Influence of protective hydrophone housing on its receiving sensitivity

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The purpose of the carried-out examinations was to verify the receiving sensitivity of the hydrophone placed inside a protective housing. In order to increase resistance to damage, the hydrophone Reson TC4032 has been adapted to work in difficult environmental conditions. Using a comparative method, we analyzed the receiving sensitivity within a predetermined frequency band. The experiment was carried with two hydrophones: the examined one, and a reference one. An underwater speaker with a function generator was used as the sound source. The studies have been conducted in a water tank under laboratory conditions. In situ studies have determined the decrease of the receiving sensitivity of the hydrophone equipped with the protective housing.

Keywords: calibration, hydrophone, protective housing, hydroacoustic monitoring system

1. Introduction

Warships during operations are at risk from the enemy. One of the factors affecting the detection of a ship is generated by noise. It is very important to be able to control its level. The vessel's noise measurement system, mounted on one of the Polish Navy's ships, required the use of a protective housing to protect the sensor during normal operation. The sound part belongs to the most delicate parts of hydrophones. Application of the housing extends the lifetime of the device. This has a big impact on the reliability of the entire system. The system measures the noise generated by the ship, and serves to improve passive defense of the ship. This is a very important element that gives information about the noise level generated by the ship [1-6]. An important aspect of the entire measuring system is to check the impact of the protective housing on the hydrophone's reception efficiency. An incorrectly measured noise level could lead to an erroneous assessment of its actual level, which, in turn, would directly affect the risk to the vessel.

This article first describes the calibration of the RESON TC4032 hydrophone. Next, the results of the studies and their comparison with the results obtained by the reference hydrophone are presented.

2. Calibration of the reference hydrophone

The impact of the housing on the sensitivity of the hydrophone was tested using a comparative method. As a pattern the same type of hydrophone as the tested one was used. RESON TC4032 was supplied by the manufacturer with a calibration report. This report contained the directional characteristics of the sensor and the receiving sensitivity as a function of frequency. The reference sensor, after two years of use, has been sent to the manufacturer for recalibration. The calibration was carried out in the RESON measuring laboratory. Calibration results showed that the average sensitivity in the analyzed frequency band increased by 1.4 dB. The detailed differences are shown in Fig. 1 [7]. Double calibrated hydrophone RESON TC4032 was a reliable reference sensor.

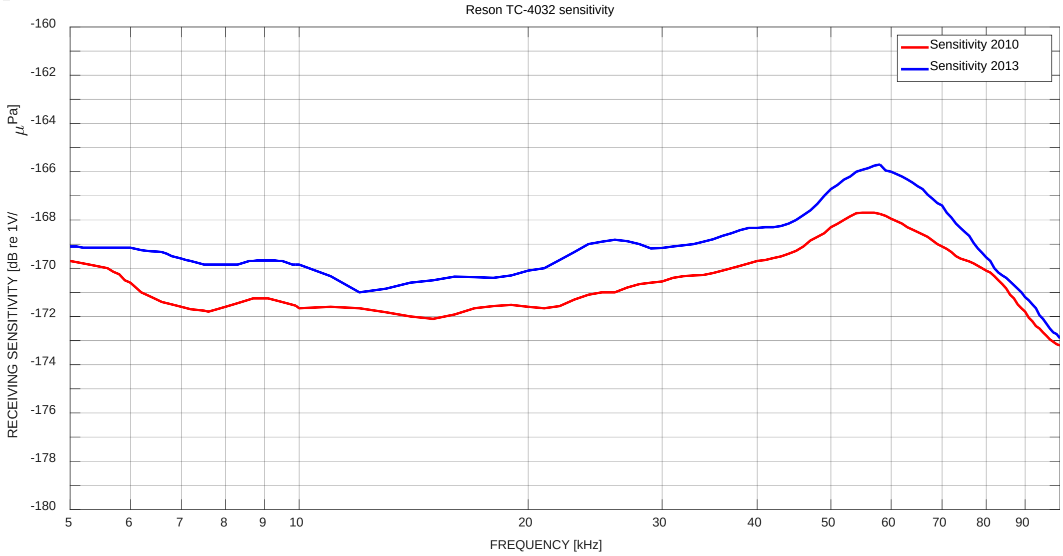

Fig. 1. Calibration characteristics of the reference hydrophone.

