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SELECTION OF THE MODEL AS A FACTOR FOR CONTROL OF DIGITAL SPACE-TIME PROCESSING OF HYDROACOUSTIC SIGNALS IN THE MULTI-BEAM ECHO SOUNDERS

Streszczenie: W oparciu o dane psychologiczne, bezpieczeństwo nawigacji, technologie zintegrowane z komputerem rozważa się wdrożenie zwiększenia wydajności nawigacji na Morzu Czarnym. Zaprezentowano schematy algorytmów charakterystyk kierunkowości w dziedzinie częstotliwości: urządzenie z „opóźnieniem i sumowaniem" oparte na zastosowaniu szybkiego algorytmu transformaty Fouriera.

Słowa kluczowe: sonar, czynnik ludzki, echosonda wielościeżkowa, szybka transformata Fouriera.

WYBÓR MODELU JAKO CZYNNIKA PRZETWARZANIA PRZESTRZENNO-CZASOWYCH DANYCH CYFROWYCH, CZYLI SYGNAŁÓW HYDRO-AKUSTYCZNYCH DLA WIELOWIĄZKOWYCH SONARÓW

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1. Introduction

The solution to a problem is always presented as an action. The course of formation for an action is always latent, and the process of implementing an action can be latent when it is carried out in the mind and explicit when it is realistically.

The activities and being of seafarers, the relationships between crew members are formed by formal powers enshrined in the charter and job descriptions. Such requirements are based on the diversity of maritime traditions, professional ethics, unwritten rules and "laws", the imitation of which forms the professional characterological features of seafarers.

It is assumed that such activities should pragmatically develop acceptable forms of intra-group interaction and the productive functioning of the group in isolation. To some extent, this happens: one can observe how some isolated groups of different directions borrow from the sailors the stylistic characteristics of labour and everyday relationships.

But the development of the fleet does not stand still, radical technical and technological transformations have occurred, that while increasing the economic efficiency of maritime transport, have made fundamental changes to the structure of activities of ship specialists. The widespread introduction of computer-integrated technologies has transformed the conditions and content of the work of the ship's crew. In the foreground we see the "human factor". In this situation, the responsibility of each specialist for the safety of crew members has significantly increased, emotional tension and monotony of labor have increased, and physical activity decreased when specialists performed their functional duties. Improving the speed of ships is accompanied by increased noise and vibration in the ship's premises. There is a dilemma of the factors' portability limit of the ship's environment, in relation to this are no self-adjusting mechanisms in the human body. The transition of a ship from one climatic zone to another, time zone changes impede adaptation, the body has a need for the self-actualization to new realities.

Features of the social isolation as an extreme socio-psychological situation in the life of marine crews does not stop them from solving urgent control and guidance tasks for the moving objects of various nature, which lead to the need for the formation and justification ways of solving of the new problems for building information-analytical control systems as in monitoring of a significant scale, updating large volumes of geospatial data, and overcoming restricted areas [1].

To increase the productivity of navigation in the Black Sea, where a detailed topographic survey of the bottom relief is required: in this situation preferred to use survey complexes with a multi-beam echo sounder. When using a multi-beam echo sounder, it is possible to obtain a full coverage of the bottom with acoustic pulses in the direction transverse to the movement of the tack, where there is a high coating density along the tack, low coverage across. The calculation of the depths in the contact spot of a multi-beam echo sounder is complex, it may include hundreds of iterations, providing for filigree detection of underwater objects. The value of the results of the depths of the multipath echo sounder is higher than the number of physical rays and makes it possible to obtain the n-number of results of depth values from one contact spot [2].

2. Measuring instruments for hydroacoustic

Hydroacoustic devices designed to determine the vertical distance to any underwater object are called echo sounders. Their work is based on the reflection of sound waves during their dissemination in the marine environment from oncoming obstacles.
To ensure the safety of navigation using multi-beam echo sounders, which are part of the navigation equipment.
- The echo sounder is designed for high-precision measurement, visual representation, registration and transmission of depth data to other ship systems. It operates at all forward speeds of the vessel from 0 to 30 knots in areas with sharply changing bottom topography, rocky, sandy and silty soil, as well as in conditions of strong aeration of water, icy and snowy sludge, crushed and broken ice.
- Range depth measurement under the vibrator in the range from 1 m to 200 m.
- Echo sounder must have:
  – a shallow depth scale covering 0.1 depth ranges;
  – large depth scale covering the entire range of depths.

