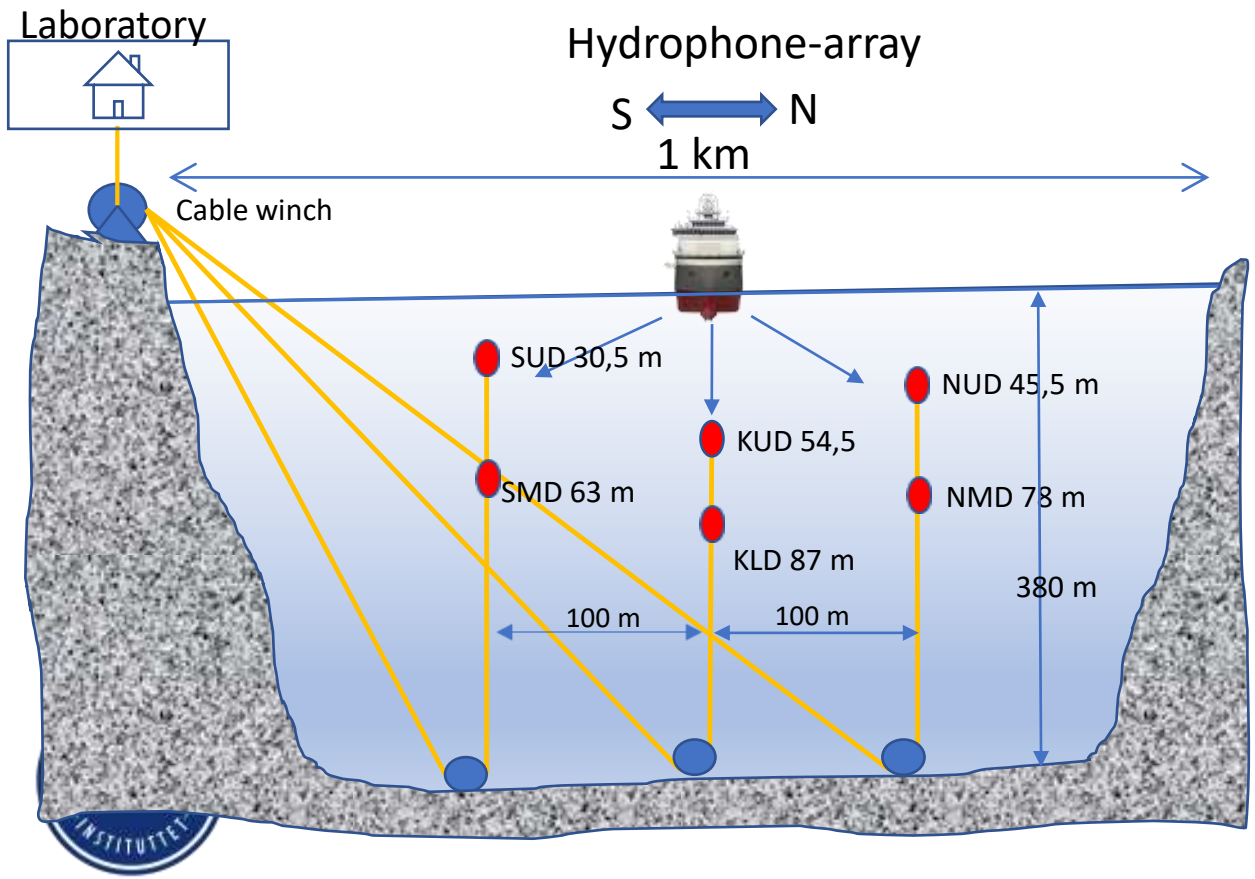
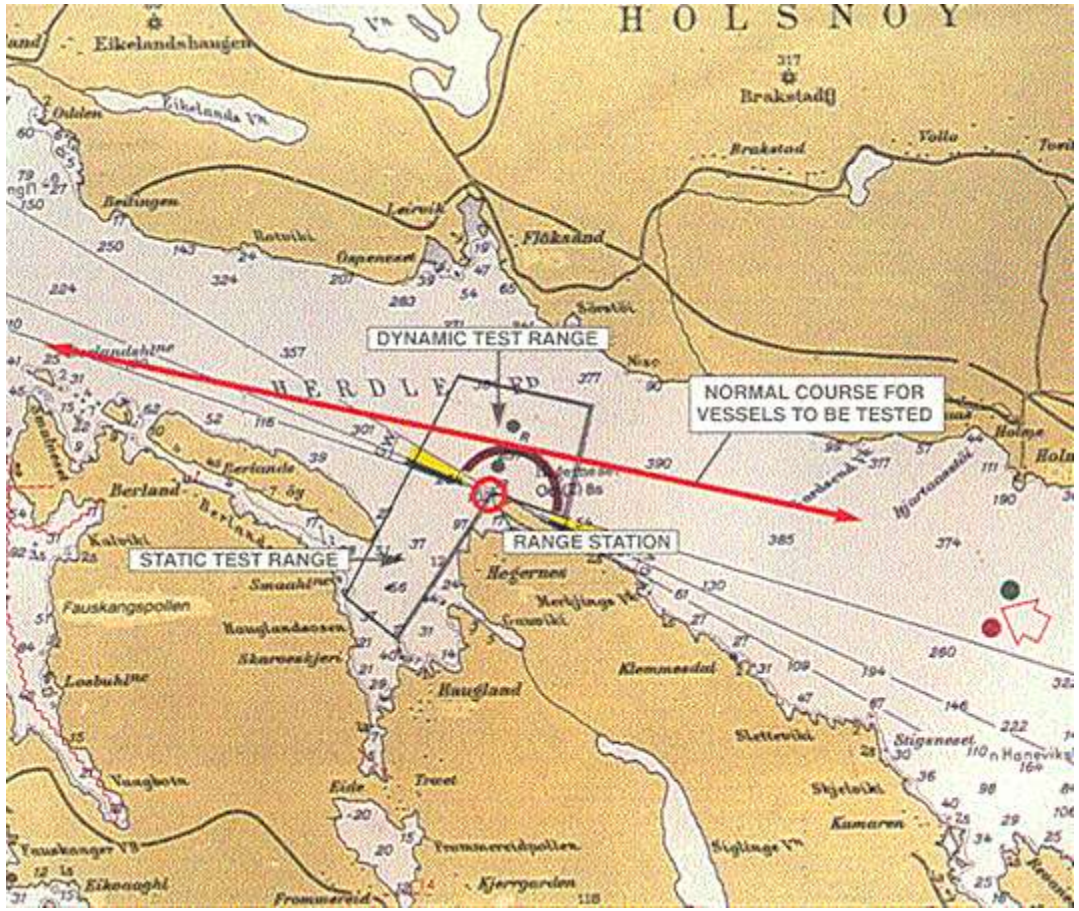
Noise-ranging of IMR research vessels

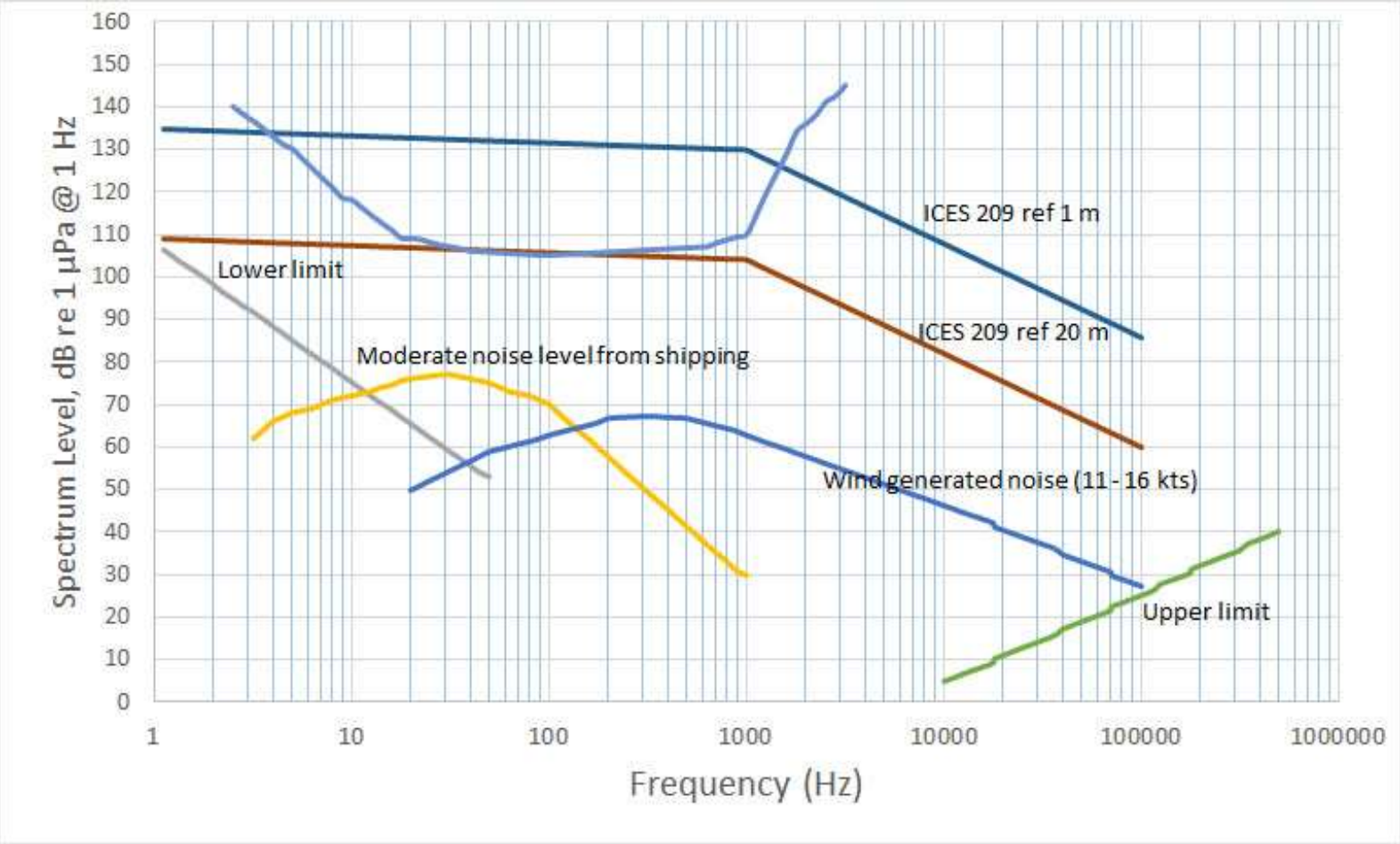
All RVs are noise-ranged in 2017 and 2018 at the acoustic range owned by the German, Dutch and Norwegian navies. The range is sited at Hegernes in Herdlefjord outside Bergen. Ther vessels runs East/West – courses, and the measurements are carried out when they pass the hydrophones. The hydrophones are arranged such that they can measure side aspects at both sides simultaneously, and in addition, the keel aspect.