3. Protective housing of hydrophone

It was very important to choose a suitable material for the protective housing of the TC4032 hydrophone. Materials were sought resistant to mechanical damage, resistant to seawater and to overgrowth with biomass in water, but at the same time minimizing the attenuation of acoustic waves. After a series of researches it was found that the housing should be made of acid-proof stainless steel. The housing consisted of two threaded elements. This facilitated the assembly and replacement of the sensor. The hydrophone did not occupy the whole space in the housing. The free space was filled with silicone oil. This design was chosen to match the impedance of the acoustic channel. Preliminary tests showed too large a drop in receiving sensitivity. Because of this, the housing was modified. The final product was made according to the technical drawing shown in Fig. 2. The protective housing has significantly increased the resistance to mechanical damage. In addition, stainless steel is not adherent, so it does not overgrow with the biomass just like ordinary steel. Therefore, the housing made of this material was easy to keep clean.

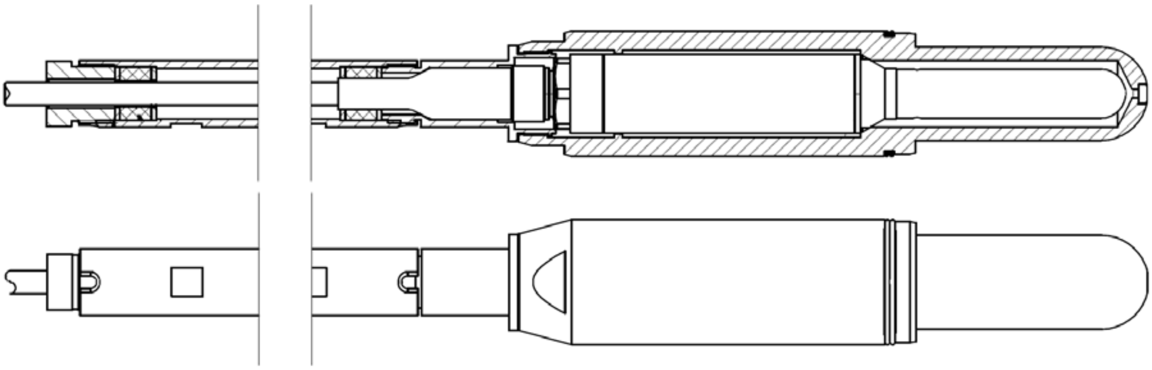

Fig. 2. Technical drawing of the protective housing.

4. Materials and methods

The study was conducted using RESON TC4032 hydrophones enclosed in the protective housing to verify their receiving sensitivity characteristics. Experiments were conducted using a comparative method. As the reference sensor the RESON TC4032 double-calibrated hydrophone, described above, was used. The first (manufacturer's) calibration took place in 2013 and the second one in 2015. The Agilent 33220A function generator connected to the IPA 300T amplifier and the Lubell LL-9642T underwater speaker were used as the acoustic source. The tested hydrophone was connected to the Tektronix TDS 3054B digital oscilloscope. The research was conducted in laboratory conditions in a 140 cm x 120 cm x 83 cm water tank.

