METHODS OF DATA EXTRACTION FROM SUB-BOTTOM PROFILER'S SIGNAL

GRAŻYNA GRELOWSKA, EUGENIUSZ KOZACZKA
WOJCIECH SZYMCZAK

Polish Naval Academy
69 Śmidowicza Street 81-103 Gdynia, Poland
wojciechszymczak@poczta.fm

Data obtain during sounding Gdańsk Bay with SES-2000 Standard parametric sub-bottom profiler has two types of information: envelope and pure signal. First is used to plot echograms in real time and contain envelope of echo. The second one is stored during sounding and can be processed after recording data. Comparison of results will be shown and discussed. First step in investigation was proper configuration of small measurement vessel detailing localization of echosounder antennas and perypherical units (GPS, heading, motion sensor MRU-Z and navigation devices) complementing information of measurement system. There are different types of research (for example looking for buried objects or investigation of sediments layers) which require separate configuration of software working with sub-bottom profiler. Various settings will be presented and interrelated with real data. Very important in work with stored sounding data is proper post-processing realized with software dedicated to parametric echosounder SES-2000 standard and Matlab which give possibility of clear presentation in 3D with precise measurement methods what will be presented on echograms coming from works on sea in 2009 year.

INTRODUCTION

Bathymetrical measurement system with sub-bottom profiler SES-2000 was installed on 10,5 m length small survey vessel. Parametric echosounder antenna was installed on starboard and multibeam EM3002 transducer on port, 100 cm below water surface on special mounting arms. Additional navigation devices were tested in different localizations and finally mount in

places which best suit to their needs. GPS was installed in the center line of vessel, close to deck what minimalize speed value and position errors. Motion sensor – MRU-Z was fitted near center of gravity. After mounting devices, measurements were done to define lever arms for each bathymetrical unit. Signals form GPS, heading and motion sensor are distribute to different devices through multiplying modules. With calibrated small measurement vessel trials on Gdańsk Bay were done and interesting denouement connected with processing and sounding will be bring up.

1. METHOD OF PROCESSING DATA

Analyzing data obtain during survey should be precede by knowledge about sounding pulses and methods of echo visualization on echograms. At Figure 1 is plotted sounding pulse (frequency 4kHz and two pulses) which was measured at 4 meters from transducer. Calculated depth resolution of such configuration gives value 37,5 cm.
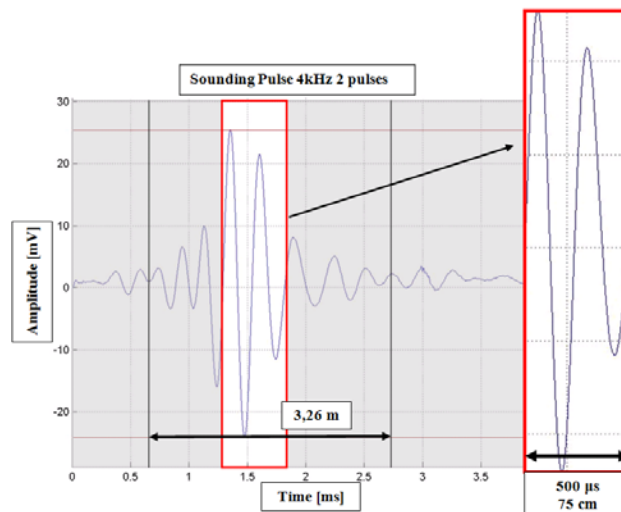

Fig.1. Sounding pulse measured 4 m from transducer

Method of visualization data, will be shown on example, when operator was sounding concrete wall. Plots shown on figures below, where stored with Tektronix oscilloscope connected to analog output of echosounder, which provide filtered and amplified signal just before sending it to analog-digital converter (such signal is shown in Figure 2). Figure 3 illustrate calculated envelope from pure echo signal.
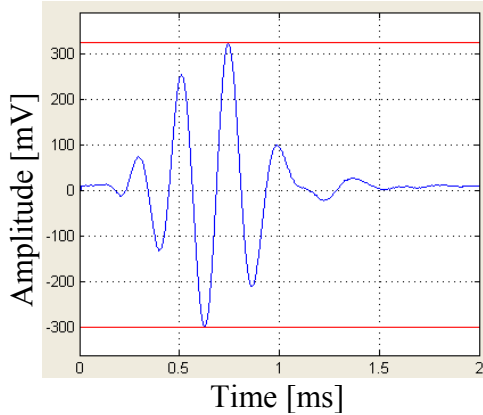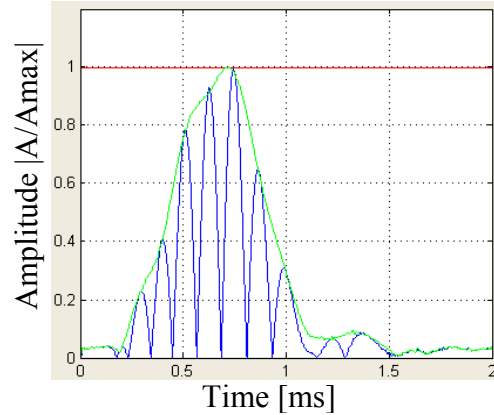
Fig.2. Echo of sounding pulse