The probe pulse repetition rate should be:
  - no less than 36 pul./min in the shallow depth range;
  - no less than 12 pul./min on a scale of large depths.

Permissible values of the measurement error of depths at a speed of sound propagation in water with = 1500 m/s should not exceed:
± 0.5 m on a shallow depth scale or ± 2.5% of the measured depth, whichever is greater;
± 5.0 m on the scale of large depths or ± 2.5% of the measured depth, whichever is greater.
The operational and technical characteristics of the echo sounder should not deteriorate when the ship rolls to ± 10° and pitching up ± 5°.
Separate readings are allowed for side rolls greater than 100 and/or pitching more than 50, as well as a strongly inclined bottom profile or on rocky ground.
- The sounder kit should include one or more vibrators, a main unit with a built-in depth indicator, a device for recording depths, remote repeaters, as well as a translation device for transmitting data to other ship systems.
The design of the echo sounder should provide for the ability to display the current depth on the depth gauge and record the measured depths in the depth recording device.
- The design of the echo sounder should provide the presentation of depth information simultaneously in two ways:
  – in a graphical form showing the depth profile on the navigable path;
  – in digital form, showing the depth profile on the path traversed by ship.

The graphical form for displaying depth information should provide the ability to observe the bottom profile in at least 15 minutes.
- The scale for displaying depth in graphic form must be at least:
  – 1 m: 5 mm - on the shallow depth scale;
  – 1 m: 0,5 mm - on the scale of large depths.

The graphic form of the display should be automatically accompanied by time stamps with a resolution not exceeding 0.1 of the maximum value of the depth of the scale used.
Digital depth indicators should be a multiple of 0.1 m.

- The echo sounder should provide sound and light alarms about the vessel going to a predetermined depth. The ability to manually set a given depth should be provided smoothly in the range from 1 to 100 m or discretely (5, 50, 100 m).
- In the echo sounder, an amendment input device shall be provided to determine the depth below the deepest part of the vessel.
- In the design of the echo sounder, sound and light alarm should be provided about the occurrence of technical malfunctions that affect the reliability of the displayed information, as well as the disappearance of the supply voltage and a critical change in the parameters of the ship network.
- An echo sounder recorder should record depth information with time stamps for the previous 12 hours. At the same time, it should be possible to restore recorded information in coastal conditions.
- Sounder readings can be recorded on paper tape or other media.

When using paper tape, appropriate marks should be provided on its front side informing that less than 1 m of paper is left to the end of the roll.
- Measurement of very shallow depths is allowed by installing on the vessel a separate echo sounder that provides measurement on the scale of very shallow depths and at least half the scale of shallow depths.

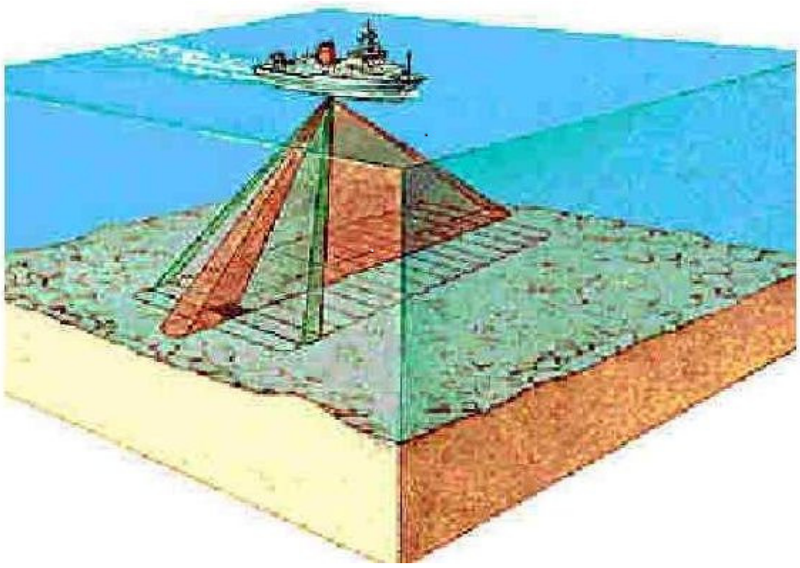

Figure 1. Multipath Echo Sounder Operation.

