SEAFLOOR CLASSIFICATION USING MULTIBEAM SONAR

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The paper presents the method of seabed identification and classification using multibeam sonar echoes. The proposed approach is based on calculation of a set of parameters of an echo envelope. The parameters are extracted for each consecutive beam allowing the estimation of their dependence on the seafloor incident angle, and then the relation between seabed type and calculated echo parameters and its angular dependence is investigated. The paper concerns the experiment which has been carried out in Gdansk Bay in November 2008, and some comparisons of the results with those obtained during previous experiment in September 2007. The results for several bottom types are presented and discussed. It was confirmed that the information extracted from multibeam seafloor sensing data, e.g. "water column" recordings, may be useful in seafloor characterisation.

INTRODUCTION

The seafloor characterisation methods using parameters extracted from single beam echo are well known and verified (see [1] or [2] for example). The proposed, newly developed approach relies on calculation of a set of echo parameters for each consecutive beam of multibeam sonar. Then, the parameter dependence on the seafloor incident angle is estimated and used in seafloor type classification.

This paper presents the results of the experimental verification of the proposed method. The experiment was carried out in Gdansk Bay region in autumn 2008 and relied on acquisition and processing multibeam sonar data records from several, different bottom types. This work is continuation of the previous stages of the investigation [3],[4], which were based on previous experiments.

1. MATERIALS AND METHODS

The scheme of the applied approach was shown in Fig. 1. In more details the experiment has been described in [3].

The set of the echo envelopes corresponding to particular beams was obtained as a multibeam sonar output. After detection of a bottom echo in the received signal, the set of echo parameters listed below was calculated for the appropriate part of each beam echo, with averaging of obtained values for the whole set of echoes of the same transmission angle (for all swaths). The seafloor was assumed to be approximately flat, therefore the transmission angle was assumed to be equal to the incidence angle.

The following groups echo parameters were calculated:
I. Basic parameters: echo total energy, echo maximum amplitude, echo duration time.
II. Parameters related to statistics of the echo energy: echo energy mean, standard deviation and skewness (normalised third statistical moment).
III. Parameters describing the echo envelope geometric shape: center of gravity along the time axis [2], normalised moment of inertia [2] with respect to the axis containing its gravity center, and fractal dimension interpreted as a measure of its shape composedness.

The data used in the experimental verification of the proposed approach were acquired by the Kongsberg EM 3002 sonar in Gdańsk Bay region of the Baltic Sea in November 2008.

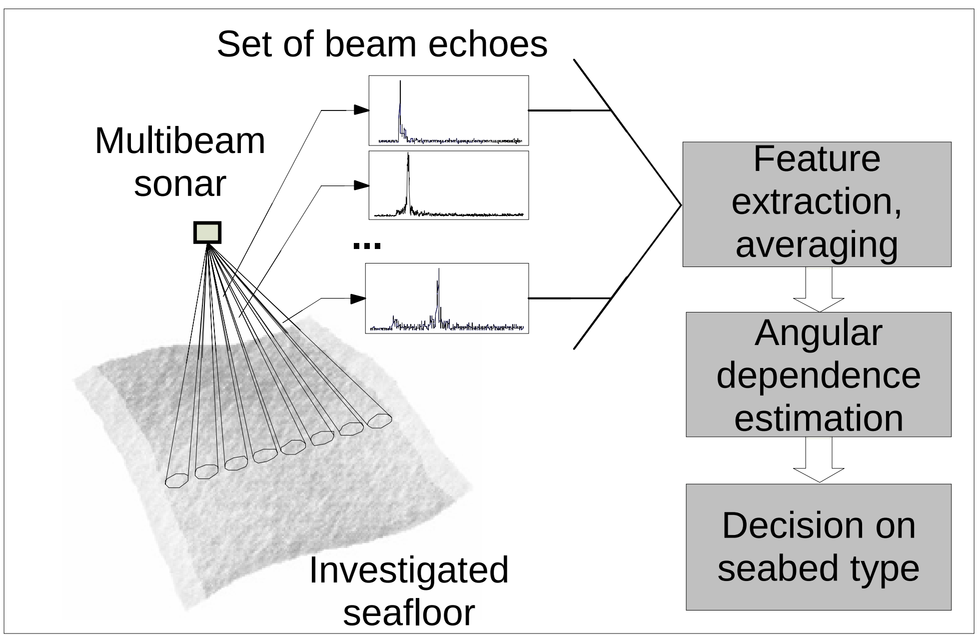


Fig.1. The used concept of multibeam echo processing for seafloor characterisation

Several sites of different seabed types were investigated: mud, sand and mud mixed, fine grained sand and sand on the clay. The information about seafloor type was taken from the geological map of the Gdańsk Bay. The sonar operating frequency was 300 kHz, the width of beams: 1.5° x 1.5°, the transmitted pulse length: 0.15 ms, the echo sampling rate: 7.1465 kHz.