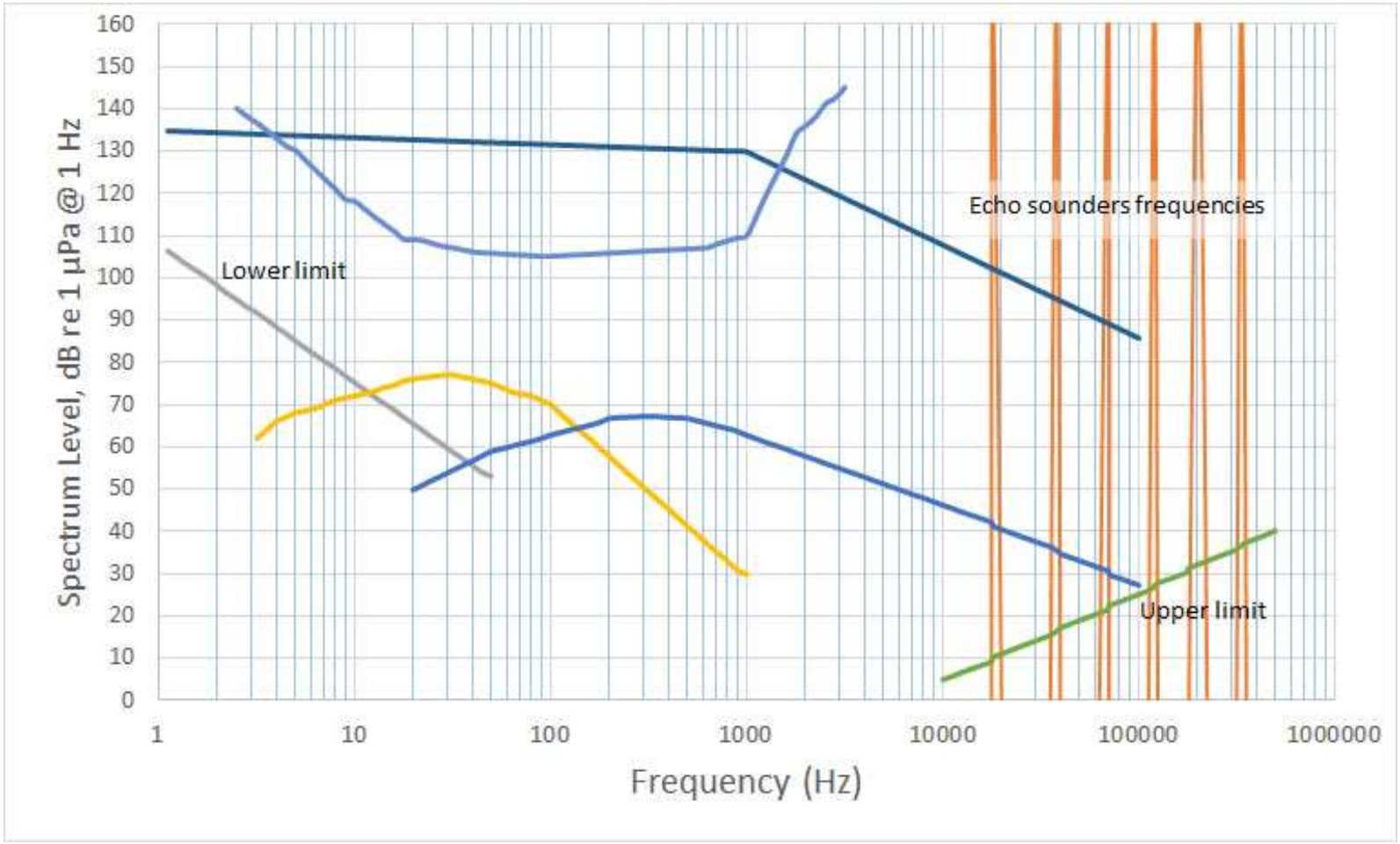
ICES CRR 209 published1995

ICES recommend an upper limit for underwater radiated noise from fisheries research vessels, and this shall be obtained at survey speed 11 kts, (ICES CRR 209,1995). The figure shows the levels referred to 1 m distance from the vessel and the levels after 20 m transmission loss. The idea is that the vessel shall approach a fish as close as 20 m before it shows avoidance behaviour.



Signal-to-noise ratio for hydro-acoustic instrumentation

It is also important that the noise level at higher frequencies, >1000 Hz, is as low as possible in order to have good signal-to-noise ratio for the shipborne sonar systems



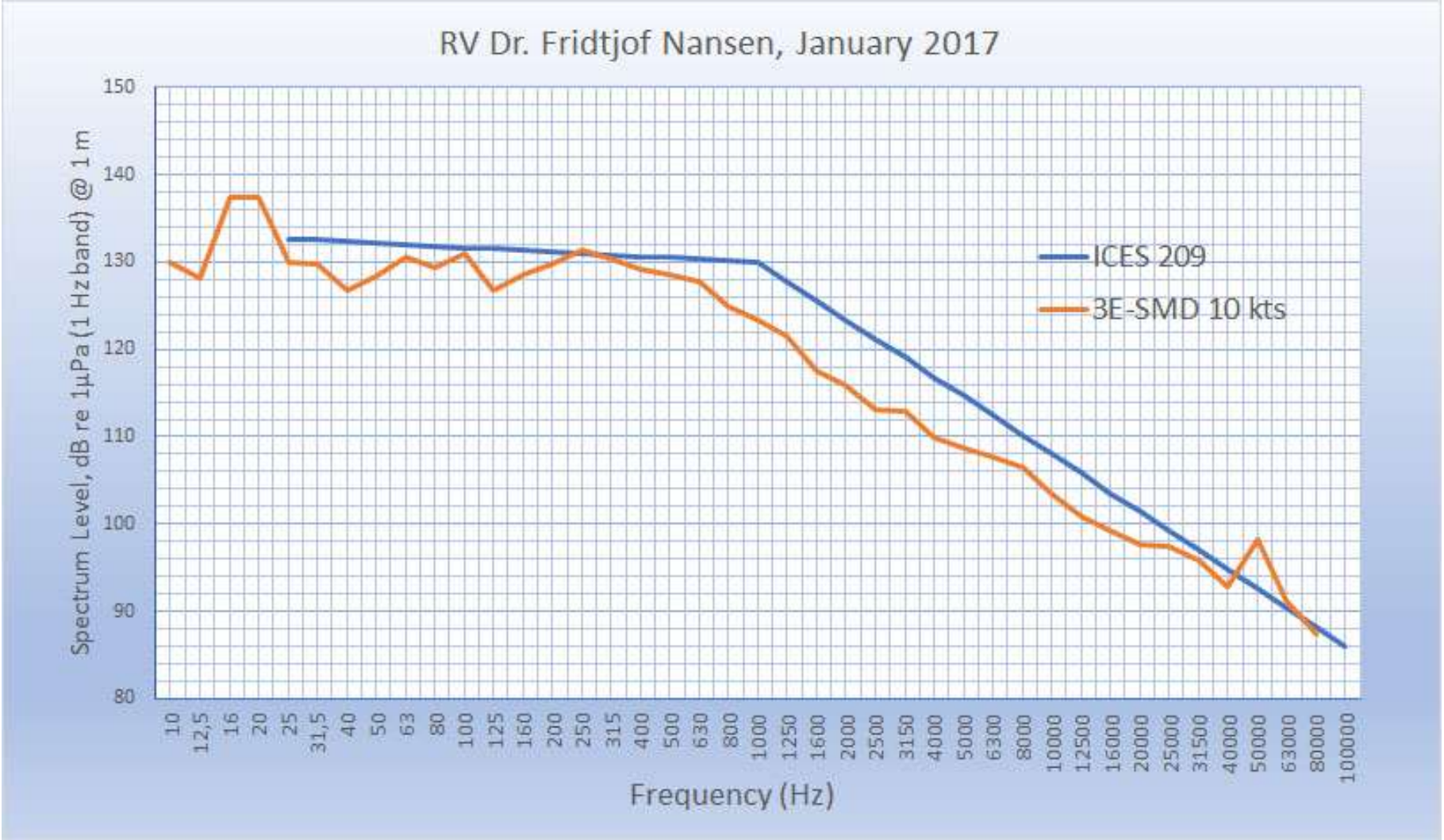
What is the impact if we allow higher noise level at the lower frequencies< 1000 Hz ?

- The figure show how the sound level at 200 Hz decreases as function of distance.
- It is assumed that a cod react with avoidance behaviour when the level exceed 105 dB (hearing threshold + 30 dB according to ICES 209.
- A vessel in compliance with ICES 209 will approach to 20 m before the fish responds.
- A vessel with level 5 dB above ICES 209 will scare the fish at 40 m distance.
- A vessel with level 10 dB above ICES 209 will scare the fish at 70m distance.
- A vessel with level 15 dB above ICES 209 will scare the fish at 130m distance.

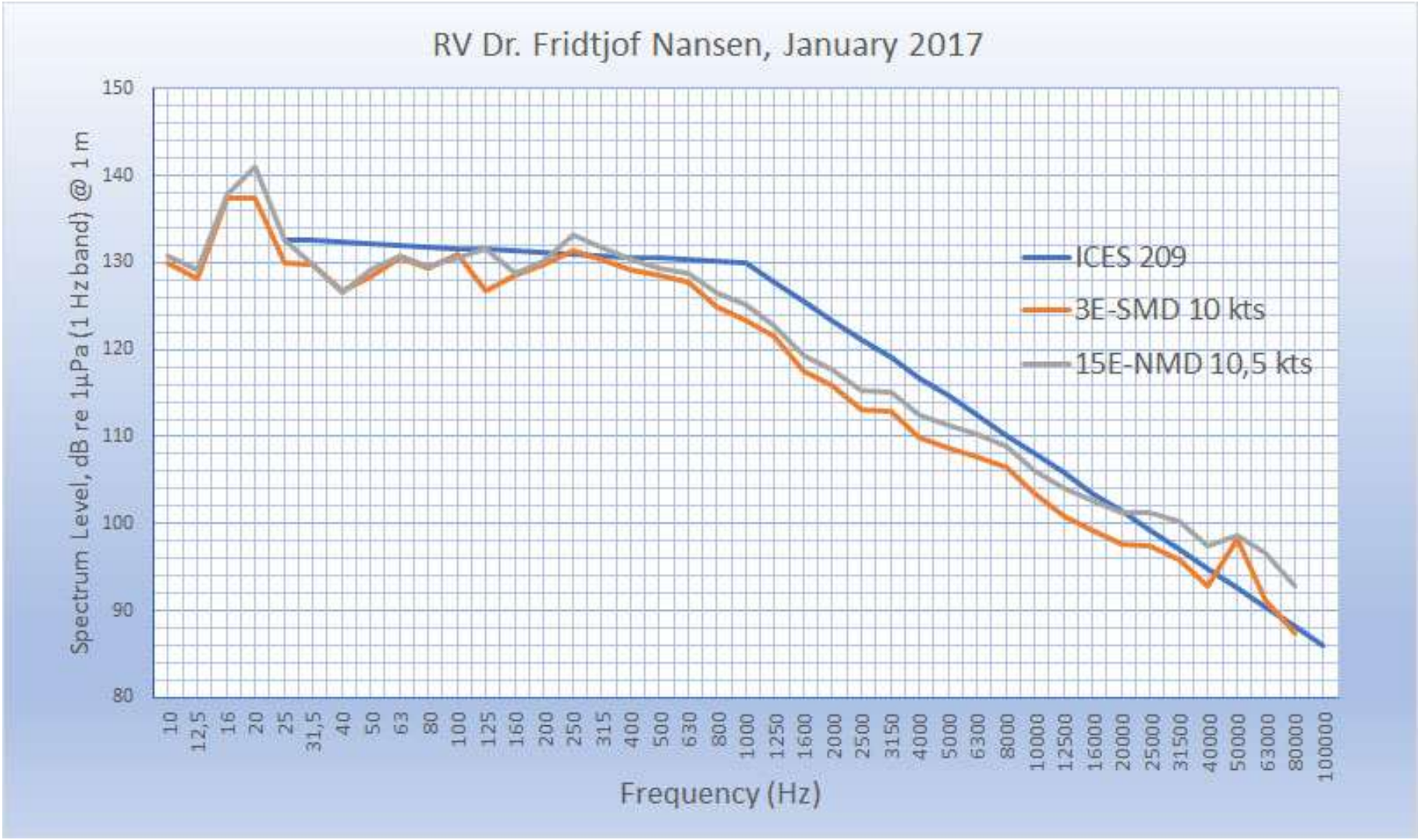
RV Dr. Fridtjof Nansen

- Built: 2016
- Length: 74,5 m, Beam: 17,4 m
- Machinery: diesel-electric
  (2 x 1710 kW / 1 x 1140 kW)
- Propulsion: 2 x 1500 kW AC motors
- 5 blades Fixed Pitch Propeller
- URN requirement: in compliance with ICES 209 at frequencies > 25 Hz

