THE ONE–THIRD–OCTAVE SPECTRUM AS A METHOD OF VESSEL IDENTIFICATION

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The subject of the examinations carried out is hydroacoustic noise in coastal zones. Under these conditions natural noise and the noise from moving vessels affect each other, as well as interference from industrial infrastructure located close to the coast. Both natural noise and noise caused by human activity affect the detection and identification of noise sources in these conditions. Experiments have been performed by the mobile measuring module in the Gulf of Gdansk. This showed that it can extract spectrum components, based on the results of underwater noise. These components allow the detection of moving objects. The collected database of measurements enabled the comparison of one-third-octave spectra of three different ships. The components specific to the type of vessel could extracted as a result of comparison. Consequently one of the three tested vessels could be identified.

INTRODUCTION

This article presents a method of detection and attempts to identify the source of hydroacoustic noise in the coastal zone. This method is based on the one-third-octave spectrum. The first chapter contains a description of the measurements. The second chapter describes the algorithm for the one-third-octave (OTO) spectrum normalized to the maximum spectrum level. It also presents the results for the ambient noise and noise from three ships. In the third part the opportunity to develop an algorithm to identify vessels and the carrying out of more research to verify an algorithm is proposed.

1. MEASUREMENTS

The measurements were carried out using a multi-sensor mobile measuring platform designed and made by the Polish Naval Academy. [1, 3, 4, 5] The module contained hydroacoustic, hydrodynamic, magnetic, electrical and seismic fields sensors. The measurements were performed in the Gulf of Gdansk near the seaway to the port of Gdynia.

The module was placed on the seabed at a depth of 20 m, and connected with the ship-base via hybrid electric-fiber optic cable of a length of 1km. During the measurements all sources of noise such as engines or a generator were excluded. All devices used battery power. The ship-base was anchored at a distance of about 800 m from the measuring platform. In this way the impact of noise from the ship-base was reduced.

Recorded vessels sailed directly over the measuring module or close to it. The vessels' routes were recorded via AIS (Automatic Identification System), which contains information about the current position of the vessel. In this test, three different ships were recorded, 4 transitions for vessel "A", and for ships "B" and "C" 2 transitions. The direction of movement and speed of the ships were the same for all eight transitions.

2. RESULTS

In order to detect vessels as sources of underwater noise frequency analysis of the recorded signals was performed. First, the one-third-octave spectrum of recorded ambient was calculated. Ambient noise was recorded when there was no ship or other source of noise in a radius of 2 km from the measuring platform. To determine the one-third-octave spectrum the following parameters were assumed: a Hann window, a spectrum determined for each 1 s of the analyzed signal for every 2 s signal which resulted in a 50% overlap. The one-third-octave spectrum was obtained from the fast Fourier transform (FFT) [2].

$$X(f) = \sum_{n=0}^{N-1} \left(x(n) \cdot 1{,}633 \cdot w(n) e^{-\frac{2\pi i}{N} nk} \right), \tag{1}$$

where w(n) is the Hann window function:

$$w(n) = 0{,}5\left(1 - \cos\left(2\pi \frac{n}{N-1}\right)\right). \tag{2}$$

A spectrogram obtained as the result is shown in Figure 1.

