THE OLD AND NEW PROCEDURES FOR THE INVESTIGATION OF UNDERWATER SIGNATURES

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This paper presents the results of old and new techniques for the investigations of underwater acoustic fields radiated by different objects. In the Navy Test and Evaluation Ranges (NTER), we monitor the ship radiated underwater noise, pressure and other signatures. They are of major importance to sea mines, surface ships and submarines. The NTERs contain an accurate measurement system consisting of a bottom-mounted hydrophone array, which is used for different running vessels. We also have a special laboratory ship and a transportable multi-sensor module, which is the most recent Polish Naval Academy product. Nowadays, the problem of protecting the civilian and military harbor facilities is becoming more and more important. There is always a threat to the ports from submarines and terrorists who dive under the water.

INTRODUCTION

For more than thirty years, extensive research and development have been carried out on physical field measurements to control them and to decrease their levels to a minimum. A significant progress in knowledge and improvement in techniques have been realized over these years. As a result, it becomes more and more important to consider new digital techniques, particularly in the design stage.

Specialists conduct vessels' measurements very often both statically and dynamically, sometimes with ships moving from very slow run to their full speeds. The vessels under test are arranged to run at a constant speed and constant course. Stationary trials, with ships or submarines moored to buoys, enabled to detect the acoustic contributions of a particular machinery system to be estimated. Some years ago during such measurements analogue broadband tape recordings were made. After some time these recordings have been subjected to analysis with different frequency bands.

As a result, those methods of measurement of the rotational and translation components of the vibration or structure borne sound levels on a stationary vessel and a moving ship were a mixture of analogue and digital techniques. When the ship was rigid, two hydrophones were hanging beneath its bottom. Several shakers were installed; in this way we created on-board vibration plus underwater noise-analyzing systems. Methods of determining an acoustic field generated by a surface ship from regular vibration distribution are not complicated, but some difficulties can be caused by irregular vibration sources.

Currently, the transportable multi-channel module was manufactured by the Naval Academy personnel. This new, compact, flexible, equipment can be launched and recovered from the small support vessels, the size of a big boat.

Another reason for such research is the effect of the noise from naval and merchant ships into the biological environment, because noise from ships elevates the natural ambient sound by 20–30 dB [1].

1. THE OLD AND NEW METHODS OF MEASUREMENTS

Extensive experience is needed during measurements and in order to reduce the signatures of radiated noise. Earlier analogue, now digital advanced acoustic analysis systems enable data to be analyzed on-line; so that results are quickly available. Wherever noise measurements are undertaken, experienced acoustic range staff organize and conduct the evaluation program and analyze the data. Next the experts have to interpret the results, diagnose each problem and report the findings with recommendations.

Firstly we conducted 1/3 octave analysis, some time ago the Navy initiated a new program for accurate and very narrow-band analysis of ship's noise. The recordings were carried out by means of the array or using the special module with hydrophones. Previously several hydrophones were strung in a line along the bottom in shallow water. The depths were from 10 to 60 m. Now we measure in the fixed acoustic range or we can put the module to measure the physical field everywhere.

