Acoustic analysis of remote-controlled surface and underwater vehicles

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Technological progress has made the use of remotely controlled objects moving on the surface and underwater, for a variety of purposes, become extraordinarily popular. The widespread use of such vehicles enables unauthorized use. Therefore, knowledge of the hydroacoustic field characteristics makes it possible to identify by passive underwater observation systems.

The paper presents the results of narrowband and one-third-octave frequency analyzes of remote-controlled surface and underwater vehicles. The change in sound pressure was recorded for vehicles moving a short distance away from the hydrophone. The research was carried out in difficult conditions, propagation, at a small depth in the coastal zone [1].

Keywords: hydroacoustic, remotely operated vehicles, signatures

1. Introduction

Remotely operated vehicles (ROVs) can be used for different tasks. Especially these activities which are related with entertainment as follows:

- the typical object movement in the open space
- photography and video recording in public areas by devices installed on ROV
- carrying small items that do not threaten security in general.

Presented scope of use vehicles is not a threat to the average user. However this requires analysis when used by unauthorized persons, who may use such facilities for illegal purposes, namely by:

- entering into a closed space
- performing photography and video recordings in private areas without the owner's permission or space excluded from use (military zones, strategic objects) [2]
- moving prohibited goods (smuggling across the border), and security threat (explosive materials, or other from CBRN group – Chemical, Biological, Radiological and Nuclear)

2. Types of remotely operated vehicles

Remotely operated vehicles occur in different types. First division is based on the type of space in which the object moves:

- UAV - unmanned aerial vehicles, commonly called "drones”
- RCV - land-based remote control vehicles
- USV - unmanned surface vehicles
- ROUV - remotely operated underwater vehicles, more commonly called ROVs

Another division from the point of view of typical propulsion solutions is shown as follows:

- Surface with electric engine propulsion
- Surface with two/four stroke engine propulsion
- Surface with jet engine propulsion
- Underwater with electric propeller propulsion
- Underwater with undulating propulsion

3. Real conditions investigation

The studies were conducted in Górki Zachodnie on the Martwa Wisła estuary. The measurement base was placed on the quay. The hydrophone was located at a distance of more than 100 m from the shoreline, at 5 m depth on the bottom. The acoustic wave propagation conditions are difficult due to the small depth of the reservoir [1, 3].

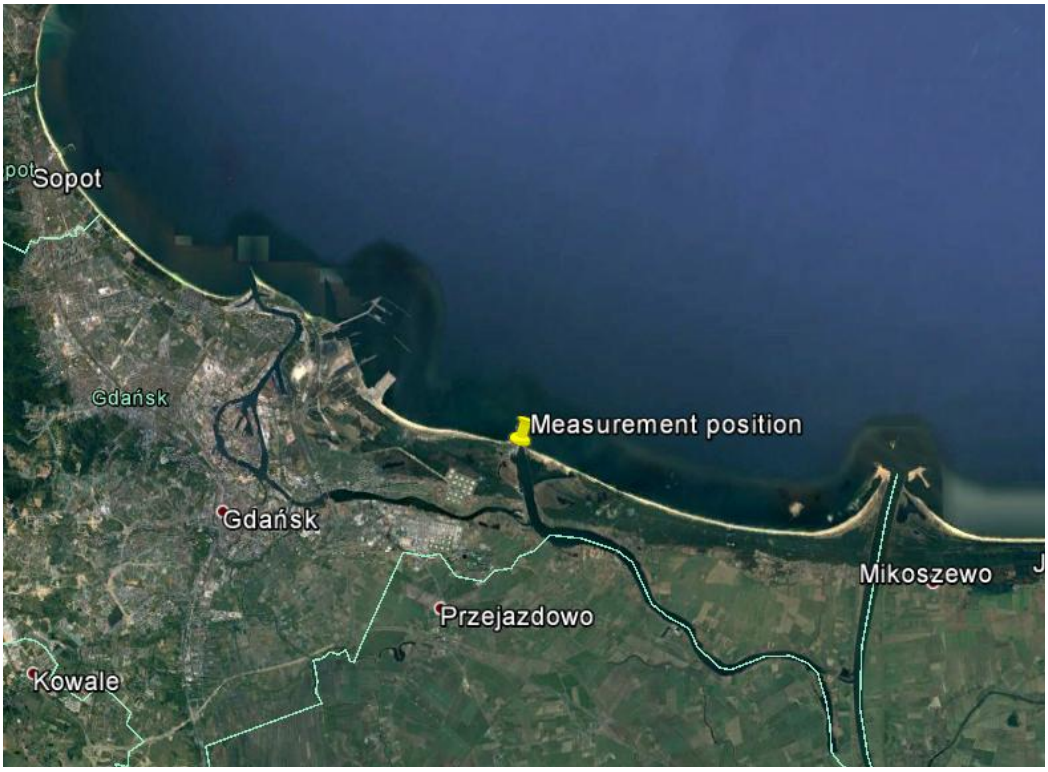

Fig. 1. Geographical position of carried-out measurements.