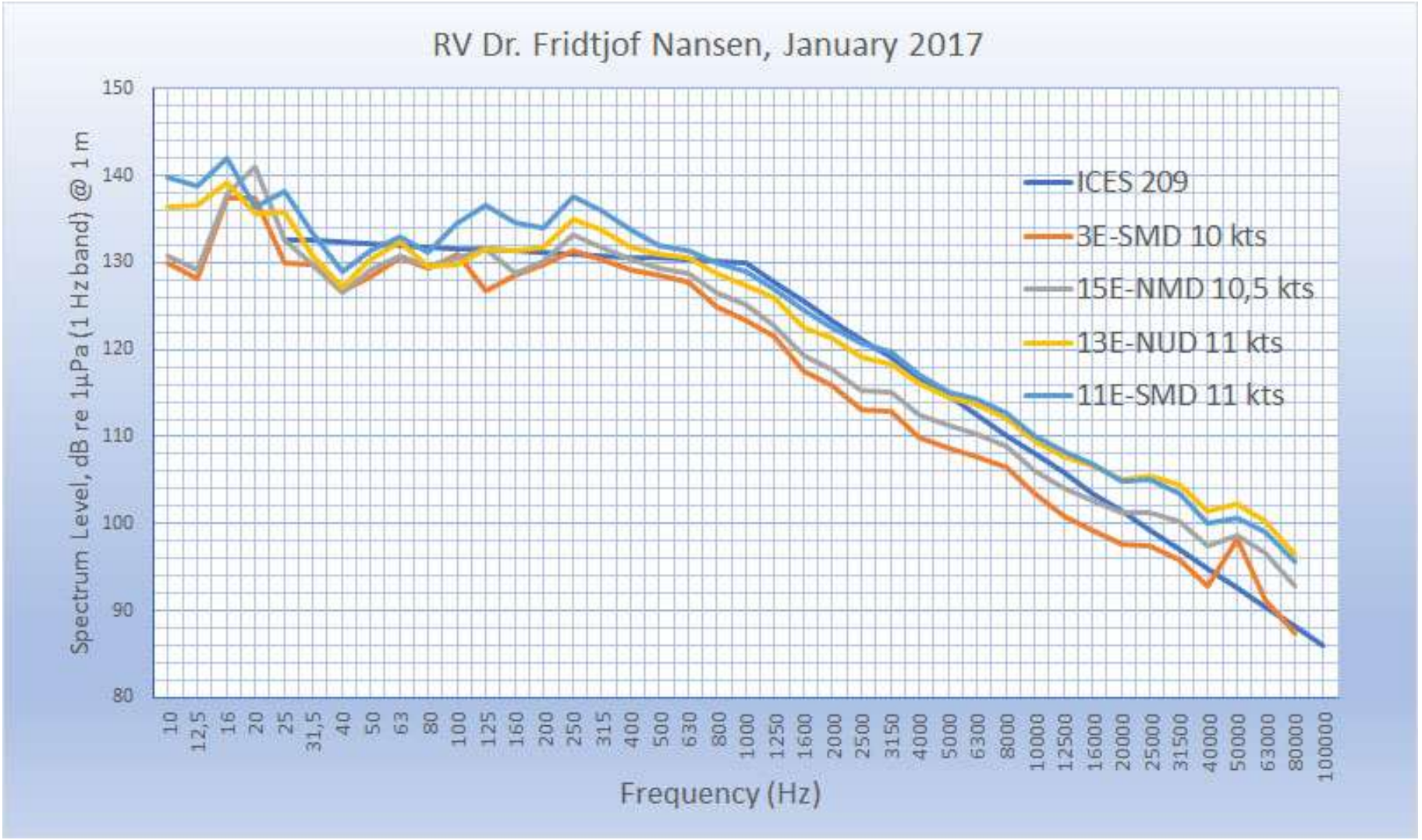
RV Dr. Fridtjof Nansen was noise ranged in January 2017. The curve shows the levels at10 kts.



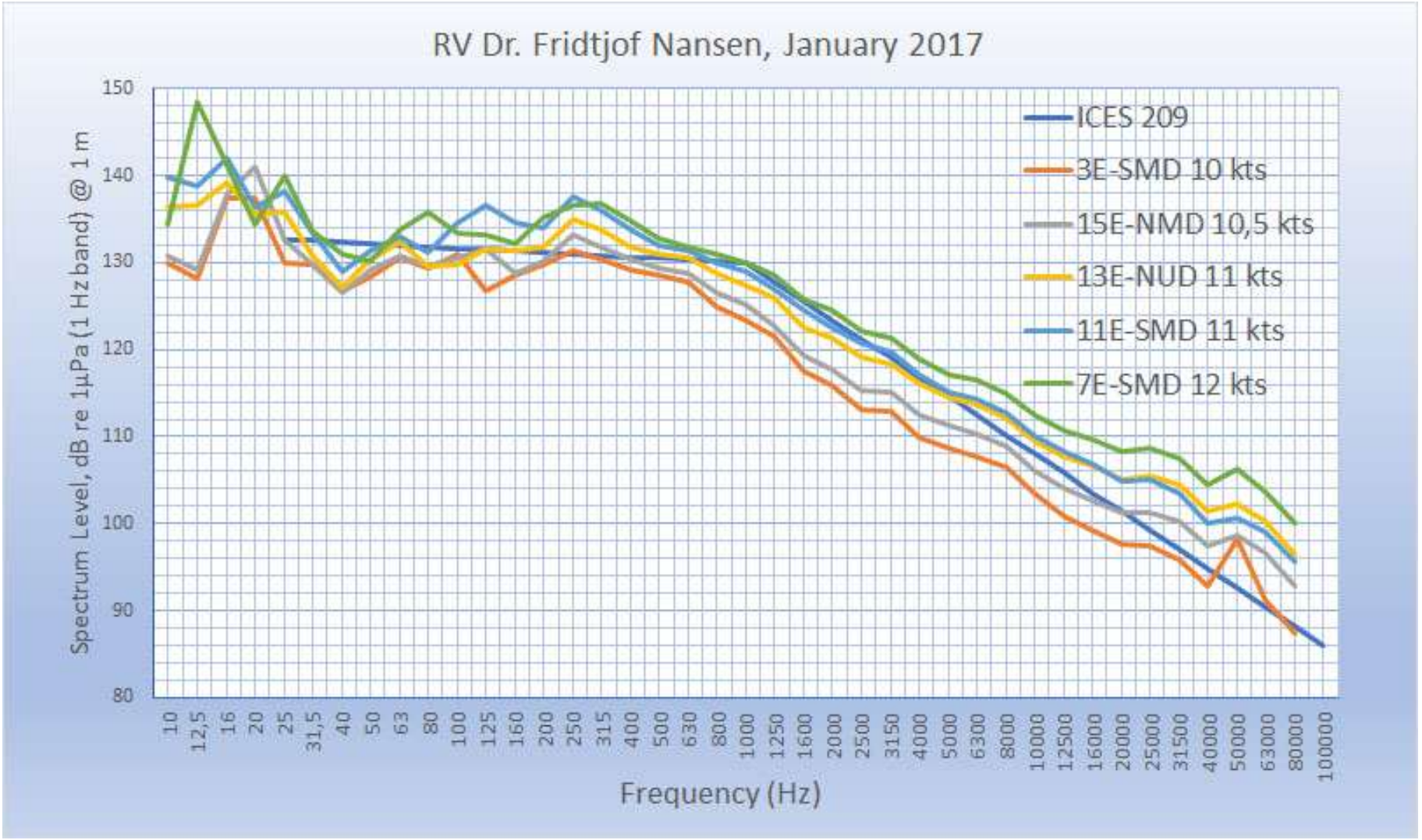
A minor increase in speed, to10,5 kts, gives significant increase of the levels



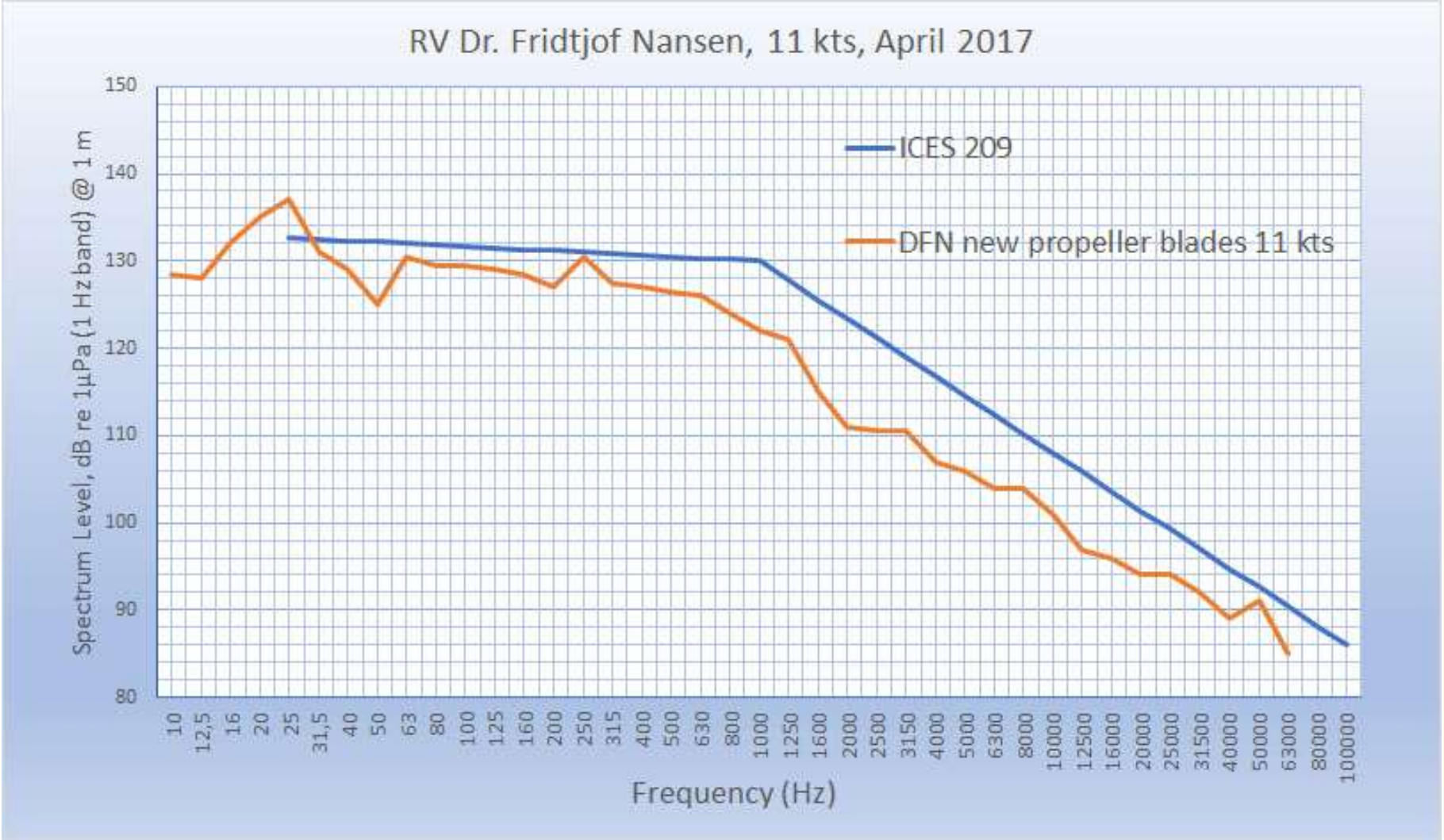
At 11 kts most of the curve exceeds the requirements. It is evident that the propeller cavitates heavily, and the noise increase quickly with increasing speed.



On basis of these measurements, the propeller was not accepted.
The shipyard was committed to order new blades with improved design.



The new propeller appeared to have the phenomena «singing propeller», but after grinding «anti-singing cuts» in the trailing edge of each blade, the propeller was accepted.

