EXAMINATION OF ACOUSTIC WAVE PROPAGATION IN REAL CONDITIONS

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Elastic waves are the primary transmission medium in water environment. Acoustic waves are not as strongly attenuated as electromagnetic waves. Sound is used in all kinds of underwater communication systems and sonar devices. Starting from a simple single beam sonar to multi-beam hydrographic echosounders. Thus the issue of the phenomenon of sound propagation in water is the base for understanding the work of underwater hydroacoustic systems[1].

INTRODUCTION

The measurement was intended to compare the results of the recorded signals in real conditions with the equation describing the transmission loss at the seawater [2].

$$TL = 20\log r + \alpha r_1, \tag{1}$$

where: TL – transmission loss, r – distance from the source in meters, α – the attenuation factor in [dB/km], r_1 – distance from the source in kilometers.

1. LABORATORY TESTS

The first test was performed in the water tank sized 1430 mm length, 1215 mm width, and 930 mm high. It was used an audio track as a source, which includes sine wave generator, power amplifier and underwater loudspeaker. In the receiving track was placed a hydrophone at a distance of 1 meter from the loudspeaker. The signal from the hydrophone was recorded on a real-time system communicates with the PC via an Ethernet interface. Application installed on the computer allowed to make changes parameters of the measuring module (in this case a hydrophone), and the recording and data control on the fly by the user. Laboratory diagram of the measuring system is shown in Figure 1.

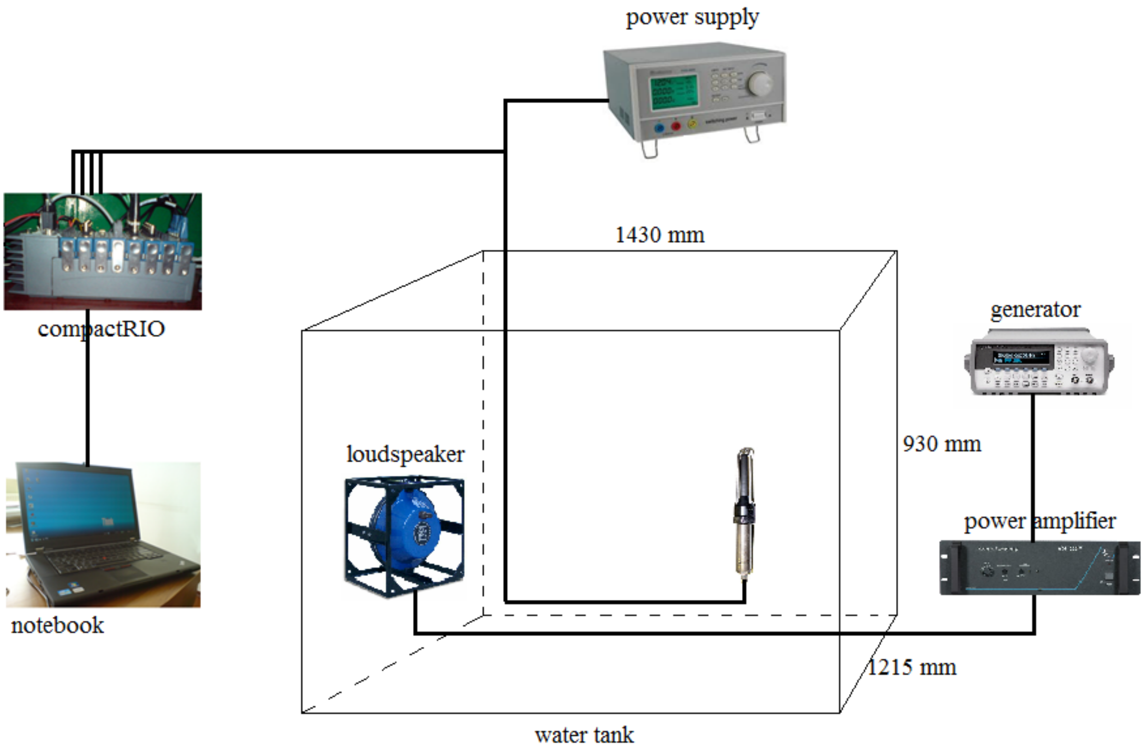

Fig.1. Laboratory diagram of the measuring system.