Fig. 2. Bird's-eye view of the marina in Górki Zachodnie.

The research involved recording the noise coming from moving remotely controlled vehicles. Surface vehicles were moving along a given trajectory from west to east with maximum available speed for each of tested surface vehicles. The trajectory ran through the point that was placed above the hydrophone. This solution made it possible to analyze the noise coming from the smallest possible distance from the sensor [4]. The position of the sensor was indicated by a colored buoy which was clearly visible from the quay. Underwater vehicles involved in the trials were moving a short distance away from the hydrophone due to their low top speed in comparison to surface vehicles [5].

Fig. 3. Measurement system used during trials.

Measurements of the noise generated by moving surface and underwater vehicles were based on a hydrophone with very high receiving sensitivity RESON TC-4032. Signal from sensor was recorded by a recorder equipped with a 24-bits A/D converter. Recorder NI9188 was delivered by National Instruments company together with A/D converter NI9234. Data was recorded with dedicated applications installed on a computer with Windows OS. First one NI Signal Express have made it possible to prepare parameters of signals which will be recorded. Second one application NI Measurements & Automation Explorer have made it possible to properly configure devices used during measurements.

Vehicles used during investigations were divided into two groups connected with the space they move in. In the surface vehicles group two types of vehicles were analyzed. The first one was an electric vehicle. The length is 75 cm, width 20 cm. Its maximum speed is 20 km/h. The second vehicle was equipped with a two stroke engine. The length is 120 cm, width 30 cm. Its maximum speed is 40 km/h. Both surface vehicles were controlled by radio. Pier position facilitated their control within the measurement range of the hydrophone.

Fig. 4. Remotely controlled surface vehicle with two stroke engine propulsion.

The second group of vehicles was underwater vehicles. The first tested underwater vehicle was an undulation propulsion vehicle. Equipped with two side fins (one on each side) and one tail fin. The length is over 1.2 m, the diameter is 30 cm. Its movement speed was up to 5 km/h. The tested vehicle was connected to the operator console to provide power and communication. The second underwater vehicle was a vehicle equipped with 5 electric propellers. Propellers allow the vehicle to move in every possible direction.

Fig. 5. Remotely operated underwater vehicle with 5 electric propellers propulsion.

Acoustical analysis was performed using two different methods [6, 7]. The first one, the narrowband enhances the characteristic frequencies in the band to 2kHz with a resolution of 1Hz. The obtained results allow comparison of the signal character to the results of analyzes of noise from typical surface watercraft, as small as RIB and as large as merchant vessel.

The second method was a one-third-octave analysis using digital band-pass filters with center frequencies corresponding to successive one-third-frequency frequencies. The analysis includes the frequency band up to 20kHz, associated with a maximum sampling rate of A/D converter, i.e. 51.2kHz. Obtained results are given on Figures from 6 to 9.

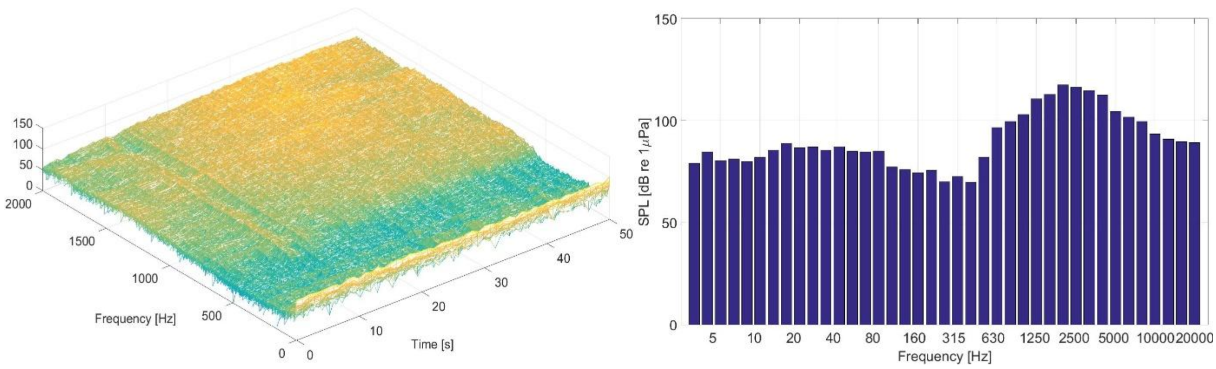

Fig. 6. Spectrogram and OTO spectrum of underwater vehicle with undulating propulsion.

