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SHIPPING NOISE

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The aim of this paper is to present the result of the experimental research associated with the transmission of acoustic energy generated by a moving ship and its impact on the marine animals. The methodology of evaluation of the transmission of vibration energy from the ship's mechanisms into the sea environment is given and some examples of underwater characteristics of ship's noise are shown. All of these characteristics should reflect individual features of the source that is a moving ship or a warship. Knowledge of them gives information what steps should be undertaken to obtain specified characteristics of the source. Besides, the characteristics allow to assess, which factors are the most disadvantageous to the surrounding and whether their reduction is possible without changes of operational variables of the ship.

1. Introduction

Problems of generation and noise control in air are in general outline well recognized, and in certain cases noise limitation gives satisfying results. Because of direct disadvantageous influence of noise on man, noise control is topical and stimulates activity of State and NGO organizations. Their main goal is the diminution to minimum of impact on man of undesirable vibroacoustical effects.

We are confronted with considerably worse situation in water environment. Binding law of particular states or the EU Directives concerning care for natural environment lack clear rules forcing owners of technical devices to limit the level of underwater noise.

The only exception, however loosely connected with care for natural environment, is the limitation of underwater noise produced by warships. Military techniques utilise phenomena of generation and propagation in water of the acoustic waves produced by ships, for monitoring their movement in a fixed sea area with the possibility of their classification and identification [4]. This fact forces the users of military equipment to

lower noise produced by their individual ships in limiting case to spectral level of the environmental noise. Besides, in use also are various manners and methods of changes in time and spectral structure of ships' noise so as to make their immediate classification and detection difficult or even impossible.

Taking into account that this paper does not deal with military utilization of noise produced by ships and other underwater sources, we shall pay our attention mostly to quantitative characterization of this noise with indication on its disadvantageous influence on natural underwater environment. It is commonly known, that impact of noise on organisms living in water is harmful, similarly to that of noise in aerial environment on any living organism, not only on man.

Though the formal interest in the kind of impact noise has on life of underwater organisms is casual and incidental, it is well known, for instance in the case of migration of shoals of fish caused by movement of hunting-ships. Also not seldom in popular science press are found reports on reasons of anomaly behaviour of sea animals.

We were informed several times recently that unexpected swimming out of whales onto nearby beaches at sea coasts of Mexican Gulf has been observed. This caused mass-deaths of these marine mammals facing extinction.

As one of the basic suggested reasons, were the devices used for echo-ranging during navy exercises. This assumption can be of essential cognitive value, since it may happen that signals radiated by sonars would show certain resemblance to locating signals produced by whales.

The essence of the matter is not fully explained. Instead undisputed is the fact, that acoustic signals, especially those of high intensity have a detrimental impact on life and normal development of sea fauna. Because additionally sea-organisms use acoustic signals for mutual communication and also for environmental observation, the influence of noise in this respect is of disadvantageous and sometimes even destructive character.

2. General characterization of noise produced by ships and warships

Among acoustic waves produced by ships and warships could be distinguished those, which are closely connected with maintaining navigational parameters, that means with fixing stationary or dynamic position of the ship [1].

This noise is produced mostly by driving and auxiliary systems. The noise level depends mainly on resistance putting up by the environment to the moving object, what usually is connected with forward speed or rapid change of acceleration in case of manoeuvre movements. Apart from that to increase the safety of shipping echo-locating systems are used, that allow to detect stationary and moving navigational obstructions, to determine the depths of the reservoir and to evaluate the speed of a ship.

Besides, ships, depending on their character, are equipped with underwater detection systems, known as sonars, which additionally increase underwater noise radiating acoustic impulses of very high peak values of acoustic pressure.

Ships used to investigate properties of water environment, and in particular those of the sea-bottom, have a special influence on underwater noise level, though incidental in the total scale. In those researches generally are applied sources of impulse character (known as boomers) and also all kinds of underwater explosions and electric discharges.

