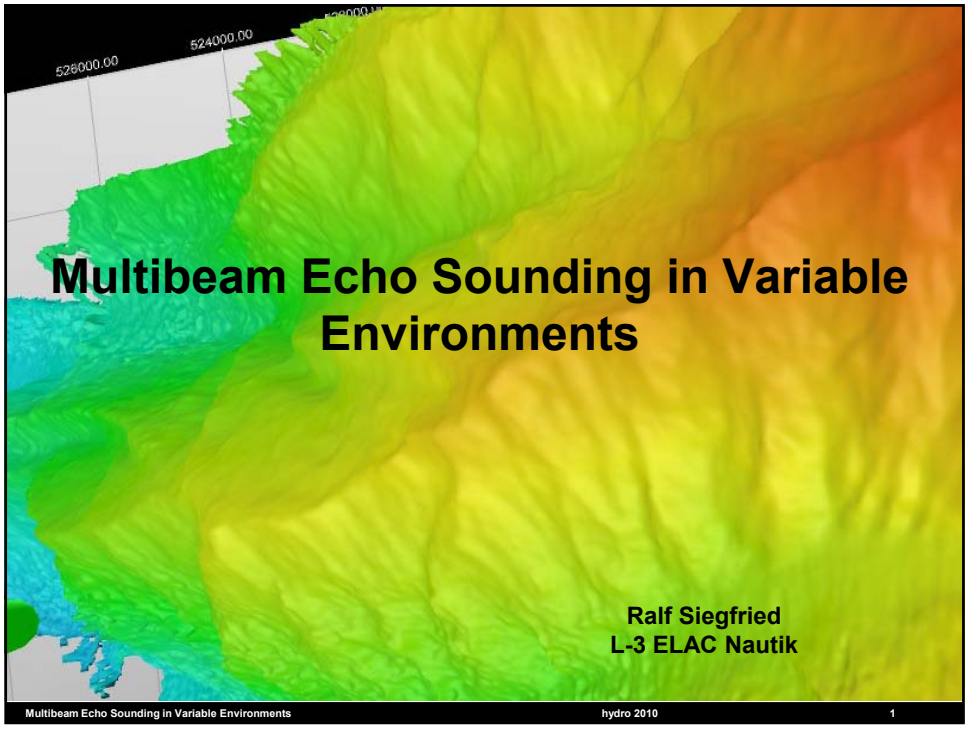

Multibeam Echo Sounding in Variable Environments

Ralf Siegfried
L-3 ELAC Nautik

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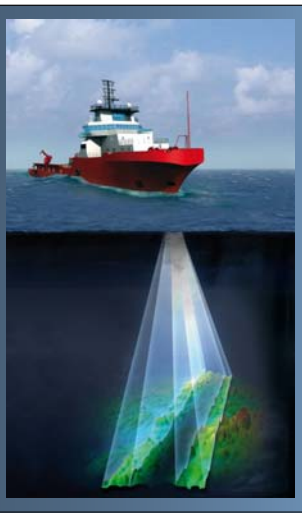

- A multibeam echo sounder is the ideal sensor for getting the real bottom topography
- A multibeam system delivers water depth information of a wide swath across the ship
- Bottom coverage up to 5.5 times water depth
- But normally such echo sounders are only installed on special survey vessel

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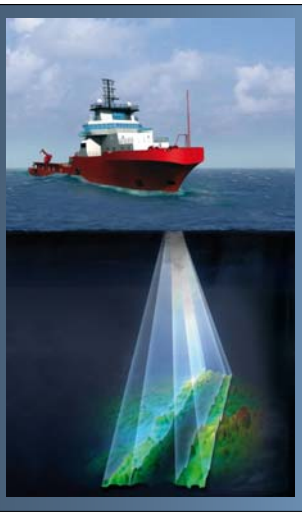
Introduction (2)



- Send out a sonar signal (ping) from projectors mounted along the ship's keel.
- The signal, generated in the transmitter sub-system, travels from multiple projectors but forms a single beam projected across a swath under the ship.
- The sonar signal travels to the sea floor and reflects off the bottom.
- The amount of reflected energy depends on the bottom type and grazing angle.
- At the ship, hydrophones mounted across the bottom of the ship (across-ship) listen for the reflection of the sonar signal.
- They convert the sound to electrical signals and send these signals to the echo processor electronic assembly for depth calculation.

