Pressure Inlet Valve
1.g. Vent



Validation measurements are being carried out, and the plan is to conduct a laboratory intercomparison with project partner NPL. NPL has their own coupler reciprocity facility, and also a laser pistonphone for the calibration of hydrophones down to 0.5 Hz.

TESTING OF SOUND LEVEL METERS IN THE INFRASOUND RANGE

Sound level meters (SLM) are the instruments of choice for any noise measurement, but their use is restricted to the audible frequency range. A few instruments on the market already offer infrasound extension kits. Since the governing standard IEC 61672 “Electroacoustics – Sound level meters” provides neither requirements nor testing methods for frequencies below 10 Hz, these SLMs cannot be tested and certified by internationally accepted procedures within the extended frequency range. As a direct consequence, any low frequency noise assessment as part of a legal action is usually dismissed because the performance of the measuring instrument cannot be trusted.

A review of published national guidance documents for low-frequency noise assessment in Europe showed the need to extend the application range of IEC 61672 at least down to the 1 Hz third-octave band (the review can be found on the Infra-AUV website). As a first step of implementation, early methods for electrical testing have been developed within the Infra-AUV project. This has a particular relevance to practical work since many of the infrasound performance requirements can be tested electrically if the SLM provides for an electrical input. PTB is currently developing a setup to automatically test a collection of low-frequency characteristics including frequency weightings, third-octave bands, level linearity and more. The experience obtained will be contributed to international standardisation work in IEC TC29 “Electroacoustics”. Challenges will arise from novel technology elements. For instance, PTB tested a sound level meter equipped with a MEMS microphone system. The specific problem here is that testing at the electrical input neglects important electronic components which are typically integrated in the microphone package and inaccessible. Novel testing strategies have been developed based on acoustic measurements, as a complement to electrical testing.

Acoustical testing of a sound level meter

The work made in this project has the goal to provide the basis for a future standardisation of infrasound measurement technology and thus facilitate certification of infrasound noise meters. A discussion has already started in the standardisation community and a proposal is under development for an extension of IEC 61672 to cover the infrasound frequency range.

INNOVATIVE INFRASOUND FIELD CALIBRATION SYSTEM

The CEA has developed a portable infrasound calibration system to transfer traceability to the International System of Units (SI) to the field. This device, called SMIT (for Système de Métrologie Infrasonore de Terrain in French), is composed of a portable infrasound dynamic pressure generator, a geophysical field digitizer, a HBK type 4193 microphone, and the on-board electronics necessary for measurement and processing of the results. SMIT weighs about 30 kilograms in its prototype version. Coupled with a laptop computer, the system allows the calibration of any type of geophysical infrasound sensor at the location where the measurement will be performed in the field, for the moment from 0.1 Hz to 100 Hz. The method is a comparison method with a laboratory calibrated microphone (transfer standard), whose susceptibility to the environment is known. Both the sensor to be calibrated and the microphone are coupled to the cavity of the infrasound generator. The signal-to-noise ratio is sufficient for such a microphone to be used as a transfer standard.

The CEA field calibrator system

SMIT has been successfully tested at different locations, different temperatures (from -2°C to 40°C) and different altitudes (from 0 m to 4000 m) in France during 2022, validating the method and the behaviour of the device in the field. In addition, it was deployed on the IS26 infrasound station of the CTBTO (Comprehensive Nuclear-Test-Ban Treaty Organization) in Germany (17 °C, 900 hPa), and implemented with MB2005 and MB3 microbarometers that were previously calibrated in the laboratory (23 °C, 1000 and 900 hPa). This comparison between the laboratory and the field in a real environment demonstrated the equivalence of the methods.

This is the first time that traceability to SI units has been brought to the field for infrasound sensors. The sensor alone is calibrated, so another method must be used if the whole measurement system, including any Wind Noise Reduction System, is to be characterized.

This device is still a prototype, and work will continue to better understand the behaviour of the reference microphone, and to gain more experience with the device in the field to reduce the measurement uncertainties. A new version is also in development to reduce size and weight, and to improve the performance and quality of the measurement results for future calibrations.

