HYDROACOUSTICS
4, 61-64 (2001)

STATIONARY SONAR FOR SHALLOW WATER

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The aim of the paper is checking possibility of building active stationary sonar designed for work in very shallow water, depth 8 - 10 m. Sonar is designed for monitoring very weak and moving targets by TS about –20 dB at the range up to few hundred metres.

This paper presents construction of wide-sector sonar consists of two linear transducers. Beampatterns of the transducers are adjusted to conditions existing in very shallow water, particularly to minimize bottom and surface reverberation and effect of multi-path propagation.

Below are presented results of tests and measurements made for different types of targets and different environmental conditions – including: state of the sea, strong aeration of the near surface water, and influence of different sound propagation conditions for detection of the targets.

The paper contains results of influence few types of signal processing for improvement SNR, thus increasing probability of the targets detection.

INTRODUCTION

The paper presents active stationary sonar designed to work in very shallow water. The primary purpose of the sonar is safeguard harbour entry or seaway from intruders: divers, swimmers and small autonomic underwater vehicles [1]. Protection is realised by detection, localisation and tracking of moving targets in the monitored sea area.

1. DESIGN OF THE SONAR

Sonar is provided with two multi-section transmitting-receiving linear transducers. Transducers are installed on the pier or breakwater and linked with electronic rack including transmitter and receiver, which are situated on the pier to. Transmitter connected by means of electronic switch triggers almost simultaneously two transducers. Echo signals in analog form from transducers are sent through pre-amplifiers to conditioning circuit, and then to signal acquisition circuits, which send them in digital form via fibre optic cable to console. Console is situated in a distant room. Block diagram of the sonar is shown in the Fig. 1.

The sea environment distorts a transmitting pulse when it travels to and from the target. Transmitting pulse interacts in a complicated manner with the sea surface, sea bottom, sub sea bottom structure and water sound speed profile. The performance of active sonar in shallow water is therefore dependent upon the acoustic propagation conditions of the environment;

specifically sea depth, state of the sea, sound speed profile, reverberation and noise. On reception of the signal the sonar system must attempt to extract the signal from the noise and reverberation.

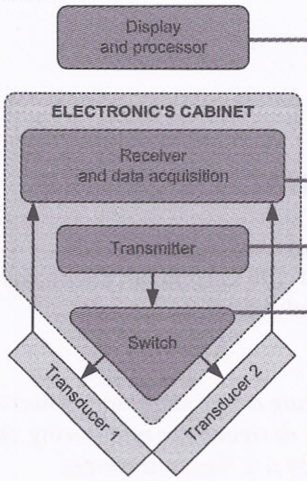


Fig.1 Block diagram of the active stationary sonar

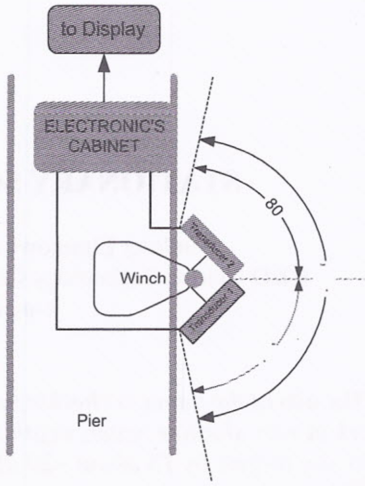


Fig.2 Example of sonar installation

2. BEAMPATTERNS OF THE TRANSDUCERS

Horizontal, wide beampattern is formed through an electronic bending of the linear transducer into cylindrical one, using the method of generating phase delays of signals driving staves of the transducer. The single transducer is designed for work in a horizontal sector 80^0. Observation sector of 160^0 is obtained by installation two transducers in relation to each other at definite angle, what is shown in Fig. 2. By using the opportunities of generating phase delays of the signals driving staves of the transducer, so called "electronic support" is possible to sonify narrow section steered at any direction with considerably more powerful source level. Measured horizontal beampatterns of the single transducer are shown in Fig. 3.

