Investigation of characteristics of cylindrical piezoceramic transducers used in systems for underwater monitoring and management

Ivan Ivanov[1], Stojan Kolev[1], Bistra Nenova[1], Vassil Kossev[2]
1 - ivo1942@abv.bg; 2 - s_kolev@abv.bg; 3 - bistranenova@hotmail.com; 4 – backomail@yahoo.com
1 - IMSETHC-BAS, Sofia, Bulgaria; 2- Accenture Bulgaria, Sofia, Bulgaria.

Abstract: *The frequency characteristics of hydroacoustic cylindrical piezoceramic transducers in transmission and reception modes have been determined. The measurements were performed in pulse mode in a pool measuring 200x20x6 meters. The processed results from the measurements of the main characteristics are shown with tables and graphs.*

Keywords*: UNDERWATER ACOUSTIC CYLINDRICAL PIEZOCERAMIC TRANSDUCERS*.

1. Introduction

For the study and development of the underwater space in most cases the specific features of the propagation of hydroacoustic signals in the aquatic environment are used [1].

2. Experiments and results

In the control systems of objects in the underwater space, undirected (circular) radiation and reception of hydroacoustic signals in the horizontal plane is required. This is realized through the use of cylindrical hydroacoustic antennas constructed on the basis of cylindrical piezoceramic elements.

Effective underwater monitoring is realized by electronic scanning of diagrams with well-defined orientation in the horizontal and vertical planes. This is ensured by multi-element hydroacoustic antennas with a cylindrical active surface.

A study of cylindrical hydroacoustic antennas constructed on the basis of cylindrical piezoceramic elements with outer diameters: 19mm, 28mm, 42mm and 54mm from left to right (Fig. 1) and a multi-element module for hydroacoustic antenna with a cylindrical active surface (Fig.4). The cylindrical antenna based on a piezoceramic cylinder with an outer diameter of 28 mm is shown in the form before hermetically sealed.

The measurements were performed in the deep-water basin of the Center for Hydro and Aerodynamics at IMSTCA-BAS. On the Fig.2 shows the schematic diagram of the measurement process used to measure the antennas. Measuring instruments from the company Bruel§Kjær are mainly used, namely: frequency generator type 1013, gating system type 4440, measuring hydrophones type 8100 and type 8101. The signals are monitored on the oscilloscope screen.

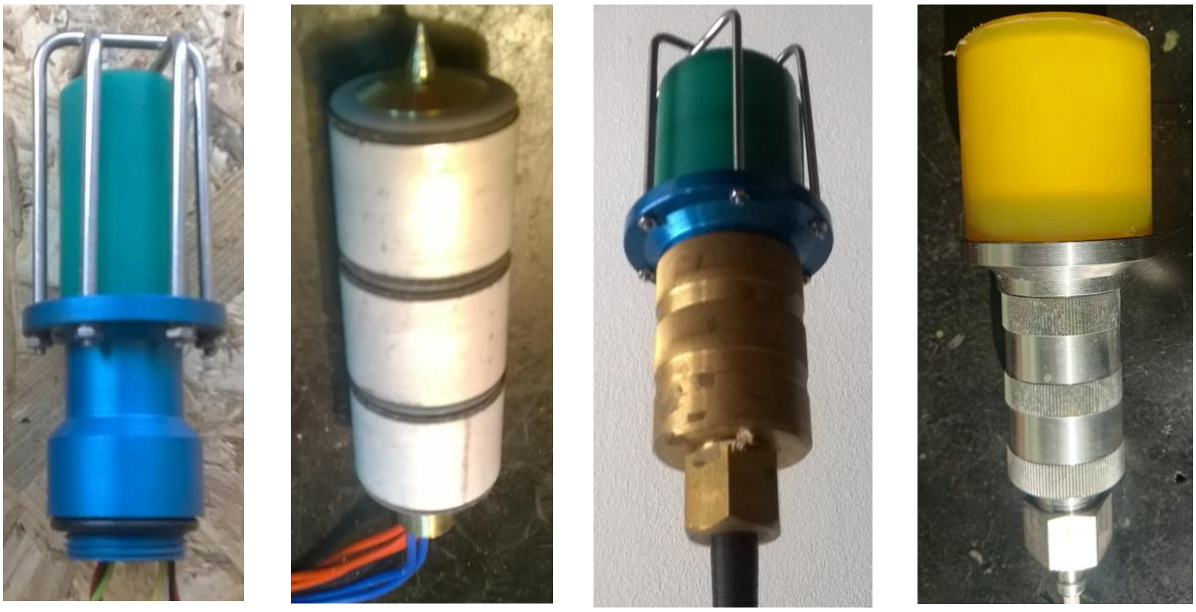


Fig.1. *The studied cylindrical underwater acoustic antennas*

During the measurements, to determine the characteristics of the tested antennas in radiation mode, the antennas and the hydrophone type 8101 are immersed at a depth of 3m and at a distance of 3m between them.