Gabrielson-Charbit method

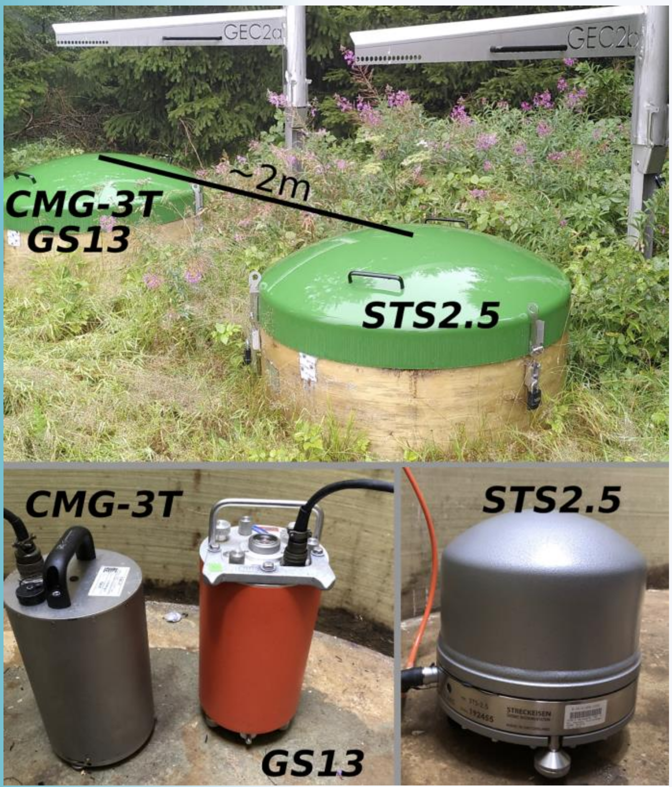
The so-called Gabrielson-Charbit method is a method of relative calibration of co-located sensors, and is the means favoured by CTBTO for implementing on-site calibration of infrasound sensors. The process is completely passive, but requires a reference sensor to be located alongside the 'live' sensor used for monitoring. On the basis that at certain times, both sensors are exposed simultaneously to some form of ambient stimulus, the output data streams are captured for offline analysis. The signals are broken down into frequency bands and time periods are identified when the two signals have high coherence, indicating that the simultaneous exposure assumption holds. The relative response of the two sensors can then be calculated, and over time the long-term temporal trend in this response can be collated.

FIELD TRIAL ON ON-SITE SEISMOMETER CALIBRATION

In August 2022, three seismometers (one 3-component Streckeisen STS2.5, and two vertical component Geotech GS13 devices), were re-installed at the International Monitoring System (IMS) seismic station PS19 in Germany, having been removed for calibration at PTB.

The objective of the study was to evaluate the use of a modified version of the Gabrielson method for on-site calibration of seismometers, with the additional feature of using a calibrated and traceable reference sensor. The calibration method results in the frequency response ratio of the two sensors, so the calibration of the reference sensor enables measurement traceability to pass to the sensor under test.

The first preliminary analysis focussed on the magnitude of the vertical component. For each day, the gain ratio is calculated between a station sensor (CMG-3T; three-component) and the reference (STS2.5), which are co-located in neighbouring

