SURVEY OF UNDERWATER GAS PIPELINES ON THE OB RIVER
WITH PARAMETRIC SEDIMENT ECHOSOUNDER SES

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There are many different risks of damage for underwater pipelines, especially for their involuntary free spans over the shallow-water areas. The first SES survey on the Ob River in 2005 evidences high effectiveness and usefulness of this narrow beam parametric sediment echosounder for engineering monitoring of underwater gas pipelines. All free spans of the underwater pipelines both hung in water column and exposed on river’s bottom were revealed very reliably, including very narrow scour by 5–10 m wide and 4–5 m deep. Pipes buried by sediments were revealed there sometimes in depth up to 5 m beneath the river bottom. The collected SES data over the Ob River could be very important for scientific researches of topography-forming and sedimentological processes and subaqueous flow-transverse bedforms in rivers as well as for modeling of the after-effects due to anthropogenic intervention in natural regime of the rivers.

1. INTRODUCTION

A lot of underwater pipelines for transportation of gas, oil, fresh water etc are running through large and small rivers. There are many different risks of damage for the pipelines, especially for their involuntary free spans over the shallow-water areas. Predominant hazards are vessels, anchors and any trawling deep diving objects. The bottom morphology of the rivers is controlled by the sediment dynamics, and subaqueous flow-transverse bedforms are most peculiar features, which are formed in the natural flow channels. Free spans of pipes on the bottom of rivers with migrating dunes and ripples are usual and breakage due to bending of the pipes is other real hazard here. Divers and several acoustic technologies are used for inspection is a pipe buried within bottom sediments, laid up on bottom surface or hung above it in the water column. Sidescan sonar is most applicable one, but it provides no information about depth of buried pipes beneath rivers’ bottom. Different linear sub-bottom profilers (sparker, boomer, chirp sonar etc) are used for measuring of the depth (Kalinin et al., 1999; Wille, 2005), but their vertical and horizontal resolution is often low for revealing underwater pipelines.

Fig. 1: General View of the underwater main gas pipelines across Ob River near Andra, satellite image (http://earth.google.com). Location of the survey area is indicated by red box. Inset: photo of the pipes entry in the river.
Set of large pipelines was constructed some decades ago for transportation gas from Siberia to Europe and the main pipelines are crossing several rivers. The longest underwater part is the Ob River crossing from 2 km to 4 km wide in different seasons (Fig. 1, 2). Very high-resolution seismic reflection profiling was carried out in summer 2005 here. Parametric sediment echosounder “SES-2000 compact” (Fig. 3) was used firstly in Russia for survey over such water areas. The survey was conducted in the period 26 August to 31 August 2005 during systematic inspection of the underwater pipelines’ technical condition, which is carried out yearly by engineering company “POVDODGAZENERGOSERVICE”, AS “Gazprom”. These routine works usually include echo-sounding and side-scan sonar survey only.

Fig. 2: The river bank during summer water lowstand shows exposed part of bottom, which consists from alternating layers of mostly sandy to silty sediments.
A- fragment of build pipe by about 1 m diameter;
B- sinking load on the pipe.

Fig. 3: Diving vessel class of “Yaroslavetz”. Red arrows show equipment position on board. Parametric sediment echosounder “SES-2000 compact”:
A- electronic block and notebook;
B- transducer.
C- installation of the transducer.
D- petrol generator for electric power (220 V, 50 Hz) supply.

2. NONLINEAR ACOUSTICS, NARROW BEAM PARAMETRIC ECHOSOUNDER SES, METHODS

Nonlinear acoustics
Company “Innomar Technologie GmbH” (Rostock, Germany) produces the SES family of sub-bottom profilers based on nonlinear acoustics (Hansen, Muller, 1999; Wunderlich, Muller, 2003; Lowag, Heuvel, 2004; Wunderlich et al., 2005). For nonlinear sound generation two signals of slightly different high (primary) frequencies are simultaneously transmitted at high sound pressures. Due to nonlinear interactions in the water column in front of the transducer, difference (secondary) frequency is generated. It is low and can be used for sub-bottom sediments profiling and embedded object detection. The high primary frequency signals may be used for the exact determination of the water depth (bathymetry survey). In comparison with linear echosounders, parametric systems have following advantages:

- Possibility to generate narrow sound beams at low frequencies with small transducers. Beam width is nearly independent of the sound wave frequency.
- Small and portable transducer and system dimensions allow the use for different applications and the installation on small boats too.
- High system bandwidth, which allows transmitting very short signals without ringing, gives high vertical resolution.
- Small beam width also at low frequencies and high pulse repetition rate result in high horizontal resolution.
- The directivity of the difference frequency has no side lobes.
- A narrow beam without side lobes and short pulses results in less volume of bottom reverberation and increases signal-to-noise ratio for detection of weak reflectors.
- Nearly constant directivities for the primary frequency and the different secondary frequencies at transmitting offer new possibilities refer to classification.
- The use of the parametric systems ensures bathymetry and sub-bottom survey results with high accuracy.

**Narrow beam parametric echosounder SES-2000 compact**

High resolution data of echosounders SES are ensured by narrow beam without side lobs, high frequency range and high pulse repetition rate of sounding signal. Main technical parameters of the used echosounder SES-2000 compact (Fig.3):

- Primary frequency: 100 kHz.
- Secondary frequencies: 5, 6, 8, 10, 12, 15 kHz.
- Beam width: ±1.8° at transducer size of 22cm x 22cm.
- Electrical pulse power: > 12 kW.
- Pulse width: 66µs up to 500 µs.
- Pulse repetition rate: up to 50 pulses per second.
- Water depth range: 1m – 400m.
- Operating range: 5m – 200 m.
- Penetration: up to 40m, depends on sediment.
- Layer (vertical) resolution: down to 5cm.
- Accuracy 100 kHz: 0.02m + 0.02% of depth.
- Accuracy 10 kHz: 0.04m + 0.02% of depth.

**Methods**

The 2005 survey over the Ob River underwater pipelines was conducted on board of diving vessel class of “Yaroslavetz” (Fig. 3). All electronic equipment (Fig.3A) was installed in pilot cabin. The SES transducer (Fig. 3B) was mounted on the side of the vessel using light metal pipe (Fig. 3C) at a depth of 60 cm. Petrol generator “Yamaha” by 3 kVA output (Fig. 3D) was used for electric power (220 V, 50 Hz) supply. Accurate positioning of the vessel was guaranteed by onboard differential GPS. Average speed of the vessel ranged from 14 km/h (with stream) to 9 km/h (against). Innomar’s software tool ISE provides near real-time post-processing of the collected SES data and operation procedure could be corrected on-line. Several test profiles were surveyed to find the best system settings, first of all the adjustable low frequency. Acoustical signal by 8 kHz and 2 pulses (signal length 250 µs) ensured best vertical resolution 10–15 cm at acceptable penetration up to 5 m. Operating range by 6-8 m depth was chosen to receive highest pulse repetition rate up to 30–40 s⁻¹, hence excellent horizontal resolution. Bathymetry maps were compiled from collected primary (100 kHz) frequency SES data, assuming average sound velocity of 1450 m/s (Fig. 4).

![Fig. 4: 3D Bottom topography of the survey area compiled from the collected high primary frequency SES data.](image-url)
3. RESULTS: DETECTION OF GAS PIPELINES WITH PARAMETRIC ECHOSOUNDER SES

Underwater pipes produce echoes in sub-bottom profiler’s records in the form of typical diffraction hyperbolas (Kalinin et al., 1999; Wille, 2005). The SES survey over underwater gas pipelines across the Ob River revealed all free spans both hung in water column (Fig. 5) and exposed on river’s bottom (Fig. 6) very reliably. Their height above the bottom is measured to within few centimeters.

