Activities of the Underwater Sound Reference Division, USA: 2015-2017

Introduction:

The Underwater Sound Reference Division (USRD) is a laboratory within the research and development enterprise of the United States Navy. Conceived in the early 1940's as a defense laboratory for underwater sound, the USRD continues to maintain a principal role in underwater acoustic measurement, calibration and testing in the United States.

The USRD maintains a complex of six measurement facilities that provide a broad range of frequencies, temperatures and hydrostatic pressures representative of conditions throughout the world's oceans. It also operates a standards program for the design, manufacture and distribution of acoustical devices. In addition to the U.S. Navy, the USRD supports other government agencies, non-governmental organizations, academia and industry by providing access to its laboratory facilities and through a leasing program for calibrated acoustic reference standards and transducers. The USRD is located in Newport, Rhode Island USA and continues in its original mission to provide measurement facilities, measurement methodology research, technical consulting and calibrated reference standards to a diverse client base.

Project Briefs:

NIST and USRD are coordinating to complete the process required to assign USRD as the NIST Designated Institute (DI) for sound in water. In support of that objective, USRD has updated its quality management system (QMS) for compliance with ISO/IEC 17025 as it prepares for accreditation under the National Voluntary Laboratory Accreditation Program (NVLAP). In addition, USRD has undertaken studies to update and/or develop uncertainty budgets for transducer calibrations performed under the proposed scope of accreditation.

The USRD participated in Key Comparison CCAUV.W-K2. Primary calibrations of two commercial hydrophones were performed using three-transducer spherical wave reciprocity over the frequency range of 250 Hz to 500 kHz. Measurement results and uncertainty budgets were provided to the pilot laboratory (National Physical Laboratory, UK) in 2016.

The USRD has recently completed a study to implement a complex, primary calibration for hydrophones at frequencies ranging from 1 Hz to 2 kHz. The calibration method employed a reciprocity coupler; a closed cavity in which the requirements of acoustical reciprocity can be realized. The combined, expanded uncertainties for magnitude and phase at 1 Hz were 0.1 dB and 1°, respectively. Results of the study were recently published in Metrologia.

The USRD completed a study on behalf of the U.S. Department of the Interior (DOI), Bureau of Ocean Energy Management (BOEM) to characterize the acoustic fields radiated by high-resolution marine geophysical survey systems to better understand the potential impacts to marine ecosystems. Detailed acoustical characterizations were performed for 18 different marine geophysical survey systems operated by the United States Geological Survey (USGS) in waters of the U.S. Exclusive Economic Zone (EEZ). A technical report documenting the study was published on the BOEM Environmental Studies Program (ESP) Information System (https://www.boem.gov/Environmental-Studies-EnvData/). A manuscript was also submitted for publication in the IEEE Journal of Oceanic Engineering.

The USRD completed a project to develop complex calibration methods for the hydrophones installed in line arrays. Efficient methods were developed to simultaneously measure the magnitude and phase response of hundreds of digital acoustical data channels in a line array at low frequency. Results of the study were published in the IEEE Journal of Oceanic Engineering.

USRD personnel provided ongoing technical support for Navy environmental stewardship programs. In particular, USRD has provided measurement standards, technical consulting and field support for biologists working to understand the impact of certain anthropomorphic noise sources to marine ecosystems. Project results have been published in refereed journals, book chapters and abstract compilations.

The USRD supports the academic and professional development of scientists and engineers through mentoring, sponsorship and service on academic committees at several colleges and universities. Recently graduated students have earned one Ph.D. and one M.S. degree in Ocean Engineering and two M.S. degrees in Engineering Acoustics. USRD is currently providing mentorship and support to another eight students pursuing graduate degrees in science and engineering. In addition, USRD hosts Summer Faculty Fellows from various U.S. universities to support research and development programs in underwater acoustic transduction.

The USRD provides test and calibration services for approximately 80 U.S. and international clients each year. In many cases, USRD provides customers with direct access to USRD measurement facilities to witness tests and calibrations of their devices.

The USRD Transducer Standards program maintains an inventory of 600 calibrated acoustic reference standards and transducers for use in USRD facilities and distribution through its leasing program. The USRD leases 350-400 devices to about 100 U.S. and international clients each year.

Select Publications in Underwater Sound: 2008-2017

Slater, W., Crocker, S.E., and Baker, S., "A primary method for the complex calibration of a hydrophone from 1 Hz to 2 kHz," *Metrologia*, in press (2017) doi: 10.1088/1681-7575/aa87f7

Crocker, S.E., Fratantonio, F.D., Hart, P.E., Foster, D., O'Brien, T.F., and Labak, S., "Characteristics of the acoustic fields radiated by certain high-resolution marine geophysical survey systems," *IEEE J. Ocean. Eng.*, in review (2017)

Iafrate, J.D., Watwood, S., Reyier, E.A., Scheidt, D.M., Dossot, G., Crocker, S.E., "Effects of pile driving on the residency and movement of tagged reef fish," *PLoS ONE,* 11(11): e0163638, (2016) doi: 10.1371/journal.pone.0163638.

Iafrate, J.D., Watwood, S.L., Reyier, E.A., Gilchrest, M., and Crocker, S.E., "Residency of Reef Fish During Pile Driving within a Shallow Pierside Environment," *Adv. Exp. Med. Bio.*, 875, pp. 479-487 (2016) doi: 10.1007/978-1-4939-2981-8_58.

Crocker, S.E. and Smalley, R.R., "Calibration of a digital hydrophone line array at low frequency," *IEEE J. Ocean. Eng.*, 44, pp.1020-1027 (2016) doi: 10.1109/JOE.2016.2527118.

Iafrate, J.D., Watwood, S.L., Reyier, E.A., Gilchrest, M., and Crocker, S.E., "Residency of Reef Fish During Pile Driving within a Shallow Pierside Environment," *in The Effects of Noise on Aquatic Life II*, pp. 479-487 (2016) doi: 10.1007/978-1-4939-2981-8_58.

Crocker, S.E., “Primary calibration of hydrophones in the frequency range of 250 Hz to 500 kHz using three-transducer spherical wave reciprocity,” NUWC-NPT Technical Report 12217 (2016) [Online] http://www.dtic.mil/docs/citations/AD1017650

Crocker, S.E. and Fratantonio, F.D., “Characteristics of sounds emitted during high-resolution marine geophysical surveys,” Bureau of Ocean Energy Management Report 2016-044 (2016) [Online] http://www.data.boem.gov/PI/PDFImages/ESPIS/5/5551.pdf

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) doi: 10.1121/1.4898739

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) doi: 10.1121/1.4800573

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) doi: 10.1121/1.4800565

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, pp. 589-606 (2012) doi: 10.1109/JOE.2012.2206852

Piquet, J.C. and McLaughlin, E.A., “The use of real or complex coupling coefficients for lossy piezoelectric materials,” *IEEE Trans. Ultrasonics, Ferroelectrics and Frequency Control*, 56, pp. 821-826 (2009) doi: 10.1109/TUFFC.2009.1105

Forsythe,S.E., Leinhos, H.A., Bandyopadhyay, P.R., “Dolphin-inspired combined maneuvering and pinging for short-distance echolocation,” *J. Acoust. Soc. Am.*, 124, EL225 (2008) doi: 10.1121/1.2960936