The MARS Project: Identifying and Reducing Underwater Noise from Ships in the St. Lawrence Estuary

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1 Introduction

The Marine Acoustics Research Station (MARS) is an applied research project dedicated to understanding the underwater noise radiated by ships and proposing efficient methods or actions for its reduction. This project relies on the design and operation of world-class instrumentation deployed in the St. Lawrence Estuary, offshore of Rimouski (Québec, Canada). Two measurements systems are here developed and combined: the URNS station (Underwater Radiated Noise Signatures) and the OBAVSI system (On-Board Acoustic and Vibratory Sources Identification).

2 The URNS station

The URNS platform consists of four vertical arrays of three hydrophones. A picture and a schematic view are provided in upper and lower parts of Figure 1, respectively. The geometry of the arrays makes it possible to implement measurements in accordance with the ANSI/ASA S12/64-2009 standard [1] for precise and efficient measurement of radiated underwater noise. The four arrays are used to form two port / starboard measurement points, both separated by 8 km and moored closely to the two shipping lanes of the St. Lawrence off Rimouski. Each port / starboard measurement point includes two arrays separated by less than 1 km. Such configuration for acoustic signature measurements allows that (1) candidate ships are not required to significantly deviate from their routes, and (2) a ship's signature on both port and starboard is evaluated from a single passage.

The antennas are energy self-sufficient and can communicate their data in nearly real time. They are launched and recovered from ISMER-UQAR Coriolis II vessel, and typically operated from May to November. In addition to recording the candidate ship's signatures, they continuously acquire ambient noise created by all traffic, as well as geophony and biophony to provide a complete picture of the soundscape of the St. Lawrence Estuary. All the results obtained are compared to existing databases of St. Lawrence seaway [2].

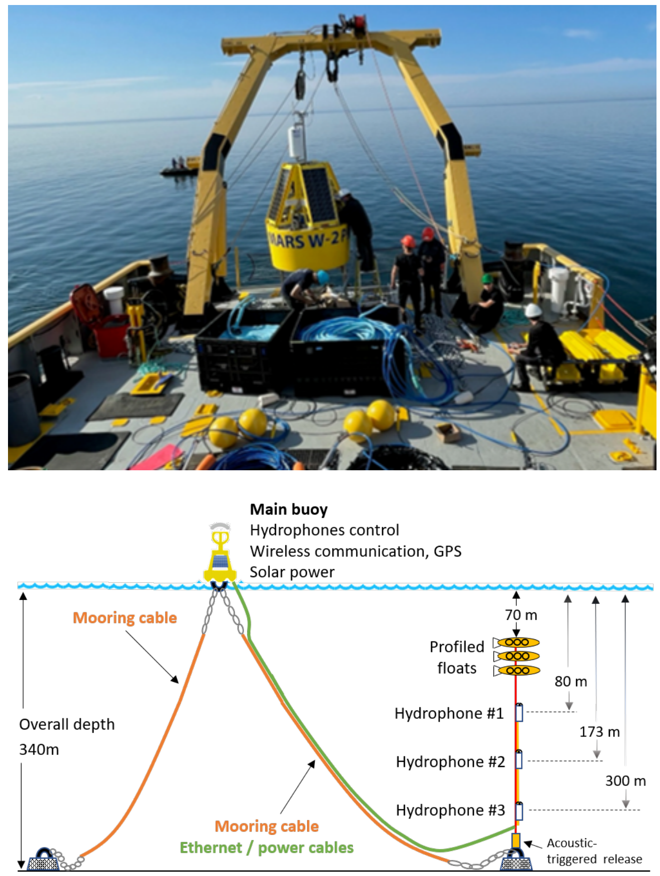

Figure 1: Upper part - A picture of one of the buoys before its deployment from ISMER Coriolis II vessel. Lower part - Description of the common configuration of each of the four individual buoys.

