31st International Congress on Sound and Vibration

6 Sun - 11 Fri, July 2025
ICSV31
Incheon, Korea
31st International Congress
on Sound and Vibration
The annual congress of the International Institute of Acoustics and Vibration (IIAV)

NOISE EMITTED BY A CRUISE SHIP DURING DOCKING: MEASUREMENTS USING AN ACOUSTIC CAMERA

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Cruise ships are complex systems that generate significant noise, even during docking operations, where continuous activities such as supply replenishment, maintenance, and operation of systems (e.g., electrical, HVAC, sanitary water) take place. This noise affects both the onboard environment and the surrounding areas. In this study, noise emissions from a newly manufactured cruise ship were investigated during its final docking phase at the shipyard. Onboard noise levels were measured using sound level meters, identifying key zones of interest. Concurrently, an acoustic camera was employed to assess noise propagation in the harbor environment. By applying beamforming algorithms, noise spectra from the selected zones were analyzed and compared to the onboard measurements. The results showed strong agreement between the two methods, validating the acoustic camera as a robust tool for quantitative noise analysis. Additionally, the acoustic camera proved advantageous in scenarios where traditional sound pressure level measurements are limited by the scale and complexity of the subject, such as large ships and dispersed noise sources. This highlights its value in marine noise studies and its potential for broader applications in similar challenging environments.

Keywords: Cruise ship noise, beamforming, environmental noise monitoring, shipyard acoustics, marine noise emissions

1. Introduction

The impact of airborne noise generated by ships has become an increasingly prominent concern in the maritime sector, particularly in the case of large cruise ships and, more generally, passenger vessels [1-3]. As a general assumption, ship noise emissions can be broadly categorized into three main classes: airborne noise, structure-borne noise, and underwater radiated noise. The first two affect the internal areas of the ship, impacting both crew and passengers, while the latter concerns the external underwater environment, with significant effects on marine fauna [4-9]. Even when stationary during docking, cruise ships emit continuous broadband noise due to auxiliary systems such as HVAC units, generators, and maintenance operations, potentially affecting both onboard environments and nearby communities.

Conventional noise measurement methods, relying on single-point microphones, frequently fall short when attempting to identify and spatially resolve the diverse and distributed sources of noise typical of such large-scale vessels. On the other hand, ports serve as vital nodes in global maritime transport, yet they are also significant contributors to urban noise pollution, particularly in coastal cities where residential zones often lie in close proximity to port infrastructure.

In recent years, shipbuilders and operators have been under growing pressure to address airborne noise pollution from ships, especially in inhabited coastal areas. Airborne noise, which originates from sources such as ventilation and air conditioning systems, engine exhausts, and machinery outlets, indeed, impacts not only the crew and passengers hosted onboard but also the surrounding areas (third parties), particularly in coastal regions near ports [10-11].

In response to these challenges, recent years have seen significant advancements in noise prediction models and mitigation technologies. Classification societies, including Lloyd's Register [12], Registro Italiano Navale [13], American Bureau of Shipping [14], Det Norske Veritas [15], and Korean Register [16], have introduced new standards and class notations aimed at regulating and monitoring acoustic emissions. These regulations emphasize the importance of incorporating noise control measures early in the ship design process to meet evolving requirements and minimize environmental impact.

However, despite improvements in modeling techniques, discrepancies between predicted and actual noise levels persist. As a result, accurate measurement campaigns and continuous refinement of predictive tools are crucial for developing reliable acoustic digital twin models of ships.

In recent years, the deployment of acoustic camera technology has gained momentum as a robust and non-intrusive method for assessing environmental noise. A novel methodology based on acoustic imaging was proposed in [17], which demonstrated the utility of beamforming-based techniques for characterizing complex port noise scenarios, enabling the spatial discrimination of sources that are otherwise inseparable using traditional instrumentation. Building on this framework, subsequent studies applied acoustic cameras in situ to port environments: in Genoa, ship docking operations were monitored, and key source mechanisms were identified [18]; in Nice, an investigation of a Ro-Pax ferry highlighted the prominence of HVAC and mechanical ramp noise during loading and unloading [19]; and in Livorno, dynamic measurements of cargo ship pass-by underscored the prevalence of low-frequency emissions and the importance of synchronized multi-array configurations [20].

This study contributes to this evolving body of work by presenting a case study on a newly constructed cruise ship during its final dockside testing phase. Using an outdoor-calibrated acoustic camera array, noise sources were localized and spectrally analyzed from a distance, demonstrating the feasibility of spatially-resolved noise mapping under real operational conditions. The results aim to support future mitigation strategies and regulatory guidelines for maritime acoustic emissions.

