

Testing of bubble curtains to mitigate hydro sound levels at offshore construction sites (2007 to 2011)

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Projektträger

Koordination



Bundesministerium
für Umwelt, Naturschutz
und Reaktorsicherheit



Content

- Definition of sound pressure levels
- Offshore construction sites
- Use of a large radius bubble curtain at FINO3
- Use of a layered bubble curtain at *alpha ventus*
- Comparison of both attempts
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- Summary and conclusions



Definition of sound pressure levels

- SPL in dB:

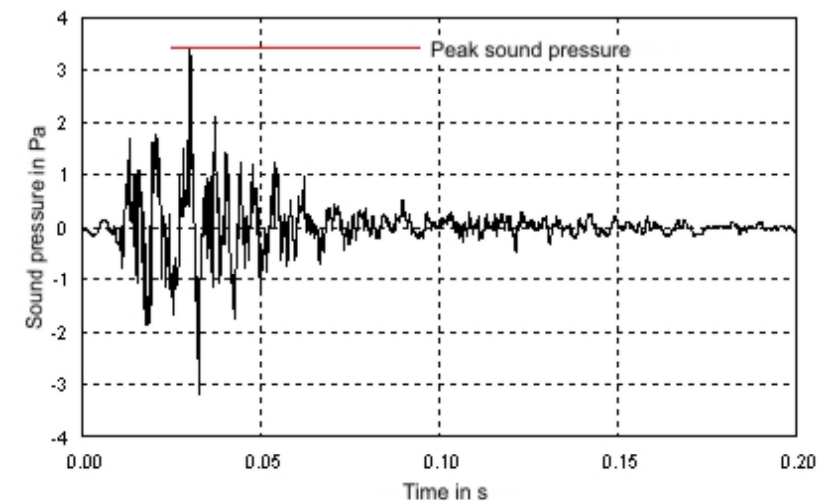
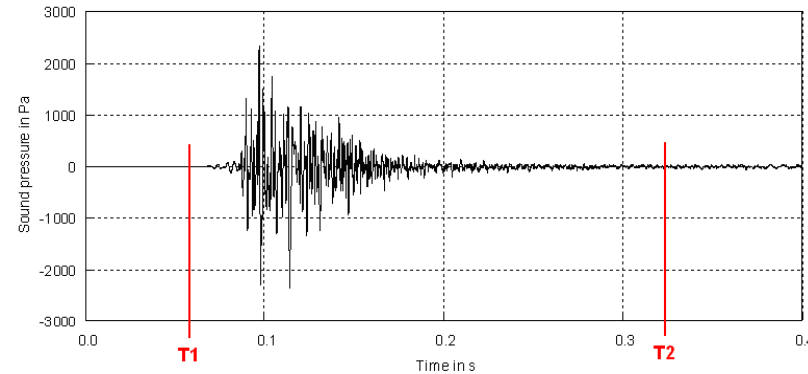
$$L = 20 \log (p_{rms} / p_0)$$

- Sound exposure level (SEL) in dB:

$$L_E = 10 \log \left(\frac{1}{T_0} \int_{T_1}^{T_2} \frac{p(t)^2}{p_0^2} dt \right)$$

- Peak level (PL) in dB:

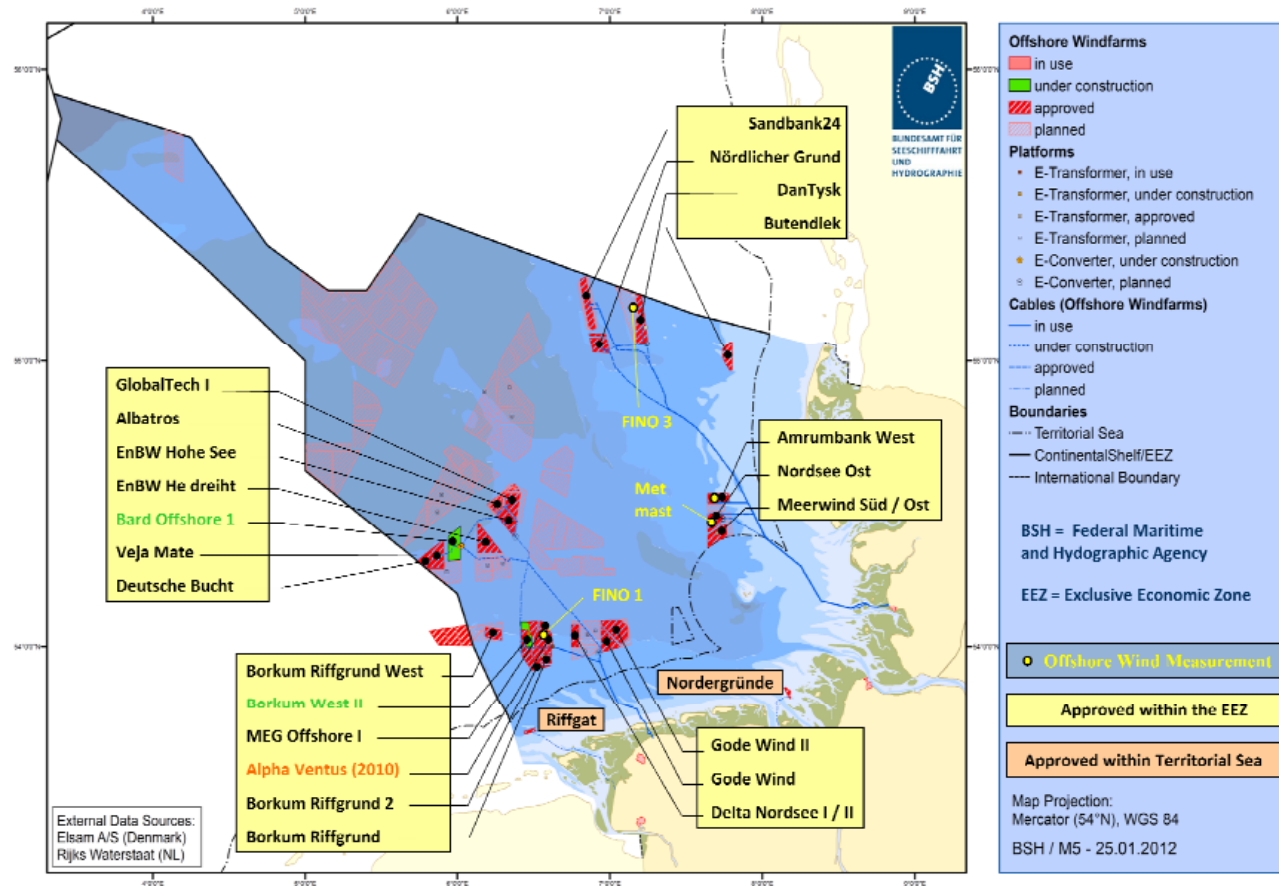
$$L_{peak} = 20 \log (|p_{peak}| / p_0)$$



(Source: Elmer, K.-H. , Betke, K. , Neumann, T. : *Standardverfahren zur Ermittlung und Bewertung der Belastung der Meeresumwelt durch die Schallimmission von Offshore-Windenergieanlagen – „Schall II“*)



