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RESEARCH OF EFFICIENCY OF ALGORITHMS AND PROGRAMS FOR CLASSIFICATION OF SOURCES OF IMPULSE RADIATION IN THE TASK OF HYDROAUDIO MONITORING THE TRADE ZONE

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This article includes the description the of developed complex of programs for simulation the multibeam of channel of propagation of sound , procedures of simulation of impulse signals with the set characteristics on an input of the hydroacoustic channel, of algorithms of formation of signals onto output of a receiving channel, definition of their parameters (frequencies, durations impulses, deviations of frequency) and the algorithms of recognition, used for modelling estimation of efficiency of recognition of impulse sources for various gidrology-acoustical conditions, in depending on distance up to a source and a level of noise of the sea. Shown probabilities to of correct classification of signals of explosive sources, signals cetacea and signals of a hydrolocator in depending on distance for areas Barents sea and sea of Japan .

The computer simulation executable with the purpose of prediction of efficiency of recognition of type of sources of impulse signals, such as a signal of hydrolocator, of toothead whales, of underwater explosions, assumes obtaining estimations of probabilities of correct and erroneous recognition of the specified sources for the set type of hydroacoustic conditions depending on distance up to sources of a signal and signal-noice conditions. Signals of hydrolocators, as a rule, are sequences of tonal or multifrequency impulses of various duration or the composite signals, composed of of frequent-modulated and tonal impulses adjoining to each other. According to available information the frequency range of such signals is 2,8-4,0 кГц, and deviation of frequency of impulses in structure of composite signals can be from 20 up to 150 Hz. A attribute of signals toothead whales, in particular killer whale, is of presence of frequency modulation in sequences of sound impulses. Duration of a signal and deviation of frequency were selected on the basis of statistic processing of real signals kill whale and pilotwhale. The main attribute of a signal of underwater explosion is modulation of a power spectrum in a range of frequencies 10-1000 Hz with period Df=1/T, where T a time interval between front of a shock wave and the first pulsing of a gas bubble. The law of allocation of T value is distribution uniform in a range 5-100 msec. For account of the distortions, inserted by the hydroacoustic channel, a computer program use realize model of the multibeam channel with constant parameters. With the help of this program compute ratios a signal/noice for the selected horizons of radiation and reception, quantity of the rays coming on horizon of reception, delay between rays and appropriate factors of focusing. Thus realize enough adequate registration of the factors forming an acoustic field on an input of a receiving tract.

Simulation of an impulse signal begin with synthesis of a radiated signal in the form of digital countings according to theorem Kotelnikov, with the parameters respective a composite signal of a hydrolocator, or a signal toothead whale. At simulation of a signal of explosion the fragment of real record of the explosion, containing a shock wave and the first pulsing of a gas bubble, was used. Creation of a signal on an input of the antenna was carried out by summing the signals coming to a point of reception{trick} on separate rays according to calculated delays and factors of focusing (Fig.1 and 2 illustrate operation of this procedure. Fig.1 show the oscillogram of an explosive signal on an input of the hydroacoustic channel, and on рис.2 the oscillogram of the same signal on distance of 50 km from a source in conditions of the Barents sea with depth of a place 200м) .

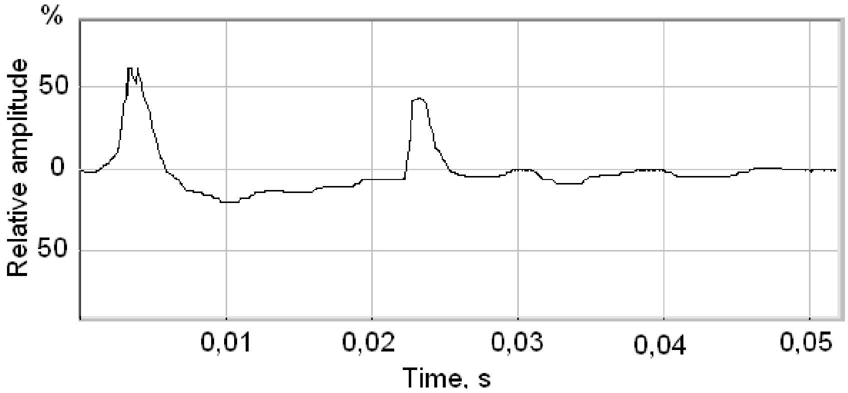

Fig.1. The oscillogram of the initial explosive signal.

