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VISUALISATION FORMS IN PASSIVE SONAR WITH TOWED ARRAY

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This paper presents forms of visualisation used in modern underwater systems, a topic covered at two previous Seminars. This year's presentation describes how imaging is organised on the monitors of a passive sonar with a long acoustic array, towed behind the ship's stern, part of a modernisation project at the Department of Marine Electronics Systems. The introduction gives an overview of the design of the sonar and the type of signals received and used for imagining. The article then describes the other factors, which are important for how images are organised, i.e. the operators' tasks, the settings and how they are presented, other data from additional sonar sensors, how the systems works with the other on-board systems, operator training and ergonomics. Examples of images are included.

Key words: hydroacoustics, passive sonars, towed array, imaging forms.

1. Introduction

Passive, long range sonars with acoustic arrays towed at long distances from the vessel are used on ships and submarines. They are used for obtaining the bearing and the distance to alien ships and torpedoes, treated as sources of specific noise.

To obtain the right conditions for listening to signals from these sources (in practice in the order of a nautical mile), it is important to place the array at a far distance from the vessel generating its own noise, and in the case of a ship it is important to tow the array below the wake, because it cuts off sound propagation and produces noise.

Energy distribution in the spectra of noise generated by the vessels detected (especially by slow moving submarines) shows a concentration in a very low frequency range – of the order of about fifty hertz. The length of the acoustic waves received could be as much as about fifty meters, so to ensure proper directional read, the array must be several hundred meters long. Towed behind the array is a stabilising line, about fifty meters long.

Figure 1 shows the spatial arrangement of the system comprising the ship, cable and array.

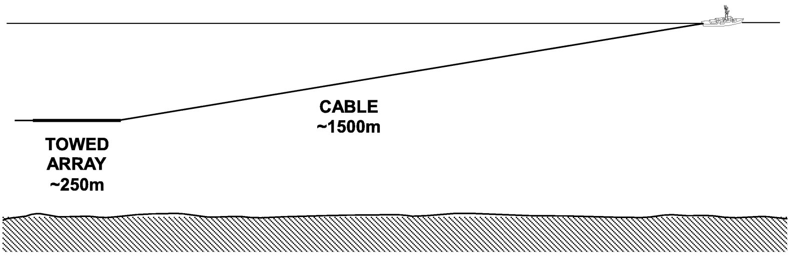

Fig. 1. Spatial proportions of the system: the towing ship, cable and array.

2. Sonar structure

The array has a row of several hundred hydrophones, combined into sections. Listening to the band of the lowest frequencies of about a dozen hertz uses hydrophones from the entire array, and for the higher bands (usually up to 1.5 kHz) from proportionally shorter sections. The last section of the array has watertight containers with a compass, hydrostatic pressure sensor and thermometer, the other containers carry the electronics: pre-amplifiers, multiplexers, sampling systems and processors for managing and ensuring two-way transmission of data (the ship sends the settings, e.g. preamplifier gain control) through the cable.

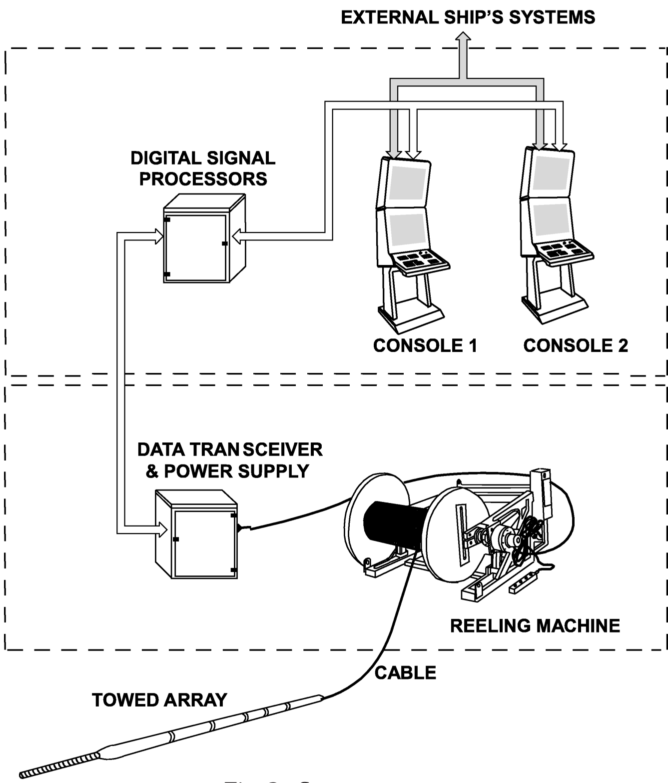

Fig. 2. Sonar structure.

