Noise generation of commercial ships

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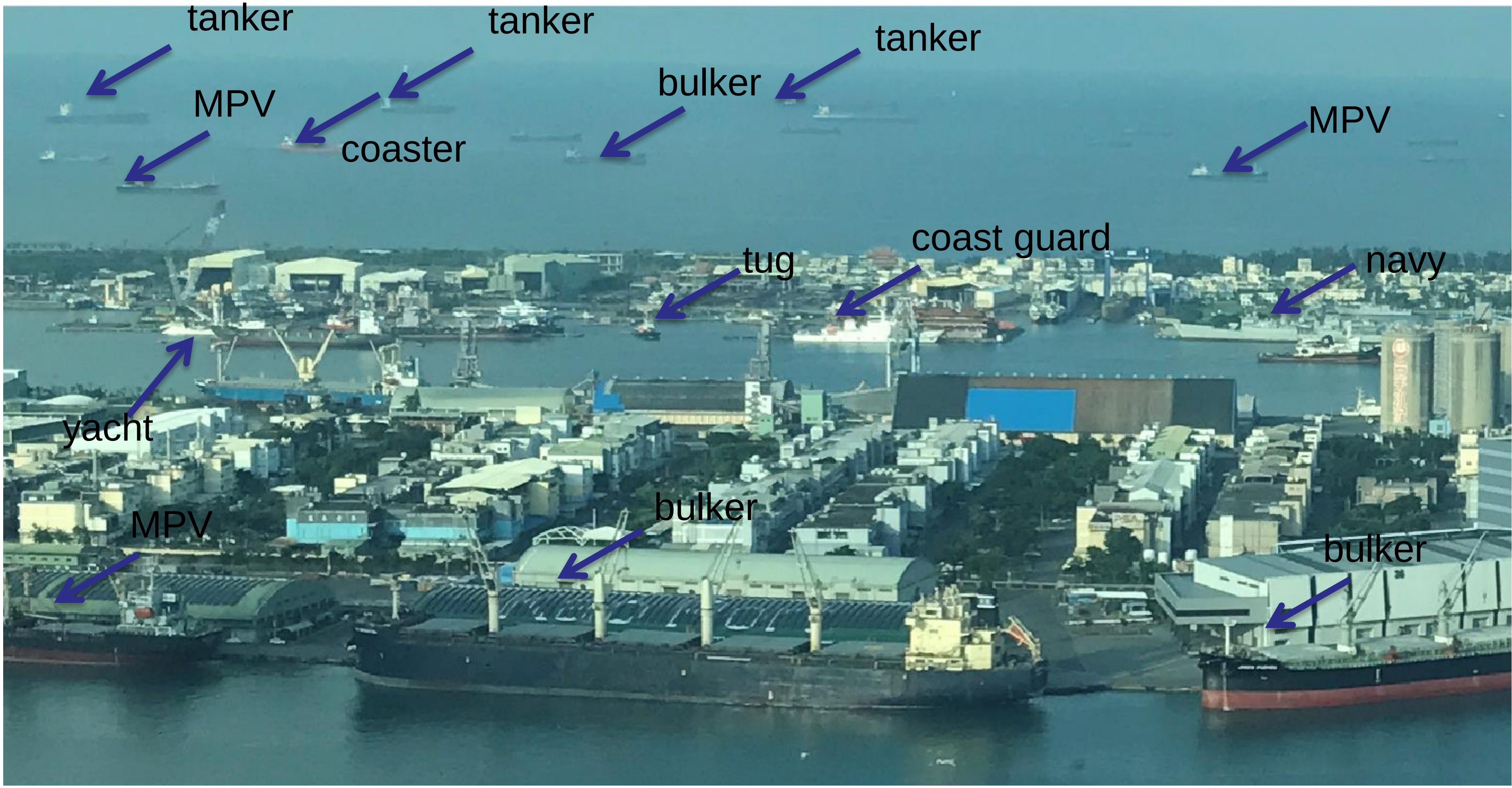
Target

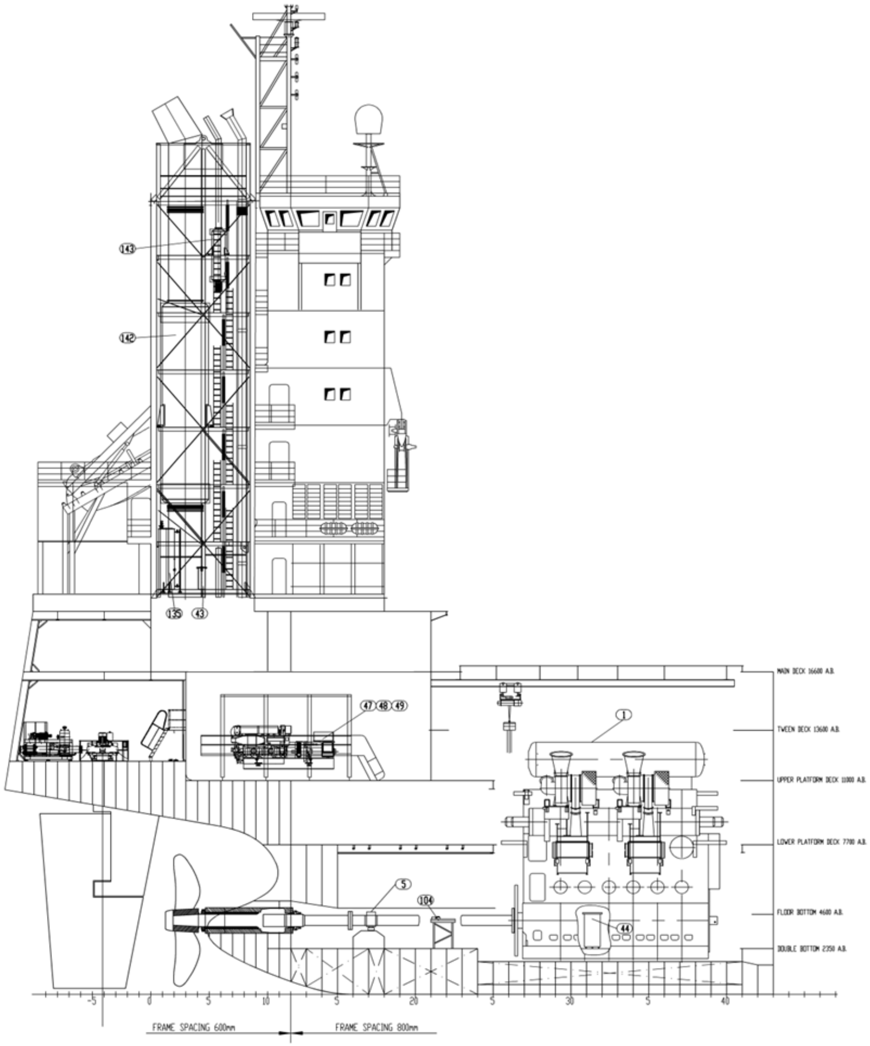
- **Relate ship noise to architectural features!**
- **Do meaningful underwater radiated noise measurements!**
- **Find the ship in the environment!**

What is a ship?