This kind of generation, which could be compared to action of pressure waves in the air (shock-waves), is in our opinion, most harmful since, because of low compressibility of water, effect of these waves is very intensive.

There are also destructive disturbances of continuous or impulsive character, that appear in case of research determining the properties of the medium by means of underwater nonlinear sources. So, just as in case of infrasonic sources in the air, disturbances produced by parametric sources in water can have adverse impact on the environment.

It remains to underline distinctly, that noise propagates in water to considerably greater distances and with considerably lesser losses than it takes place in the air [6]. In effect, local strong extortions are no longer local as regards interaction. Besides, reverbrational effects, in bulk as well as surface, boost these adverse effects.

It also has to be noticed that there exists a certain other phenomenon, which is usually associated with positive propagative features of sea, namely the creation of acoustic channels, through which main part of energy propagates almost without losses. If for instance, such channel will be situated in such a way, that noise caused by technical and military activity of people will get into its area, and at the same time the area of habitual staying of marine animals will be included in this channel area, life of the animals in this area beyond all doubt will be disorganised, and its dynamics will depend mainly on character and level of noise.

Turning ourselves to classic classification of noise produced by ships [5], it is possible to segregate them into:

- noise generated by devices active dynamically placed inside and on the surface of the hull, mainly by engines, propulsion and auxiliary, and system of transport of mechanical energy-shafting,
- noise produced by ship propellers,
- acoustic effects connected with cavitation of propellers and flow around the underwater part of the hull.

3. Characteristics of underwater noise radiated by the ship

At the law speed of ship, the ship's auxiliary generator is the main source of the underwater noise generated by ship [3]. It radiates tonal components that contribute to almost all of the radiated noise power of the ship. They are independent of the ship's speed. Few of components are strong enough to be contributors to high-speed signature. The tonal levels of ship's service diesel generator are nearly stable in their amplitude and frequency. The wide-band energy of the noise generated by ship's auxiliary generator is proportional to the square of generated power.

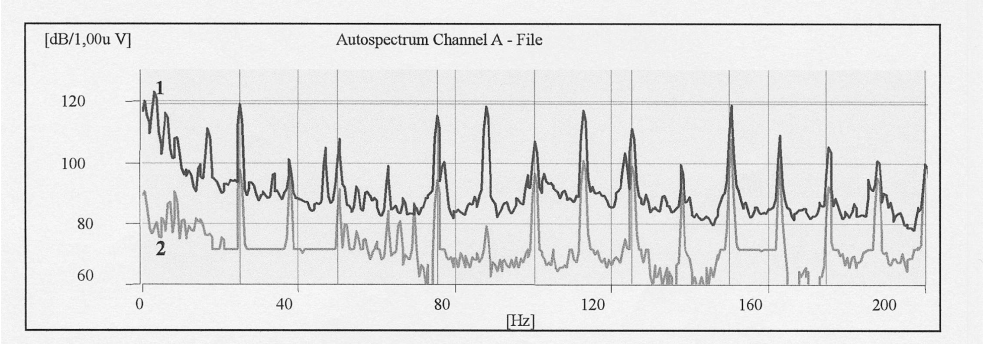

Fig. 1. Characteristics of underwater noise at the low speed of a ship: 1 – spectrum of the underwater noise, 2 – spectrum of the acceleration of the auxiliary generator.

At the higher speed of ship in the spectrum of the underwater noise appear discrete components that could be associated with mechanical activity of propulsion engines as well as propellers. They are mainly noticed in the frequency range up to 100 Hz.

The propulsion engine is a main source of underwater noise for a moderate speed of the ship. The tonal components are connected with firing rate. The tonal level is not stable in general because of variations of loading the propeller for different sea state. The radiated power at the fundamental firing rate frequency is related to engine horsepower and can be estimated up to 0.1% of the total engine power. Analyzing the vibration energy caused by diesel engine that is converted into acoustic energy one should take into account the possibility of occurring structural resonances as these may play a great role in determining the radiation efficiency of the ship's engine tones.

