Underwater Noise Simulations for the Defense Research Vessel WFS PLANET

DEGA Workshop "Underwater Acoustics“

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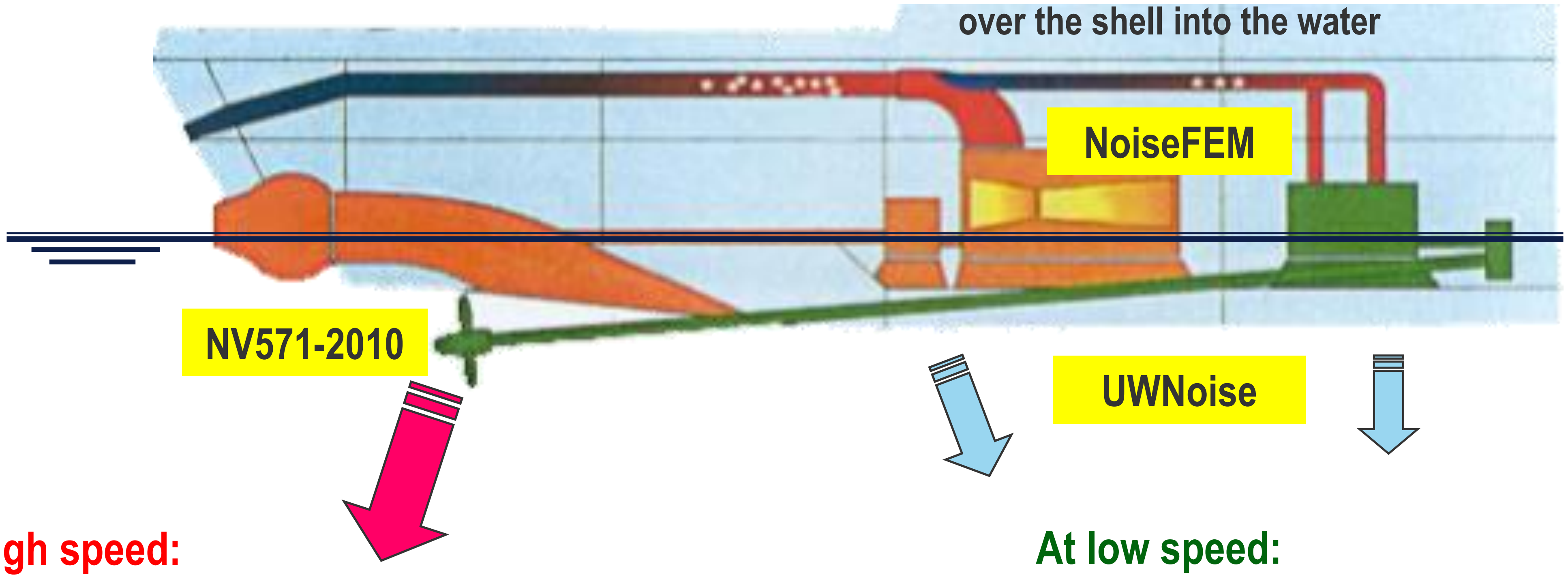
Presentation Content

- Overview of DNV GL‘s
  Underwater Noise Prediction Method and used Programs
  - NoiseFEM
  - UWNoise
  - NV571-2010
- Simulation results for a slow vessel speed operating condition, 9kts and result discussion
- Simulation results for a fast vessel speed operating condition, 14kts and result discussion
- Todo(s)

Vessels Underwater Noise Sources and Radiation Types

Propulsion Sources are radiating direct into the water

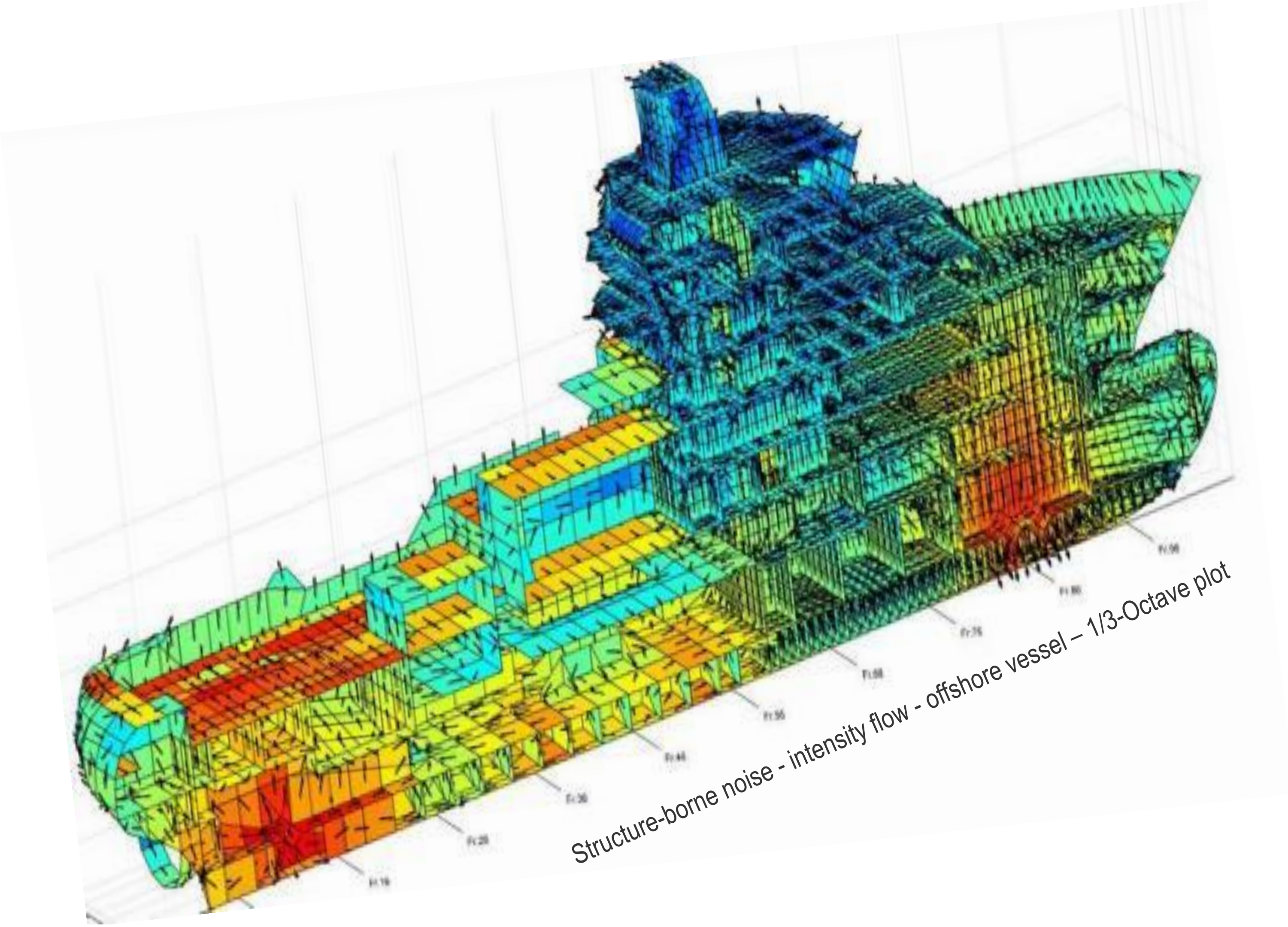
Other Sources are exciting the structure and radiating over the shell into the water