Ship noise and architectural features

Noise sources onboard

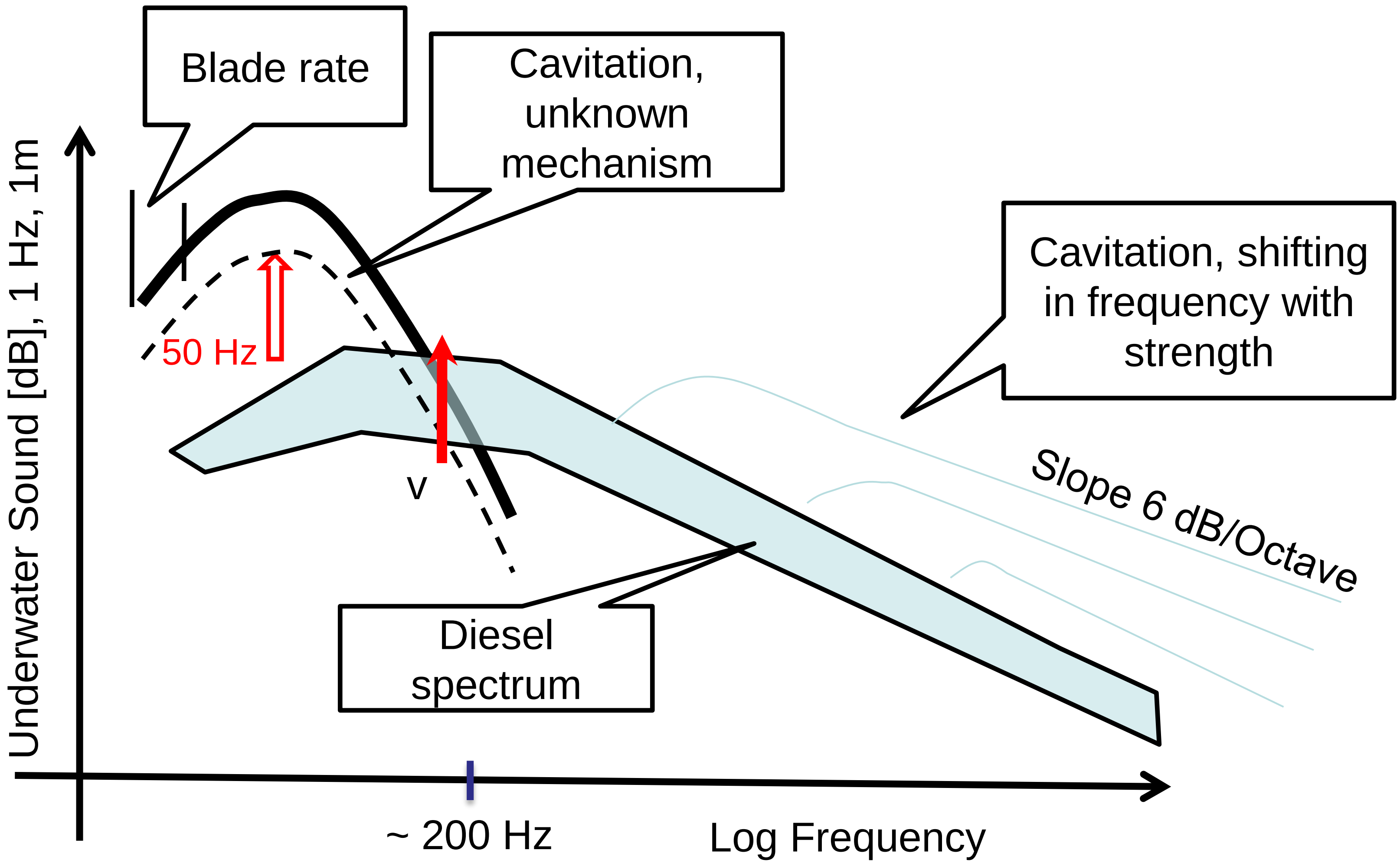


2-stroke diesel

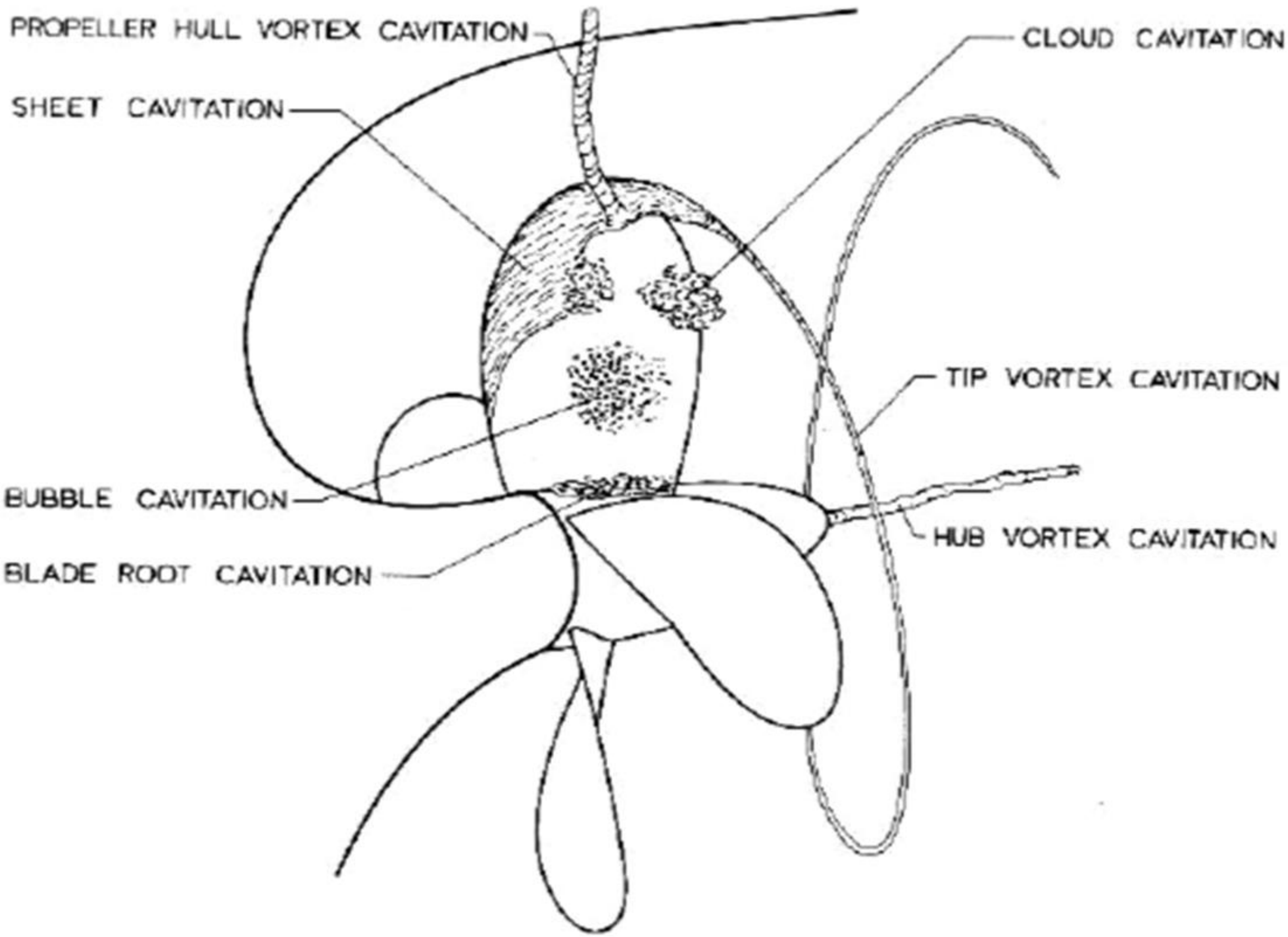
4-stroke diesel

propeller

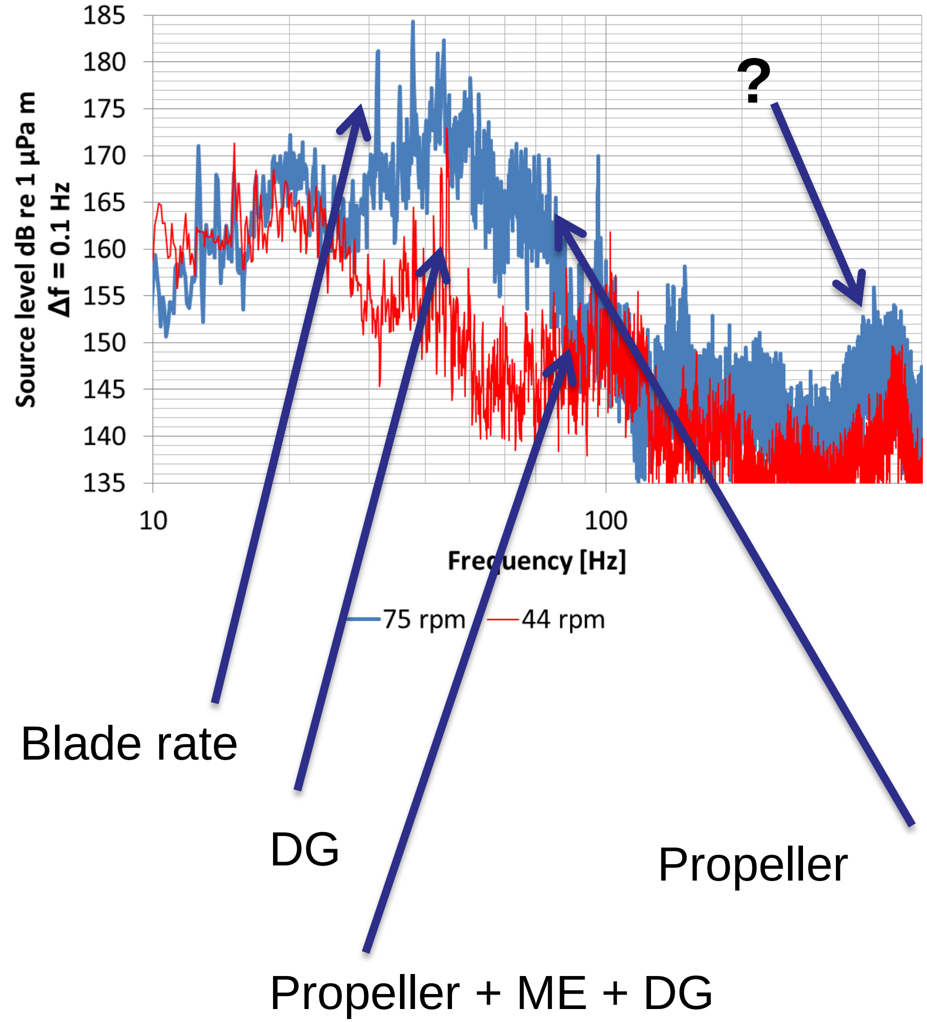
Characteristics of noise contributions



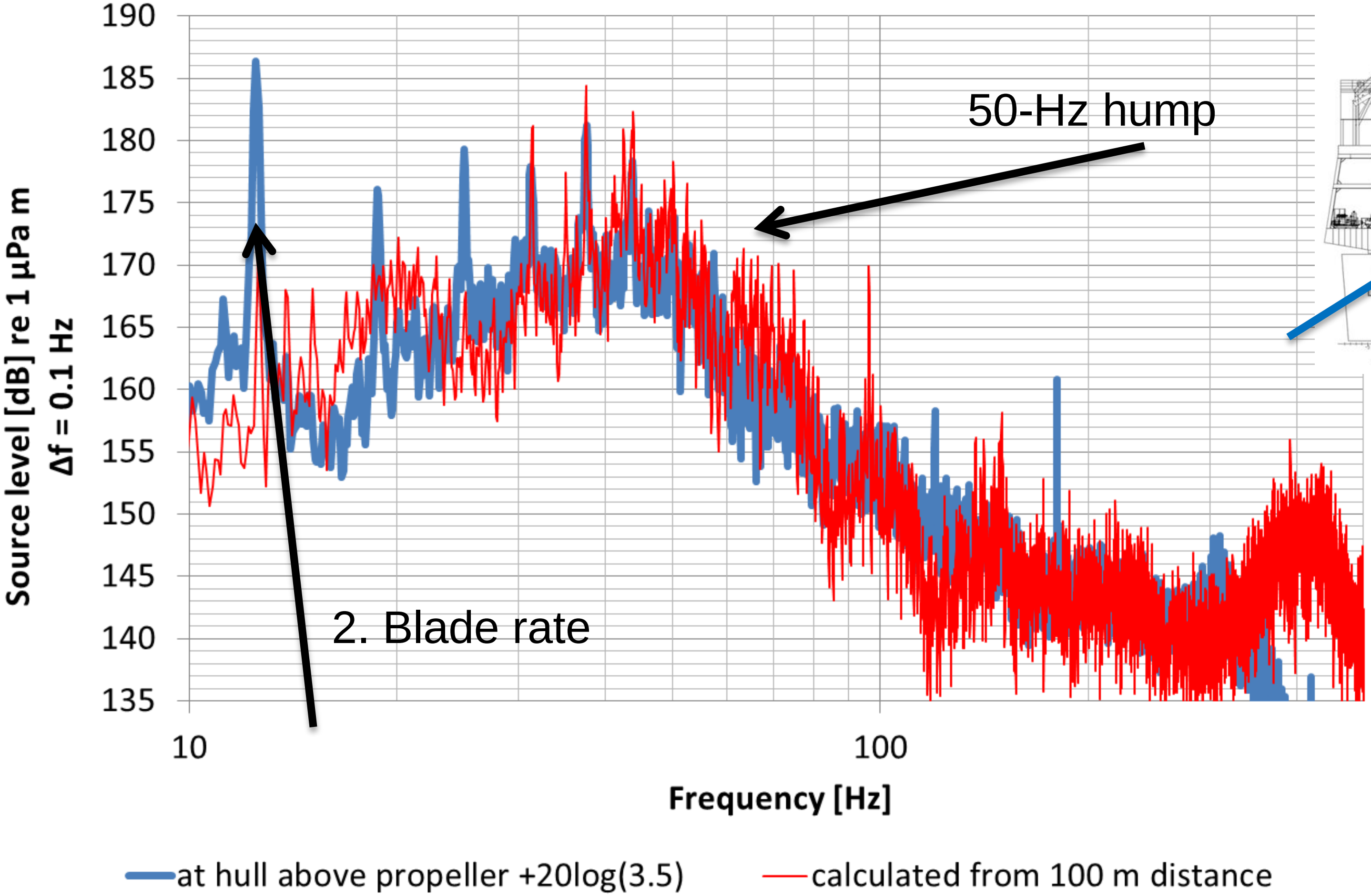
Propeller cavitation: the main source of underwater noise

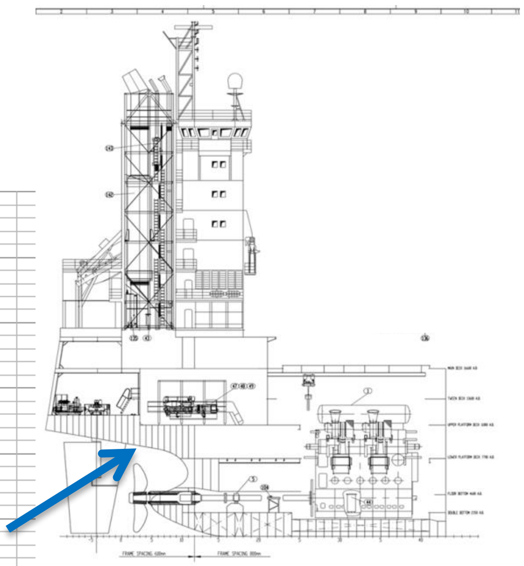


Individual contributions

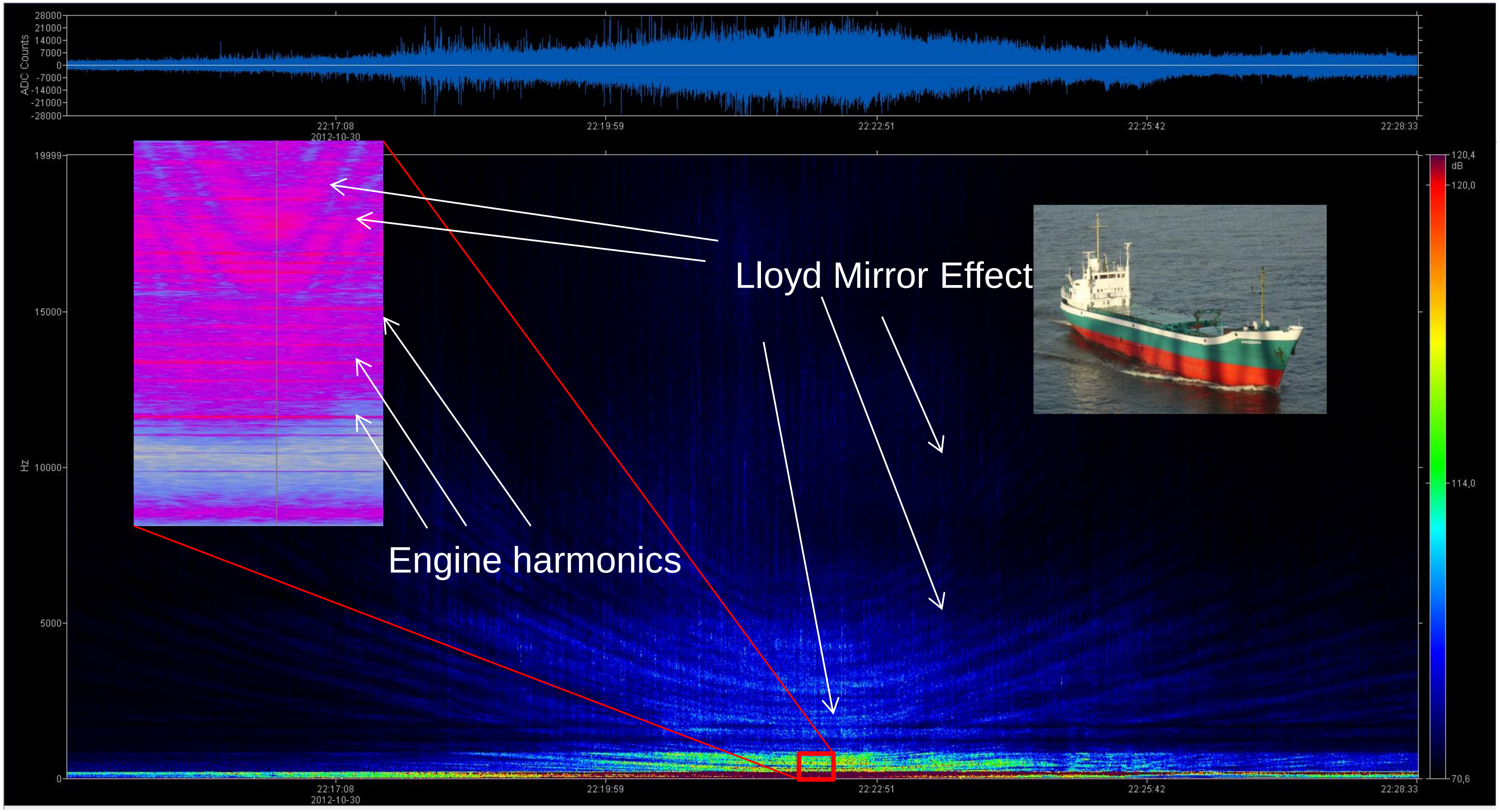


Measurement on the ship vs. measurement at a distance, 75 rpm





A small ship in the Baltic Sea



Note: LME causes hyperbolic pattern → point source → propeller (and a dominating sound path)

No LME with machinery tones. Allows identification of engine

Noise generating mechanisms and what you can do: Propeller

Low frequency cavitation	
Level	**80** log(speed/CIS) and block coefficient
Characteristics	Broad band + blade rate tonals
What you can do	• „better“ propeller (= increase CIS) • reduce speed • wake equalization devices?

High frequency cavitation	
Level	**60** log(speed/CIS) and block coefficient
Characteristics	Broad band, often modulated, sometimes impulsive
What you can do	• decide whether you care (not well researched, likely f(form of cavitation)) • „better“ propeller (= increase CIS)

Big problem: making a propeller more efficient increases cavitation related noise!!

