

Activity Report

CCAUV/15-November

Underwater Sound Reference Division, United States/ Underwater Acoustic Metrology

Introduction

The Underwater Sound Reference Division (USRD) is the organization sanctioned by the National Institute of Standards and Technology (NIST) to provide traceable underwater acoustic transducer and hydrophone calibrations for the U.S. Navy, industry, research, and education. Initially conceived as the U.S. Navy's primary laboratory for the measurement of underwater sound during WWII, the USRD continues to maintain a principal role in the numerous and varied facets of underwater acoustic measurement, calibration and testing. As a government organization, the USRD mission is to ensure the accuracy of acoustic measurements throughout USRD facilities, measurement methodology, and transducer standards. The USRD provides access to measurement facilities and a wide range of calibrated transducer types within the United States. The USRD maintains a complex of six measurement facilities that provide a broad range of frequencies, temperatures, and hydrostatic pressures. The USRD also maintains an inventory of calibrated underwater transducers and reference standards that can be used to verify acoustic measurements at different facilities. Reference transducers and acoustic sources are updated and modernized as new technologies emerge. The USRD is located in Newport, Rhode Island and continues in its original mission to provide measurement facilities, measurement methodology research, technical consulting, and calibrated transducer standards to a diverse client base.

Selected Efforts

- Round Robin (RR) transducer calibrations among USRD facilities continue to be conducted every six months (more often if required), which effectively provide a reference base among the different facilities. There are four USRD RR transducers covering various frequency ranges with quantifiable acoustic calibration under extreme environmental conditions. The last RR, along with Electroacoustic Calibration Simulator (ECS) calibrations conducted across USRD facilities were completed in June 2015. RRs are ongoing in the USRD as of the writing of this report. The ECS box continues to be circulated amongst the USRD facilities on a quarterly basis, as it provides a useful tool to maintain the same levels of the simulated transducer driving conditions across the test facilities. The ECS box employs a critical tool that separates calibration equipment uncertainties from those in the transducers themselves. The USRD continues to support the CCAUV on behalf of NIST through participation in international Key Comparisons that are relevant to its role in underwater acoustic metrology. The USRD is participating in the international Key Comparison for the calibration of hydrophones in 2016.
- The USRD is currently providing scientific and technical services related to a study funded by the U.S. Department of the Interior (DOI) Bureau of Ocean Energy Management BOEM to characterize the acoustic fields radiated by marine geophysical survey systems as a critical first step to understanding the potential impacts to marine ecosystems. The work is being performed under an interagency agreement between BOEM and the Naval Undersea Warfare

Center, Division Newport. Upon completion of the study, a comprehensive report will be available to U.S. and international audiences through the bureau's Environmental Studies Program.

- The USRD developed, and recently finalized ten U.S. Navy Metrology and Calibration (MetCal) Local Calibration Procedures (LCPs), which have all been approved by Navy MetCal, Corona Division. (See list of LCPs on the last section of this report.)
- The USRD continues to be involved in the development of measurement methodologies for the characterization of multi-layered materials at varying angles of incidence. As well, USRD researchers, in collaboration with other NUWCDIVNPT researchers, have fabricated several prototype Carbon Nanotube (CNT) underwater acoustic transducers, which were subsequently successfully calibrated in the USRD in 2013.
- The USRD is currently engaged in efforts to secure NIST National Voluntary Laboratory Accreditation Program (NVLAP) accreditation, which will in turn make the USRD accredited to ISO/IEC 17025. Plans are to secure accreditation in the summer of 2016. Upon NVLAP accreditation, the USRD will pursue consideration by NIST to be considered as a NIST Designated Institute (DI) in the area of underwater acoustic metrology.

Publications/Conferences/Chaired Committees

Crocker, S.E., "A system for self-localizing near field data processing", US Patent 9001614 (2015).

