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MONITORING OF UNDERWATER OBJECTS MOVEMENT IN HYDROGRAPHY

The role and abilities of contemporary underwater navigation systems in movement monitoring of hydro-acoustic detection means and underwater objects visual identification is described in this paper. There are no problems with positioning and movement monitoring of objects located or moving over the Earth surface at present. Unfortunately, these systems could not be applied in case of objects that move below water surface.

MONITOROWANIE RUCHU OBIEKTÓW PODWODNYCH W HYDROGRAFII MORSKIEJ

W niniejszym artykule przedstawiono rolę i możliwości współczesnych systemów nawigacji podwodnej w monitorowaniu ruchu środków wykrywania hydroakustycznego oraz identyfikacji wizyjnej obiektów podwodnych. Pozycjonowanie oraz monitorowanie ruchu obiektów na powierzchni Ziemi nie stanowi obecnie problemu. Niestety, systemy te nie znajdują zastosowania w przypadku obiektów przemieszczających się pod powierzchnią wody.

1. INTRODUCTION

There are no problems with positioning and movement monitoring of objects located or moving over the Earth surface at present. Satellite positioning systems GPS (Navstar, Glonass) give us possibilities in tracking on-land objects (e.g. cars) and sea surface objects (e.g. vessels and ships). Unfortunately, these systems could not be applied in case of objects that move below water surface. The specific and changeability of the sea as well as inland water environment cause difficulties. The number of objects moving under water surface is increasing constantly[3]. This increase is connected with humans' growing interest in sea bottom areas with regard to natural resources, historical artifacts or military circumstances.

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Some of the near-bottom activities (underwater pipes constructing, laying cables on sea bottoms, searching and identification wrecks, searching bottom mines or exploring natural resources) require accurate data about the location of objects and means (bathyscaphes, underwater vehicles – ROV (Remotely Operated Vehicle), AUV (Autonomous Underwater Vehicle), Towfish sonars, divers). One of the more efficacious ways of such means movement monitoring is use of underwater navigation systems based on hydro-acoustic.

2. NEEDS IN POSITIONING AND MOVEMENT MONITORING OF UNDER WATER SURFACE OBJECTS (MEASURING MEANS)

There are various forms of human activities in water environment connected, inter alia, with laying and checking cables on sea bottoms and underwater pipes constructing, examination of technical condition of hydro-technical structures, wrecks and underwater obstructions searching, localizing and identifying. They need number of monitoring and measuring instruments and systems. They can be divided into groups such as towed instruments (Towfish sonar, magnetometer), cable controlled systems (ROV, PVDS - Propelled Variable Depth Sonar) and autonomous systems (AUV, UUV - Un-tethered Underwater Vehicle). A few selected measuring means are shown on figure 1.

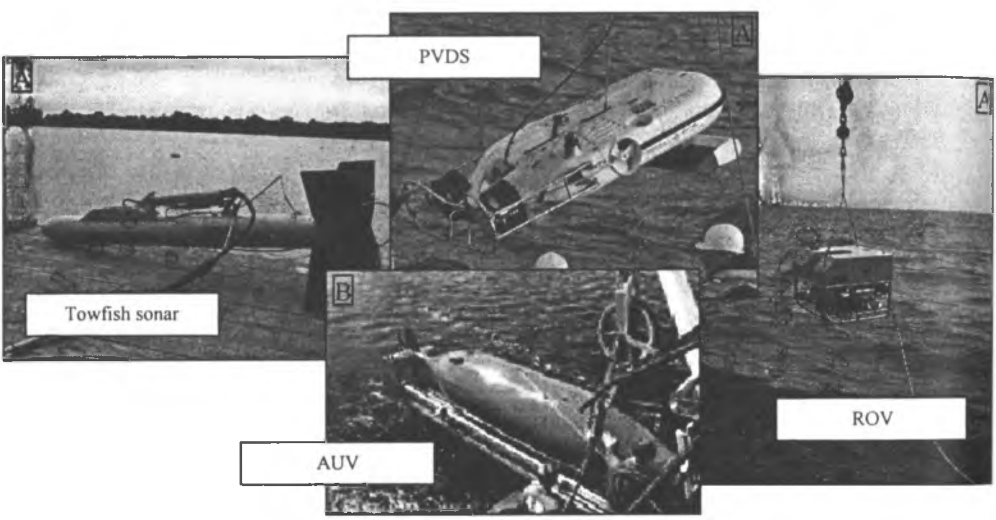

Fig.1. Examples of contemporary measuring means working in water and used in hydrography
Sources: A – photo by D. Grabiec (2004, 2005)
B – Simrad-Kongsberg documents.

