Parametric Sediment Echo Sounder SES-96 for Dredging Applications

Dredging companies have a great interest in exact information about the dredging area and the existing material conditions, like sediment structures, sediment types and sediment volumes. New technologies can increase the efficiency of retrieving the needed information and data. The necessary high accuracy of the results sometimes is difficult to realise because of the bad signal to noise ratio during dredging activities or the siltation process after dredging.

What is the actual dredging level? Where are outcrops of rock? What is the thickness of the coverage of a pipeline? What is the thickness of the siltation? What is the thickness of the dredging material? Is there enough material in the sand borrow areas?

These are only some questions, which had to solved during our last survey activities with SES-96 light or SES-96 standard .

Parametric Effect

The echo sounders of Innomar´s product line SES-96 use the parametric effect. Therefore there are a lot of advantages in comparison to the use of a dual frequency echo sounder or a linear sub-bottom profiler.

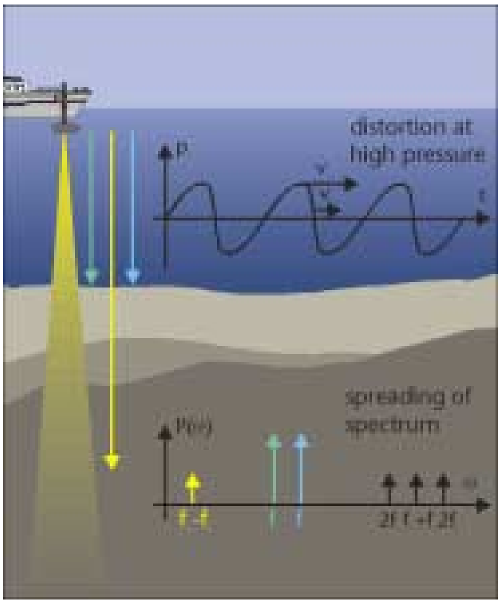

Figure 1: Description of the parametric effect

Transmitting sound waves under high sound pressure results in non-linearities at the sound propagation. If two slightly different high frequencies are transmitted, they interact in the water. Sum and difference frequencies are generated. The high frequencies h_f can be used for the exact determination of the water depth. The generated difference frequencies l_f are able to penetrate the bottom and give information about the sub-bottom structure.

The generation of the difference frequency is limited by the properties of the transducer and by the efficiency of the parametric effect. The efficiency increases with the difference of the transmitted primary signals. Otherwise the efficiency of the system decreases because of the band limited transducer. So there is a task of optimising.

Advantages of SES-96

The generation of the difference frequency with the parametric effect has some advantages against the direct transmission of the l_f.

Properties of the h_f-signals like the aperture and the bandwidth are also valid for the l_f-signals.

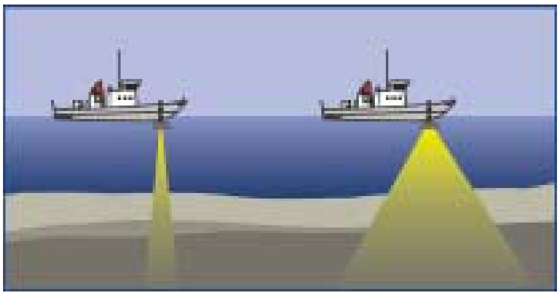

Figure 2: Beam width

The half power beam width at the SES-96 system is +/-1,8° for all generated frequencies l_f = 4, 5, 6, 8, 10 or 12kHz at used primary frequencies around 100kHz. This beam width results in the same footprint of the sound beam for all frequencies. At 5m water depth the footprint is 0,31m x 0,31m.

Additionally the beam has no side lobes, so the survey in small areas, like harbour basins becomes possible with reduced influences from the side.

The size of the SES-96 transducer sound area is only 0,2 x 0, 2m². The system is mobile. To get the same half power beam width with a linear echo sounder at 6kHz you would need an transducer with a sound area of 3,3 x 3,3m². The small half power beam width is important to get high horizontal and vertical resolutions. Especially the reverberation from the bottom surface increases at larger half power beam width`s and you will not get useful data from the first one or two metres below the bottom surface. The small half power beam width results in a more realistic picture from the layer structures or from objects below the bottom surface.

Further the small half power beam width also at the low frequencies is very useful during surveys in dredging areas with siltation. With common echo sounders sometimes it is not possible to measure the real bottom also at low frequencies, because of the back scattering from particles and the attenuation of the sound in the water column.