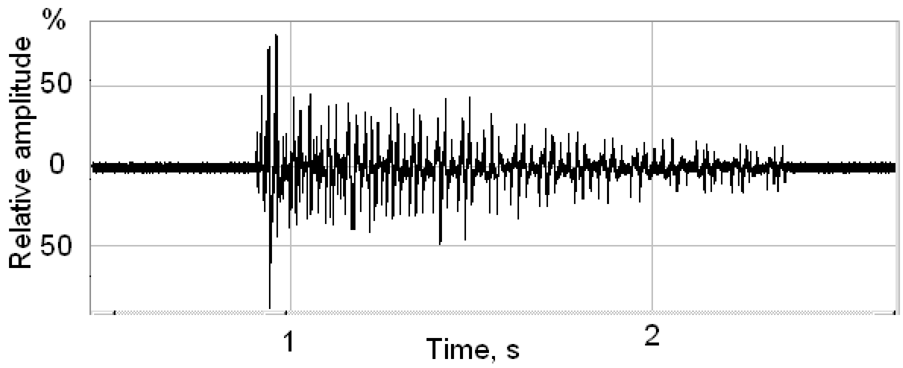

Fig. 2. The oscillogram of a modeling signal on distance of 50 km.

Further occur a detection and measurement of parameters. For detection of signals the algorithms which are carrying out fast Fourier transform and calculation of a spectrum of power in a time window, moving in process of of calculations along realization of a signal are used. Next in spectral area compare maximum of spectral density with a threshold value which is defined by level of a false alarm. After the first exceeding a threshold in a current spectral window occur sequential accumulation of the spectral quantums which have exceeded a threshold, or zero - by nondetection of signal. Thus form a envelope of amplitude. Sequences of frequencies by detection form the frequencies envelope. Simultaneously at each exceeding a threshold compute the criterion " a discrete component (DC) - not DC " and form the array of its values is . After decision-making concerning the end of a signal compute impulses duration and intervals between them. With usage of the array of criterion " DC - not DC " determined the type of the detected signal . If the signal belong to category tonal then occur a definition of his parameters, otherwise occur cepstral processing and accept solution on reference of a signal to category of explosive or noise impulses. Taking into account the measured parameters of a voice-frequency or polyharmonic signal occurs its attribution to signals sonar, or to sounds toothead whales. In each point along a distance by method of Monte-Carlo organize statistics of solutions, sufficient for estimation of probabilities of correct and incorrect recognition (20 variations of noise spectrums). As an alternative class the source of a sound of type the impulse noise was used. The simulation of cetacea signals occur according to most often meeting configuration of sonographic portrait of toothead whales - a so-called ascending configuration [1]. Typical aspect of such signals is resulted on fig.3. As enough satisfactory approximation the signal of type specified on fig.3 was approximated by a voice-frequency impulse duration 1,0 s with linear frequency modulation with deviation of frequency of 700 Hz and initial frequency of 800 Hz. The scale structure of a signal not take account. Duration of a signal and deviation of frequency choose on the basis statistical a processing to real signals of a killer whale and pilot whale. The estimation of average duration of a signal compose T_{AV} = 1s, while an estimation of standard deviation (SD) of duration S_T = 0,39 s. Accordingly average deviation of frequency was estimated by dev $_{av}$ =622 Hz with SD $_{Sdev}$ =290 Hz.

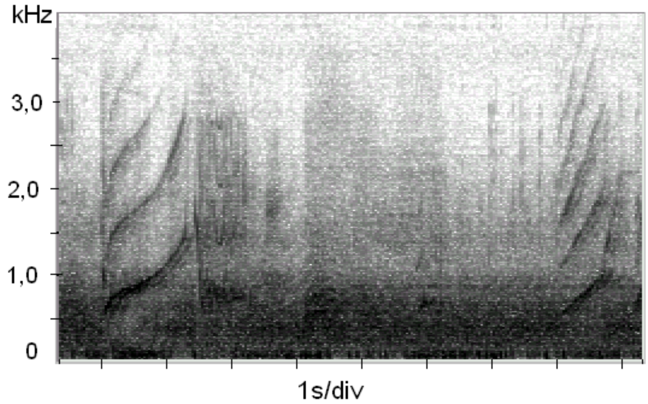

Fig. 3. Spectrogramm a sound killer whale with an ascending configuration sonogramm a portrait

