Detection of objects buried in the seafloor: Experimental Sediment Sonar EXSESO

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Introduction

With the Experimental Sediment Sonar (EXSESO) FWG investigates the detection and classification of objects buried in the seafloor. Because the demonstrator system is ship mounted, the experiments were close to real operational conditions at sea. The test sites are located in the Baltic Sea near Kiel. Spheres and cylinders filled with concrete were used as targets. Having equipped some of the objects with a transponder, target position can be checked with high accuracy. CW-pulses with a maximum bandwidth of about 5 kHz were transmitted. The center frequencies of 10 and 20 kHz meet both the requirements of penetrating into the seafloor and providing sufficient resolution. An additional conventional sidescan sonar is attached to the EXSESO platform. Thereby two images of the same scene are obtained: A highly resolved picture of the sea bottom can be compared to a low frequency image containing information from the sediment.

Experimental Setup

Both the receive and transmit antenna are planar phased arrays mounted on a common platform that can be tilted mechanically to any starboard direction. The receive antenna is made of 1296 hydrophones grouped to 108 single staves. The beams from its signals can be steered electronically to about 20 degrees in azimuth and 50 degrees in elevation until the first grating lobes come up. The sketch in Figure 1 shows the integration of the antenna on PLANET together with the beamwidths.

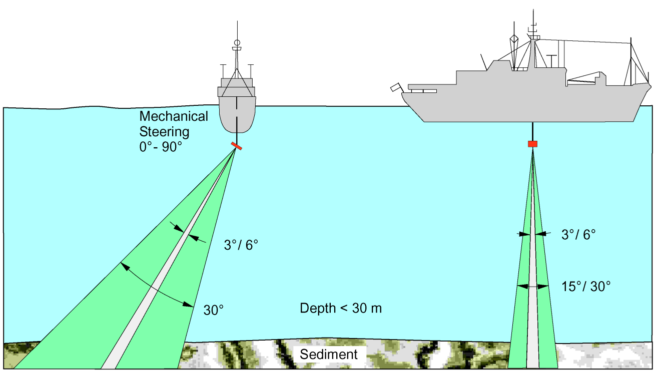

Figure 1: Integration of the EXSESO antenna on PLANET. Transmitter and receiver beam widths in green and gray, respectively. The minor number is valid with operational fequency of 20 kHz, the second refers to 10 kHz. Vertical transmitter beam width, shown in the left part of the figure, is 30 degrees at both frequencies. Water depth at the test sites varied between 15 and 30 meters.

The sediment at the test sites was fine sand or mud. The disturbed sediment volume must be kept as small as possible, because in this area the acoustic impedance is changed. Therefore it is likely to get the backscattering characteristics of this whole volume rather than the desired target echo. In order to minimize the disturbances in the sandy sediment, most of the objects were equipped with special water jet facilities. Support by divers is still necessary. Additionally, some of the test sites were prepared more than half a year before the measurements in order to let the sediment settle to its natural state.

If the targets are flush buried or only slightly covered by sediment, the echo from the object will always be masked by the bottom reverberation. If the targets are buried very deeply, the echo fades out by transmission loss. So, a favourable depth can be expected, where the echo can be separated in time. Some test targets were also buried that way.

Beamforming and Displays

The scene in front of the antenna is scanned on a regular grid of focus points for every sonar ping. In a polar reference frame, the positions of the foci resemble the phase fronts and propagation directions of the spherical waves sent out by the transmitter. A cartesian reference frame fixed to the sea floor is better suited for, e.g., combining information of different pings. Figures 2 and 3 show examples.

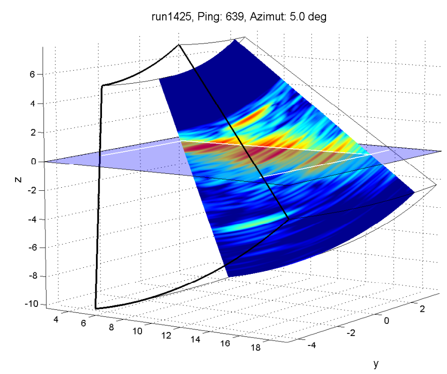

Figure 2: Space in front of the antenna sampled on a polar grid of foci. Beams with different elevations for one ping at a particular azimuth are displayed. The sea floor is drawn as shaded horizontal plane.