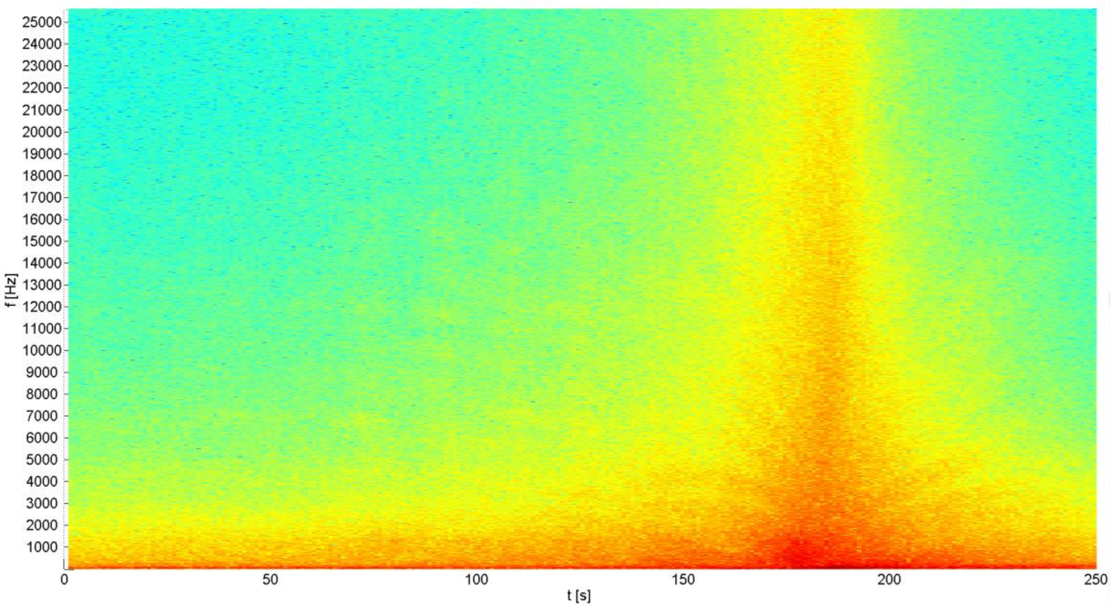

Fig. 1. Spectrogram of noise from moving vessel.

Narrowband spectrum obtained from 1 s of spectrogram is shown in Figure 2.

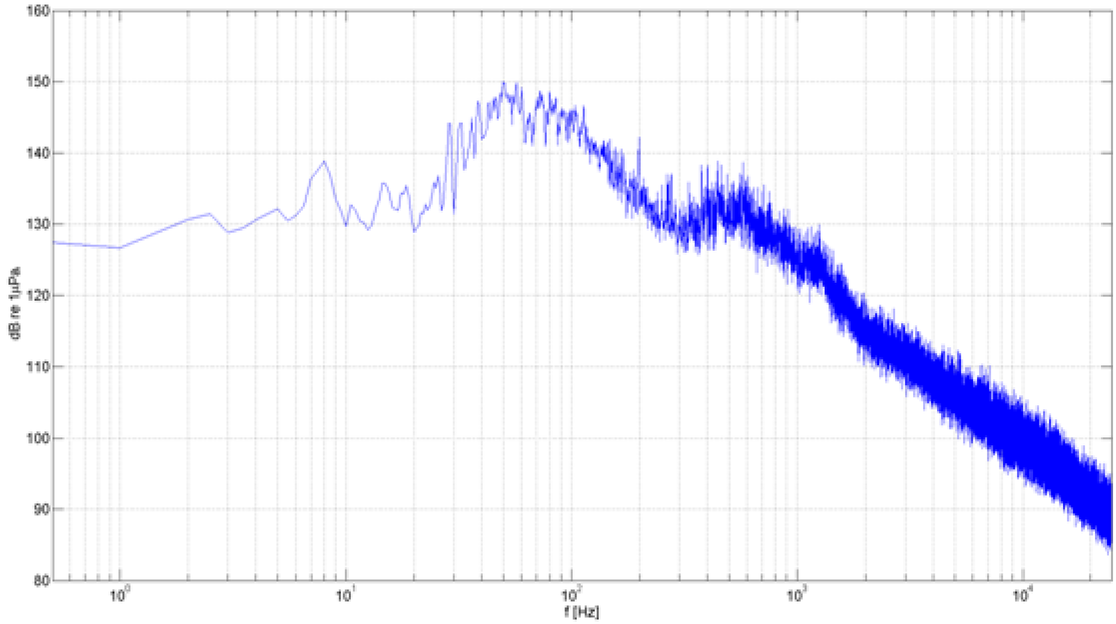

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Fig. 2 Narrowband spectrum of 1 s of signal.