Characteristics of the frequency response of used underwater loudspeaker Lubell in the axis perpendicular to the speaker is shown in Figure 2. Frequency response characteristics for different angles from an axis perpendicular to the speaker to parallel to the speaker axis is shown in Figure 3.

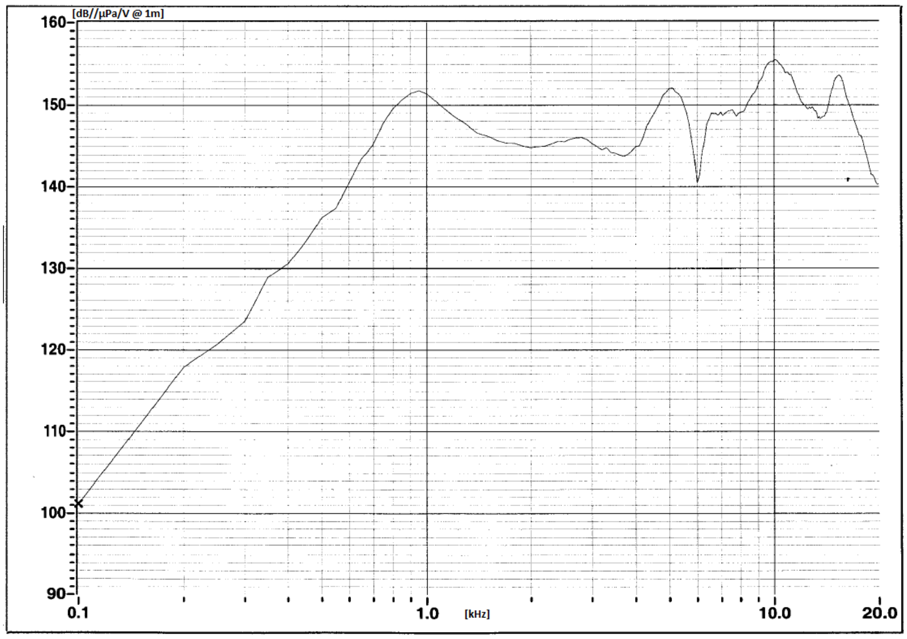

Fig.2. Frequency response characteristics for speaker axis at a distance of 1 m from speaker.

For the central position of the receiver relative to the loudspeaker at a distance of 1 m the recorded signal level difference between the signal of f = 400 Hz and a signal of f = 1 kHz was 21 dB. The situation was slightly different for the location of the receiver other than the central position relative to the speaker. However, small differences can be seen for f = 400 Hz, and for f = 1 kHz there are no visible changes.