![Fig. 5: The Ob River, underwater gas pipelines within water column. Pipeline crossings. “SES-2000 compact” image.](image1)

![Fig. 6: The Ob River, underwater gas pipeline on the river’s bottom. Pipeline alongside. “SES-2000 compact” image. The distinct visible segmentation is caused by the sinking loads showed in Fig. 2B.](image2)

Detection of buried pipes is difficult depending on bottom conditions: its topography, lithological and physical properties of bottom sediments and their structure. Besides, generation of present pattern of the river bottom was affected by anthropogenic activities. Deep trenches were dredged here first and pipes were laid inside then. These trenches filled up with soil are seen distinctly on the SES echoprints (Fig. 7, 8). Gravels and large stones as well as strong artificial objects are scattered over their top for protection from erosion by currents. Such protection methods for underwater pipelines as fixing and burying them by casting shiploads of stones are usually applied everywhere (Wille, 2005). Unfortunately, the protective loadings could prevent from penetration of high frequency acoustic signals beneath and visible strong hyperbolic reflections seem to be generated sometimes by these hard heterogeneities but not by buried pipes themselves. In other places, one can see some parts of the trench but not the pipe inside.

In general, three natural morphological zones were distinguished in the Ob River cross-section: two deep near costal channels separated by shallow bottom zone (so-called “oseredok”). Each of the zones is characterized by individual bottom conditions therefore different capability of signal penetration for detection of buried pipes. The best conditions are near right eastern bank of the river, where bottom consists of soft silty and clayey sands. Buried pipes were revealed there in depth up to 5 m beneath the bottom (Fig. 7, 8).
In two other zones, penetration was limited due to more compact or heterogeneous bottom sediments. Especially poor bottom conditions are over middle shallow zone, where natural erosion and sediments reworking processes are extremely active. Main free spans of the underwater pipelines are observed just here. Several other free spans are observed near eastern bank, particularly within narrow scour of stream which is flowing into the river. Exclusively, unique technical parameters of the narrow beam parametric sub-bottom profiler SES allows to see the small pipe by one meter in diameter in such scours by 5–10 m wide and 4–5 m deep (Fig.9).
The SES survey distinguished general small-scale local lateral changeability of bottom conditions over this area of underwater gas pipelines across the Ob River. Neighbour pipes closely spacing by 50–60 m are located on sites with absolutely different bottom topography and sediments structure. Therefore, various acoustical techniques would be testing for detection the underwater pipelines. The pipe will be “seen” by linear sub-bottom sediment profilers with wide beam under slant angles already earlier and still later indicated by longer mustache-like tails (Kalinin et al., 1999; Wille, 2005). However, location and depth of buried pipe can be determined from these data quite roughly. The diffraction hyperbola in the narrow beam parametric sub-bottom profiler SES records is very short (Fig. 5, 7–9) since the pipe is “seen” very distinct under near vertical angle only, and that secures high accuracy of the determination. SES survey over embedded pipeline in a German lake showed similar results (Wunderlich, Muller, 2003).

The collected SES data over the Ob River could be very important for scientific researches of topography-forming and sedimentological processes and the subaqueous flow-transverse bedforms in rivers and especially in the Ob River. Most interesting could be migrating subaqueous dunes up to 1–2 m high, their morphology and inner structure are seen very detailed on the SES records (Fig. 7, 8). Usually, the records of the side-scan sonar and the echo sounder are used for determination of the dunes parameters (e.g., Francken et al., 2004). However they show pattern of current bottom topography only. These data do not make clear former features in bottom sediments, which document history of the paleoenvironments’ development. Therefore, the side-scan sonar and echo sounder records could be supplemented essentially with the SES data showed distinctly structure of the bottom sediments. Besides water depth, current velocity and sediment composition are the main factors, which control the dunes’ development. Therefore, the studies should be multidisciplinary including high resolution seismic survey as well as sediments coring and current measurement. Sites for the coring and measurement could be selected from the very detailed SES data. The data allow study anthropogenic influence on channel processes that is important for projection of any underwater engineering constructions. Prediction of the after-effects due to anthropogenic intervention in natural regime of the river can be modeling only and knowledge of topography-forming and sedimentological processes and migrating subaqueous flow-transverse bedforms is essential. Just bottom sediments dynamics is most difficult and least studied problem.
In general, the first results of the SES survey, 2005 on the Ob River evidence high effectiveness and usefulness of this parametric sub-bottom profiler for engineering monitoring of underwater gas pipelines. In our opinion now, the high resolution narrow beam parametric echosounder SES seems to be the best among all sub-bottom profilers for such work.

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References