The bottom depth was in a range approximately between 10 m and 50 m. 500 swaths from each of four seafloor types were processed.

2. RESULTS

The obtained calculation results for selected parameters of beam echoes are presented in Fig. 2 in a form of plots of a dependence of parameter value on a beam transmission angle for 4 bottom types.

For all cases of bottom type, the value of total echo energy (Fig. 2a) decreases with the increase of the incident angle. It is generally in line with theoretical predictions, with the results obtained from previous experiment in Gdansk Bay region [3][4], and with those obtained by other authors [5]. However, the another prediction, namely, that the harder seabed material, the higher echo level, which was proved by previous experiments [3], is partially satisfied by the results shown in Fig. 2a. In specific, the echo level from muddy bottom is too high in general in comparison with other bottom cases, which fact needs the further explanation. However, it must be noticed that the not fully reliable ground truthing method was used here.

The obtained results show that the parameters like the maximum amplitude or those describing the statistics of the echo values (for instance – the echo energy mean presented as an example in Fig. 2b) are strongly correlated with the echo total energy (Fig. 2a) and in general do not introduce the additional significant information. This result is in line with those obtained previously.

The results obtained for the echo duration time (Fig. 2c) are also in agreement with expectations in general, and with previous experiments [3]. For all seabed types, the echo length increase with the beam angle increase (for angles of 10° and greater). This effect is connected with the increase of a bottom footprint size and the amount of the incoherent scattering for greater angles of incidence. At the same time, the echoes from mud as well as from sand are characterised by the significant increase of length for angles very close to 0°. As previously, the direct observations of the beam echo waveforms revealed that this effect is due to the occurrence of the volume scattering component. Probably, in a case of mud it occurs because of very soft sediment material, while in a case of coarse grained sand may be connected with low bottom depth.

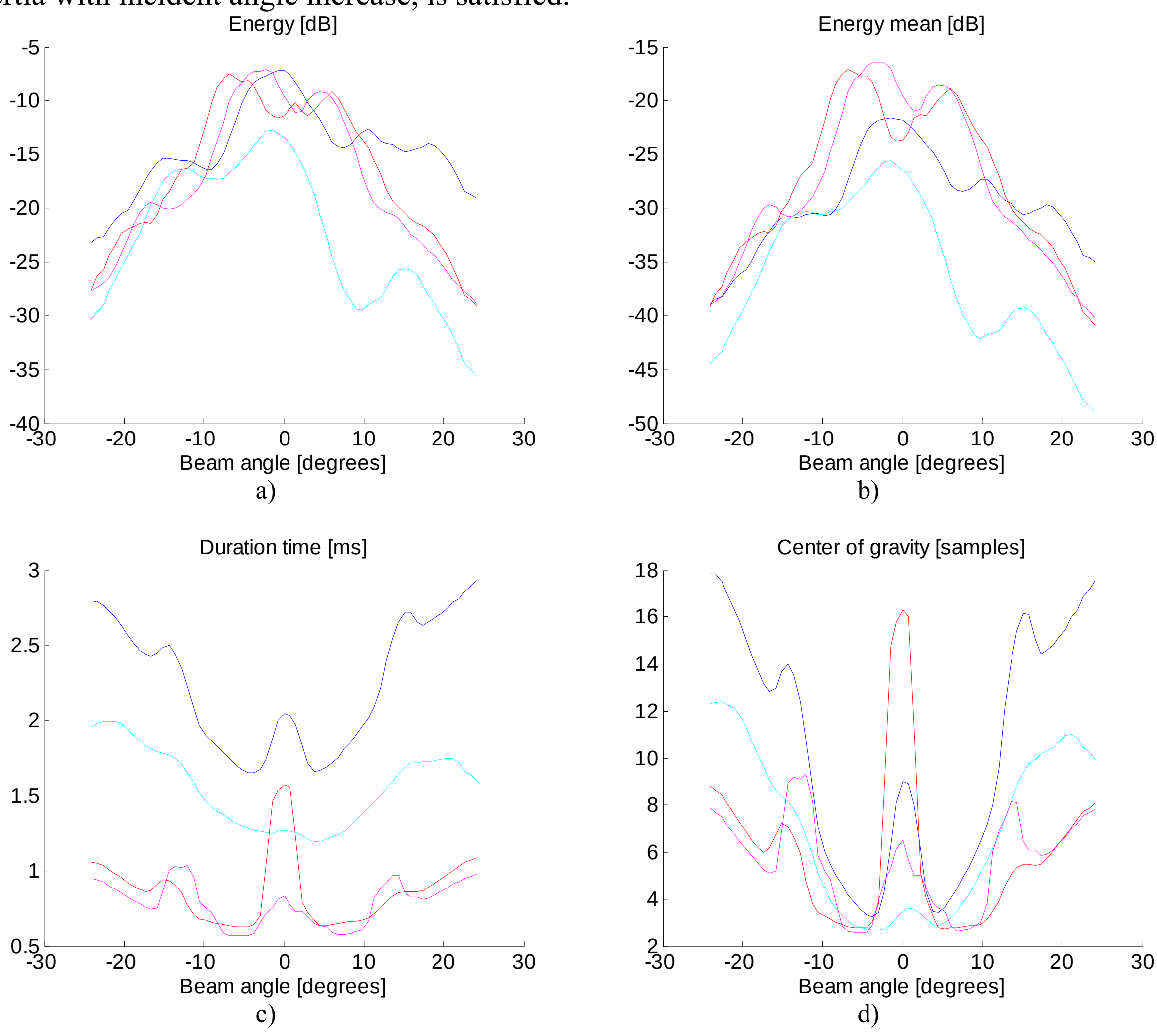
This effect is even more visible in a center of gravity case – Fig. 2d., especially for sandy bottom. It proves that the energy amount of volume scattering is significant in this case.