The high bandwidth of the system allows to generate very short signals. It is possible to transmit really one wave at 12kHz without ringing. So the use in shallow water regions and survey results with high resolution become possible.

SES-96 System Overview

The systems SES-96 *light* and *standard* consists of a 19 inch rack in a robust and portable device (weight: light: 33kg, standard:45kg), the transducer with the cable (weight: 32kg) and a colour printer.

The SES-96 system uses two primary frequencies near 100kHz to generate difference frequencies mentioned above. The possible transmission of very short pulses without ringing effects, for instance one sinus pulse of 12 kHz, results in very good resolution of layers and objects up to 5cm layer thickness. Depending on the survey task has to be chosen the most effective difference frequency.

Figure 3: SES-96 light during a survey in the Netherlands

Figure 4: SES-96 standard during a survey in Lebanon

Figure 5: Transducer of SES-96 light and standard

Figure 6: Mount of the transducer at a survey boat

The accuracy of the depth measurement is given with 0,02 m +0,02% of the water depth for the 100 kHz and the smallest range.

With the system SES-96 *standard* it is also possible to steer the sound beam electronically. This is used to correct the ship movements in a range of about +/-5 degrees for roll and pitch movements. With an optional transducer the system can steer the beam for the roll direction in a range of +/- 16 degrees. The actual ship movement including the heave is measured by a motion sensor. Sensors from Seatex, TSS and Octans are supported. The roll/pitch correction can be made on-line, the heave correction on-line or off-line.

Position data

Any possible navigation system on the market can be used, which has an ASCII-Interface, like NMEA. The data are digitally stored for the high and the low frequency. Additionally the information from a GPS receiver and the Motion Sensor data and the system parameters are stored.

Data Storage/ Data Plots

The data (L_f signal, H_f signal, Position data from GPS receiver, Pitch, roll, heave, if a motion sensor is connected) are stored digitally for replay or post processing with the ISE-software:.

Plots of the echo data can be generated on-line and off-line.

Pulse repetition rate

SES-96 normally uses a pulse repetition rate of up to 30 pulses per second, which is the base for good object detection.

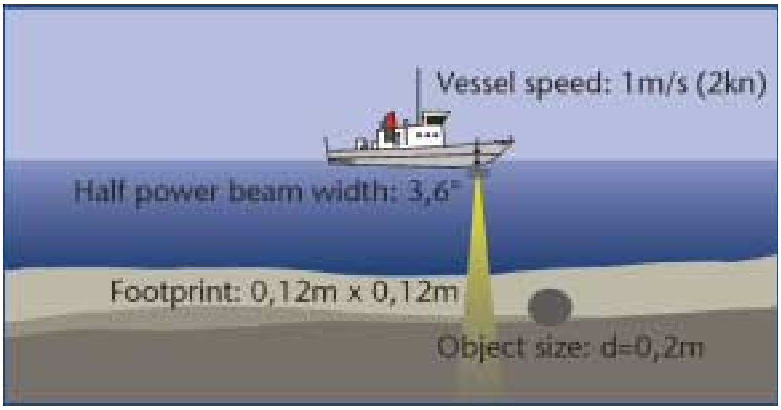

Figure 7: Pulse repetition rate at searching for objects

A higher pulse rate increases the chance of multiple hits of embedded objects and their identification as an object.

Number of hits depending on the pulse repetition rate at a ship velocity of 2m/s and 5m depth. The reflector size is 0.2m:

Pulse repetition rate (pulses/second)	5	10	20	30
Number of hits	1	2	4	6

After signal processing (for instance stacking), only a few signals originating from the object would be left. To detect objects with a diameter of 0.2m the vessel's speed must be lower than 1m/s. At a velocity of 2m/s and a pulse repetition rate of 30/s single objects ("reflectors") with a size of more than 0.4m can be detected.

The pulse repetition rate can be raised to 60 pulses per second at short signals. That makes sense for object search in shallow water.

Results from surveys for dredging applications

During the last month were realised a lot of survey projects for dredging companies. The most important survey sites have been the Netherlands, Germany, India, Lebanon and Hong Kong.

The main tasks of the realised surveys were:

- Determination of the depth with high accuracy.
- Determination of required dredging levels for the construction of breakwaters
- Estimation of sand masses
- Investigation in areas with siltation, Determination of the thickness of the siltation
- Determination of the thickness of mud
- Investigation of the coverage of pipelines

The following two examples will show you some results by using the SES-96 system.

