WIDEBAND, MODULAR DIVER DETECTION SONAR (DDS)

ANDRZEJ ELMINOWICZ, WŁADYSŁAW MĘCIŃSKI, MARCIN OKUNIEWSKI

R&D Marine Technology Centre
Dickmana 62, 81-109 Gdynia, Poland
andrzeje@ctm.gdynia.pl

The complete protection of naval harbours, port approaches and anchorages requires the underwater continuous monitoring and threat detection such as divers, their delivery vehicles or AUVs from safe distances.

R&D Marine Technology Centre (CTM) has began designing and building of the new generation, modular, wideband Diver Detection Sonar (DDS), based on cylindrical multielement piezocomposite transducer made by Materials Systems Inc. (Littleton, USA).

The paper describes key features of the DDS technology demonstrator and specific technological principles of the sonar construction. The first DDS harbour trials are planned take place during May 2010.

INTRODUCTION

The growing needs of high value assets underwater protection by high performance quality portable acoustic devices, have results in the development of advanced sonar technologies such as DDS. The designed technology demonstrator (TD) of DDS is the first attempt of our R&D Centre leading to next generation of sonars designed to operate in shallow water.

The new array [1] has been designed and manufactured with Materials Systems Inc. (Littleton, USA) cooperation. CTM designed hardware and software solutions. It has significant improvement in operational parameters of sonar, enables adaptation of sonar to specified protected object, as well as adaptation to propagation and environment conditions.

DDS is the specialized sonar designed for detection and classification of small underwater objects i.e. a diver, a small underwater vehicle, a floating explosive charge in the sea area with demanding high reverberation level.

2. DDS CONFIGURATION

Presented technology demonstrator design is based on sonar technology developed for naval mine detection and countermeasures applications. TD of DDS has been designed as composite system with under and above water modules. Both modules are connected by cable: power supply and data (ETHERNET) transmission.

