Analysis of the Variability of Ship Acoustic Signatures Measured as a Function of Hydrophone Configuration

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1 Introduction

Maritime transport is the main anthropogenic source of noise in the very low frequencies. For conservation purposes, it is critically important to improve understanding of noise pollution and its impact on marine life in order to implement mitigation and regulation programs. The Marine Acoustic Research Station (MARS) project (`www.projet-mars.ca/en`) is dedicated to understanding and measuring the underwater noise radiated by ships and to proposing appropriate mitigation measures to reduce it. Measuring underwater noise emitted by ships is a complex task that is strongly influenced by measurement conditions [1, 2]. The american standard ANSI/ASA S12/64-2009 [3] describes a protocol developed to standardize methods for measuring and calculating underwater noise emitted by ships. However, it is often not possible to comply with its many restrictions, and any modification is likely to add uncertainty to the final measurement [4]. The MARS station is an acoustic measuring station deployed each year in the Laurentian Channel, designed to measure the acoustic signatures of ships as closely as possible to the standard [3]. An experiment was carried out, using the R/V Coriolis II, collecting 113 repeated measurements of its acoustic signature. An analysis of the variability of the measurements with speed, distance from the hydrophones and configuration of the hydrophones highlighted the importance of complying with the measurement protocol to perform an accurate measurement of ship's emitted sound. This study provides qualitative and quantitative insights on the uncertainties associated to the measurement of an acoustic signature, depending on the conditions of the measurement.

2 Method

2.1 Acoustics data : MARS station

The acoustic data comes from the MARS station, which consists of four moorings (E1, E2, W1 and W2) located near the St. Lawrence Seaway off Rimouski (figure 1). These four moorings have been deployed alongside the westward shipping lane, two on the port side (E1 and E2) and the other two on the starboard side (W1 and W2). The E1 array did not comply with the standard due to a deployment problem, these data could not be used.

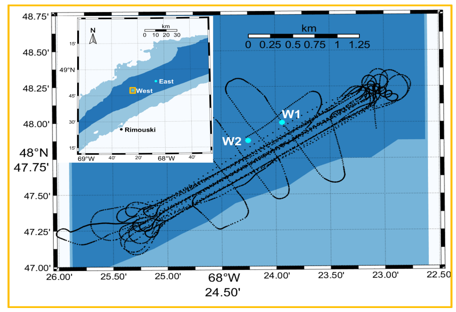

Figure 1: Study area. The locations of the MARS station arrays are specified. Two arrays are located to the east to measure signatures on the port side and two to the west to measure signatures on the starboard side. The zoomed-in area shows an example of the Coriolis II passing over the western array at different distances.

The station is located in a strategic zone for measuring the noise of ships travelling on the St. Lawrence seaway. Each mooring consists of a three hydrophones vertical arrays, at depths of 80, 173 and 300 m. The depths were chosen so that when a vessel passes at 300 m of an array, the angle of measurement of each hydrophone coincides with that recommended by the standard (15°,30° and 45° respectively). The station has been deployed using R/V Coriolis II for the ice-free months of 2021 and 2022.

2.2 R/V Coriolis II repeated measurements

During the arrays deployment and recovery missions, the R/V Coriolis II carried out repeated passages in front of the MARS hydrophone arrays, following the recommendations described in the standard [3]. Each passage was made following a straight line at a specified distance from the arrays, while maintaining constant navigation conditions. The resulting dataset comprises 113 passages, at 200, 300 and 400 m from each array, and at speeds of 2, 6, 8, 10, 12 and 14 knots.

2.3 Data Analysis

For each passage of the R/V Coriolis II, a monopole source level (MSL) spectrum was calculated for each hydrophone, a byproduct of the measurement of acoustic signatures automatically performed as one of the main deliverable of the MARS project. The MSL metric treats the ship's source sound level at 1 m, taking into accounts multiple paths by applying a precise propagation model Between Ship's stern and the measuring hydrophone [5]. In this study, we used MSL spectra on third-octave bands from 20 to 500 Hz. From the MSL spectra calculated for each hydrophone of an array a

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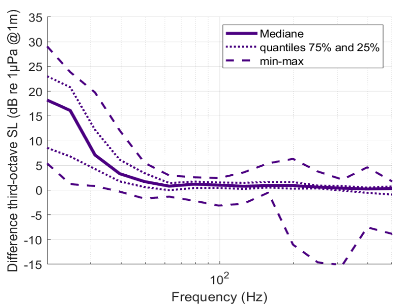
MSL spectrum can be built for the array, as the average power of the three hydrophones.

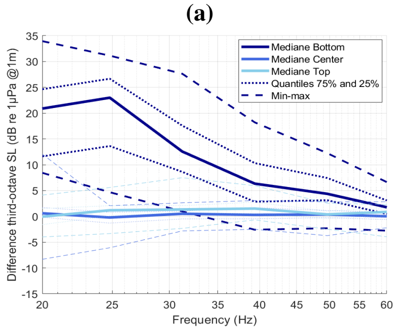
Comparative analyses can be made of the noise spectra emitted by the hydrophones and the array signatures. Given that the Coriolis made passes in front of the two western arrays under the same operating conditions, it is possible to see the uncertainties in the method by comparing the signatures obtained by the two arrays.

3 Results

The R/V Coriolis II made a total of 113 passes in front of three MARS arrays (E2, W1 and W2). This analysis focused on 27 runs, recorded simultaneously by arrays W1 and W2, therefore collecting data in identical operating conditions (i.e. with identical distance to closest point (dCPA) and speed). We analyzed the difference between the signatures of the two arrays (2a), and the difference between the spectrum acquired by each pair of hydrophones at similar depth (i.e top, center and bottom hydrophones of each arrays) (2b).



(a)



(b)

Figure 2: (a) Median, quartiles, and extrema of the difference between the signatures collected by the arrays W1 and W2, and (b) detail of the difference between the spectrum collected by each pair of hydrophones of similar depth (i.e., W1 top – W2 top, W1 center – W2 center and W1 bottom – W2 bottom), with a zoom on the low frequencies (20 – 60 Hz).

The difference between the signatures provided by W1 and W2 is below 1 dB in the 50 – 500 Hz frequency range. However, there is a clear bias in the low frequencies (20 – 50 Hz), W1 measuring up to 18 dB more than W2 (figure 2a). A similar analysis on each pair of hydrophones of similar depths shows that the bias is generated by measurement differences between the bottom hydrophones only, W1 bottom measuring up to 23 dB more than W2 bottom while the difference between the center and top pairs of hydrophones is below 1 dB on the whole spectrum (figure 2b).

4 Discussion and conclusion

On the 27 compared signatures collected by the arrays W1 and W2, we identified a clear bias at low frequencies (20 – 50 Hz) between the two bottom hydrophones that affects the acoustic signatures and needs to be addressed. Such difference could be caused by higher level of self-noise generated by the bottom part of the W1 mooring. We will also investigate how our sound propagation model would be affected by an error in the mooring localization, that could result in systematic over or under estimation of the low frequencies near the bottom.

Description and quantification of uncertainties in the measurement of acoustic signatures is a necessary task, to allow comparison of measurements taken in different locations and by different acoustic recording stations. This preliminary study highlights the very satisfying agreement (< 1 dB) on the 50 – 500 Hz frequency range between the 27 pairs of signatures compared. A measurement bias was detected from one of the bottom hydrophones at low frequencies (20 – 50 Hz). Further analysis to identify its cause is currently in progress to improve knowledge of our mesurements uncertainties and provide ways to mitigate errors.

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