2. Methodology

The measurement campaign was conducted at a shipyard during the final docking phase of a newly manufactured cruise ship. The primary objective was to assess the ship's noise emissions during auxiliary operations while docked, using both conventional sound level measurements and advanced acoustic imaging techniques. The pressure levels recorded by the Acoustic Camera (AC) were compared, at certain frequencies, with histograms of noise sources measured on the ship's port side. This comparison aims to verify whether the area of maximum pressure level identified by the AC corresponds to the location where the highest noise levels are measured on board. To achieve this, the frequencies showing pressure peaks are analyzed, their exact positions are determined, and whether the color map generated by the AC aligns with the distribution of onboard noise measurements is verified.

2.1 Instrumentation and Setup

Noise propagation in the harbor environment was assessed using an Acoustic Camera (AC) system consisting of a Star48 AC Pro microphone array (gfai tech GmbH, 2019), integrated with a 48-channel data acquisition unit (mcdRec) and a personal computer equipped with NoiseImage software for real-time processing and post-analysis. Key technical specifications of the system include:

- Sampling frequency: 48 kHz
- Operational frequency range: 66 Hz – 13 kHz
- Calibration: Factory-calibrated according to certified standards
- Array resolution: Determined by the Half-Power Beamwidth (HPBW) criterion, varying with source frequency and distance

The system is optimized for broadband sources rather than single-frequency emitters. As an example of spatial resolution, two incoherent sources at 1 kHz can be distinguished at a 10-meter separation, while sources at 5 kHz can be resolved at approximately 1 meter, assuming an observation distance of 150 meters.

During the campaign, the acoustic array was positioned at a distance ranging from 170 to 250 meters, ensuring a field of view encompassing the full extent of the ship’s hull and operational zones. The system orientation was adjusted to maximize the visibility of potential sound sources (see Fig.1).

Figure 1: Site location.

2.2 Data Acquisition and Post-Processing

Acoustic data were recorded continuously in 1-minute intervals during docking. The data were subsequently processed using the NoiseImage software (gfai tech, 2021). The analysis followed a multi-step procedure:

- General Acoustic Imaging: Time-averaged Acoustic Photos (APs) were generated using beamforming algorithms applied to signal segments of at least 10 seconds in duration.
- Source Localization: The dominant noise sources were identified through visual inspection of the APs, represented by chromatic maps that highlighted areas of maximum sound pressure level.
- Spectral Analysis: Specific acoustic regions of interest were isolated within the APs. For each, the frequency spectrum of the perceived noise was computed, enabling a detailed characterization of the source mechanisms.

This methodology allowed for the identification, localization, and spectral analysis of the primary noise sources associated with dockside operations.

3. Results

For an initial validation of the measurements obtained with the Acoustic Camera (AC), a comparison was carried out, at selected frequencies, between the data acquired by the AC and the measurements taken on board. Specifically, data recorded on the ship's port side were extracted from the measurement database. For each selected frequency, the location of the noisiest source on the ship was identified to verify any overlap in the noise directionality (as indicated by both the AC and the onboard measurements). As an example, the comparison at 500 Hz is shown here.

As shown in Fig. 2, the AC identifies the most significant noise source at the position marked by the pointer and the color map, corresponding to approximately 220 meters from the AC antenna location, with a sound pressure level of around 28.2 dB.

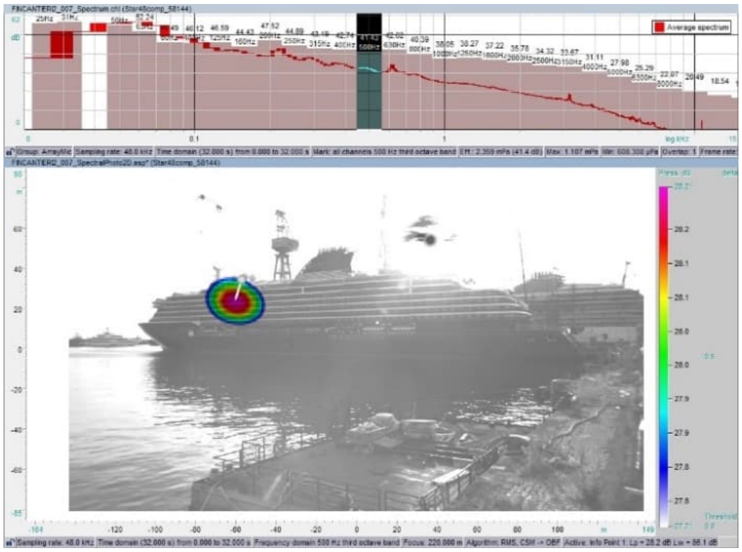

Figure 2: 500 Hz AC results

The onboard measurements taken along the ship’s port side, as shown for that frequency in Fig. 3, highlight four distinct noise sources (represented by red and orange bars): three related to ventilation systems and one related to air conditioning. Among the most intense sources, two (red bars) are located in the same area highlighted by the AC measurement.

