Note

Recent Progress in Sub-Bottom profiling—the SBP 120 example.

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Abstract

Recent narrow beam sub bottom profilers achieve improved performances in terms of signal-to-noise ratio and resolution. Thus, the potential of these systems for detection of buried objects and also the inversion of sediment geo-acoustic parameters are high provided the device characteristics are correctly known. This note gives an overview of the results that can be obtained with a high resolution sub bottom profiler and stresses the importance of calibrating these systems when characterizing the geo-acoustic properties of sediments.

Résumé

Les sondeurs de sédiments récents, à faisceaux étroits, présentent des performances améliorées en termes de rapport signal sur bruit et de résolution. Ainsi, les potentialités de ces systèmes pour la détection d'objets enfouis et également l'inversion des paramètres géoacoustiques des sédiments sont élevées à condition que les caractéristiques des appareils soient correctement connues. Cette note donne une vue d'ensemble des résultats qui peuvent être obtenus avec un sondeur de sédiments à haute résolution et souligne l'importance de l'étalonnage de ces systèmes pour la caractérisation des propriétés géoacoustiques des sédiments.

Resumen

Los recientes perfiladores de sub-fondo de haz único han obtenido resultados mejores en términos de proporción señal/ruido y de resolución. Así pues, el potencial de estos sistemas para la detección de objetos enterrados y también la inversión de parámetros geo-acústicos de sedimentos son elevados siempre que las características de los mecanismos se conozcan correctamente. Esta nota proporciona una visión general de los resultados que pueden obtenerse con un perfilador de sub-fondo de alta resolución y destaca la importancia de calibrar estos sistemas al caracterizar las propiedades geoacústicas de los sedimentos.

Introduction

Sub bottom profilers are commonly used to explore the first sediment layers below the seafloor. Most sub bottom profilers use the same transducers for transmission and reception and a single wide beam (~30°). Because of their high signal level and low frequencies they work well under many conditions. However, it is not possible to tell from which direction echoes are arriving. Moreover, it is not possible to characterize quantitatively the geoacoustic properties of the sediments. Thus, the potential of recent devices working with new technologies and offering improved performances is very high. This is the case of the SBP 120 sub bottom profiler.

Description

The SBP 120 sub bottom profiler, developed by Kongsberg (Norway) is installed onboard the French Navy hydro-oceanographic vessel *Beautemps-Beaupré*. It operates with two large arrays (about 7 m long) used for emission (Tx) and reception (Rx) mounted in a Mills cross configuration. This innovative architecture is built around a technology similar to that implemented on bathymetric multibeam echo sounders; it has been designed as an add-on to the bathymetric EM 120 deep water multibeam echo sounder with which it shares the receiver array and the preamplifier.

The frequency band of the system is 2.5–7 kHz. Thanks to large Tx and Rx arrays, the resulting two-way beam pattern is 3x3° at 4 kHz. Moreover, it is possible to choose the number of transducers used for emission and reception through the acquisition software, so that the operator can adjust the directivity of the beams to the geometry of the local environment (from 3°x3° when the maximum number of transducers is used to 12°x12° when a quarter of emitting and transmitting arrays is used).

Although various signal types can be emitted, linear chirps are most commonly used because of their good performance in terms of signal to noise ratio improvement.

As the SBP 120 can operate with narrow beams, vessel movements are compensated using motion sensor data. Bathymetric data from the EM 120 deep water multibeam echo sounder and the EA 400 shallow water single beam echo sounder are integrated in order to adjust automatically the acquisition delay to the depth and to steer beams perpendicularly to the bottom (to avoid the loss of reflected energy on sloping seafloor). The SBP 120 also integrates GPS data to record data location.

Performance

The SBP 120 sub bottom profiler has a much narrower beam width than a conventional subbottom profiler. It thus provides higher angular resolution and deeper penetration into the bottom because transmission loss is reduced. Moreover, with a large transmission array with up to 96 transducers, a significantly higher source level can be produced, compared to the other class of narrow beam sub bottom profilers. Thus, the signal to noise ratio is significantly improved. Theoretically, for linear frequency modulations between 2.5 and 7 kHz, the vertical resolution is about 0.22 ms two-way time (TWT), which corresponds to 17 cm for a sound speed of 1,500 m/s. Experimentally, vertical resolutions lower than 0.35 ms have been actually observed on recordings. The source level is above 220 dB re 1 Pa @ 1 m in the frequency band. The theoretical penetration depth can be estimated using the sonar equation for a homogeneous horizontal layer of sediments lying on a hard basement. The results are consistent with the penetration up to 100 m actually achieved at sea in soft sediments.

(left) The hydro-oceanographic vessel Beautemps-Beaupré, (right) The SBP 120 transmission array.

While previous sub bottom profilers allowed only qualitative imaging of the geological environment, this system can also be used to characterize quantitatively the sediment geoacoustic parameters, provided a precise knowledge of the acquisition device characteristics is available.

Calibration

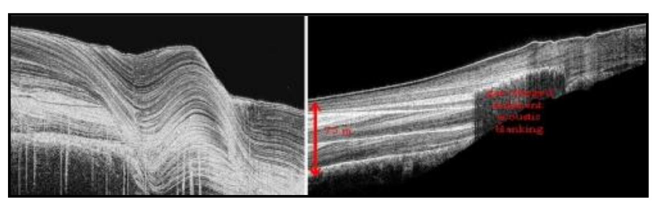
Before the integration on the hull, the mechanical and electronical characteristics of the system were measured by the manufacturer in a tank. The corresponding source level, receiving sensitivity and receiver gains were provided during the delivery of the SBP 120. To ensure the reliability and the validity of the manufacturer's measurements, cross correlations have been drawn between the acoustic recordings of the SBP 120 and *in situ* measurements by comparing the impedance contrasts estimated from the sub bottom profiler data and those measured in the sampled sediments (density and velocity were measured in the water column, especially at the sea-bottom interface and in the sampled sediments).