The task of the first devices group is underwater objects discovering only (they can be used for the identification in some propitious circumstances). The others groups are used not only to discover but also to identify and verify underwater objects. These are mostly done by means of underwater TV inspection. These devices provide many data useful in various maritime applications. Unfortunately, this data could be incomplete or deformed. These deformations are caused by local environment circumstances (hydrological, meteorological) that directly affect measuring means and / or improper methodology of measurments. There is a need to understand that in opposition to land survey there are no possibilities to provide stable and time lasting measurement platform that could be a survey reference during water survey. Of course there are some technical solutions (stabilizers and gauges of roll, pitch and heading, dynamic positioning systems) but they can run properly only in narrow variation range of measuring parameters. Additionally the weather and hydrological elements are changing very dynamically. Drift, leeway and sea-way are the most important and well-known ones.

Each of mentioned elements is very important for quality of data acquired during hydrographic survey. Each of them could cause problems and sometimes-significant errors in determination of underwater object location as well as its presentation. That is why monitoring of measuring means movement is so important at the present time. Working with towing sonar is an excellent example how that knowledge is essential and how affects on quality of survey. There is need to considerate two crucial things while survey is performed. One of them is survey surface vessel yawing. The second one is related to hydrological circumstances of sea environment.

Vessel yawing is related to steering impreciseness. This impreciseness could be a result of a weak skilled steersman (weak ability to control vessel over given steady course). The other reasons of it could be prolonged reaction time of steersman decision – vessel response arrangement (not enough precision in steering engine work, hull construction) or hydro-meteorological circumstances (heavy stern wave). Resulting towing sonar path is not a straight line, see Fig.2.

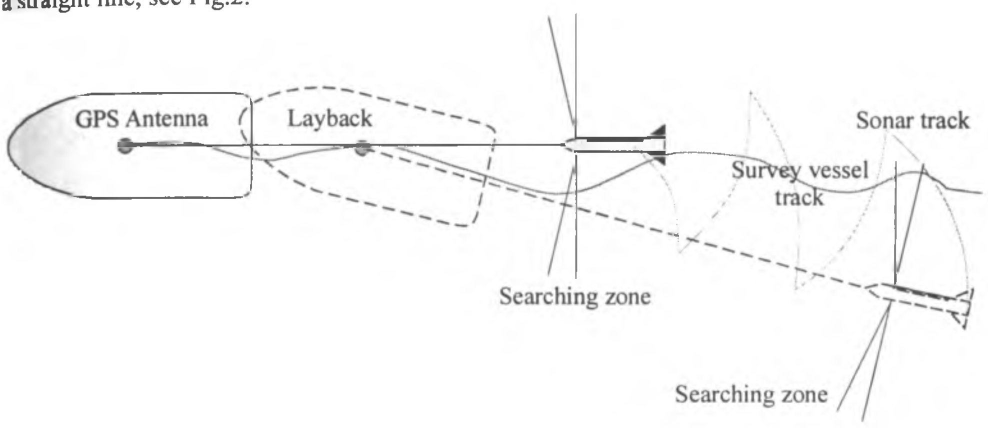

Fig.2. Survey vessel yawing influence on operating towed sonar
Source: based on M. Szatan, Migracja danych w hydrograficznych systemach pomiarowych wykorzystywanych w dZH MW, praca studyjna, AMW 2005, s. 46.

Cable-rope (combined rope for towing sonar and connecting it to vessel to exchange data and control signals) paying out and back ensuing horizontal and vertical displacements. Taking into consideration that the sonar head forms hydro-acoustic beam perpendicularly to the sonar head face so it is obvious that any displacements could have huge influence on quality of sonar images and accuracy of discovered underwater objects positions. These positions are calculated referring to the sonar head location and orientation. A bearing and a distance are used as parameters. So errors in these values propagate into final position of underwater or bottom object. Errors of measured values are related to distance between sonar and GPS antenna (layback) and to towing speed.

