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APPLICATION OF SOME ECHO PARAMETERS TO THE SEABED CLASSIFICATION - METHODOLOGICAL ANALYSIS

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The paper presents the methodological analysis of acoustical seabed classification procedure, which aim is to define the most appropriate bottom echo parameters as an input set. Several acoustical and statistical features of echo envelope were compared with morphological features of bottom sediments and a set of parameters was proposed: integral backscattering strength, time of reverberation, radius of autocorrelation, fractal dimension, moment of inertia, and skewness. It was shown using real echoes from seafloor, that this set may be a good descriptor of sea bottom sediments and may be used in classification procedures. In addition, the spatial distribution of echo skewness within Polish Economical Zone of Baltic Sea was presented as an example and compared with sediments allocation map.

INTRODUCTION

None of already developed acoustic methods offers sufficiently effective, general characterisation of seabed and sediments, so the problem of acoustic seafloor identification and characterisation is still the subject of extensive research. Two opposite approaches are known here: the first is based on calculation of a large number of different echo parameters, without detailed consideration of their physical meaning, while the second is to evaluate only one or a couple of well known physical quantities characterising scattering on seafloor, as backscattering strength or first/second echo energy.

The presented work is an attempt to compile those two approaches by investigating the importance of proposed different echo parameters in sediments classification also from the physical point of view. The differences of their values obtained for selected echoes from particular types of sediments configurations within the area of Southern Baltic Sea are shown and discussed. In addition, the spatial distribution of the echo "skewness" is presented as an example.

1. BOTTOM ECHO PARAMETERS

Searching for the set of echo parameters which would characterise the sediments structure physical properties satisfactory, we selected the following 6 quantities:

1. The **integral backscattering strength** S_{bs} - the logarithmic measure of the energy value integrated for the total echo signal duration [3]. This parameter is well verified as bottom hardness index, but possess no information about sediment structure.
2. The **time of reverberation** T_{90}, defined as the time in which 90% of the echo energy returns [1]. The larger value of T_{90} indicates wide layer of soft sediments under the seabed surface, which allows the signal to penetrate seafloor more deeply.
3. The **radius of autocorrelation** function of echo envelope c_r. It is smaller in a case of occurrence of strong differences in echo signal level for two adjacent samples (see Fig. 1 in Section 3). Therefore it will allow for distinction between the echoes from very hard seafloor or with clearly visible layers and echoes without strong peaks or level changes in their waveform.
4. The **Hausdorff fractal dimension** D calculated using method of log-log slope estimation of echo envelope power spectrum [2]. As it was shown previously [1], in the case of domination of volume scattering, the fractal dimension has smaller value for smoother echo from harder bottom and greater value for more corrugated irregular echo from softer, more layered seafloor.
5. The normalised **moment of inertia** of the echo envelope, in respect of horizontal axis containing its gravity center.

$$I = \frac{\sum_{i=1}^{N} [(i - i_c) \cdot \Delta t]^2 \cdot p_i^2}{\sum_{i=1}^{N} p_i^2}, \tag{1}$$

where Δt is the sampling rate, i_c - the sample number corresponding to position of gravity center of the echo signal, p_i - the acoustic pressure value sampled at the time t_i.

It describes how the echo energy is concentrated around the gravity center. The small value of I denotes short echo (or longer with one peak in its middle part), while greater value corresponds to longer echo with several parts of relatively high signal level, which may indicate sediment layers.

6. The **envelope skewness** – the third statistical moment of instantaneous signal value. In calculating the envelope skewness coefficient, the pressure p_i for consecutive samples acts as the probability density function $W(x)$. The authors use the term "skewness of echo" for this parameter. It measures the asymmetry of an echo shape along the time axis. The negative value of *skew* indicates the localisation of the large part of echo energy in the beginning part, with tail of relatively low signal level (as in Fig. 1a and b). The positive *skew* value informs that the majority of energy is focused in the end part of echo (Fig 1c and d). In that way, it may describe some features of sediments structure.

2. EXPERIMENTAL RESULTS

The defined 6 parameters were calculated for registered echo signals scattered on different seabed and sediments types in the area of the Polish Economical Zone of Southern Baltic. ELAC 4700 echosounder working at frequency of 30 kHz and transmitting the pulses of 0.3 ms duration was used. The envelopes of bottom scattered signals were sampled at 3 to 9 kHz frequency and stored together with the information about the echosounder adjustments and ship position. The information about the true type of seafloor was obtained from geological maps [4].

The example of the echo envelopes and calculated parameters for selected 4 types of seafloor are presented in Fig. 1. The echoes from hard sand (Fig 1a) and more soft, fine-grained sand (Fig. 1b) differ significantly from the echoes from more layered seafloor (Fig 1c and d). In d) case, scattering on several, relatively hard sediment layers is recognisable.

