Identification of Sources and Their Directivity in the Global Underwater Radiated Noise from a Merchant Ship

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1 Introduction

Global marine traffic is intensifying and generates noise with potential adverse effects on marine species. Traffic noise indeed contributes to continuous anthropogenic noise, known to affect communication, echolocation and stress levels, impacting marine animal behaviour, social life and nutrition. To limit the effects of marine traffic on the environment, traffic noise must be reduced in the entire ocean. The current standard (ANSI/ASA S12/64-2009, [1]) models a ship's acoustic signature as a single, punctual and omnidirectional source. However, the noise sources under consideration, like engines and propellers, are actually spatially distributed over the ship's dimensions. This work aims to identify individual noise sources and establish their directivity pattern in order to better understand and model underwater noise radiated by ships.

The MARS (Marine Acoustic Research Station, https://www.projet-mars.ca/) is specifically designed to measure individual ships' acoustic signatures according to the current standard [1], including in its optimal configuration four vertical three-hydrophone arrays at 80 m, 173 m and 300 m. It is deployed in the St. Lawrence Estuary (Eastern Canada), in 350 m deep water, along the commercial shipping lane in order to have minimal impact on ships' route when their acoustic signature is measured.

2 Method

In this study, the same cargo/passenger ship was measured in the station with three passages with different speeds: 4.9 $m.s^{-1}$ (9.5 knots), 7.1 $m.s^{-1}$ (13.8 knots) and 7.4 $m.s^{-1}$ (14.3 knots). The slowest ship speed was sampled on starboard, and the two other ship speeds were sampled on port side. The underwater radiated noise was sampled from different listening angles (Figure 2). From these three passages, azimuthal maps are built for specific frequency peaks to represent the underwater radiated noise and the variation of the source level on the listening angles. The directivity of the specific frequency peaks is shown by the azimuthal maps.

The acoustic signature (Figure 1) of a ship passing through the station is measured from the recorded noise of the ship, averaged on angles ranging from 60° to 120° (Figure 2) following the method presented in [2] . The ship is considered as a punctual acoustic source. A propagation model is used to account for propagation loss and establish the emitted noise level at 1 m from the source (SL in dB *re* $1\mu Pa^2 .Hz^{-1} .m^{-1}$).

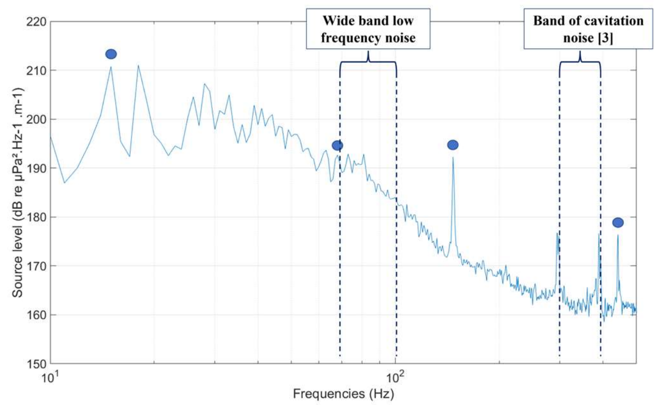

Figure 1 : 1 Hz resolution spectrum of the ship passage 14.3 knots). Blue points illustrate the chosen wide bands low frequency of cavitation noise.

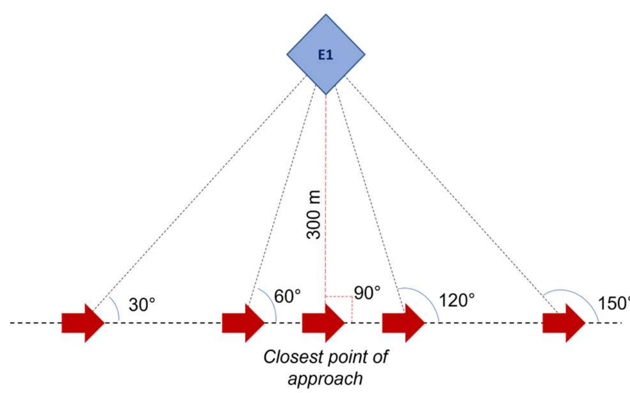

Figure 2 : Listening angle method of the passing ship in the MARS station. Red arrows illustrate the ship direction.

The source level narrow-band spectra (1 Hz resolution), created to establish the acoustic signature, is used here to analyse the frequency content of the underwater radiated noise (URN) and identify features such as frequency peaks corresponding to machinery and wide band low frequency noise typical of cavitation (Figure 1) [3]. For the frequency peaks of the machinery, noise level is averaged on a 10 Hz frequency band centered on peak frequency. For the wide band

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low frequency noise, characterising cavitation noise, noise level is averaged on the 70 – 105 Hz and 340 – 360 Hz bands [3].URN is measured from a wide range of angles, from 30° (bow) to 150 ° (stern) on port side (respectively 330° to 210° on starboard), as the ship passes through the station (Figure 2). Each identified frequency band of interest is then analysed individually. A directivity map is built, representing the emitted noise level for a varying emission angle (Figure 4).