Offshore construction sites



FINO 3: Research platform

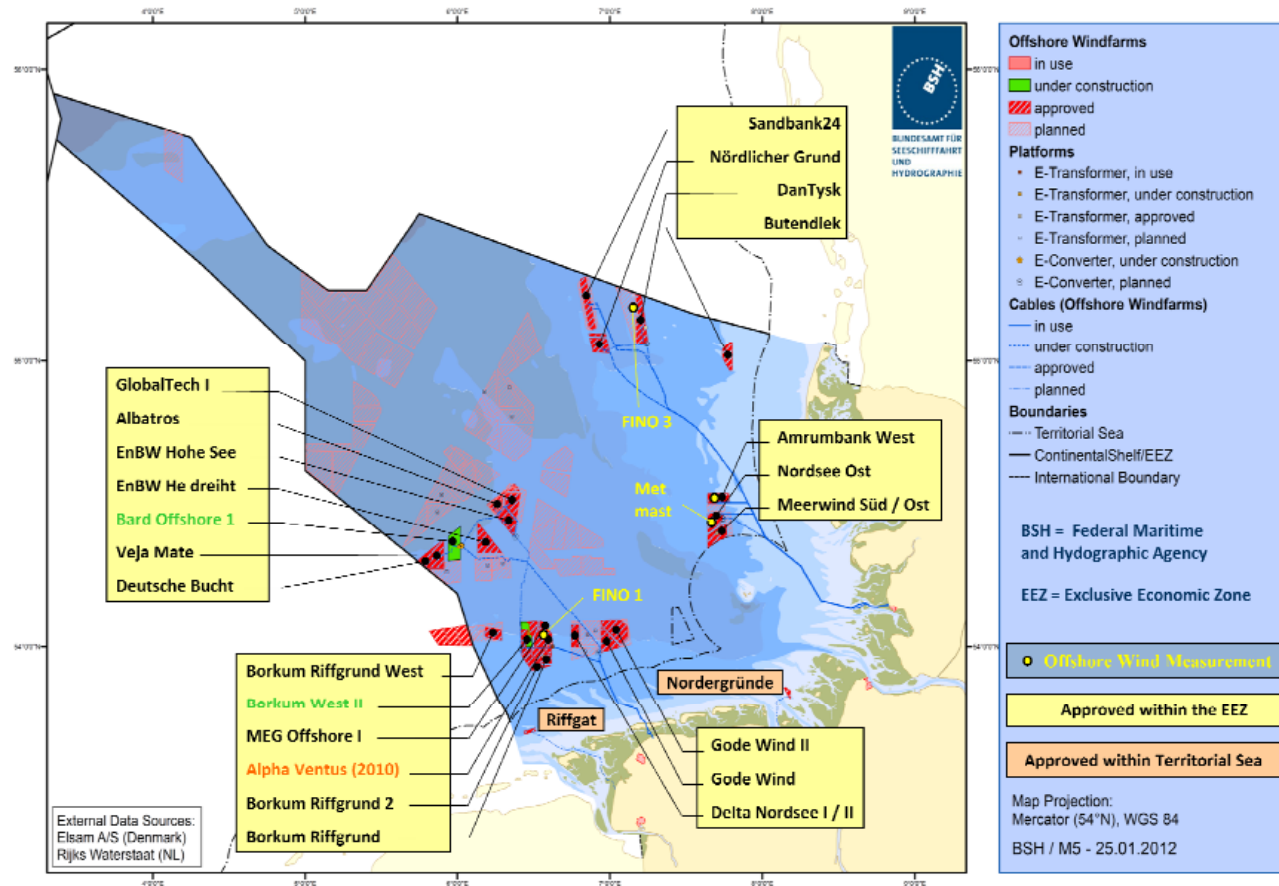


Source: <http://www.fino3.de>

Offshore wind parks and transformer platforms - German North Sea



Offshore construction sites



Alpha ventus:
First German offshore wind farm



Offshore wind parks and transformer platforms - German North Sea



FINO3

- Monopile with a bottom diameter of 4.75 m
- Piling energy up to 800 kJ



Bubble curtain at FINO3

Source: <http://www.fino3.de>