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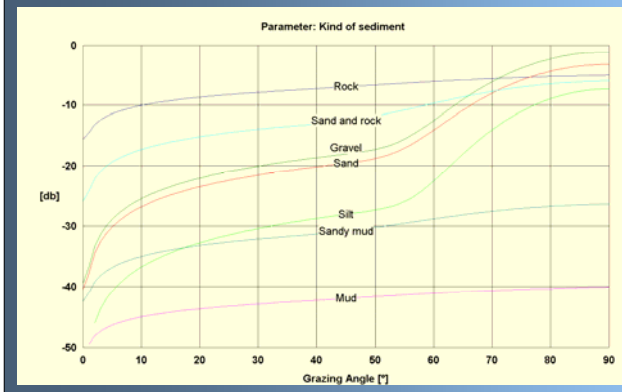
Environmental driven required dynamic

Bottom sediments



- Backscatter coefficient depends on sediment type
- Backscatter coefficient depends on the grazing angle
- Silt e.g. has a dynamic range of ~ 30 dB

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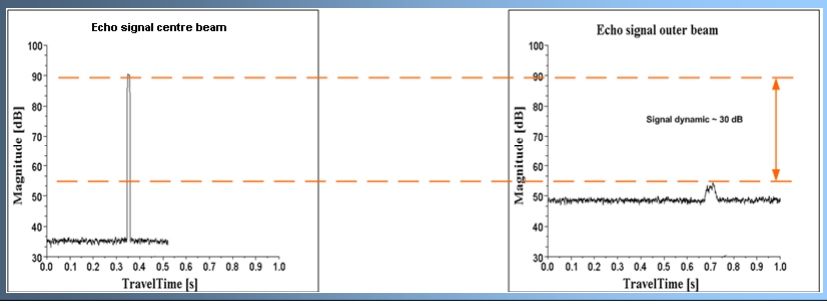
Environmental driven required dynamic

Nadir signal enhancement

The multibeam echo sounder receives echoes from the nadir with much higher magnitudes than echoes from the outer beams. This is due to the nature of the bottom scatter curves as well as to the longer travel time of the wave to the outer beam.

Reduced S/N at he outer beam

Sufficient dynamic at stave level is required



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Environmental driven required dynamic
Signal fading

➢ Strong destructive interference may result in temporary failure of depth measurement due to a severe drop in the Signal-to-Noise Ratio

➢This is caused by varying random changes in the amplitude and phase of the signal.

➢Signal-fading phenomena can drastically affect the performance of a multibeam echo sounder.

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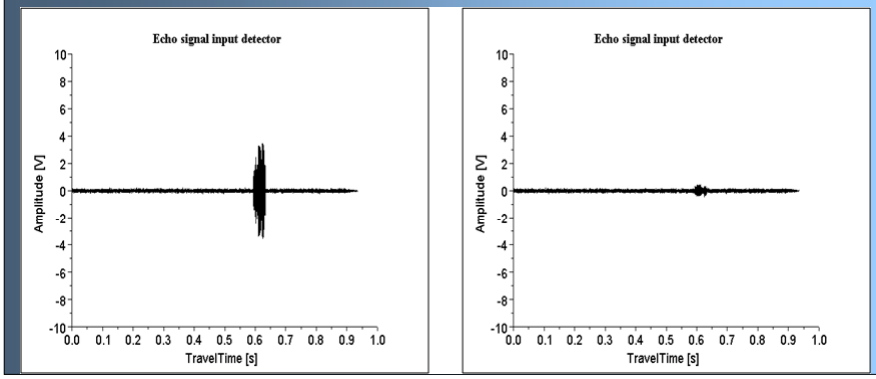
Environmental driven required dynamic
Signal fading

Echos of two succeeding pings. Due to the fading effect the second echo is significantly lower.

