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Sound Intensity Measurements for Identifying Dominant Transmission Paths in Shipboard Partition Walls

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Onboard airborne sound insulation measurements were carried out on a multi-deck offshore vessel comprising accommodation and public spaces to investigate the acoustic behaviour of partition walls with spatially varying sound transmission characteristics. While conventional sound insulation measurements provide a single-number index, they offer limited insight into the physical transmission mechanisms governing the result. Therefore, sound intensity measurements were applied as a complementary diagnostic method.

The study focuses on two representative partition wall configurations: a long, lightweight cabin-to-cabin partition without sanitary units and a public space-to-cabin separation incorporating ventilation inlet and outlet elements. Sound intensity measurements were performed using a Microflown Scan & Paint 3D system, allowing spatially resolved mapping of sound energy flow through the separating structures.

The results show that, for long partition walls with limited structural stiffness, sound transmission is dominated by panel vibration over a large surface area rather than by localized defects. In contrast, for partitions connected to public spaces, the dominant transmission paths were found to be concentrated around ventilation elements, indicating locally dominant weak points despite otherwise adequate partition wall construction.

The measurements demonstrate how sound intensity techniques can effectively distinguish between globally radiating partition wall behaviour and locally leaking elements, which cannot be resolved using standardized insulation indices alone. The findings underline the importance of structural stiffness and detailing of service penetrations, such as ventilation inlets and outlets, in onboard acoustic design.

This work illustrates the added value of 3D sound intensity measurements for diagnosing sound transmission mechanisms in complex shipboard environments and supports their use for targeted design optimization and verification in shipboard acoustics.

1 Introduction

Ensuring adequate airborne sound insulation between accommodation spaces is an important aspect of acoustic comfort on board modern offshore vessels [1]. Cabins, corridors and public areas are often located in close proximity within lightweight structural arrangements, which makes effective control of sound transmission a challenging design task. In such environments, sound insulation performance is influenced not only by the basic construction of partition walls (hereafter referred to as partitions) but also by structural stiffness, connections between elements, and service penetrations such as ventilation systems.

Standardized airborne sound insulation measurements, typically expressed through single-number ratings such as the weighted apparent sound reduction index (R'_W), are commonly used to assess the acoustic performance of separating structures [2]. While these indices provide a convenient measure for verification purposes, they offer limited insight into the underlying physical mechanisms governing sound transmission. In practice, measured insulation performance may be influenced by distributed wall vibration, flanking transmission, or localized leakage paths, which cannot easily be distinguished using conventional measurement methods alone. This works tries to explain some of the uncertainties found in R'_W measurements as reported in [4].

To better understand the dominant transmission mechanisms, spatially resolved diagnostic techniques can be applied. Sound intensity measurements allow the mapping of sound energy flow through surfaces and structural elements, enabling the identification of areas where sound radiation or leakage is concentrated. Such methods provide valuable information for distinguishing between globally radiating panels and locally dominant weak points, thereby supporting targeted design improvements and troubleshooting in complex environments [4].

This paper presents a case study in which 3D sound intensity measurements were applied onboard a multi-deck offshore vessel comprising accommodation and public spaces. The study focuses on two representative partition configurations: a long cabin-to-cabin partition wall with limited structural stiffness and a public space-to-cabin separation incorporating ventilation components. By combining conventional airborne sound insulation measurements with spatially resolved 3D sound intensity measurements, the dominant transmission paths through these structures are identified.

The aim of this work is to demonstrate the added value of 3D sound intensity measurements as a diagnostic tool for understanding sound transmission mechanisms in shipboard partition walls and to illustrate how the resulting data can support acoustic design and verification in marine applications.

2 Measurement methodology

To investigate the sound transmission behaviour of the investigated partition configurations, a combination of conventional sound insulation measurements and 3D sound intensity measurements was applied. The standardized airborne sound insulation measurements provide an overall assessment of the acoustic separation between spaces, expressed through the apparent sound reduction index. However, these measurements alone do not reveal the physical transmission mechanisms responsible for the observed performance.

Therefore, 3D sound intensity measurements were carried out as a complementary diagnostic technique. By mapping the spatial distribution of acoustic energy flow through the separating structures, it becomes possible to identify dominant transmission paths and distinguish between globally radiating partition wall behaviour and localized leakage through specific elements.

The applied measurement methods are described in the following sections.

