AUTONOMOUS HYDROACOUSTIC SOUND VELOCITY PROFILER

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The paper presents the autonomous hydroacoustic sound velocity profiler collaborating with ordinary PC by small box included interface & battery charger. The measurement and calibration methods and block diagram of the meter are presented as well as principles of operation, data collection, selection and transmission. There are described three versions of this meter – dropped from "normal" ships, installed in the light hull of submarines and casings in the hulls of variable depth sonar antennas.

INTRODUCTION

The meters (profilers) of sound velocity distribution in water are a necessary tool for predicting the operating conditions of underwater acoustic systems. There are two basic methods for determining the distribution – the indirect and direct method. The indirect method measures the depth distribution of parameters that determine the velocity of sound wave propagation in water. This is then the basis for determining the distribution of the velocity, e.g. using Leroy's empirical formula [1], [4]:

$$c = 1492{,}9 + 3(t-10) - 6\cdot 10^{-3}(t-10)^2 - 4\cdot 10^{-2}(t-18)^2 + 1{,}2(s-35) + \\ - 10^{-2}(t-18)(s-35) + h/61 \qquad (1)$$

where c [m/s] is the velocity of sound propagation, t [°C] – water temperature, s [$^o/_{oo}$] – salinity, and h [m] – depth.

Called CTD (conductive ≈ salinity, temperature, depth), the method is used when other important oceanographic parameters are being measured, i.e. when sound velocity is not the primary parameter. Please note the varying effect of changing parameters on sound velocity:

$$\Delta c/\Delta t = 3{,}4 m/s\ /1^oC \qquad \Delta c/\Delta s = 1{,}2 m/s\ /1^o/_{oo} \qquad \Delta c/\Delta h = 1{,}7 m/s\ /\ 100 m \qquad (2)$$

For example when water temperature changes by 0.5°C the effect is the same as a change of depth by 100m. This allows some simplification in how the meters are designed. First, if we assume that salinity remains fairly stable (e.g. river mouths are not included), we can choose not to take this measurement and put the value $35^{o}/_{oo}$ for oceans, $7^{o}/_{oo}$ for the Baltic or $0^{o}/_{oo}$ for inland waters. Second, if we assume that the sounder will be submerged at a constant speed, there is no need to measure the depth; the thermometer and timer will be sufficient. This type of sounder is usually for single use (disposable yet cheap), dropped from aircraft communicating with radio hydrobuoys, from submarines and ships; it sends water temperature data by radio or an underwater acoustic channel.

For collaboration with hydroacoustic systems the meter's primary function is to give an accurate description of sound velocity profiles in different bodies of water – inland and sea waters – especially along the Baltic coastline, i.e. in waters of varying salinity without having to collect any other hydrographic data. Consequently, indirect methods are ruled out. Another important design assumption was the universal application of the meter – it can be fairly easily dropped from ships, installed in the light hull of submarines and casings in the hulls of variable depth sonar antennas.

1. THE MEASUREMENT METHOD

Sound velocity in water is measured by measuring the time it takes for ultrasound pulses to go from the ultrasound transducer to the acoustic mirror and again to transducer. The pulses cover a measurement base "with the flow " and "against the flow" helping to eliminate the effects the movements of the measurement cylinder have on the results of the readings. The additional gain is the possibility to reduce the meter's geometrical dimensions.

Given these measurement conditions, the following relation describes the velocity of sound propagation c_w:

$$c_w = N\frac{2d}{t_N} \tag{3}$$

where N is the number of measurements in a series, d is the length of the measurement base (the distance between the transducer and acoustic mirror), t_N is the time a series takes for N pulses to transit along the base.

The required measurement accuracy should be better than 1‰ (defined as ±0,5m/s). The only value in formula (3) which cannot be easily determined with the necessary accuracy is the length of base d. Therefore, the most reliable method for calibrating meter readings is to do it by measuring sound velocity in distilled water at a measured temperature and to zero the variance in the readings against the value from the formula:

$$c_w = 1400+5,02\cdot T-0,055\cdot T^2+0,0003\cdot T^3 \qquad T[°C] \tag{4}$$

selected from several similar empirical formulas for sound velocity in distilled water in the temperature function.

2. METER DESIGN

Each version of the measurement set comprises three basic elements: profile meter proper, interface and a PC with the necessary software. Figure 1 shows a block diagram of the measurement set designed for ships.