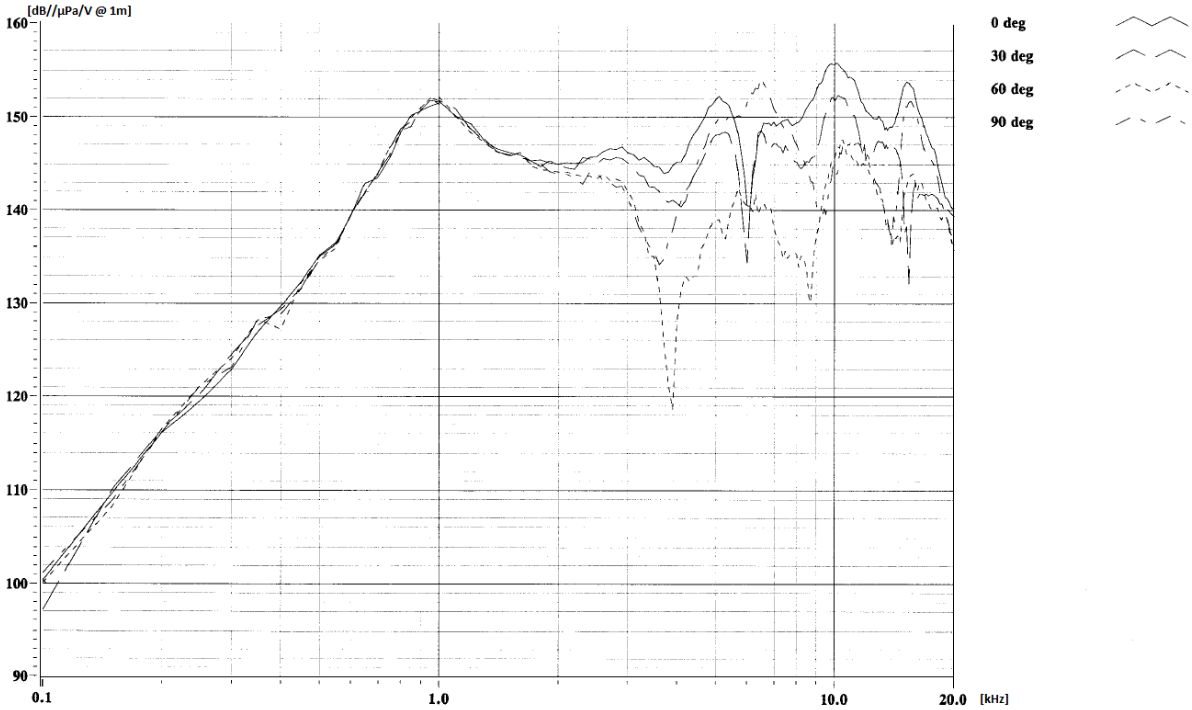

Fig.3. Frequency response characteristics for different angles at the distance of 1 m from loudspeaker.

In laboratory tests, the signal was generated at 400 Hz frequency using the function generator. The peak-peak voltage value of signal next to the power amplifier was 45 V. For a signal with a frequency of 1 kHz and the same amplitude settings on the generator and the power amplifier gain the voltage was 44 V. The level of recorded signal at the frequency 400 Hz was 161 dB, whereas at 1 kHz the level was 184 dB at 1 meter from the loudspeaker. The difference in the values due to the frequency response of the speaker [3]. A hydrophone Reson TC-4032 was used as a receiver from the same series, which was used in marine research. The calculations take into account the voltage sensitivity for a particular model as supplied hydrophone calibration note.

2. MARINE MEASUREMENTS

Destination tests were carried out on the German range in Aschau in the Eckernfoerde Gulf (Figure 4).

Fig.4. Designation of marine research in the satellite photo.

In the marine research was used the same test track as in the laboratory. The whole transmitter part was placed on motorboat, which was located directly above the measuring module placed on the bottom [4]. In this way hydrophones were placed in a horizontal plane at a depth of 23 m directly under the boat. The real tilts of the measuring module were controlled during measurements using the motion sensor. Hydrophones were placed at the vertices of an equilateral triangle with a side length equal to 25 cm. The loudspeaker was under the boat at a depth of 2 m. Location of motorboat relative to the measuring module was determined with an accuracy of 1 m. There was used underwater navigation system with ultra short base to precise positioning of the measuring module. There was affixed transponder with underwater battery on the measuring module enclosure, while at the motorboat was installed transceiver with GPS. The boat was moving at low speed, and at that time underwater navigation software has recorded the results of the position of the measuring module with the transponder relative to the transmitter on motorboat (Figure 5).

Fig.5. Underwater navigation system for the measuring module positioning.

After a few recordings there was verified the location of the measurement system using a remotely operated vehicle (Figure 6). The motorboat was placed at a specific position as indicated in underwater navigation and then the vehicle was placed into the water. After descending to the bottom it was confirmed the correct place of the system on the bottom, and also there was verified the physical state of the module.