Reduced S/N at he outer beam

Sufficient dynamic at stave level is required



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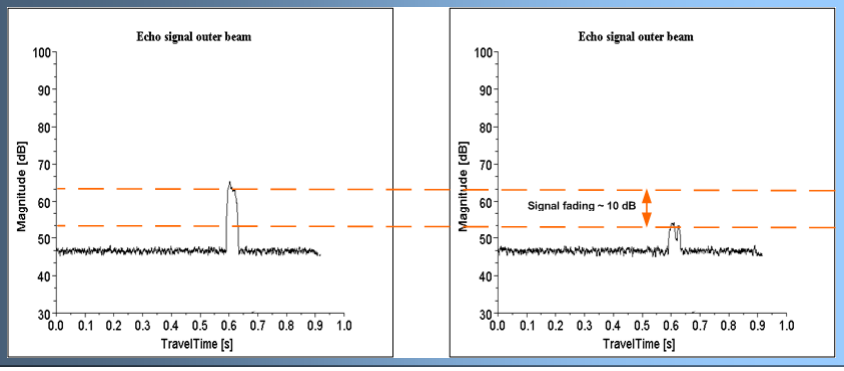
Environmental driven required dynamic
Signal fading

Echos of two succeeding pings. Due to the fading effect the second echo is significantly lower.

- Reduced S/N at he outer beam
- Sufficient dynamic at stave level is required



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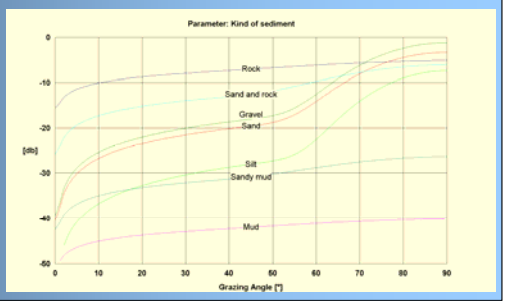
Environmental driven required dynamic
Sediment change

- A change of the sediment will affect the dynamic behaviour of the multibeam echo sounder.
- This is due to the different backscatter behaviour of the different sediment types.



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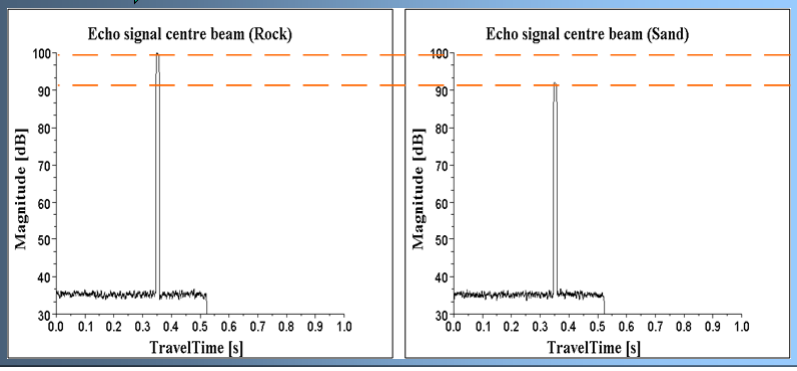
Environmental driven required dynamic

Sediment change

Different echo magnitudes for rock and sand from the centre beam (nadir).

Reduced S/N at he outer beam

Sufficient dynamic at stave level is required



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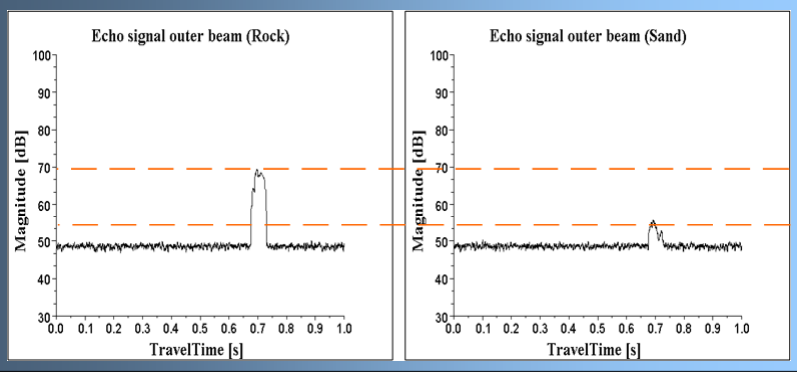
Environmental driven required dynamic

Sediment change

Different echo magnitudes for rock and sand from the outer beam.

