HYDROGRAPHIC ECHOSOUNDER FOR SOUNDING INLAND WATERS

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This article describes a new echosounder model designed specifically for institutions responsible for the management of inland waterways, artificial and natural reservoirs, and marine coastal waters. The basic requirement related to the need of sounding shallow waters is measuring the smallest possible depths. Using separate transducers (sending and receiving) and attenuating them, and introducing a high dynamic range TVG circuit allowed the measurement of depths from 20cm at a maximum range of 100m. Water temperature is measured in order to include sound velocity corrections. The echosounder is manufactured using modern technology, with a PC 104 computer, robust FLASH memory emulating a hard disk, 8 inch color LCD panel, thermal printer with paper band for instant profile printouts, and a floppy disk drive for permanent storage. The echosounder interfaces to GPS.

INTRODUCTION

Institutions responsible for managing inland waterways, artificial and natural reservoirs and marine coastal waters, as well as organizations conducting research on such waters, must use high precision hydrographic echosounders. Due to the special requirements, commercially available (and cheap) yacht and fishing echosounders cannot be used. About 10 years ago, the same team developed and built an echosounder which is still in use in some locations. Several eras have passed since that time, especially regarding computer technologies, hence the obvious need for building a modern version of this type of echosounder.

1. PHYSICAL LIMITATIONS RELATED TO MEASUREMENTS

The basic requirement reported by users of the echosounder mentioned above is the possibility of measuring smallest possible depths (about 0.2m) at a maximum range r of approximately 100m. This generally implies the need to minimize the duration of the sounding pulse emitted by the echosounder's transmitter. The duration of this pulse, plus the fading time of transducer mechanical resonance vibrations, are the "dead zone" when receiving echo signals (and determining depth) is impossible. To minimize this zone, the sounding pulses should be as short and as weak as possible (which conflicts with the need to achieve long ranges), separate transducers should be used for transmitting and reception, and the transmitting transducers should be specially attenuated to minimize vibrating after stopping the electric stimulation It is necessary to apply appropriate time variable gain (TVG) in the receiver to minimize the amplification of strong echo signals received (and crosstalks from the transmitting transducer) from smallest depths, and to increase the amplification for