2.1 Sound insulation measurements (ISO 16283-1)

Airborne sound insulation measurements were performed in accordance with ISO 16283-1 [5], which specifies field measurement procedures for determining the sound insulation between rooms in buildings. Although originally developed for building acoustics, the methodology is commonly applied in shipboard environments to evaluate the acoustic performance of accommodation spaces.

The measurements were conducted onboard a multi-deck offshore vessel under harbour conditions, with external noise sources minimized as far as practicable. A dodecahedral omnidirectional loudspeaker was used to generate broadband excitation noise in the source space, typically pink noise, to ensure consistent excitation of the partition walls. The sound pressure levels were measured in both the source and receiving spaces using a calibrated measurement microphone. Multiple microphone positions were used in each room to obtain spatially averaged sound pressure levels in accordance with the standard.

The airborne sound insulation was determined in terms of the (frequency dependent) apparent sound reduction index $R'(f)$, derived from the measured sound pressure level difference between the source and receiving rooms, corrected for the acoustic absorption in the receiving room. The apparent sound reduction index is calculated according to Equation (1):

$$R'(f) = L_1 - L_2 + 10 \log_{10}\left(\frac{S}{A}\right), \quad (1)$$

where L_1 is the source room level, L_2 is the receiving room level (dB). S is the partition area (m^2) and A is the equivalent absorption area derived from reverberation time measurements. Frequency band results were determined in one-third octave bands and subsequently reduced to the single-number rating R'_W, following the procedures defined in ISO 717-1 [6].

The measurements were carried out for several representative separations between accommodation spaces, including cabin-to-cabin partition walls and corridor-to-cabin partitions. The resulting sound insulation indices provide an overall measure of the acoustic separation between spaces and form the basis for further diagnostic investigations using 3D sound intensity measurements.

When performing these measurements, a sound source is placed in the source room. Preferably, the source is positioned in a corner of the room to excite a large number of room modes and to achieve a more uniform excitation of the sound field. However, as shown in Figure 1, this placement can be challenging in practice when accommodation spaces are fully outfitted with furniture and interior elements.

Figure 1: Measurement setup in an finished (a) accommodation space with (b) dodecahedral sound source

2.2 Sound intensity measurements (Microflown Scan & Paint 3D)

To obtain additional insight into the mechanisms governing sound transmission through the investigated partitions, sound intensity measurements were carried out using a Microflown Scan & Paint 3D system **Error! Reference source not found.**[8]. Sound intensity techniques allow the direct determination of acoustic energy flow through surfaces and therefore enable the identification of dominant transmission areas.

Sound intensity describes the flow of acoustic energy in a sound field [9]. Because it is a vector quantity, it provides information not only about the magnitude of acoustic emission but also about the direction of sound propagation. The instantaneous sound intensity is defined as the product of sound pressure and acoustic particle velocity

$$\mathbf{I}(t) = p(t)\mathbf{u}(t). \tag{2}$$

Sound pressure and acoustic particle velocity exhibit level and phase differences that depend on the characteristics of the sound source, measurement distance, and frequency [11]. In practice, stationary sound fields are commonly analysed in terms of the active, or propagating, component of the complex sound intensity averaged over time, given by [11]

$$\mathbf{I} = \left[I_x, I_y, I_z\right] = < p\ \mathbf{u} >_t = \frac{1}{2}\ Re\{p\ \mathbf{u}^*\}, \tag{3}$$

where $\langle\cdot\rangle_t$denotes time averaging. Since sound pressure and particle velocity are measured simultaneously, the three-dimensional acoustic intensity vector can be obtained directly without additional approximations. This quantity provides directional information about the flow of acoustic energy through the investigated surfaces.

During the measurements, the source room was excited with broadband noise using the same loudspeaker arrangement as applied during the sound insulation measurements. The Microflown 3D intensity probe measures both three-dimensional particle velocity and sound pressure simultaneously, allowing the active sound intensity vector to be determined.

The Scan & Paint 3D method combines acoustic data with position tracking to generate spatial maps of sound energy flow across a volume. By moving the probe across the investigated structure, areas with increased sound radiation or transmission can be clearly identified. These spatially resolved measurements complement conventional sound insulation measurements by providing information on where sound transmission occurs within a separating structure. An example of the measurement setup is shown in Figure 3.

Figure 2: Performing a Scan & Paint 3D measurement on a partition surface

3 Investigated partition configurations

Two representative partition configurations were investigated to analyse sound transmission between accommodation spaces. The selected cases reflect typical arrangements encountered in multi-deck offshore vessels.