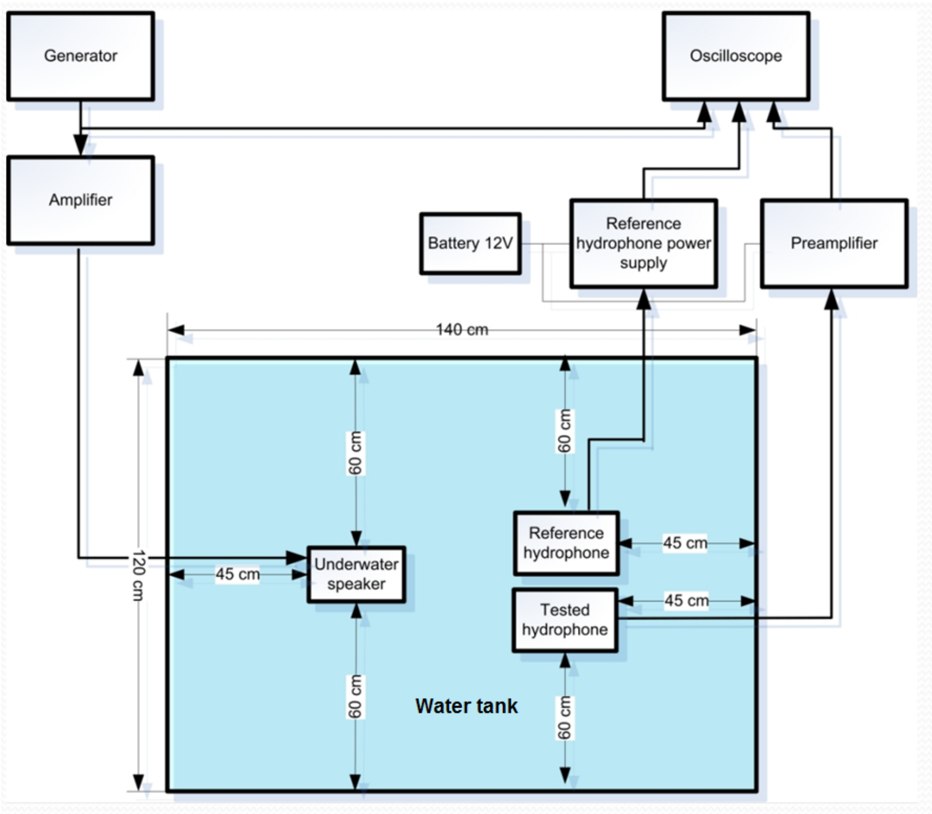

Fig. 3. Block-diagram of devices used for testing the RESON TC4032 hydrophone placed in the housing.

The study was conducted using the comparative method for the frequency range from 5 kHz to 20 kHz with a 0.2 kHz step and from 20 kHz to 22 kHz with a 1 kHz step. Both hydrophones, test and reference were mounted in the positioning system holder. At first, the hydrophones were positioned as shown in Fig. 3. Then, the acoustic pressure generated by the underwater speaker was measured and the receiving sensitivity of the hydrophone determined from the calibration report for the chosen frequency

$$S(f) = 10^{\frac{M_R(f)}{20}}\left[\frac{V}{\mu Pa}\right] = \left(10^{\frac{M_R(f)}{20}} * 10^9\right)\left[\frac{mV}{Pa}\right]$$

where:

S(f) – voltage sensitivity (linear scale)
$M_R(f)$ – receiving sensitivity (logarithmic scale)

appointed the value of pressure on the hydrophones:

$$P(f) = \frac{V(f)}{S(f)}[Pa]$$

where:
P – pressure
V – voltage at the hydrophone output

Then, knowing the pressure measured by the reference hydrophone, the effective voltage at the output of the hydrophone under test was determined as and appointed the receiving sensitivity of the tested hydrophone.

$$S_H(f) = \frac{V_H(f)}{P(f)}\left[\frac{mV}{Pa}\right]$$

where:
S_H – voltage sensitivity with housing (linear scale)
V_H – voltage at the hydrophone with housing output

On a logarithmic scale the efficiency $M_H(f)$ was determined as:

$$M_H(f) = 20 * \log_{10}(S_H(f) * 10^{-9})\ [dB\ re\ 1V/\mu Pa]$$

The hydrophones were placed so that the minimum distance from the reflecting surface was 45 cm (see Fig. 3). With this setting, signals up to 600 μs can be received without reflections. The waveform of generated signals contained 5 sinusoidal periods with the repetition period of 1 s. The selection of the waveform generated and the distance from the reflecting surface allowed the reception of the entire transmitted signal without reflection for frequencies above 8.4 kHz (duration of 5 periods equals 595.24 μs). For frequencies below 8.2 kHz, pulses of 600 μs duration were used to determine the mean value of the received signal.