At high speed:
Sound portion emitted by the main propulsion propellers or/and water-jets dominates the radiated noise

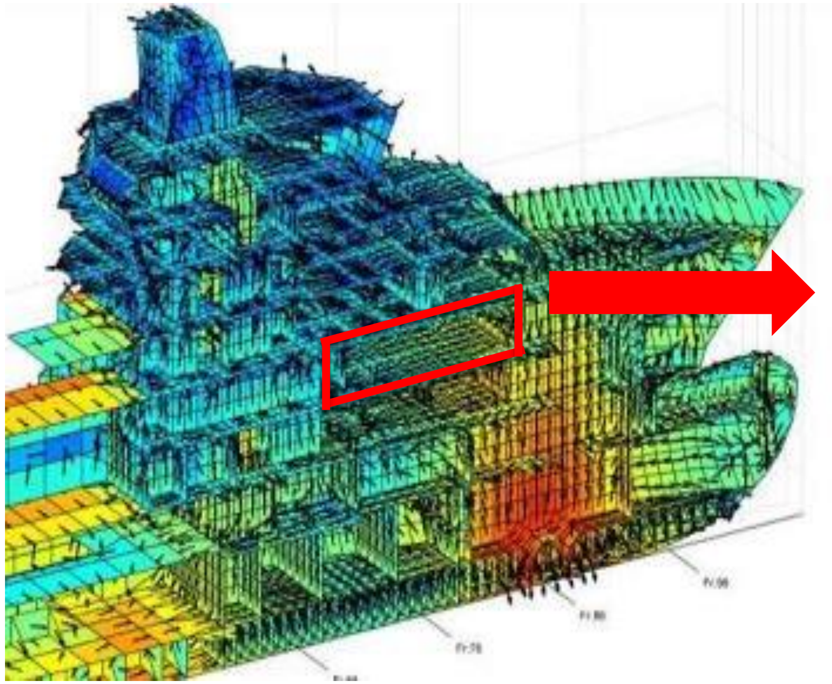
At low speed:
Sound portion emitted by the machinery mainly dominates the radiated noise of the whole vessel

