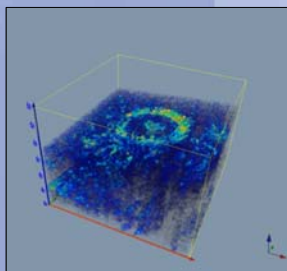
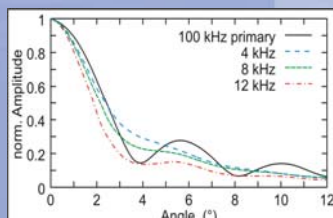


Three-dimensional investigation of buried structures with multi-transducer parametric sub-bottom profiler as part of hydrographical applications

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Parametric Sub-bottom Profiler Technology



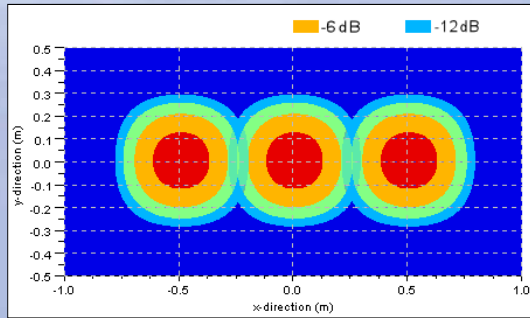
- Non-linear (parametric) technology gives narrow sound beams for low frequencies (SES-2000: 3.6°) using small transducers for high lateral resolution and low reverberation
- Transmit pulses of parametric systems have no ringing effect and can be as short as one sine cycle resulting in a very high vertical resolution and the possibility to work in extremely shallow waters
- The transmit directivity has no side-lobes and reduces ambiguities significantly
- Parametric sub-bottom profilers can have very high ping rates (SES-2000: up to 50 pps)



Multi-Transducer System SES-2000 *mtx*



- Parametric beam pattern allows transducer configuration without overlapping foot prints



Foot print of 3 transducers with a separation of 50cm at a distance of 5m



Multi-Transducer System SES-2000 *mtx*



- Multi-transducer configuration provides higher data density compared to single transducer survey
- Transducer separation is adjustable in relation to required lateral resolution, water depth and survey platform
- Positioning and attitude determination for rigid line array of transducers is easier than for floating or towed receiver arrays in combination with non-directional sources

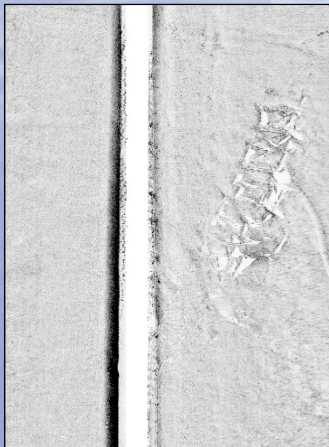


Application of multi-transducer SBP system

- Apart from pure archaeological survey, the identification and mapping of heritage to be protected is a common task for hydrographical surveys
- Examples are pre-dredging surveys for harbour channel extensions, marine constructions, coastal protection, pipeline and cable route surveys, wind farm installations, etc.
- MBES and Side Scan are limited to seabed features, but interesting structures and cultural remains may be found buried by sediments



Archaeological Site Investigation: Site 1

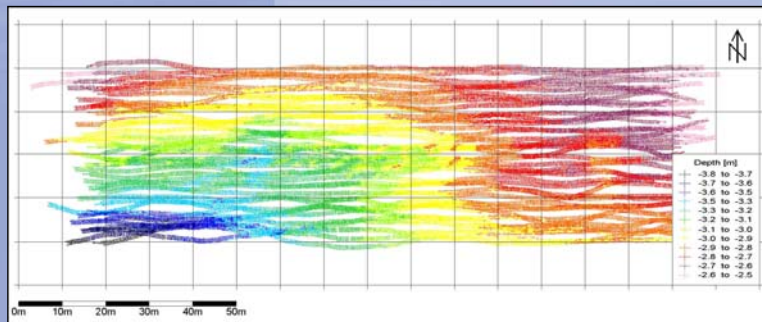


- Wooden pieces were recovered during dredging works for a channel which were dated into the Viking period (~740 AD)
- Further investigation with a Side Scan Sonar has shown rectangular wooden structures on the bottom of the Schlei
- The visible structure has a length of approximately 70m and is located in a water depth of about 3m
- Archaeologists believe that the structure is several hundred metres long and was probably built to act as a barrier for military protection