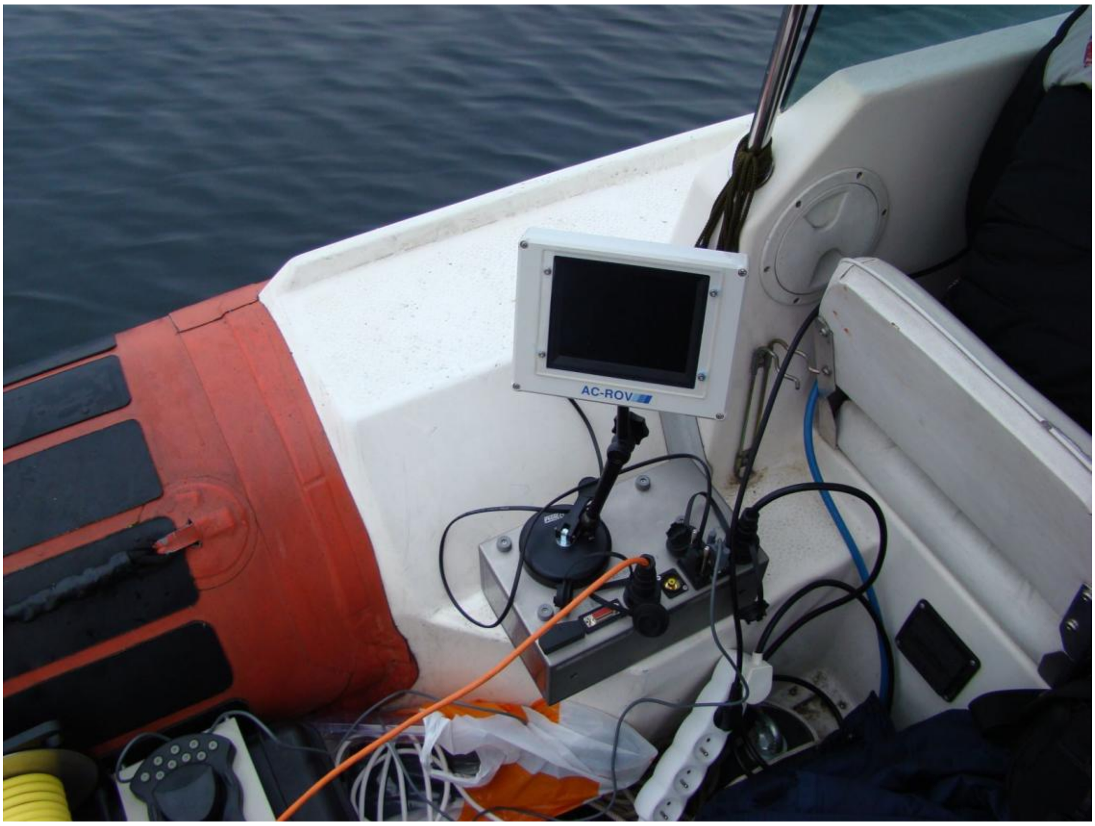

Fig.6. Control panel of remotely operating vehicle.

The tests were performed for continuous harmonic signals with a frequency of 400 Hz and 1 kHz. Frequency response for used underwater loudspeaker allowed tests for such frequency values. Besides, as known to lower frequencies are less attenuated in the water. The limit of the near field of the tested frequencies are properly 3.75 m at 400 Hz and 1.5 m at 1 kHz and the speed of sound c = 1500 m/s. In practice, it is assumed that the far field begins at the distance from the source is not less than the wavelength or not less than twice the largest dimension of the source. In the space between the speaker and the receiving antenna there was not any obstacle that would introduce changes in the propagation signals tested in water.

In the first phase there was generated a continuous sinusoidal signal with a frequency f = 400 Hz and the same amplitude as in a laboratory test. The measuring module received this signal by three hydrophones and transmit data on the fly to the operator console located on coastal station. The operator recorded signals on the hard drive and watched all the changes on the computer screen. Results of the collected data processing in the form of narrow-band spectrum in the band from 100 Hz to 1600 Hz are shown in Figure 7.