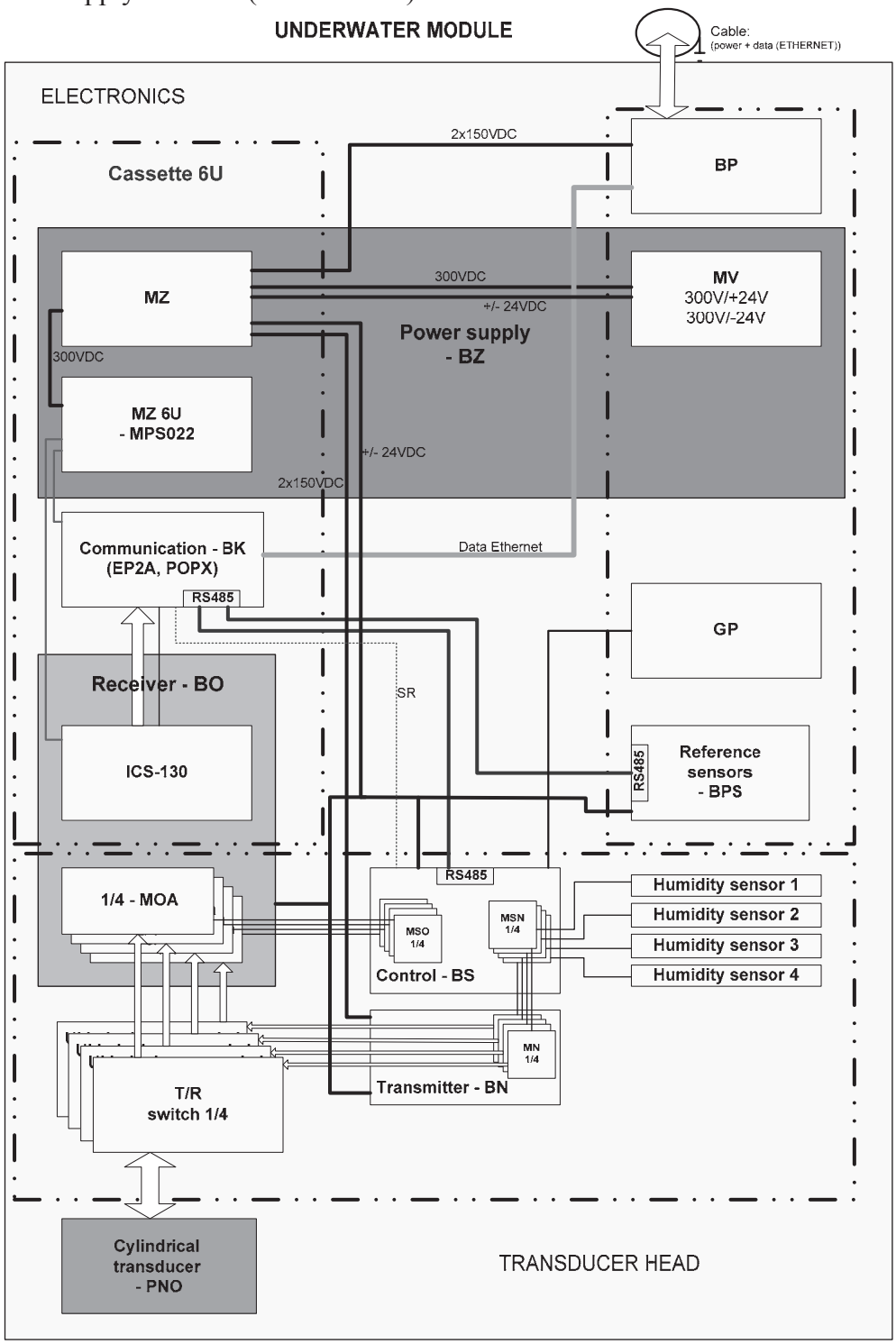

Fig.1. Block diagram of DDS underwater module

Underwater module (UM) is in cylinder form. It can be placed on the sea bottom or suspended in column water. It consists of transducer, transmitter, receiver, power supply, data transmissions and processing blocks – see Figure 1.

Above water module, consists of display, power supply, data transmissions and processing blocks (Figure 2).

The signal and control data are transmitted from UM to above water module via copper-based cable (1 GB Ethernet LAN - cat. 7e + power supply lines) - cable length up to 100 meters.

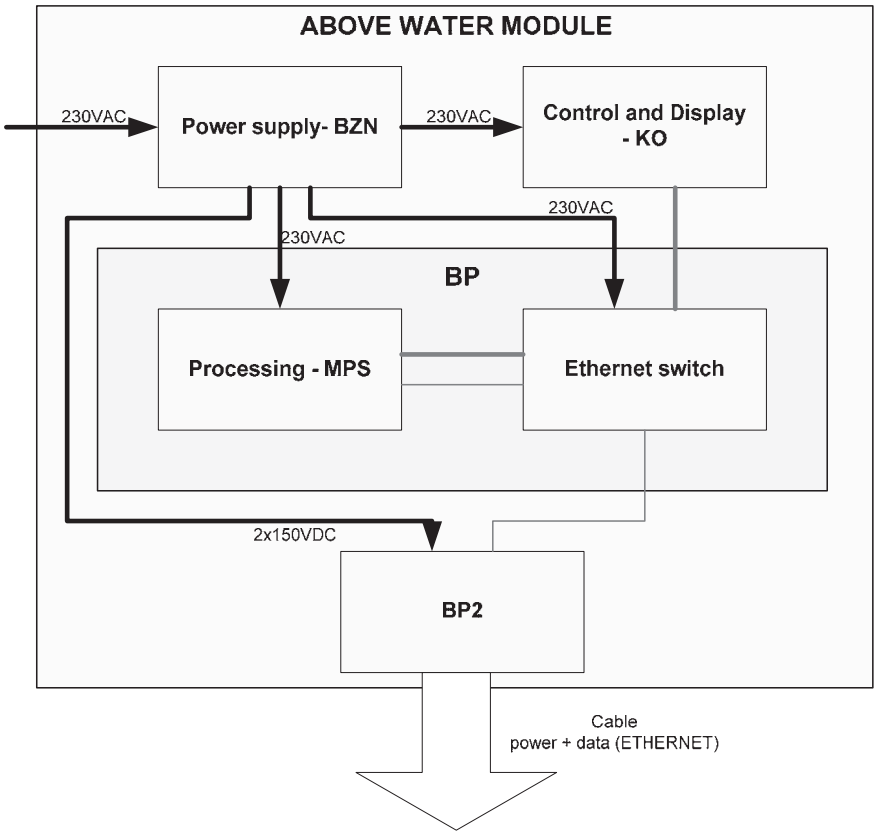

Fig.2. Block diagram of DDS above water module

DDS TD basic technical parameters:

- transducer has been designed (for TD) as piezocomposite cylindrical array (diameter - 355 mm and height - 170 mm) with 180^{o} aperture and 64 elements, transducer can be submerged up to 30 m,
- frequency range 60 kHz ÷ 80 kHz with LFM up or down ,
- searching sector 90º with 32 beams spaced with 3º,
- source level about 205 dB ref 1μP/1 m,
- underwater module dimension 100 cm length, 59 cm diameter,

DDS feature:

- detecting of underwater targets up to 1000 metres range,
- built-in auto diagnostics system,
- tracking up to 10 underwater objects,
- able to cooperate with other sonar systems i.e. acoustic barriers mono, bi and multi-static system to make an integrated system. It can operate in a wide range of environments.

The underwater module can be located in many different ways, on the seabed looking upwards, suspended by cable or else pole or over the side from a jetty.

It is assumed, DDS construction will be based on the commercial off-the-shelf (COTS) units. In the future, modules size and their number may be decreased by utilize the newest electronic technology. We provide the possibility to easy expand of antenna aperture to 360° and 128 elements.

3. UNDERWATER MODULE

The underwater module contains transducer, matching and tuning blocks, electronically controlled transmitters and receivers, power supply system, digitizer and multiplexer of the received signals from transducers and transmitting blocks. This part also contains an altitude and heading reference sensor, which monitors the orientation of the underwater part and allows the motion compensating. The digitizer and transmitting blocks are installed in the standard rugged case. Others blocks are make in state-of-the-art technology. The underwater module offers high corrosion resistance.

TRANSMITTER

The transmitter consists of 64 independent amplifiers. All of them are tuned and matched to a single element impedance of transducer. Simultaneously, they are separated from receiving input. Structurally they are divided into four blocks, each covering 16 transmitting channels. Every block has individual control system which programming the parameters of transmitted signal.

RECEIVER

The receiver is constructed from four blocks, containing 16 independent receiving channels each (four channels per module). Received from each stave of the transducer echo signals are conditioned. Signal conditioning consists of gain, bandpass filtration and symmetrization. Next symmetrical echo signals are sending to ADC block (two ICS-130 ADCs). Main part of the conditioning circuit is the voltage controlled VGA (variable gain amplifier) which has 120dB gain dynamics range. The one block of 16 receiving channels is managed by the one RCM (receiver control module) which produces the control voltage. The RCM includes TVG and AGC loop and a test signal generator.

TRANSDUCER

The new transducer is made as a multielements cylindrical piezocomposite (piezoelectric ceramic rods in a polymer matrix) array – cylindrical array with 180^{o} aperture and 64 elements.