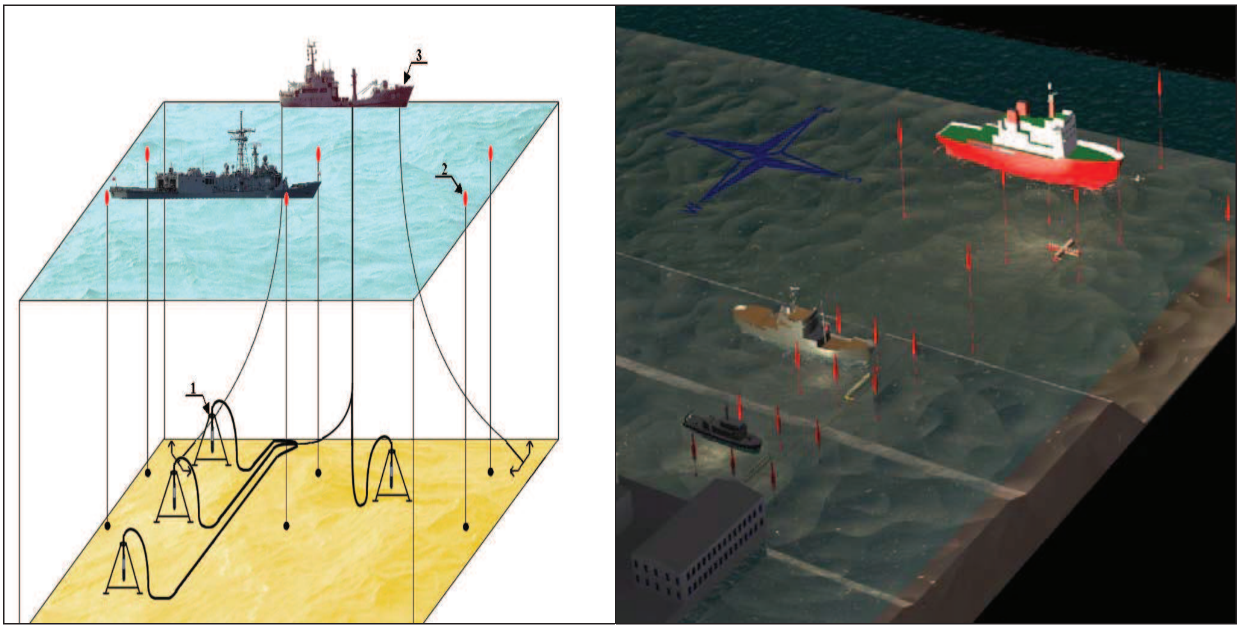

Fig. 1. The old and new methods of acoustic measurements at ranges

After the measurement contributions of the individual machinery system is assessed, and the effectiveness of noise reduction program can be determined. In the past the analogue sound pressure levels were recorded and analyzed. Currently, because of small sea depths, the sound intensity program is created. This phenomenon was explained in many publications [2, 3, 4, 5].

On the basis of these results, we determine the maximum values of the sound pressure levels (in analogue way – old method, digitally – new method) for different speeds of ships. It is shown in figure 2. The vessel under test is arranged to run at a constant speed and a constant course to receive a measurement at a known distance and time.

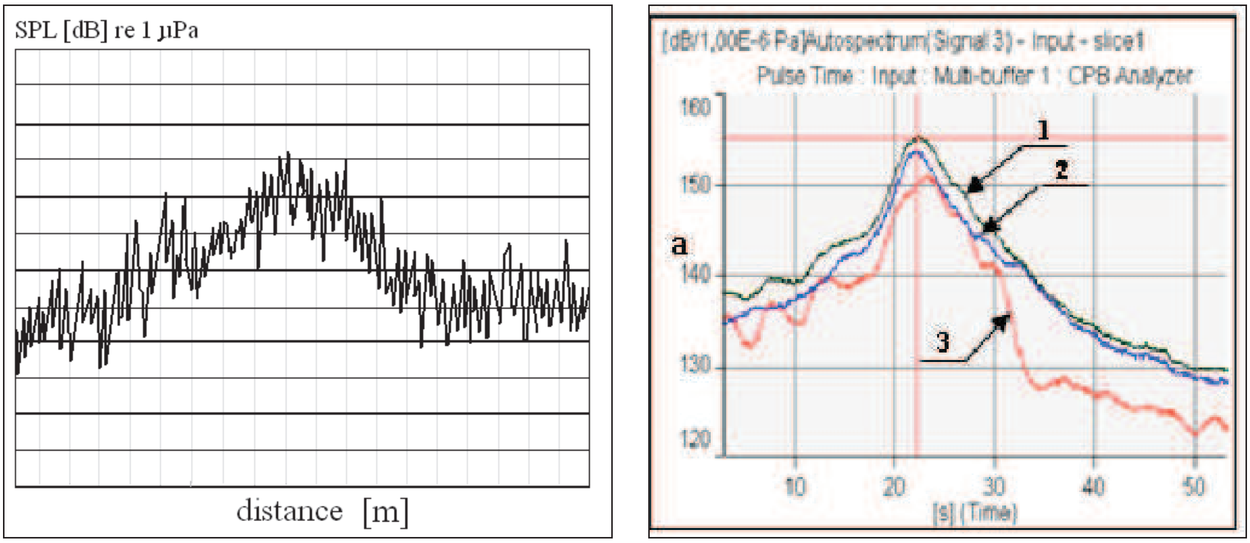

Fig. 2. The sound pressure levels recorded by using analogue (left) and digital technique (right)

Some years ago the ship was often rigid, several hydrophones were hanging beneath ship's bottom and quite a few shakers were installed; in this way we created the on-board vibration plus underwater noise-analyzing systems. All was documentation on a magnetic tape recorder.