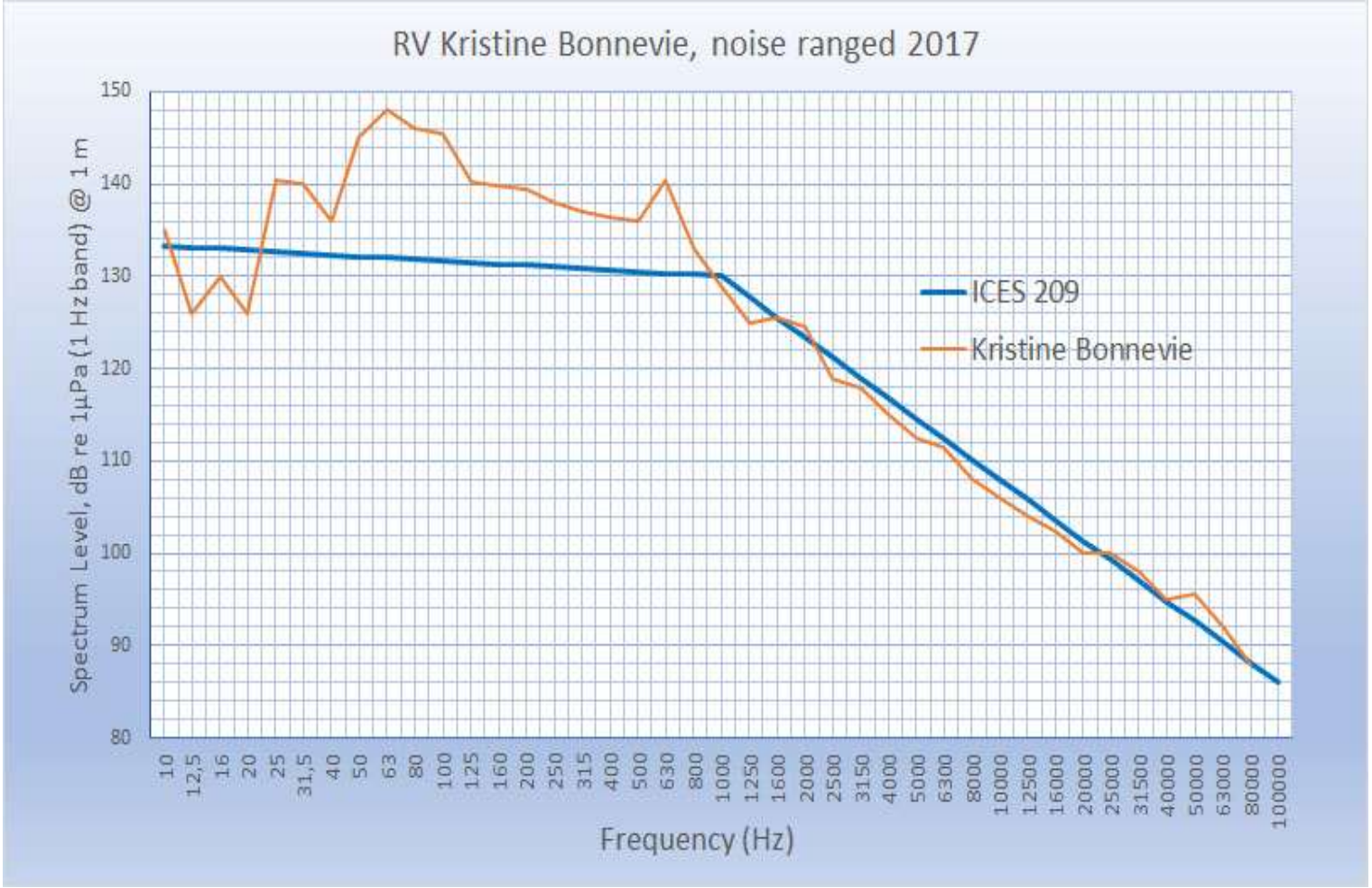


RV Kristine Bonnevie

- Built: 1993
- Length: 56,75 m, Beam: 12,5 m
- Machinery: 2717 Bhp
- Reduction gear
- Controllable Pitch Propeller

RV Kristine Bonnevie was noise ranged May 2017

- The levels are close to ICES 209 in the frequency range >1000 Hz. This means the propeller has relatively low cavitation.
- The higher levels in the lower frequency range <1000 Hz, are caused by vibrations in the engine, reduction gear and other machinery.



RV Kristine Bonnevie: theoretical «avoidance behaviour distance» for cod

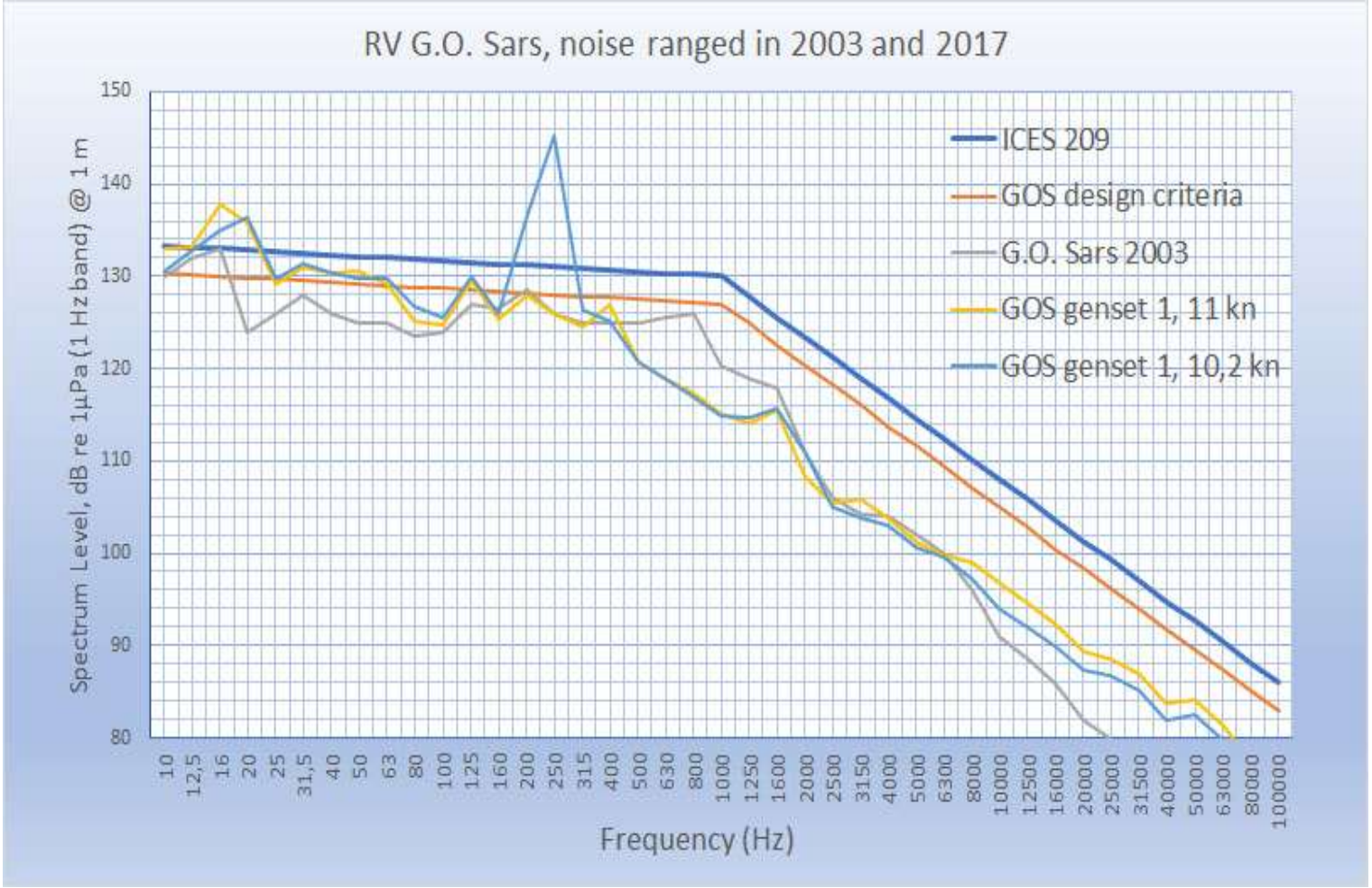
- It is assumed that cod has the lowest threshold of avoidance behaviour at 200 Hz.
- At 200 Hz, the level from RV Kristine Bonnevie is 8 dB higher than the level specified in ICES 209.
- This means that cod will react at a distance of 55 m (theoretically).

RV G.O. Sars

- Built: 2003
- Length: 77,5 m, Beam: 16 m
  (18 m in stern)
- Machinery: Diesel-electric
- 3 x 3250 kVA generatores
- Propulsion: 2 x 3000 kW DC-motors
- 5 blades Fixed Pitch Propeller
- Noise requirements: 3 dB below ICES 209

RV G.O. Sars was noise ranged December 2017.

- The noise requirement was 3 dB lower than ICES 209.
- Measurements 15 years later shows a slightly increase at the lowest frequencies.
- This may be caused by changed characteristics of the shock absorbers on the engines.
- In the speed range 9,5 – 10,5 kts the phenomena «singing propeller» was observed. This has not been observed in previous measurements.
- The cause will be investigated, and steps to rectify the damage will be taken.

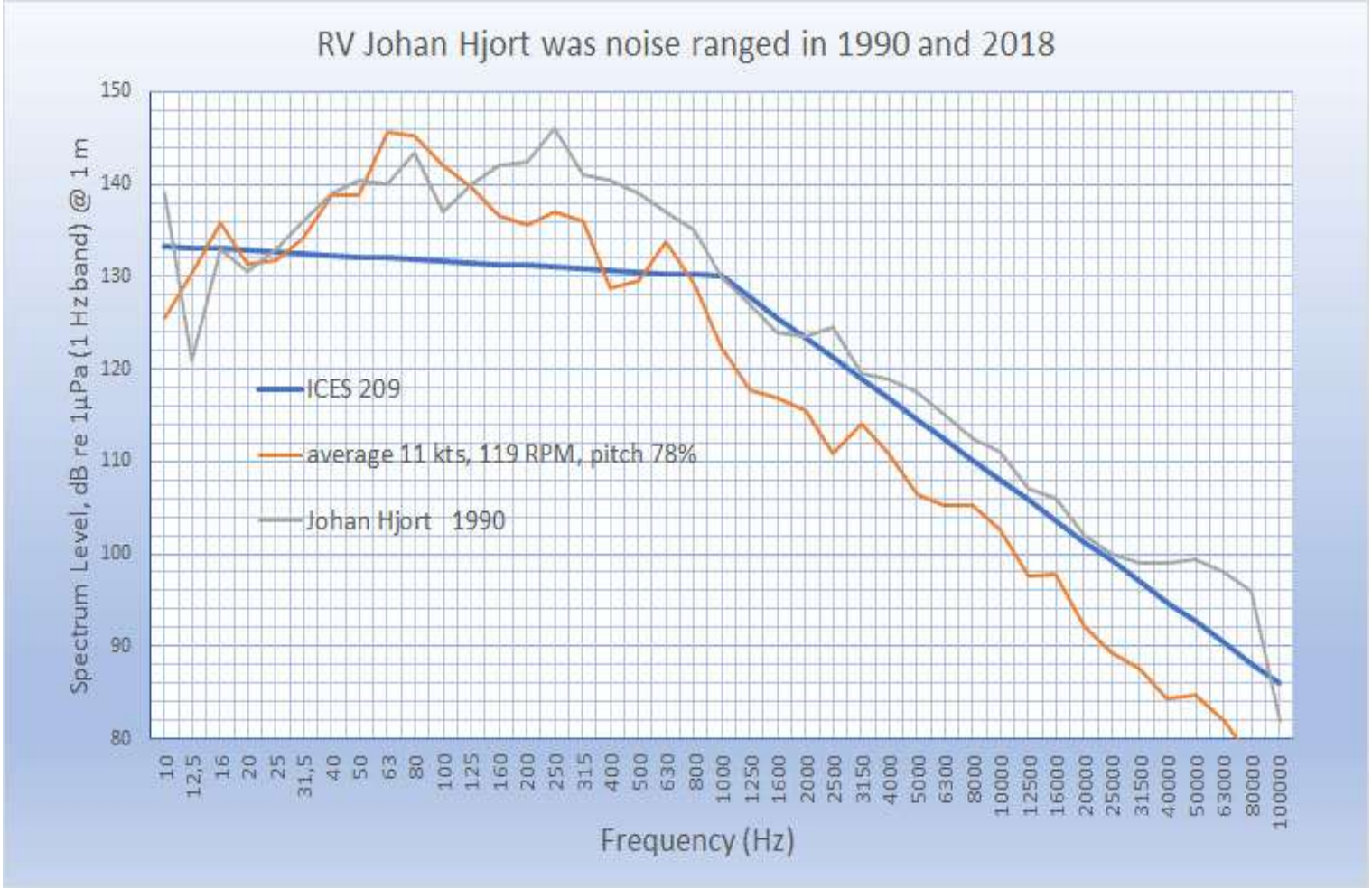


RV Johan Hjort

- Built:1990, Upgraded: 2017
- Length: 64,4 m, Beam: 13 m
- Machinery: diesel 1900 kW
- Shaft generator 800 kW, can also be utilized as propulsion motor
- Reduction gear
- Switchable between diesel propulsion and diesel-electric propulsion.
- CPP with nozzle