Reduced S/N at he outer beam

Sufficient dynamic at stave level is required



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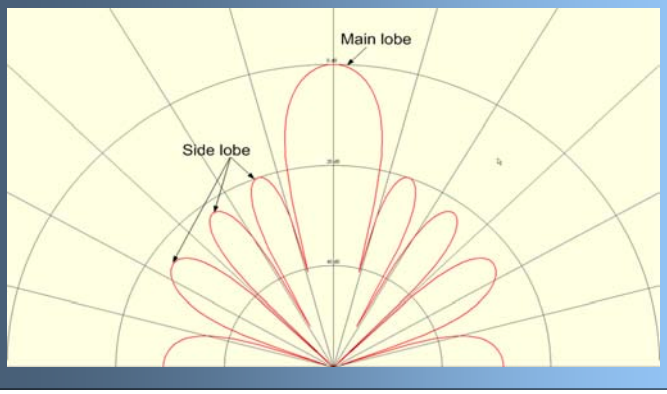
Limited system capabilities

Side lobe effects

Side lobes and grating lobes are both unwanted parts of the sonar beam emitted off axis that produce artefacts due to an error in positioning the returning echo.



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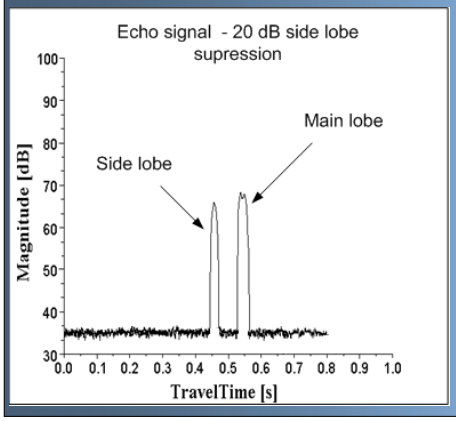
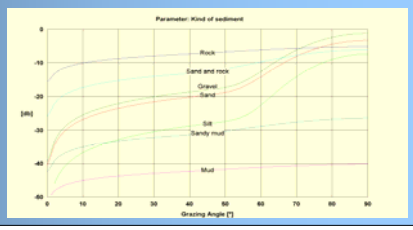
Limited system capabilities

Side lobe effects



- **The system receives the echo from the main lobe as well as from the side lobe.**
- **The backscatter coefficient at the side lobe angle is significantly higher than the backscatter coefficient from the main lobe angle.**
- **Both echoes are consequently at the same level and the S/N (or ratio between main and side lobe echo) is small**



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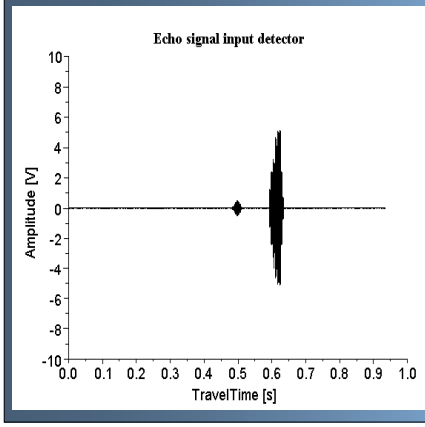
Limited system capabilities

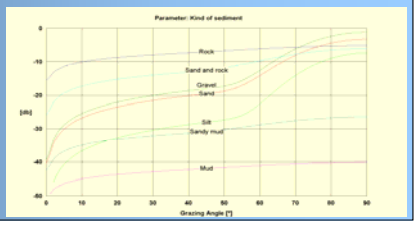
Side lobe effects at limited system dynamic



➢A limited system dynamic makes the detection performance worse.