Hydrophone used for the calibration

The conclusions were that significant discrepancy could happen with errors up to 20% on the impedance estimates. Moreover, comparison of reflection coefficients derived from the data with reflectivities measured with other calibrated sensors showed a difference of about 10 dB for some frequencies which confirmed the problem of calibration on the SBP 120. Several hypotheses can explain the difference between the manufacturer's data and the real values. The error for the source level might be quite important for several reasons.

These values were extrapolated from 12°x12° beam measurements (the length of the array was reduced in the tank due to the limitation in the measurement facilities) to a 3°x3° beam. Far field conditions are also difficult to reach with large arrays, especially for high frequencies. Reverberation during the measurement process in the tank might also have distorted the results, particularly at low frequencies. At last, values could have changed after integration of the array on the hull (emission and reception).

A calibration at sea was then required to determine the device electronic characteristics. The procedure was the following. At a depth of 2000 meters (deep waters were chosen in order to respect the far field conditions and to avoid reverberation); a calibrated hydrophone fixed on a cable was immersed at a depth of 1,000 m under the *Beautemps-Beaupré* in station above a flat seafloor. The hydrophone position was precisely known because it was equipped with an ultra-short baseline. So it was possible to monitor its position in real-time (and to record it) to ensure it was lying in the narrow emission beam. The emitted signal was recorded by the hydrophone and after compensating from transmission loss (absorption in the water column and geometrical spreading); the comparison with the theoretical emitted signal gave the source level of the emitting array. The secular echo returned after reflection on the seafloor was also recorded and the comparison with the signal recorded by the SBP 120 allowed determining the receiving sensitivity of the sensor and the receiver gains. Emitted signals were single frequencies varying between 2.5 and 7 kHz (for several beams: 3°x3°, 6°x6° and 12°x12°). Thus, after the processing of the records, it was possible to determine the source level and the receiving sensitivity of the device in its frequency bandwidth. A difference up to 10 dB was observed at low frequencies, which confirmed the initial observations.



Examples of seismograms recorded with the SBP 120. The good performances of the system make it possible to image complex structures.

Acquisition Configuration

Sub bottom profilers exploit the specular echo returned by the acoustic impedance discontinuities. It is then necessary to make sure that the echo that comes from the coherent reflection is correctly recorded. For this purpose, when imaging the complex structures or the sloping seafloor, the size of the arrays (i.e., the number of active transducers) must be reduced to increase the beam width, because the angle between the axis of the receiving beam and the specular direction must remain within half the beam width for successfully recording the coherent reflection.

Preprocessing
During the acquisition, raw data have been recorded after beam forming therefore several pre processing steps are applied before the seismogram interpretation. First, raw data are corrected from the source level, the receiving sensitivity, and the receiver gains determined with the calibration procedure. Then, the time series are obtained by cross correlating the received signal with the theoretical emitted chirp. Finally, a correction of the geometrical spreading is applied.

Applications
The multi beam architecture of the SBP 120 leads to interesting possibilities in the field of detection and localization of buried objects. When using wide beam sub bottom profilers, buried objects can be identified by their classical crescent-like echo structure. However, they cannot be localized precisely due to the lack of angular discrimination. Thanks to its narrow beam, the SBP 120 system substantially removes this strong limitation of classical systems and makes it possible to resolve echoes arriving from different directions. It may be used in the field of the detection and the localization of buried objects.

The potential of the SBP120 is also high in terms of modelling of the sedimentary environment. Geoacoustic parameters are generally difficult to obtain because inversion systems often suffer from poor sensitivity and nonuniqueness. Moreover, measurements on *in situ* samples are local, heavy and destructive. Thanks to its high performances, the SBP 120 can also be used to quantitatively characterize geoacoustic parameters in sediments such as the absorption coefficient (estimated with a spectral ratio method), the reflection coefficient, the impedance contrast and the micro roughness (derived from Eckart's model).

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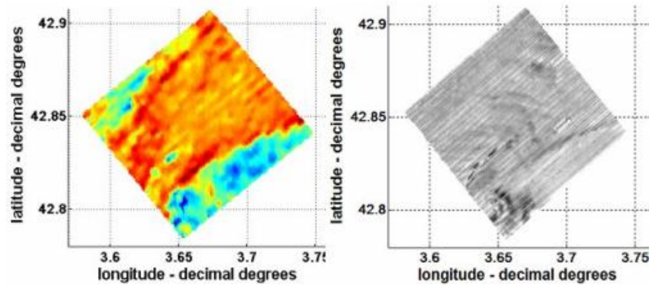

Estimation of the absorption in the sediments in a 5 mile squared area (left) and comparison with the backscattering imagery (right). Estimates derived from SBP 120 data are in good agreement with the backscattered energy.

[1] Theuillon et al., "High-Resolution Geoacoustic Characterization of the Seafloor Using a Subbottom Profiler in the Gulf of Lion", *IEEE J. Ocean. Eng.*, vol. 33, no. 3, pp. 240–254, Jul. 2008.

Biography of the Author

Gwladys Theuillon received an engineering degree in hydrography and oceanography from ENSIETA, Brest, France, in 2002. She joined Service Hydrographique et Océanographique de la Marine (SHOM), Brest, France where she worked as an hydrographer on the French Navy ship *Beautemps-Beaupré*. Afterwards she has been a research engineer in Underwater Acoustics. Since 2008, she has been working in the Department of Policy, Plans and External Relations.