The most efficient underwater noise source of the ship is the propeller. One part of its noise is connected with blade rate, This signal and its harmonics make usually the dominant contribution to low frequency tonal level at high speeds of the ship [2].

Frequencies of spectrum components in the low range, connected with activity of propulsion engine and propeller, changes with speed of the ship because they depend on rotational speed of mechanisms.

Besides, at higher speeds, a broadband noise covering approximately range from 100 Hz to several kHz accompany the motion of a ship. It is connected with phenomena of cavitation on the propeller and flow around an underwater part of the hull. The features of the spectrum in this frequency range are also influenced by factors depending on speed of the ship, as for instance setting of propeller, progress in cavitation, etc.

4. Measurement methods and facility

The best location for the measurement facility, used in evaluation of hydroacoustic characteristics of noise radiated by classical ships as well as underwater ships, is in places where the ambient noise is the smallest and the depth of sea is high enough that the bottom could be treated as reflectionless.

As sensors of acoustic pressure are used vertical and horizontal arrays of hydrophones mounted so that impact of environment motion, especially waved sea surface is minimalized. Signals from acoustic transducers are transmitted to the registering and analyzing laboratory. On the basis of the result of these measurements [4], a set of characteristics that determine individual distinctive features of the examined source is obtained.

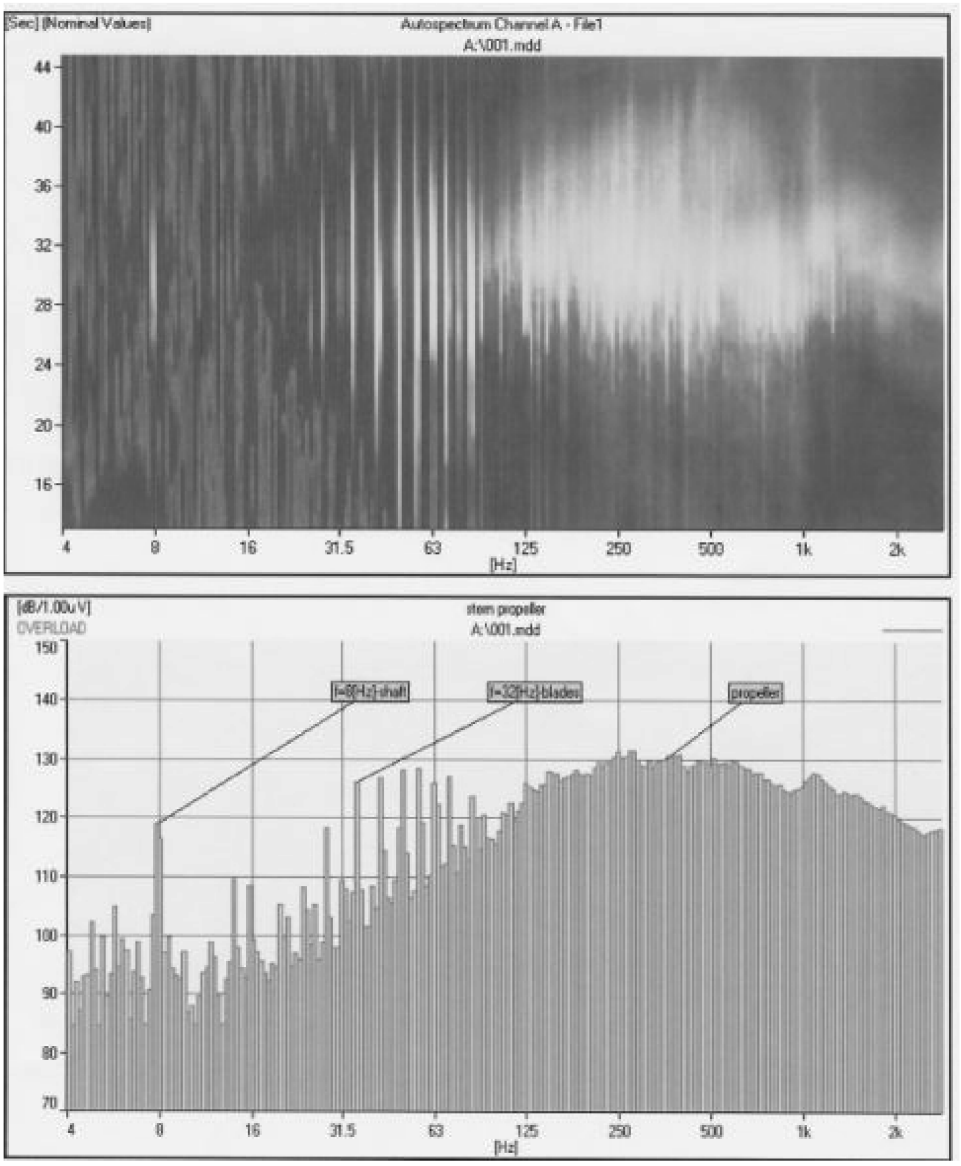

Fig. 2. Spectrogram of the underwater noise of a ship moving with a moderate speed and its instantaneous spectrum.

The set of characteristics contains among others: instantaneous spectra of underwater noise of the ship, characteristics illustrating changes in pressure level with the distance from the ship at fixed depth, set of correlation and coherence functions and directivity patterns.

Moreover for each measurement are determined spectrograms, that combine features of spectral characteristics and functions connected with changing of position of the source relatively to the receiving antenna.