Noise generating mechanisms and what you can do: Engine

Low speed (2-stroke) diesel engines: harmonics of shaft speed (60 to 150 rpm)
Medium speed (4-stroke) diesel engines: harmonics of half rpm

propulsion:	**500 to 600 rpm**
auxiliary:	**600, 720, 750, 900 rpm**

Assuming constant power/weight ratio and some decorrelation with size

Level ~ 15log(mass) , propulsion diesel 20log(speed) (if constant rpm)

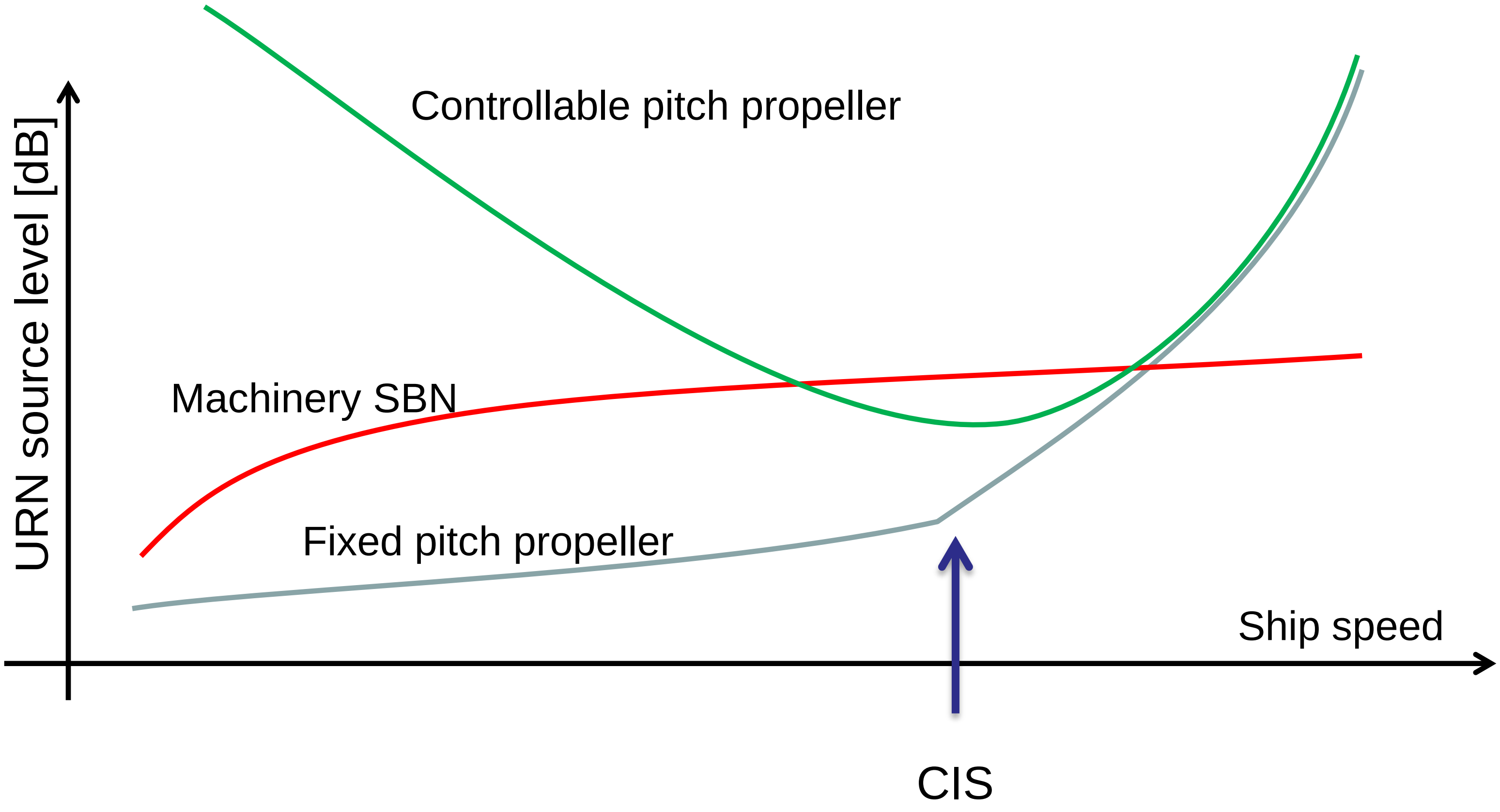
A resiliently mounted 4-stroke diesel has a similar contribution as a 2-stroke diesel.

Rigidly mounted diesels are about 15 dB noisier.

4-stroke diesels can be controlled by good resilient foundations

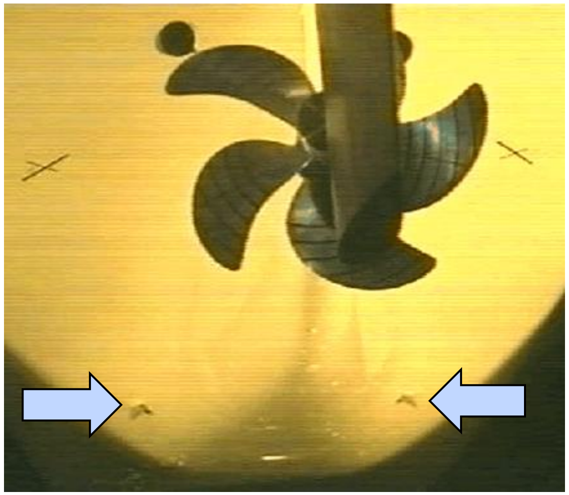
4-stroke diesels dominate in high power twin screw ships such as cruise liners

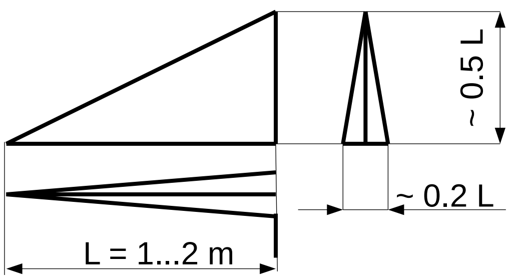
Engineering estimation of source levels, fixed pitch



Wake Equalization Devices: efficiency ↑ + noise ↓?