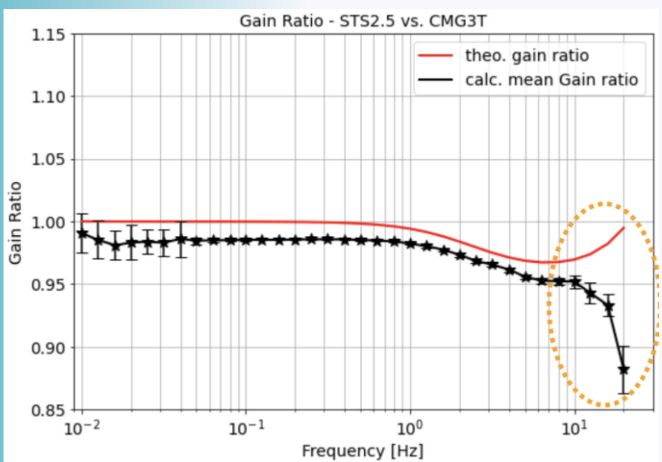


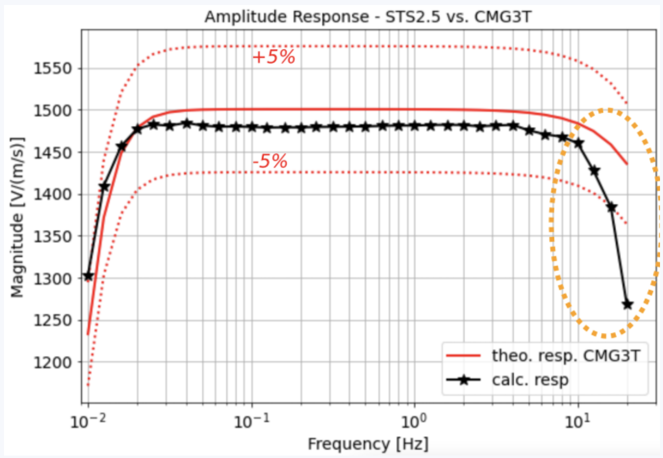
Seismometer installation at PS19

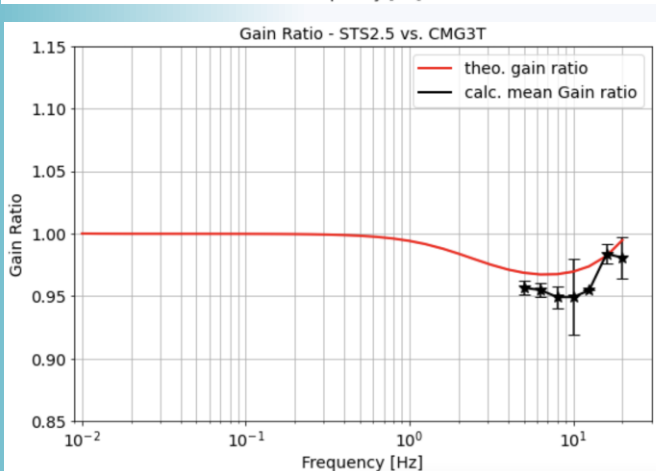
vaults at a distance of about 2 m. The gain ratio is calculated only for time segments for which two similarity conditions between both sensors are fulfilled: the coherency is greater than 0.98 and the cross-correlation is greater than 0.8.

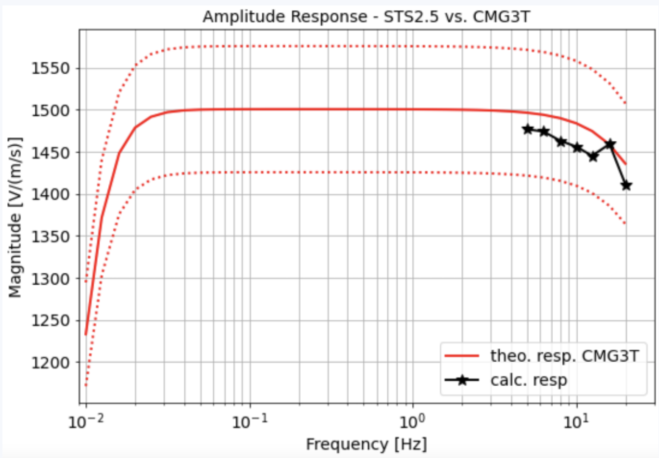
In comparison with the theoretical response of the sensor given by the manufacturer, the estimated response shows a good fit with less than 5% deviation of the theoretical value (upper plots). Obvious features are the significant fall-off at frequencies greater than 8 Hz, and the overall shift to smaller values, which needs further analysis.

Experiments were conducted with seismic stimuli created using a portable electrodynamic seismic vibrator source, and simple hammer blows on the ground. Using the seismic vibrator source single frequency (18 Hz) or sweep signals (10-100 Hz) of 10 s in length could be excited. A first analysis shows that the response at the higher frequencies (>10 Hz) can be determined using the signals from the excitation experiment (lower plots).









The study is also considering the possibility of using a single calibrated sensor to derive the responses of all sensors within an array, as there are two similarly calibrated seismometers (GS13) installed at a distance of 1400 m from one another. Initial results indicate that this may be feasible for frequencies up to about 1 Hz.