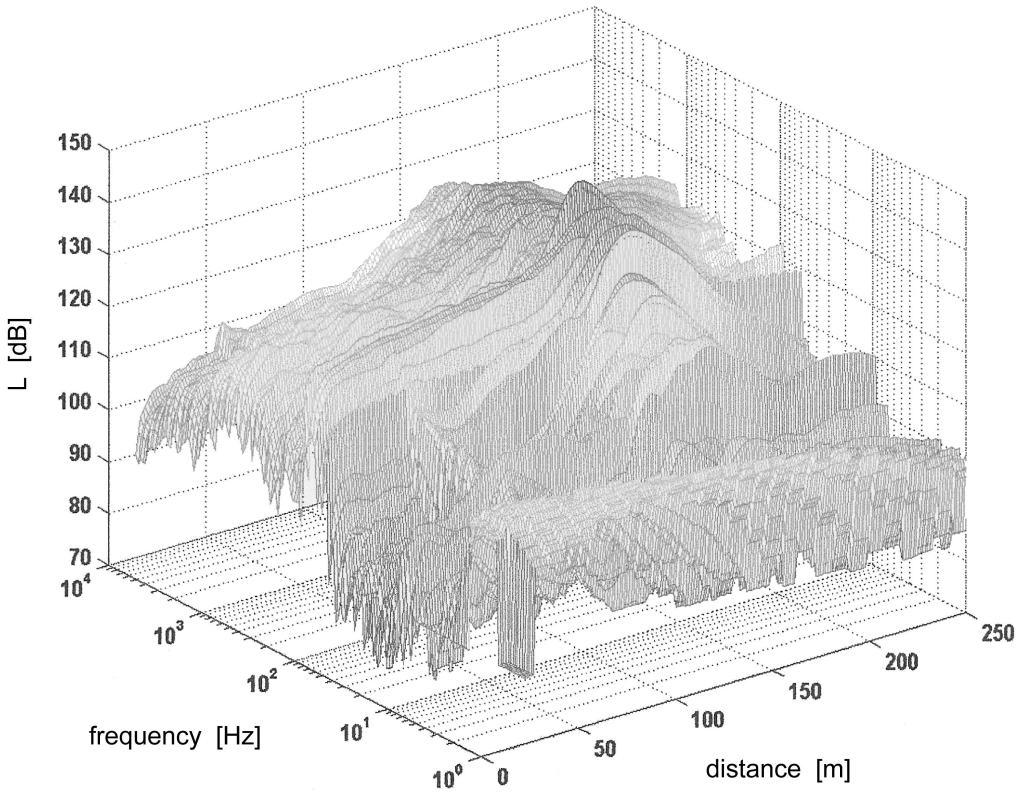

Fig. 3. Underwater noise spectrogram in 3D form.

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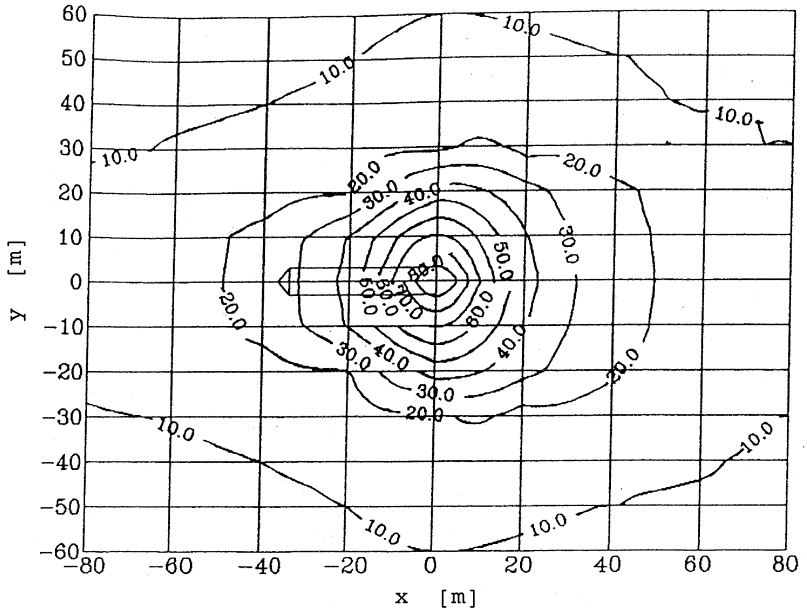

Fig. 4. Directivity pattern of the underwater noise radiated by a ship.

5. Noise produced by sonars and other devices used in underwater environment

This type of noise is mainly of pulse character, while pulses are usually modulated in amplitude as well as in frequency and phase.

As we depend on relatively big range of these devices, instantaneous power of pulses is relatively big, considerably greater than power of underwater noise produced by propulsion machinery in the frequency range used by sonars, respectively. Though their energy is considerably smaller, however the pulse character, particularly strong impulses, evoke vague feeling of threat interpreted by marine animals, that happen to be in the way of the impulse, as a direct impact of wave of pressure towards their body, and thus cause spontaneous escape from the affected areas.

If on top of that the mechanism of a location organ of an animal can come within the range of frequency with the echo-ranging device, then in the course of panical escape wrong estimate of parameter of the reservoir can take place. The fact of false estimate of communication position by the leader of the herd can worsen the situation additionally, and eventually lead to the extinction of the whole herd.

6. Conclusion

Noise is a domain related to adverse impact not only on human beings, but it enhances also wide area of biological life in the air as well as water environment. Hitherto the existing legal normatives do not concern normalization of noise and definitions of its

admissible values in water environment. It leads to the conclusion, that human attitude towards their behaviour on waters and on seas should be object of similar attention as it has in the area of counteracting the adverse impact of noise on human organism.

The earlier we begin to introduce due legislature normalizing our activity in the seas and inland reservoirs, the greater chances that our true sense of common supreme good that is life on earth will be maintained, in the full meaning of these words and friendly conditions for life of not only human future generations but whole life on the planet called earth will be preserved.

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