Upper and lower frequency limits for the centre frequencies *f* were set up as follows.

$$f_{low} = \frac{f}{\sqrt[6]{2}} \tag{3}$$

$$f_{high} = \sqrt[6]{2} \cdot f \tag{4}$$

In the next step spectrum band levels designated by f_{low} i f_{high} were summed up:

$$Y(f_{OTO_n}) = 20 \cdot \log_{10}\left(\sum_{f=f_{low_n}}^{f_{high_n}} 10^{\frac{X(f)}{20}} \right) \tag{5}$$

The result is a one-third-octave spectrogram Fig. 3.

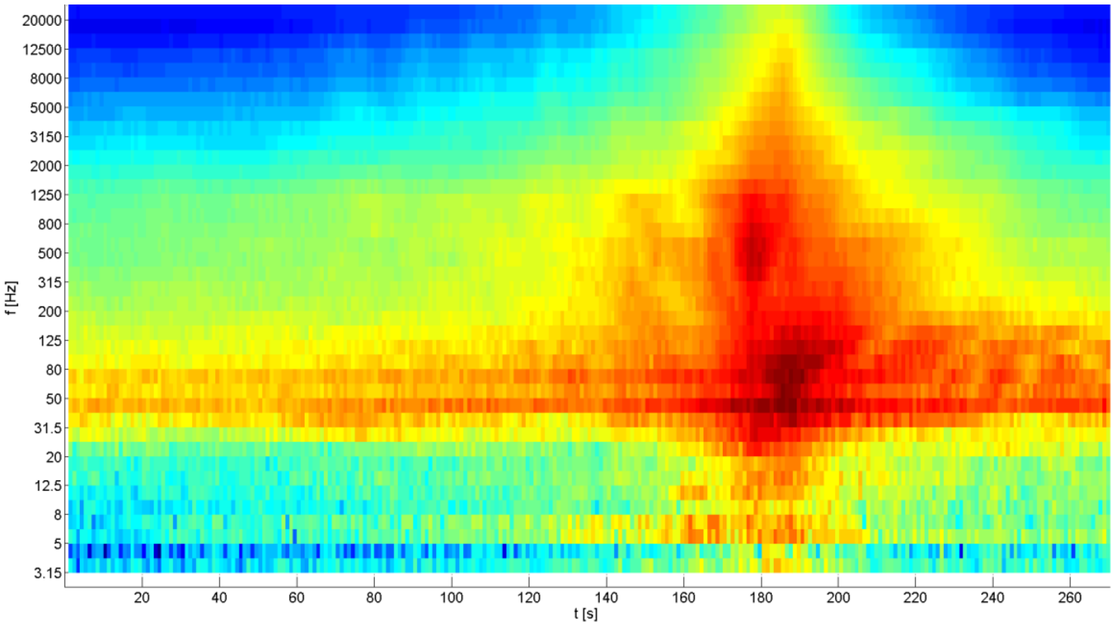

Fig. 3 One-third-octave (OTO) spectrogram.

A time moment was chosen, for which the maximum level obtained by the maximum value of the one-third-octave spectrum. Maximum values of the one-third-octave spectrum are strongly dependent on the distance to the source of the noise from the measuring platform. Therefore, they were normalized relative to the average value (Fig. 4). This approach allows the comparison between different transitions independently of information about the distance between the ship and measuring platform.

