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"Journal of Economics and Social Sciences"

Numerical model of ultrasonic multi-channel data transfer for servicing subsea production complex

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Abstract

Various researchers focused on different problems, and we can conclude that a single effective communication design with a specific algorithm that could be used in all types of underwater channels was not found. The design of the transmission is highly dependent on the conditions of the canal, as various schemes are used in shallow and deep water, and various algorithms in turbulent and calm waters. The type of channel alignment also depends on parameters such as channel estimation and coding. The ever-growing demand for bandwidth, efficiency, spatial diversity and the performance of underwater acoustic communications has opened the door to using Multiple Input Multiple Output (MIMO) technology. In this paper, we propose a method of ultrasonic data transmission under water based on the MIMO technology (Many emitters, many receivers, or MIMO – Multilpe Input - Multiple Output). This approach will allow for multi-channel data transmission in water and significantly increase the speed of information transfer.

Keywords: Ultrasound, MIMO, Subsea production complex, Doppler environment shift;

1. Introduction

A significant potential of Russia's energy resources is concentrated in the Sea of Okhotsk in the east of the country. A total of 16 deposits have been discovered on the Sakhalin shelf, 6 are under development (Odoptu, Chayvo, Arkutun – Dagi, Piltun – Astokhskoye, Lunskoye, Kirinskoye) [1–3].

Currently, data transmission technology under water is an urgent task. With the help of robots, people explore the depths of the seas and oceans. There is a wired connection between a person and an underwater robot. A range of very low frequencies is used for wireless communication underwater, but it is not possible to provide a sufficiently wide data transmission band in this range. Optical communication is also hampered by the presence of small scattering inhomogeneities in the water. With the help of ultrasound, it is possible to implement wireless communications underwater [4, 6].

By means of autonomous underwater uninhabited vehicles (AUUV), continuous monitoring of oil fields is possible, which will increase the reliability of these oil production systems. AUUV will transmit data about the total condition of equipment for subsea oil and gas fields into online broadcasting. In the event of any kind of damage, it will be possible to quickly eliminate the refusal with minimal product loss, as well as minimize environmental damage [5].

There are many ways to transfer data. But in all methods, data transmission occurs on the principle of electrical signals. Electrical signals are translating into computer language bits that are digital or analog signals that transform into electrical impulses. The totality of all types of data transmission is called a data transmission channel. It includes such means of data transmission as: Internet networks, fixed lines, points of reception and transmission of data. Data transmission channels are divided into two types: analog and discrete. The main difference is that the analog type is a continuous signal, and the discrete, in turn, is an intermittent data stream.

It is proposed to use a matrix of 8 ultrasonic emitters, and for receiving a matrix of 8 receivers. Using matrices of microphones and emitters provides many channels for transmitting information over longer distances with minimizing noise levels. Unlike single-channel acoustic communication systems under water, the proposed solution will allow tens of times to increase the bandwidth of data transmission channels in water because of multichannel. In addition, the proposed system automatically adapts to the mutual movement of the source and receiver and changes in the distribution environment (currents, turbulent flows, salinity contrasts ...) by using certain calibration signals.

The matrix of emitters is mounted on board the AUUV, while the matrix of receivers is located on the buoy. In turn, the buoy has a connection with the subsea production complex (SPC) monitoring department.

2. Numerical simulation of multichannel ultrasonic data transmission under water

The receiver gets the sum of the signals with different phase raids. The signals are summed with weights.

$$B_m = \sum_{n=1}^{8} H_{nm} \cdot A_n$$

it was decided to take the Gauss function as an inhomogeneity, which is described as:

$$f = c_1 + (c_2 - c_1) \cdot e^{-\frac{(x-0.1)^2+(y+0.05)^2+z^2}{r_n^2}}$$

, where x, y, z – coordinate axes, r_n – heterogeneity radius.

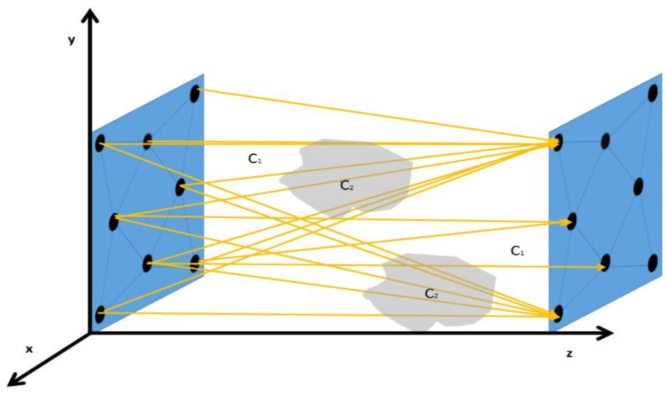

Fig. 1 – Task geometry.

This simulation was conducted in the Mathcad environment.