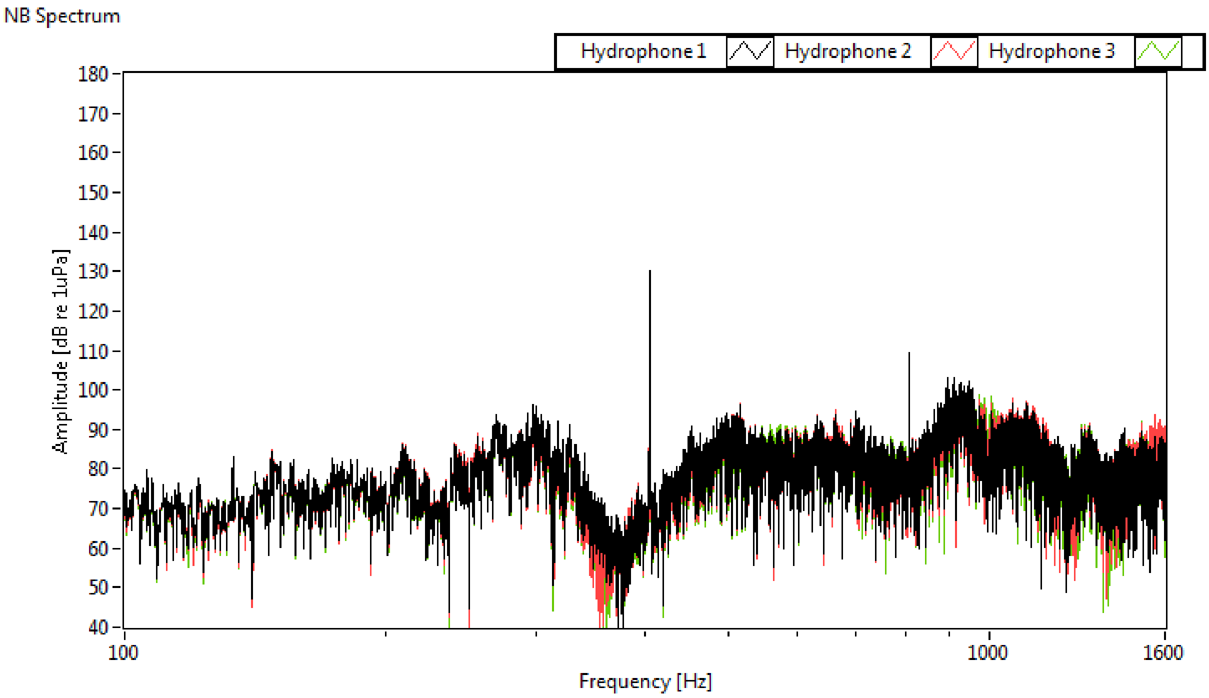

Fig.7. Narrow-band power spectrum of the received signal for f = 400 Hz.

Another form of presentation data recorded in marine research is One-Third-Octave spectrum of the same signal (Figure 8). Both spectra were obtained using the same settings for the fast Fourier transform.