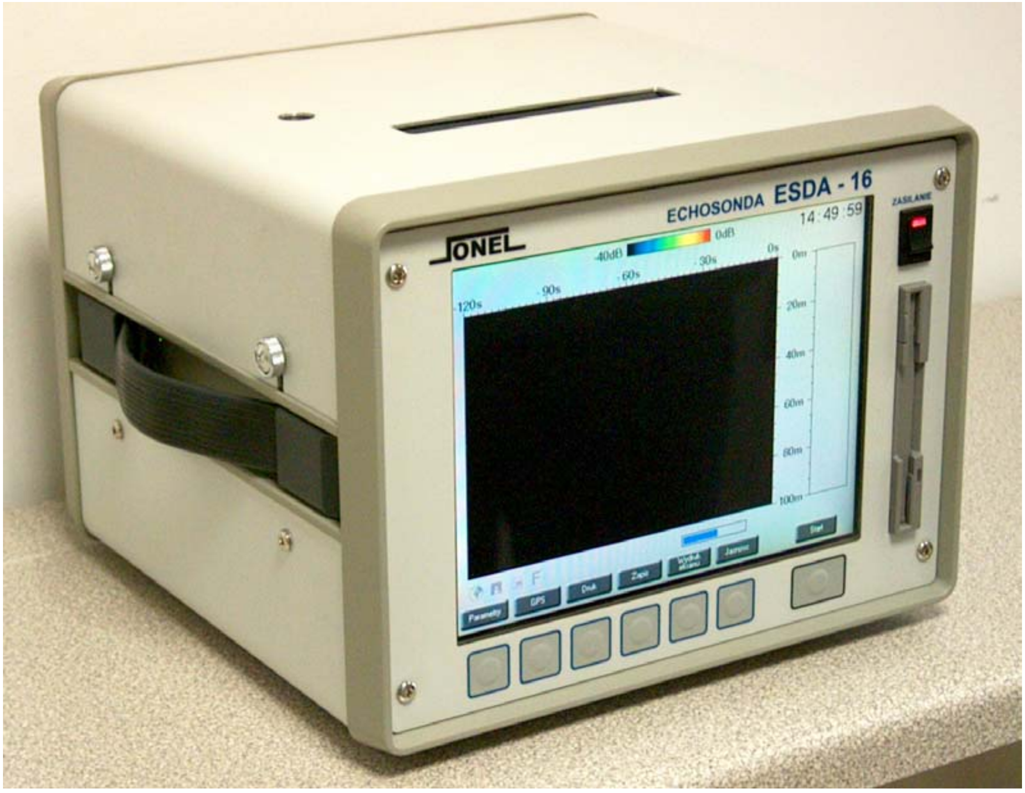

Fig. 1. The echosounder

longer delays when the receiver is waiting for weaker signals from larger depths. All these solutions were utilized in the new echosounder, plus manual gain control. The duration of transmitting pulse is 100µs at 400W (source level 97dB). The TVG with *20log(r)* characteristics has a dynamic range of 40dB.

The second important requirement is to ensure the best possible measurement accuracy. The most critical issue is sound propagation velocity which depends mainly on water temperature. The measurement head with ultrasonic transducers incorporates a water temperature sensor. In deep inland reservoirs, especially in summer, significant temperature differences occur between surface and deeper water layers. Therefore, it was assumed that the sound velocity would be determined by measured temperature for depths down to 10m; for larger depths, the water temperature is assumed to be 4^{o}C which proves to be a good approximation for the majority of the season. It is also possible to introduce salinity which also has some (far less significant than temperature) influence on the sound propagation velocity. Therefore, the echosounder can also be used at sea with equal precision. In such conditions the accuracy of depth measurements is better than 0.5%.

Another requirement is the type of expected information about the bottom. If the only important information required is the depth itself without any particular attention paid to the type of bottom, a relatively high frequency of the sounding signal can be used. The 200kHz signal is relatively well reflected by each type of bottom surface, so the leading edge of the echo pulse precisely determines the measured depth. Low-frequency signals (20-30kHz) penetrate the bottom structures yielding more information about its type or stratification. Owing to the option of alternate pulsing and receiving, the echosounder can operate with two frequencies. However, the use low-frequency transducers significantly increases the size and weight of the measuring head, worsens its mechanical performance in water, and leads to higher costs. The increased size and weight of a double-frequency head are due to the complex technology of low-frequency transducers (”sandwich” type) and the proportionally larger diameter needed to achieve a similar beamwidth. The 200kHz transducers are about 5cm in diameter; the beamwidth is 9^o (directivity index 27dB).

The echosounder properties presented above are based on the physical background of depth measurements. Apart from this, users have their own, strictly technical requirements.

2. TECHNICAL FEATURES

The list of users' technical requirements starts from the very basic ones. The echosounder should be as small as possible with regard to the limited space available in boat cabins. Since different electric systems are used on board, it should accept different power supply voltages. Mounting solutions and robustness of the echosounder should ensure failure-free operation in storm conditions. On the other hand, the device must be easy detachable without any special tools. The operating temperature should range from 5^o to 40^oC.

The design of the measuring head mounted on the outer part of the boat bottom must compensate the bottom curvature so that transmitting and receiving transducers are directed vertically downwards. Therefore, customized heads with different internal transducer fixing components need to be made for different boats. The head should be as flat and streamlined as possible, it should also protect internal elements from mechanical damage. The head casing material must be acoustically transparent. Fastenings should provide sufficient strength and tightness, and should not significantly affect the bottom structure. Figure 2 shows a head with 200kHz transducers embedded in polyurethane, which meets all the requirements.

Fig. 2. The measuring head

Basic functions of the echosounder should, on the one hand, make it possible for an inexperienced user to use it, but, on the other hand it should also allow to store data for further advanced use, such as analyses, databases, or map plotting. Therefore, the measurements must always be related to the geographical position. This means that the echosounder must interface to a GPS receiver. This requirement has significant technical consequences as it determines the structure of the echosounder. The block diagram is presented in Figure 3.

