

DISTURBANCES IN NOISE PROPAGATION GENERATED BY A MOVING SHIP IN SHALLOW WATER

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Noise propagation generated by a moving ship in shallow water is always associated with energy loss because of absorption and the fact that sound is scattered by medium inhomogeneities, also resulting in a decrease of sound intensity with range. Furthermore sound propagation is strongly dependent on fluid space geometry and dimension, as well as reflection and transmission loss through the sea bottom. The geometrical dimensions of the measured ship and shallow water are comparable. The depth of water is usually less than the length of the ship, so machinery vibration - due to propulsion machinery and auxiliary machinery - acoustic noise in the compartments below the waterline, flow noise and propeller noise are not generated by the hull of the ship from one point only. Hydroacoustic measurement range is designed with the purpose of exploiting and distinguishing these effects because of the amount of information they each bring; they allow to identify a different class of ship, although interpretation of spatial distribution is very difficult because of sound propagation in shallow water. This paper presents experimental research into the noises of moving ships, measured on the sea bottom, with reflection about the influences of sound propagation on the results of underwater acoustic measurement ranges.

INTRODUCTION

Research of sound disturbances generated by the objects immersed in shallow water have a history dating back to The World War II. The first observations of fluctuations in the level of sound – which was then called the *transmission anomaly* – was briefly mentioned in literature [1]. The latest investigation about underwater noises focused strongly on spatial distribution of noises around moving objects including the interaction between the ship and the sea bottom. This paper shows investigations relating to sea bottom observed phenomena. It presents results of analysis based on the measurement of data gathered from the new acoustic range from the Gulf of Gdansk, and was made by The Gdansk University of

Technology in cooperation with The Polish Naval Academy. The main aims of the investigations were:

- The determination of distribution of underwater noises on the bottom of the sea for use in marine mines countermeasure (MMCM) area,
- To expand the methods of the hydroacoustics investigation, in relation to the spatial distribution of hydroacoustics noise from the hull of a ship.

1. METHOD OF INVESTIGATION

The main method of the investigation is a dynamic method of measuring underwater noises. The sensors there are directly on the permanent special construction which is situated on the bottom of sea. The directional buoys lead ships straight above the underwater section of hydrophones. This method allows the calculation of longitudinal and transverse (spatial) distribution of underwater sound generated by the hull of a moving ship. The measurement of the transverse and spatial distribution of underwater noises required more than one sensor, but investigation into the distribution of longitudinal acoustic energy emitted by the hull of a ship only requires one sensor. During this investigation eight hydrophones was used. The appearance of range from the investigations and object of investigation are presented in Fig.1.

This dynamic method of hydroacoustics measurement requires knowledge of the harmonics of the main noise sources. This can be realized in a few ways. e.g. two groups of researchers take part in investigations; the first group on the acoustics range measure underwater noises and the second group on board the investigated ship measure the vibration from the main sound sources. Another way is using information from previous investigations into a ship's vibration with the same settings of parameters of the ships' mechanisms. This method allows one to check the correctness of measured underwater noise [3]. The examinations are conducted at different depths. The knowledge of the position of harmonics of the main mechanisms in the spectrum of the ship's underwater noise is very important. Harmonics of the main mechanisms almost always appear in the spectrum of underwater sounds.

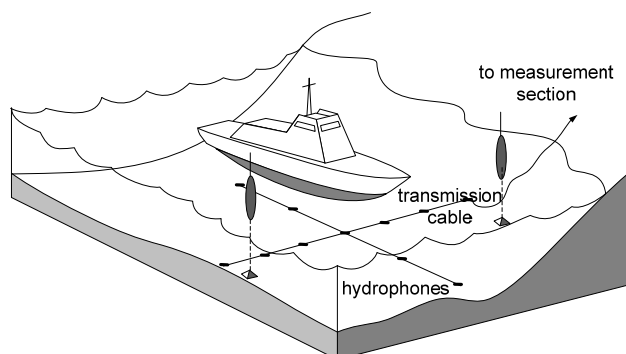


Fig. 1. The dynamic measurement of the ship's noise – one of the methods of investigation into sources and spatial distribution of underwater noise.

In this examination, the harmonics relating to the generating sets were a base of localization from another ship's mechanisms. The analysis of the low frequency band (during this investigation to 200 Hz) allows one to determine source characteristics, such as:

- Number of shafts and multiple shafts effects,
- Shaft rate,
- Number of propeller blades,

- Frequency of current generated by generating sets,
- RPM of main engines and generating sets,
- Cavitations effects,
- Detection of source changes e.g. 1. Shift in frequency caused by change in the propeller revolution rate, 2. Changes of vibration level or underwater noise dependent on the technical state of the ship.