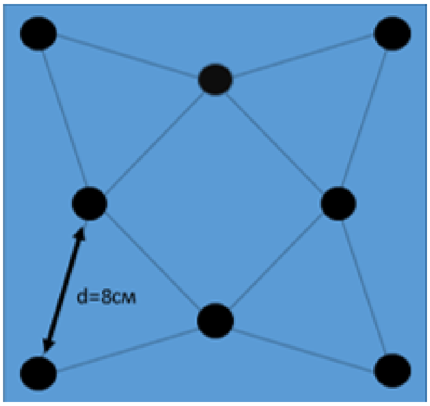

Fig. 2 – Emitter microphone array and microphone receiver array.

The emitter array of microphones and the receiver array of microphones look the same. An equidistant arrangement on the plane of 8 elements was chosen, since such an arrangement of microphones is optimal so that the signals merge less with each other.

It will be impossible to reconstruct the emitted signals if we ignore the influence of inhomogeneities of the environment.

To consider the heterogeneity of the environment, the system is calibrated using the LFM (linear frequency-modulated signals) signals, sending a signal from each emitter in turn with a certain delay.

Each emitter operates at the same frequencies, but everyone has their own amplitude and phase (8 possible options). The passband of the sensors is 37 – 40 kHz. A communication channel is a homogeneous environment with calculated behavior. It is proposed to use amplitude – phase modulation with eight possible combinations of amplitude and phase (Pic 3).

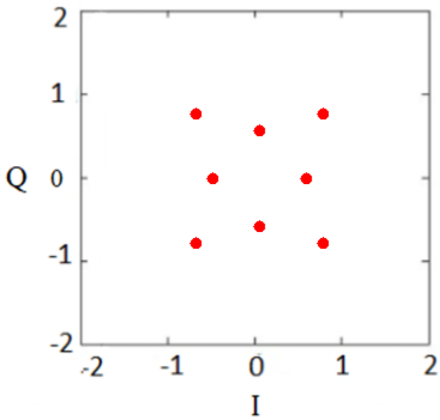

Fig. 3 – Amplitude – phase values of eight different complex plane codes.

All emitters operate simultaneously (while having a different amplitude and phase of the signal), and each sends its own sequence of codes. From the receiving matrix (B), 8 different signals arrive at the receiving controller, the complex amplitude of each of which is a linear combination of the complex amplitudes of the emitted signals with different weights factors.

2.1. Numerical modelling of the influence of inhomogeneities of the distribution environment

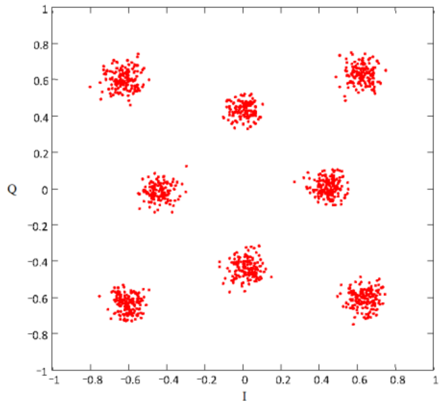

Fig. 4 – Recovered amplitude-phase values of eight different codes on a complex plane, considering the heterogeneity of the environment.

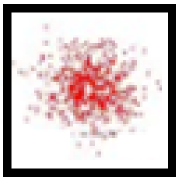

Fig. 5 – Recovered cloud.

A cloud, in our case, will be named all possible options for recovering the original message. Since the boundaries of each cloud are distinguishable, we can talk about good accuracy of restoration and the correctness of this method. According to the simulation results, it was found that the connection under water, considering the heterogeneity, will be more stable and accurate.

3. Conclusion

The main technologies for mineral exploration and production of subsea oil and gas fields and the main types of data transmission are presented.

There is no doubt that the development of subsea hydrocarbon production is the most important factor in the development of the domestic oil and gas industry and a guarantee of the country's energy security. Also, one of the urgent tasks is the transmission of data under water. The development of hydrocarbon deposits on the continental shelf of the Barents, Kara, and Okhotsk seas, characterized by severe climatic conditions, will require the use of innovative and technological approaches. The only field in Russia with an underwater production complex today is Kirinskoye. Some underwater technologies used in the fields of other countries are already tested today, have high operational reliability and are ready for use in freezing waters.

The main parameter in oil and gas production is reliability, which directly depends on the monitoring of underwater production complexes. By reducing the time to eliminate refusal, the damage to the environment and losses in production will be cut down. With proper monitoring, the condition of pipelines and UPC will be within acceptable limits.

Acknowledgments

We express our gratitude and deep appreciation to Petr V. Burkov, Doctor of Technical Sciences, Professor, Division for Oil and Gas Engineering, Tomsk Polytechnic University, and Liudmila M. Bolsunovskaya, Candidate of Philology, Division for Foreign Languages, Tomsk Polytechnic University for the valuable advice and comments on the article

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