Fig.3. Envelope of received pulse

After measurement length of signal is 1,5 m, but not all parts of it should take part in visualization, what is shown in Figure 4 where gray flat area is Threshold - LF Min Level for small echoes and noise. Changing this value can strongly change visualization model and help during examination of received information. At Figure 5 typical echogram describe result of sounding, with all cutting filters set to minimum values.
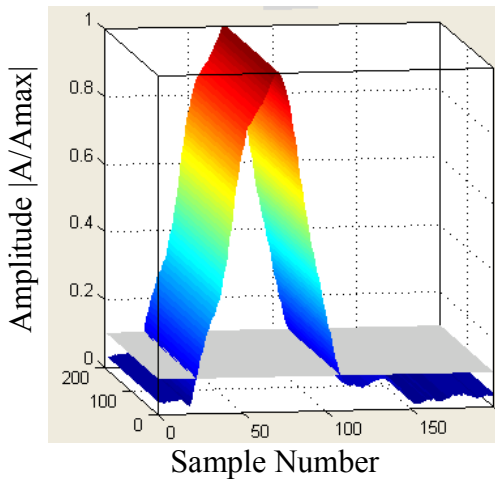

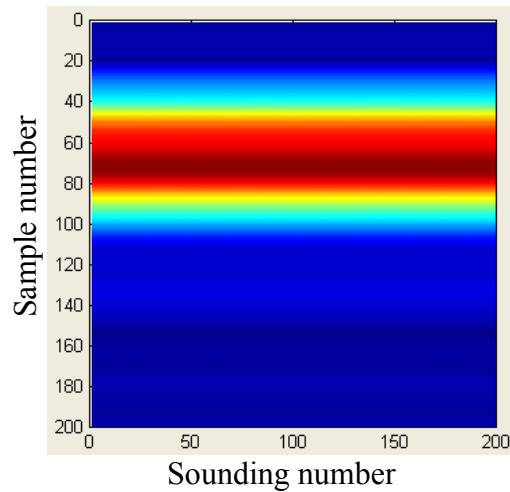Fig.4. 3D visualization in Matlab

Fig.5. 2D echogram from Matlab

During analyzing results from survey at the Gdańsk Bay, data received from stationary measurements in 30 m water tank were used. Important was setting depth resolution for different sounding pulses depending on frequency (4,6,8,10,12 - 15 kHz) and pulses value which represent number of cycles. Increasing pulses number increase transmitted signal energy (better signal to noise ratio), but decrease depth resolution:

$$Depth\_resolution = \frac{t*c}{2}$$

Where: t – time,
                 c – sound speed in water

At Figure 7 is shown result from sounding two sediments layers which were placed in configuration shown on Figure 6, where distance between them is 35 cm. Looking at result,

characteristic point can be notice which affect, during calculating envelope, drop which on echogram is show as free space, which length depends on threshold level and type of data visualization but it is correlated with free space between layers.
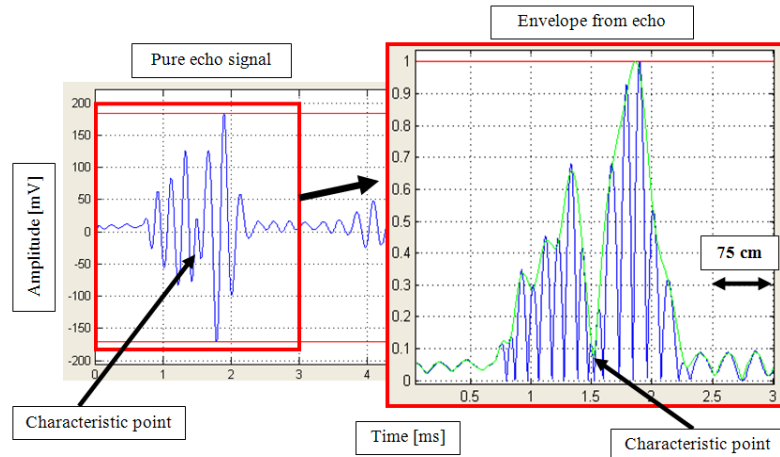