Both hydrophones used to determine the characteristics of the tested antennas in reception mode are from the company Bruel§Kjær.The tested antenna and the hydrophone type 8101 are located at a distance of about 1m from each other and at a depth of 3m. The type 8100 hydrophone is used for broadcasting and is located 3m from the imaginary line connecting the tested antenna and the receiving hydrophone tin 8101 also at a depth of 3m.

The shape of the signals is observed on the screen of the oscilloscope, and their current values are read by the measuring amplifier type 2607. The measurements use pulses with a duration of 2ms, where there is no overlap between the direct and reflected pulses.

In all measurements, the transmitter is excited with a peak voltage of 8V. Figure 3 shows the graphs of the frequency characteristics of the tested antennas. The different level of radiation of the resonant frequencies of the antennas is a result of their characteristics of directivity in the vertical plane (left graphs). The decrease in their sensitivity in the reception mode is due to their smaller receiving surface.

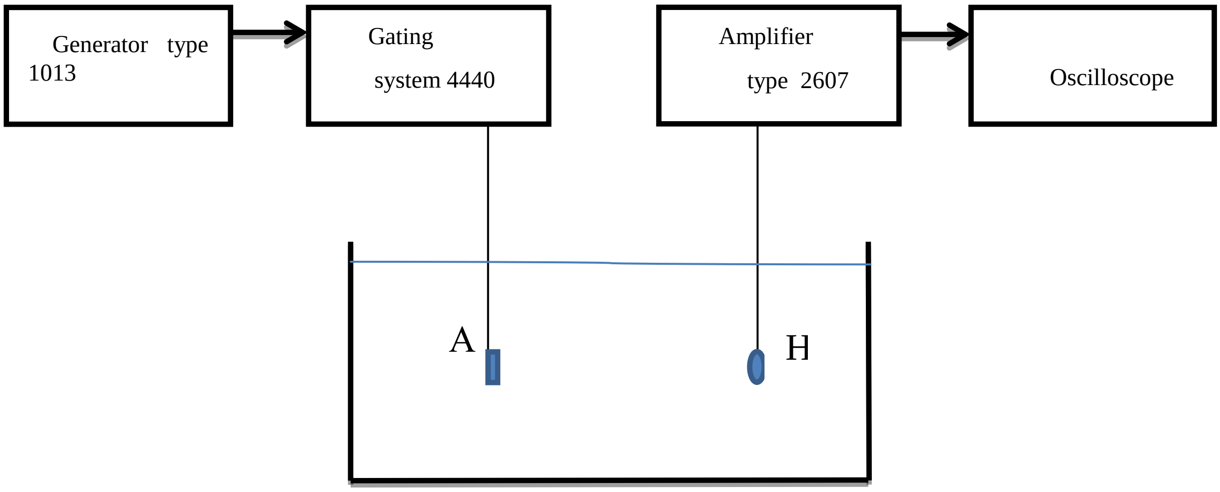


Fig.2. *Schematic diagram of the measurement process*

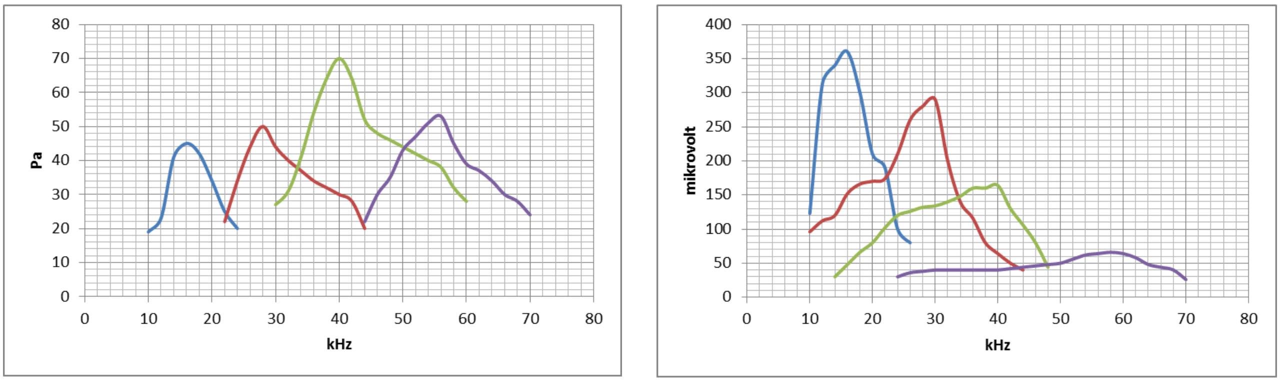


Fig.3. *Frequency characteristics of the antennas - on the left in broadcasting mode, on the right in receiving mode: blue - diameter 54mm, red - 42mm, green - 28mm and violet - 19mm*

The change in the directional characteristics of a multi-element module (Fig. 4) for a underwater acoustic antenna with a cylindrical active surface at frequencies other than its resonant one was studied.