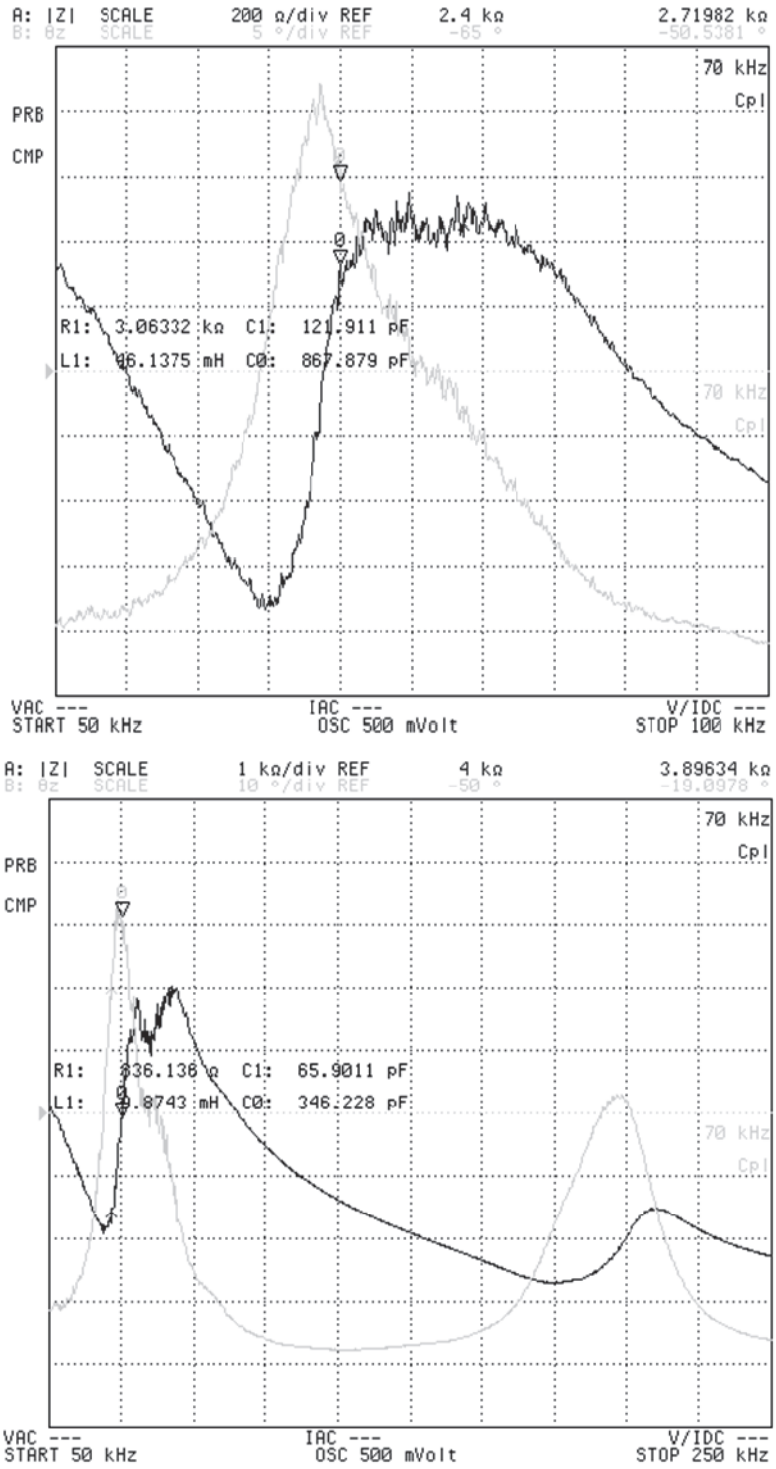

Fig.3. Two examples of impedance parameters for single element

Transducer has been created with the cooperation of Materials Systems Inc. (Littleton, USA). The composite structures reduce the acoustic impedance closing it to impedance of the seawater – it means greater power can be projected to the water. Moreover this ensures low side lobe level of vertical transmit beam. The single element impedance of piezocomposite transducer is presented in Figure. 3

POWER SUPPLY

Main power supply for electronics in underwater module is ± 150 VDC. To meet requirements for supply all DDS blocks, the voltage is converted by high efficient DC/DC converters. Simultaneously this main voltage is used directly for supply of the transmitter power amplifier stage.

DATA TRANSMITING

Analog signals from 64 receiving channels are digitized and transmitted to the above water module by 1 GB Ethernet.