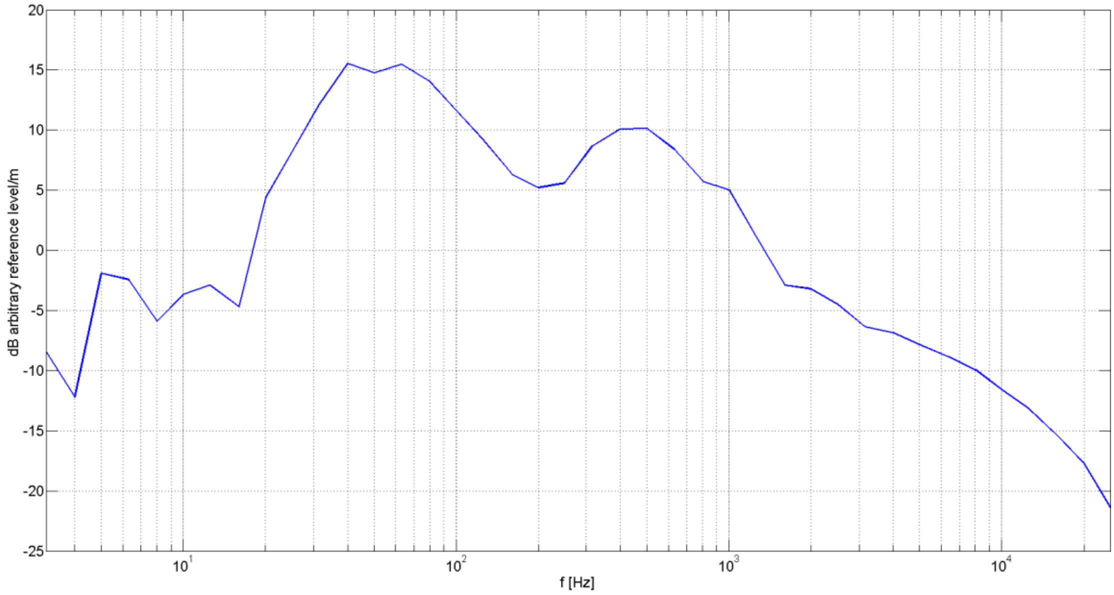

Fig. 4 Normalized maximum values of one-third-octave spectrum.

The first analysis of data was related to ambient noise. It was obtained when there were no vessels in a radius of 2 km from the module. Figure 5 illustrates the OTO spectrum for the 10 moments of the recorded background. Discrepancies of about 4-5dB occur in the band below 100 Hz. In the remaining band differences do not exceed 2 dB.

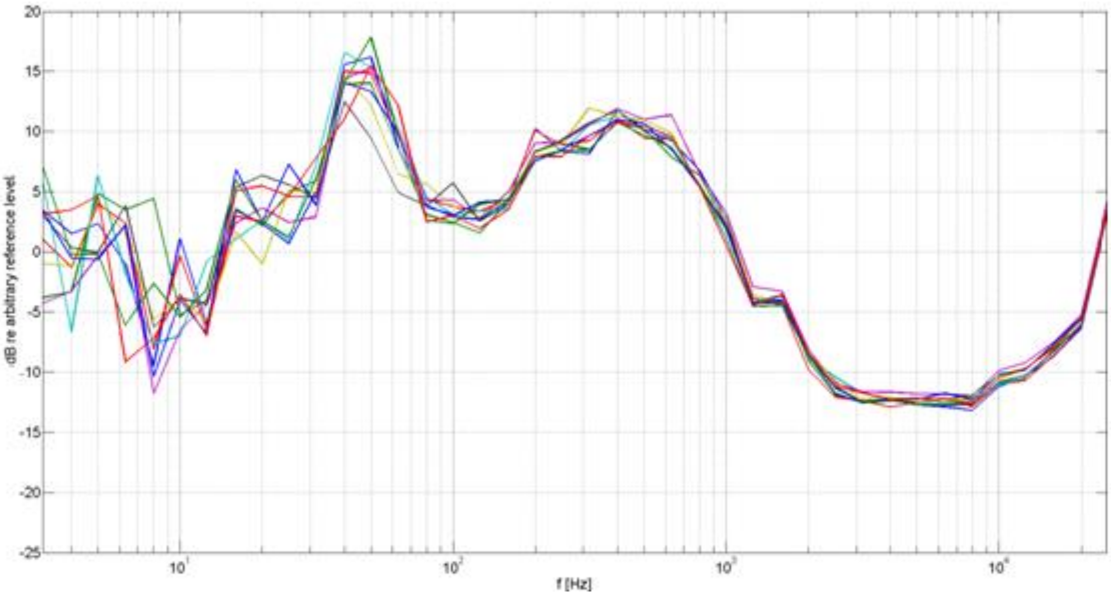

Fig. 5 Normalized one-third-octave spectrum for ambient noise.