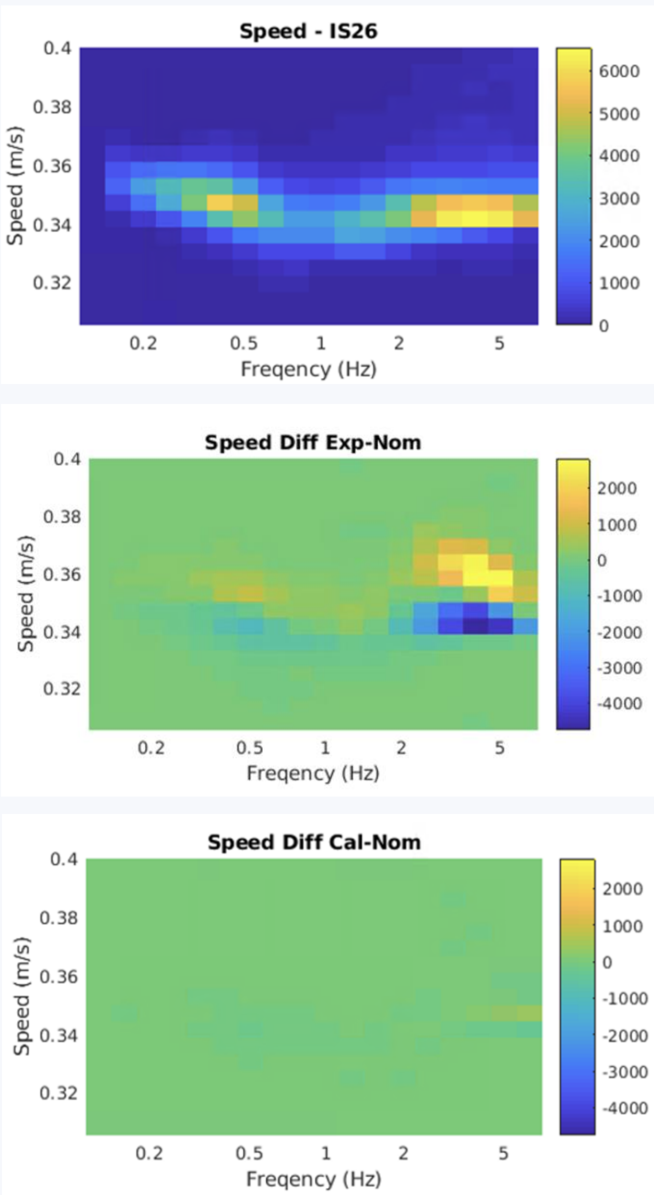
The next steps in the study will consider the horizontal component data as well as the phase in the response estimation process, a comparison between all installed calibrated sensors, and an integration of other relevant parts such as pre-amplifiers and data-loggers in the on-site calibration procedures.

THE USE OF IN-SITU CALIBRATION FOR THE MONITORING AND CORRECTION OF DETECTOR DEFECTS

A challenge of atmospheric infrasound measurements is the wind-generated turbulent noise. One method to reduce this noise is to use a pipe-array Wind-Noise Reduction System (WNRS). This system samples the pressure field over an array that is large compared to the size of the turbulent eddies (noise), but small compared to the wavelength of the infrasound in the frequency band of interest (0.01-4 Hz). Therefore, the wind-noise is effectively averaged out, while the signal remains largely unaffected.

Although these systems work quite well, when defects are present, such as blocked inlets or flooded pipes, the infrasound response of the system can be affected, resulting in errors in the observed signal. A method to calibrate and monitor the status of these systems is by use of a co-located reference sensor, which is directly open to the atmosphere (without WNRS). Then by determining the ratio of the detector-under-test (DUT) to the reference for times when the two signals are highly coherent, we are able to use the Gabrielson method to determine the response of the DUT. This procedure is currently used to monitor the status of the detectors, but we will show that it can also be used to correct signal, such that the proper wave parameters (back azimuth and trace velocity) can be retrieved.

A temporary WNRS was installed at the same location as the H5 element at IS26, Germany. Several different defects were introduced to this temporary system, such that we could compare the measurements of different defective systems against that of the normally operating H5 element. By determining the response of the DUT, removing this response from the observed signal, we are able to retrieve the correct signal. The example results below are for a system with 24 out of the 32 inlets blocked with rubber stoppers.



The top panel shows the speed histogram as a function of the frequency using the normal IS26 array. The second panel is the difference of the speed histogram between the defective system and the normally operating one. There is an observed increase in the velocity at high frequency due to the change of the detector response caused by the defects. When we correct the signal, the results shown in the third panel are obtained, which is the difference between the corrected, defective system, and the normally operating one. To better see the improvement, the scale was set to the same as the second panel. There is almost no difference from the normally operating detector, demonstrating that the signal was properly corrected using the calibration results.