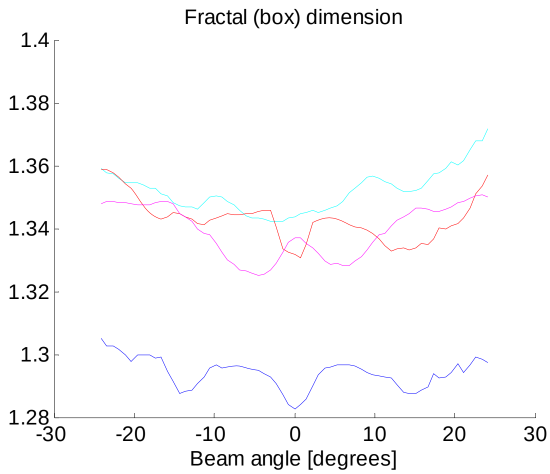
As previously [3][4], the obtained angular dependence of the echo moment of inertia (Fig. 2e) has more regular and smooth shape for all bottom cases, in comparison with other parameters. The quantity defined as the average slope of the angular dependence of this parameter may be used as a distinctive parameter in seabed classification. The increase of the echo moment of inertia value for higher angle of incidence may be explained by its relation to the echo length increase (see the previous paragraph) and the more uniform distribution of energy in an echo for angles more different from 0°.

Unfortunately, the results obtained for fractal dimension of an echo envelope (Fig. 2f) are neither consistent with previous for this case, nor with predictions that this parameter should increase for higher angles of incidence. Although fractal dimension values may be used for easy separation of mud from other bottom types, its dependence on bottom type for 3 other types, as well on the incidence angle, is not clearly visible. This fact requires further investigation and explanation.

The direct comparison of the obtained parameter values for the currently described and for previous experiment would be interesting. However, this is impossible for a great part of calculated parameters due to applied different sonar settings, what resulted in different ranges of values of parameters related to echo energy for example, presented in this paper and in previous ones.

Such comparison was possible for the echo shape parameters like moment of inertia for instance, the calculation of which includes the normalisation of the signal level. Fig. 3 presents the integrated results for angular dependence obtained for this parameter during the currently described experiment (November 2008, solid lines) and during the previous experiment (September 2007, dashed lines). It is well visible, that the obtained values are in the same range. What is more, the general rule that the harder bottom, the lower increase of the echo moment of inertia with incident angle increase, is satisfied.