Fig.6. Measurement layers

Fig.7. Echo and envelope of received signal

2. DATA RECEIVED FROM SOUNDING

At Figure 8 data from sounding Gdańsk Bav are displayed, where rang of sediments penetration reach 40 meters (starting point is set to 50 m below sea surface). Frequency of pulse is 4 kHz and 2 pulses. Two charts below describe comparison of data:

SES data – contains 480 samples used to draw echograms in real time.

RAW data – contains 5120 samples which are stored parallel with SES file, but can be process after recording.
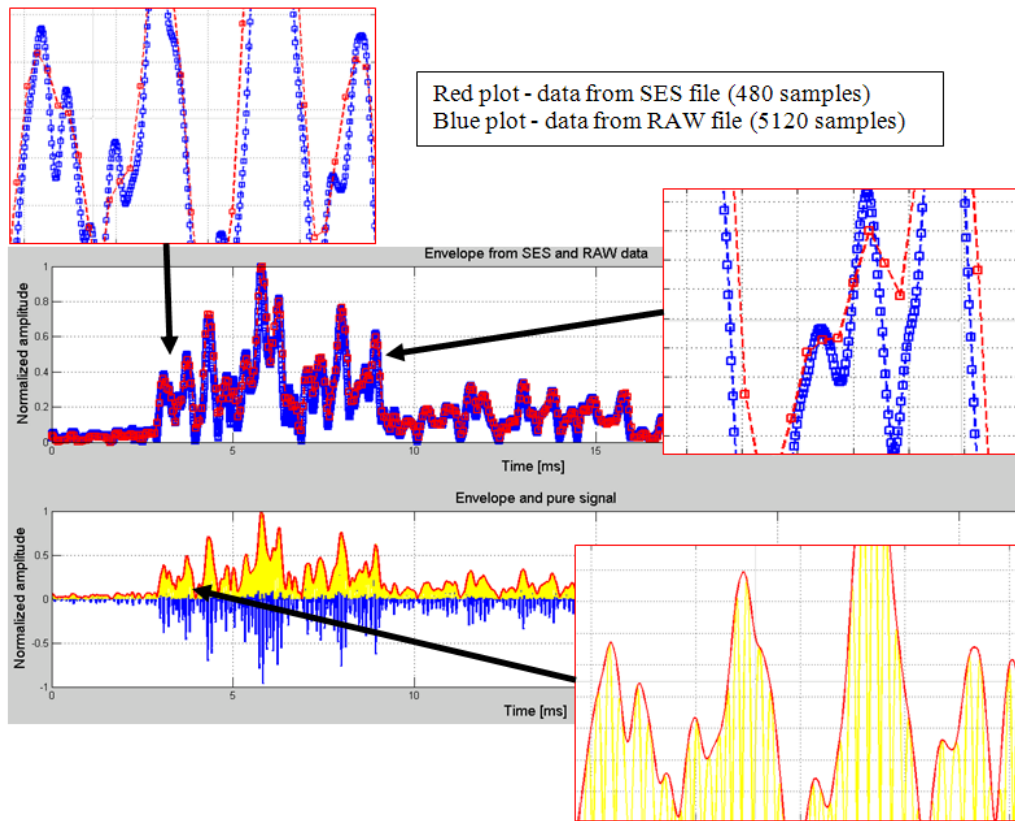
Fig.8. Comparison of *.SES and *.RAW data

At upper part of Figure 8 interesting comparison of data were zoomed. Difference in quality can be observe, showing clearly that slow sampling bring errors connected with resolution, what cause losing for example information about rapid drops of envelope, what can be very important for searching object buried not deep. At bottom part of Figure 8 calculated envelope from record pure echo signal is shown – zoomed fragment show all details without errors. After research, with post-processing tools small changes can be observe and examine using raw files with pure echo signal.