The in-situ calibration has been demonstrated to allow for the correction of signals when defects are present. This means that, when there are defects detected in the detectors, but they cannot be fixed right away, this procedure could be used to correct the signals, and retrieve the correct wave parameters. This could reduce the loss of detections, and improve measurement accuracy when defective detectors are identified.

Figures: Speed-frequency histograms. Top panel is using the normally operating IS26 element, the middle and bottom panels are the differences of the defective system and the corrected defective system, respectively, from the (top) nominal system .

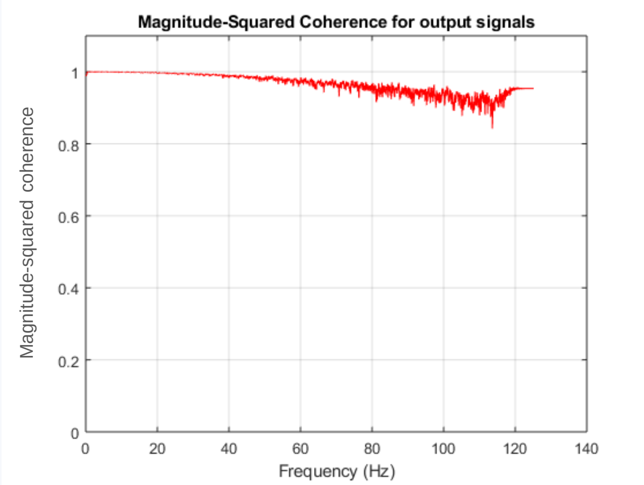
IN-SITU CALIBRATION OF DEEP OCEAN HYDROACOUSTIC SENSORS

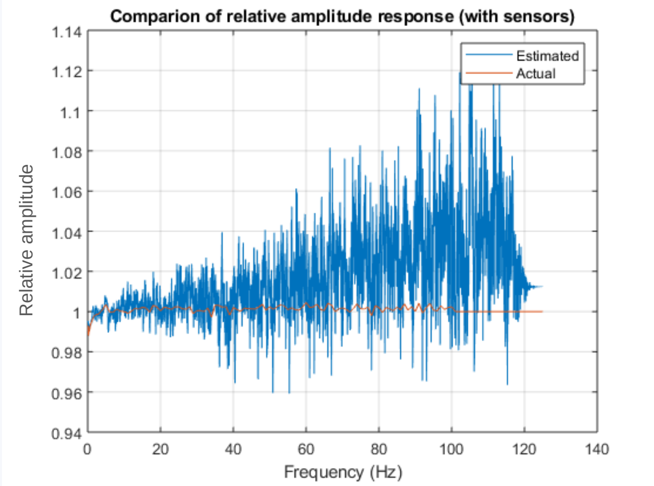
The objective of the study is to understand the extent to which a mixture of anthropogenic and natural sources of sound can be used for the in-situ calibration of the hydroacoustic sensors within the International Monitoring System of the CTBTO. For this purpose, the Gabrielson method this time applied to the calibration of hydrophones, is under examination, using data recorded by two sensors that are essentially co-located. Simulated data is being used to investigate the extent to which that method can be applied in the context of deep ocean hydroacoustic sensors. Another aspect is to propose an approach to evaluate the uncertainty associated with the calibration of one sensor considering the other sensor as a reference sensor for which calibration information, comprising a frequency response with associated uncertainties, is available.

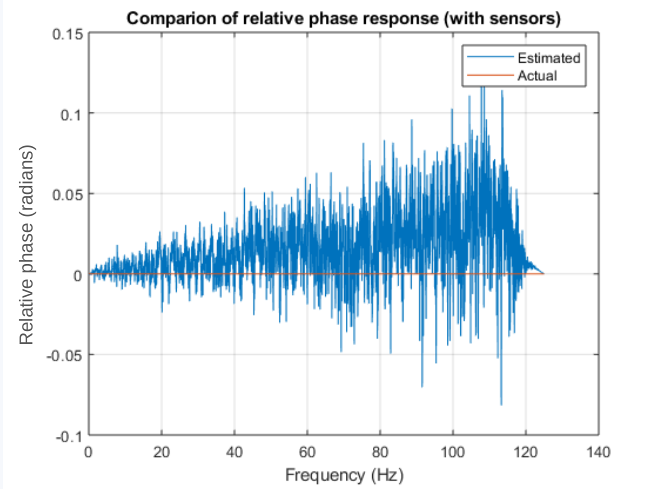
A sound field is simulated in a way that is deterministic, in the sense that it is known what the sound field is at any location, but appears random to the sensors, arising as the superposition of many different sources of sound. The sound field has the property that the coherence between the field at two locations decreases with increasing distance between the locations. We consider two steps in the data processing of the simulated signals recorded by the sensors. The first is to evaluate the magnitude-squared coherence function between the signals. It is a function of frequency and measures on a scale from zero to one frequency-domain correlation between the two signals. The second is to evaluate the relative amplitude and relative phase responses for the two sensors for comparison with the known responses used for the simulation of the signals.