The first configuration consists of a cabin-to-cabin partition separating two adjacent accommodation spaces. The partition wall extends over a relatively large uninterrupted surface without sanitary units or other stiffening elements. Such partitions are typically constructed as lightweight panel systems within the vessel's interior structure, which may result in relatively low structural stiffness. See Figure 4 for the drawing of this first configuration.

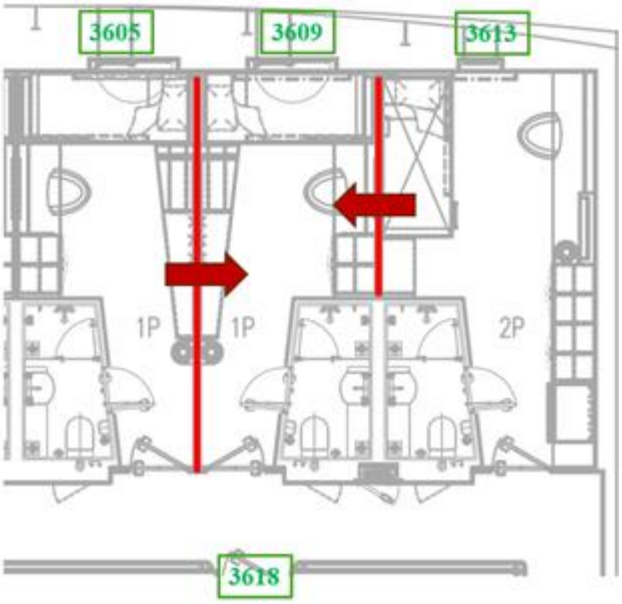

Figure 3: Configuration 1 – partition walls between cabins

The second configuration concerns a separation between a public space and an adjacent cabin. In addition to the primary partition wall, this configuration includes ventilation inlet and outlet elements connected to the vessel's ventilation system. These elements introduce service penetrations through the separating structure and may influence the overall sound transmission behaviour. See Figure 5 for the drawing of this second configuration.

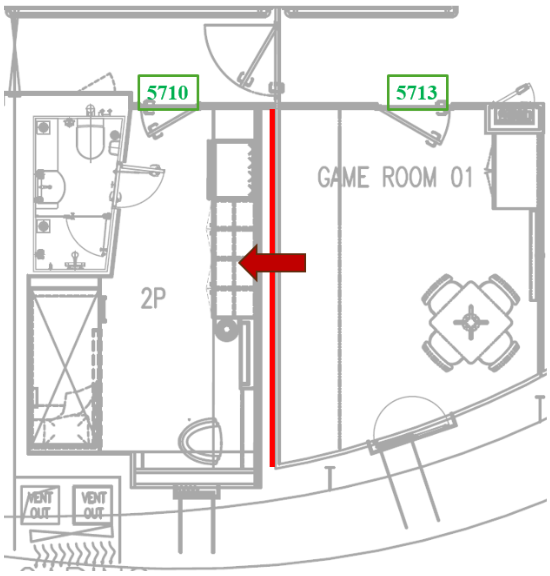

Figure 4: Configuration 2 – partition between cabin and public space

4 Results

This section presents the results of the sound insulation measurements and the corresponding 3D sound intensity measurements for the two investigated partition configurations. The combination of both methods provides quantitative performance metrics as well as insight into the dominant transmission mechanisms of the separating structures.

4.1 Cabin-to-cabin partition wall

The first investigated configuration concerns the cabin-to-cabin partition wall separating two adjacent accommodation spaces. Conventional airborne sound insulation measurements were performed according to ISO 16283-1 to determine the apparent sound reduction index of the separating structure.

The measured results indicated that sound transmission through this partition was primarily governed by the partition wall construction itself rather than by localized leakage paths. To further investigate the underlying transmission mechanisms, sound intensity measurements were carried out on the surface of the partition wall using the Microflown Scan & Paint 3D system.

The resulting 3D sound intensity vector field showed a relatively uniform distribution of radiated sound energy across a large portion of the partition wall surface. This behaviour indicates that the partition wall panels were excited over a significant area and contributed to sound transmission through distributed panel vibration. No clear localized transmission points were observed within the scanned area. The results therefore suggest that the acoustic performance of this partition is dominated by the global structural response of the partition wall rather than by specific weak points or discontinuities.