In all cases the installation of the SES-96 system at the survey site was done within some hours.

Figure 8: Transducer installations during surveys in India and Hong Kong

Different test profiles were surveyed to find the best system settings, for instance the adjustable low frequency. The penetration depth always depends on the bottom material. In general is the penetration depth of low frequencies higher than the penetration of high frequencies. Against this stands the rule, that the resolution increases, if higher frequencies are used and decreases, if lower frequencies are used. To get high resolutions of layers the signal length should be as small as possible. Only at bad signal to noise ratios like during dredging activities the chosen signal length has to be longer to get better results.

Depth values in the echo plots are related to the measured sound velocity in the water column. A sound velocity probe was used to measure it. Advanced signal processing techniques in the control software SES for Windows generate high resolution pictures already during the survey. Therefore it is possible to adapt the survey to the existing conditions. The water depth values of both channels, the low and high frequency, will be automatically calculated and are also provided at an online ASCII output. Innomar's post processing software tool ISE 2.5 was used to correct the echo data with separately recorded tide information, to digitise the sediment layer information and to extract the data into compatible ASCII formats.

Survey in India (Arabian Sea)

The figure below shows an echo print from a survey in India, where one main task was to find a rock layer beneath softer material. Any colour in the echo plot is the result of a received sound wave. If in the material the acoustical impedance has changed (product of density and sound velocity) the sound will be partly reflected. Simple described, a border of two different materials results in a line on the echo plot. Additional influences are noise, reverberation effects, sounds from ships, reflections from objects in the water and in the bottom and others. The signal is processed in the SES-96 system and as a result the colour in the generated echo plots is an indicator for the change of the signal strength, not for the amplitude of the signal like in other echo sounders. From left to right the softer material changes from more sandy to more clayey. Especially in areas with clay could be detected a lot of layers with high resolution. The depth in this region was between 6m and 15m. The reached penetration was up to 10m. The client has taken some boring probes in the area. The material classification of the probes and the information of the echo sounder data were put together. Differences of the sound velocity in water and in the sediments were corrected. The results of the boring probes and the post processed echo prints have shown a good correspondence. In the result a map with the depth of the rock layers was created.

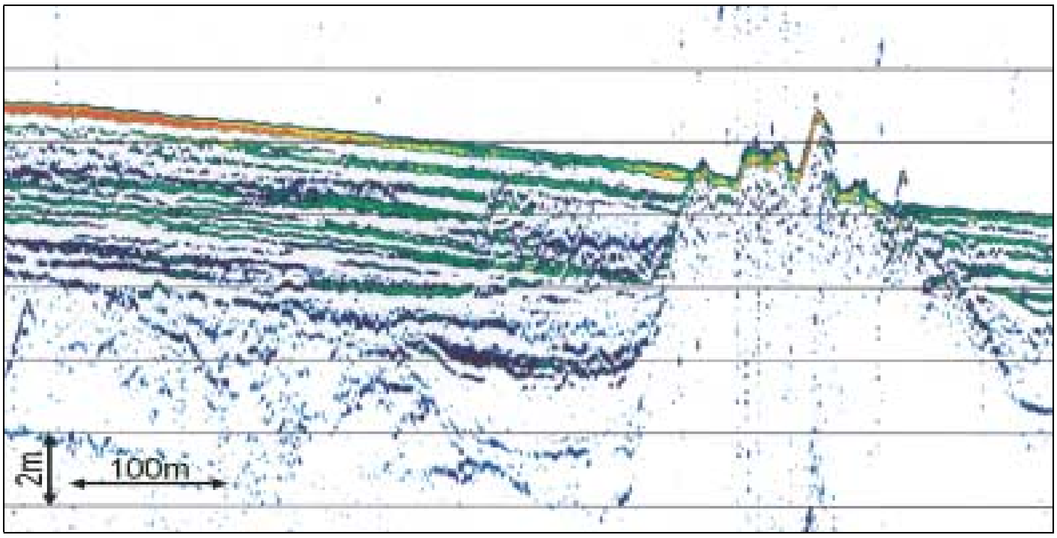

Figure 9: Echoplot sample with different clay and sand layers and a rock outcrop

One task during the survey was to find sand borrow areas. Surrounded areas were explored. The results from the survey in one bay were processed to estimate the sand resources. With the ISE 2.5 software were digitised the upper and lower border of the sand layer. These two borders are visualised in contour maps. Within two days it was possible to determine the volume of the sand layer in the explored bay, including the survey and the processing.