Taking into account hydrological environment influence, currents and tides should be considered. A significant problem is to assure towed measuring mean movement along planed path in water regions where horizontal and vertical water movements occur. The towing surface vessel can stay on set profile line (planed track) by active leeway adjusting or by use of a jet steers or DP systems. But in case of towed mean one could observe mean shift along current direction. Linear and angular values of it depend on length of cable-line linking towing vessel with towed device. These problems could reduce searching strip from 200m to 45m, for example, and cause wrong position determination of underwater object. There are two sample sonograms from hydrographics works on Fig.3 that presents unintended shifts of sonar heads influence on quality of sonar images. There could be clearly seen sonar image deformations as indirect echoes, stretched zones of hydro-acoustic shadows and gaps and irregularities in elements of scanned objects illuminated by sonar beam and in their shadows.

Hydrographic tasks peculiarity in conjunction with pointing towards cost and time of work reduction require a few different measuring means co-working at the same time in the same water region. They become mobile underwater objects for sonar system operator. Knowledge where and how they are distributed is essential for work safety. Underwater collisions could bring to serious damage or total loss of them. It is very important considering that prices of this kind of measuring means come from hundreds of thousands up to over million of Euro.

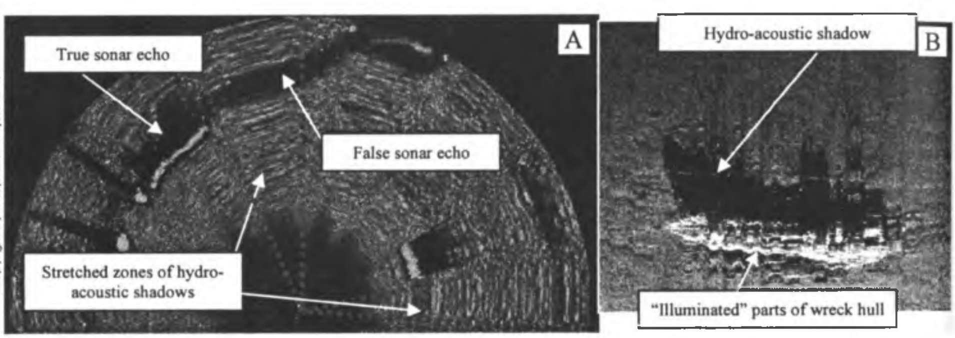

Fig.3. Hydro-meteorological circumstances of sea environment influence on sonar images
Sources: A – own NUG documents (2004),
B – dZH MW documents (ORP *Heweliusz* 2004 surveys).

It is evident that knowledge on location of such means in water space (distribution of objects under water surface), their heading and movement monitoring is essential not only for quality of obtained data but for work safety as well. One of the most common solutions to avoid this kind of problems is use of underwater navigation system.

3. INTRODUCTION TO UNDERWATER NAVIGATION SYSTEMS – TYPES AND TASKS

As it is mentioned in preface sea surface positioning is based on GPS technology. It provides a truthful, inexpensive solution used in hydrographs, sea service and general sea daily work, but GPS signals do not spread through the water environment. The answer for this problem is a system based on acoustic signal triangulation. In general each of hydro- acoustic underwater navigation systems is composed of two units: transmitter and receiver. Transmitter sends hydro-acoustic signal of set frequency. This pulse activates receiver that responds immediately. Specialized computer built in transmitter unit calculates accurate position of receiver relative to themselves and a vessel in consequence.

During last few years there was only several such systems. Some of the best known and frequently used are HPR system – *Hydroacoustic Positioning Reference System 350, 400* made by Simrad-Kongsberg, *Fusion* and *Scout* systems of Sonardyne, as well as *GAPS* system of IXsea. Contemporary underwater positioning systems use a few different measuring and calculating methods. These methods could be mixed and combined to achieve flexibility and high efficacy and accuracy. Some of them could be distinguished: LBL (Long Base Line), SBL (Short Base Line), USBL (Ultra Short Base Line) and other modification of them diverse named by their originators for example MULBL - Multi-User Long Base Line, LSUSBL (Long, Short & Ultra Short Base Line), LUSBL (Long & Ultra Short Base Line). Each of these systems required slightly different initial task. For example, LBL system required a set of transmitters allocation on sea bottom before work has begun. Furthermore time consuming and expansive calibration stage is required to achieve precise system readouts but only in area where system is placed. And then accurate position fixing of underwater objects equipped with transponders is possible – in sea conditions it means 1 to 3 meters in average. This kind of systems is used in water regions where dredging, hydro-technical objects constructing works on sea bottom are done. That is mean in places where there is need to monitor many underwater objects with high accuracy in appointed bottom area.

