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Determination of the ship detection area in the coastal region

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ABSTRACT

The paper presents the results of the investigations of the noise produced by ships at the background of ambient sea noise in the coastal region. It has been noticed that the ships' spectra can be classified into a few groups. The shape of the broad-band noise spectrum envelope has been chosen as the criterium of classification. The area in which the signal generated by a ship can be distinguished from the ambient noise has been preliminarily estimated.

INTRODUCTION

The noise field at the sea in the coastal region is significantly influenced with the technical noise, especially connected with the human's activity. Interpretation of acoustic signals observed in this region is difficult. It is caused by the stochastic occurrence of discrete spectral spikes in the frequency characteristics of noise. These spikes, which may be of high level, are produced by mechanical devices working at the shore.

The characteristics of the acoustic background of coastal regions limits in a great extent the detection, localization and identification of ships. Therefore the investigations of underwater noise generated by ships are carried out together with the investigations of the ambient noise. The ambient noise is on one hand a component of the technical noise and on the other restricts the range of detection because of the required signal to noise ratio (SNR).

The aim of the carried out investigations was to determine the characteristic features of the broad-band noise emitted by ships. It would allow to discover the presence of ships in the observed region relatively early.

THE METHOD AND THE RESULTS OF INVESTIGATIONS

The investigations of the influence of the ship's motion on the ambient sea noise were carried out basing on the results of the measurements of both the ambient noise and the noise emitted by ships. The measurements were performed in the Gulf of Puck region and the western part of the Gulf of Gdańsk. The investigations concentrated on changes in the acoustic characteristics of ships as a function of distance. They were carried out for different types of ships moving with different speeds. The measuring probes were placed close to the sea bed at depths from 10 to 50 m. The registered signals spectra were analyzed in the frequency band from 10 Hz to 2560 Hz with the resolution of 10 Hz. It was the basis for classification of ships into groups. The characteristic features of spectrum envelopes decided on classifying a ship into one of the groups. One group could contain more than one type of ships. The shape of spectrum characteristics is much influenced with the kind of main engines mounted within the hull (low-speed, medium-speed or high-speed). Ships of similar dimensions and draught but with different kinds of main engines considering the