At the present time, we can use for acoustic and vibration measurements the real-time digital frequency analyzers, that have less than 0.1 Hz narrow-band bandwidth filters. This advanced acoustic analysis system enables data to be analyzed on-line, so that effects are quickly available.

At low ship speeds, discrete component lines of the spectrum nearly almost always originate from the ship's diesel generator [1]. The main component is a strong discrete line at 25 Hz; also the most characteristic component is the peak at frequency 50 Hz. These components correspond to the basic frequencies of the European ships' electric generators. The AC power line frequencies (harmonics of 50 Hz) are distributed throughout the whole spectrum of the vessel noise [5, 6].

In the past, there were a lot of 1/3 octave spectra recorded. Now we have very narrow spectra successfully registered up to several harmonics of basic frequencies. Some of these harmonics are strong enough to be contributors to both the low-and high-speed signatures.

In figure 3 (right) there are presented clearly visible some characteristic spectral components, which are reflecting both the frequencies and levels of work of the main propulsion systems and the auxiliary machinery. These tonals are located in the frequency band up to about 100 Hz.

Because we are going to determine spatial distribution of the hydroacoustic energy it is necessary to know vibration velocity distribution of the acoustic wave sources. Therefore we establish the vibration velocity distribution on the surface of ship's hull and inside vessel (on the engine frame and the hull's plating).

In figure 3 (left) we can see different underwater noise sources such as: a swimming diver (red line), an underwater vehicle (green line) and an old conventional Diesel powered submarine (blue line). In figure 3 (right) we can see a very narrow – band acoustic signature of a surface ship.

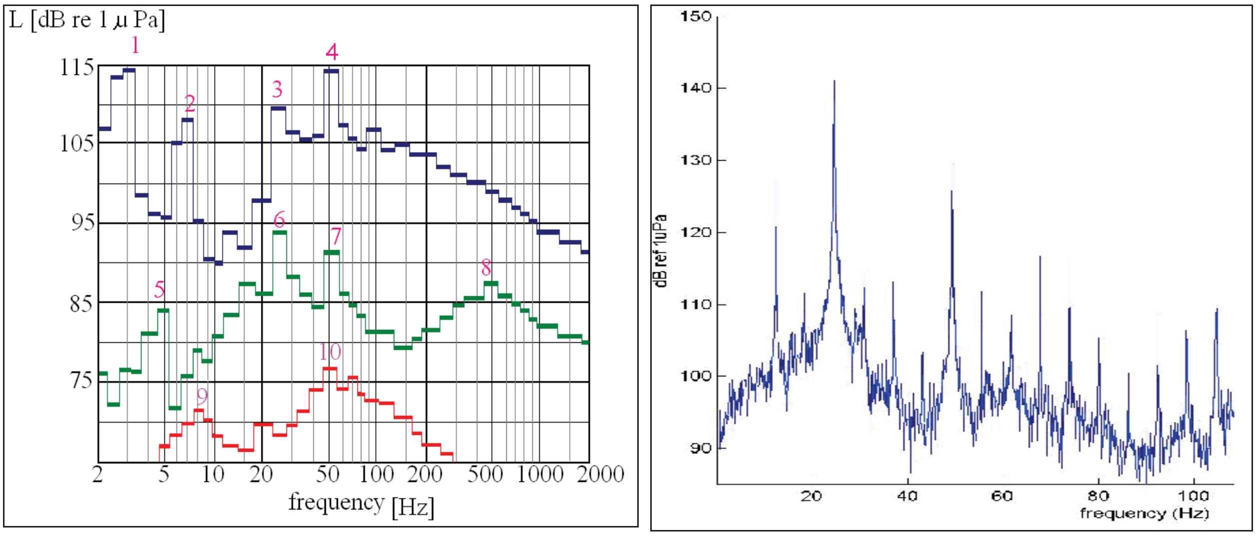

Fig. 3. 1/3 octave spectra and a very narrow spectrum of the underwater signals

At low ship speeds, discrete component lines of the spectrum nearly almost always originate from the ship's diesel generator [2], [4]. The main component is a strong discrete line at 25 Hz; also the most characteristic component is the peak at frequency 50 Hz. In 1/3 octave spectra those frequencies are also seen (points 4,7,10). These components correspond to the basic frequencies of the European ships' electric generators.