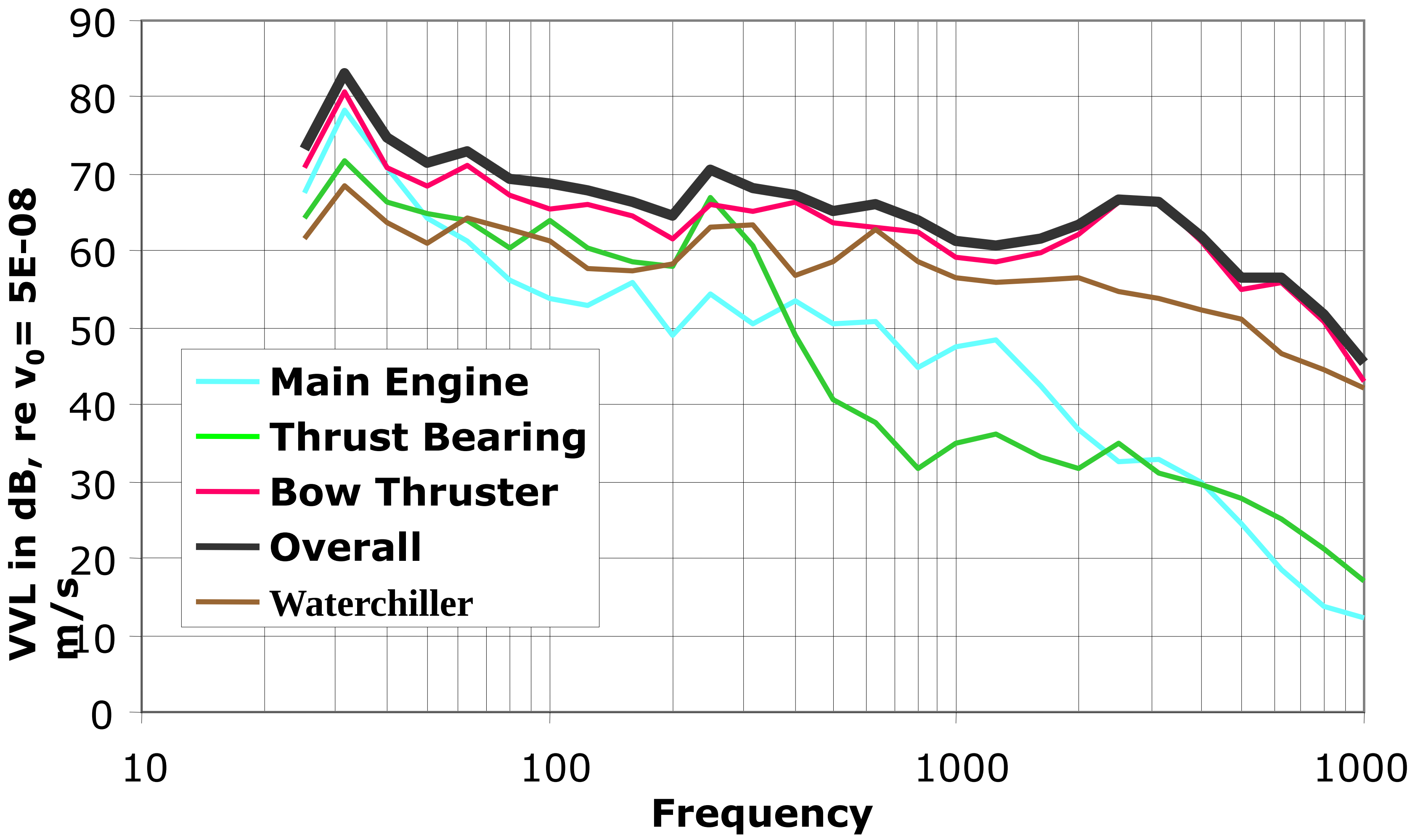
NoiseFEM - Noise Flow Analysis



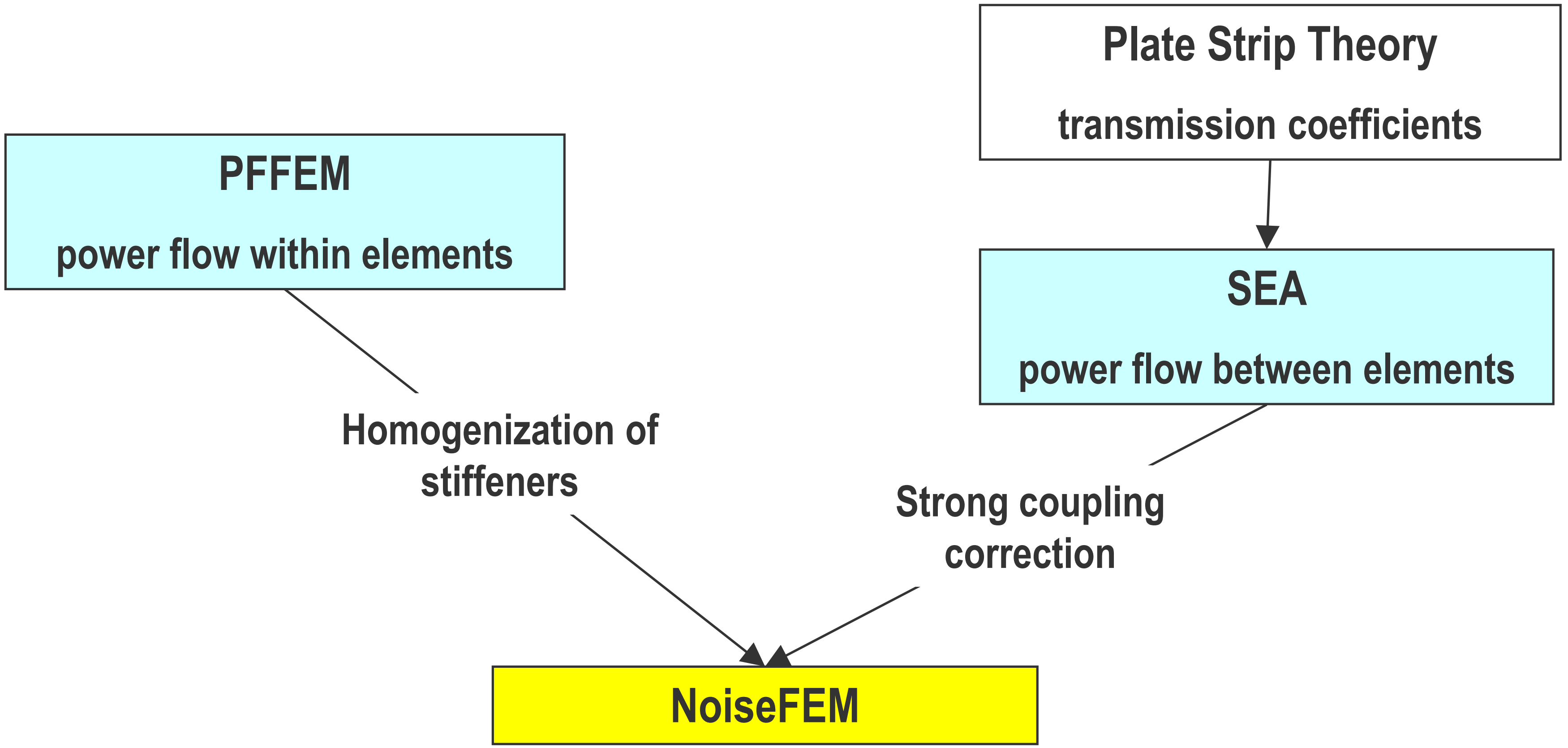
- Simulation of **structure-borne noise propagation** through the ship structure
- Similar to SEA methods but **based on 3D FE model** of the vessel, as e.g. used for global vibration analysis
- Validated by extensive full scale mock-up measurements
- Client's benefits**:**
  - **optimization** of structure **against noise propagation**
  - derivation of **reliable noise transmission coefficients** as a basis for air- and water-borne noise predictions for unconventional ship designs

Example Noise Source Portions in NoiseFEM





Methods combined in NoiseFEM



Benefits of NoiseFEM against the pure Classical SEA

	Classical SEA	NoiseFEM
1. Power flow between subsystems	SEA approach	SEA approach
2. Power flow within the subsystem	---	PFFEM
3. Coupling between subsystems	Weak coupling assumes diffuse sound fields	Strong coupling (special DNV GL approach) better handling of diffuse and non-diffuse sound fields
4. Loss factor within the subsystem	SEA approach	PFFEM
5. Transmission coefficient	Beam theory	Plate strip theory
6. Stiffeners within the substructure	Stiffened plate as subsystem	Homogenization approach (special DNV GL approach)
7. Excitation	SEA approach	Similar to SEA structure-borne sound power input and test bed vibration velocity level at any substructure possible
8. Post-processing	Difficult visualization of power flow	Visualization of intensity in each subsystem (element)

UWNoise – Under Water Noise Radiation

- *Global FE Model*

  or

- *Framewise FE Model*

Plate Strip Theory
Transmission coefficients

NV571

Propeller source

EBEM
Energy Boundary Element Method
(N. Vlahoupoulos)

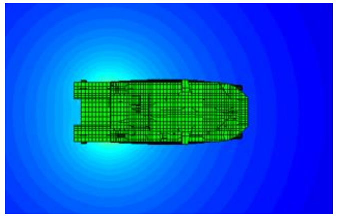
Power or normal level excitation on Structure