By comparing the physical dimensions of the researched ship with the spatial distribution measured under the hull's sound, one can describe the areas of the maximum transmissivity of acoustic energy. Acquirement of this knowledge is necessary during the project phase of a ship's construction, especially for military applications. The method of comparative spectral analysis, based on FFT analysis of characteristics of harmonics tracking in k records, where k depends on the length of measurement data and the length of the ship. This idea of comparative and spatial distribution spectral analysis of underwater noise radiated by a moving ship is presented in Fig. 2 and 3.

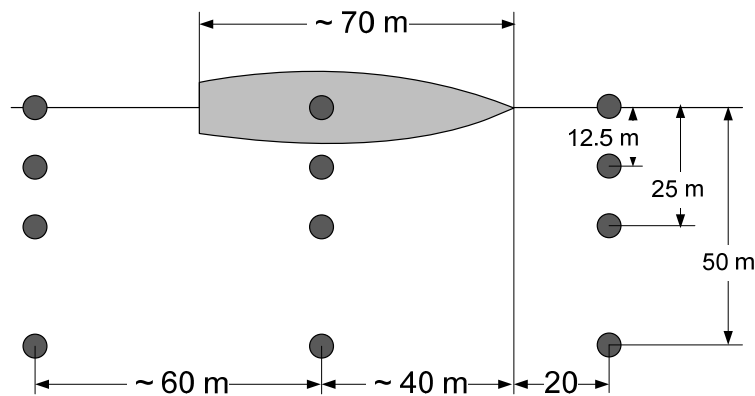


Fig. 2. Arrangement of points to comparative spectral analysis of underwater noise radiated by a moving ship. In this paper there is an assumption of symmetric distribution of a ship's noises.

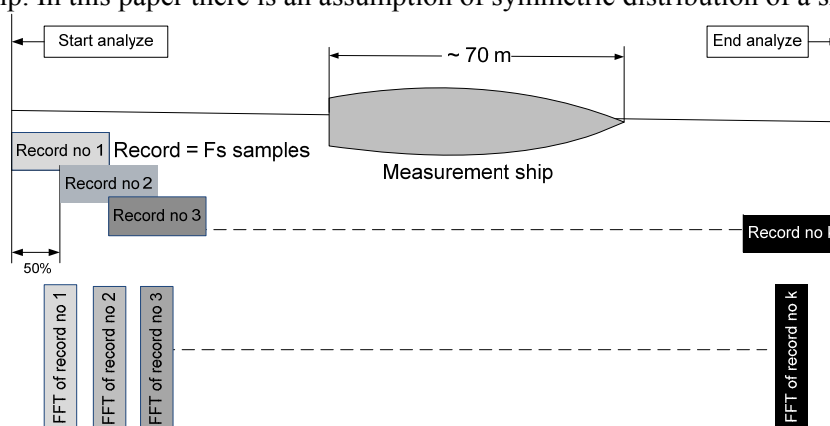


Fig. 3. The dynamic measurement of a ship's noise – the method of measurement and analysis of spatial distribution of a ship's noises underwater (speed 10 knots)

2. RESULTS

The sea bottom distribution spectral analysis of underwater noise radiated by the moving ship was made in the following steps [3]:

- Identification of the harmonics of the main mechanisms (with known parameters) in the power spectrum of the ship's underwater noise, directly under the hull of the investigated ship, Fig. 4.,
- Comparative spectral analysis of the underwater noise radiated by the moving ship, based on the power spectrum of the ship's underwater noise in locations around the ship. Examples of the results are shown in Fig. 5. and 6., In general Fig. 6 sees the most diversity of harmonics levels, but the highest level does not always derive from the power spectrum of the ship's **underwater noise which there were the nearest sensor, so another approach is presented in next step,**
- Comparative spectral analysis of underwater noise radiated by the moving ship was based on chosen harmonic tracking on the sea bottom around the ship, according with the method shown in Fig. 2. Results are shown in Figure 7,
- Fig. 8. presents results of broadband calculation of spatial distribution of the ship's noises in shallow water (20 m).