The module contains 96 piezoceramic elements divided into 16 groups of 6 elements. They are mounted on a cylindrical surface with a radius of 330mm and a sector width of 172mm. Eight groups are used for one directional diagram. By switching the displayed groups, three directional diagrams can be formed.

A device has been developed to ensure the measurement of the directivity patterns of the module. It, together with the module, is mounted on the trolley of the deep-water pool. This ensures that the module is immersed to a depth of about 2 m. The distance between the module and the receiving hydrophone, which is immersed at the same depth, must fulfill the condition $\mathbf{R} > \mathbf{D}^2 / \boldsymbol{\lambda}$ [1], where **D** is the maximum linear size of the module and **λ** is the length of the emitted acoustic wave.

At **D** = 0.18m the distance between the module and the measuring hydrophone must be greater than 2.3m at **λ** = 0.014m. In the process of measurements the distance between them is 3m. The measurements are performed using the schematic diagram of Fig.2.

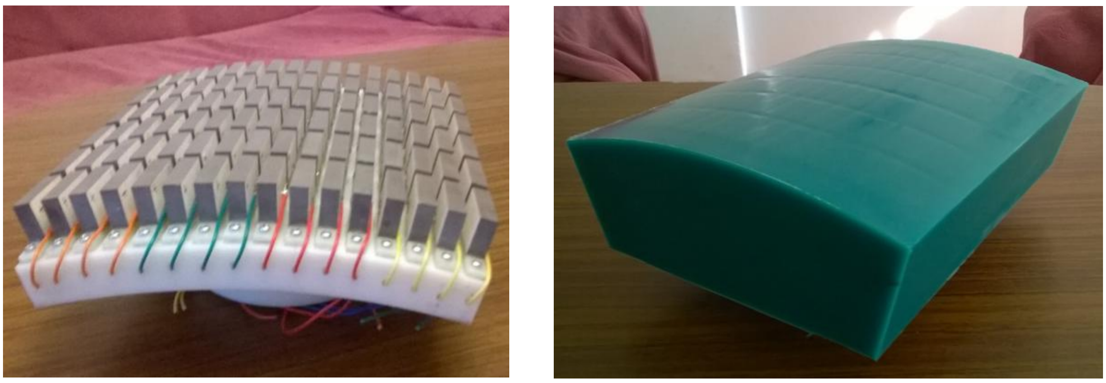
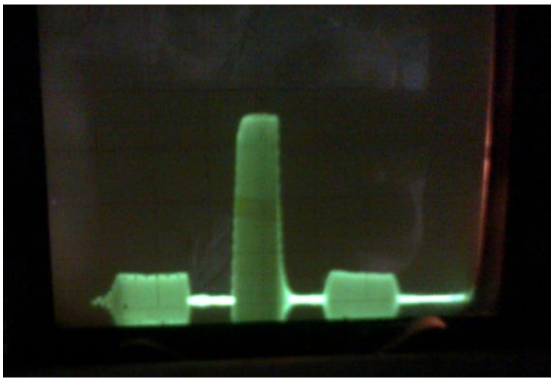


Fig. 4. *Multi-element cylindrical underwater acoustic antenna module: before hermetically sealed (left) and after - (right)*

The measurement process begins with immersing the module and the hydrophone at the same depth and at a distance between them of three meters. The monitoring of the signals is performed on the screen of the oscilloscope - fig.5. The leftmost pulse, observed on the screen of the oscilloscope is the electrical impulse applied to some of the elements of the module. The middle pulse is the acoustic pulse received by the hydrophone. It is the carrier of the information about the directed properties of the part of the module, which is connected to the generator through the gating system, when it is rotated around its axis. The rightmost pulse is the signal reflected from the surface of the pool. Pulses with a duration of 1 ms are used in the measurement. The maximum of the signal is sought by turning the module. The maximum of the received signal is then sought by changing the immersion depth of the measuring hydrophone. After completing these procedures, the resonant frequency of the antenna (module) is determined. For the given module it is 107kHz.