The principle of operation of the echo sounder is to use the echo method, the essence of which is as follows: to determine the depth, it is necessary to measure the time it takes for the sound to travel to the ground, and to know the speed of sound. For this purpose, different methods are used in navigation echo sounders: rotating disk, rotating drum, endless belt, electronic circuits.

Radiation and reception of acoustic vibrations are produced by acoustic antennas. The main elements of antennas are electro-acoustic transducers with the ability to convert electrical or electromagnetic energy into mechanical and vice versa.

When radiation in a vibrator under the influence of an alternating electric or magnetic field comes into vibrational motion, which is transmitted the aquatic environment. In the receiver vibrator, the receiving surface, under the action of an acoustic wave reflected from the ground, begins to perform mechanical vibrations, which are converted into an electrical signal.

3. Two Models of Digital Signal Processing of a Multipath Echo Sounder

At present, digital signal processing is widely used in hydroacoustic systems and complexes for various purposes [3–5].

Digital signal processing is implemented on a modern elemental base - digital processors and programmable logic integrated circuits, with the ability to reprogram, increasing productivity.

Synergetics of digital signal processing is formed according to the requirements of solving specific problems, in this case, navigation safety, which are determined by algorithmic and software.

The application of methods and algorithms for digital signal processing in sonar is only a matter of using them in multipath echo sounders. Concerning other hydroacoustic means of the indicated purpose, multibeam echo sounders have several advantages:

— fundamental independence of the method of spatial-temporal signal processing when mapping the bottom surface from its relief;

— the ability to build three-dimensional images of the bottom topography, isobaths;

— spatial selection in the vertical traverse plane, that increasing the signal-to-noise ratio, and hence the measurement accuracy;

— the ability to perform high-performance studies in a wide sector without a "dead zone" under the carrier and without the use of additional sonar devices;

— multifunctionality of multipath echo sounders;

— the ability to work in sonar modes of side view and of navigation echo sounder.

Using advanced methods and algorithms for digital signal processing, high-speed signal processors in modern echo sounders it is possible to digitally generate directivity characteristics of the emitting and receiving antennas; implement complex algorithms for optimal processing of echo signals; reprogram the main modes and parameters of the multi-beam echo sounder; create banks of sounding signals.

Controlling the position of the main lobe of the directivity characteristic for spatial filtering of signals such as plane waves coming from a given direction is called the procedure for generating directivity characteristics in sonar. It is known that in order to detect a plane acoustic wave arriving from a given direction using an equidistant linear antenna array against a background of white isotropic noise, it is necessary to compensate for the difference in the moments of arrival of the wave-front: to each element of the array, and then add the time-delayed signals.

Simple algorithms that are implemented in the time domain are often called a “delay and add” device. The scheme of one of the algorithms for the formation of directivity characteristic in the frequency domain is shown in Fig. 2 [6].