Water depth of about 22 m

Bubble curtain around pile with a radius of 70 m

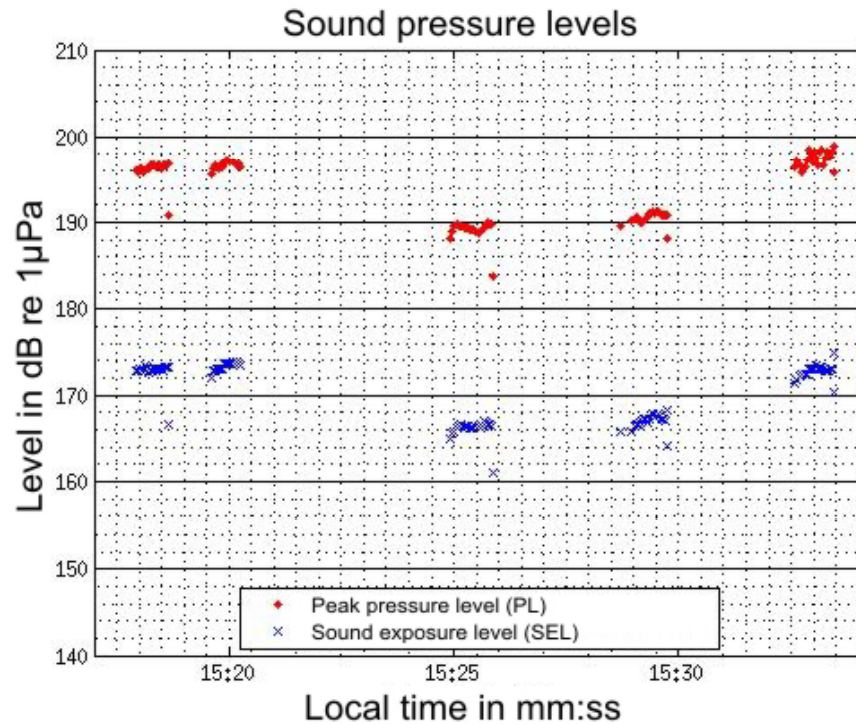
Hydro sound pressure measurements at a distance of

- 245 m south
- 910 m east

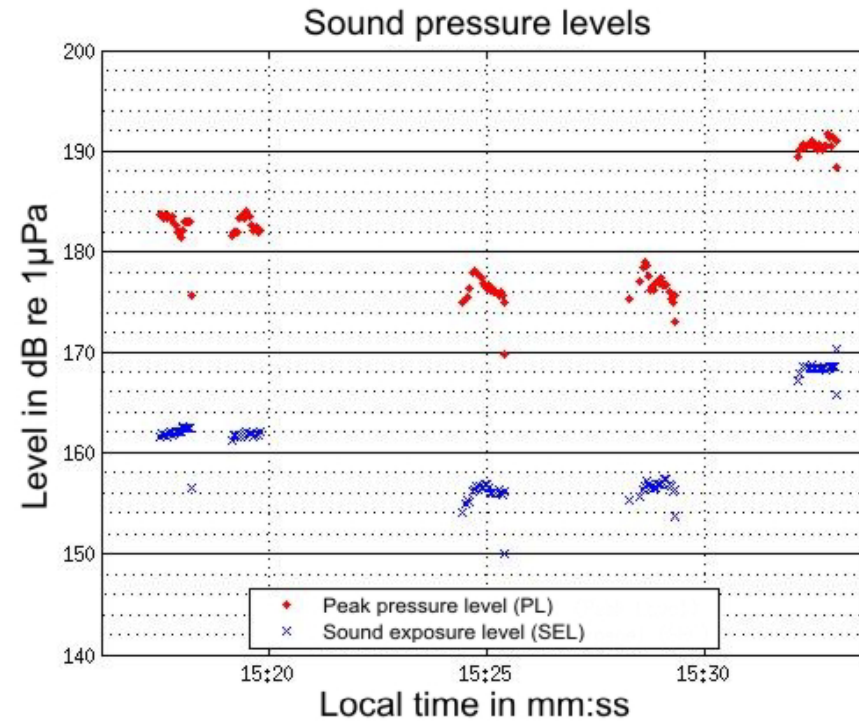
Short test after pile driving with 20 % of piling energy



FINO3



Sound pressure levels at a distance of 245 m



Sound pressure levels at a distance of 910 m

Sound reduction:

Peak Level (PL)

Sound Exposure Level (SEL)

