AN AUTOMATED REAL-TIME VESSEL SOUND MEASUREMENT SYSTEM FOR CALCULATING MONOPOLE SOURCE LEVELS USING A MODIFIED VERSION OF ANSI/ASA S12.64-2009

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1 Introduction

Underwater noise from vessels permeates many of the world's oceans. While vessel sound emissions are at levels typically below those that would be acutely injurious to marine fauna, this noise can interfere with normal use of sounds, such as for prey and predator detection, socialization and mate attraction. Exposures to vessel noise over extended times, especially in key habitat areas, is likely to lead to chronic adverse effects including reduced feeding efficiency and difficulty finding mates.

Assessments of the effects of shipping noise on marine fauna often use acoustic propagation models to predict the levels of sound exposure. These models require accurate vessel sound emission source levels. American National Standards Institute (ANSI) standard S12.64-2009 (reaffirmed in 2014) describes procedures for measuring underwater sound from ships. The standard deals with radiated noise level (RNL) source levels that assume 20 Log(r) transmission loss (TL) between the vessel positions and the measurement hydrophones. That approach does not account for interference from surface and seabed reflections. Most acoustic models directly account for these effects, and therefore require monopole source levels (MSL). MSL assumes all acoustic energy originates at a single point in the water, at a specified depth.

Few fully systematic measurements of source levels of large commercial vessels are available. A few recent studies have published source levels obtained from large numbers of vessel passes, but those measurements are typically partly opportunistic, with hydrophones in shallow water or located several kilometers distance from the vessel paths. Also, most of the existing published measurements report RNL but not MSL.

The Strait of Georgia Underwater Listening Station (ULS) and JASCO Applied Science's PortListen™ processing software were designed to obtain systematic measurements of large numbers of vessels in relatively deep water (173 m). The system reports RNL measurements in approximate conformance with ANSI/ASA S12.64 (2009) Grade-A processing but with Grade-C geometry and noting only single vessel passes are acquired per transit. MSL calculations are made similarly but with a modified back-propagation method.

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2 Methods

2.1 Acoustic Monitoring Equipment

Two seabed-mounted tetrahedral arrays, each with 4 calibrated GeoSpectrum M-15 hydrophones, at 1.5 m separation (Figure 1) and a calibrated GeoSpectrum projector, are deployed on Ocean Network Canada (ONC)'s Strait of Georgia East Node. The arrays are separated by approximately 43 m. All 8 hydrophones are sampled at 64 kHz (24-bit) by JASCO AMAR-G3 recorders. Synchronized data are streamed to shore in near real-time (5-minute files) via the VENUS undersea network.

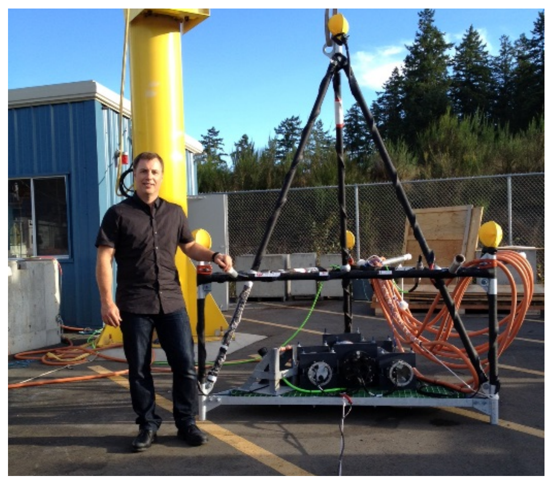

Figure 1. One of two tetrahedral hydrophone arrays comprising the Underwater Listening Station (ULS).

The systems were deployed on September 21, 2015.All components remain fully functional and in-calibration as of August 1, 2016.

2.2 Location, Vessel Paths and Tracking

The ULS is deployed on the seabed in 173 m depth, along the northbound shipping route, approximately 30 km southwest of Vancouver BC. Vessels are tracked with a dedicated Automatic Identification System (AIS) deployed on-shore near the ULS. Vessel pilots are requested to sail vessels through a measurement transit area, consisting of an entrance funnel, measurement zone and exit zone (Figure 2). This approach ensures that the vessels are not turning or accelerating during the measurement. The measurement zone (shaded region in Figure 2) allows closest point of approaches (CPA)'s from 250-550 m.

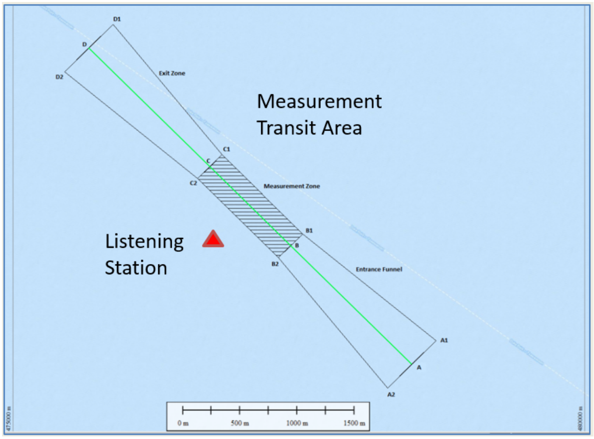

Figure 2. ULS and Vessel Measurement Transit area.