NoiseFEM
Structure borne noise propagation

Vibration level on structure

UWNoise
Radiated underwater noise

UW-Noise level

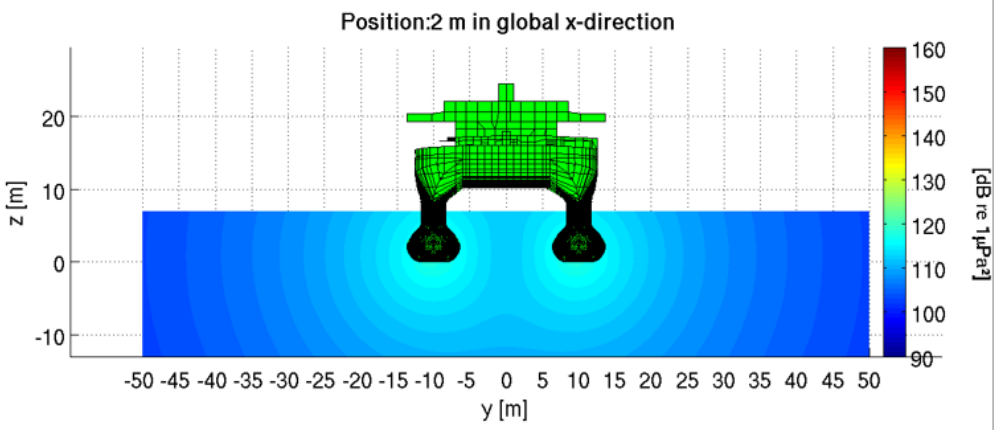


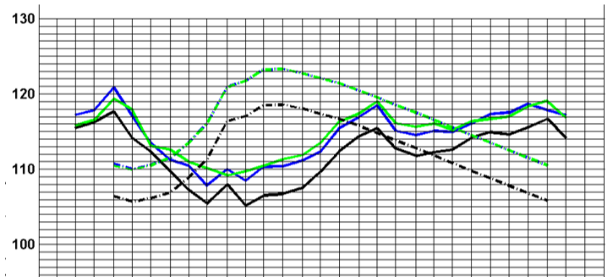
SEA
Power flow between elements

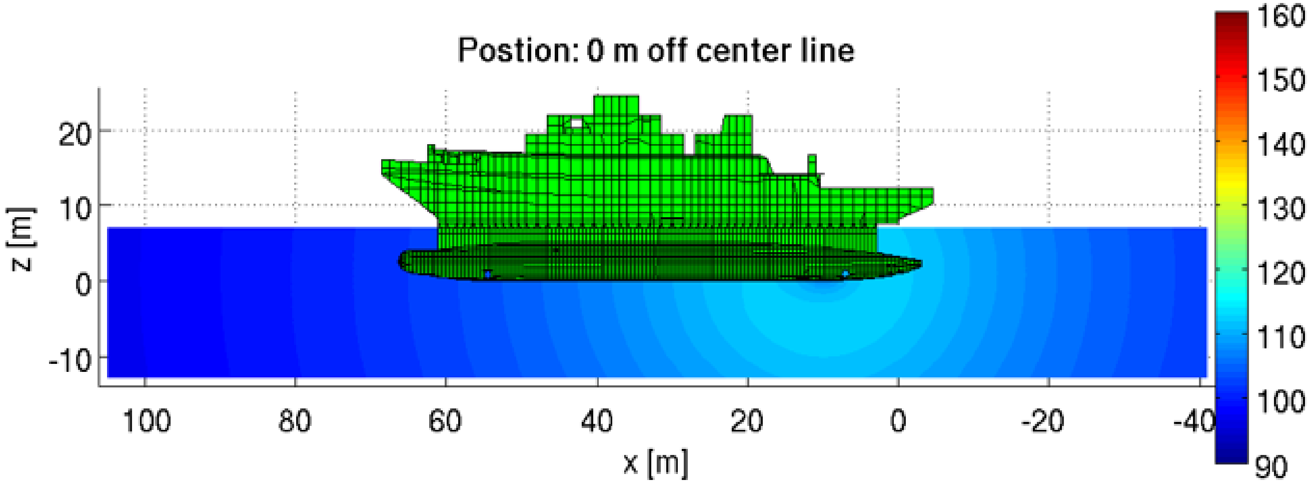
PFFEM
Power flow within elements

Calc. of radiation efficiency
(G.Maidanik/L.Rummerman/F.G. Leppington)

UWNoise – Under Water Noise Radiation

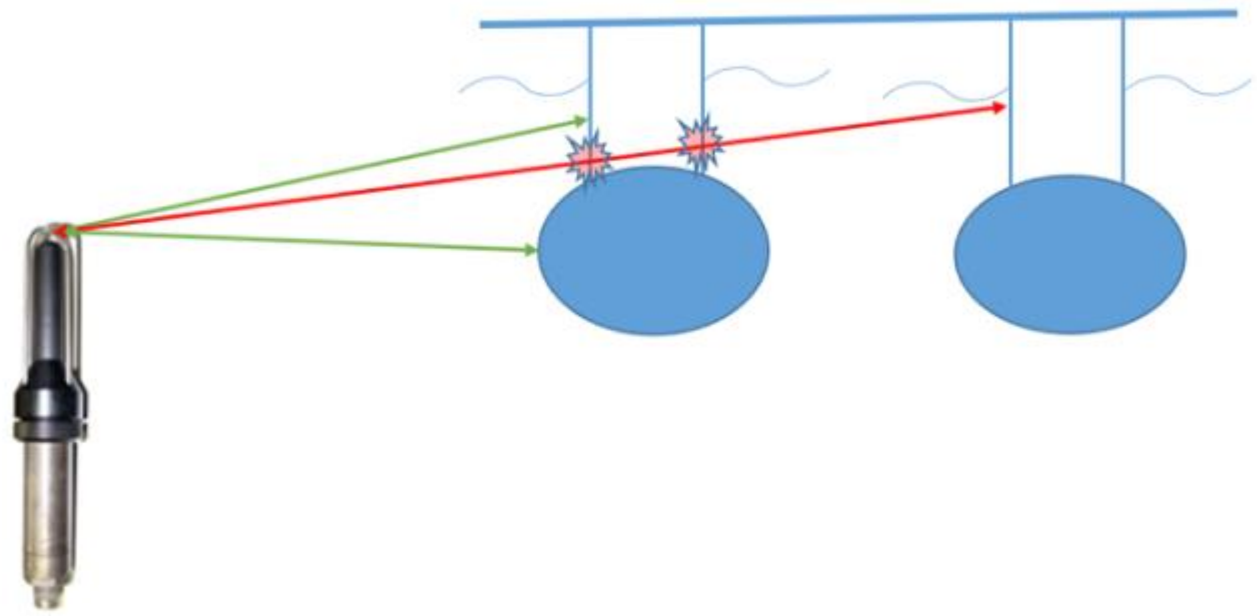






- Simple radiation approach for a variable group of elements, in general the shell for under water noise
- Phase information is already lost in the SEA, the method is energy based
- Radiation efficiency is based on the formula of Maidanik
- Each selected element is a mono-source
- The shell is transparent for the mono-sources
- A smart geometric shell element selection for a given Hydrophone position in the water avoid mono-sources that a shaded by the vessel structure

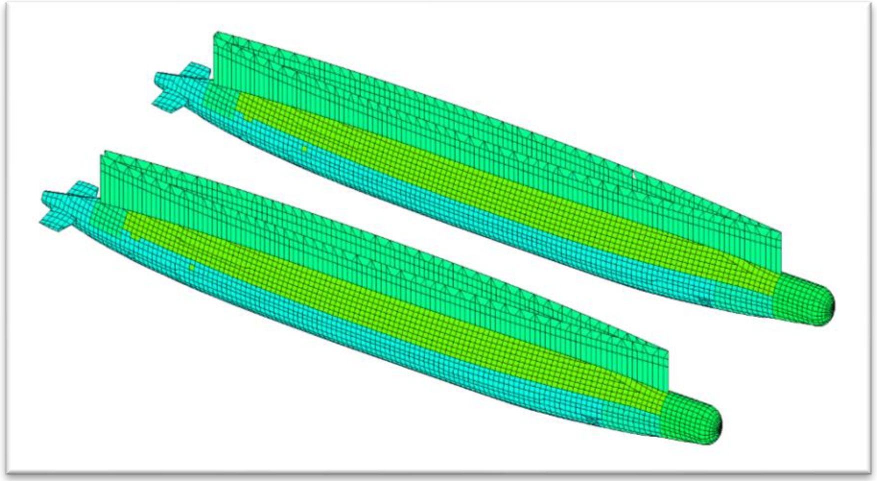
UWNoise – Geometric Shell Element Selection