distance of 245 m

9 dB

6 dB

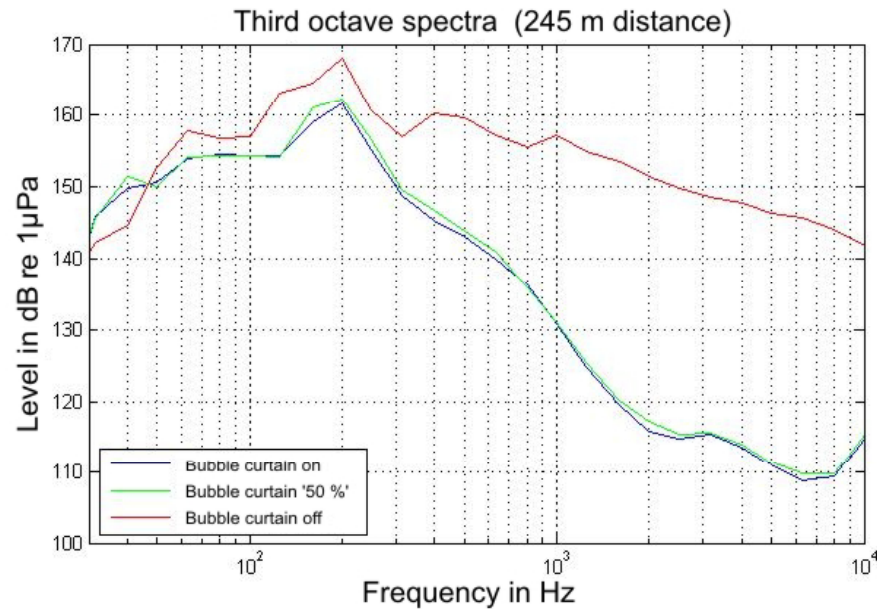
distance of 910 m

14 dB

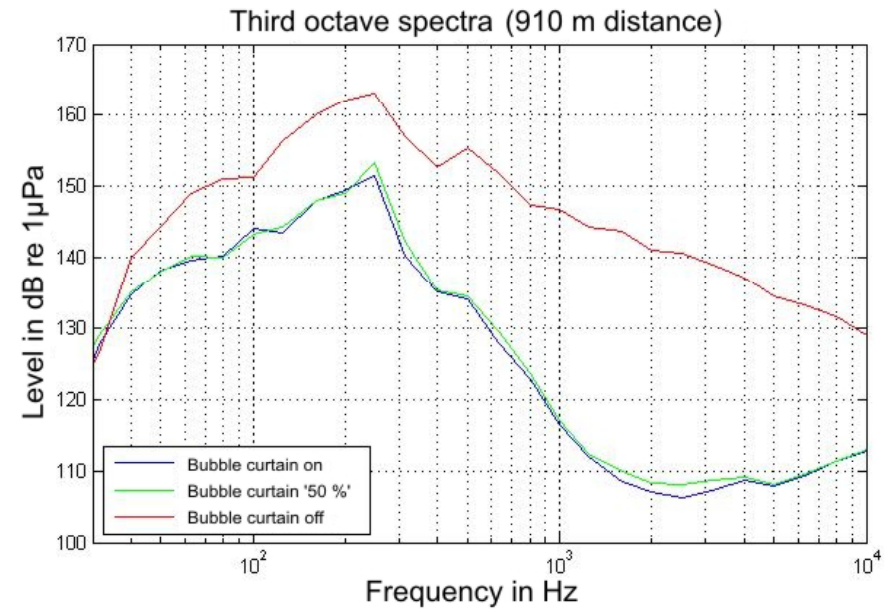
12 dB



FINO3



Third octave spectra at 245 m south of pile



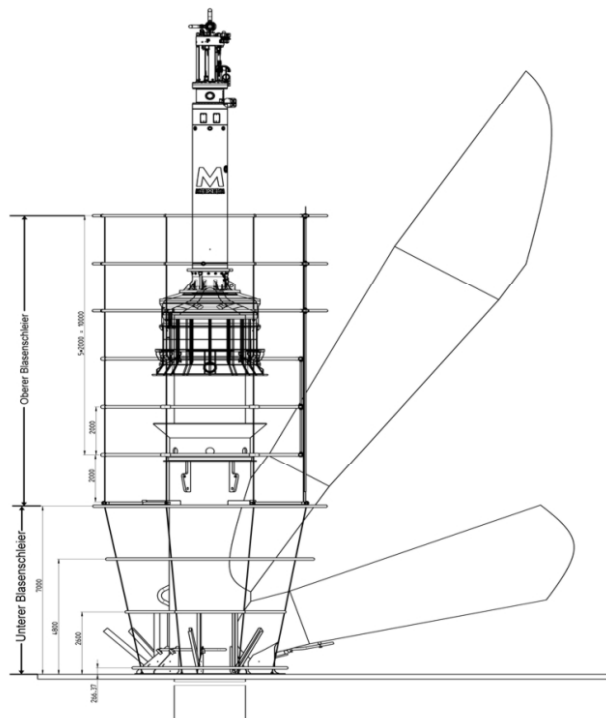
Third octave spectra at 910 m east of pile