5. Results

In the first phase of the study, the wall thickness of the housing was chosen to be 10 mm. For this protective housing, the average receiving sensitivity was -187 dB re 1V / µPa. The resulting receiving sensitivity did not meet the design requirements, so the wall thickness of the protective housing was reduced to 6 mm and the hydrophone in the new housing was tested again. After reducing the wall thickness of the housing, the average receiving sensitivity of -181.4 dB re 1V / µPa was obtained (see Fig. 4).

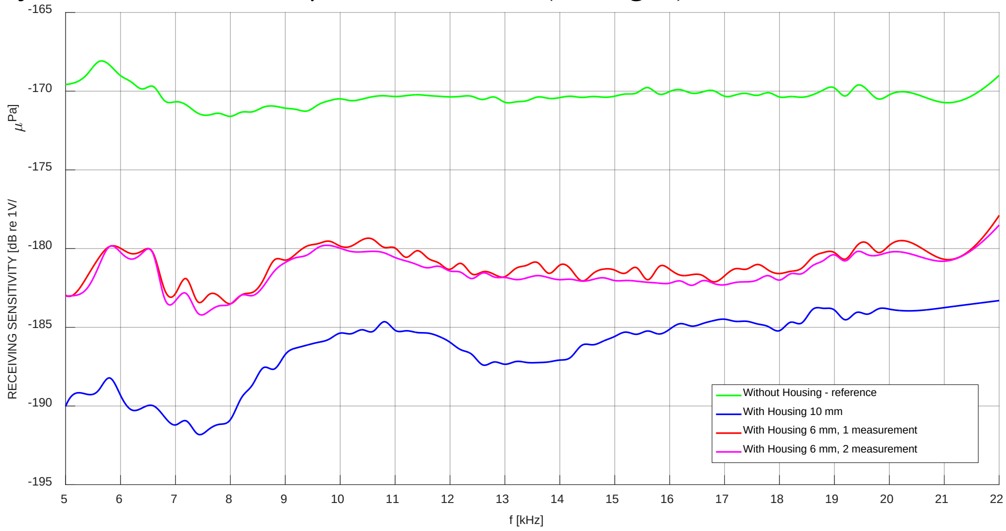

Fig. 4. Receiving sensitivity *vs* frequency for tested hydrophones.

The maximum attenuation caused by the protection housing was 13.5 dB (see Fig. 5) for the lower frequency band. The average attenuation induced by the housing for the entire frequency band investigated was 10.67 dB.