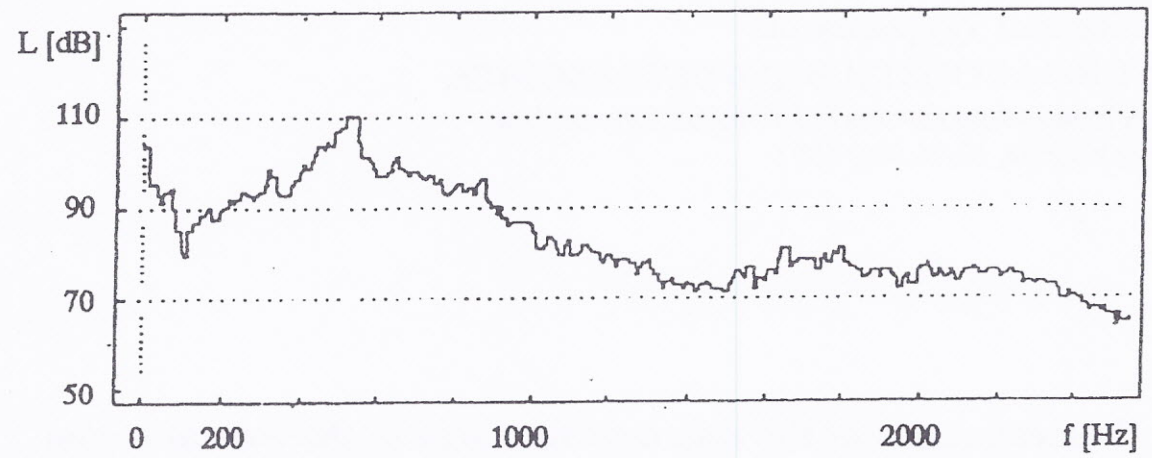

Fig.1. Frequency characteristics of a ship with a high-speed engine

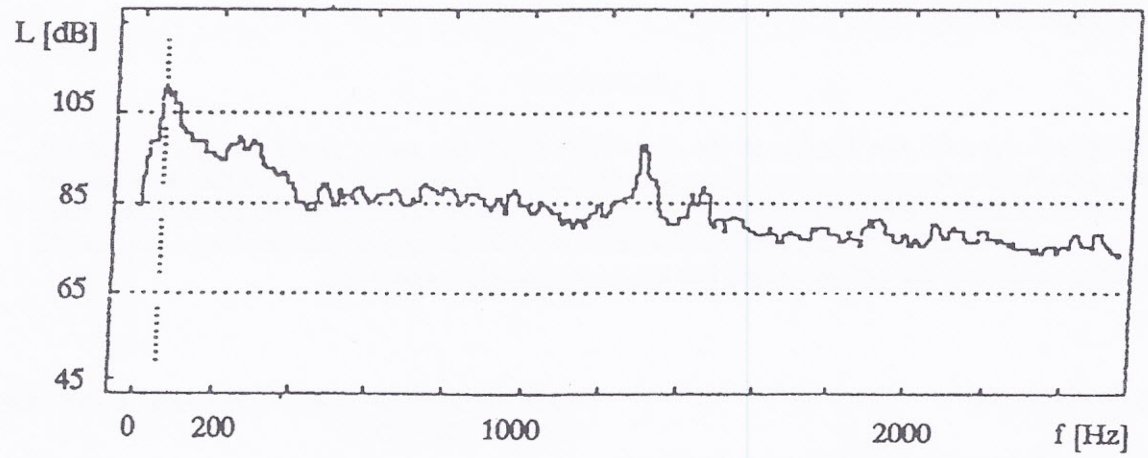

Fig.2. Frequency characteristics of a ship with a low-speed engine

rotational speed are classified differently. The sample spectrum envelopes characteristic for two types of ships have been presented in the figures 1 and 2. The shapes of these envelopes differ in the distribution of the acoustic energy in a function of frequency.

The frequency characteristcs for a ship with an engine of fast rotations has been presented in the figure 1.

The main features which distinguish the envelopes of ship noise spectra are:

- the band of maximal radiation energy 250Hz-600 Hz
- the band of 600Hz-1500Hz in which the amplitudes of spectrum components lower gradually while the frequency increases; the difference between the highest and the lowest level is approximately 25 dB
- the band of 1500Hz-2500Hz in which firstly a gradual growth (of about 3 dB) can be observed, followed with lowering of the amplitudes of spectrum components.

The frequency characteristcs for a ship with a low-speed engine has been presented in the figure 2.

The main features which distinguish the envelopes of ship noise spectra are:

- the band of maximal radiation energy 10Hz-300 Hz
- the band of 400Hz-1000Hz in which the radiation energy is uniformly distributed; the level of spectrum components in this band is about 20 dB lower than the maximal values in the first band
- the band of 1200Hz-1600Hz in which two local maxima can be observed; the pressure level of the first one is about 10 dB higher than the components of the second band whereas the pressure level of the second maximum is about 5 dB lower than the level of the first one
- the band of 1600Hz-2500Hz in which the amplitudes of spectrum components lower gradually while the frequency increases; the difference

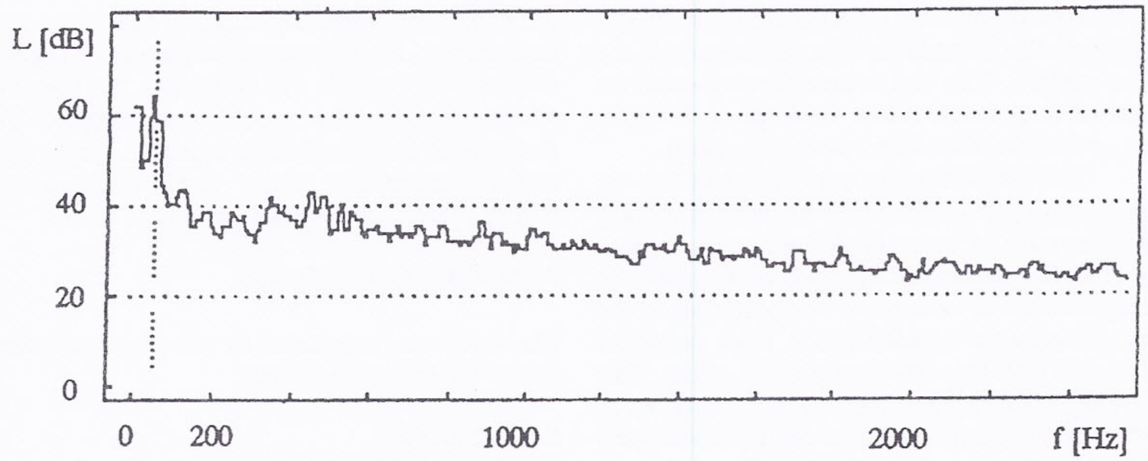

Fig.3. Frequency characteristics of ambient noise in the coastal region for the sea state 2-3