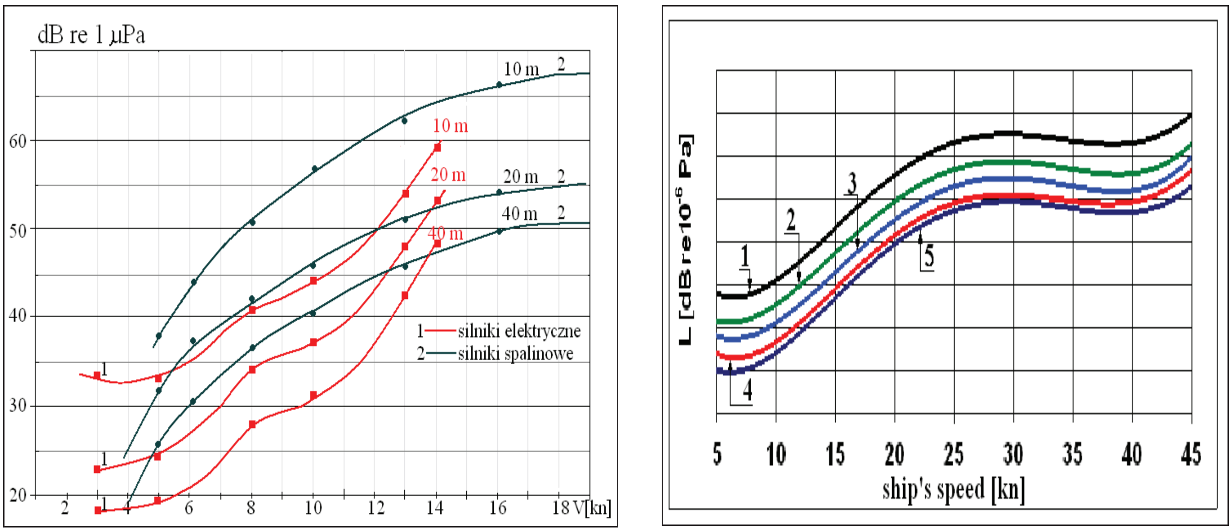

Fig. 4. The sound pressure levels as a function of ship's speed

The AC power line frequencies (harmonics of 50 Hz) are distributed throughout the whole spectrum of the vessel noise [4, 6].

Earlier the ships' noise signatures were hand-made drawings, now automatic instrumentation sketches the whole procedure on-line. The measurement results of the underwater noise signatures and their propagations are compared to each other. Always hydroacoustic pressure levels are selected.

Understanding the variability of ambient noise in the sea is essential, so we must investigate changing of wind, waves, rainfall etc. Understanding the ambient noise variations is necessary for a lot of naval applications.