The vessels' measurements started after recording the ambient noise. At the beginning vessel "A" was measured, which ran four times over the measuring module. The obtained normalized spectra for vessel "A" have a distinctly different character to the background spectrum. It is possible to detect the source of noise in the background noise environment based on the normalized one-third-octave spectrum. At the same time, the normalized spectrum of vessel "A" has a similar shape. There are differences of 7-13dB in the transition number 3 for 16Hz and 20Hz, and below 4 dB at 10 Hz in the transition number 4. Two different types of vessels were measured in order to determine whether the shape of the normalized one-third-octave spectrum was characteristic for the type of vessel. Normalized one-third-octave spectra also have a characteristic shape for ship "B". Higher differences of several decibels occur only for a frequency range below 10Hz. Ship "C", like the other two vessels, has the characteristic shape of its normalized one-third-octave spectrum.

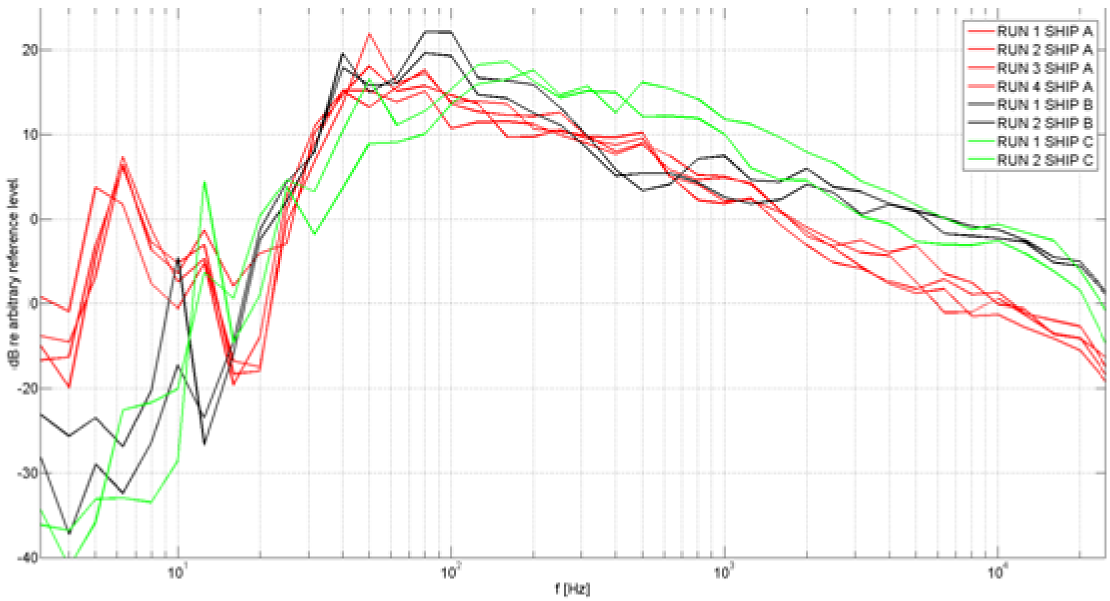

Fig. 6 Normalized maxima of one-third-octave spectra for all ships.

Figure 6 presents a comparison of a normalized one-third-octave spectrum of all measurements for three ships. The comparison showed that all three vessels have a similar shape of spectrum. However, one can see a little difference between them. It is possible to identify vessels as sources of noise using a suitable algorithm for the comparison of the normalized one-third-octave spectra.

3. CONCLUSIONS

The results proved that it is possible to identify different types of vessel on the basis of the normalized one-third-octave spectra obtained from measurements. Measured vessels were of various types: vessel "A" – a passenger ship, "B" – a cargo ship and "C" – a tug. The characteristic shape of the spectrum allows the identification of the type of vessel, however not a particular vessel. In further examination, an algorithm for the comparison and identification of a normalized one-third-octave spectra should be developed. Next, different ships' measurements of the same type, and a greater number of vessels of another type, should be developed. This will both verify the algorithm, as well as the possibility of vessel type identification will be checked.

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