The most important parameters of the measuring head, power supply unit, transmitter and receiver are presented above. The digital part is based on a commercially available PC 104 mainboard with a graphic card and FLASH memory which substitutes a hard disk to improve mechanical resistance of the echosounder. The mainboard interfaces to peripheral devices via A/D and D/A converters, and I/O ports. Controlling the transmitter required designing an additional circuit.

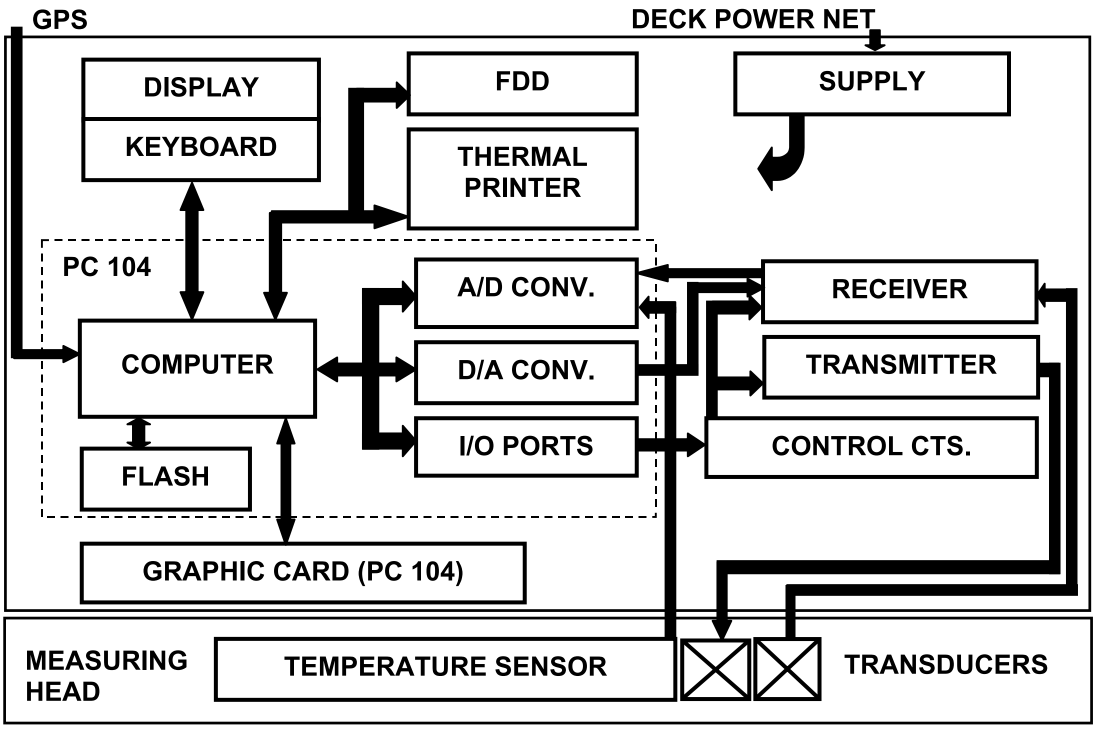

Fig. 3. Block diagram of the echosounder

To register sounding test results online, a commercially available B/W thermal printer is used with paper rolls up to 15cm wide. Apart from bottom profiles, headers, markers, and time are printed. The scale of the printout reflect the scale of the image on the display. To obtain at least a modest grayscale on the printouts, dithering is used. For small echo amplitudes, noise amplitudes exceeding the black threshold are rare. The higher the echo level, the more frequently overdrives occur. An echogram example is shown in Figure 4.

A simplified keyboard and easy control of the echosounder minimize the workload of the operator who is busy steering the boat. The keyboard has only seven keys plus a separate power key. The key functions change (context keyboard) for different operating options, and every keypress is shown on a display installed above the keyboard.