- Sound reduction up to 35 dB at frequencies > 1000 Hz
- Maximum energy at about 200 Hz



Alpha ventus

6 tripod structures and 6 jacket structures



Draft of the layered bubble curtain at alpha ventus by MENCK

Water depth of about 28 m

Layered bubble curtains at 2 pile sleeves of tripod AV9

4 layers pre-installed onshore

Mobile system with 6 layers could not be installed offshore because of bad weather conditions

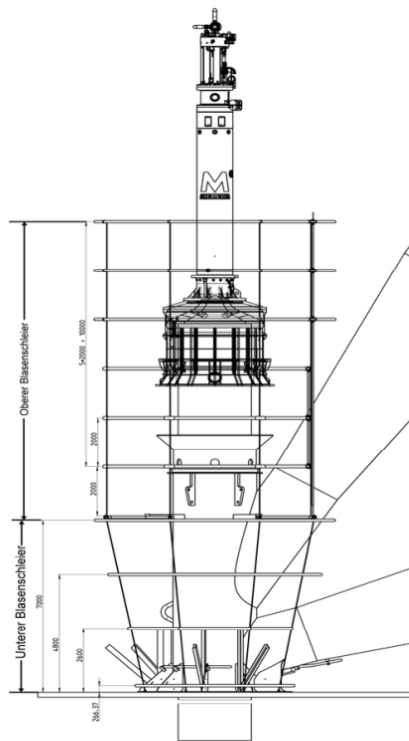
Hydro sound pressure measurements at a distance of