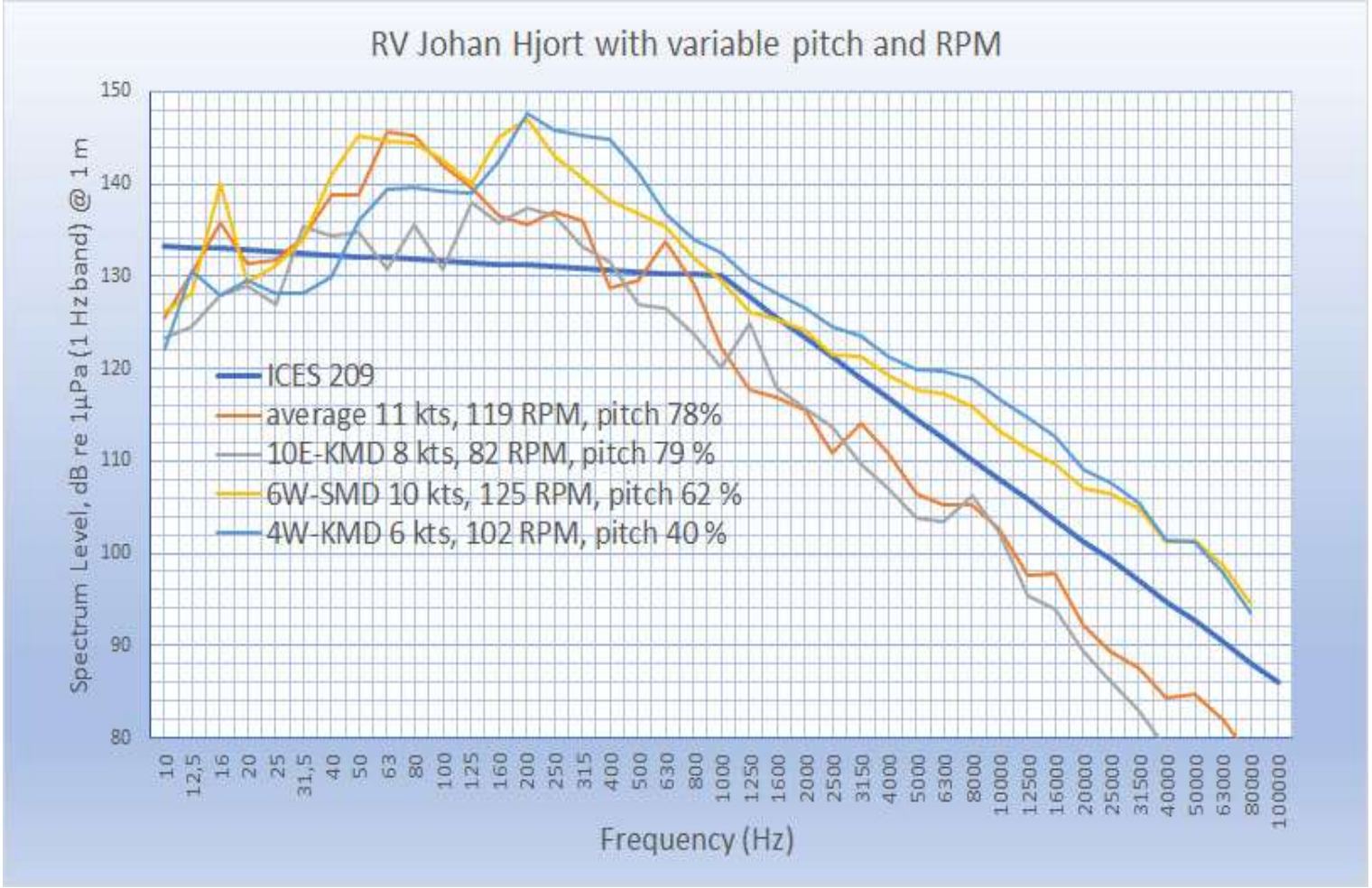
RVJohan Hjort, upgraded in 2017

- RVJohan Hjort was upgraded in 2017 with new «hybrid» machinery and propulsion system, including new propeller.
- The figure shows the original levels from 1990 compared to the levels measured in 2018.
- With optimal setting of pitch and RPM, the new propeller is considerably better than the original.



Effect of controllable pitch propeller

- This figure shows some of the problems with controllable pitch propeller.
- When the speed is reduced from 11 kts to 8 kts by reducing RPM and maintaining the pitch, there is a minor difference in the levels at the high frequencies (but they increase at the lower frequencies).
- When the speed is reduced by reducing the RPM, it is obviuous that the propeller is cavitating.

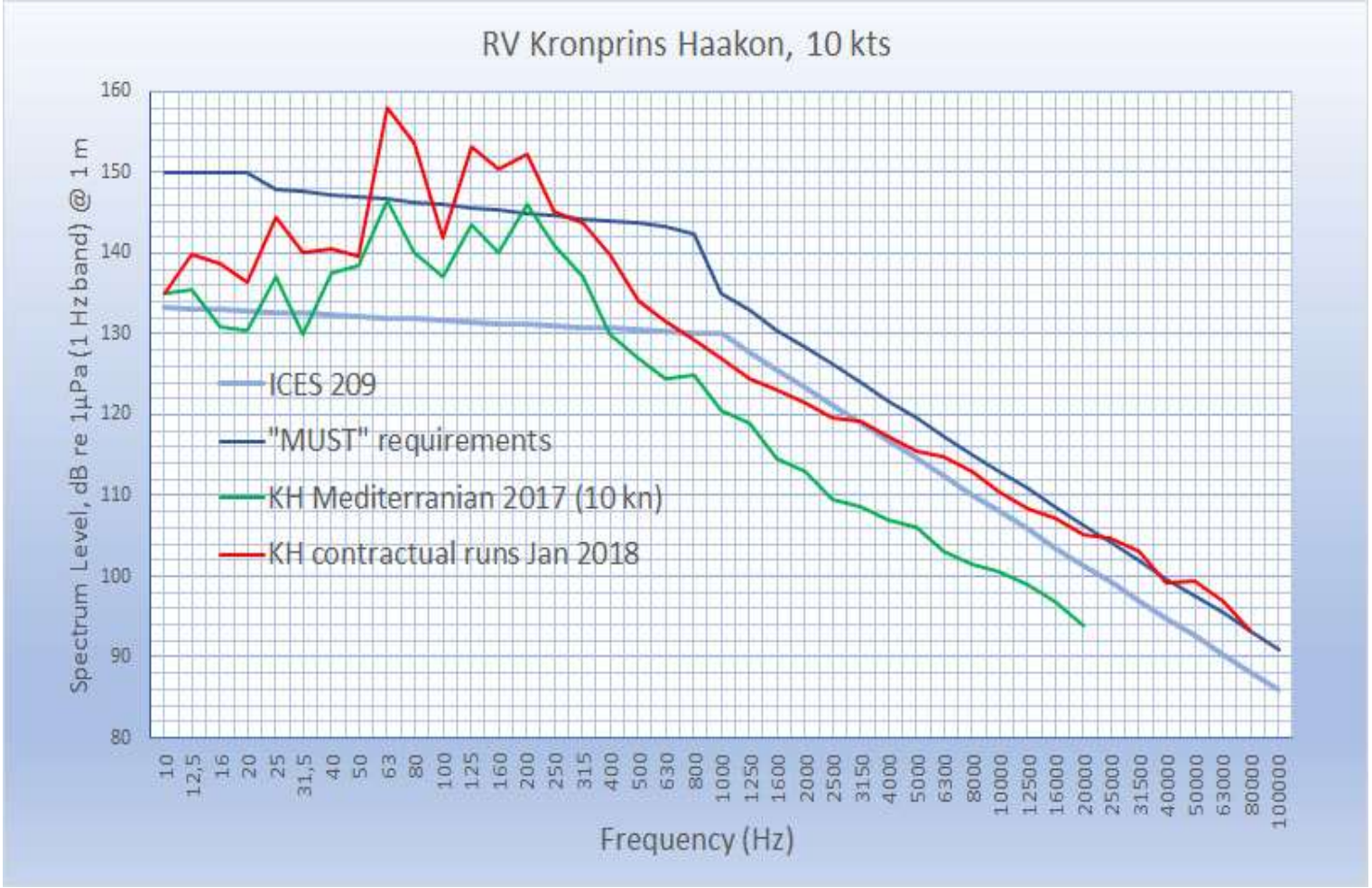


RV Kronprins Haakon

- Built: 2018
- Length: 100 m, Beam: 21 m
- Ice Class: Polar Class 3
- Machinery: Diesel-electric
- 2 x 5 MW and 2 x 3,5 MW diesel-generators
- Propulsion: 2 x azimuth thrusters each 5,5 MW
- 2 x 5-bladed propellers with fixed pitch and nozzles.

RV Kronprins Haakon was noise-ranged in January 2018

- Due to its ice-going properties and the mechanical power transmission of the azimuth thruster, it is not possible to meet the recommendation in ICES 209.
- A special requirement was made for the max underwater radiated noise which is significantly above ICES 209. In addition, the requirement for speed for this noise requirement was set to 10 kts.
- The vessel was first measured by DNV in the Mediterranean with a provisional measurement scheme and the figure shows that the levels mostly is well below the requirement.
- In accordance with the contract, the vessel was to be measured at a permanent measuring station, and this was carried out at Hegernes in January 2018. The results from this are considerably higher.
- The differences can partly be explained by different measurement methods and different factors used to compensate for the transmission loss between measurement the hydrophone and the vessel.



The noise range at Hegernes use hydrophone array configuration similar to most standards for measurement of underwater sound from ships :

ANSI-ASA S12.64, ISO PAS 17208 og BV Rule Note nr. 614. The hydrophones are suspended in the water column. These standards also use the same factor for compensation of transmission loss.

20 log r (r=distance between hydrophone ans vessel)

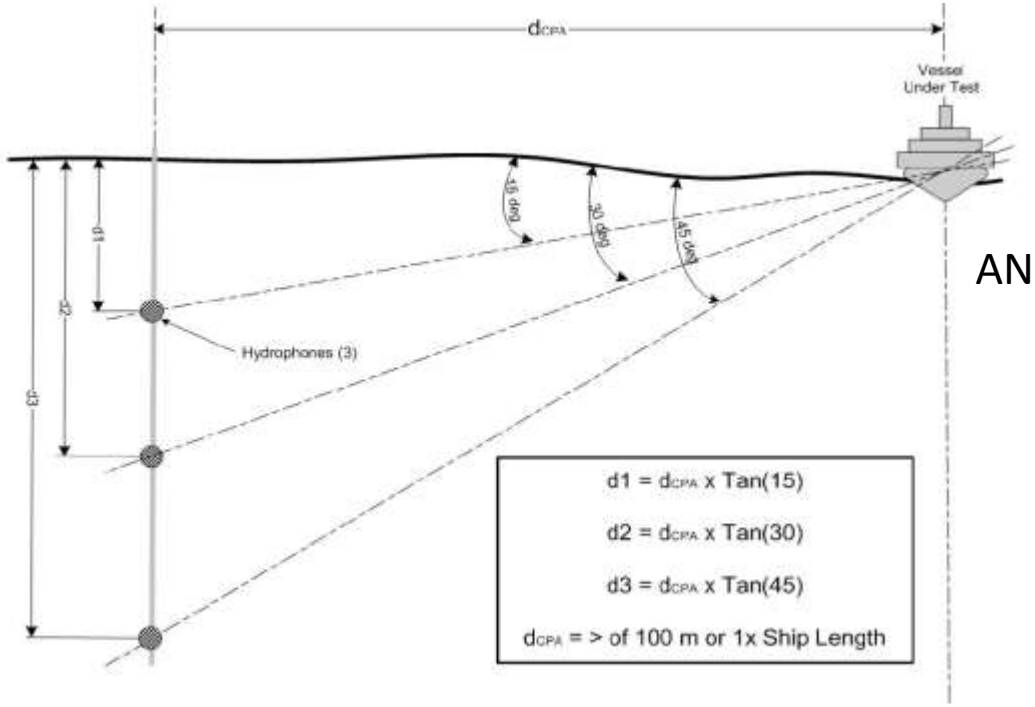
DNV places one hydrophone in a cage on the seabed and compensate for transmission loss with:

18 log r

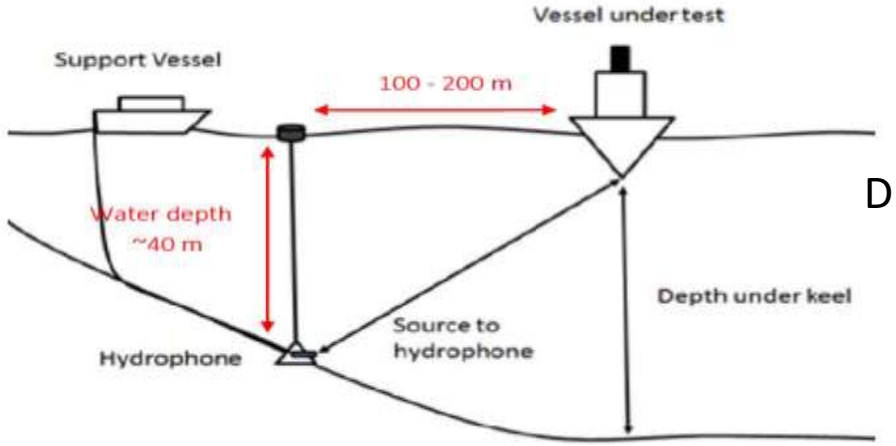
At 100 m distance the difference in compensation is:

20 log (100) – 18 log (100) = 4 (dB)

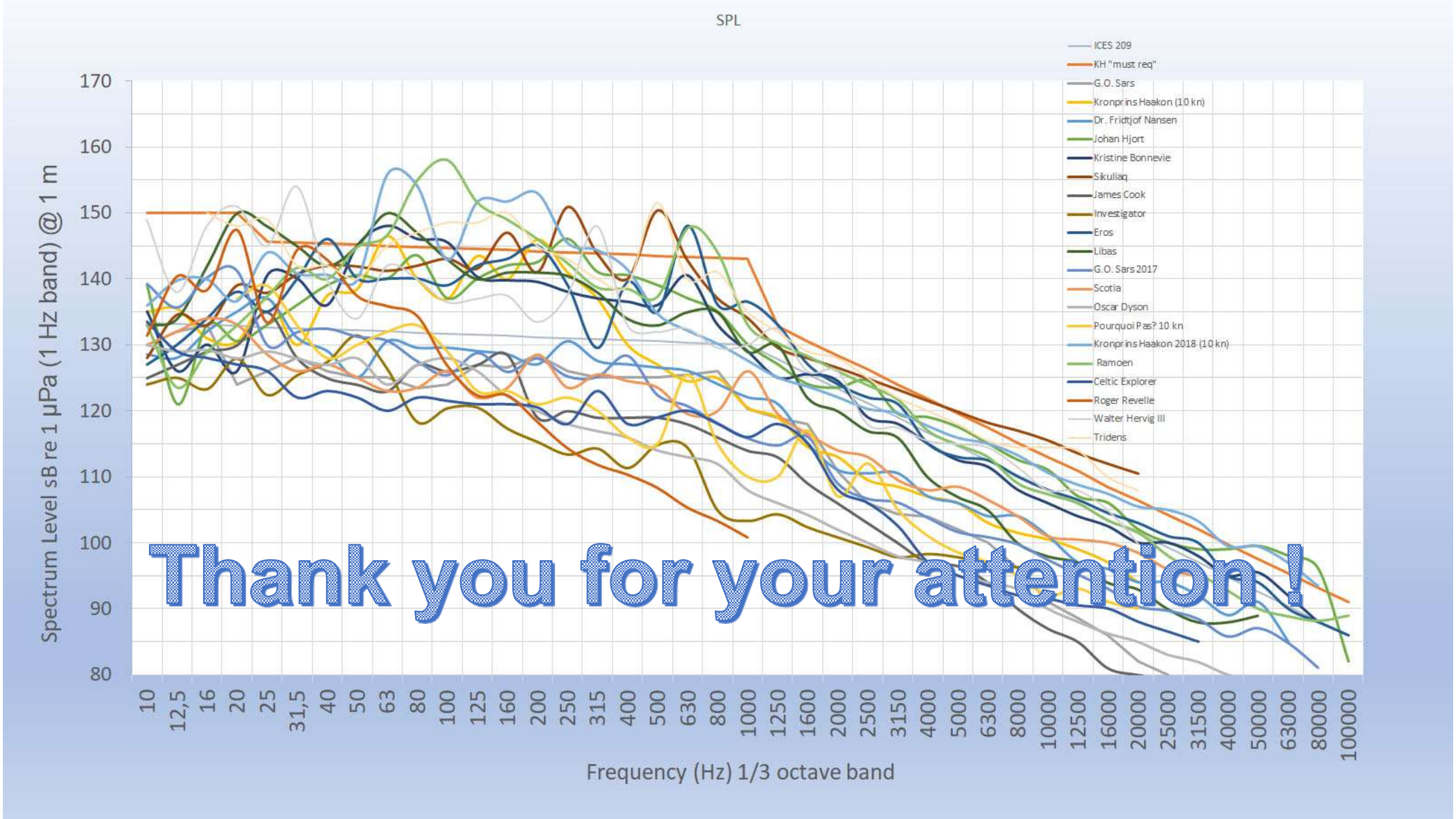
This means DNV will calculate a level **4 dB lower** at a distance of 100 m under the same conditions.



ANSI-ASA

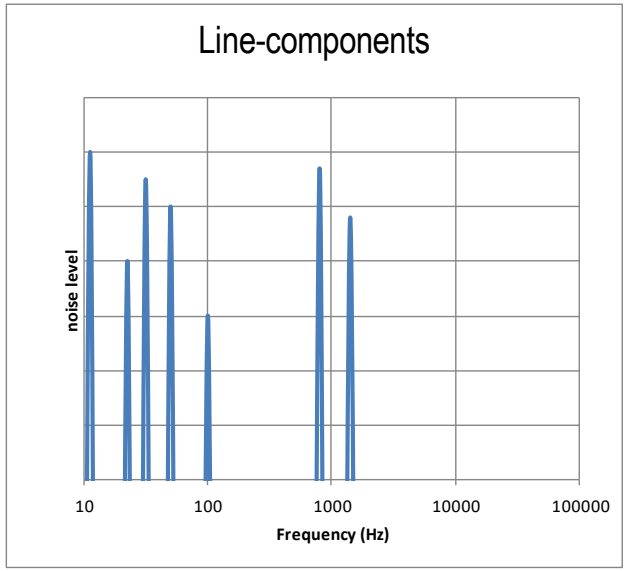


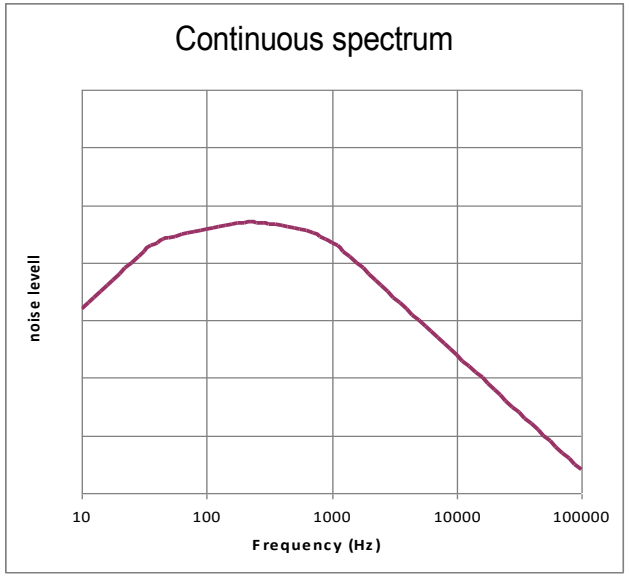
DNV

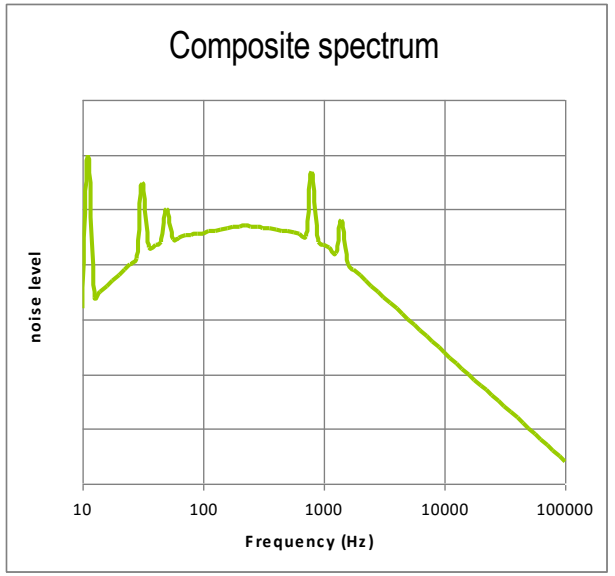

SPL
ICES 209
KH "must req"
G.O. Sars
Kronprins Haakon (10 kn)
Dr. Fridtjof Nansen
Johan Hjort
Kristine Bonnevie
Sikuliaq
James Cook
Investigator
Eros
Libas
G.O. Sars 2017
Scotia
Oscar Dyson
Pourquoi Pas? 10 kn
Kronprins Haakon 2018 (10 kn)
Ramoen
Celtic Explorer
Roger Revelle
Walter Hervig III
Tridens
Spectrum Level sB re 1 µPa (1 Hz band) @ 1 m
170
160
150
140
130
120
110
100
90
80
10
12,5
16
20
25
31,5
40
50
63
80
100
125
160
200
250
315
400
500
630
800
1000
1250
1600
2000
2500
3150
4000
5000
6300
8000
10000
12500
16000
20000
25000
31500
40000
50000
63000
80000
100000
Frequency (Hz) 1/3 octave band
Thank you for your attention !

More background slides!

Underwater radiated noise from vessels is a composition of line-components and wide band (continuous) spectrum.