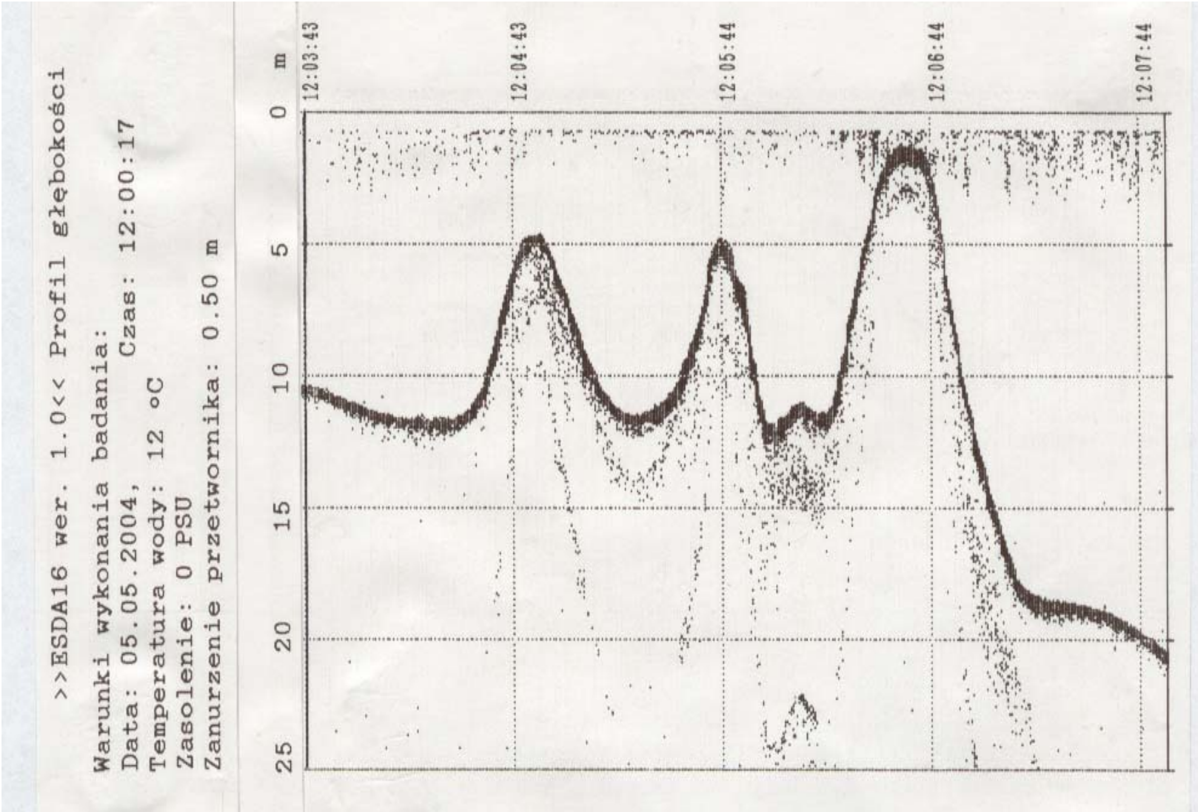

Fig. 4. Sample echogram printout

The echosounder incorporates an 8-inch color LCD display. Apart from the keyboard support function, the main part of the screen is occupied by a scalable echogram. The right side of the screen shows a vertical ruler with echo signal envelope for each transmission (A type imaging). A moving pointer beside this ruler shows when a decision is made about the arrival of bottom echo which determines the current depth, displayed digitally and stored in a file. The decision criterion is the sufficient energy of the echo signal (amplitude and duration). The pointer enables the operator to control the validity of automatic decisions which may be misleading in particularly disadvantageous conditions, e.g. when sounding a steep bottom. The measured water temperature is also displayed. The depth scale takes into account the depth correction.

Figure 5 shows the display right after power-on and Figure 6 the display view during measurements. Figure 7 shows the settings management window and Figure 8 shows the window for the measurement data file management. In order to reduce the space occupied by the data, the files are in the text format; they do not allow to retrieve full echograms. The files are stored on floppy disks and may be transferred to computers for further processing as described above.