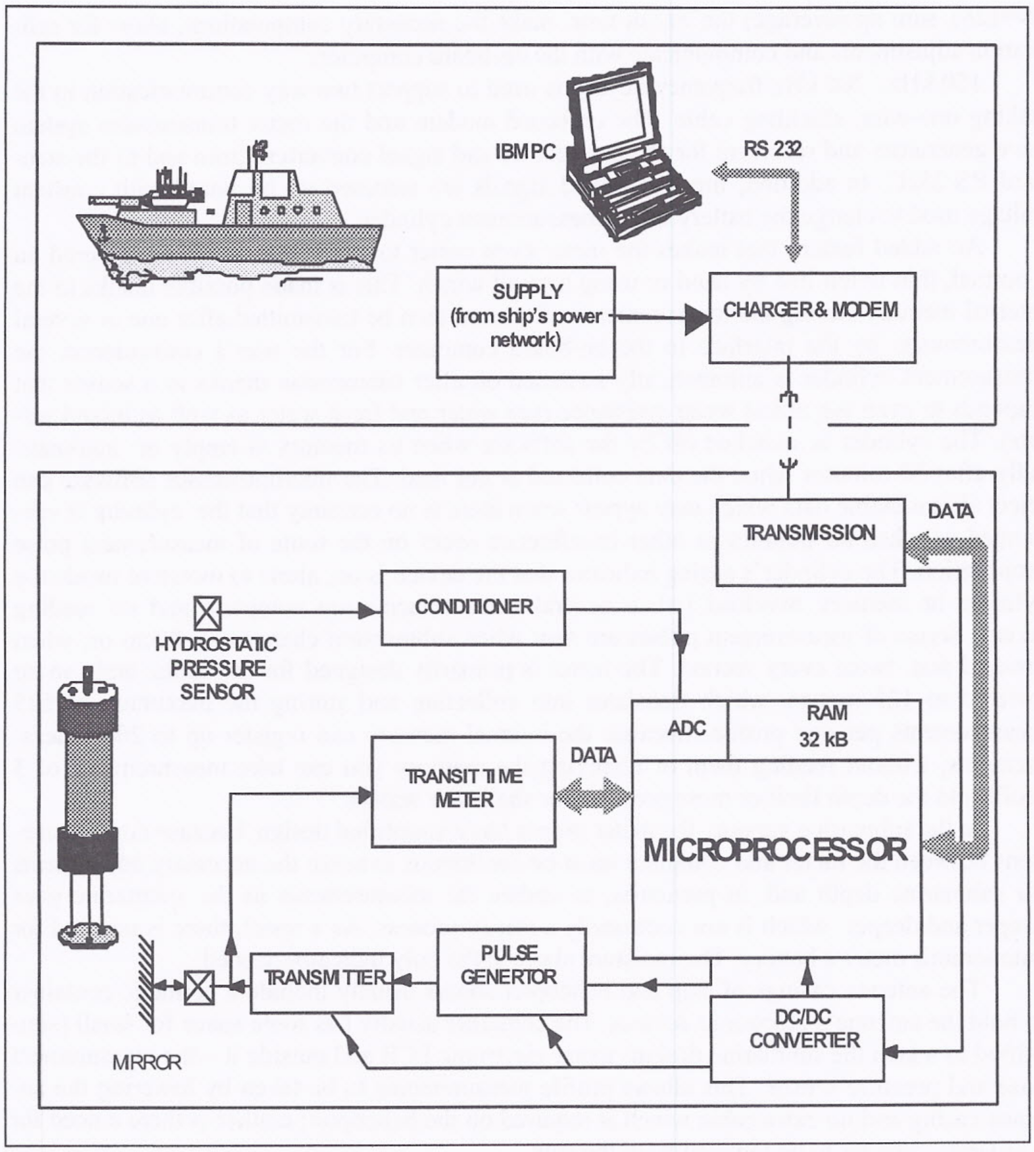

Fig. 1. Block diagram of the measurement set.

The principal component of the meter is the processor linked with the usual environment (RAM, EPROM) and special components such as the pressure sensor (measuring the depth of submersion) and devices to measure the pulse transit time and to generate series of pulses activating the ultrasound converter. When the transmitter sends a pulse, the clock pulse meter is opened. Once received by the transmitting and receiving converter, the ultrasound pulse is converted into an electric signal to be amplified; once it reaches the desired level, the meter is closed. Consequently, the number of pulses determines the transit time, which in the relation (3) is given as t_N. The role of the microprocessor is to control the measurement cycles

(N=128), sum up (average) the transit time, make the necessary computations, allow for calibration adjustments and communicate with the on-board computer.

150 kHz / 200 kHz frequency keying is used to support two-way communication in the linking one-wire, shielding cable. The on-board modem and the meter transmission system have generators and receivers for the frequencies and signal converters from and to the standard RS 232C. In addition, the transmitted signals are summed up on board with constant voltage used to charge the battery in the measurement cylinder.

An added feature that makes the meter even easier to use is that it can be lowered on a normal, thin nylon line by hand or using a small winch. This is made possible thanks to the internal memory storing the measurements which can then be transmitted after one or several measurements by the interface to the on-board computer. For the user's convenience, the measurement cylinder is automatically switched on after submersion thanks to a sensor that responds to even the tiniest water resistance (sea water and fresh water as well as inland waters). The cylinder is switched off by the software when its memory is empty or automatically after 30 minutes when the data collected is not read. The microprocessor software can reject all unreliable data which may appear when there is no certainty that the cylinder is submerged or when air bubbles or other interference occur on the route of measurement pulse propagation. The cylinder's casing indicates that the device is on, alerts to moisture inside the cylinder or memory overload (when several measurements are complete and no reading taken). Series of measurement pulses are sent when submersion changes by 20cm or, when lowered fast, twice every second. The meter is primarily designed for the Baltic and can be lowered to 125 meters, which translates into collecting and storing the maximum of 625 measurements per one profile. Because the internal memory can register up to 2000 measurements, without reading them or emptying the memory you can take measurements of 3 profiles to the depth limit or more profiles for shallower waters.