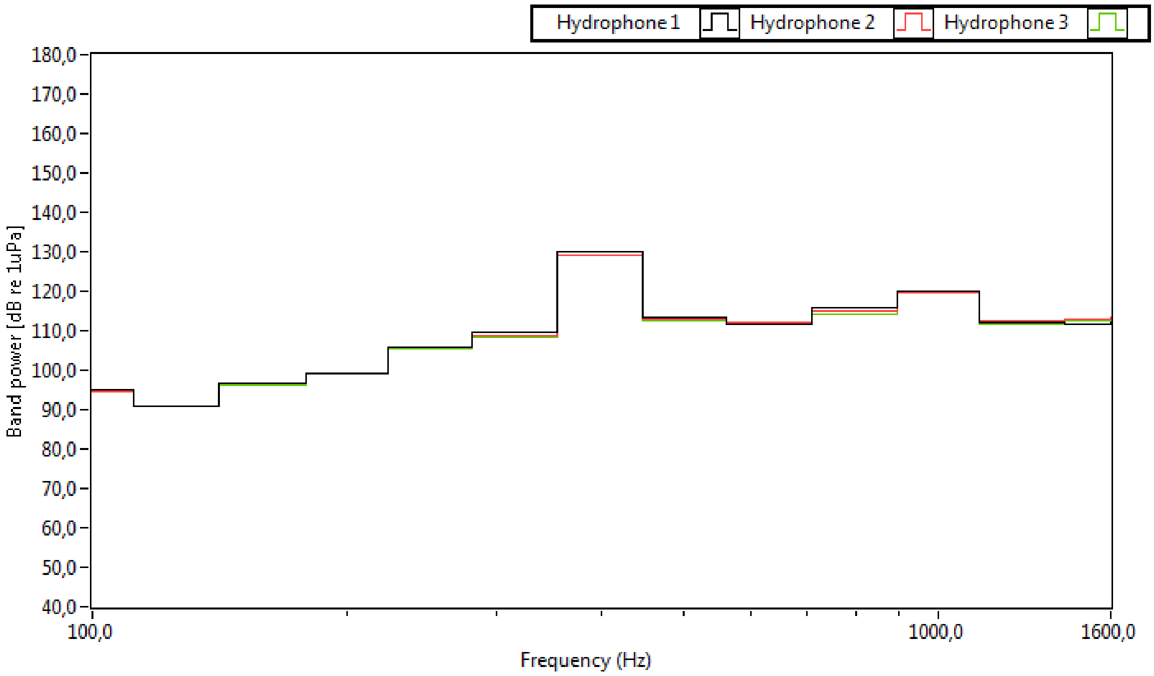

Fig.8. One-Third-Octave spectrum of the received signal for f = 400 Hz.

After recording the signal of lower frequency transmission path settings were changed. In this phase there was generated continuous harmonic signal at a frequency of 1 kHz and the same amplitude as in the laboratory measurements. An important element of the study was an accurate representation of transmitted signals parameters, so before start recording there was verified peak-peak voltage values of the signal on the loudspeaker terminals. Narrowband and One-Third-Octave spectra for 1 kHz signal are shown in Figure 9 and Figure 10.

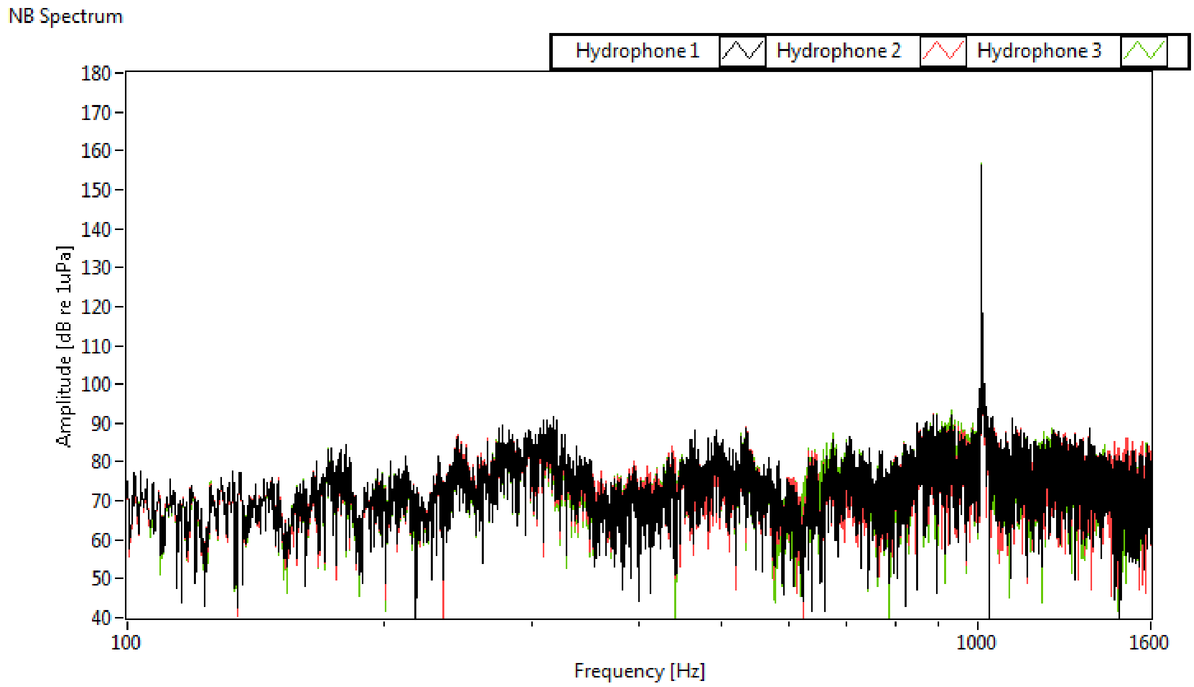

Fig.9. Narrow-band power spectrum of the received signal for f = 1 kHz.