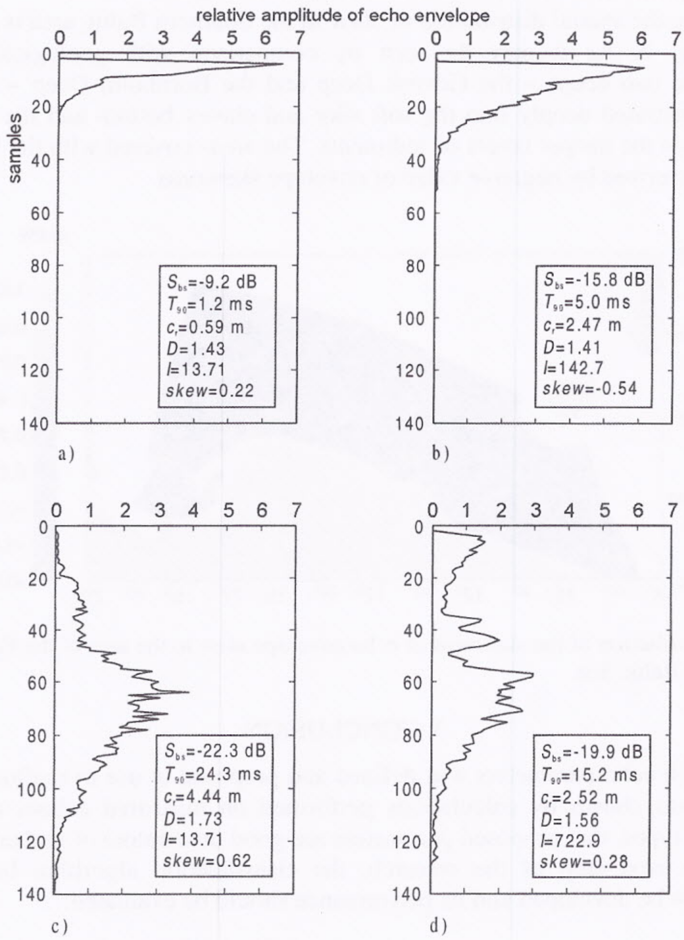

Fig.1. Echo envelope with calculated parameters: a) marine medium-grained sand, b) marine fine-grained sand, c) clayey silt on the mud, d) marine fine-grained sand deposited in thin layer on the mud

The differences in parameters values are visible. S_{bs} is the highest in the hard sand case (a) and the lowest in the mud case (c). T_{90} is significantly longer in c) and d) cases of layered seafloor, but similarly as S_{bs}, it possesses no information about sediment structure. c_r allows for the recognition of echo with very strong peak from hard sand (a) (c_r = 0.59 m) and the echo from soft, muddy bottom (c) (c_r = 4.44 m), which has no relatively strong changes of signal level from one sample to the next due to the absence of clearly visible hard sediment layers. Fractal dimension D has greater value for longer and more corrugated echoes in (c) and (d) cases, what indicates more layered and softer sediments. Moment of inertia I is relatively small in the (a) and (c) cases, where the main part of echo energy is focused near its gravity center: both for short echo from hard sand and for long echo from mud. The opposite case may be seen in (d), where presence of several relatively hard layers is the reason for greater *I* value. *skew* is positive and relatively large specially in (c) and also in (d) case, where the gravity center is clearly below the middle of echo on the time (or depth) axis. It also carries the useful information about seafloor sediment structure.

In addition, the spatial distribution of *skew* in the Southern Baltic area is presented as an example in Fig. 2. As it may be seen by comparison with geological map, clearly distinguished are two deeps – the Gdańsk Deep and the Bornholm Deep – where acoustic signals have penetrated deeply into the soft silty and clayey bottom and the echo energy is coming back from the deeper layers of sediments. The areas covered with the layer of sand or gravel are characterised by negative value of envelope skewness.

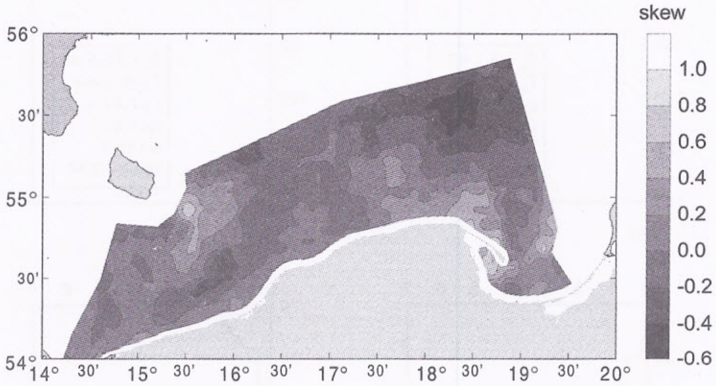

Fig. 2. Spatial distribution of the skewness of echo envelope *skew* in the area of the Polish Economical Zone of Southern Baltic Sea

3. CONCLUSION

The set of 6 echo parameters was defined and proposed to use in seafloor classification procedure. In was shown by calculations performed on measured echoes envelopes from several seafloor types, that proposed parameters are good descriptors of seabed and sediments features. In the next step of the research, the classification algorithm based on that 6 parameters might be developed and its performance should be evaluated.

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