3. METHODS OF POST-PROCESSING VIZUALIZATION

Searching for difference between sediment facilities or checking the layer of mud or silt covering sandy bottom it is important to set in proper way threshold for minimum values, making visible substantial differences. Additionally algorithm defining colors distribution should be set to logarithmic or linear mode. Using Matlab as programming software to visualize data, two examples are shown below. Each echogram contains two parts – on left side visualized are sounding results where penetration is up to 3 meters and on the right side we can observe echoes from layers laying 15 meters from bottom. Scale of color is set to linear mode. On Figure 9 threshold is set to minimum, that's why all details can be seen, but typical it is difficult (especially in logarithmic color scale mode) to check layer of mud laying on hard bottom. At Fig. 10 threshold level was set on level that cut picks of envelope coming from low echoes. It can be

observe that three thick layers which were as first bottom layer, now are covered with 3 m thick sediment.
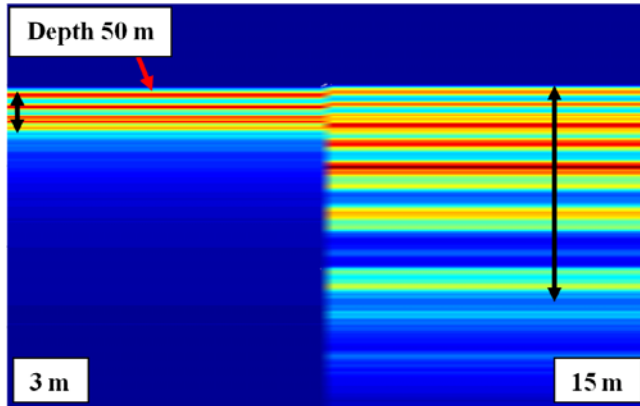

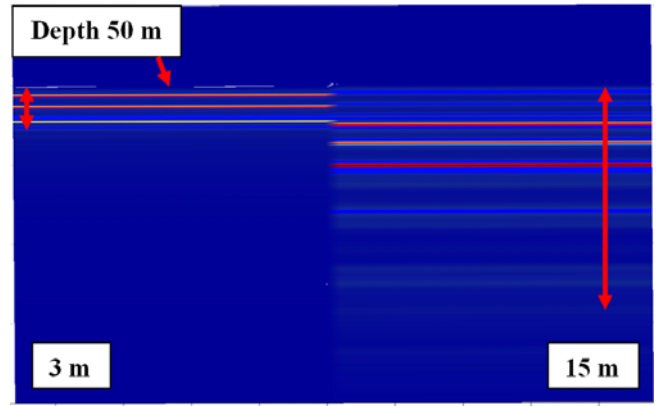Fig.9. Echogram with minimum threshold value

Fig.10. Echogram with high threshold value

The same comparison can be shown in 3D view of envelopes – what is shown at Fig. 11. Envelope used in such comparison in this case is an averaged from soundings, what make its peaks smooth. Additionally, when data include a lot of noises it is possible to use stacking (adding consecutive echo signals and receiving new one) and smoothing function which decreases its influence for results.
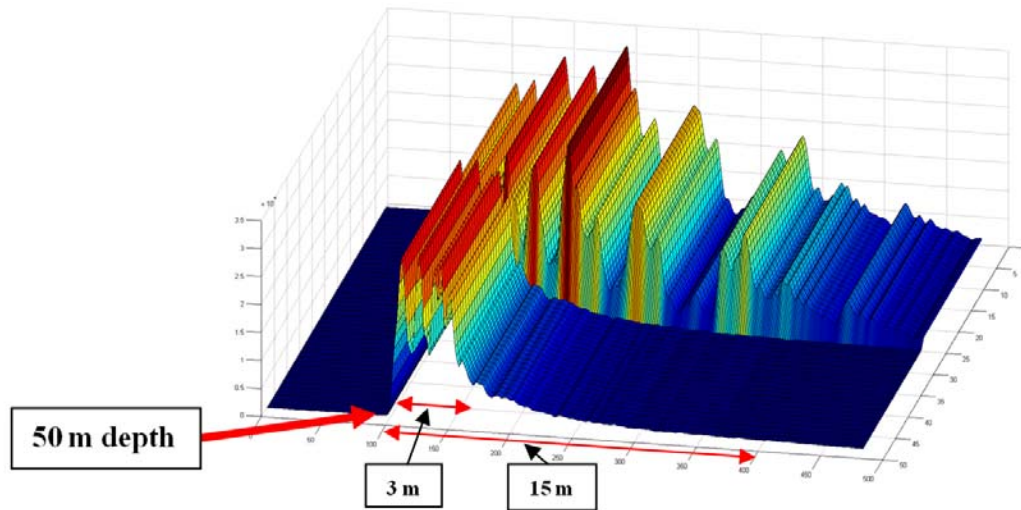