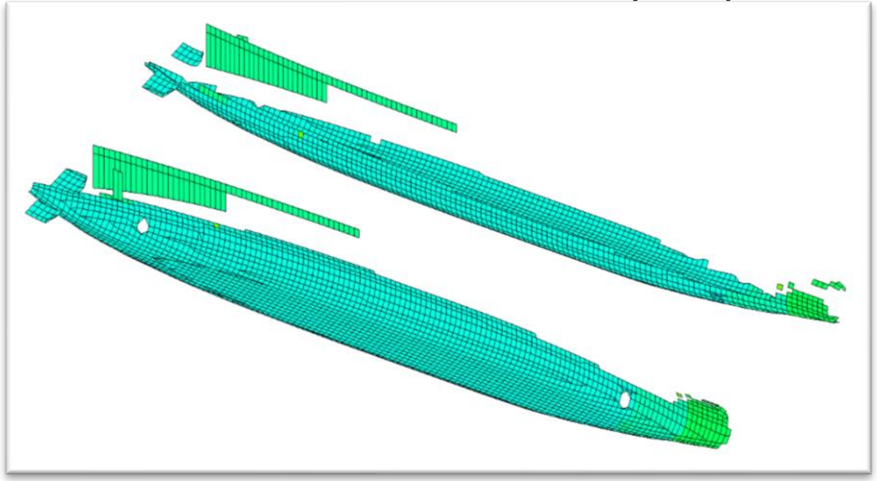
Hydrophone position x,y,z

Element centre points x,y,z

All water immersed shell elements



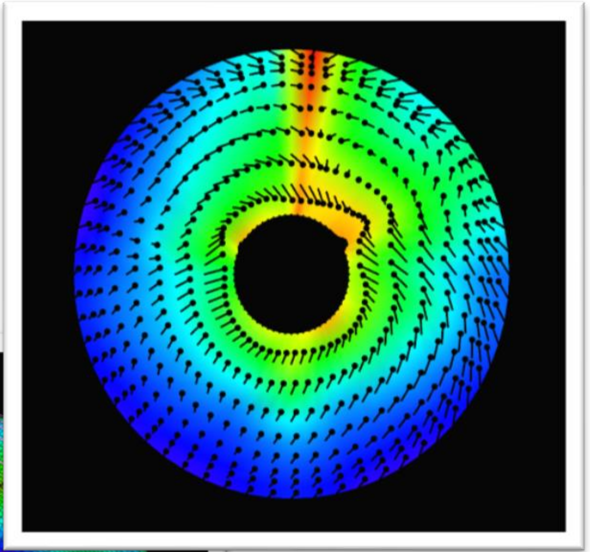
Selected elements for keel hydrophone

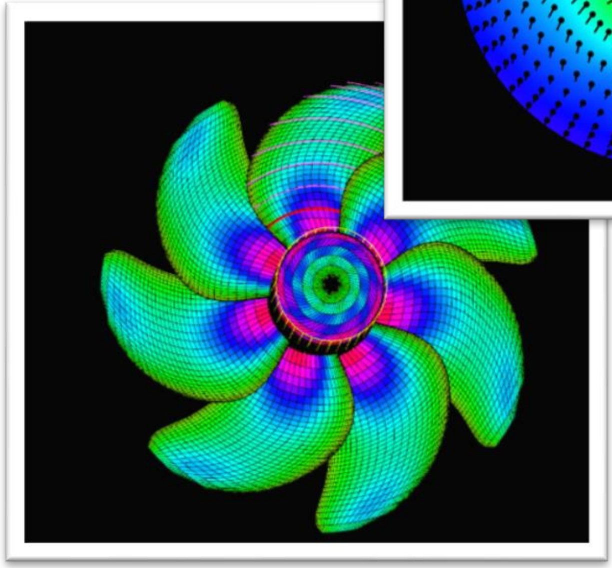


Calculation Program NV571-2010 – Propeller Source Strength

- Calculations Results of NV571
  - Unsteady loading of the propeller, forces and moments transferred to shaft
  - Extent of cavitation on the propeller blades
  - Pressure fluctuations on hull induced by cavitating propeller
  - Propeller hydro-acoustic noise source strength

- Needed Input
  - Propeller geometry
  - Hull lines
  - Nominal or effective wake distribution, model or full scale
  - Propeller RPM, ship speed and draft to propeller shaft





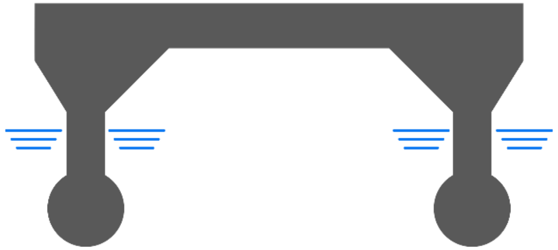
Calculation Program NV571-2010 – Methods

- Effective wake:
  Based on method for body of revolution and actuator disc. Scale effect can be included.
- Hydrodynamic loading:
  Unsteady lifting surface theory solved by discrete vortex lattice method.
  Effect of cavitation is not included.
- Cavitation:
  As above, including source/sink distribution to simulate the cavities
- Pressure fluctuations:
  Source/sink distribution to represent propeller blades, vortices to represent loading. The cavities are simulated by time-dependent source/sink distributions considered as distribution of monopoles. The effect of free surface and the presence of the hull on the free stream pressure are calculated by semi-empirical method.
- Noise from cavitating tip vortices is estimated by the so-called tip vortex index method (TVI method) and added to the blade frequency components from transient sheet cavitation.