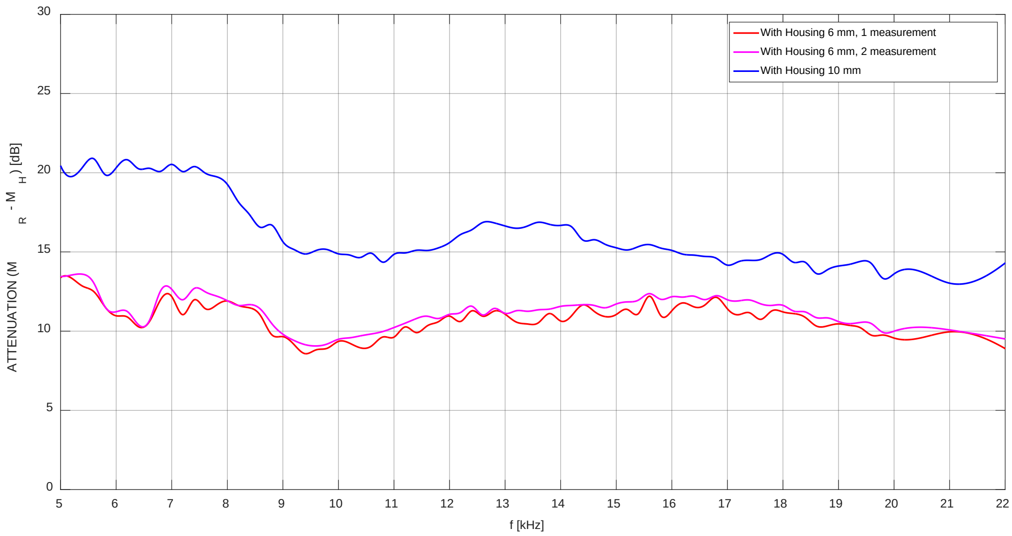

Fig. 5. Attenuation vs frequency for tested hydrophones.

6. Conclusions

Hydrophone RESON TC 4032 in the housing has been verified for proper operation. It has been shown that the tested sensor has a receiving sensitivity of -180.4 dB re 1V / µPa ± 2.7 dB. Lowering the sensitivity level across the entire frequency band is in the range of 8.5 to 13 dB relative to the hydrophone without the housing. Research has provided important information on how the receiving sensitivity varies with frequency in the tested band. The voltage response for the TC4032 sensor in the stainless steel housing with a thickness of 6 mm has met the technical requirements of the ship's noise monitoring system. In this way, a compromise was reached between the sensor performance and its resistance to mechanical damage. The hydrophone placed in the protective housing will extend its service life, which has a direct impact on the reliability of the noise monitoring system. The next step in the study will be to carry out tests by the mobile measuring range, that will enable us to determine whether the hydroacoustic field monitoring system indications fulfill requirements and expectations [8,9,10].

References

[1] E. Kozaczka, G. Grelowska, Shipping noise, Archive of Acoustics Vol. 29, 2, 169 – 176, 2004

[2] I. Gloza, K. Buszman, Signals parametrization method of sailing vessels, Hydroacoustics, Vol. 19, 27-36, 2013.

[3] K. Listewnik, Calculation of the range of ship’s noises influence on the bottom of sea, Polish Journal of Environmental Studies, Vol. 19, 4A, 80-84, 2010

[4] M. Weryk, E. Kozaczka, G. Grelowska, Study of Noise Propagation for Small Vessels, Archive of Acoustics Vol. 40, 2, 267-272, 2015.

[5] K. Listewnik, SOME ASPECTS OF NOISE MEASUREMENT OF SHIPS, Proceedings of 20th International Congress on Sound and Vibration, July 2013, Bangkok, Thailand, pp 4.

[6] G. Grzeczka, K. Listewnik, M. Kłaczyński, W. Cioch, Examination of the vibroacoustic characteristics of 6 kW proton exchange membrane fuel cell, Journal of Vibroengineering, Vol. 17, 7, 4025-4034, 2015

[7] K. Buszman, I. Gloza, R. Jozwiak, K. Listewnik, The calibration of hydroacoustic channel of mobile measurement module, Proceedings of the 2nd International Conference and Exhibition on Underwater Acoustics, 367 – 372, 2014

[8] I. Gloza, K. Buszman, The multi-influence passive module for underwater environment monitoring, Hydroacoustics, Vol. 14, 47-54, 2011.

[9] I. Gloza, K. Buszman, Examination of acoustic wave propagation in real conditions, Hydroacoustics, Vol. 16, 11-18, 2013.

[10] K. Buszman, K. Listewnik, T. Sobczynski, SENSITIVE AND CLASSIFIED DATA EXCHANGE AND HANDLING IN THE EU: A CASE STUDY, Vol. 11, 2, 2015.