Vortex-Generator-Fins





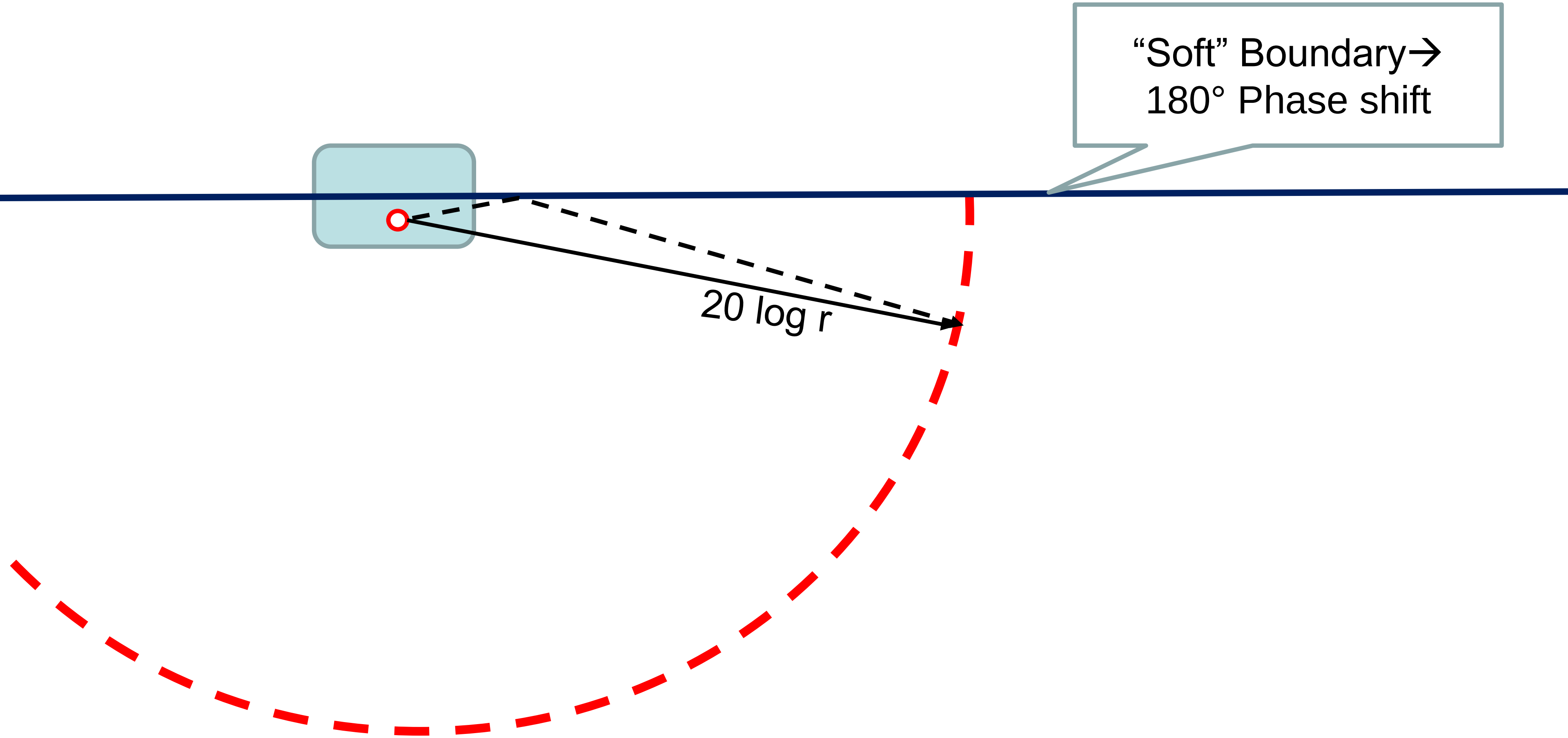
Mewis-Duct

Schneekluth-Nozzle

Pre-Swirl Stator

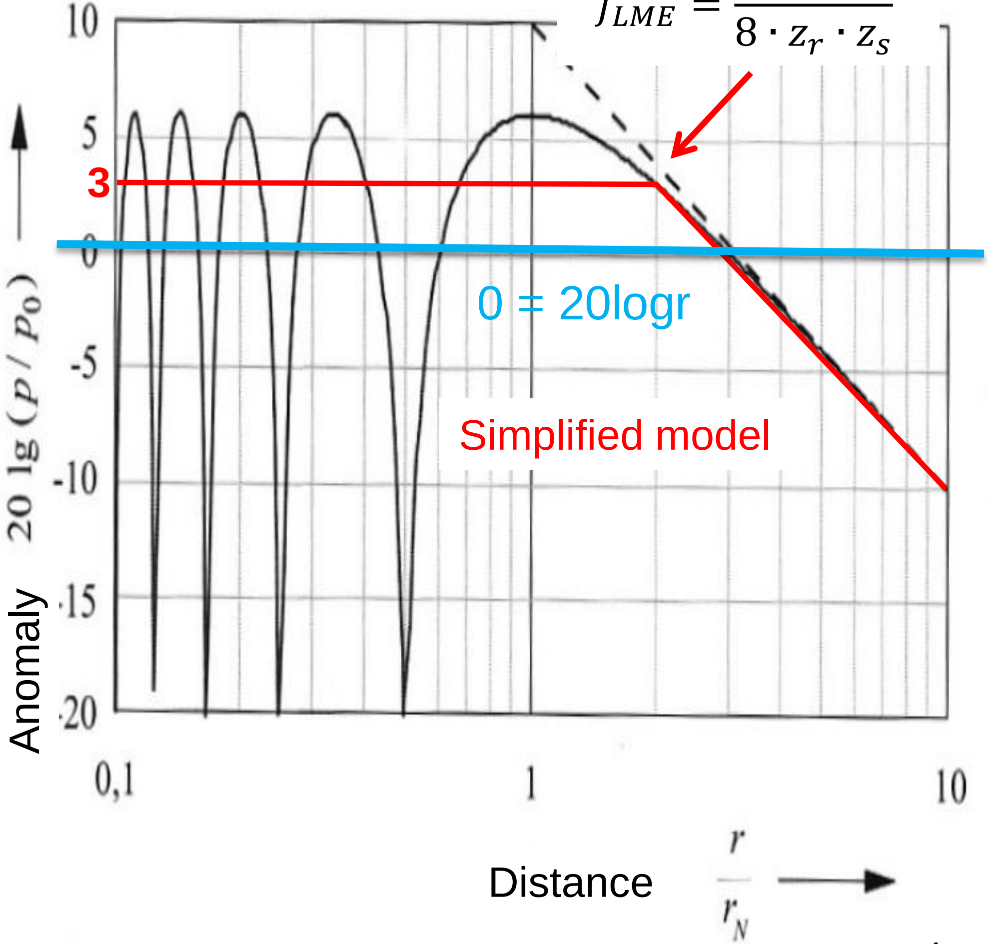
Meaningful underwater radiated noise measurements