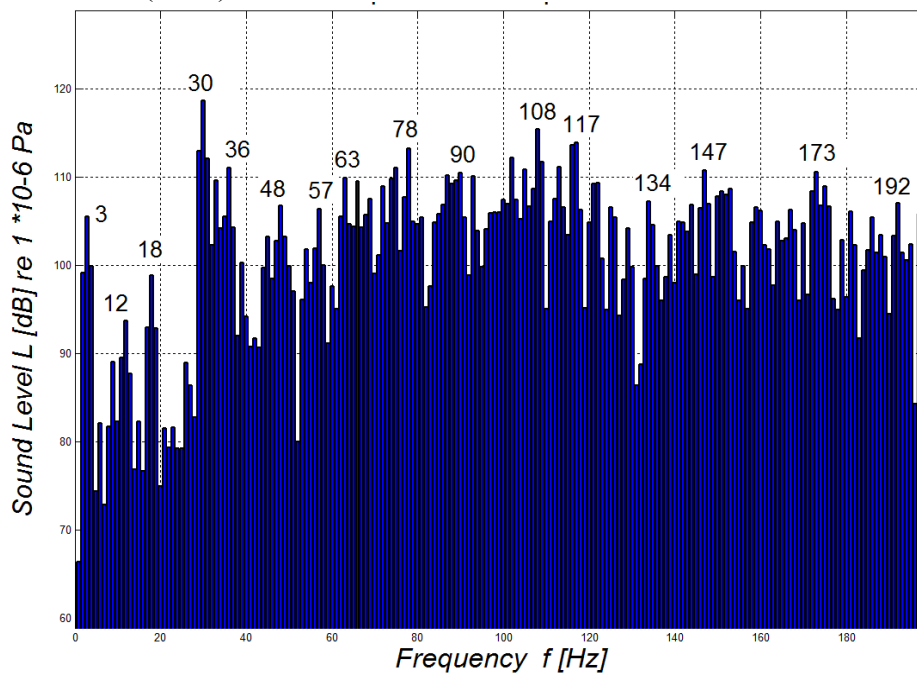


Fig. 4. The spectrum of the investigated ship's underwater noise

Fig. 7 presents sound “stripes” on the bottom of the sea. These can be caused by the Lloyd Mirror Effect; acoustic shadowing and diffraction in a shallow water environment [2]. The separation between the near field, the interference field and the far field is recognized by equation [1]:

$$l_0 = \frac{4d_1d_2}{\lambda} \quad [1]$$

Where: l_0 – reference distance between source and receiver, d_1 – the distance from water surface to source of sound, d_2 – distance to the receiver on the sea bottom, λ – the wavelength of the sound.

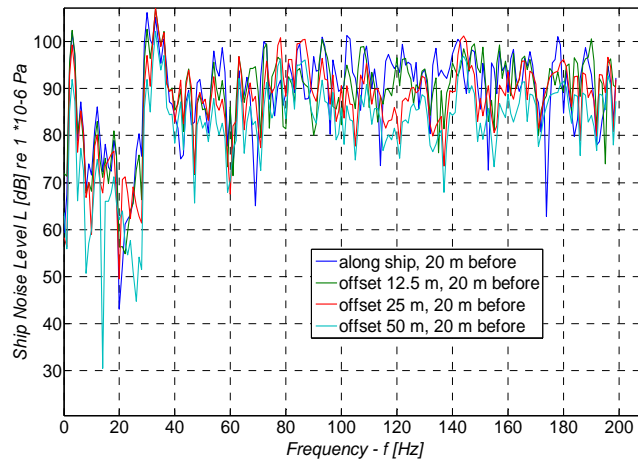


Fig. 5. The comparative spectral analysis of underwater noise radiated by the moving ship.

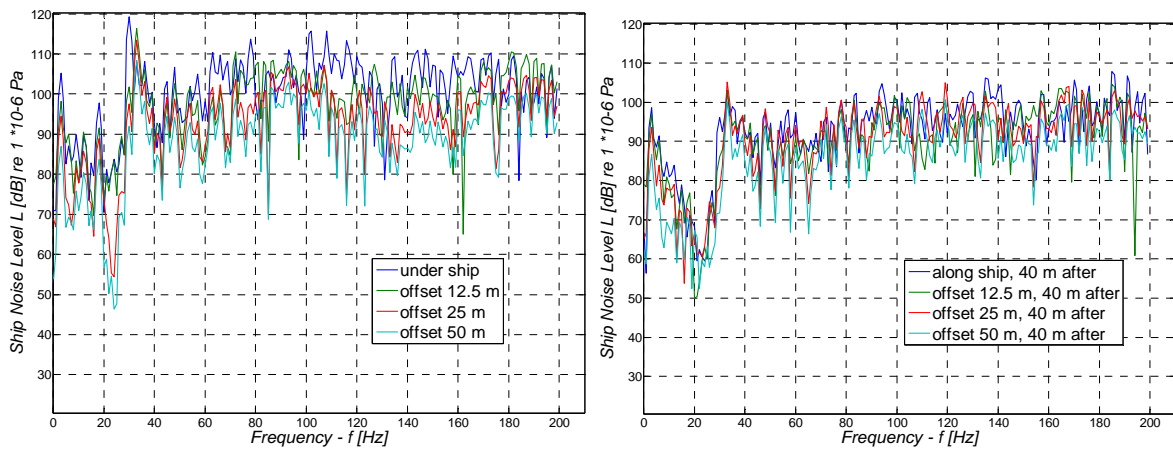


Fig. 6. The comparative spectral analysis of underwater noise radiated by the moving ship.