Fig.11. 3D presentation of data in Matlab software

Depending on type of research:
    a) examination of sediments layers
    b) searching for buried object
operator should chose proper configuration of software working with parametric echosounder. Having knowledge that envelope contain constant number of samples, not depending on range, when searching for small buried object on flat bottom and constant depth, the start sampling

range can be set 1-2 meters above bottom and range can be set to the smallest value – which is 5 m. It will give highest resolution giving sampling in step 0,01 m what make possible to observe small changes of reflex sounding pulse. When main point of survey is investigation of the sediment layers up to 30 meters below bottom, operator should set start range for example 4 – 5 meters above bottom layer and range should be set to 35 – 40 meters. Resolution is not so high but in this case it is not so necessary. If something interesting in structure was notice, for example 10 meters below bottom, sounding should be make one more time with sampling window set as in searching for buried object but with start range value proper to actual situation.

At figures below are shown results of sounding from software to show data in real time (Figure 12 - differential view, 13 – full envelope view) and results after post-processing in software dedicated to this type of data (Figure 14 – envelope with 15 colors, 15 – envelope with 30 grayscale colors). Bottom on this examples is on 46 – 48 m below sea surface and penetration range in maximum point reach 27 meters.
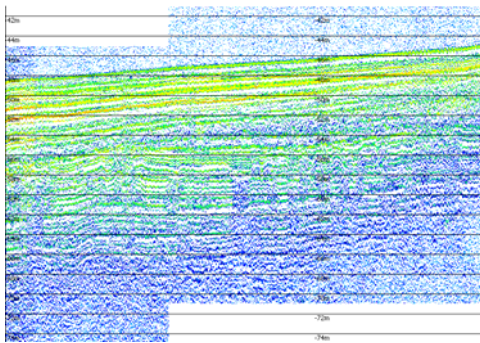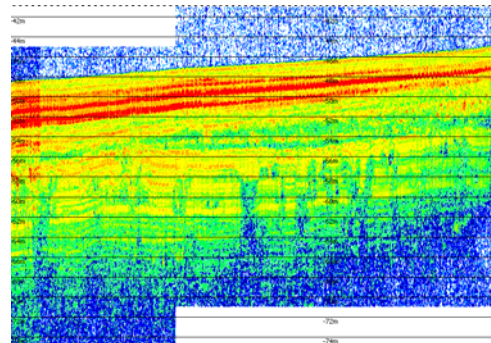

Fig.12. Envelope from 480 samples – 6kHz 2p

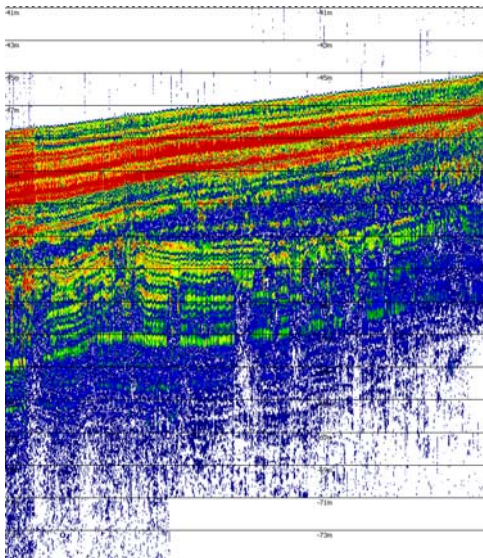Fig.13. Envelope from 480 samples – 6kHz 2p

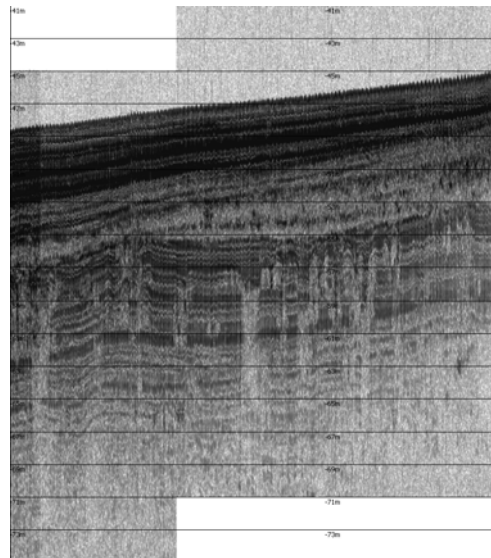Fig.14. . Envelope from 5120 samples – 6kHz 2p