Crocker, S.E. and Smalley, R.R., "Proof of concept for the complex calibration of a digital hydrophone line array at low frequency", IEEE J. Ocean. Eng., in review (2015).

Évora, V. M. F., Crocker, S. E., and Paolero, A., "The Underwater Sound Reference DivNpt (USRD): An Overview of Capabilities, Facilities, and Recent Advances in Calibration Methods", **Invited Presentation**, 3rd International Underwater Acoustics Conference & Exhibition (UACE), Crete, Greece (2015).

Évora, V. M. F., **Session Chair**, 3rd International Underwater Acoustics Conference & Exhibition (UACE), "Underwater Acoustic Calibration, Facilities and Standards", Session 6C, Crete, Greece (2015).

Paolero, A., "The Underwater Sound Reference Division Evolution of Acoustic Transducer Calibration ", **Invited Presentation**, 2nd International Underwater Acoustics Conference & Exhibition (UACE), Rhodes, Greece (2014).

Évora, V.M.F., Paolero, A., and Ricci, V., "The Evolution of Acoustic Transducer Calibration and Evaluation of Sonar Transducers and Arrays in the Underwater Sound Reference Division (USRD)", Maritime Systems and Technology (MAST) EurAsia Conference, Istanbul, Turkey (2014).

Huang, D., "Constant beamwidth transducers: A tribute to Kim Benjamin", **Invited Keynote Speaker**, 167th Meeting of the Acoustical Society of America, J. Acoust. Soc. Am., 135 (4) Pt2, 2212, Providence, Rhode Island (2014).

Huang, D., **Session Chair**, 167th Meeting of the Acoustical Society of America: Engineering Acoustics 2pEA Session: "Transduction," Providence, Rhode Island (2014).

Crocker, S.E., Nielsen, P.L, Miller, J.H., Siderius, M., "Geoacoustic inversion of ship radiated noise in shallow water using data from a single hydrophone", J. Acoust. Soc. Am., 136, EL362 (2014).

Crocker, S.E., Nielsen, P.L, Miller, J.H., Siderius, M., "Nonlinear inversion of ship radiated noise in shallow water", Proceedings of the 2nd International Conference and Exhibition on Underwater Acoustics, 653-570 (2014).

Crocker, S.E., "Recent advances in methods for the comparison calibration of linear hydrophone arrays at low frequency", Proceedings of the 2nd International Conference and Exhibition on Underwater Acoustics, 1089-1096 (2014).

Crocker, S.E., "Measurement of complex sensitivity of data channels in a hydrophone line array at very low frequency", US Patent Application Ser. Nr. 61/984090 (2014).

Huang, D., **Session Chair**, 166th Meeting of the Acoustical Society of America: Engineering Acoustics 3pEA Session: "Non-Traditional Electro-Acoustic Transducer Design II: Contemporary Micro-Mechanical Devices," San Francisco, California (2013).

Huang, D., **Session Chair**, 166th Meeting of the Acoustical Society of America: Engineering Acoustics 5aEA Session: "Mufflers, Waveguides, Materials, and Other Topics," San Francisco, California (2013).

Huang, D. and Howarth, T., "First look: Acoustic calibration of Carbon Nanotube transducers", **Invited Keynote Speaker**, 166th Meeting of the Acoustical Society of America, J. Acoust. Soc. Am., 134 (5) Pt2, 4091, San Francisco, California (2013).

Nielsen, P.L., Siderius, M., Miller, J.H., Crocker, S.E., and Giard, J., "Seabed characterization using ambient noise and compact arrays on an autonomous underwater vehicle", POMA, 19, 0700303 (2013).

Gebbie, J., Siderius, M., Nielsen, P.L., Miller, J.H., Crocker, S.E., and Giard, J., "Small boat localization using adaptive 3-D beamforming on a tetrahedral and vertical line array", POMA, 19, 070072 (2013).