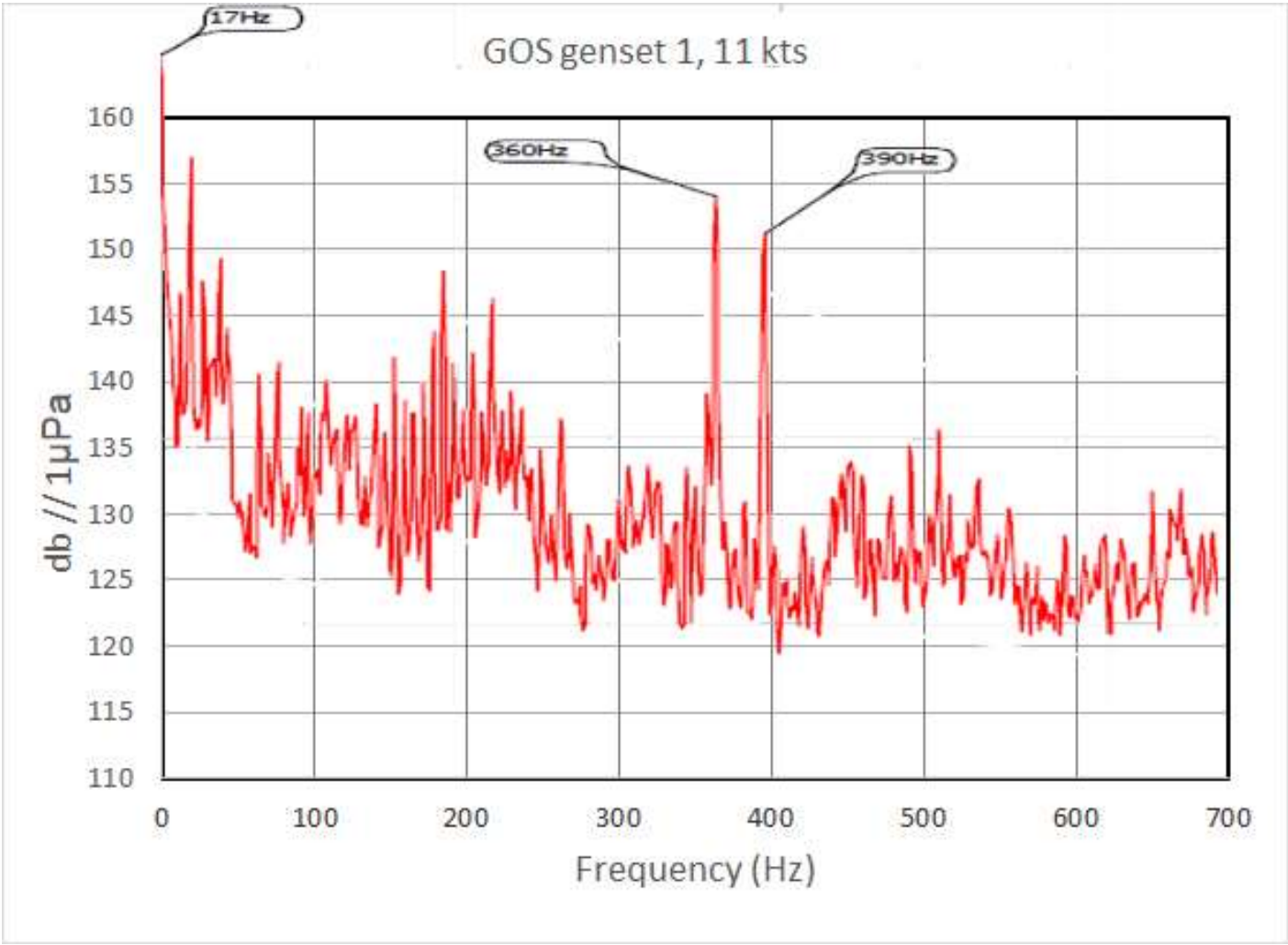
Examples of line components:

- Blade rate = n propeller blades x rpm / 60 (~10Hz)
- Cylinder firing rate in diesel engines (~ 32 Hz)
- AC frequencies (50-60 Hz)
- Reduction gear and ”singing” propeller (~ 800 -1000 Hz)
- Slot frequency (in generators) (~ 1400 Hz)

Continuous spectrum is generally generated by propeller cavitation and flow noise

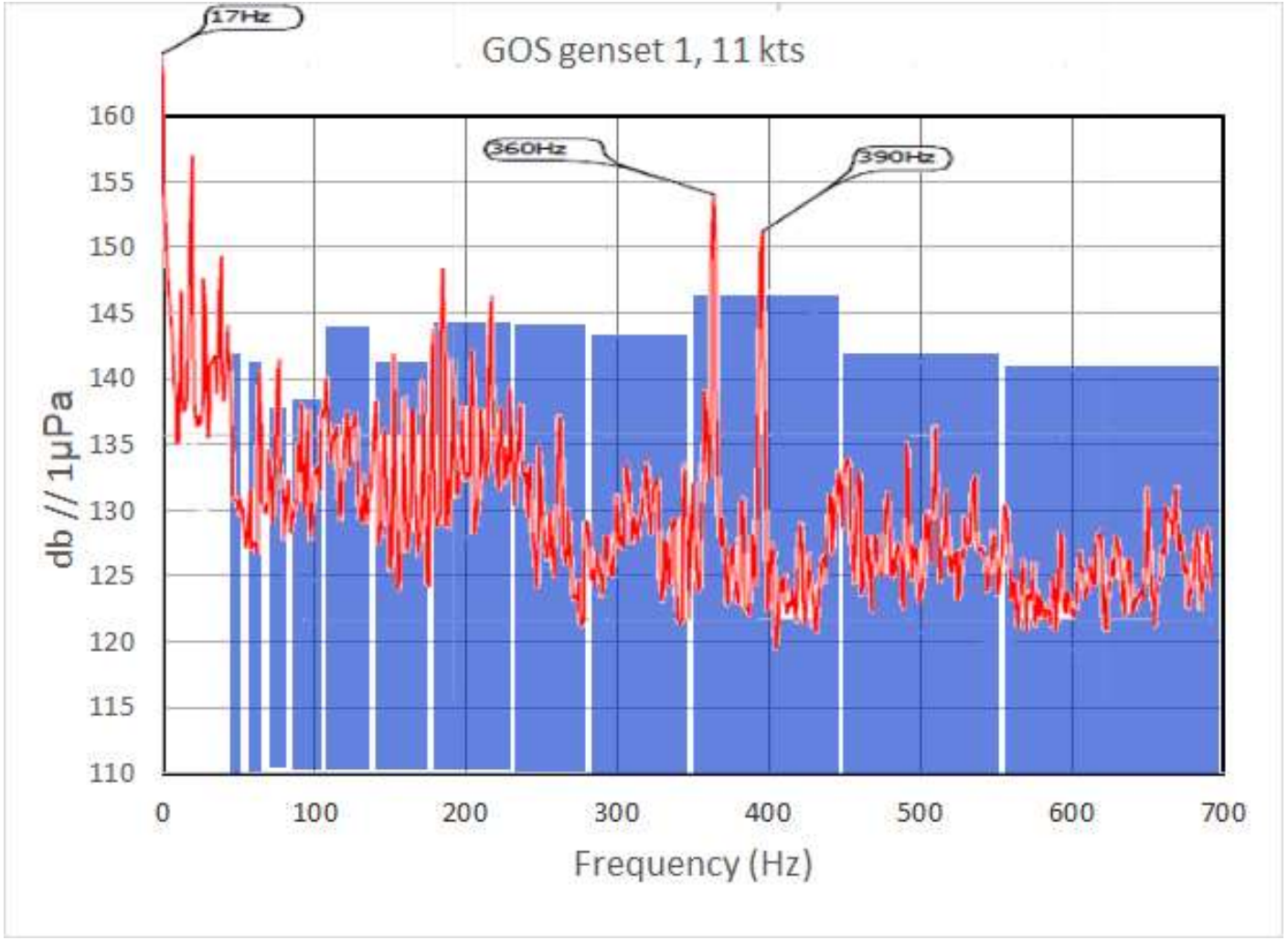
Narrow band data

- Narrow band data shows details in both line frequencies and the continuous spectrum, «white noise»
- The figure shows a small section (0 – 700 Hz) of the total spectrum
- We can see tonal components superimposed on the continuous spectrum.



1/3 octave band

- 1/3 octave filters are used in the measurements.
- The average level in each 1/3 octave band is recorded.



Band Level (BL)

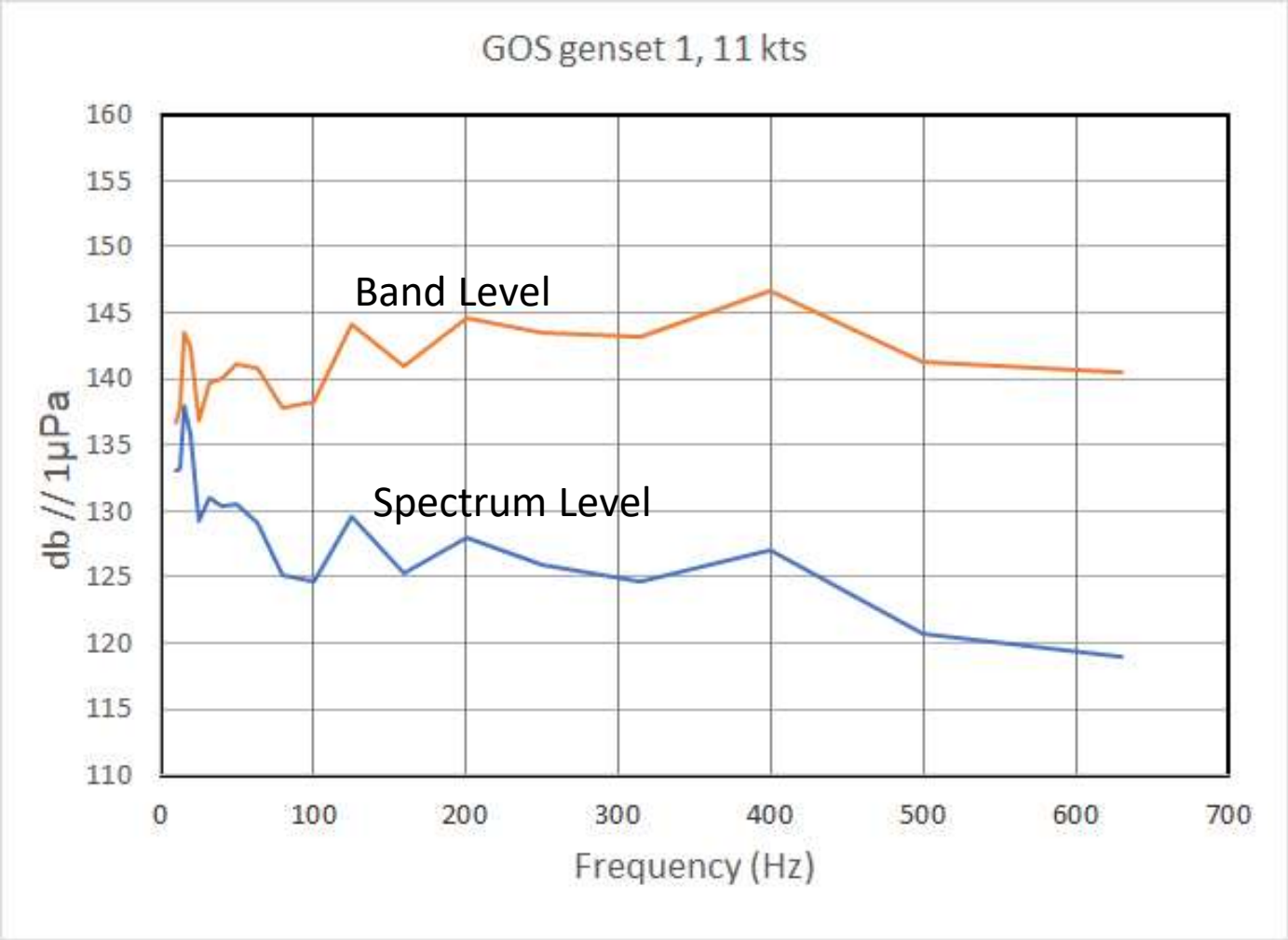
- Band Level is usually presented as a curve.