This observation is consistent with the structural characteristics of the investigated partition wall configuration. The partition extends over a relatively large uninterrupted area and does not contain additional structural elements that would increase its stiffness. As a result, the partition wall panels can radiate sound over a broad surface when excited by airborne sound in the source room. This can be observed in Figure 6 by the red vectors, which present a high intensity. The white part in the picture is a mirror. In addition, the vectors are predominantly oriented away from the corridor side towards the hull, indicating a net energy flow through the partition wall consistent with distributed panel radiation.

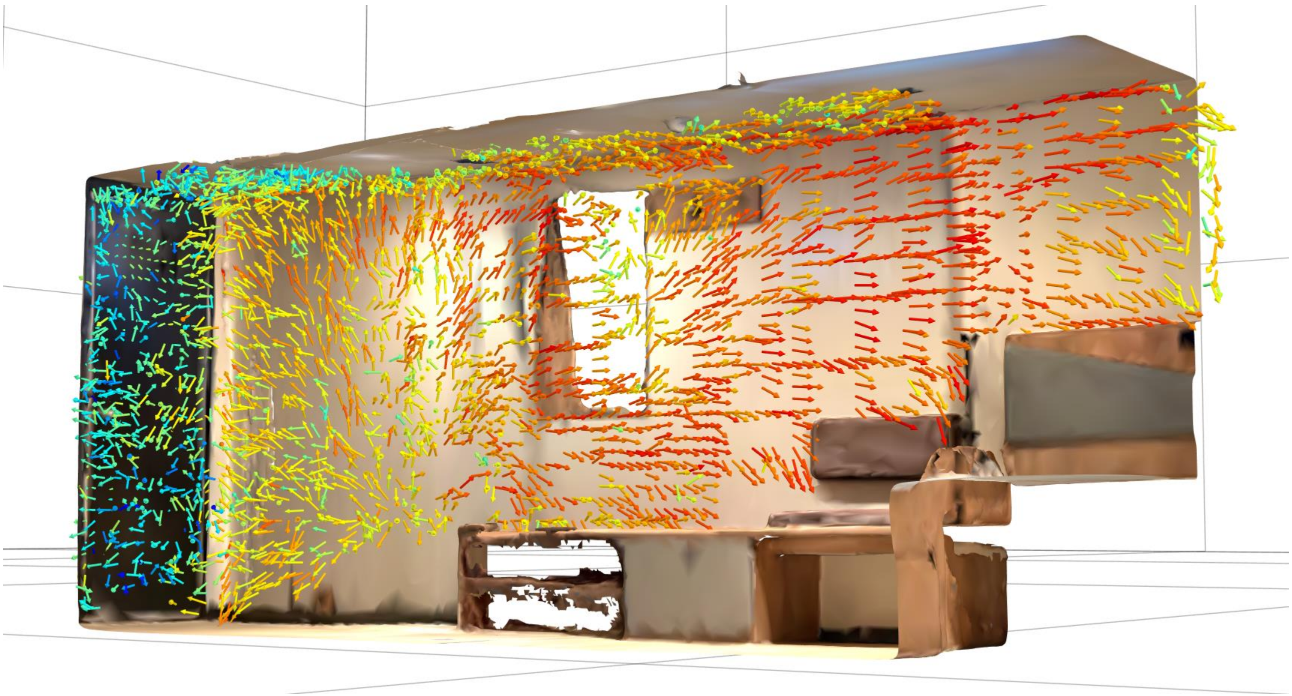

Figure 5: Sound intensity distribution on the cabin-to-cabin partition (configuration 1) for the frequency area of 1500-3000 Hz

4.2 Public space-to-cabin partition wall

The second investigated configuration involves a separation between a public space and an adjacent cabin. In addition to the partition wall itself, this configuration includes ventilation inlet and outlet elements connected to the vessel's ventilation system.

Sound insulation measurements indicated that sound transmission was not uniformly distributed across the separating structure. To identify the governing transmission paths, sound intensity measurements were performed on the partition wall sections surrounding the ventilation components, as well as on adjacent structural surfaces.

The sound intensity maps revealed that most of the transmitted acoustic energy was concentrated around the ventilation inlet and outlet elements. In contrast to the cabin-to-cabin partition, the surrounding partition wall surfaces showed relatively low levels of radiated sound energy. This indicates that the dominant transmission paths were associated with the ventilation components rather than with the partition wall panels themselves. The vectors near the ventilation opening show a clear outward and spatially distributed orientation, indicating that the airflow path acts as a localized source of transmitted acoustic energy into the cabin.