3 The OBAVSI equipment

The OBAVSI equipment (On-Board Acoustics and Vibratory Source identification) consists of a set of tachometers, microphones and accelerometers deployed in parallel at strategic locations on ships to identify and rank vibroacoustic sources that contribute to underwater noise (that is mainly sources related to machinery and propulsion, including cavitation). A first part of the work is mostly dedicated to machinery noise (engines, gears), with the aim of identifying internal sources and paths of transmission from the sources to outside the ship. A second part of the network is focused on the detection of cavitation from an array of accelerometers positioned near the propeller but inside the ship. Indeed, the modulation at the blade passing is due to the variation of cavitation noise generated by each passing blade, and can be identified using techniques like Detection of Envelope Modulation On Noise (DEMON) [3]. To allow flexible and convenient measurements and data storage, a specific equipment has been designed and

∗Presenter, on behalf of the whole team - olivier.robin@usherbrooke.ca built (Figure 2). This system was designed to be operated very easily (a simple start/stop button), and can handle up to six Integrated Electronics Piezo-Electric (IEPE) sensors like accelerometers and microphones. It is based on a Raspberry Pi small single-board computer on which 3 two-channel data acquisition cards (Measurement Computing MCC 172) are stacked. This card features analog-to-digital 24-bit converters with a maximum sample rate of 51.2 kS/s/Ch. The calibration, acquisition and storage of signal is based on a Python^{TM} code. Measurements are automatically stored for monitoring, which can last up to one month.

Figure 2: Picture of the current OBAVSI equipment, an autonomous 6-channel recorder.

4 An example of what brings URNS + OBAVSI

Figure 3 provides a typical example of how results can be gathered and compared. It is meant to be a general example, and therefore the investigated ship is kept anonymous. Using height and color codes, the level and contribution of vibration components to radiated noise are depicted in the upper part of Figure 3. The peak-normalized height of the peak is between 0 (minimum) and 1 (maximum) as compared with other measurement points. The color indicates if the contribution to radiated noise is limited, average or important. The upper part of Figure 3 has to be put into perspective with the mid part of Figure 3 (corresponding vibration power spectral density) and the lower part of Figure 3 (corresponding underwater noise power spectral density). The vibration and acoustic spectra are calculated for synchronized time frames.

It is apparent from Figure 3 that combining information taken onboard on ships and by the station makes it possible to link the most problematic underwater noises to their actual sources in ships (identification and ranking). The combination of URNS and OBAVSI ensures a quality diagnosis over a wide range of operating conditions, that can be varied when passing through the URNS station. Making informed decisions is eased, and so the most efficient noise mitigation actions can be proposed to each ship. This makes it possible to adopt a pragmatic approach for the solutions proposed for noise reduction, and to maximize their environmental impact.

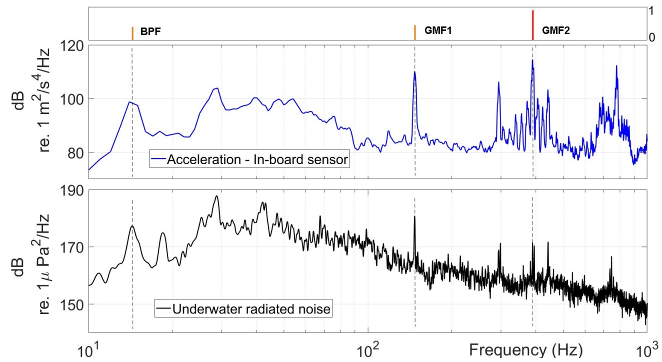

Figure 3: Example for an accelerometer located close to a ship's stern. Upper part - Importance and contribution of notable and identified frequencies (BPF: Blade passing frequency; GMF: Gear mesh frequency). Mid part - Onboard measurement result using OBAVSI, given in terms of acceleration power spectral density - Lower part - Measurement results for radiated underwater noise at URNS (spectra are calculated for the same time frame - the dotted black vertical lines identify the notable vibrational frequencies of the main sources on board).

5 Perspectives

This short paper presented the main components of the MARS project, a unique instrumentation system, that started in early 2021. While the project implementation has been slowed by the COVID pandemic, 38 signatures were measured for 34 participating ships during year 2021. The three main goals for the following years are to (1) enlarge the number of measured signatures (up to 150 per year), (2) improve post-processing of inboard and underwater measurements, and (3) propose optimal noise mitigation actions that could be taken on voluntary ships and to test before-and-after configurations.

Acknowledgments

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