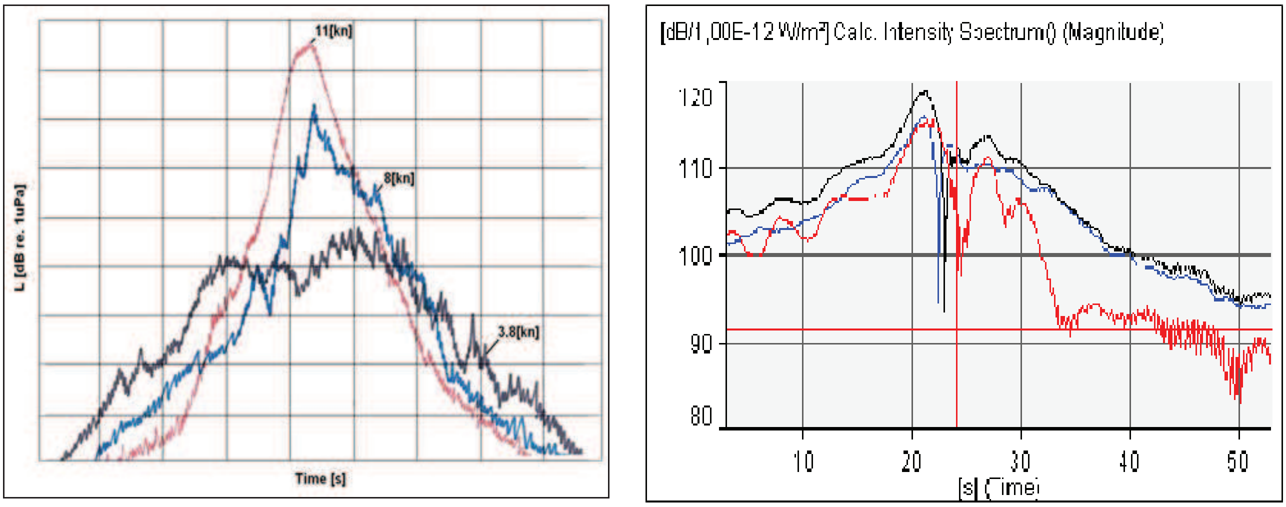

Fig. 5. The characteristic relations of the sound pressure levels (left) and the sound intensity (right). Measurements of the ships' levels were carried out at the constant depth

Maximum level hydroacoustic signatures are measured when the maximum ship's speed is reached along the bearings (right).

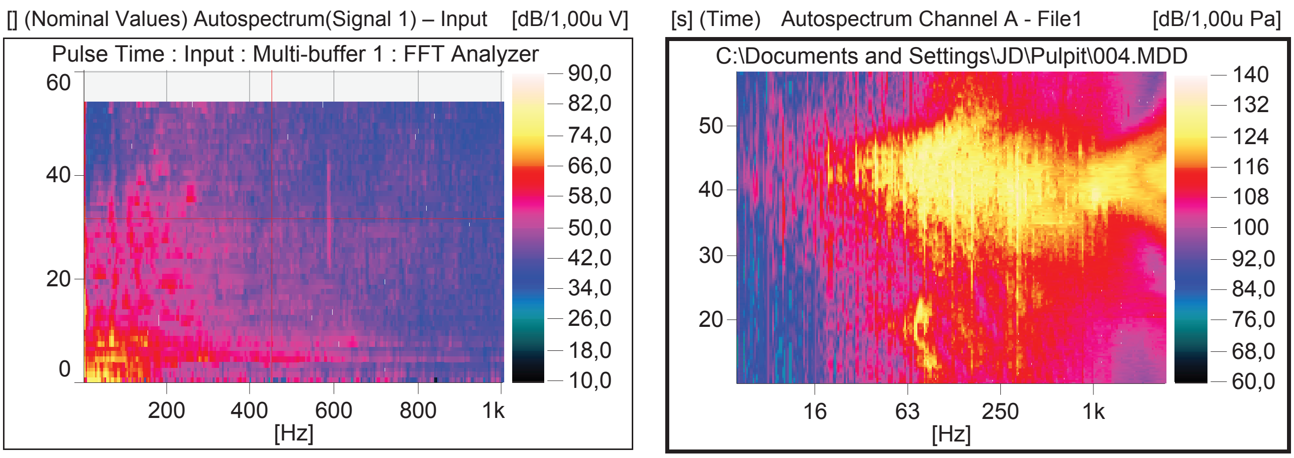

Fig. 6. The acoustic field spectrograms of a swimming diver (left) and a noisy surface warship (right)

When we are going to detected small underwater signals, for example a swimming driver (left) its important to measure the ambient noise too.

2. CONCLUSIONS

The results of the old and new researches have revealed that there is a difference between measuring the underwater signatures using different methods: the sound pressure and the sound intensity. Opposite to the pressure method the sound intensity points out precisely the different sources of noise. This paper shows that new digital techniques are more accurate and gives more potential possibilities. Each method described in this paper has specific advantages, although the sound intensity method makes the identification of the sources possible; it offers a global vision of the radiated noise.

Most of the information about the ships' noise and their vibration is of course located in the frequencies between 0 and 200 Hz. When the ship is running there are a lot of stable frequencies even when the ship's speed increase (working generators, pumps, ventilation system etc.).

Data on the ambient noise with long-range shipping elevates that natural noise without shipping at about 20 to 30 dB in the low frequencies. In addition, Ross noted that the level of noise with shipping is increased with time. This is because we have amplified number of ships and we have much more engine power per average ship [5, 7].

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