The results demonstrate that service penetrations such as ventilation openings can act as locally governing acoustic weak points in otherwise well-performing partition constructions. The measurements clearly illustrate how spatially resolved sound intensity techniques can identify such localized transmission paths, which are difficult to detect using conventional sound insulation measurements alone.

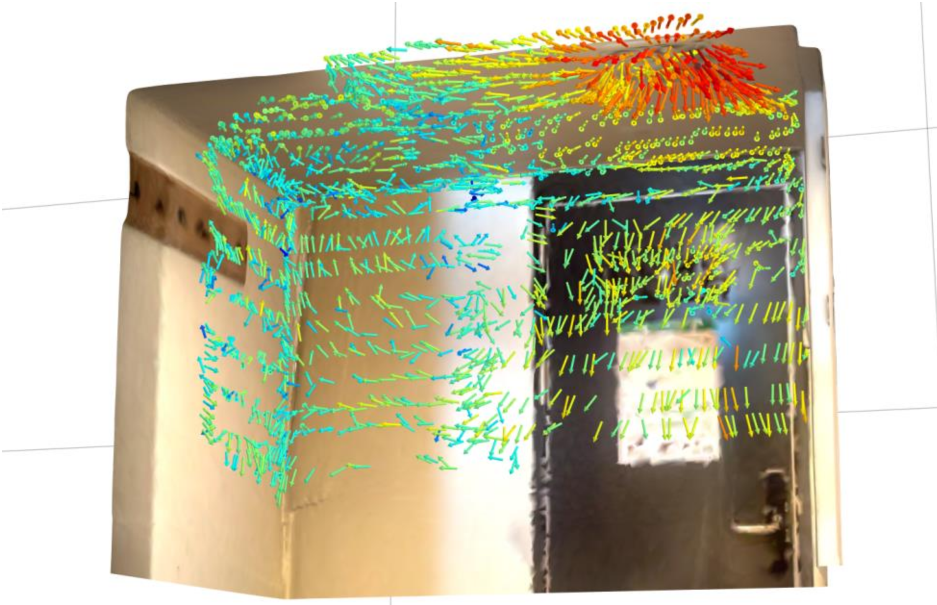

Figure 6: Sound intensity distribution on the public space-to-cabin partition (configuration 2) for the frequency area of 100-3000 Hz

4.3 Comparison of transmission mechanisms

The two investigated configurations demonstrate distinct sound transmission behaviours. In the cabin-to-cabin partition, sound transmission is governed by distributed panel radiation over a relatively large partition wall surface, reflecting the influence of structural stiffness and panel dynamics. In contrast, the public space-to-cabin partition is dominated by localized transmission through ventilation-related components.

These observations highlight the importance of understanding the underlying transmission mechanisms when evaluating shipboard partitions. While single-number insulation indices provide an overall performance metric, 3D sound intensity measurements enable the identification of the specific elements responsible for sound transmission, thereby supporting targeted design improvements and troubleshooting.

5 Discussion

The measurements demonstrate that different structural features can govern sound transmission in shipboard partitions. While conventional sound insulation measurements provide an overall performance indicator, the 3D sound intensity measurements reveal the physical locations where sound energy is transmitted through the structure.

For the investigated cases, two different transmission behaviours were observed. In one configuration, sound radiation was distributed across a large partition wall surface, indicating that the acoustic performance was governed by the structural response of the partition panels. In the other configuration, sound transmission was concentrated around localized elements associated with service penetrations.

These observations illustrate the importance of identifying the dominant transmission mechanism when evaluating acoustic performance. Depending on whether transmission is governed by global panel behaviour or by localized weak points, different design measures may be required to improve the acoustic performance.

The results show that spatially resolved sound intensity measurements can provide valuable diagnostic information that cannot be obtained from conventional sound insulation measurements alone.

6 Conclusions

This study investigated sound transmission mechanisms in shipboard partition walls using a combination of standardized airborne sound insulation measurements and spatially resolved 3D sound intensity measurements.

The results show that conventional insulation measurements provide limited insight into the physical mechanisms responsible for sound transmission. By applying sound intensity measurements using the Microflown Scan & Paint 3D system, the spatial distribution of sound energy flow through the investigated structures could be visualized.

Two distinct transmission behaviours were observed: distributed sound radiation from partition surfaces and localized transmission through specific construction elements. Identifying these mechanisms is essential for effective acoustic troubleshooting and design improvement.

The results demonstrate that 3D sound intensity measurements provide a valuable diagnostic tool for understanding and improving the acoustic performance of shipboard partitions.

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