Sound propagation at the surface



Lloyd Mirror Effect

$$f_{LME} = \frac{c \cdot r}{8 \cdot z_r \cdot z_s}$$



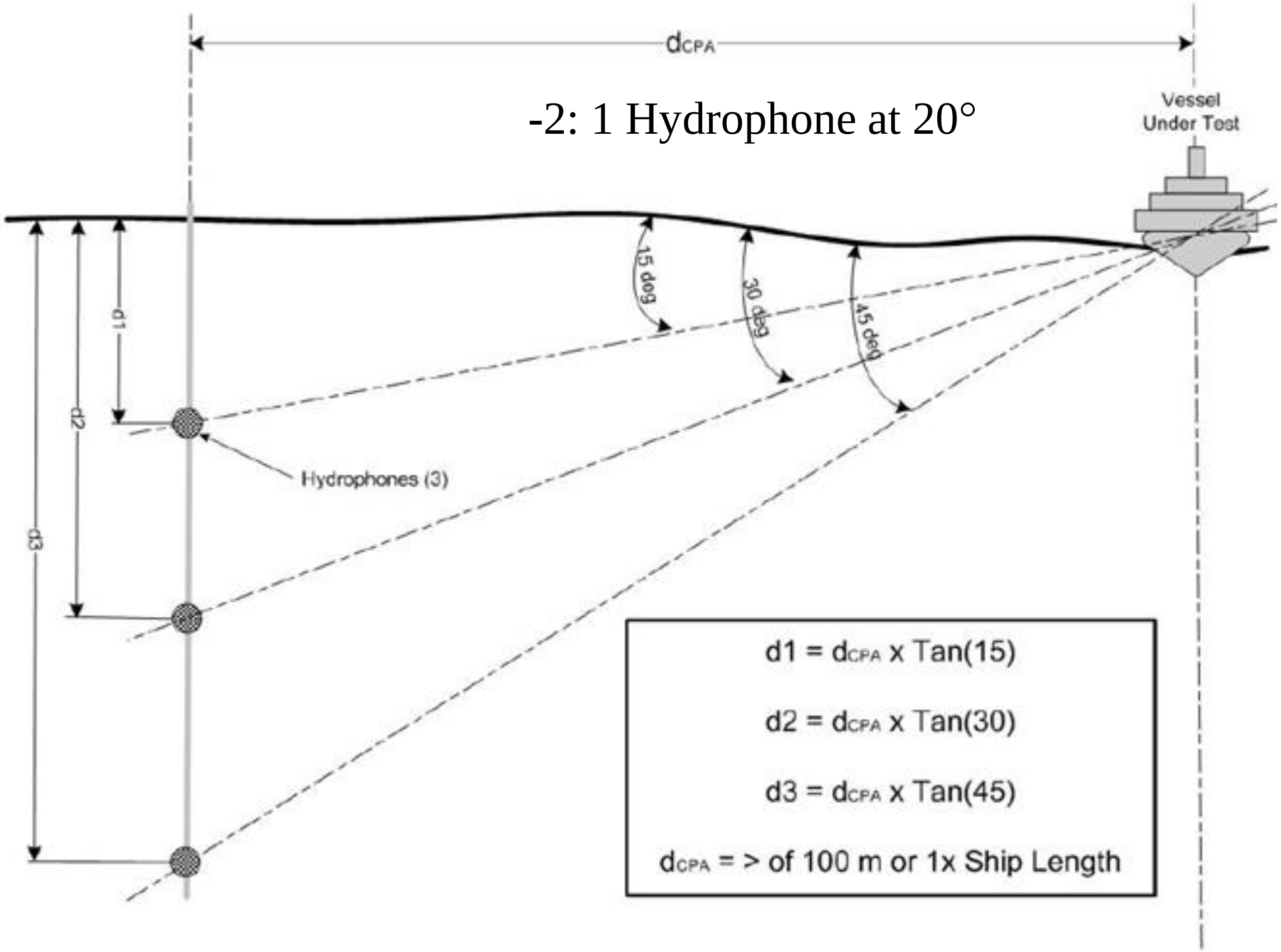
$f > f_{LME} \rightarrow SLM$ = SL_D -3

$f < f_{LME} \rightarrow SLM$ = SL_D +20•log($\frac{f_{LME}}{f}$) -3

SL_M	Monopole Source Level
SL_D	Dipole Source Level

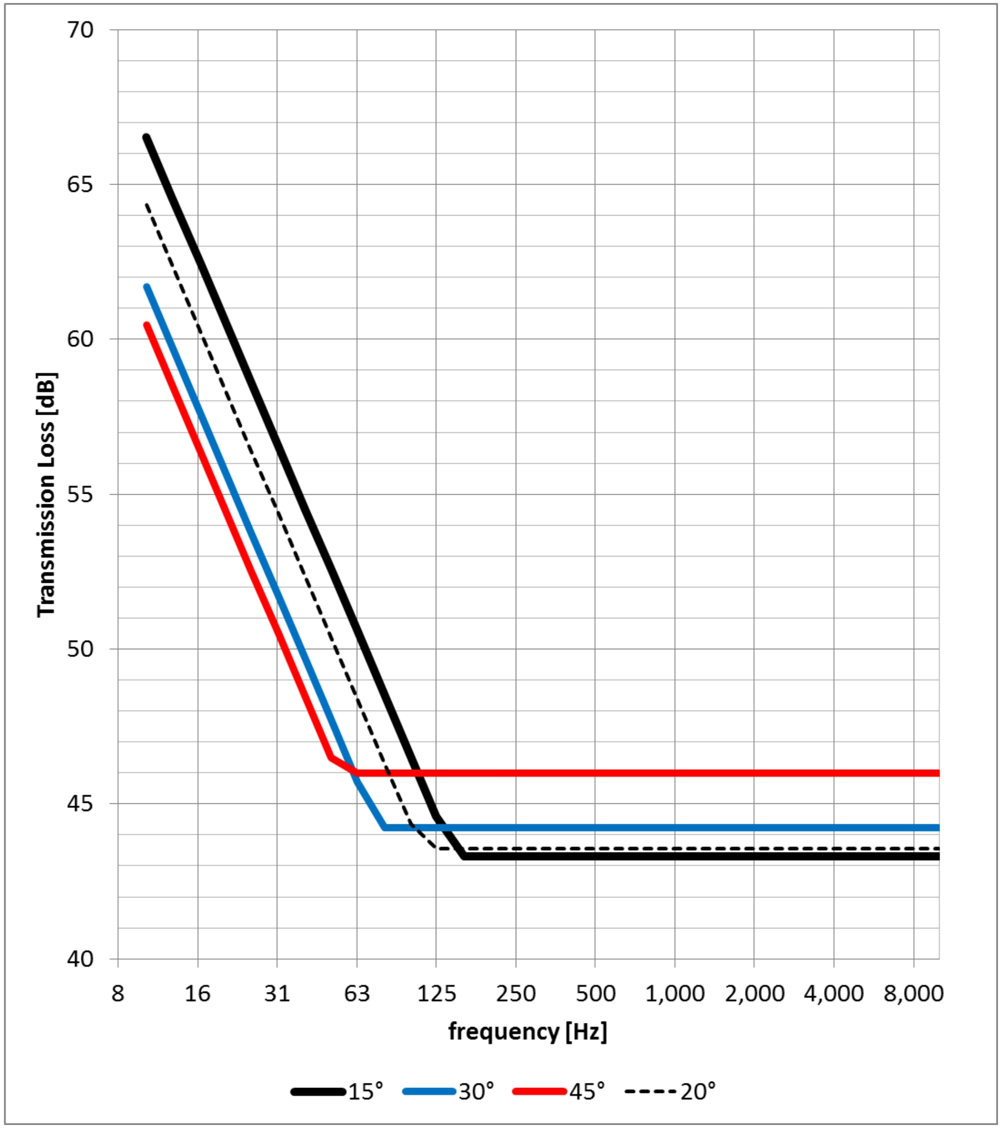
$$r_N = 4 \cdot z_s \cdot z_r / \lambda$$

Underwater Noise measurements according to ISO 17208-1



Very comprehensive measurement gear!

Actual TL according to ISO for 5 m source depth



Note:

ISO demands that each hydrophone reading is corrected with 20log (slant range) and then averaged.

This confuses the result below 150 Hz and makes it less suitable for propagation calculations

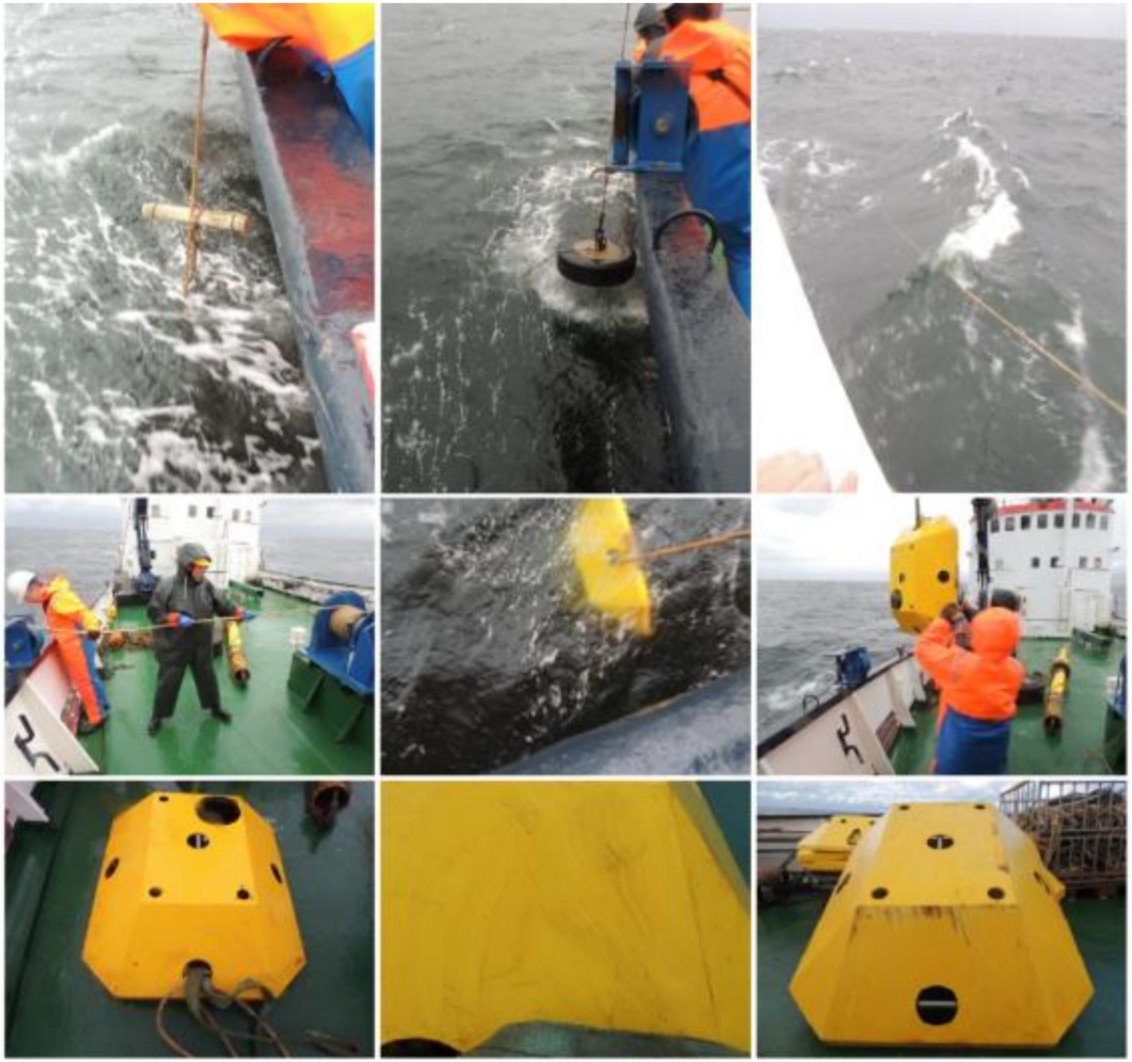
15° reading may be affected by strong variations in the sound speed profile

Instead: use just one reading or use one hydrophone at 20°, find or assume source depth, correct for monopole level yourself