2.3 Source Level Calculation Software System

Acoustic data and AIS data are processed automatically in real-time by the JASCO Applied Science's PortListen™ software. The system uses a combination of AIS and acoustic tracking to extract a data window, defined by the time period over which the vessel's acoustic centre is within ±30° of the CPA. It then processes a single acoustic channel in 1 second time periods stepped in ½ second intervals (to allow 50% overlap of Hanning time windowing prior to fft's).

The software applies the ANSI/ASA S12.64 Grade-A method for back-propagation distance: it determines instantaneous vessel range (R) each 1-second time step through the data window. The RNL back propagation of 20 Log(R) is applied to the band levels of each step. MSL back-propagation is performed each second with predictions from Parabolic Equation model RAM, modified to treat shear wave reflection losses up to 5 kHz, and an image reflectivity model at higher frequencies. MSL back-propagation requires a source depth, which we define as a Gaussian distribution centred at the shaft depth minus 0.7 of the propeller radius, when that information is available, or half the vessel draft otherwise.

The software calculates background noise in each frequency band when the vessel is more than 2 km away. The measured source band levels are accepted only if they exceed the background levels by 10 dB or more. The levels are corrected if they exceed background by 3-10 dB, and they are rejected if they are less than 3 dB above background.

3 Results and Discussion

The ULS made 846 vessel measurements of vessel passes with CPA's between 250-550 m between September 21, 2015 and July 31, 2016. Of these 304 were accepted after automatic and manual review, 249 were rejected, and 293 have not yet been reviewed. The system processes a larger set of CPA's, from 100-1000 m. There were 1623 measurements over this larger range, of which 524 were accepted, 511 rejected, and 588 not yet checked.

3.1 Vessel Noise Directivity

The system produces 1/3-octave band levels in 1 second steps through the duration of the ±30° data window. Directivity features, such as higher high-frequency levels post-CPA than pre-CPA, are apparent in many of the measurements. The system likely can produce more direction-dependent emissions information than S12.64-2009 defines.

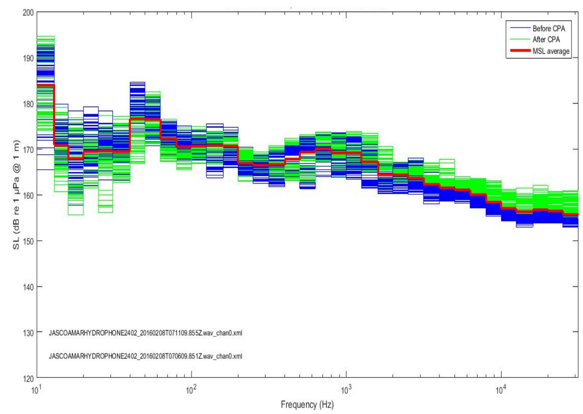

Figure 3. 1/3-octave MSL each second through the duration of the ±30° data window.

3.2 MSL Versus RNL

MSL's in 1/3-octave bands are generally greater than RNL at low frequencies (< ~100 Hz), asymptotically tending to RNL–3 dB at high frequency. Lower RNL at low frequencies is due to destructive interference from the sea-surface reflection that is not accounted for by 20 log(R) back-propagation. Higher RNL at high frequencies is due to the incoherent contribution of surface-reflected energy. A typical vessel measurement example from PortListen™, showing both MSL and RNL, is given in Figure 4.

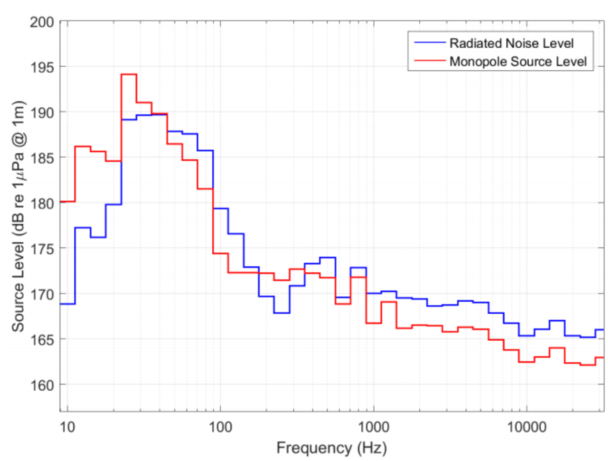

Figure 4. MSL (red) and RNL (blue) 1/3-octave band source levels measured by the ULS.

A large database of systematic source level measurements has been compiled. Analysis of these data is just starting.