In the submarine version, the meter proper has a simplified design, because communications between the meter and computer must be continuous to make the necessary adjustments for submarine depth and, in particular, to update the measurements as the submarine goes deeper and deeper which is not necessarily a steady process. As a result, there is no need for autonomous meter's battery. The moisture alarm is the only indicator needed.

The antenna casings of ship and helicopter sonars usually include a hermetic container to hold the antenna's electronic devices. The container usually has some space for small (simplified to match the submarine design) meter electronic PCB and outside it – the measurement base and pressure sensor. This allows profile measurements to be taken by lowering the antenna casing and no extra cable winch is required on the helicopter; neither is there a need for a separate cylinder to be lowered from the ship.

When the profiles are measured and data input into the on-board computer, the software will then produces images of the results as diagrams and tables. You can input (automatically provided there is a link, or by hand) the geographical position of the measurement location, register on the disk the measurement file, its date and time, print out the image and transmit data in the required format to external systems (e.g. to a hydrological database).

Further computations are done in the on-board computer to get a prediction of sound propagation routes and detection conditions in vertical sections of the water for sonar or hydrocommunications systems whose system parameters are input into the software [2], [3].

Figure 2 shows the printed page with example data and image of a profile.

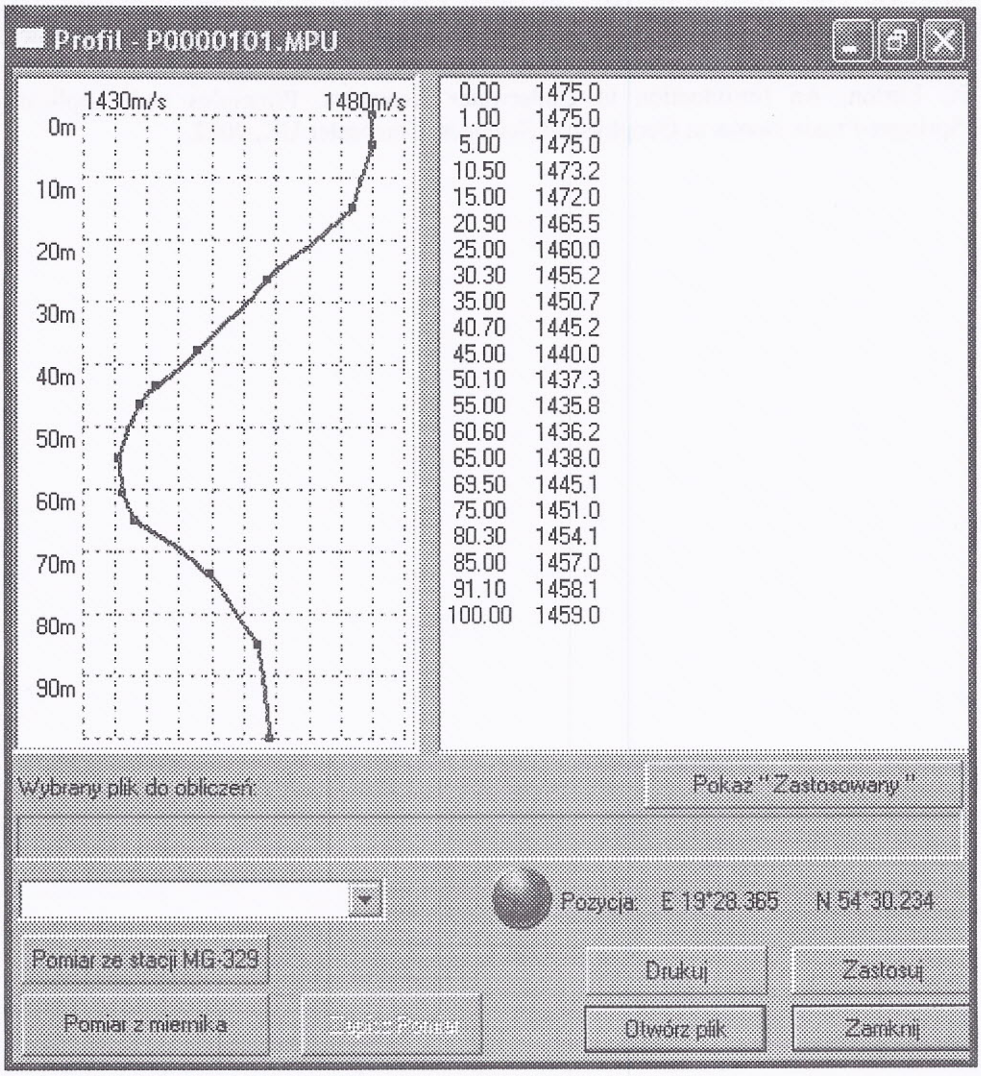

Fig. 2. Image of a spectacular profile.

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