By propagating the onboard measured pressure levels over the 220 m distance and summing them, a resulting sound pressure level of 28.2 dB is obtained at the location of the AC. It should be noted that the onboard measurements were not carried out in real time with respect to the AC measurements. This may explain why the noisiest source identified onboard was not detected by the AC—it may have been turned off during the AC measurement session. Comparisons are shown in Fig.4.

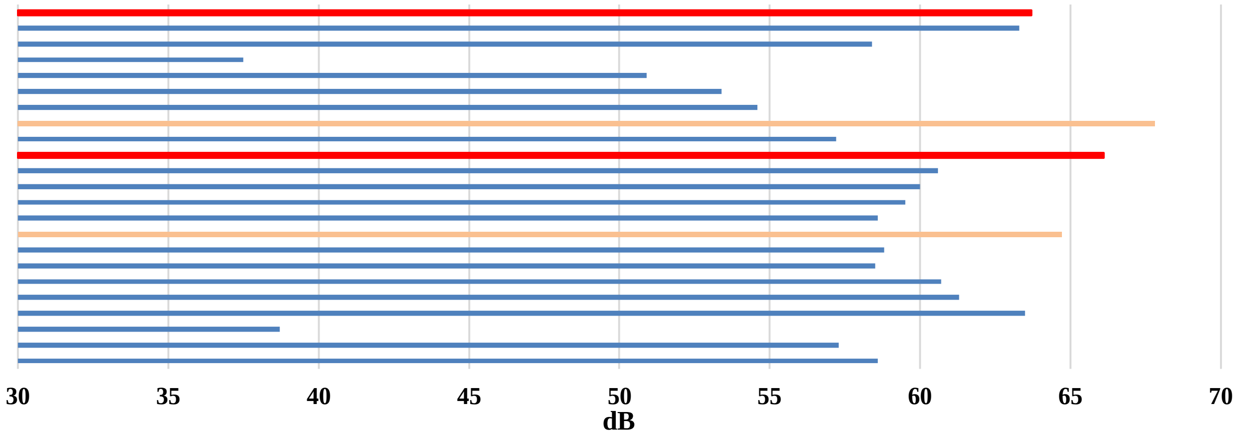

Figure 3: Experimental data for 500 Hz

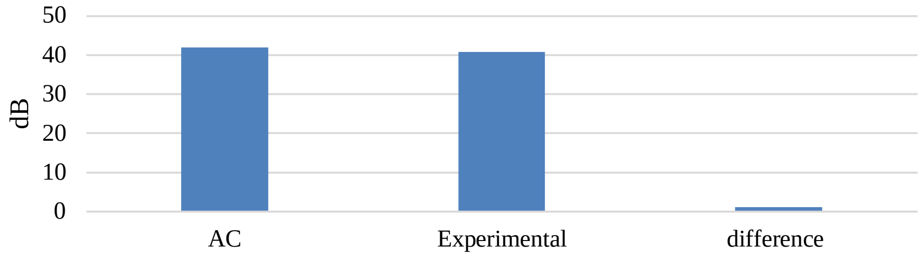

Figure 4: Comparisons at 500 Hz

For the 200 Hz data, the images extracted with the AC refer to pressure and power data reported in Table 1 at a distance of 170 m. As regards the on-board measurements, at 200 Hz, of the 3 noisiest sources identified (2 ventilation and 1 air conditioning), 2 are located exactly in the area highlighted by the AC, see Fig. 5 and Fig. 6. Carrying out the same procedure reported for the 500 Hz, a pressure level of 40.7 dB is obtained (therefore, also in this case, a maximum error of 1.2 dB). C