Calculation Program NV571-2010 – Results for UW-Simulations

Validation Object – WFS PLANET

Small Waterplane Area Twin Hull (SWATH)



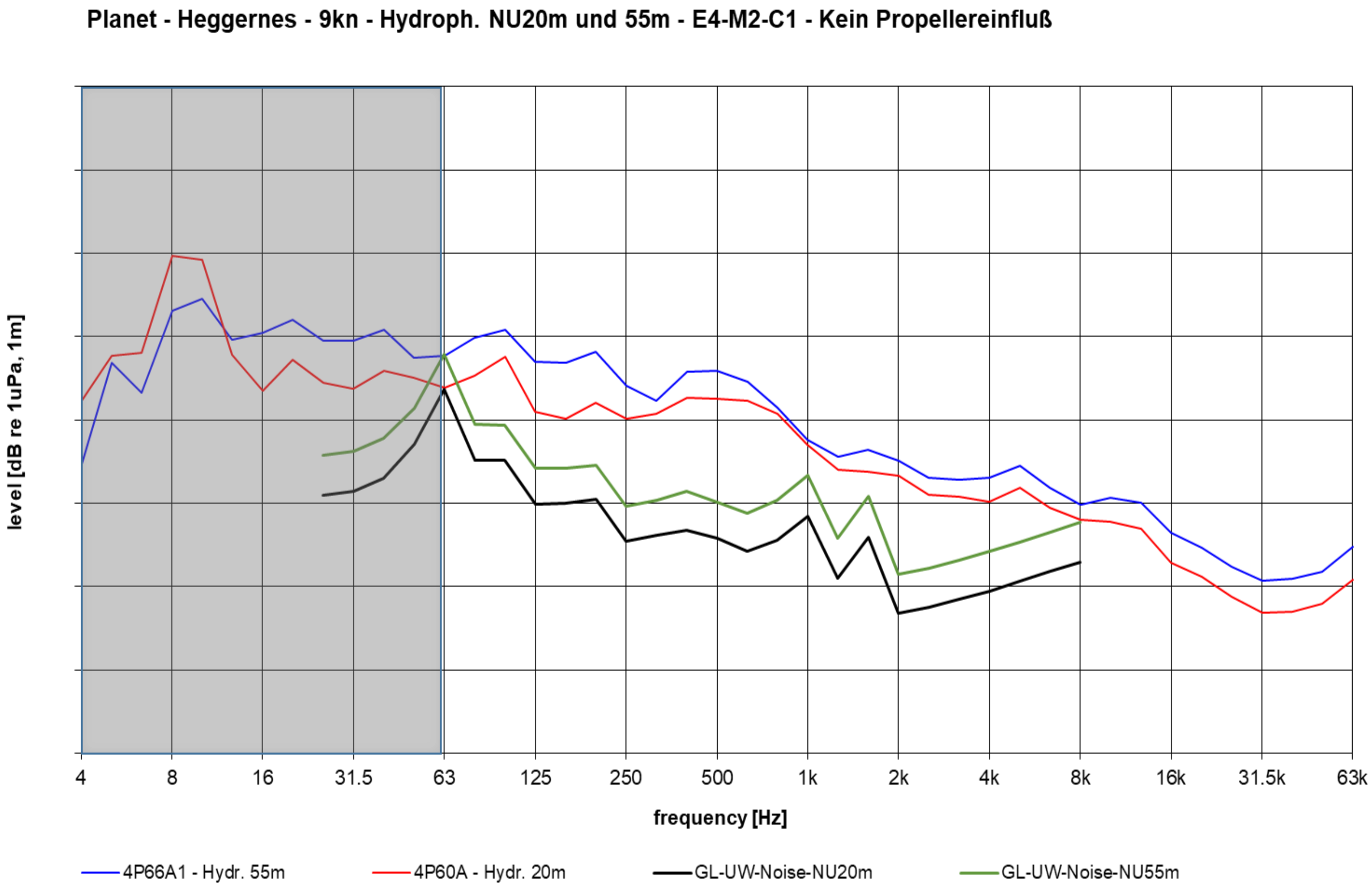
Schiffsdaten	
Flagge	Deutschland
Schiffstyp	Wehrforschungsschiff
Klasse	Planet-Klasse (751)
Rufzeichen	DRLA
Heimathafen	Eckernförde
Bauwerft	Thyssen Nordseewerke, Emden
Baunummer	537
Kiellegung	April 2002
Stapellauf	12. August 2003
Indienststellung	31. Mai 2005

Maschinenanlage	
Maschine	Dieselelektrischer Antrieb
Maschinen-leistung	4.160 kW (5.656 PS)
Höchst-geschwindigkeit	15 kn (28 km/h)
Generator-leistung	5.950 kW (8.090 PS)
Propeller	2 × Propeller

Source: Wikipedia

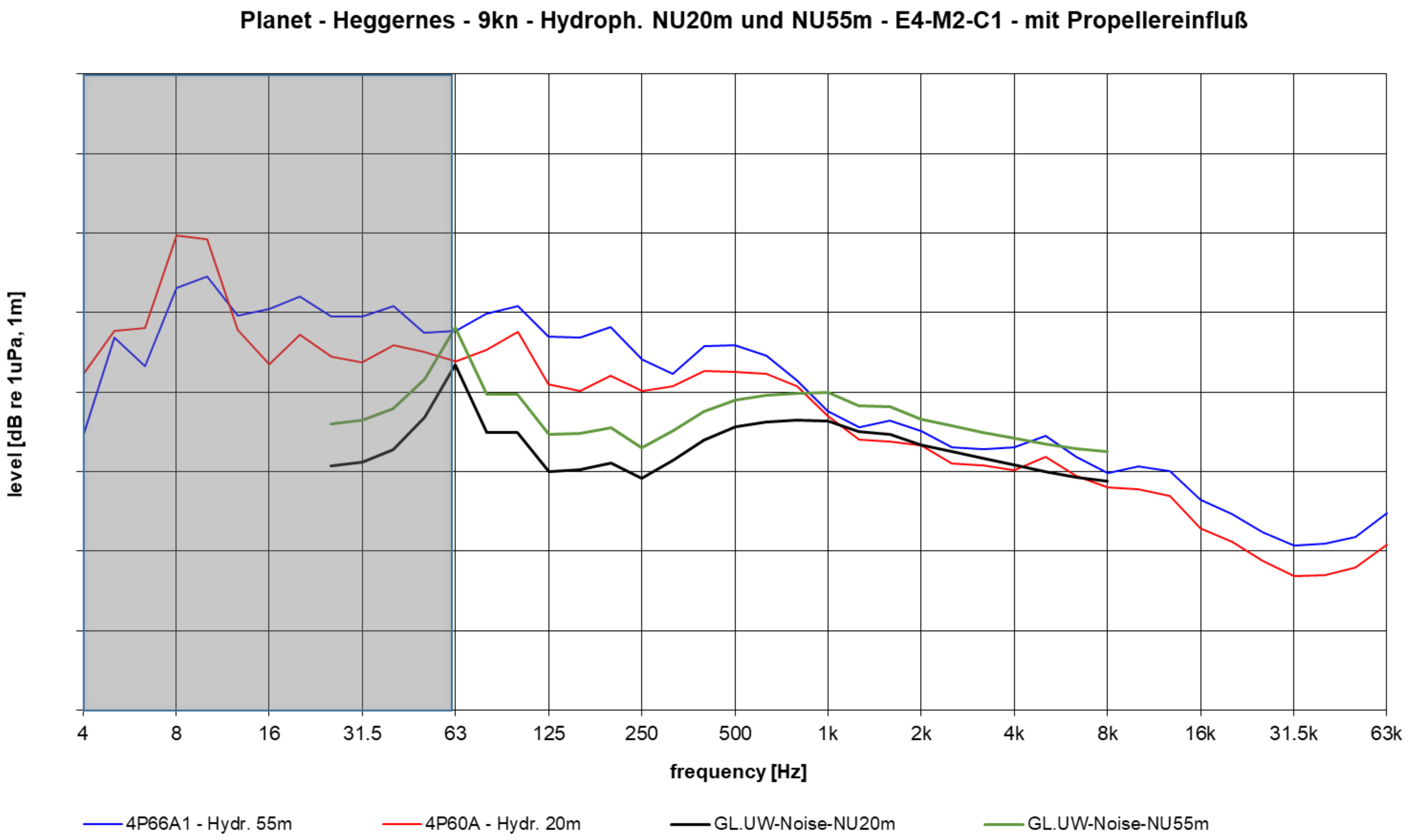
Under Water Simulation – 9kts – no cavitation expected