Gebbie, J., Siderius, M., Nielsen, P.L., Miller, J.H., Crocker, S.E., and Giard, J., "Small boat localization using adaptive 3-D beamforming on a tetrahedral and vertical line array".

Proceedings of the 1st International Conference and Exhibition on Underwater Acoustics, 357-362 (2013).

Crocker, S.E., "Method for calibrating a plurality of data channels in an acoustic vector sensor", US Patent 8756657 (2013).

Crocker, S.E., Casimiro, D.C., Cutler, R.F., and Smalley, R.R., "Method for the calibration of a hydrophone line array", US Patent Application Ser. Nr. 61/885769 (2013).

Crocker, S.E., Miller, J.H., Potty, G.R., Osler, J.C. and Hines, P.C., "Nonlinear inversion of acoustic scalar and vector field transfer functions", IEEE J. Ocean. Eng., 37, 589-606 (2012).

ANSI/ASA S1.20-2012 American National Standard Procedures for Calibration of Underwater Electroacoustic Transducers: Establishes measurement procedures for calibrating electroacoustic transducers and describes forms for presenting and assessing the resultant data (WG Chair R.M. Drake 2012).

Huang, D, "The Science of Measurement Uncertainty as Applied to Underwater Acoustic Measurements", sponsored at the Underwater Sound Reference Division (2011-2012).

Huang, D. and Paolero, A., "Low frequency acoustic sensor or array calibration waveguides of finite length," J. Acoust. Soc. Am. 129, 2643 (2011).

Huang, D., "Non-uniform array synthesis concept and theory", J. Acoust. Soc. Am., 127, 1981 (2010)

Huang, D., "Breazeale Legacy in Gaussian Acoustics", Dehua Huang, J. Acoust. Soc. Am., 127, 1844 (2010)

Huang, D. and Paolero, A., "Analysis models for the Underwater Sound Reference Division low-frequency acoustic calibration systems," J. Acoust. Soc. Am. 126, 2196 (2010).

USRD Local Calibration Procedures

NAVSEA LCP-NRA-001: "HYDROPHONES USING RECIPROCITY CALIBRATION IN THE OPEN TANK FACILITY." (2015)

NAVSEA LCP-NRA-002: "HYDROPHONES AND PROJECTORS USING COMPARISON REPLACEMENT CALIBRATION IN THE OPEN TANK FACILITY." (2015)

NAVSEA LCP-NRA-003: "HYDROPHONES AND PROJECTORS USING SIDE-BY-SIDE COMPARISON CALIBRATION IN THE OPEN TANK FACILITY." (2015)

NAVSEA LCP-NRA-004: "HYDROPHONES USING LF RECIPROCITY CALIBRATION."
(2015)

NAVSEA LCP-NRA-005: "HYDROPHONES AND PROJECTORS USING SIDE-BY-SIDE
COMPARISON CALIBRATION IN THE LOW-FREQUENCY FACILITY SYSTEM K."
(2015)

NAVSEA LCP-NRA-006: "HYDROPHONES USING RECIPROCITY CALIBRATION IN
THE LEESBURG TEST FACILITY." (2015)

NAVSEA LCP-NRA-007: "HYDROPHONES AND PROJECTORS USING COMPARISON
REPLACEMENT CALIBRATION IN THE LEESBURG TEST FACILITY." (2015)

NAVSEA LCP-NRA-008: "HYDROPHONES AND PROJECTORS USING SIDE-BY-SIDE
COMPARISON CALIBRATION IN THE LEESBURG TEST FACILITY." (2015)

NAVSEA LCP-NRA-009: "HYDROPHONES USING RECIPROCITY CALIBRATION IN
THE ACOUSTIC PRESSURE TANK FACILITY." (2015)

NAVSEA LCP-NRA-010: "HYDROPHONES AND PROJECTORS USING COMPARISON
REPLACEMENT CALIBRATION IN THE ACOUSTIC PRESSURE TANK FACILITY."
(2015)