The signal to noise ratio is increased by coherently summing up the time series at the focus points. In order to reduce computational load, the beamforming is performed in two modes:

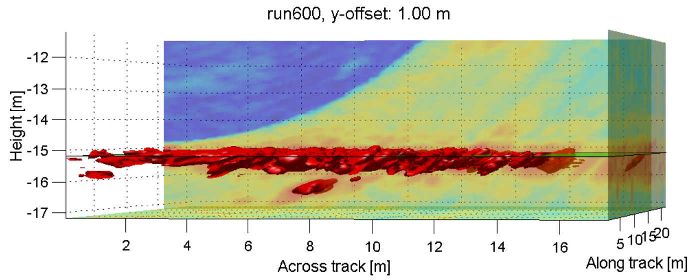

Figure 3: Space in front of the antenna sampled on a cartesian grid of foci. The surface of a properly chosen intensity level is displayed in red. Beneath the sea bottom a detection of an object can be seen. In the vertical slice the onset of bottom reverberation can be seen as a rather sharp curved line.

For target detection, time interpolation beamforming is used and only the value corresponding to the two way propagation time is calculated. The data are usually displayed on two-dimensional slices. These pictures are used to localize the detections. Then, for a few striking foci the whole focused time series are calculated. This is properly done in the frequency domain. Figure 4 shows an example. At best, from these time series some additional clues for classification may be obtained, but details are beyond the scope of this paper.

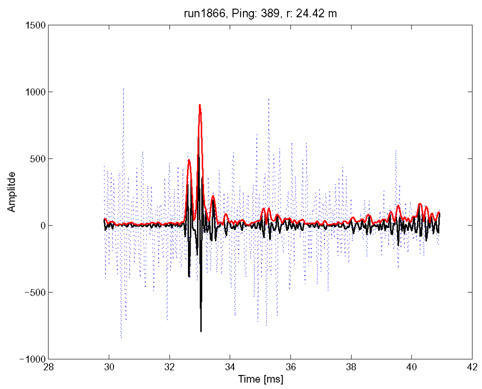

Figure 4: Example of a focused time series. After detection, the location of the object was taken as focus point. The time series of a single stave is plotted as dashed line, the focused time series is displayed in black and its envelope is shown in red.

To make shure that a detection actually corresponds to the target and not to a false alarm in the vicinity, some of the targets were equipped with transponders, which were triggered by the sonar pulse and sent an additional acoustic marker in regular time intervals. From these markers, azimuth, elevation and range of the target can be estimated for all pings. Although the transponder pings were separated in frequency from the sonar signal, those disturbed pings were not used for further processing.

EXSESO and Sidescan

The sidescan sonar maps the sea bottom with high resolution. These images can be compared with those produced by EXSESO with high spatial accuracy because both antennas are mounted on the same stable platform. A suitable way to do this comparison is to project the EXSESO beams onto the seafloor in the same way as the sidescan data. A projection plane is defined by keeping one azimuth value fixed while varying the elevations (Figure 5). The sidescan beam is fixed in azimuth to across track direction, but the sediment sonar beams can be steered. By comparing those two images, detections from beneath the sea floor can be separated from false alarms produced by proud objects and disturbances of the sediment surface.

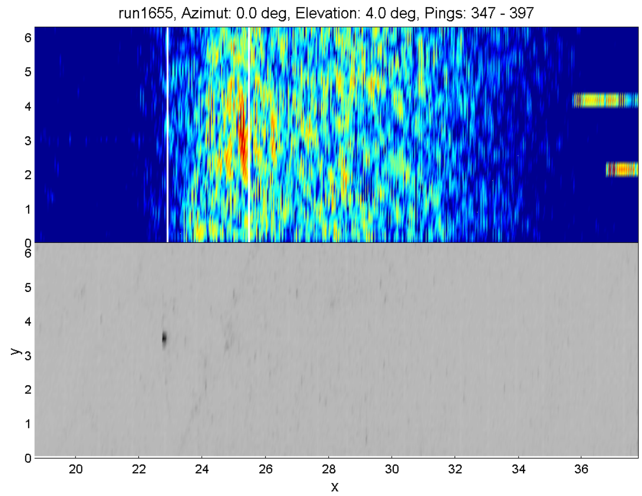

Figure 5: Comparison of high frequency and low fequency images of the same scene. In this example the buried object cannot be seen in the sidescan, but it is visible in the sediment sonar (top) at the position expected from the transponder estimate. The two white lines mark the nominal footprint of the receive beam. The highlight in the sidescan comes from a float some meters above the object.

Scanning through all azimuth angles is essential for detecting buried objects, because most of them will respond only at some singular aspects with sufficiently high target strength.

Conclusion

The experiments showed that with a low frequency sonar it is possible to detect objects buried in the sea floor, at least under convenient conditions. For typical targets, detection depends highly on the aspect angle. So, for detection there must be a search over all available azimuth beams. Combining high and low frequency information improves detection and reduces the probabilty of false alarms. In our experiments, it was hardly possible to separate the bottom reverberation from the target echo in time. After all, detection of objects buried in the sea floor still remains a challenging task.

References

[1] Detection and Imaging of Buried Objects with a Sediment Sonar. Acta Acustica united with Acustica **88** (2002), 763-766