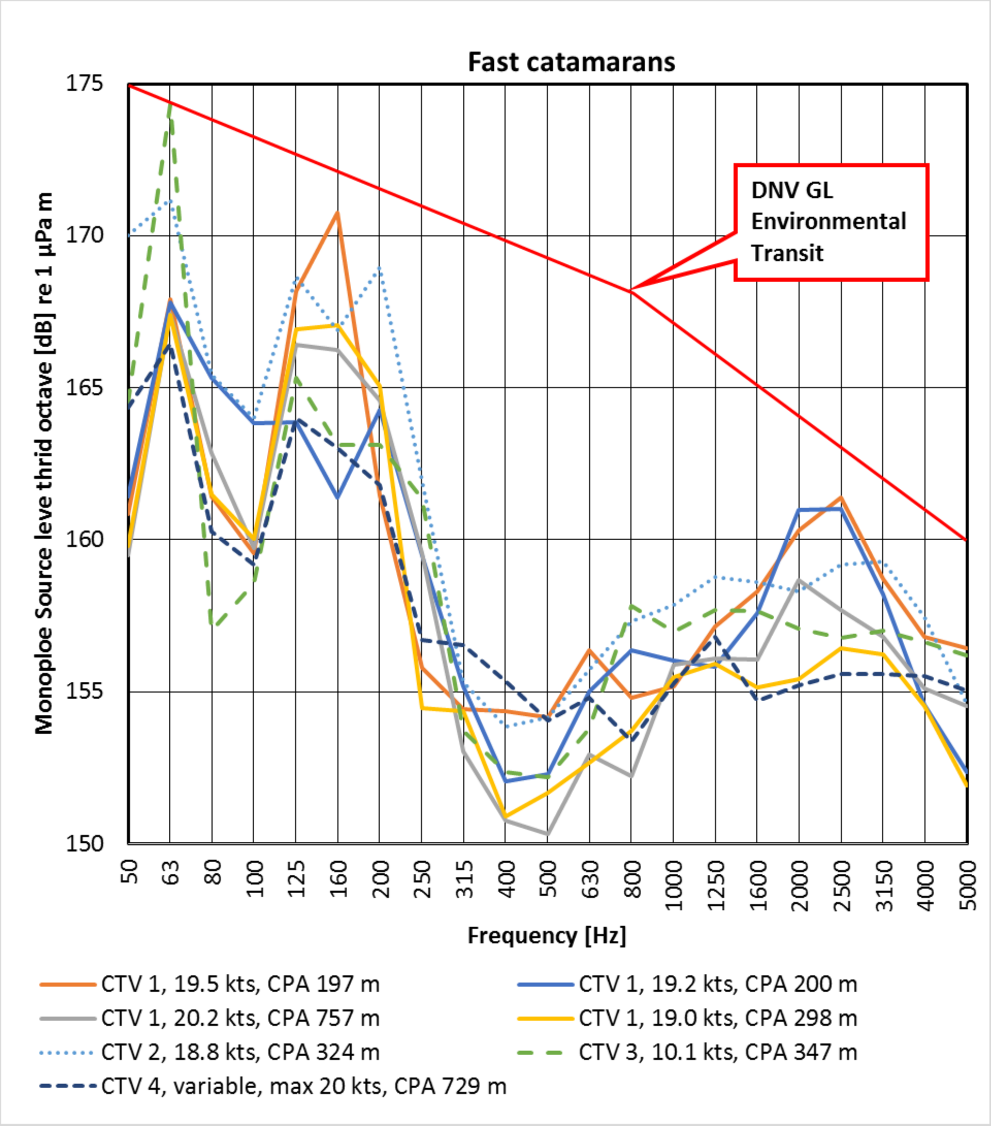
The ship in the environment

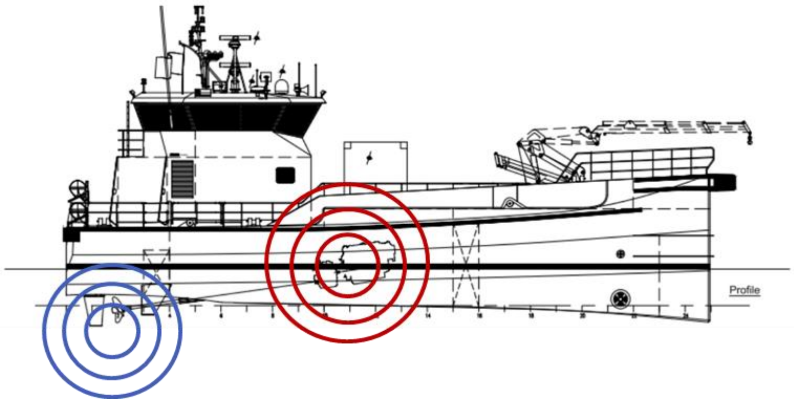
- Wind park maintenance -

Stationary recording system



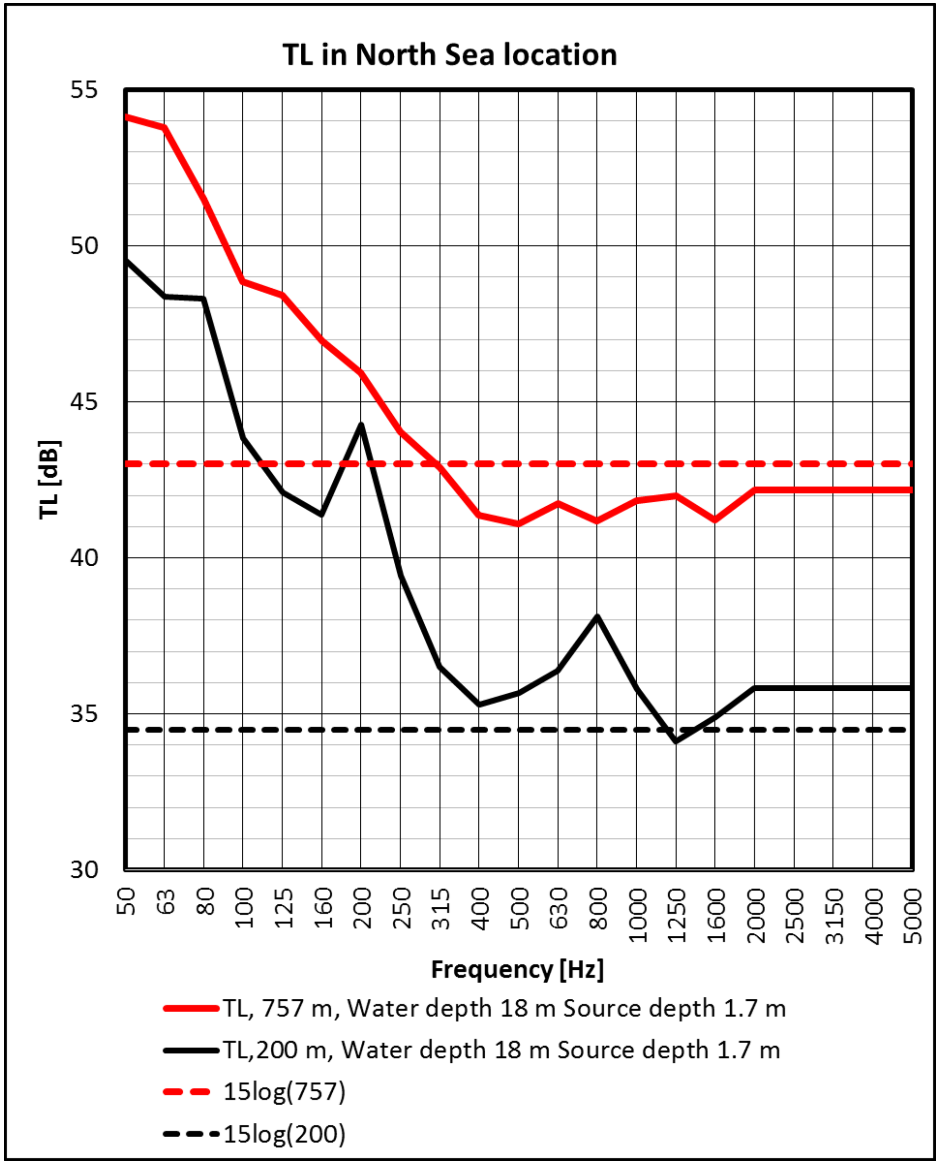
Source levels of ships underway in a wind park (shallow water 18 m)





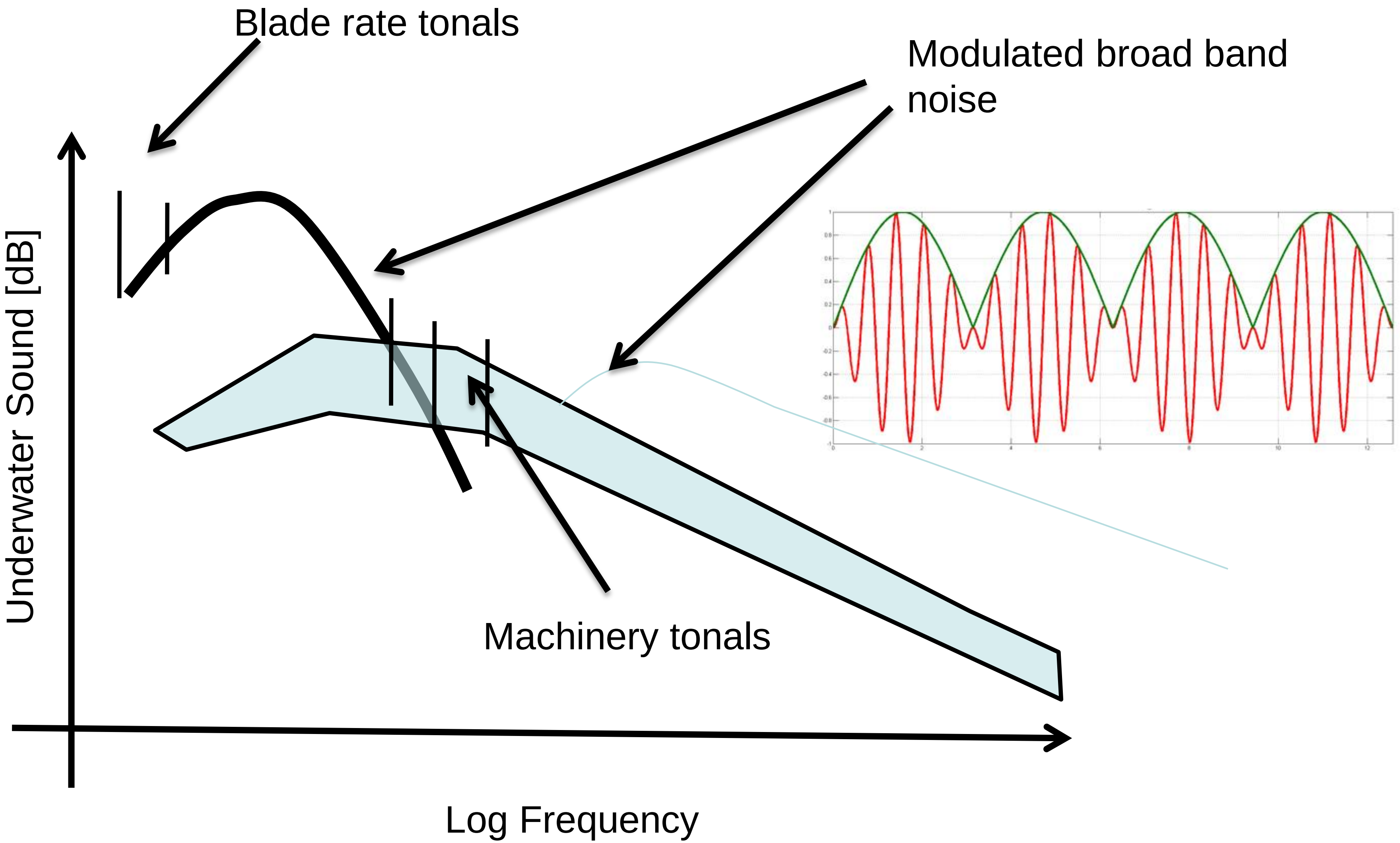
Monopole level!