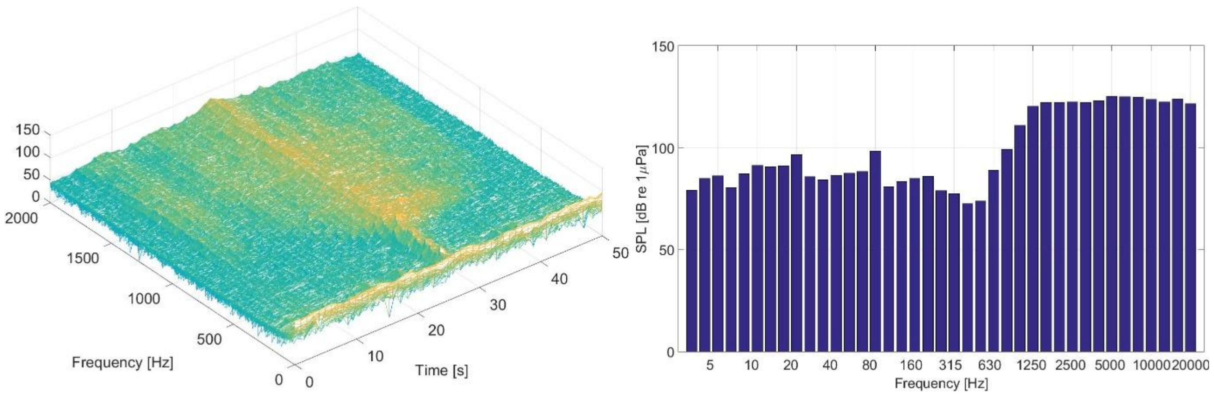

Fig. 7. Spectrogram and OTO spectrum of water surface vehicle with electric engine propulsion.

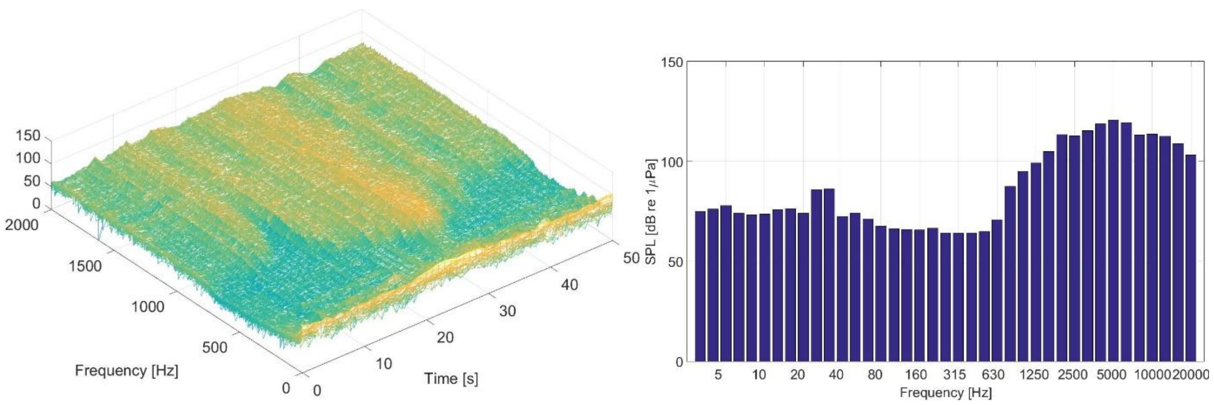

Fig. 8. Spectrogram and OTO spectrum of water surface vehicle with two stroke engine propulsion.