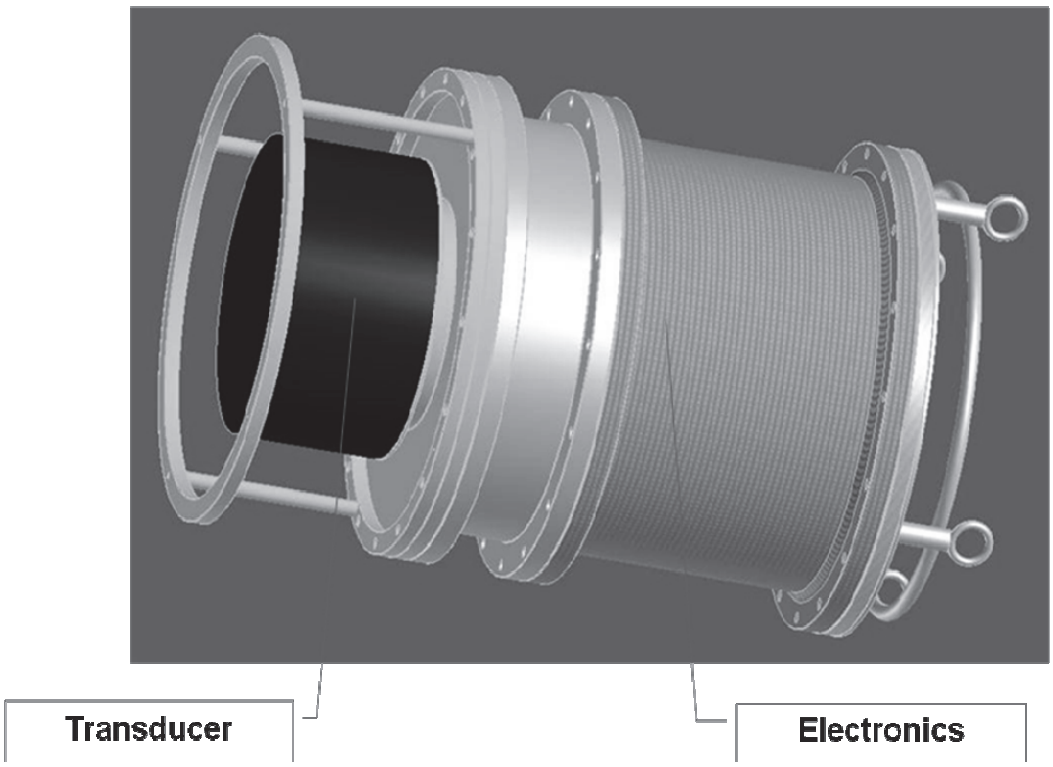

Fig.4. DDS underwater module

4. THE ABOVE WATER MODULE

The all blocks of above water module are installed in the standard rugged case. The case contains also the power distribution unit for the underwater module.

The sonar processor is installed in a rugged rack mountable computer chassis. They are connected to the underwater module via 1 GB Ethernet connection. Power supply and data transmission uses a single cable.

DATA PROCESSING

Digital signal processing consists of replica correlation, which works best with LFM pulse, beamforming, improving signal to noise ratio, elimination of constant echoes and tracking of moving targets.

The DDS sonar is provided with range prediction system to maximize the detection effectiveness. This system computes DDS performances taking into consideration environmental conditions and sonar operational parameters. Also the special procedure is introduced for the constant echoes elimination received from obstacles situated on the seabed.

Tracking of moving targets are carried out by the target detection algorithm. Parameters of the moving targets (distance, direction, speed and type of the intruder) are displayed on the LCD.

GRAPHIC USER INTERFACE

The user interface of the DDS has been designed as user friendly. For GUI laptop PC with high resolution colour display will be applied. The operator can set or read following technical parameters of the DDS sonar:

- status all blocks of DDS
- signal parameters
- range scales
- sonar performance prediction
- display formats
- target data

In DDS system the operator has possibility to chose the automatic or manual mode. He/she can select an area of interest and analyse it using magnification.

POWER SUPPLY

Power Supply for complete DDS system is 220 V AC; 50 Hz; one phase. DC power supply for underwater part is converted from AC voltage and delivered by the underwater cable.