Band Level (BL) and Spectrum Level (SPL)

- The radiated noise level is presented either as Band Level (BL) or Spectrum Level (SPL).
- The relation between Band Level and Spectrum Level is:

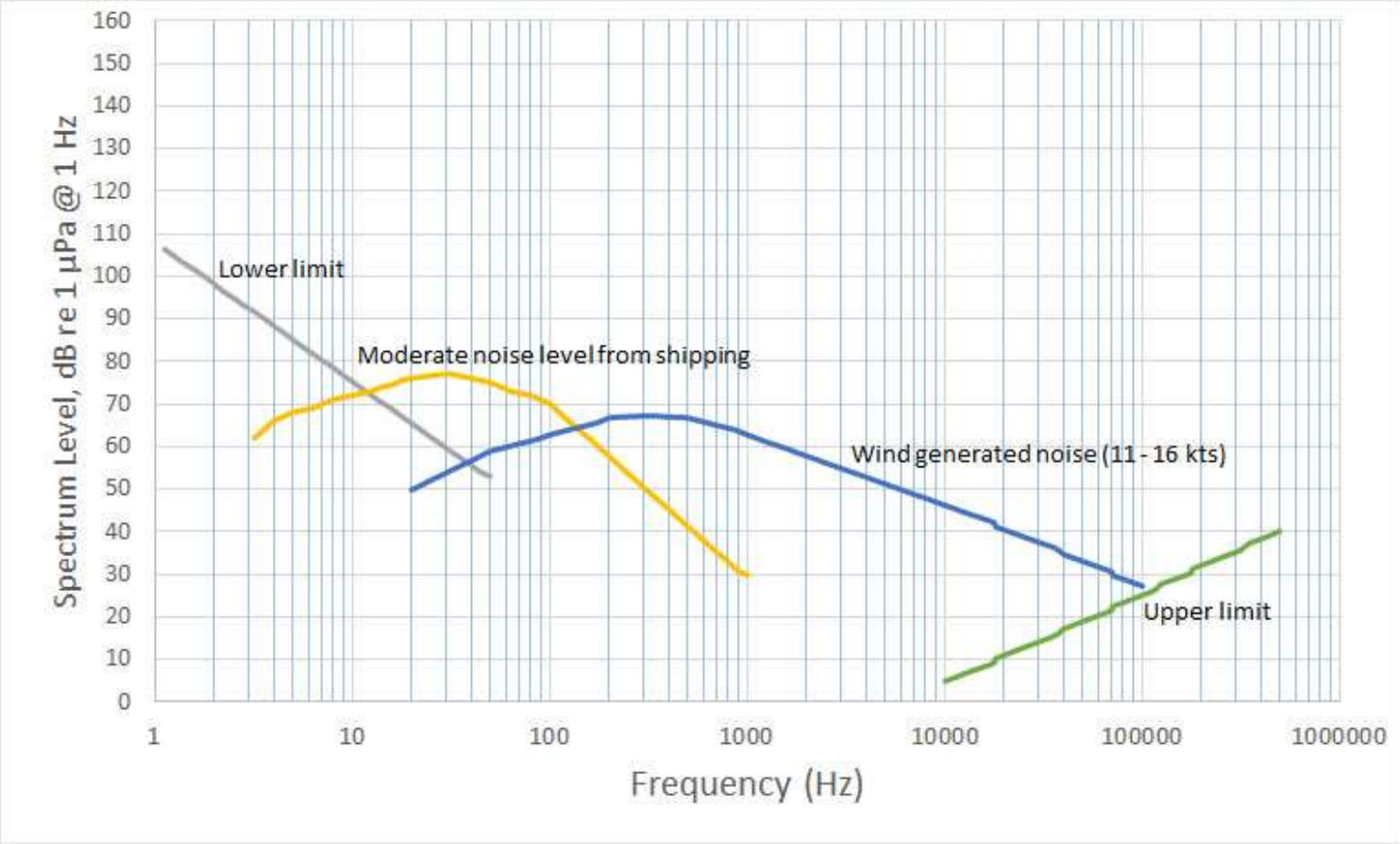
$$SPL = BL - 10 \log BW$$

where BW is bandwidth in each 1/3 octave band.



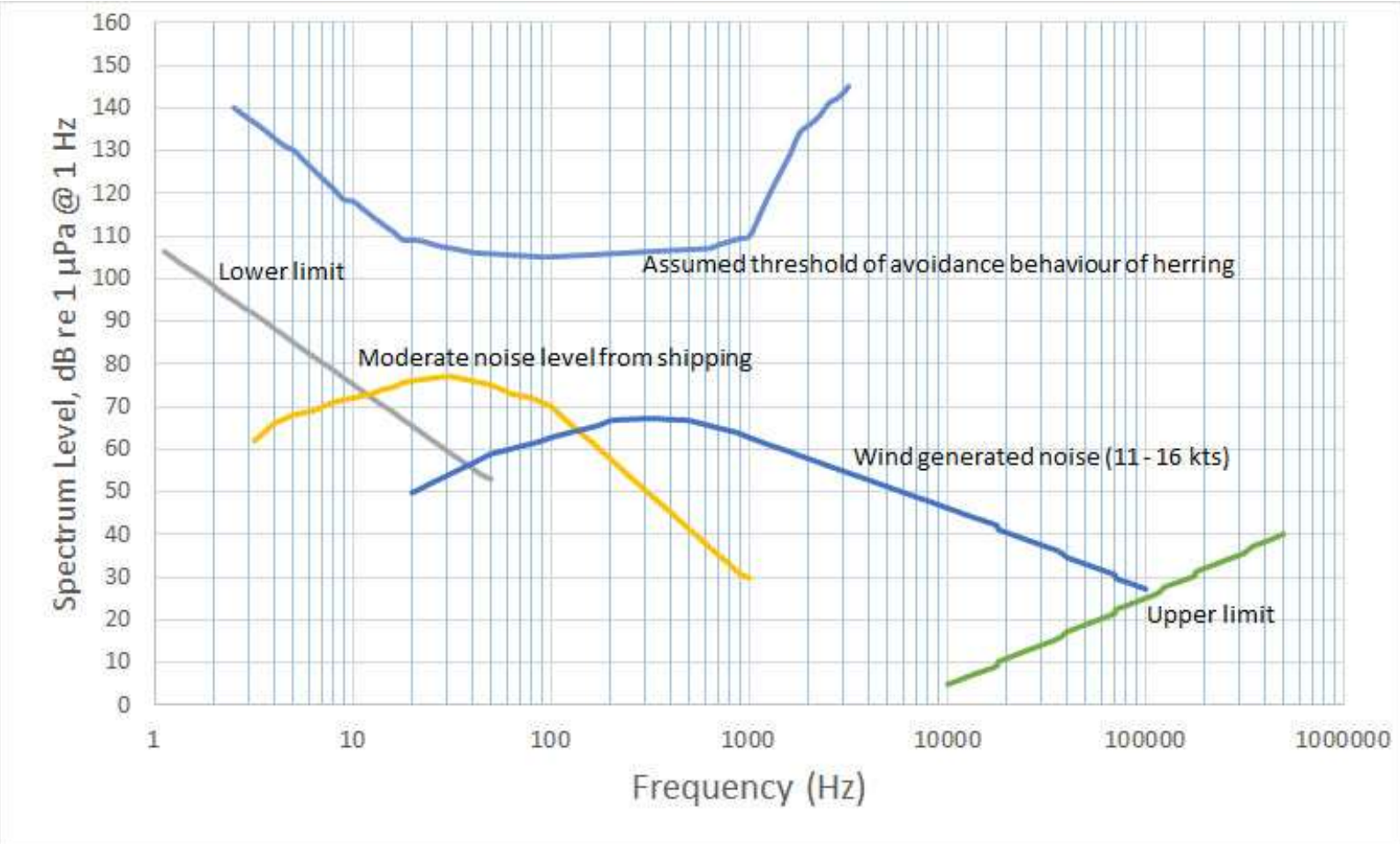
Background noise in the oceans

This figure in the frequency domain illustrates a typical noise situation in the oceans. The lowest frequencies, mainly generated by shipping, have a long range and will more or less always be present. The wind generates waves breaking on the surface and makes noise at higher frequencies. The higher frequency, the higher is the absorption of the sound in water.



Hearing threshold

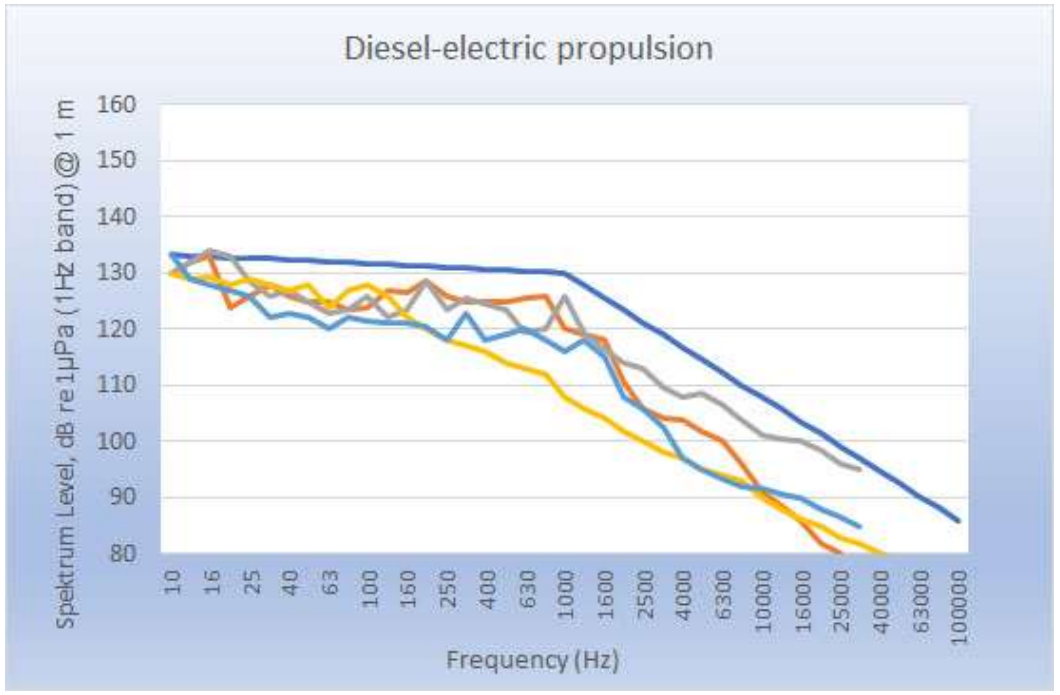
The hearing threshold for e.g. herring is low in the frequency range 10 – 1000 Hz. The threshold of avoidance behaviour is assumed to be 30 dB above the hearing threshold. In order to reduce the avoidance behaviour, the underwater radiated noise should be as low as possible in this frequency range. The noise sources are mainly machinery.



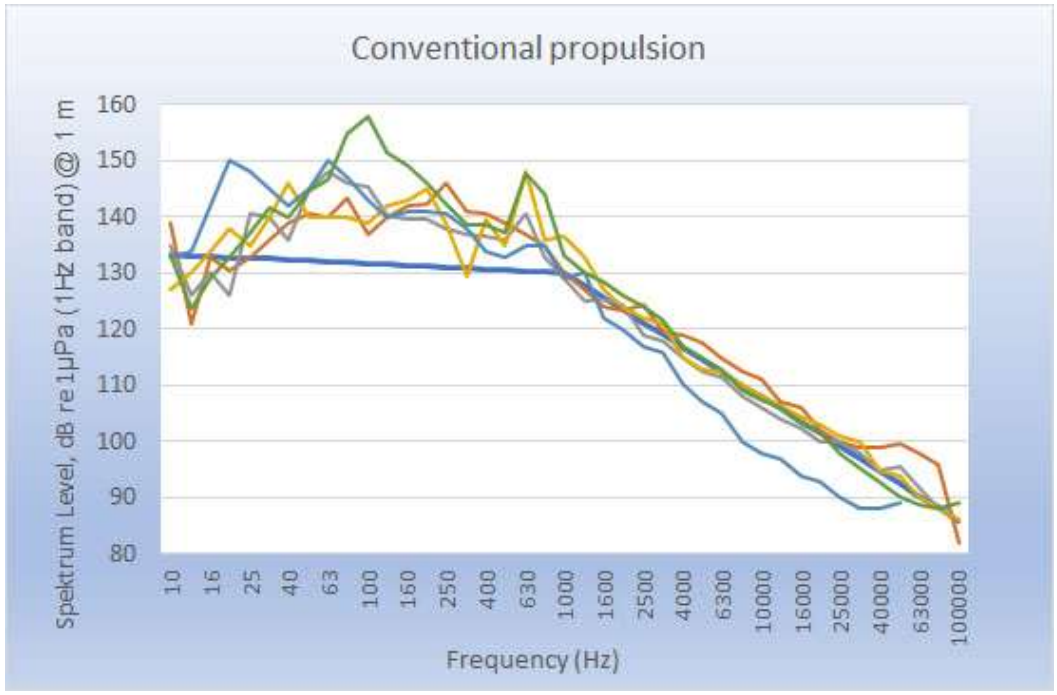
Noise reduced research vessels

After the introduction of ICES 209 in 1995, since 1998, a number of research vessels have been built with a requirement to be in compliance with the recommended limit. Common to all is that they have diesel-electric propulsion system and fixed pitch propeller with 5 blades or more

Vessels built in compliance with ICES 209 recommendation



Vessels built with conventional propulsion system, i.e. diesel engine, reduction gear and controllable pitch propeller



Conventional vs noise reduced propulsion system

The figure show noise signatures for two research vessels, one has conventional propulsion and exceeds the threshold for herring, the other is noise-reduced and meets the ICES 209 recommendation