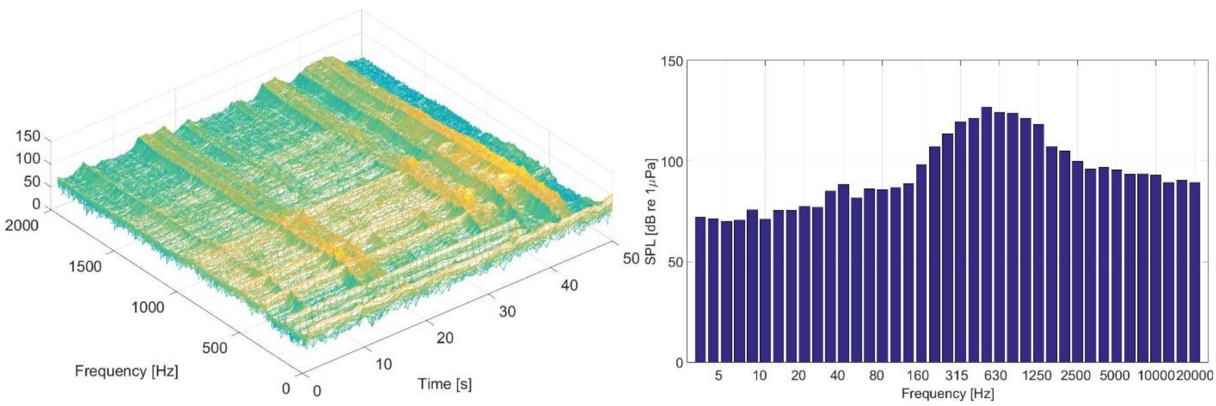

Fig. 9. Spectrogram and OTO spectrum of underwater vehicle with electric propellers propulsion.

Comparison of narrowband spectrum of remotely operated vehicles together with chosen merchant ship presented on Figure 10 shows the possibility to perform classification of different targets.

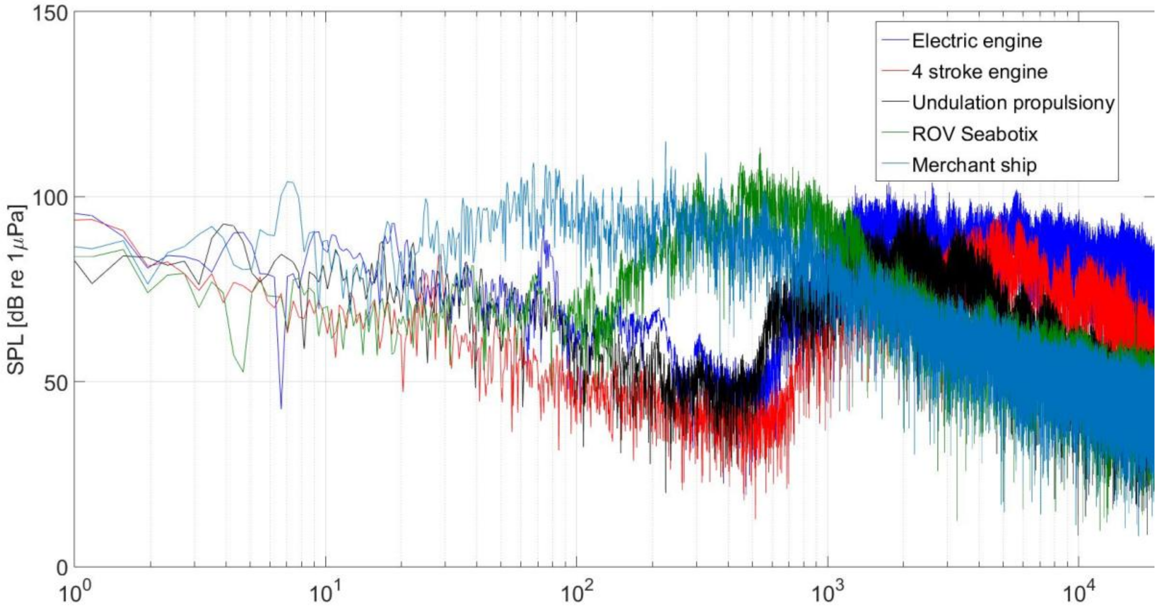

Fig. 10. Narrowband spectrum of different noise sources.

Conclusions

Acoustic analysis of tested vehicles showed the possibility of small object detection moving underwater as well as on the water surface. Remotely operated vehicles equipped with electrical and two stroke engines have similar frequency characteristic.

Investigations which have been made in previous projects of merchant vessels measuring [8] showed that the acoustical signatures of small objects are significantly different. In the point of view of SPL as well as frequencies appearing in the spectrum. These results gives possibilities for different object classification.

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