Regular USBL system mounted on vessels give possibilities to cover defined sea area. However, its installation is neither easy nor fast. This type of systems requires some additional data as current heading, roll, pitch and position of vessel to be provided continuously. Data integration of GPS, gyrocompass, heading, roll and pitch angle indicators is long lasting and complicated task. These are devices of different types, different data formats and controlled by distinct software. In addition all data should be at higher possible level of accuracy to assure reliable results. Fulfilling these requirements gives full mobility and independency in choosing work area. So it is why this type of system is commonly used by hydrographic services.

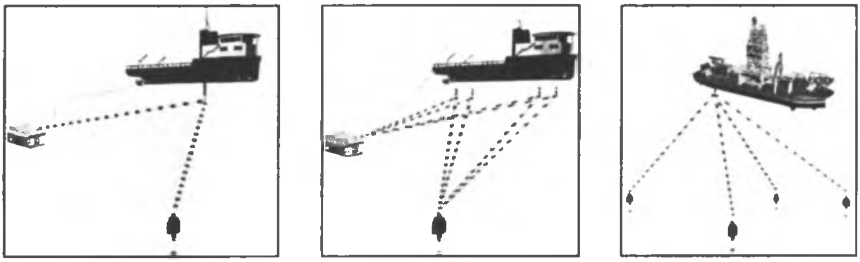

Fig.4. Examples of different arrangements of hydro-acoustic navigation systems – from left – USBL, SBL, LBL
Source: Sonardyne training papers.

In SBL technique a few transductors, at least three but usually four, are arranged in triangle or square assembled at bottom of underwater body of surface vessel. Base lines (distances between transductors) are arranged as long as possible, at least 10 meters usually. System measures acoustic transmission times counted between transponder (mounted on ROV vehicle for example) and each of transductors mounted on hull. Time and phase comparison between signals received from each of transductors allows calculate the position of underwater mobile vehicle as a function of distances to known transductors positions.

4. EXAMPLES OF PRACTICAL APPLICATION OF MOVEMENT MONITORING SYSTEM FOR UNDERWATER OBJECTS

In this part of paper results of surveys that were performed by Polish Navy hydrographic service are presented. At the end of 2003 the hydrographic service was equipped with underwater navigation system of USBL type. Till today it was used to carry out hydrographic task in conjunction with towed sonar and ROV vehicle many times. These tasks were mostly connected with searching and identifying wrecks that are inside Polish sea areas boundary. The figure 5 presents operator screen appearance. It could be easy observed that not only position data of monitored underwater objects (ROV vehicle and towed sonar are presented) are possible to be recorded but also graphical presentation of underwater situation is available to operator onboard surface vessel.