3 Results

We analysed the noise emitted by the ship during the passage at 7.4 m.s^{-1} and recorded from the hydrophone located at 173 m depth. Analysis of two spectra of the emitted noise level at 30° and 150° makes it possible to identify frequency bands where differences between noise level radiated towards the bow and stern of the ship are slightly directive (Figure 3).

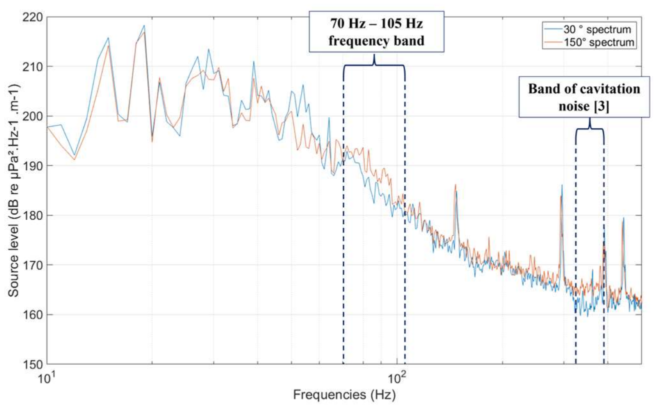

Figure 3 : 1 Hz resolution spectra of the source level (dB re 1µPa .Hz^{-1}.m^{-1}) emitted towards 30° and 150° for the passage at 7.4 m.s^{-1} (14.3 knots).

The 70 Hz – 105 Hz and the 340 Hz – 360 Hz bands in particular present a slightly offset. The corresponding wide bands noise has been identified in the literature as generated by cavitation of the propeller [3]. The directivity pattern (Figure 4) shows higher noise level emitted towards angles ranging from 90° to 140°. Such directivity pattern is consistent with the literature, noise radiated from the propeller area towards the front of the ship being masked by the hull.

Further analysis of this frequency band, using the remaining hydrophones of the antenna will be done, making it possible to complete the directivity pattern in the vertical dimension. Analysis of the noise emitted by the same ship during other passages at different speed and from both starboard and port side will allow to complete the directivity map. A catalogue of directivity patterns will be built for each identified frequency of interest, providing meaningful information to identify clusters of sounds based on their directivity and clues about their location and mechanical properties.

This method will be applied to the fleet being currently measured in the framework of the MARS project (34 vessels in 2021, ~150 per year expected in 2022 and 2023), representative of the merchant fleet. Knowledge of sources directi

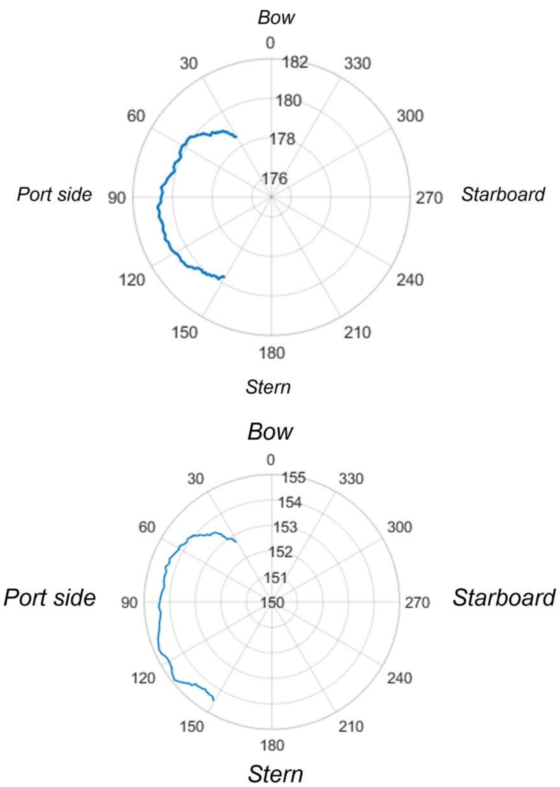

Figure 4 : Directivity patterns of the 70 Hz – 105 Hz and the 340 Hz – 360 Hz [3] frequency bands (dB re 1µPa² .Hz^{-1} m^{-1}) at 7.4 m.s^{-1} (14.3 knots).

-vity at various frequencies will allow the improvement of ships URN models and better assessment of the impact of shipping on the marine environment. Also, source directivity will improve the understanding of ship detection by cetaceans and therefore the prevention of collision risk.

Acknowledgments

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References

[1] ANSI/ASA S12.64-2009/Part 1 (R2019). Quantities and procedures for description and measurement of underwater sound from ships - part 1: General requirements. 2019.

[2] Simard, Y., Roy, N., Gervaise, C., et Giard, S. Analysis and modeling of 255 source levels of merchant ships from an acoustic observatory along St. Lawrence Seaway. *J Acoust Soc Am*, 140:143, 2002-2018.

[3] P. T. Arveson et D. J. Vendittis. Radiated noise characteristics of a modern cargo ship. *J Acoust Soc Am*, 118:129, 2000.