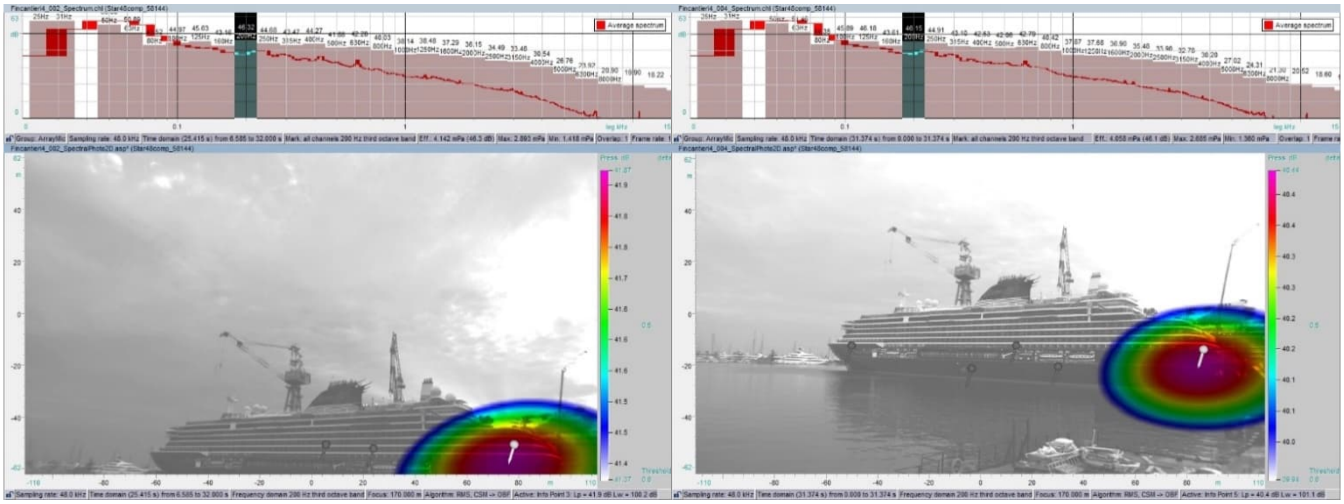

Figure 5: 200 Hz AC result

Table 1: 200 Hz.

Pressure (dB)	Power (dB)
41.9	100.2
40.4	101.1

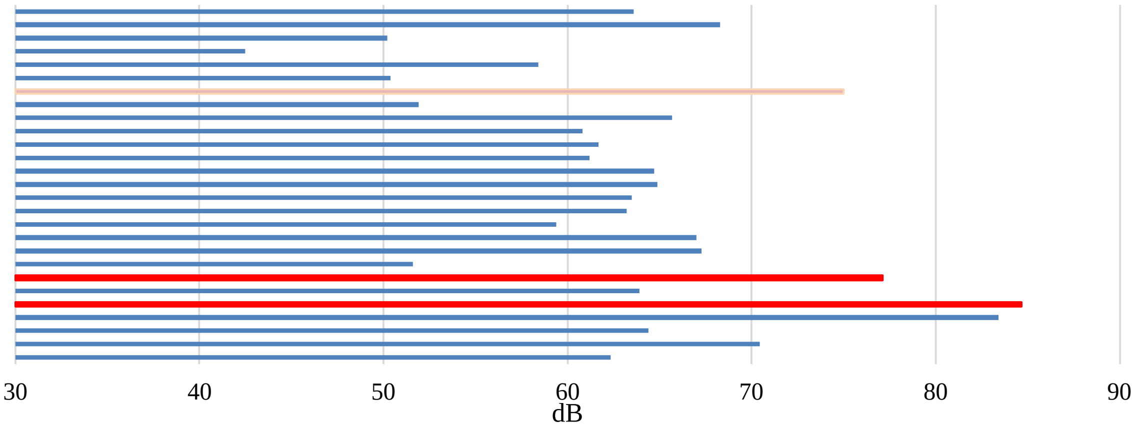

Figure 6: Experimental data for 200 Hz

4. Discussion and conclusions

In this study, the noise emissions from a newly constructed cruise ship during its final docking phase were investigated using both traditional sound level measurements and advanced acoustic camera technology. The primary objective was to assess noise propagation in the harbor environment and validate the performance of the acoustic camera in identifying and spatially resolving noise sources from large, complex systems like cruise ships.

The acoustic camera proved particularly effective in mapping the complex acoustic field around a large-scale structure such as a cruise ship, where spatial constraints and source multiplicity may limit traditional measurement approaches.The ability of the acoustic camera to resolve and quantify noise emissions from multiple sources simultaneously provides a significant improvement over traditional methods, which often fail to isolate or spatially distinguish individual sources in large, dynamic environments like ships.