The figures show some indicative results for the case of 100 sources of sound moving at the surface within a square 10 km × 10 km region with the sensors at a depth of 2 km and separated by 1 m. The top figure shows that the coherence of the signals recorded by the sensors is strong across the interval of frequencies, and the middle and lower figures show that the relative amplitude and phase responses are close to their actual values. However, the degree of agreement with the actual values rapidly decreases as the separation between the sensors increases, and for a separation of 10 m the coherence is consistently low, and the quality of the estimates of the relative amplitude and relative phase responses is consistently poor.

So far, the study has been limited to simulations as the opportunity for a sea trial is outside of the available project resources. However, should a co-operative opportunity arise to gather data from







ocean measurements, the team is ready to take it. Nevertheless, a specialised pressure vessel is available at NPL that enables measurements of hydrophones to be made under simulated ocean conditions, which will be used to gain some practical experience in operating the Gabrielson-type calibration in a pseudo-realistic environment. Ultimately this collection of studies will help to inform the design of schemes for the in-situ calibration of the hydroacoustic sensors, e.g. within the International Monitoring System of the CTBTO.

STAKEHOLDER ENGAGEMENT

CONFERENCES & WORKSHOPS

As the project enters its concluding stages, there is increasing activity in ensuring that the outputs are disseminated widely and effectively. These outputs include the provision of new calibration capabilities, input to standardisation, scientific publications and appearance at national and international meetings and conferences. The full list of publications and other useful resources can be found on the project website, and with an open access policy, all of the material is readily available.

Below are details of two events worthy of note.

INFRA-AUV at EGU2023

The Infra-AUV project has made significant progress in developing metrology solutions and calibration capabilities for the range of geophysical applications utilising infrasound, seismic and hydroacoustic technologies. These developments will be presented in an invited presentation, and in more detail through a series of poster presentations covering the full scope of the project - from laboratory developments to case studies in the field.

EGU2023, 23-28 April 2023 in Vienna

SnT 2023,19-23 June at the prestigious Hofburg Palace, Vienna.

INFRA-AUV WORKSHOP at CTBTO SnT

A key stakeholder for the research and development work undertaken in the Infra-AUV project is the CTBTO. Indeed, CTBTO's needs for new measurement standards to covering the operation of the International Monitoring System was a strong driver for the project.

A workshop is therefore being planning to run alongside the CTBTO Science and Technology Conference SnT 2023. Aimed at station operators, the workshop will illustrate the benefits of good calibration practices and show how traceability for on-site calibration of sensor systems can be achieved, and how knowledge of measurement uncertainty can lead to enhanced quality assurance and data reliability.

The workshop will be free to attend. Further details will be made available through the project website. Alternatively, anyone interested in attending can contact the Project Coordinator.

TEAM MEMBER 'BUSINESS CARD'

Laboratoire National de Métrologie et d'Essais

By developing new measurement techniques and methods and applying them via appropriate standards in all spheres of daily life, LNE plays a key role in promoting a more competitive economy and a safer society. This core activity covers eight key spheres – research and technology transfer, testing and calibration, technical assistance, certification, training and informing – and addresses the eight major priorities: safety and health, environmental impact, performance, product reliability, and cost control.

Set up in 1901 to provide services to industry, LNE was initially part of the CNAM technology and research institute. Under a 1978 consumer protection law it became a state-owned enterprise, attached to the French Ministry of Industry. As a reference laboratory, LNE is responsible for helping society to evolve and advance. Its mission is to improve the competitiveness of companies while respecting stringent requirements on consumer safety, public health, environmental protection, and energy management. In 2005 the Laboratory was entrusted with coordinating the French metrology network and representing it in an international context.