In shallow water vertical beam pattern of the transducer must be adjusted to the specific depth of the water with simultaneous attenuation of the side lobes to achieve maximal range with minimal reverberation. Non electric method of beampattern shaping [3] is used to reduce level of side lobes and simultaneously minimal level of surface and bottom reverberations. Array of the transducer is build of the staves of various sizes and equal spaced ` enters. Adjusting the radiation surface area ensures aperture weighting of the section and respective reduction of side lobes. Side lobes of the vertical beampattern in Fig. 4 are below –19 dB.

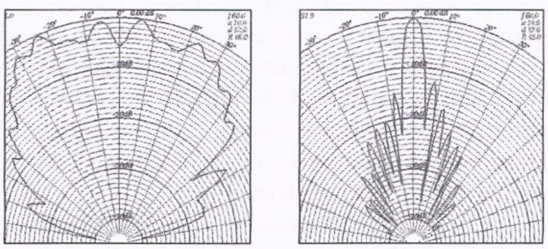


Fig. 3 Measured horizontal beampatterns of the single transducer: sector 80^0 and "electronic support"

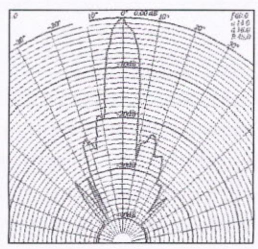


Fig. 4 Measured vertical beampattern of the single transducer

3. SIGNAL PROCESSING

Signal processing is divided into two parts: analog and digital processing. Receiving signals from each section of the transducers are conditioned in analog circuits. Signal conditioning consist of following procedures: amplification, band filtration, compression dynamics according to TVG function and equalization of signals in each channel of the receiver.

Digital signal processing consist of beamforming, improving signal to noise ratio, elimination of constant echoes, tracking of moving targets and display. Block diagram of signal processing is showed below.

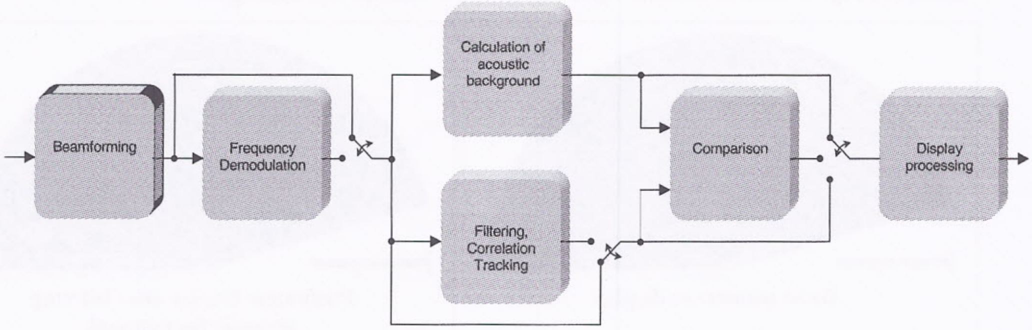


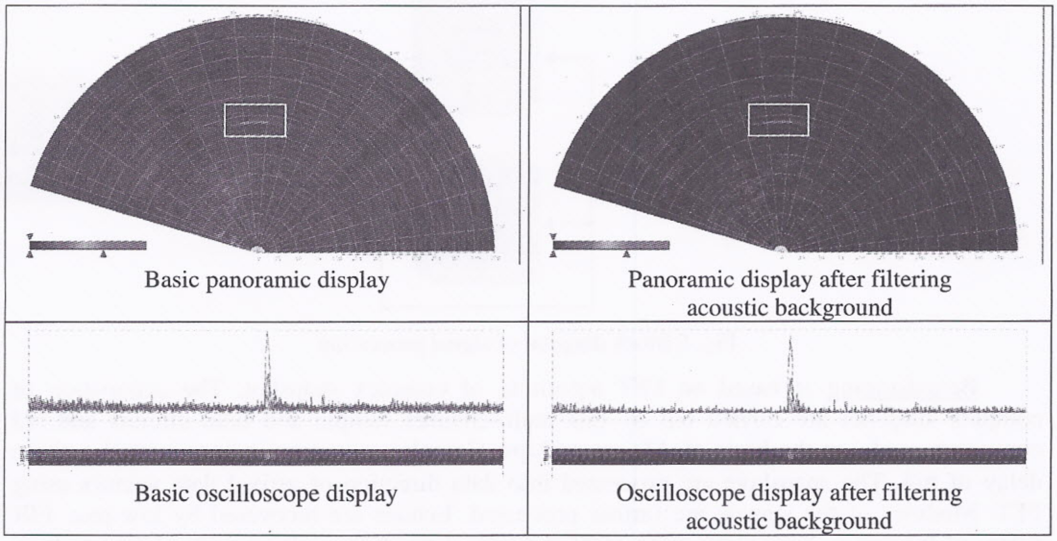
Fig. 5 Block diagram of signal processing