- Results from a former study
- No propeller source included in the simulation
- Simulation for two hydrophone positions NU-20m and NU-55m
- In general the simulated underwater noise level is too low



Under Water Simulation – 9kts – no cavitation expected

- Results from a former study
- Propeller source included in the simulation
- Simulation for two hydrophone positions NU-20m and NU-55m
- In the frequency range 125Hz-500Hz the simulated underwater noise level is still too low
- The frequency range starting from 1kHz is now in a sufficient range

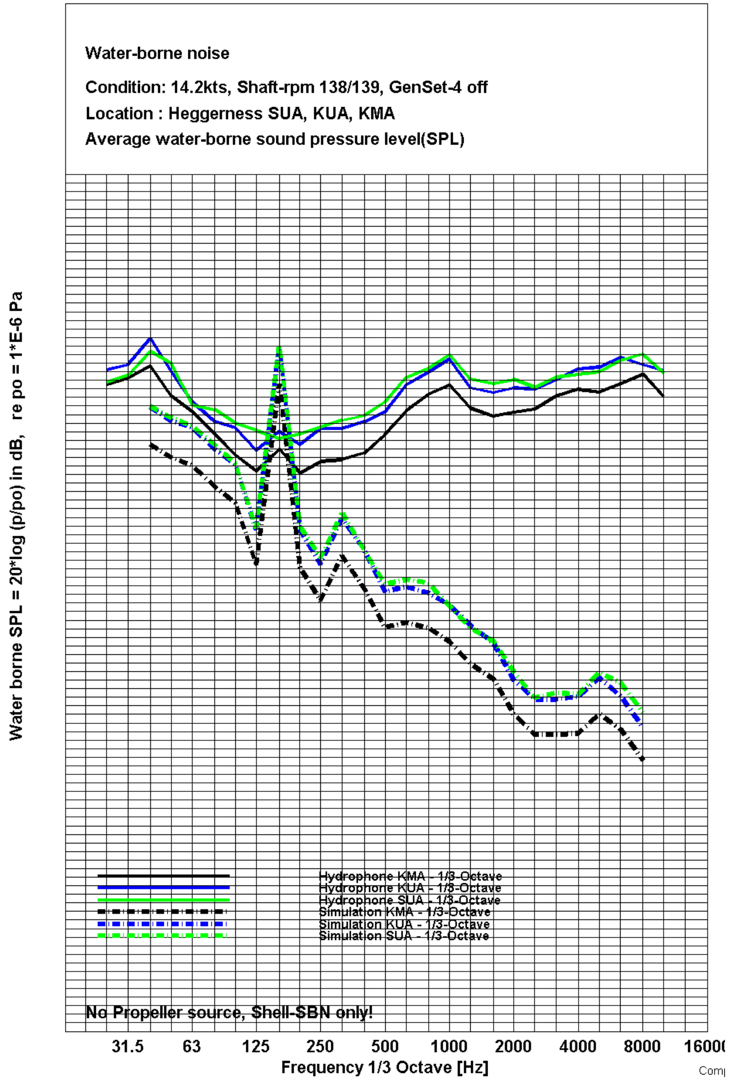


Result discussion – 9kts

- In general the consideration of the propeller source leads to a better result, but the frequency 125Hz up to 500Hz is still too low
- This short test does not include the smart geometric element selection, but this should lead to even lower levels.
- It might be that not all relevant noise sources are considered in the simulation, like smaller pumps generating none neglectable noise portions in the underwater noise level
- The environmental impact of the test range in Heggernes can not be judged
- The results from program package NV571-2010 may be not suitable for special propeller designs like the ones installed on WFS PLANET.

Under Water Simulation – 14.2kts – cavitation expected

Simulation Parameter	
Shell radiation	Yes
Propeller as a source	No
Smart geometric element selection	No
100% reflexion at the water surface	No



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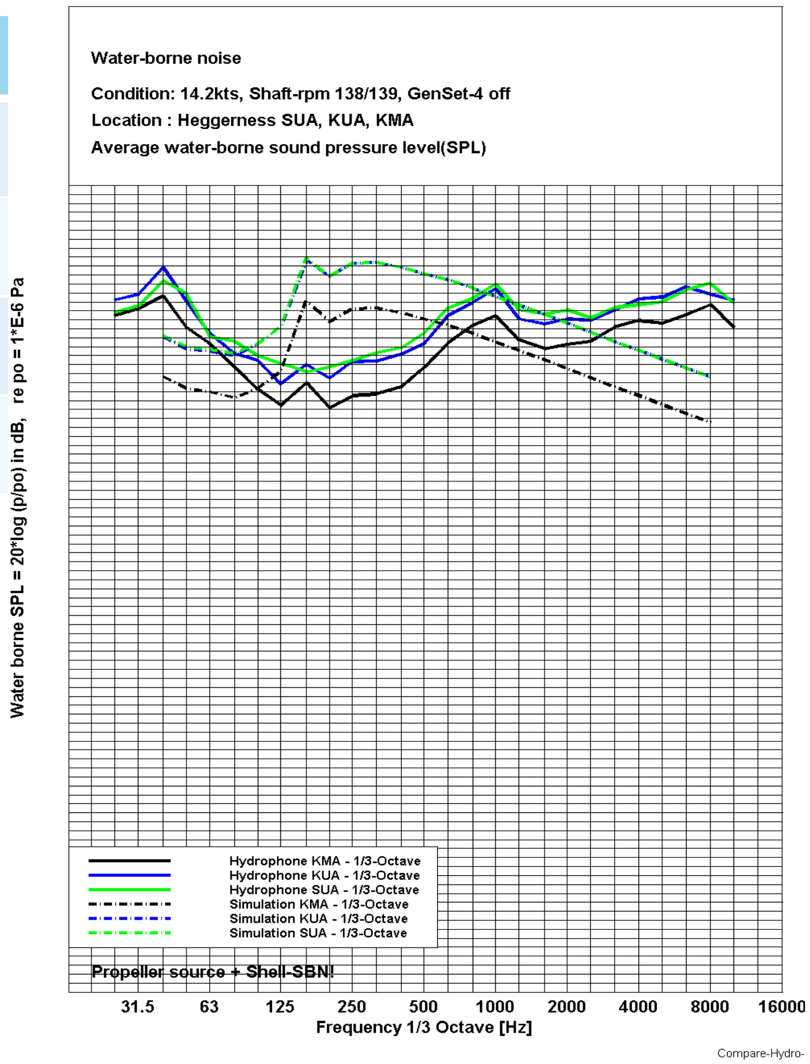