The system on board is responsible for receiving and sending the data, processing and displaying the results of listening and cooperating with the other ship's systems, such as for navigation, command and sound velocity meters. The main objective for processing the signals is to use beamforming [1, 2], with a simultaneous generation of many narrow beam patterns to ensure that noise sources (ships and submarines) are identified accurately.

There are eight computers in the on-board part. Four are used for signal processing and the other four input the settings, communicate with external systems, take care of displaying the images on four monitors installed in two consoles and of operator's training. With this layout two operators can perform different functions at the same time, e.g. keep track of the results of listening in four different frequency bands or concentrate on watching different sources. Figure 2 presents the structure of the sonar [3].

3. Signals and how they are displayed

It is important to say that a single row of hydrophones can receive in the narrowbeam patterns in one dimension only because of the array length. In the second section, the receiving is omnidirectional, making it impossible to identify clearly the location of the source, not even to say whether it is on the right or left side of the ship, not to mention the depth of the source. It is not until the ship and the array do some manoeuvring, that the source can be localised on the right or left side.

To overcome this problem, new and more expensive sonar generations come with thicker arrays (with greater hydrodynamic resistance, more difficult to handle and store etc.), but they also come with three rows of hydrophones. As a result, the array's cross-section can process signals just like a gradient array, although because the spacing between the hydrophones compared with the length of the acoustic waves is small, the beam pattern obtained is not very impressive and only gives a vague idea of whether the source is to the right or left side.

Because the modernisation project does not go as far as to change the array design, the visualisation should be presented in a way that ensures a clear display of the results of array targeting manoeuvres. Earlier, the space on both sides of the ship must be displayed symmetrically.

Specifically, the operator should carry out the tasks in this order:
- check the region with a relatively wide listening band;
- reduce the band of the analysed signals to watch a narrow range with maximal amplitudes of spectral lines from the expected spectrum of interesting targets (e.g. very low frequencies in the case of submarines);
- watch source bearings (one or more sources) generating signals in a selected narrow band and demand manoeuvres to allow the operator to identify the source (sources) to the left or right of ship's side;
- keep track of the changes in the bearing to watch and possibly identify at least an approximate source location;

- if the location cannot be identified with sufficient precision, demand to use other methods e.g. sonobuoys;
- send the listening results to the conning station.

Because the sonar is operated by two operators, one of them should focus on following a selected target (targets), while the other should keep track of the developments in the region. Because both have the same choice of visualisation types, they can support each other and watch the same or different sources (but in a different spectrum range).

Figure 3 shows the initial results of observation. The left vertical window shows the amplitude distribution of the spectrum of all signals – the current and average distribution (lighter colour) of several transmissions. The central window shows spectral distributions (colour marked amplitudes) of signals coming from the beams (directions) from several transmissions. The lower window shows the maxima of spectral distributions in the different directions. The observations help to choose (limit) both the spectrum and scope of the directions, e.g. as shown in this model situation.