REFERENCES

1. Biot, M., Borelli, D., Gaggero, T., Lembo, E., Mocerino, L., Rognoni, G., ... & Viscardi, M. (2024). Quantification of airborne noise emitted by ships based on class notation. *Ocean Engineering*, 296, 117085.
2. Bernardini, M., Fredianelli, L., Nastasi, M., Del Pizzo, L. G., Fidecaro, F., & Licitra, G. (2024). Variability in airborne noise emissions of container ships approaching ports. *Ocean Engineering*, 309, 118492.
3. Badino, A., Borelli, D., Gaggero, T., Rizzuto, E., & Schenone, C. (2016). Airborne noise emissions from ships: Experimental characterization of the source and propagation over land. *Applied Acoustics*, 104, 158-171.

4. Altosole, M., Donnarumma, S., Spagnolo, V., & Vignolo, S. (2022). Performance simulation of marine cycloidal propellers: a both theoretical and heuristic approach. *Journal of Marine Science and Engineering*, 10(4), 505.
5. Andersson, C., Johansson, A. T., Genell, A., & Winroth, J. (2024). Fully electric ship propulsion reduces airborne noise but not underwater noise. *Ocean Engineering*, 302, 117616.
6. Coppola, T., De Lorenzo, F., & Mocerino, L. (2019). The irradiated noise underwater by the ships: A state of the art. *Nautical and Maritime Culture, from the Past to the Future*, 90-97.
7. Nastasi, M., Fredianelli, L., Bernardini, M., Teti, L., Fidecaro, F., & Licitra, G. (2020). Parameters affecting noise emitted by ships moving in port areas. *Sustainability*, 12(20), 8742.
8. Traverso, F., Gaggero, T., Rizzuto, E., & Trucco, A. (2015, May). Spectral analysis of the underwater acoustic noise radiated by ships with controllable pitch propellers. In *OCEANS 2015-Genova* (pp. 1-6). IEEE.
9. Zhu, C., Gaggero, T., Makris, N. C., & Ratilal, P. (2022). Underwater sound characteristics of a ship with controllable pitch propeller. *Journal of Marine Science and Engineering*, 10(3), 328.
10. Borelli, D., Gaggero, T., Rizzuto, E., & Schenone, C. (2015). Measurements of airborne noise emitted by a ship at quay. In *ICSV22* (pp. 1-8).
11. Mocerino, L., Quaranta, F., Viscardi, M., & Rizzuto, E. (2021). Airborne noise emissions from marine vessels: An analysis based on measurements in port. In *Maritime Technology and Engineering 5 Volume 1* (pp. 349-355). CRC Press.
12. Lloyd’s Register. (2019). Design and Construction Additional Design and Construction, Procedure for the Determination of Airborne Noise Emissions from Marine Vessels. Lloyd’s Register Group Limited.
13. Registro Italiano Navale (RINA). (2021). Noise Emissions in Port Area Out-Board and Inboard, Part F, Ch 6, Section 04 (updated at July 2024).
14. American Bureau of Shipping (ABS). (2022). Guide for the Classification Notation – Underwater Noise and External Airborne Noise. ABS.
15. Det Norske Veritas (DNV). (2019). Part 6, Ch 7, Section 8 External Airborne Noise Emission – Quiet. DNV.
16. Korean Register. (2023). Guidance for External Airborne Noise from Ships. Korean Register.
17. Bocanegra, J. A., Borelli, D., Gaggero, T., Rizzuto, E. and Schenone, C. A Novel Approach to Port Noise Characterization Using an Acoustic Camera, *Science of The Total Environment*, 808, 151903, (2022).
18. Bocanegra, J. A., Borelli, D. and Schenone, C. Acoustic Camera Ship Noise Measurements During Docking Operations: A Case Study in Genoa, Proceedings of the 28th International Congress on Sound and Vibration, Singapore, 24–28 July, (2022).
19. Bocanegra, J. A., Borelli, D., Pallavidino, E. and Schenone, C. Noise Sources Evaluation of a Ro-Pax Ship by Means of an Acoustic Camera: A Case Study in the French City of Nice, Proceedings of the 29th International Congress on Sound and Vibration, Prague, Czech Republic, 9–13 July, (2023).
20. Bocanegra, J. A., Borelli, D., Pallavidino, E., Schenone, C., Fredianelli, L., Artuso, F. and Licitra, G. Acoustic Cameras Measurements of Moving Cargo Ships in the Port of Livorno, Proceedings of the 30th International Congress on Sound and Vibration, Amsterdam, Netherlands, 8–11 July, (2024).