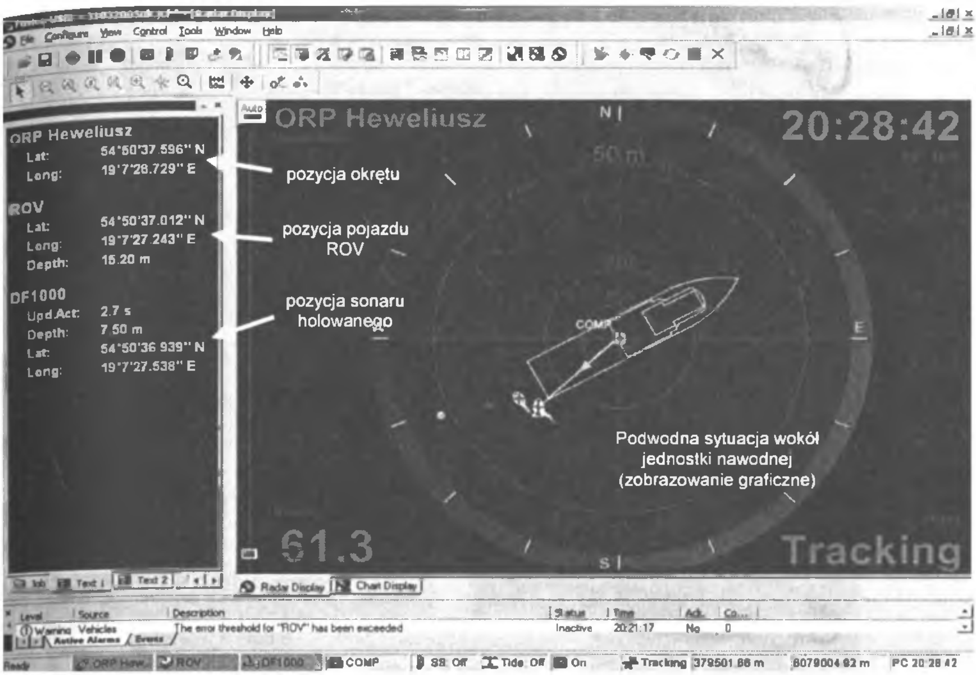

Fig.5. USBL system console presenting some data on underwater objects movement.
Source: based on dZH MW documents (ORP *Heweliusz* 2004 surveys)

Possibilities of co-operation with underwater objects are not limited to sonar and ROV like vehicles only. Due to the small size of hydro-acoustic transponders there is possible to mount them even on divers' overalls or on small parts of underwater vehicles. This gives potential possibility to use such systems in special task, for example in anti-mine operations, sabotage actions and antiterrorist operations. It makes possible own objects monitoring in actions associated with sea-bases defence to sabotage means and systems. It is important especially in hydro-acoustic intelligence operations around seaport entrance. Some examples of transponders mentioned in this paper are presented on Fig.6. Their dimensions in reference to underwater objects could be observed.

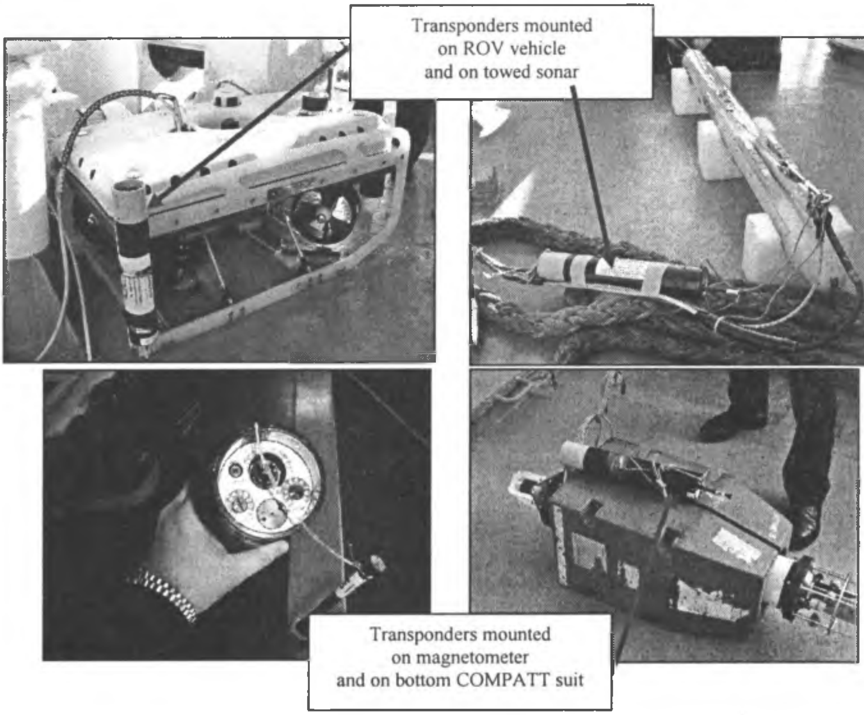

Fig.6. Selected examples of mounting of hydro-acoustic transponders on measuring means of the Hydrographic Service of the Polish Navy, Photo by D.Grabiec (2004, 2005)

5. SUMMARY

Growing human activity in underwater space is connected with exploration and exploit action ofnatural environment resources, constructing underwater installations, intensive hydrographic and oceanographic tasks. That is followed by requirement for monitoring underwater objects movement. Monitoring allows not only better tools protection, avoid damage and loss of equipment but also increases accuracy of position elements fixing and increase reliability of survey data. Underwater objects monitoring is not entire completed jet because of limited number and area of such activities carried out in Polish sea areas. However, taking into account potential possibilities of using underwater navigation systems in hydrography, in activities connected with our country military defence and in hydro-technical and geophysical task carried out at sea, essential is to consider proper preparation of personnel and equipment for using of such systems.

Additionally, experiences gathered during operating of hydro-acoustic underwater navigation systems could be used in many others sea applications – everywhere, where high precision in position and movement parameters fixing of underwater objects is required.

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Reviewer: Prof. Ryszard Wawruch