Transmission loss in shallow water (18 m)

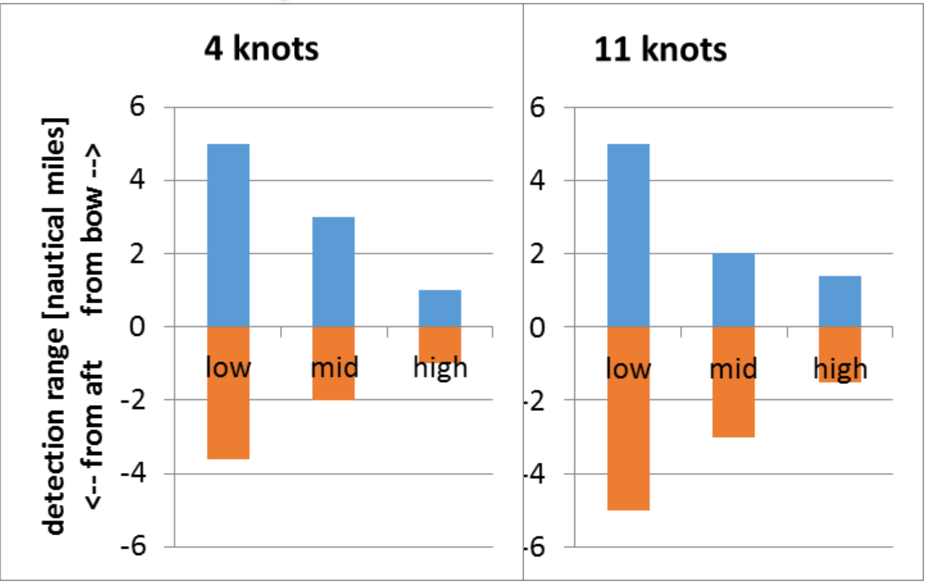


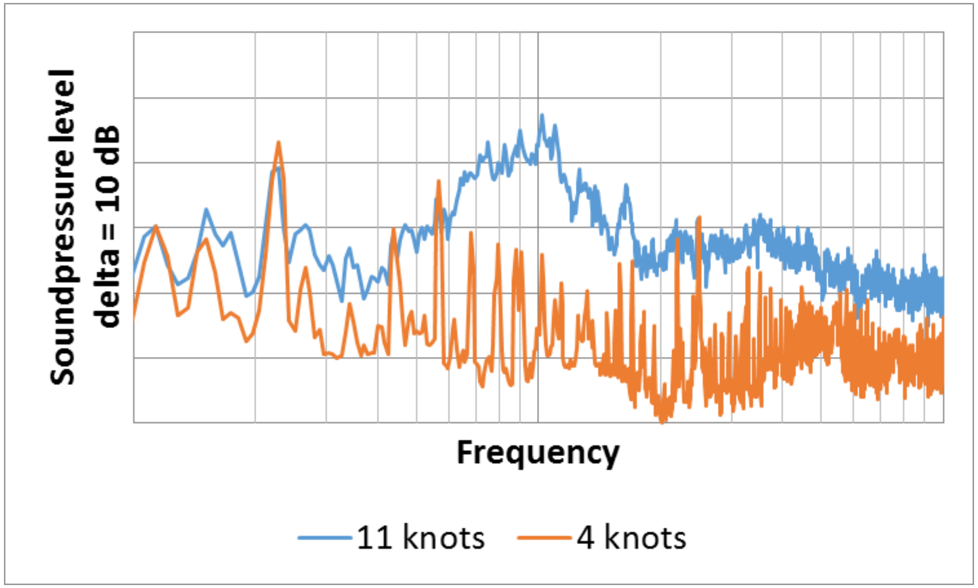
- TL calculated with parabolic equation approximation of the wave equation
- 15log(r) not bad for medium range distances at high range/depth ratios and for dipole levels

Difference between ship noise and natural noise



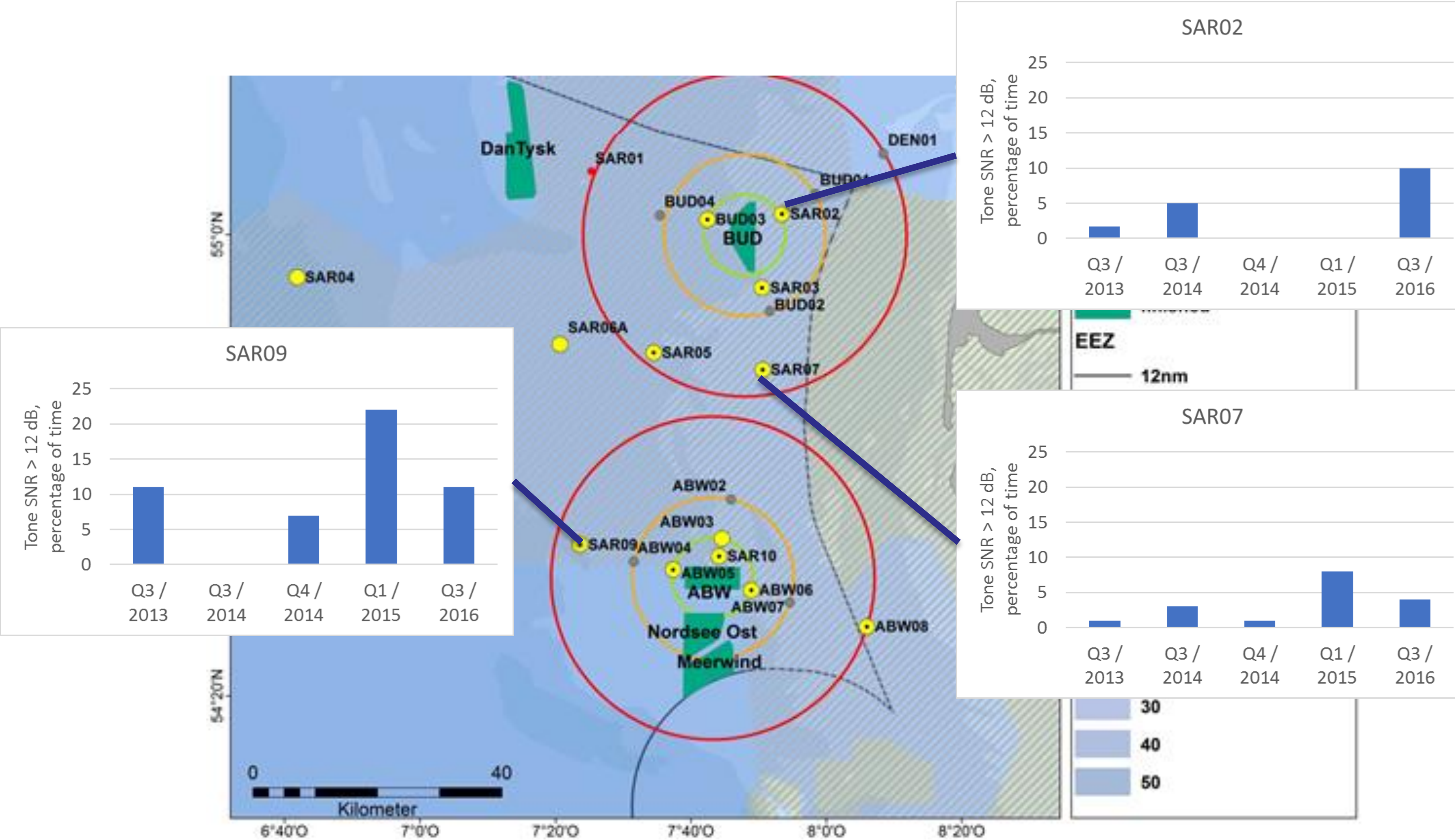
Detection by tones and amplitude modulation





- **Low frequencies** yield highest detection range
- Detection range highly determined by **content of tones**
- Detection of **broad band modulation** worked only ~ 1 nm

Results for ship detection



Indication that ship noise is more abundant after wind park installation than before

Conclusions and outlook

- Too little knowledge about acoustics at shipbuilders. Low cavitation propeller designs not a standard. Cause of low frequency broad band part of cavitation not known. Diesels and propeller only sources
  → disseminate simple design rules, do research on propeller cavitation noise beyond blade rate, investigate noise effects of wake equalization devices

- Precision measurement of underwater radiated noise according to ISO too complex
  → try to cultivate procedure based on single hydrophone usage

- Not yet clear picture of shipping noise contribution in our waters
  → improve and standardize ship detectors, scan existing data for ship presence, relate to location → get better view of shipping impact