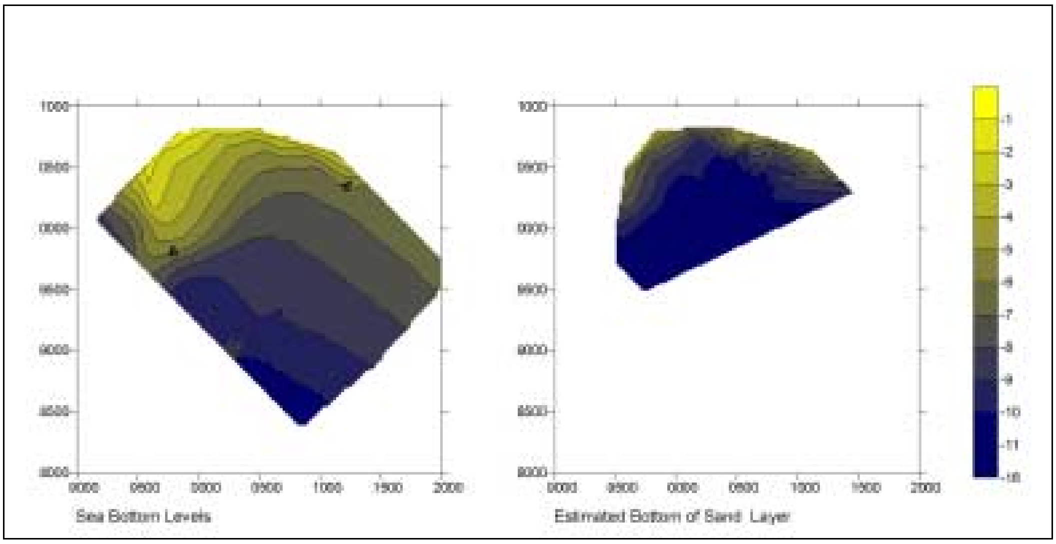

Figure 10: Contour maps of an explored sand borrow area

Survey in Hong Kong

The signal processing configuration was optimised to the signal to noise ratio, which was sometimes not very good due to a lot of particles in the water column, high ship traffic and therefore noise from vessel engines and bubble creations. Another source of noise were the dredging activities of the hopper dredgers. Compared to the acoustical environment the signal to noise ratio during the survey in Hong Kong was 20 times less than in India caused by the dredging activities and the siltation.

The siltation causes a high attenuation of the sound in the water column. So it occurs, that the depth information is lost especially at high frequencies. Against this were received very good results with the 10kHz channel of the SES-96 system.

The main task was to use the parametric echo sounder SES-96 for monitoring the siltation. Big areas with siltation also layers with different dense siltation could be detected and have been completely digitised. The siltation had sometimes a thickness of up to 6 meters. Also under these conditions it was possible with SES-96 to detect a clear bottom line below the siltation - the reached dredging level. The different colours in figure 12 at the siltation areas (the nearly flat sediment parts) are indicating different acoustical impedance`s (and therefore a different density and/or sound velocity in the sediment material). The high signal dynamic of the SES-96 systems and the small half power beam width allow the measurement of differences in the acoustical impedance in the range of one percent. The change of the acoustical impedance in the right part of the plot is less than in the left part and indicates a more soft siltation (probably not so old as on the left side). The penetrations on the left and right of the figure show layers much deeper than the depth of the multiple signals. During the processing the water depth was digitised from the HF channel (red line, figure 11). Additionally the dredging level was digitised, also below the siltation (black line, figure 12).

The whole area contained a lot of high spots (see figure 11), with a height of sometimes more than 5 meters. These spots are the result of the dredging activities. In the 15kHz channel of the standard echo sounder plots these high spots are often not visible caused by the steep slopes of the spots. This results also in a wrong digitisation, because these spots are skipped. The volume calculation becomes inaccurate. The SES-96 has also in the low frequency channel these high spots detected. The reason for this better performance is mainly the smaller beam width and therefore the smaller footprint.

Different from the echo print figure 9 in figure 12 is shown the amplitude of the received echo signals. Because of the low signal to noise ratio it was not useful to analyse the differentiated amplitude.

After the digitisation of the water depth and the dredging level were done charts with the calculated layer difference. Compared to the results from the linear echo sounders system were found calculated volumes more near the real dredging volumes.