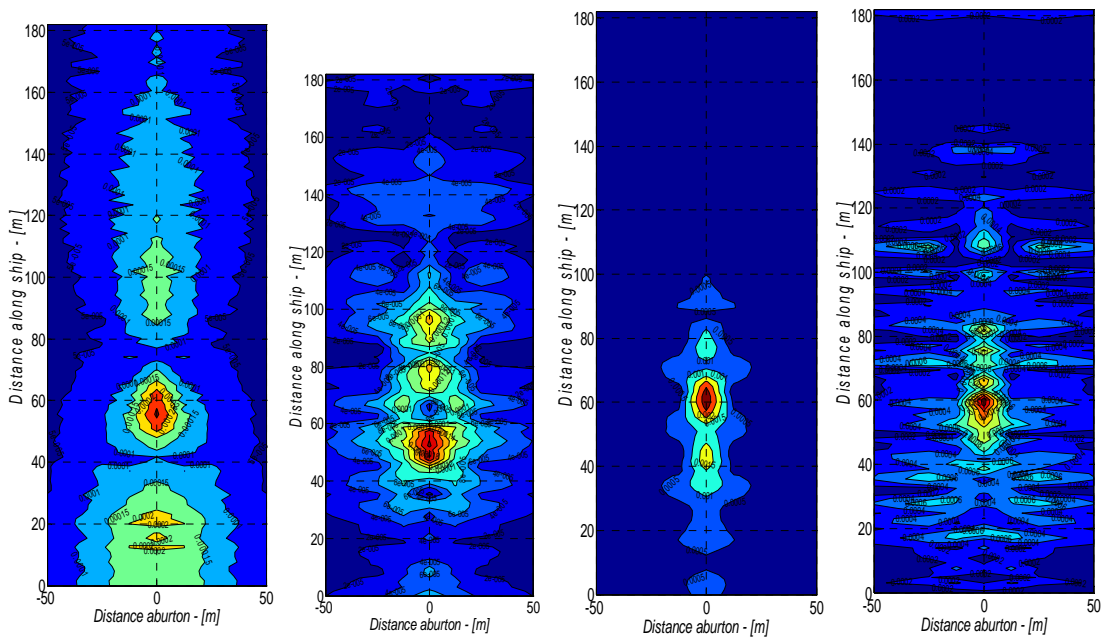


Fig. 7. From left to right: 3 Hz, 12 Hz, 30 Hz and 108 Hz single tone analysis of underwater noise radiated by the moving ship.

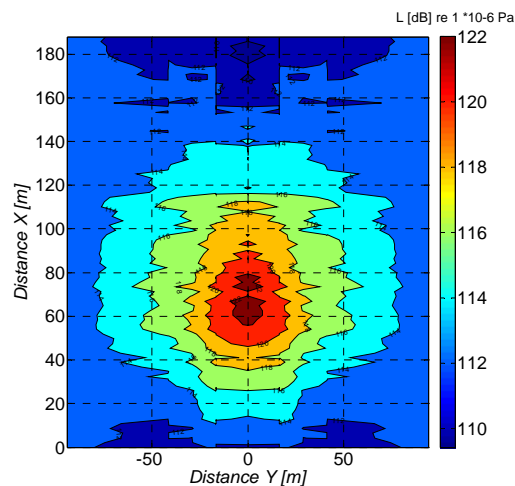


Fig. 8. The spatial distribution of the investigated ship's underwater broadband noise

Decreasing sound level appears [1] when $l/l_0 = 1/2, 1/4, 1/6, \dots$ and increasing levels could be higher (to 6 dB), when $l/l_0 = 1/3, 1/5, 1/7, \dots$. **The measurement of the conditions where the receiver were immersed at $d_2=20$ m and the source of approximately $d_1=3$ m, so l_0 was about 17 m.** As a result of the calculations we obtain that the minimum frequency is about 100 Hz, **with lower frequencies calculated in reference distance takes values smaller than the real.** The observed changes in the level of sound are still there and they are not explained by the theory of interference.

3. SUMMARY

Investigations of disturbances in sound propagation generated by a moving ship in shallow water allows one to conclude the following:

- Based on the measured underwater noise generated by the ship, it is possible to reach conclusions about the influence of underwater noises, generated from the hull, on the bottom of sea.
- The experience gathered during this research, shows that distribution of the noise levels from the hull of the ship could help describe the influences of the acoustic signature of a ship, on the chosen objects and points at/on the bottom of sea.
- Calculation of underwater sound distribution allows one to observe sound “stripes” on the bottom of the sea, which can be caused by the Lloyd Mirror Effect - acoustic shadowing and diffraction in shallow water environment. The next examinations will focus on vibration analysis from the hull of a moving ship.

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