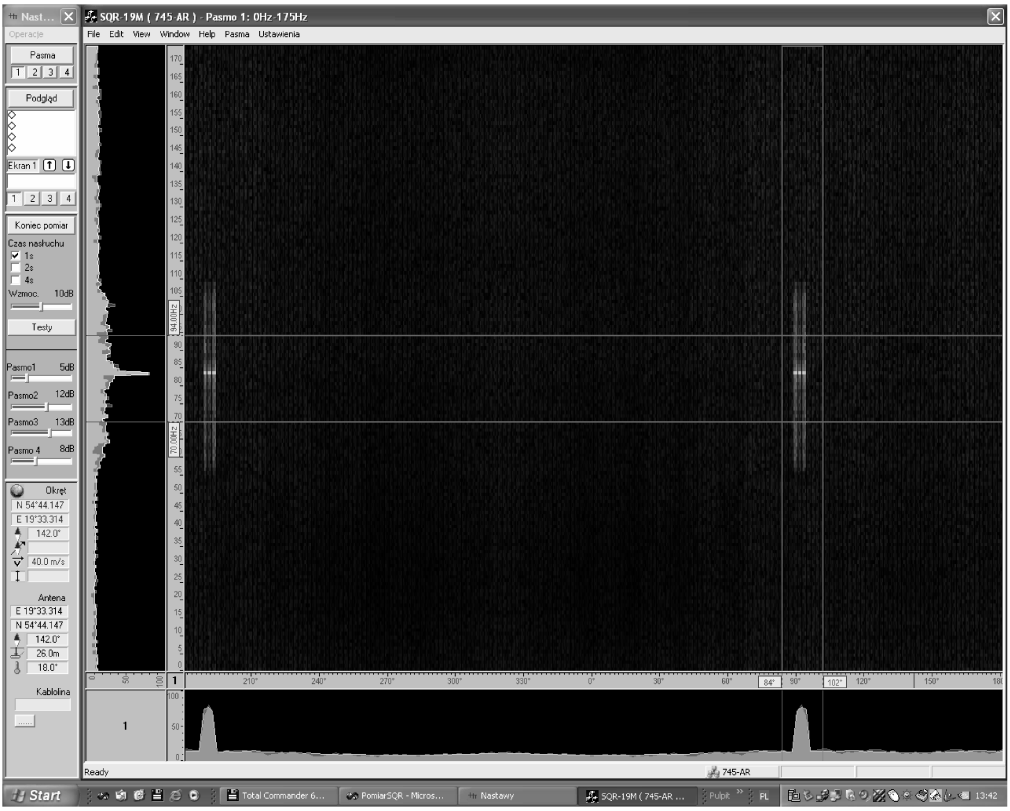

Fig. 3. Early results of observation.

Figure 4 shows the screen with windows and the successive steps of the operator. In the first window on the left-hand side you can see how the level of amplitudes of lines is controlled in a selected spectrum range, the second shows the histogram of bearings during manoeuvres (“waterfall” image [4, 5]), and the third a concentration of the bearings suggesting the location of the source.

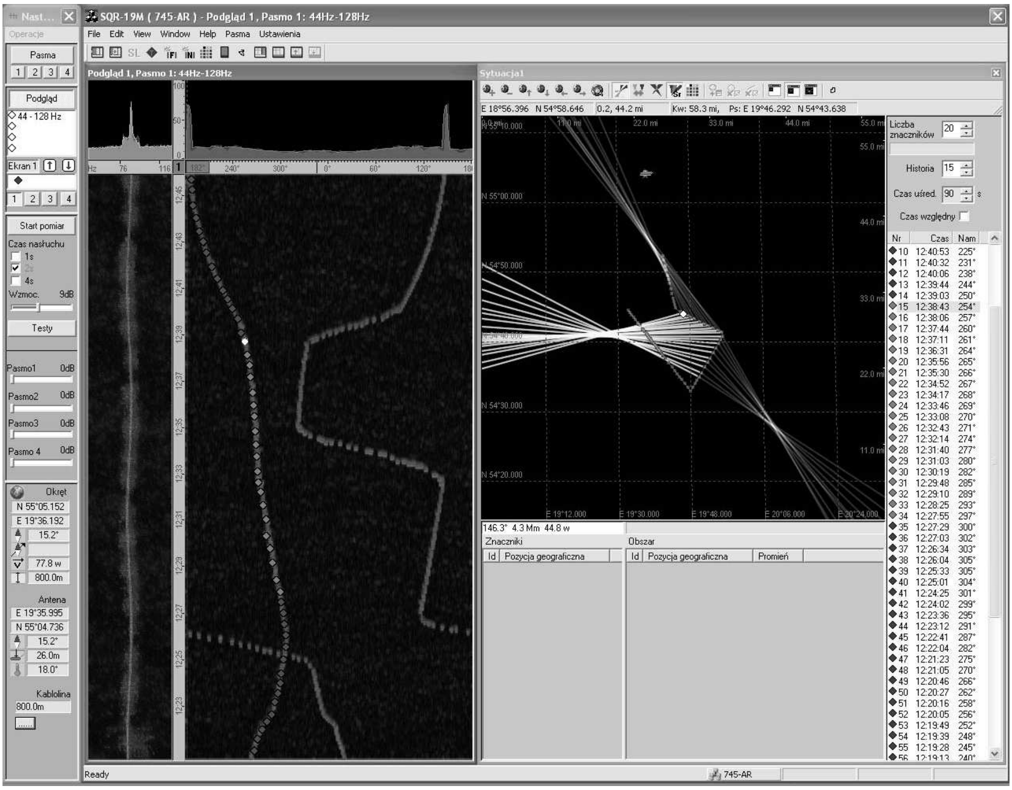

Fig. 4. Basic form of sonar visualisation.

4. Conclusions

As you can see, with the digital structure, the signals can be processed and displayed in different forms. Apart from the options shown, the system can link reference points to the ship’s course or to the north, it can change the scale (zoom) and average maximal or other levels of signals or spectral distributions for single or multiple cycles, etc. [6, 7].

The screens have toolbars, but also a lot of other information (selected by the user) such as the current system settings, the ship’s and array’s navigation data, the hydrology of the region, the markers and marker identification and geographical position, the status and content of communications with external systems, alarms and emergencies. There are separate images for the other systems, e.g. for measuring the hydrological conditions.

All this can be achieved in a friendly and familiar WINDOWS environment, and is designed to help the operator (who has other workload too) with detecting and following targets and informing the command systems.

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