Beamforming is based on FFT algorithm of complex snapshot. The acquisition of complex snapshot are carried out by fast multi-channel sample and hold circuits and a/d converters made on the basis of AD microchips. Complex sampling is done with the phase delay of $\pi/4$. The snapshots are processed into data direction of arrival data vectors using FFT. Modules of the signals are farther processed. Echoes are recovered by low-pass FIR filters of frequency bandwidth from 1500 to 6 Hz, depending on the length of transmitting pulse and type of distortion of the signals.

Elimination of constant echoes. Sea reverberation and noise level is a factor, which limits performance of hydroacoustic system, especially in coastal, very shallow water. Also influence of echoes `- received from objects situated on the seabed like stones or wrecks - on detection and tracking of moving targets is undesirable. Therefore procedure called "elimination of constant echoes" is introduced. This procedure is supported of creating acoustic background of fluctuating, but constantly existing echoes in the monitored sea area. Acoustic background is non-stop calculated and refreshed. Average echo level is calculated with taking into consideration reverberation, noise and underwater objects for individual ranges in adequate number of pings. Extra, acoustic background can be smooth by application filtering according to transmitting pulse length. Operator can display acoustic background and subtract it from just received echoes. The result of described method is shown in Fig. 6.

Tracking of moving targets is carried out with the help of target detection algorithm according to the last square criterion and Kalman's filtration. Parameters of the moving targets (distance, direction, speed and type of the intruder) are displayed on the console. Existing and on-line updated base of constant echoes makes it possible to filter them from the moving target processing increasing reliability of tracked target. In case of very weak target operator can switch on "electronic support". "Electronic support" makes it possible to steer the narrow and more powerful transmitting beam towards the weak or temporarily disappearing targets.

Display The limited number of colours of display requires compression dynamics of the signals. Functions of the compression transform input signals into colour data according to target strength, colour scale and threshold value using simple equations. There are three functions of compression: linear, logarithmic and exponential. Panoramic and oscilloscope displays are used to present received echoes from the monitored sea area. Because of the fact, that our eyes better differentiate brightness of the adjacent pixels than their colour, radar and black and white scales are introduced to. Panoramic and oscilloscope displays of the sonar are shown in Fig. 6. Received echo signal of diver is marked by rectangle.



Basic panoramic display | Panoramic display after filtering acoustic background

Basic oscilloscope display | Oscilloscope display after filtering acoustic background

Fig. 6 Examples of panoramic and oscilloscope displays of the sonar.

4. CONCLUSION

Complex and changeable conditions of acoustic wave propagation in the shallow water of Southern Baltic Sea require especially accurate adjusting of sonar parameters such as frequency, beampattern, source level, duration of transmitted pulse and signal processing methods to the hydrologic-meteorological situation. Sonar system, especially designed to work in very shallow water was briefly presented in this paper.

Sonar was installed in shallow water area of depth 8 – 12 m in November 1999 and has been tested during 1,5 year. The quality of sonar performance is very high, sonar can detect and track divers at the range of few hundred meters.

REFERENCES

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2. Elminowicz A., Janowski T., Kotłowski A. „Active stationary sonar for very shallow waters", UDT Europe 2000, London , June 2000;
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