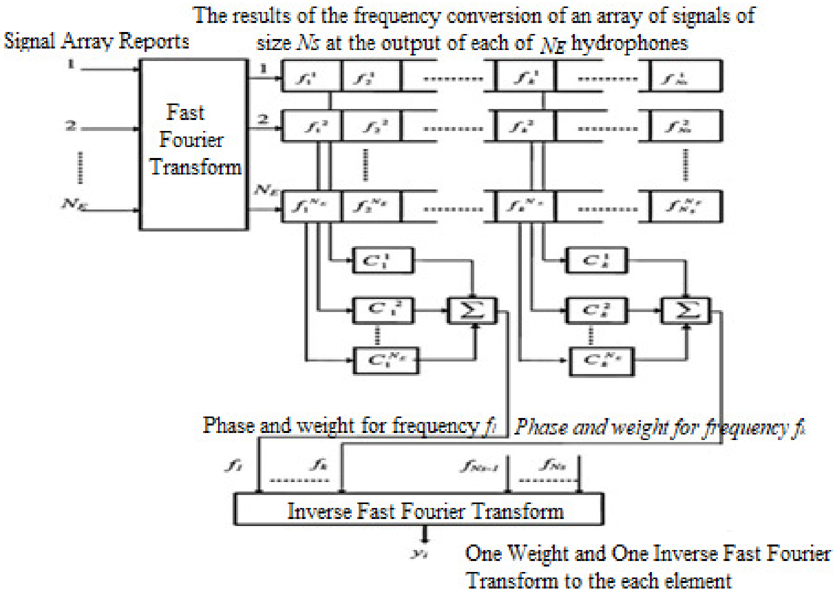

Figure 2. Algorithm for the formation of directivity characteristics in the frequency domain.

However, with many acoustic transducers and synthesized beams, such algorithms for the formation of directivity characteristics in given region require large hardware costs. In this case, it is advisable to generate directivity characteristics in the frequency domain based on the use of the fast Fourier transform algorithm for spatial processing of signals received by the antenna array. The essence of such methods is to replace the necessary time shift of the signals of elementary input channels by an equivalent change in their phase spectra in the frequency domain (Fig. 3).

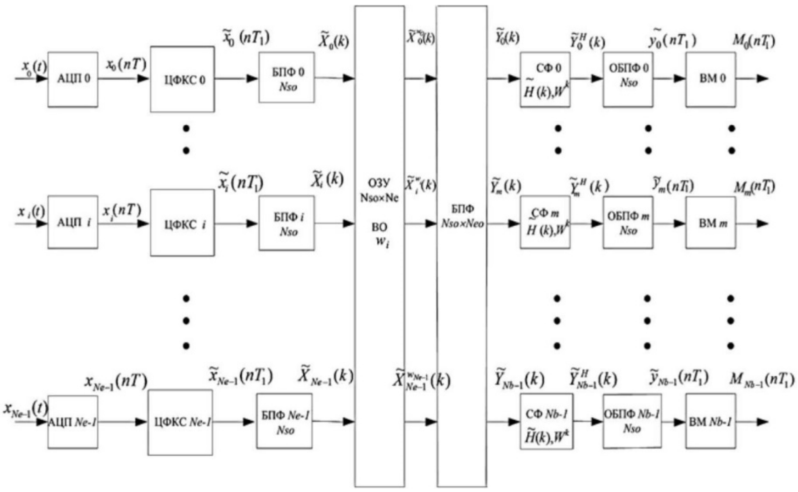

Figure 3. Formation of directivity characteristics in the frequency domain

When implementing this method, the input of the block performing the fast Fourier transform from each of the acoustic transducers is sequentially fed temporary sequences of signals. Next, the temporary implementations of the signals are converted into the frequency domain and summed at each frequency with the corresponding phase shifts and weighting factors. Thus, a signal spectrum is formed in each direction. Further processing of the received signal can be carried out in the frequency domain. If it is necessary to obtain a signal in the time domain, then the inverse fast Fourier transform is additionally performed. In this case, for the formation of each beam, the directivity characteristics must use their phase shifts and weighting coefficients, as well as perform the inverse fast Fourier transform in each spatial channel.

4. Conclusions

As can be seen, the concept of the article is related to the recognition that the effectiveness of works on the safety of navigation can be improved by using multi-beam echo sounders, which have high accuracy in estimating parameters in an extended viewing range. This is a decisive factor in the choice of the hydroacoustic means, despite its relative complexity due to the increased requirements for the processing system of echo signals. It should be noted that the methods of digital spatial-temporal signal processing in hydroacoustic systems confirm their feasibility on a modern element base in the created multi-beam navigation echo sounders.

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