Fig.15. Envelope from 5120 samples – 6kHz 2p

Software dedicated to sub-bottom profiler offer various configurations. Most important is setting frequencies of differential sounding pulses, which can be chosen in range 4 kHz – 15 kHz. Primary frequencies are set near 100 kHz, depending on differential sounding pulse. During work with geological aspects, the most important is investigation of sediments structure, the lowest frequency is required, what can be check on echograms below. When new survey area is examine, it is useful to use multi-frequency option. It allows to sound with three different sounding pulses one by another. Example of such research is illustrated on Figure 12, 13 and 14. Results shown below has got logarithmic scale of colors and software TVG set to 0,6 dB/m.

| Fig.16. Frequency 5 kHz | Fig.17. Frequency 8 kHz | Fig.18. Frequency 12 kHz |
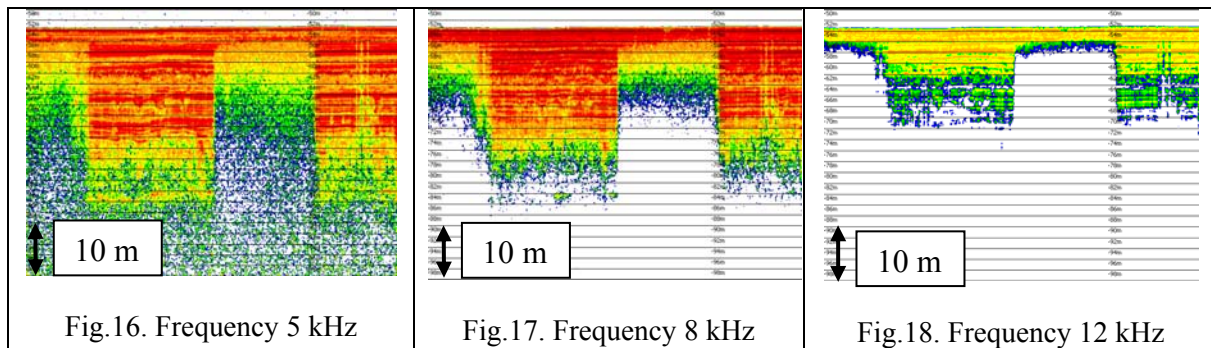
Comparing and analyzing data contain information about buried object is clear with Matlab algorithms. There are many possibilities to illustrate information in 2D, 3D, horizontal and vertical view. Having geographical position linked with sounding data it is possible to visualize different models and ranges of searching objects after survey during which sounding grid was recorded. Below will be shown example of visualization and measurement of three buried targets. Different work with colors scale, where user can define step, threshold, maximum and minimum values gives wide range of visualization possibilities.
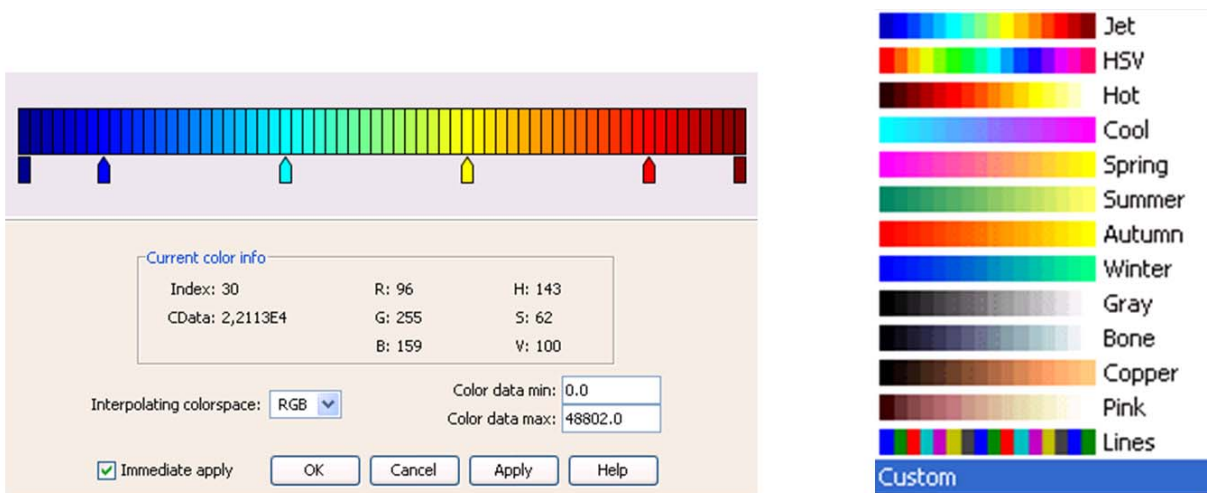