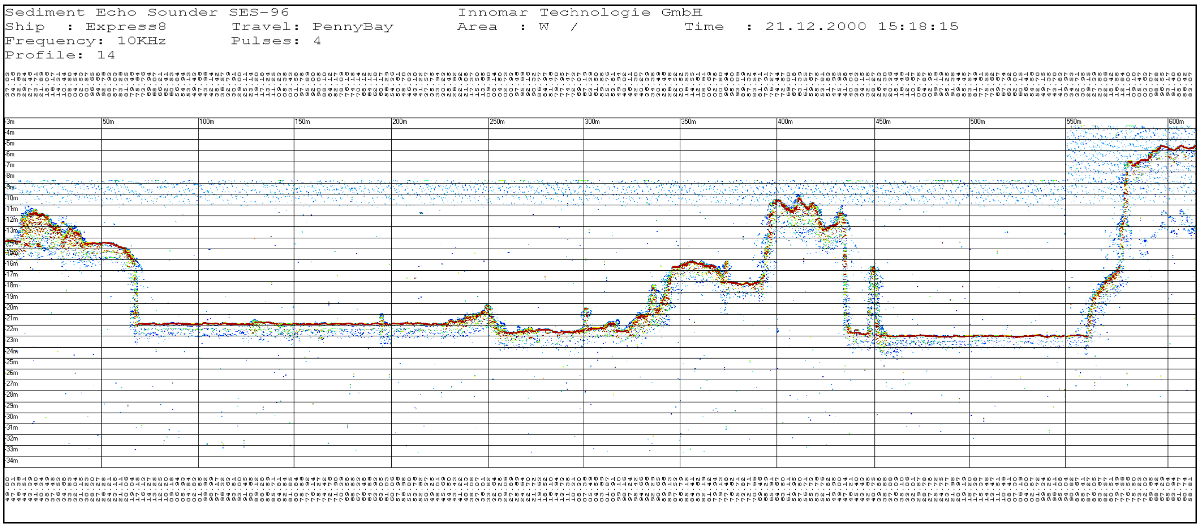

Figure 11: HF-echo plot with water depth (red line)

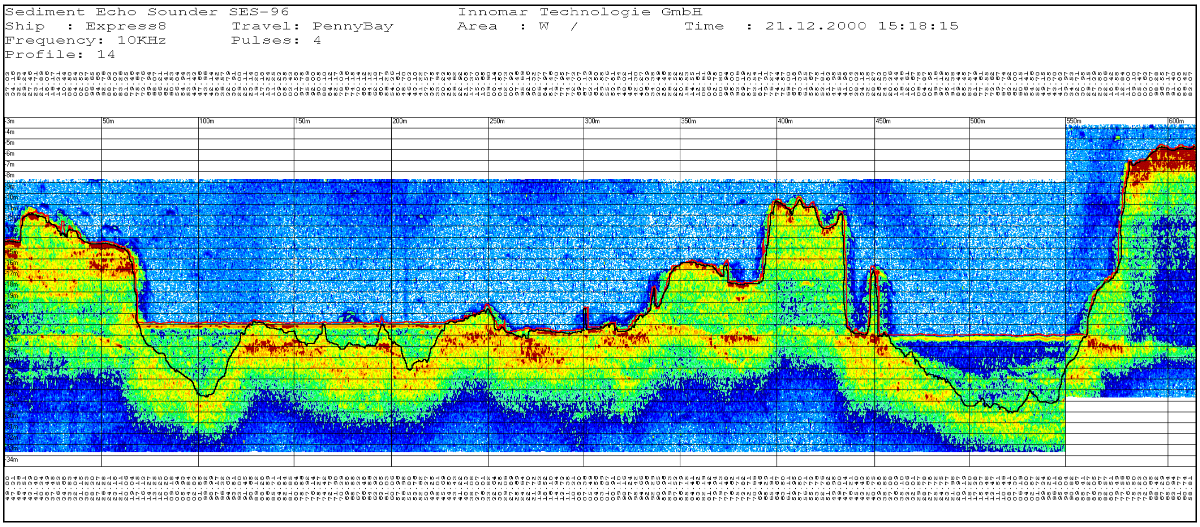

Figure 12: LF Echo plot 10kHz with overlay of digitised HF depth and digitised dredging level

During the last month were realised a lot of survey projects. In every case the survey tasks could be done with good results and more effective since with common techniques before. The results especially for volume or mass calculations have been more accurate.

So the use of the parametric echo sounder SES-96 offers the possibilities to save costs in dredging projects by realising effective surveys in the dredging areas.

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