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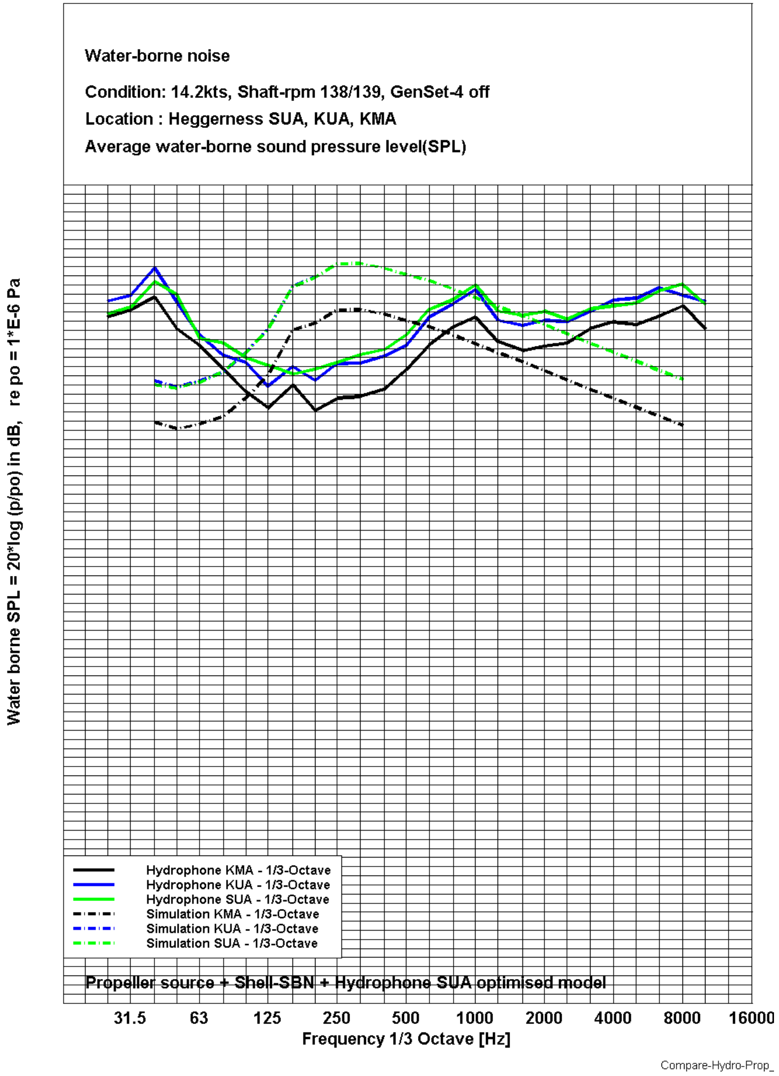

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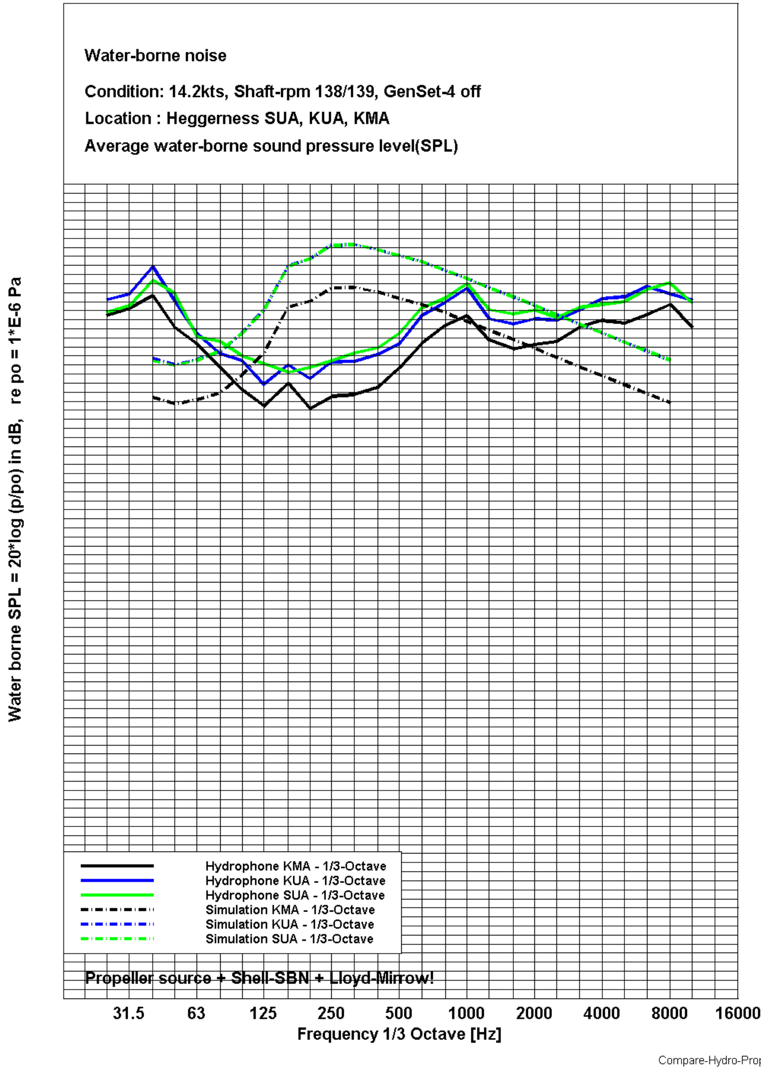

Result Discussion – 14.2kts

- The principle simulated level height is not wrong with the propeller source included, but the characteristic of the simulated under water noise level is different
- Check of the electric propulsion engine source level. It might be that the measurements are affected by electric radiation or galvanic contacts
- It might be that not all relevant noise sources are considered in the simulation, like smaller pumps generating none neglectable noise portions in the underwater noise level
- The environmental impact of the test range in Heggernes can not be judged
- The results from program package NV571-2010 may be not suitable for special propeller designs like the ones installed on WFS PLANET.

Todo(s)

- The results from program package NV571-2010 may be not suitable for special propeller designs like the ones installed on WFS PLANET. A broader validation data base might be necessary to tune the noise portion from the TVI method for such special propeller designs
- Check of the electric propulsion engine source level. It might be that the measurement chain was not sufficient isolated against electro-magnetic radiation
- Deeper investigations regarding the target level
  Is the measured test range level representative. Perform comparisons with older measurements or comparisons with similarly operating conditions

Thanks for your attention!

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