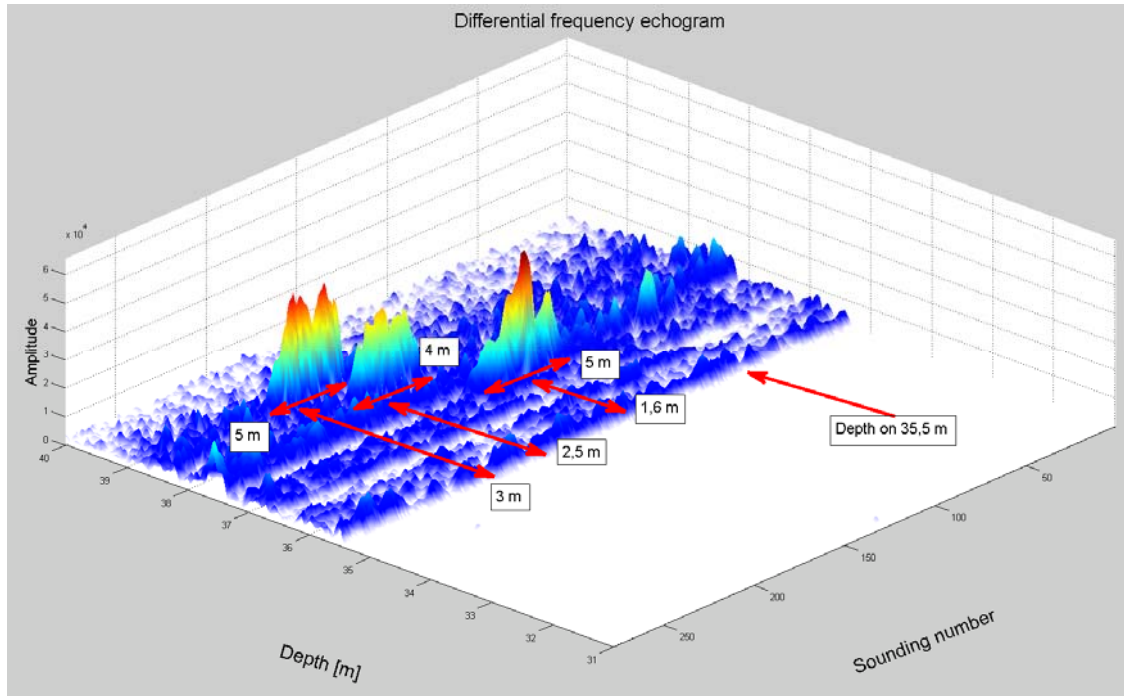Fig.19. Colors scale and default colors set

Fig.20. Three buried objects – illustrated in Matlab

4. SUMMARY

During post-processing work, algorithms of work should depend on type of research (examination of sediments layers or searching for buried objects). Analyzing data should additionally improve knowledge of operators for new survey – describing proper configuration of software working with parametric echosounder, pulses frequency and cycles number that should be set depending of actual receiving results. Methods of processing data in real time and post-processing with raw data has got many possibilities. It is necessary to have an algorithm describing proper way of effective work with data, which could be used quickly even during trials.

REFERENCES

[1]   G. Grelowska, E. Kozaczka, Nieliniowe właściwości wody, AMW, Gdynia, 1996.
[2]   K. Naugolnykh, L. Ostrovsky, Nonlinear Wave Processes in Acoustics, Cambridge University, Cambridge, 1998.

[3]   P. Blondel, A. Caiti, Buried Waste in the Seabed Acoustic Imaging and Bio-Toxicity, University of Bath, UK, 2007.

[4]   INNOMAR TECHNOLOGIE GmbH, SES-2000 Narrow-beam parametric sub-bottom profilers, Innomar Technologie, Rostock, 2008.