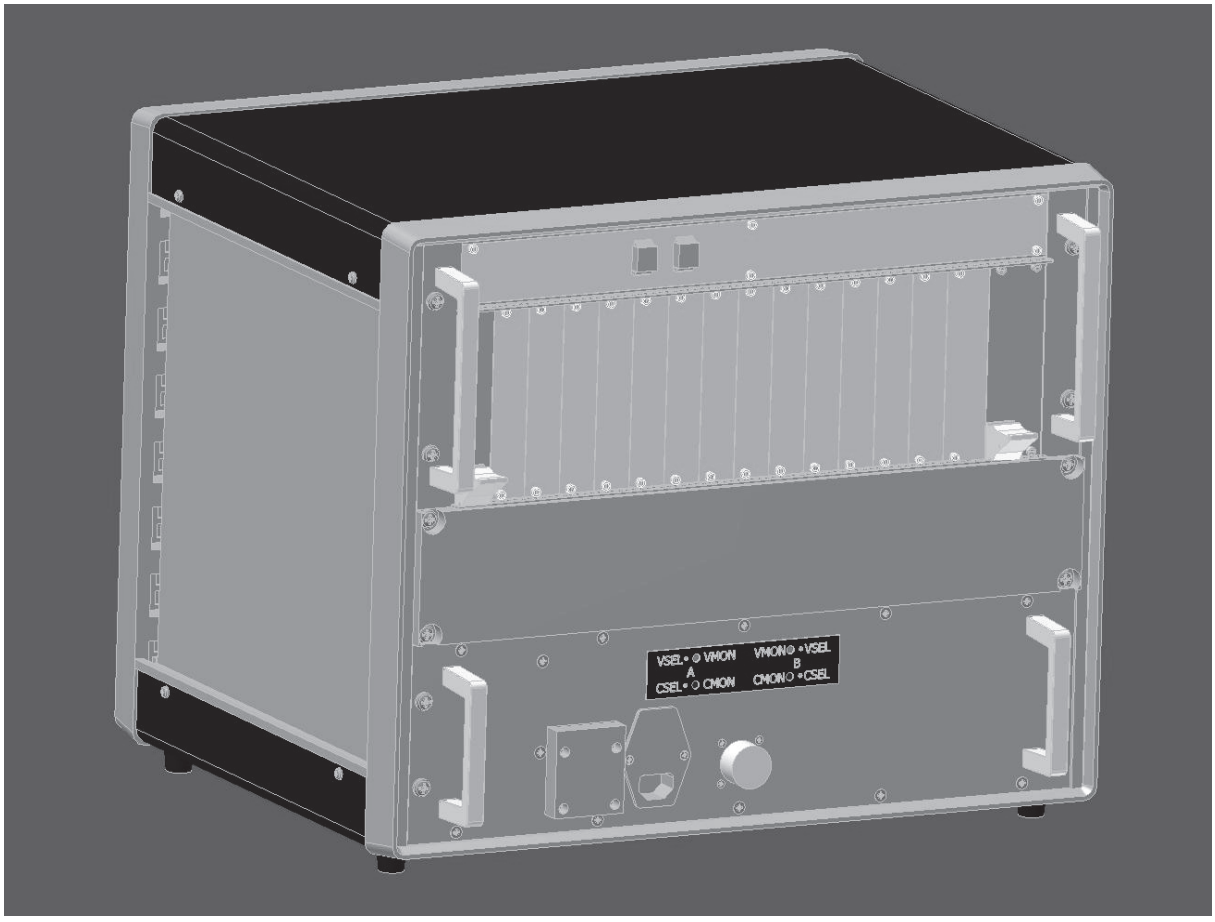

Fig.5. DDS above water module

5. CONCLUSIONS

First trial carried out in our laboratories confirmed that our Technology demonstrator should work effectively even in difficult underwater acoustic conditions.

The practical design of DDS makes it a realistic option for protecting a wide range of maritime assets.

Through operating at lower frequencies (70 kHz) with higher energy, we have obtained a longer range, increasing diver detection effectiveness.

One of the biggest goals in diver's detection is reducing the number of false alarms created by marine life. With significantly more sophisticated auto-detection algorithms and advanced computing power, reliability of this system improves significantly.

ACKNOWLEDGMENT

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REFERENCES

[1] A. Elminowicz, W. Lis, W. Męciński, Transducer for the DDS technology demonstrator, International Symposium on Hydroacoustic, Łeba, 2009.

[2] A. Elminowicz, L. Zajączkowski, DDS technology demonstrator, 55 OSA Wrocław – Piechowice 2008.

[3] T. Janowski, A. Elminowicz, K. Szworski, Data Processing of Broad–Band Signals Received by Multielement Cylindrical Transducer, 7th EEA International Symposium on Hydroacoustic, Jastrzębia Góra, 2008.

[4] A. Elminowicz, M. Okuniewski, E. Porosińska, L. Zajączkowski, Diver Detection Active Sonar, TEHOSS, Gdańsk 2005.