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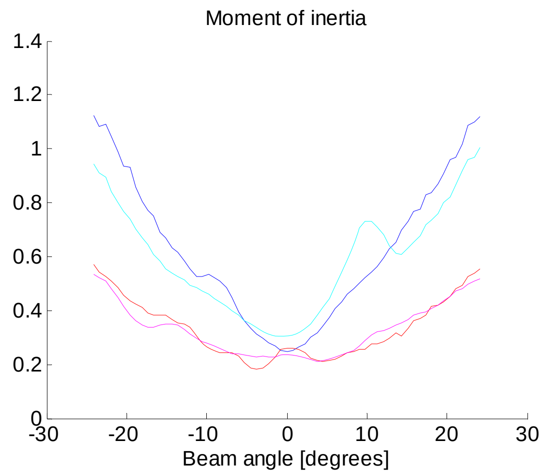

f)

Fig.2. Dependence of selected calculated echo parameter values on a beam transmission angle for 4 bottom types: mud (blue), sand and mud mixed (cyan), fine grained sand (red) and sand on the clay (magenta) for data acquired in Gdansk Bay region in November 2008

At the end, it should be pointed out that the presented results should be still treated as the preliminary due small amount of the experimental data as well as not fully reliable ground truthing.

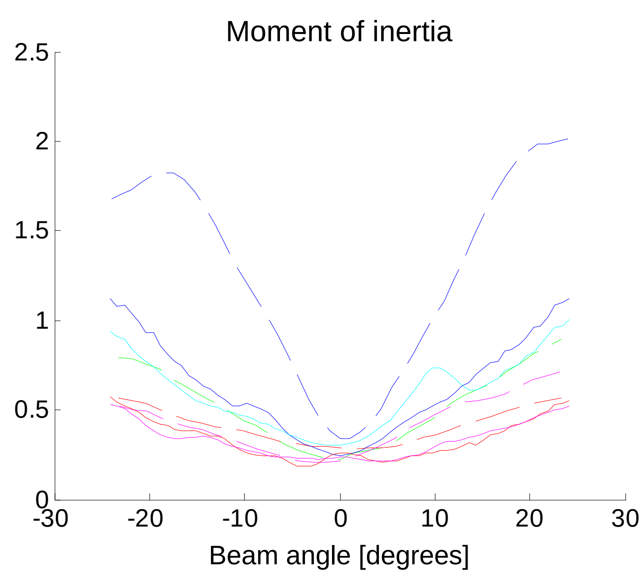

Fig.3. Dependence of an echo moment of inertia on a beam transmission angle for 4 bottom types investigated in Gdansk Bay region in November 2008 (solid): mud (blue), sand and mud mixed (cyan), fine grained sand (red) and sand on the clay (magenta) and in September 2007 (dashed): mud (blue), anthropogenic sand and mud (green), fine grained sand (red) and coarse grained sand with stones (magenta)

3. CONCLUSIONS

Following the analysis results for two last experiments for verification of the proposed method of multibeam sefloor classification, currently described in November 2008, and previous one in September 2007, two general conclusions should be stated, namely:

1. The information extracted from multibeam seafloor sensing data in a form of an angular dependence of several echo parameter value, may be useful in seafloor characterisation.
2. The experimental verification results obtained up to date are consistent partially, and the much more larger amount of experimental data is needed.

However, the usefulness of the proposed parameters of a beam echo waveform and its angular dependence in seabed classification has been preliminarily proved and the large amount of the information to be applied in a further method improvement has been obtained. In particular, it has been shown that some of echo parameters defined in more composed way, like the moment of inertia for instance, has more regular (what could mean – less sensitive to local experiment conditions) dependence on the incident angle than in a case of other parameters, i.e. echo energy.

REFERENCES

[1] Z. Łubniewski, A. Stepnowski, Sea bottom recognition using fractal analysis and scattering impulse response, Proceedings of the 4th European Conference on Underwater Acoustics, 179-184, Rome 1998.
[2] J. Tęgowski, Z. Łubniewski, Application of some echo parameters to the seabed classification - methodological analysis, Hydroacoustics, Vol. 4, 237-240, 2001.
[3] Z. Łubniewski, A. Chybicki, Seabed classification using multibeam echosounder, Proceedings of the 1st International Conference on Information Technology, Gdańsk 2008.
[4] Z. Łubniewski, A. Chybicki, Using multibeam echoes in seafloor characterisation and classification, Hydroacoustics, Vol. 11, 265-270, 2008.
[5] J. E. Hughes Clarke, B. W, Danforth, P. Valentine, Aereal seabed classification using backscatter angular response at 95 kHz, Saclantcen Conference Proceedings Series CP-45, High Frequency Acoustics in Shallow Water, 243-250, La Spezia 1997.