➢At the end of the dynamic range, the ratio between side lobe and main lobe signal decreases.

➢The level of the side lobe and main lobe signal adjust more and more at the same level.



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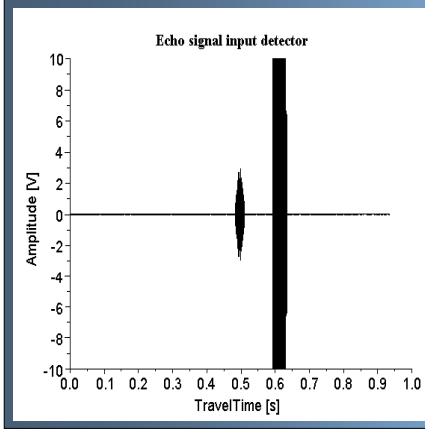
Limited system capabilities

Side lobe effects at limited system dynamic



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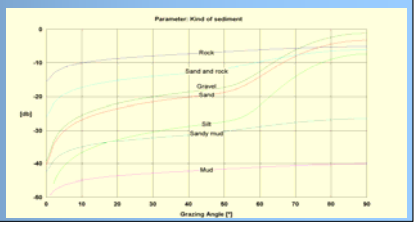

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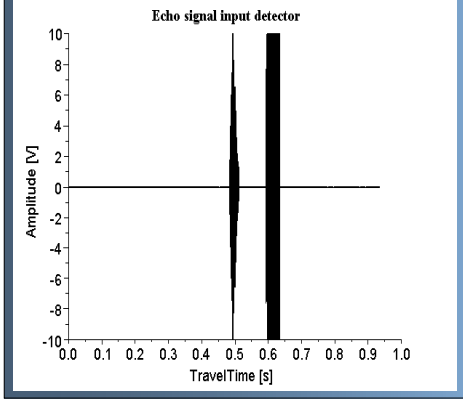
Limited system capabilities

Side lobe effects at limited system dynamic



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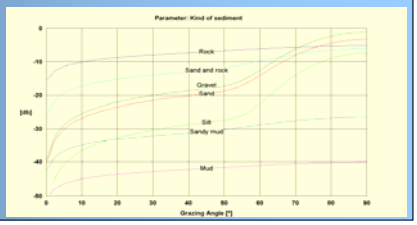

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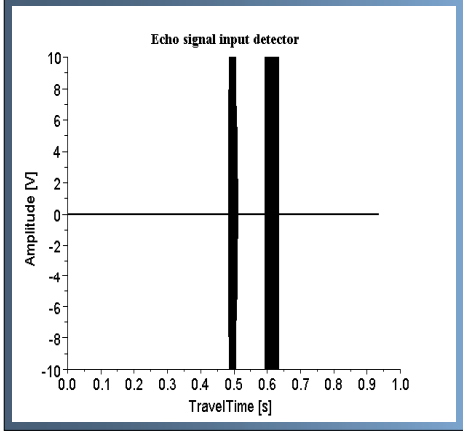
Technical approach

Side lobe effects at limited system dynamic



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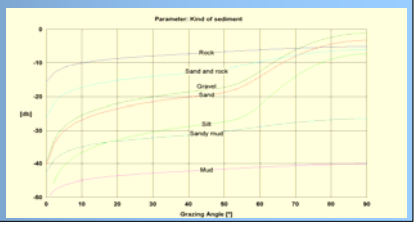

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Limited system capabilities

Probability of correct detection and false detection

- The system has to decide, which echo is a correct detection and which echo is a false detection.
- This decreasing S/N ratio decreases the probability of correct detection and increases the probability of a false alarm
- Consequently the detection performance of the multi beam echo sounder will become less accurate.