At execution of simulation presume, that work of algorithm of definition of parameters (duration of impulse and deviation of frequency) under interference distortions and random noise can be accompanied by appreciable errors of measurements as a result of which the signal can be referred to category frequent-modulated signals of hydrolocators. Therefore for the prove decision-making about belonging a processed signal to category of sounds toothead whales it is necessary to install a threshold over duration and deviations which reliably enough would separate sounds toothead whales from composite signals of hydrolocators.

Assume a density function of deviation of frequency of signals of whales as gaussian and installed a threshold of acceptances solution on deviation of frequency near to 150 Hz (the indicated value of a threshold corresponds to maximum deviation of frequency for composite signals of hydrolocators and equal to 1,6 $_{Sdev}$), we shall receive, what the probability of correct recognition of signals toothead whales from signals of hydrolocators will is equal 0,95.

To simulation were selected area Barents sea with depth of a place of 200 m and the profile of speed of the sound, belong to the summer period of observations, and sea of Japan with depth of a place of 500 m and hydroacoustic conditions of the aestivo-autumnal period . Depth of a source of radiation in both cases was set equal 60 m, and depth of diving of receiving system - is equal 198 and 498 m accordingly. The angular dependence of coefficient of reflection from a bottom corresponded to a case of strongly dismembered bottom

During simulation 6 series of statistical experiments in which the uniform grid of distances between correspondings points was used have been fulfilled. The maximum number of rays used at simulation of structure of the acoustic field, was equal 100. The receiving system had a feeble beam pattern in a vertical plane with receiving directivity index equal 1,8 dB. The reduced level noise has been accepted equal 0,5 mPa / $Hz^{0,5}$. Statistics of signals for estimation of probability of correct classification (PCC) in each point on a distance consisted of 20 realizations, differing variations of noise. In first three series of computer simulation was carried out recognition of explosions, of communication signals toothed whales and of signals of hydrolocators in Barents sea . In three next series of computer simulation were recognized the same sources of signals in conditions of sea of Japan . Reduced to 1m levels from a source of signals were set equal 10 кPa for explosions, 100 Pa for signals of a hydrolocator and 10 Pa for communication signals cetacea (in the further this class we shall conditionally name "Whale").

In the table dependences of probability of correct classification on distance for each class of considered sources of radiation and two areas are resulted.

The table (probability of correct classification)

km / Class, area	10	14,5	19	23,5	28	32,5	37	41,5	46	50,5	55	59,5
Explosion Bar. Sea	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Explosion Jap. sea	1,0	0,7	1,0	1,0	1,0	1,0	1,0	0,0	1,0	0,5 0,5	0,2 0,8	0,9 0,1
"Whale" Bar. Sea	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0
"Whale" Jap. Sea	1,0	0,6	0,9	1,0	1,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0
Sonar Bar. sea	1,0	1,0	0,0	0,0	1,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0
Sonar Jap. sea	0,0	1,0	0,0	0,0	0,0	1,0	0,0	1,0	1,0	0,0	0,0	0,0

The results of simulation related to one class of signals in different areas, for convenience of compare are placed on adjacent table lines. Feature of the results concerning explosions in sea of Japan on distances 50,5 - 59,5 km, are sharp decrease PCC. At that appropriate mistakes get in a class of noise impulse (probabilities of mistakes are shown by the upper digits in appropriate cells of the table). It is linked, visible, with a strong interference that lead to distortion of modulation of the spectrum called by a pulsing of a gas bubble. From the data in the table, follows, that all examined sorts of signals in conditions of sea of Japan on the average are recognize with greater errors, that in Barents sea what testifies to more difficult structure of the audio field. Zero values in the table correspond to those cases when the ratio the signal / noise is below of detection threshold equal 10 дБ. This results can be used at designing technical systems of hydroacoustic monitoring.

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R E F E R E N C E S

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