Through its mission of dissemination of metrological standards to the society and industry, the LNE Acoustic & Vibration department daily provides calibration, testing, legal metrology and certification services. LNE's research on Acoustic & Vibration is heavily oriented to improving calibration methods, including low frequency calibration, by working around 3 axes: Experimentation, signal processing and acoustic modelling. LNE data science and uncertainty department provides statistical methods, tools and training sessions for data analysis and evaluation of measurement uncertainties. Participating to more than ten European research projects its members develop and adapt measurement uncertainty methods to a various range of applications, from infrasound to medical imaging or nanoparticles characterization. Since 2017, the activities of the department have been extended to the understanding and use of deep learning algorithm and their use in metrology. The synergy between our core capability makes LNE a strong partner to achieve the goals of the Infra-AUV project.

lne.fr

TÜBİTAK Türkiye Bilimsel Ve Teknolojik Araştirma Kurumu

Established in 1972 and located at the Gebze Campus in the City of Kocaeli, TÜBİTAK Marmara Research Center (MAM) aims at becoming a world leading science and technology provider with its research, development and innovation capabilities in energy, climate change and sustainability, materials and life sciences.

With its customer-oriented approach, TÜBİTAK MAM offers original solutions to public, private and military agencies and institutions. These solutions are materialized through basic and applied R&D, technology transfer, innovation, system and facility construction, national standard and norm setting, professional consulting and training activities.

TÜBİTAK Marmara Research Center Materials Technologies Underwater Acoustic Laboratory (UAL) is a Designated Institute in the field of underwater acoustics. It has been established to develop the critical SONAR technologies in the field of underwater acoustic, as a work package of "National Sonar Wet-End Production and Integration Project for MİLGEM Programme". The laboratory offers unique infrastructure in Turkey to carry out research and development, production, test and characterization activities in the field of underwater electroacoustic transducers. The main infrastructure is the acoustically isolated open test tank of 15 m x 10 m x 7.5 m dimensions, fitted with a high accuracy positioning system in order to position the various sensors and sensor arrays of 100 kg and 3000 kg weight. The primary and secondary level calibration of electroacoustic transducers in the frequency range 2 – 120 kHz in open tank is accredited to ISO 17025 by TÜRKAK, the Turkish accreditation body. The laboratory is extending calibration capabilities up to about 500 kHz. The laboratory also carries out research projects to model, design, prototype and characterize various underwater electro-acoustic transducers and arrays.

UAL was the coordinator of UNAC-LOW Project, to develop calibration methods for the calibration of hydrophones and noise recorders in the frequency from 20 Hz up to 1 kHz. As part of the Infra-AUV project, UAL is now working on the development of primary and secondary calibration methods for the calibration of hydrophones down to 1 Hz.

tubitak.gov.tr

Hottinger Brüel and Kjær

Hottinger Brüel & Kjær, HBK, provides a complete portfolio of technologies that cover the entire test and measurement life cycle across every domain. While sensor hardware and DAQs remain at the heart of our offering, we also provide state-of-the-art data management software and analysis software, as well as simulation software and hardware.

HBK is the world's leading supplier of primary and secondary microphone and accelerometer calibration systems, laboratory standard microphones and reference accelerometers.

HBK-DPLA, the Danish Primary Laboratory of Acoustics, is responsible for development and dissemination of the Danish national measurement standards for sound pressure in confined air (pressure sensitivity) and vibration. HBK-DPLA is a Designated Institute in the decentralized Danish as a separate entity to ensure independent operation. HBK-DPLA conducts research in its fields of calibration, such as sound fields in couplers, calibration measurement techniques, and the influence of base material in vibration exciters. It is HBK-DPLA that is the actual partner in Infra-AUV.

HBK-DPLA co-operates with Danish Fundamental Metrology, DFM, in selected research fields and in drafting international standards for microphone calibration.

HBK-DPLA's main role in the Infra-AUV project is to extend our primary calibration capabilities towards lower frequencies, 40 mHz for microphones and 10 mHz for seismic accelerometers. The capabilities will be confirmed though comparison between the partners, and HBK-DPLA will pilot the comparison of seismic accelerometer calibrations.

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