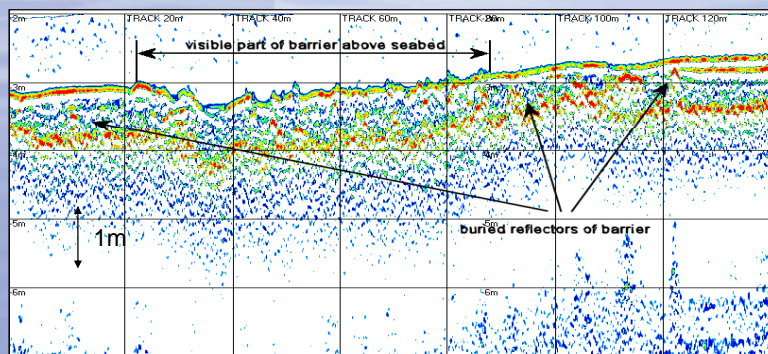


Archaeological Site Investigation: Survey

- The site was surveyed with 40 parallel lines within three hours only
- The total size of the survey area was 130 metres by 40 metres
- Due to the multi-transducer configuration a data density of about 30cm x 20cm laterally and 2cm vertically was achieved



Archaeological Site Investigation Online results

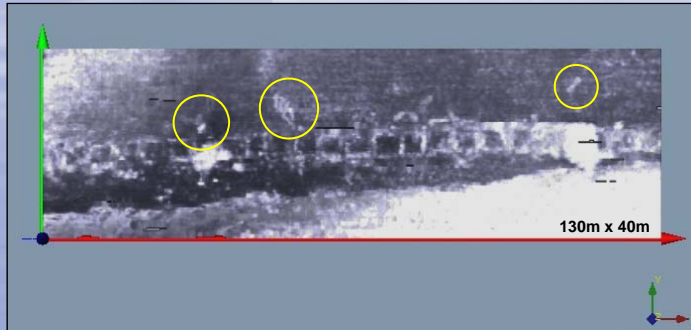


- Typical online echo plot of SES-2000 mtx system along the wooden barrier with buried reflectors and reflectors above the seabed
- A frequency of 10kHz with a pulse width of 100 μ s was used
- Vertical line spacing in the above echo plot is one metre, the horizontal line spacing is twenty metres



Archaeological Site Investigation

Offline data processing results

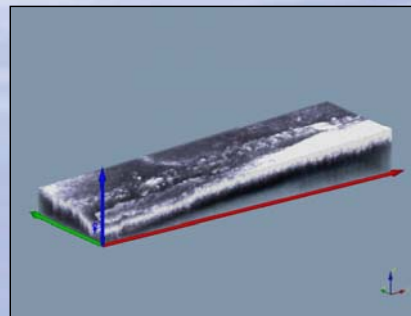
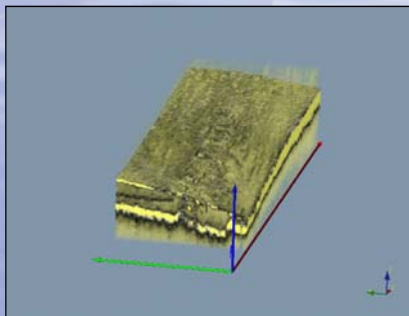


- All data gridded and rendered with a bin size of 33cm by 33cm
- The picture above shows a time slice through the volume
- The barrier can clearly be followed throughout the whole area and not only at the visible part of about 70m at the left side
- Possible locations of scattered debris identified (circles)



Archaeological Site Investigation

Three-dimensional data presentation

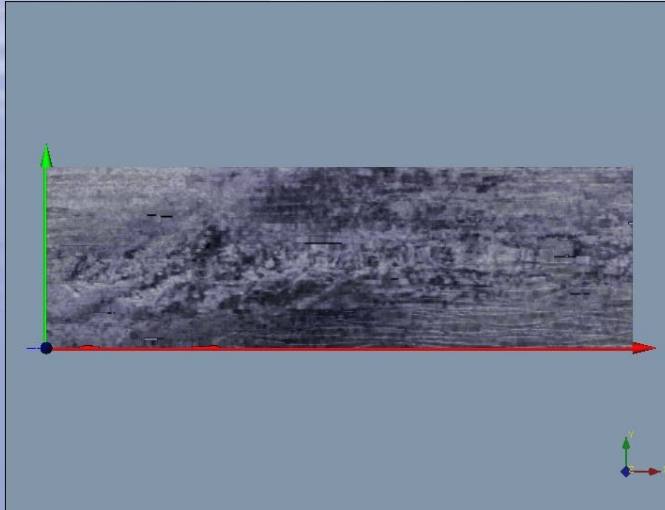


- Three-dimensional data presentation with a volume renderer allows cutting planes, time slices and different thresholds to be applied
- Interactive user navigation and movie generation is possible and makes data interpretation much easier, than with single sub-bottom profiles