When the module is rotated in the horizontal plane, the levels of the signals received by the hydrophone are measured from the oscilloscope screen. After processing the measured data we get the graphs from fig.5. Each of the graphs presents the pattern of orientation in the horizontal plane for a certain part of the elements of the antenna array. The blue was obtained by emitting the left eight vertical groups of the modulus. Red - in the broadcast of the middle eight groups and green is the result of the broadcast of the left eight groups. The width of these directional diagrams at the minus 3dB level is 8˚. The angle between two adjacent diagrams is also 8˚.



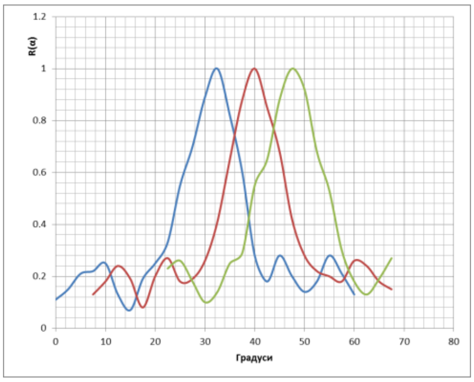


***Fig. 5.** The signals from the oscilloscope screen on the left and the measured directivity diagrams of the module on the right*

Measurements were performed to determine the radiation patterns of the module and the frequencies 102 and 112kHz, which is a deviation of ± 5kHz from its resonant frequency. Processing of the results showed that the width of the horizontal radiation patterns of the module changes by ± 1.5˚. At larger deviations from the resonant frequency we do not have effective radiation.

3. Conclusion

The studied cylindrical hydroacoustic antennas, realized on the basis of piezoceramic cylinders, are used in the one-way hydroacoustic system for control of underwater objects Som1 [2] and in the two-way one Som1 / 2 [3] and ensure their efficient operation with high reliability.

An echogram from the screen of a sector sonar [4], the antenna of which is realized on the basis of the module studied by us, is shown in fig.6. The arrow shows the trajectory of a diver from 80m to 180m in an area with a depth of about 10m. In areas with depths of about 20 meters, the movement of divers is effectively observed at distances up to 220 meters.

The research of the frequency characteristics of underwater acoustic cylindrical piezo ceramic transducers is related to the creation of a system for underwater protection of coastal infrastructure objects aimed at the implementation of Work Package 2 "Intelligent Security Systems" of project BG05M2OP001-1.002-0006 "Construction and development of a Center for competence "Quantum communication, smart security systems and risk management (QUASAR)", which has received funding from the European Regional Development Fund through the Operational Program "Science and Education for Smart Growth" 2014-2020.

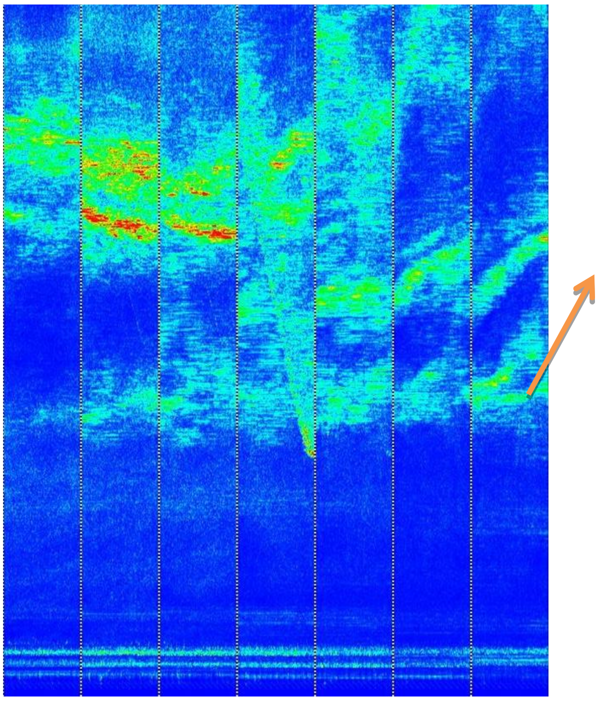


***Fig.6.** The echogram from the screen of a sector sonar*

4. References

1. P.J. Bobber, *Hydroacoustic measurements*, translation, Mir publishing house, Moscow (1974)

2. I.K. Ivanov, S. G. Kolev, Hydroacoustic system for management of underwater objects, collection "Protection of ports", pp.145-149, Sofia (2011)

3. S.G. Kolev, I.K. Ivanov, Two-way hydroacoustic system for control and monitoring, Collection of papers from *the Sixth National Conference with international participation Metallurgy, Hydro and Aerodynamics, National Security '2017*, pp. 240-244, ISSN 1313-8308, Sofia (2017)

4. I.K. Ivanov, S.G. Kolev, Sonar with electronic scanning, Collection "Protection of ports", pp.135-144, Sofia (2011)