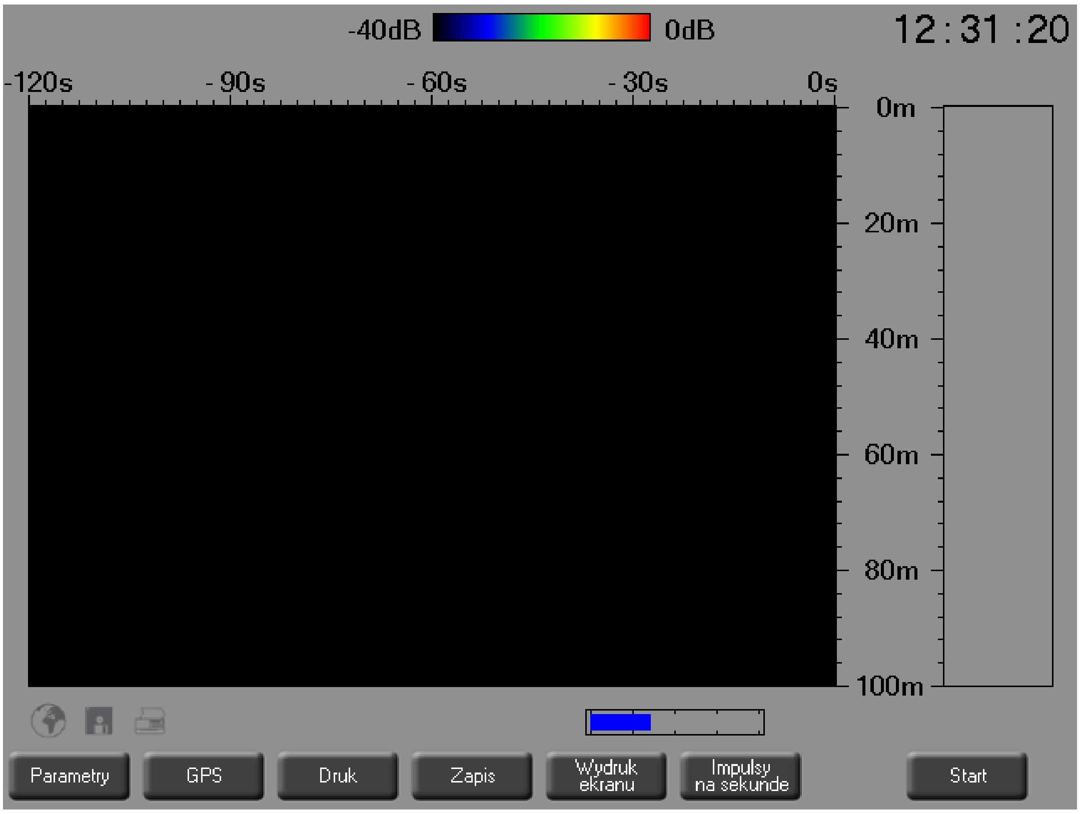

Fig. 5. Echosounder display view right after power-on

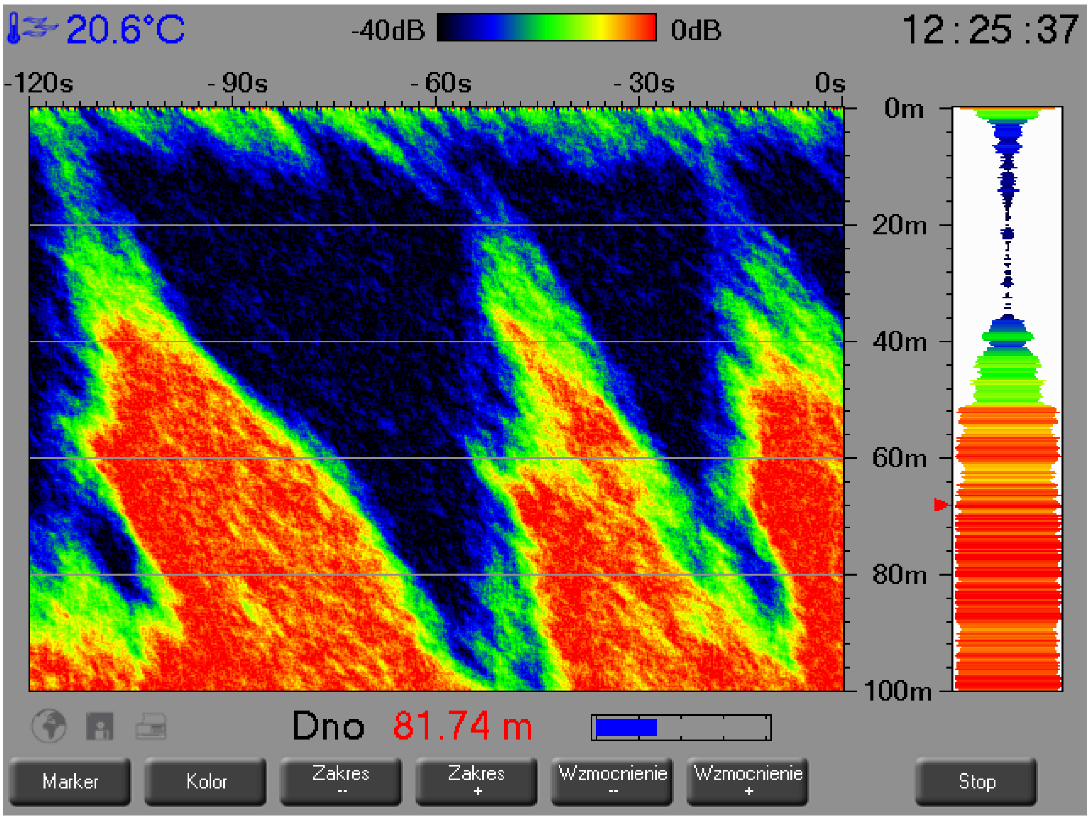

Fig. 6. Display view during measurements

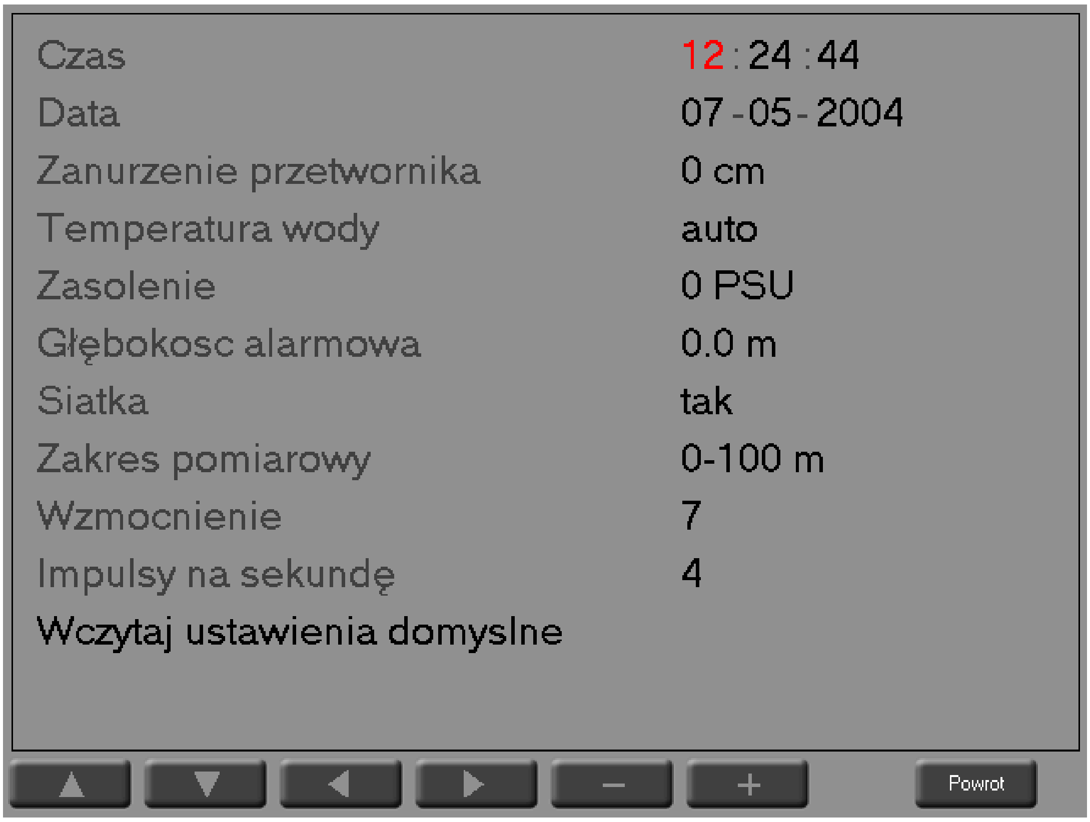

Fig. 7. Settings management window

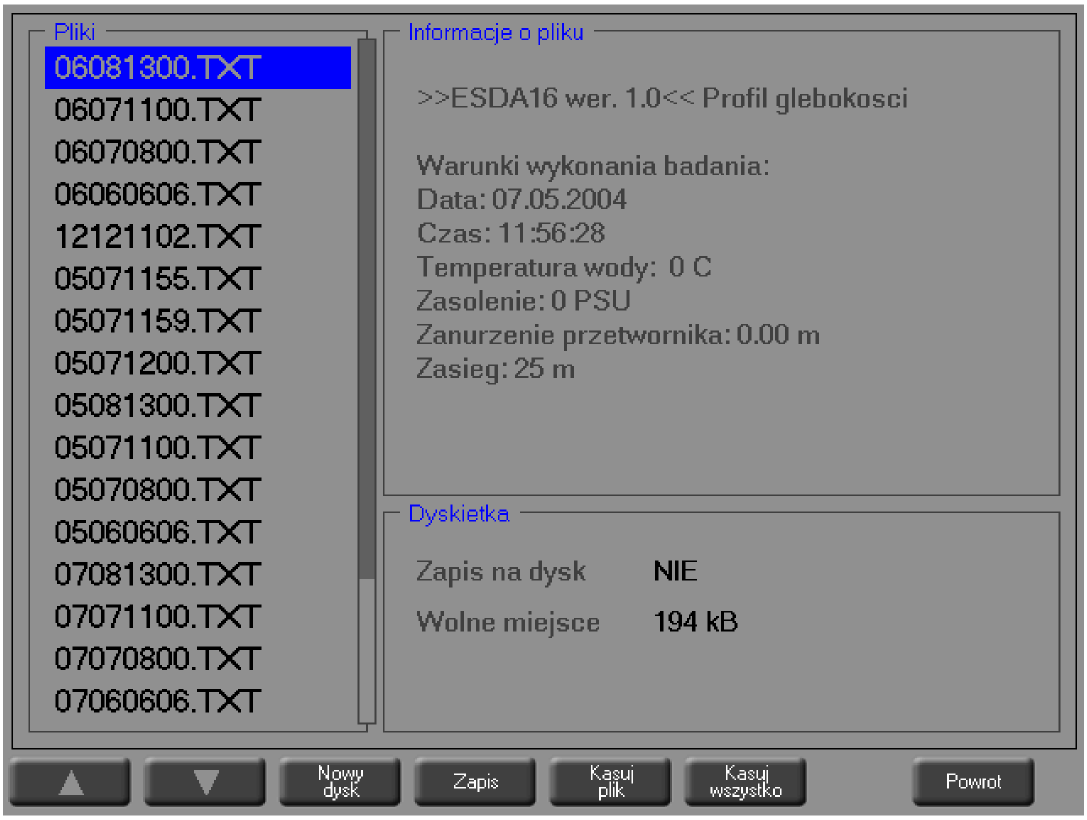

Fig. 8. Measurement data file management window

3. SUMMARY

The developed and tested echosounder was made using the most recent analog and digital components and assembly methods. Certain limitations regarding parameters (e.g. maximum range, display size, imaging palette) and software were deliberately introduced taking into account the needs of potential users, and the necessity to keep the price low for Polish users; the price must be significantly lower compared to similar professional devices offered by foreign manufacturers.

The volume of this article does not allow to discuss in detail the properties and performance of the device. Therefore, only the most important of them have been selected by the authors for this publication.