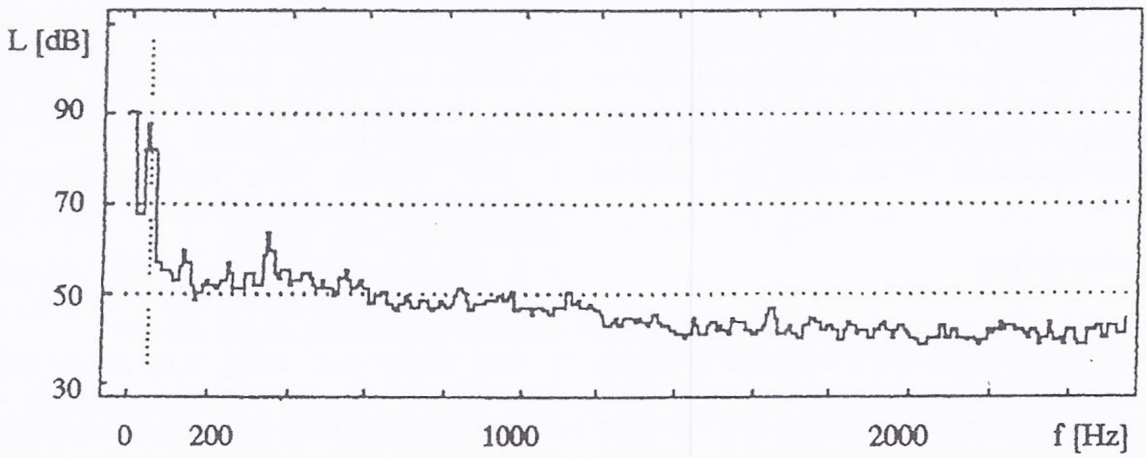

Fig.4. Frequency characteristics of ambient noise in the coastal region for the sea state 7-8

between the highest and the lowest level is approximately 6 dB

During the experimental investigations there was determined the lowest signal to noise ratio for which the ship's spectrum envelope preserves its shape. Its value turned out to be 2:1.

Fig 3 and 4 present the frequency characteristics of the ambient noise in the coastal region for the sea state 2-3 and 7-8.

The spectra presented in the figures were determined basing on the measurements carried out at a depth of 20 m. Different transmission loss models were assumed to determine the area of shipdetection on the background of the ambient noise. An empirical dependence was applied, which described the changes in the hydroacoustic signal level as a function of distance between the signal source and the detector [2]:

$$L = L_h - 20\log\frac{r_o}{h} + - 10\log\frac{r_{3/2}}{r_o} - 15\log\frac{r}{r_{3/2}} \qquad (1)$$

where:

L_h-the measured level of the hydroacoustic pressure generated by a ship moving over a set of hydroacoustic transducers placed at the sea bed of a depth h

h - the sea depth

r - the distance between the signal source and the detector in meters

r_o - the distance at which a spherical wave changes into a cylindrical one

$r_{3/2}$ - the distance between the source and the detector from which the model of propagation according to the three halves law

The formula (1) does not consider the loss linked with the attenuation of acoustic waves in the water medium. This loss is actually very small for waves of frequencies below 1 or even a few kHz even at the distances up to teens kilometers.

For measurements carried out in the sea region of a depth of 20 m in the assumed frequency band the radii of areas of different transmission loss models r_o=92m and $r_{3/2}$=356 m. Considering the signal to noise ratio there were determined the radii of areas for which the sea noise is mostly influenced with the noise emitted by a ship. This radius depends on the frequency characteristics of a given ship's type and also on the meteorological conditions.

The radius of the ship detection area, for a ship of the shape of the spectrum envelope shown in the figure 1 and for the sea state 2-3 is equal to 3500m, whereas for the sea state 7-8 is equal to 1200 m. The radius of the ship detection area for a ship of the shape of the spectrum envelope shown in the figure 2 and for the sea state 2-3 is equal to 5000m, whereas for the sea state 7-8 is equal to 1700 m.

CONCLUSIONS

The presented results of the ship's noise investigations confirm that it is possible to classify their spectra. The knowledge of the area in which the sea noise is mostly influenced with the noise emitted by ships allows to determine the optimal distribution of detectors in the observed sea region. Further investigations will require more sophisticated methods of signal processing and estimating the similarity between the spectra for determining the characteristic groups of spectra. One of the methods will be finding the functions which describe the spectrum envelopes. The decision of classification of a ship (a ship's type) may be undertaken basing on the decision trees theory applied in the expert systems.

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REFERENCES

1. B.C. Burdik, 1988, Analysis of the hydroacoustic systems, Sudostrojenije, Leningrad
2. E. Kozaczka, W. Kiciński, L. Milanowski, 1995, Experimental investigation of the propagation loss in shallow sea for the small frequency acoustic wave, Proceedings of the XIIth Symposium on Hydroacoustics, Jurata, 169-178
3. D.E. Weston, 1971, Range relation in oceanographic acoustics, Journal of Sound and Vibration, vol. 18, 2, 271-287
4. P. Scrimger, R.M. Heitmeyer, 1991, Acoustic source-level measurements for a variety of merchant ships, JASA, 89 (2), 691-699
5. C.W. Wang, D.P. Wang, R.D. Flood, 1995, Determination of environmental sensitivity of acoustic propagation on continental shelves using an equivalent fluid parabolic equation model, JASA, 97 (3), 1596-1605
6. D.E. Weston, 1990, Singing in shallow-water ambient noise, JASA, 88 (2), 1020-1031