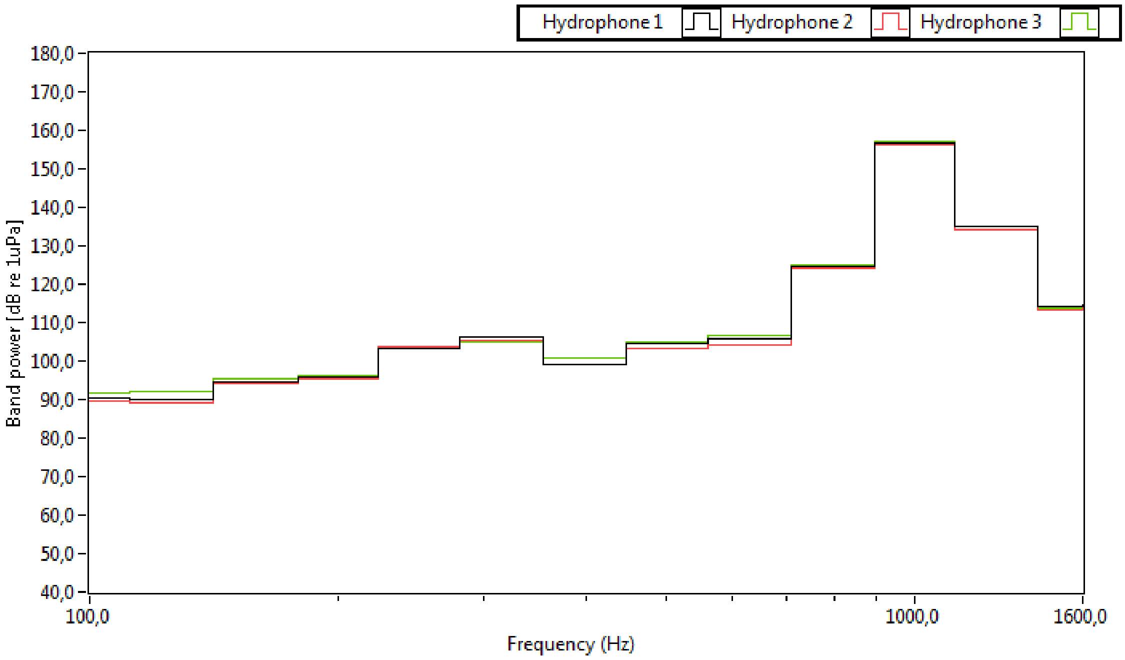

Fig.10. One-Third-Octave spectrum of the received signal for f = 1 kHz.

Using the formula for transmission losses in water medium there was theoretically determined attenuation value. For the distance between the hydrophone and loudspeaker of 21 m attenuation value was approximately 26.5 dB. For a distance of 20 m taking into account the position of 1m from the source attenuation is 26 dB. Attenuation related to the frequency both the first and second signal on the test distance is negligibly small because it is approximately 0.1 dB. For a harmonic signal with a lower frequency the level value was 132 dB. For a harmonic signal with a higher frequency the level value was 156 dB. Taking into account the calculated attenuations results were as follows:

for f = 400 Hz: SPL = 132 dB + 26 dB = 158 dB,
for f = 1 kHz: SPL = 156 dB + 26 dB = 182 dB,

As a result of these measurements, a slight difference occurs between the laboratory and the sea trials (3 dB at 400 Hz and 2 dB at 1 kHz, respectively 1.9% and 1.1%). This difference, although a small value may result from the media differences and laboratory tests which were carried out in the near field.

ACKNOWLEDGMENTS

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