Archaeological Site Investigation

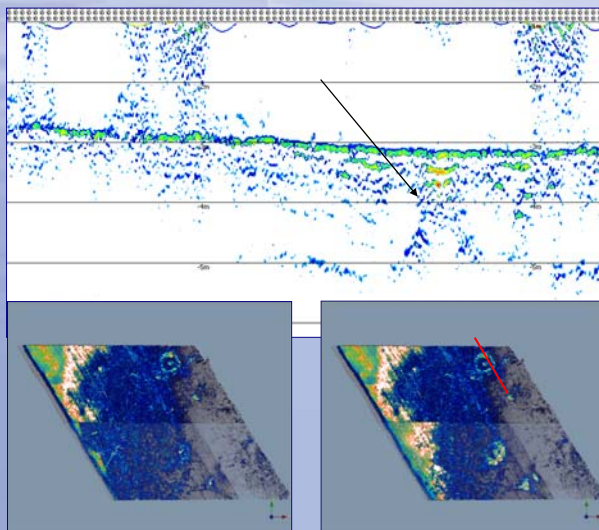
Three-dimensional data presentation (movie)



Example movie with time slices through the volume (view from top)



Site investigation prior to harbour channel extension



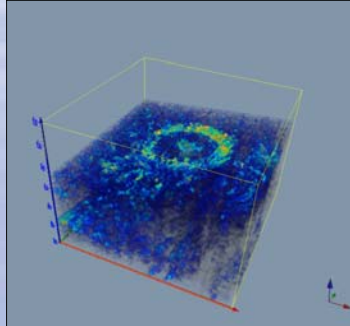
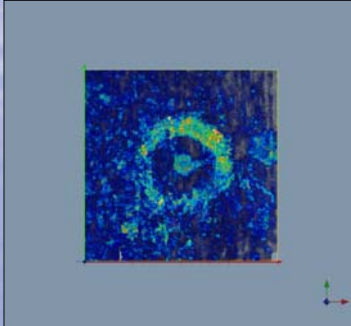
Echo print showing an unknown structure

Left:
Horizontal slice about 1m beneath the bottom surface

Right:
Horizontal slice about 0.5m beneath the bottom surface



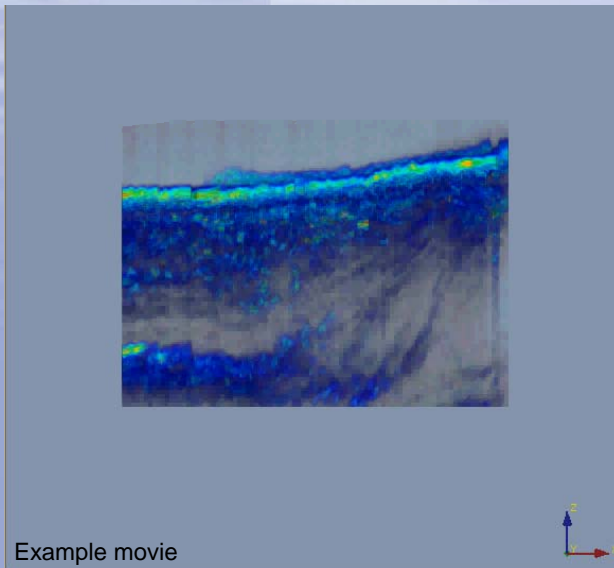
Site investigation prior to harbour channel extension



- Example from a planned extension of a harbour approach channel in a port in Northern Germany where authorities demanded a complete archaeological investigation as part of the heritage protection
- Data shows a subset of 50m x 50m in a water depth of about 3 m
- Unknown circular structures were identified which will be investigated by divers within the next few months



Data example in 3D (Movie)



Conclusions

- Technology of parametric sub-bottom profiler has been successfully applied to the detection of buried structures in shallow waters
- Combination of short transmit signals without ringing effects and very narrow sound beams results in high spatial resolution of sub-bottom data
- Narrow-beam sources in a multi-transducer configuration of a closely spaced line array increases the data density and homogeneity
- The position and attitude of rigid and boat mounted line arrays is easier to measure than for semi-rigid or floating receiver arrays
- Data sets from individual transducers do not require beam forming and are immediately ready for volume rendering after acquisition without any extensive and time consuming migration processing



Outlook

- Based on the presented prototype a commercial system will be available in near future from Innomar Technologie GmbH
- This system will have four transducers with adjustable separation and a fully integrated data acquisition system
- Data are made available for third-party processing systems and 3D data visualization packages

Boat Demo showing this system at Hydro 2010