INPUT	SIGNAL PRESENT	SIGNAL ABSENT
SIGNAL PRESENT	CORRECT DETECTION p(D)	MISS 1-p(D)
SIGNAL ABSENT	FALSE ALARM p(FA)	NULL DECISION

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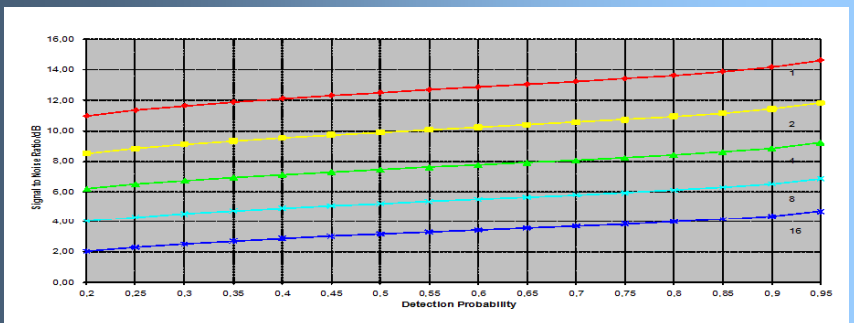
Limited system capabilities

Probability of correct detection and false detection

Signal-to-Noise Ratio as a Function of Detection Probability for Various Numbers of Independent Samples Provided by Multiple Pings on a Target



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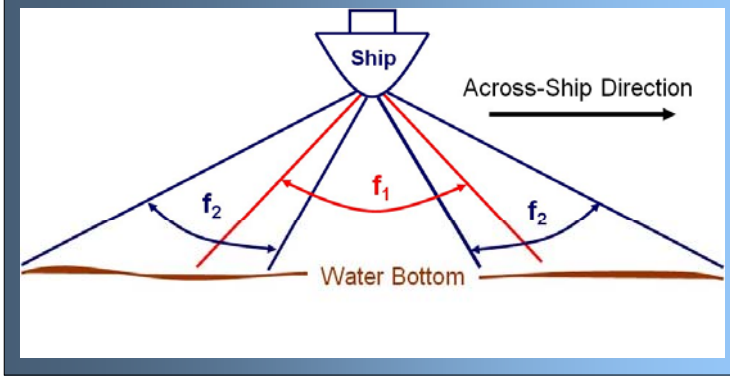
Technical approach
Multiple sector mode

An approach to reduce this required dynamic is the use of multiple frequencies in the nadir and the outer beam part of the swath.



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Technical approach
Multiple sector mode

➢The lower frequency f2 at the outer beam part has a lower absorption coefficient than the higher frequency f1 of the nadir part of the swath.

➢**Based on:** $TL = 20x\log(Range) + \alpha * Range$

(α = absorption coefficient as a function of the frequency)

The transmission loss and consequently the required dynamic range between the echoes from the nadir and the echoes from the outer beam are lower.

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Technical approach
High processing dynamic

- Modern PC's provide sufficient dynamic for the signal processing with double and quad precision.
- A state of the art 1 or 10 Gbit Ethernet network topology is required.
- A well designed data management with more multicast than broadcast messages is required to manage the data flow with double and quad precision.
- The front end processing, the preamplifier and the A/D converter are the most critical issues.
  - The best way is to use a 24 bit converter which today achieves a dynamic range between 90 and 100 dB.
  - A 16 bit converter requires at least an oversampling method in order to reduce the noise, because the minimum possible noise level is the error caused by the quantization of the signal, sometimes called Quantization Noise.

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Technical approach
Rotating Directional Transmission

- Sequentially transmit and receive, using highly directional beams, which are successively steered across the desired swath width.
- Directional transmission maximizes the transmit source level for a given power level, limited by cavitation or the power electronics. This provides a robust depth capability. High quality sounding data acquisition has been maintained by the SeaBeam system even in suspended sediment environments during ongoing dredging operations.
- The convolution between transmit and receive beam pattern optimize the side lobe suppression.

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Conclusion

- Different sediment types require high system dynamic
- Limited system dynamic and low side lobe suppression decrease the Signal-to-Noise Ratio
- Error probability is directly related to Signal-to-Noise Ratio
- Lower frequency for the outer sector and higher frequency at the centre sector decreases the required dynamic range
- RDT method has a better side lobe suppression and increase the data quality