- 500 m west
- 500 m east



Alpha ventus

6 tripod structures and 6 jacket structures



Upper system with 6 layers and lifting bodies in transport frame



Pre-installed lower system with 4 layers

Water depth of about 28 m

Layered bubble curtains at 2 pile sleeves of tripod AV9

4 layers pre-installed onshore

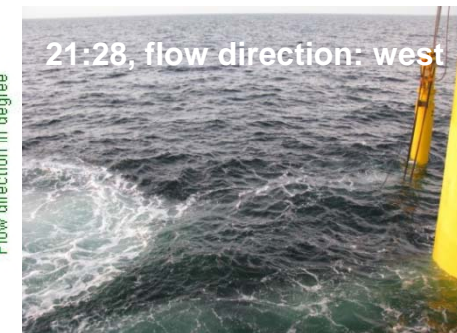
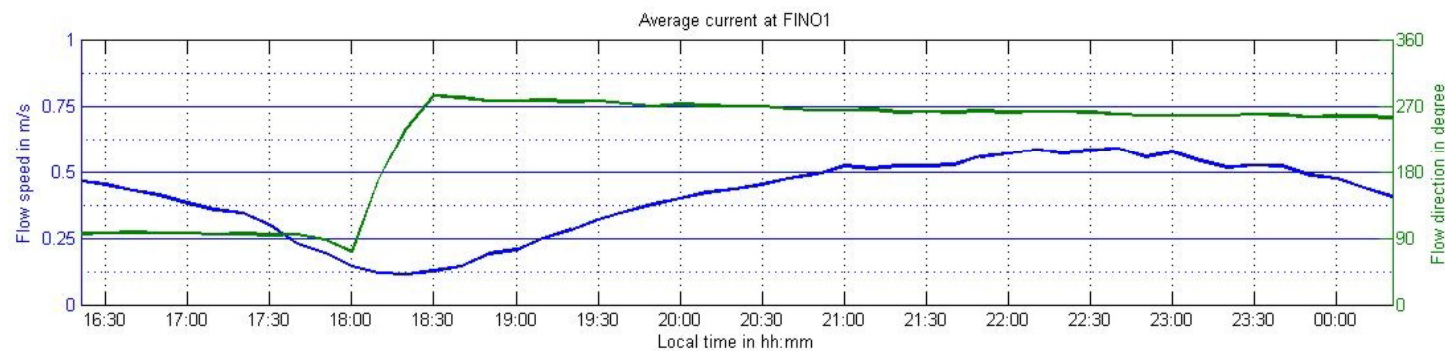
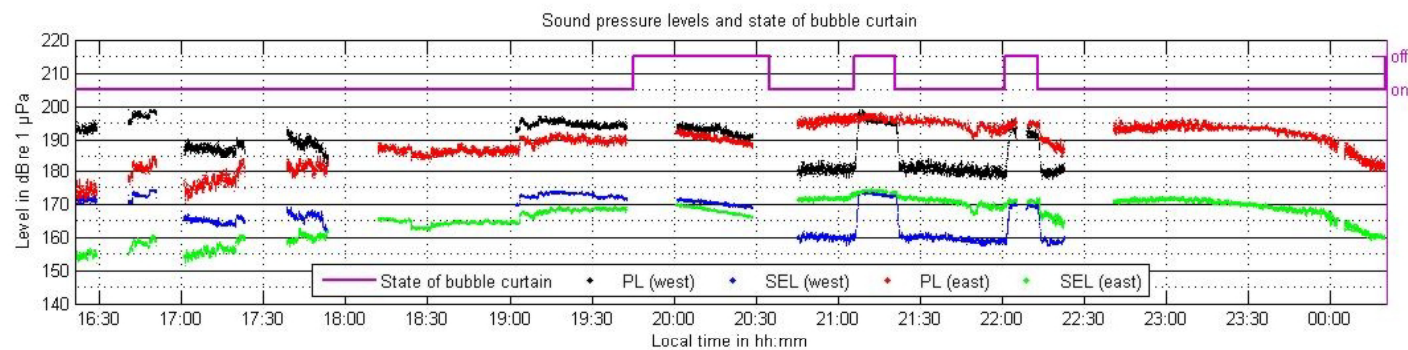
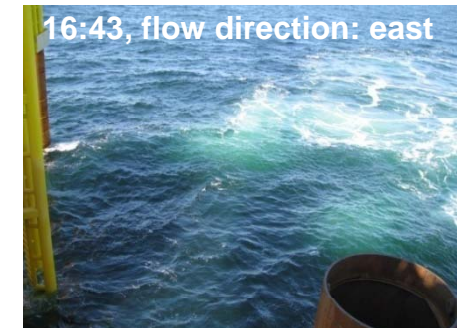
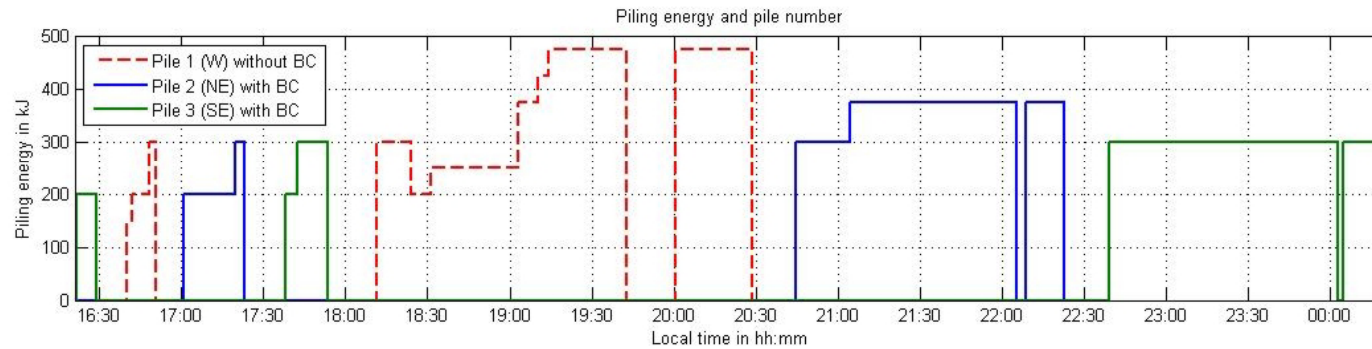
Mobile system with 6 layers could not be installed offshore because of bad weather conditions

Hydro sound pressure measurements at a distance of

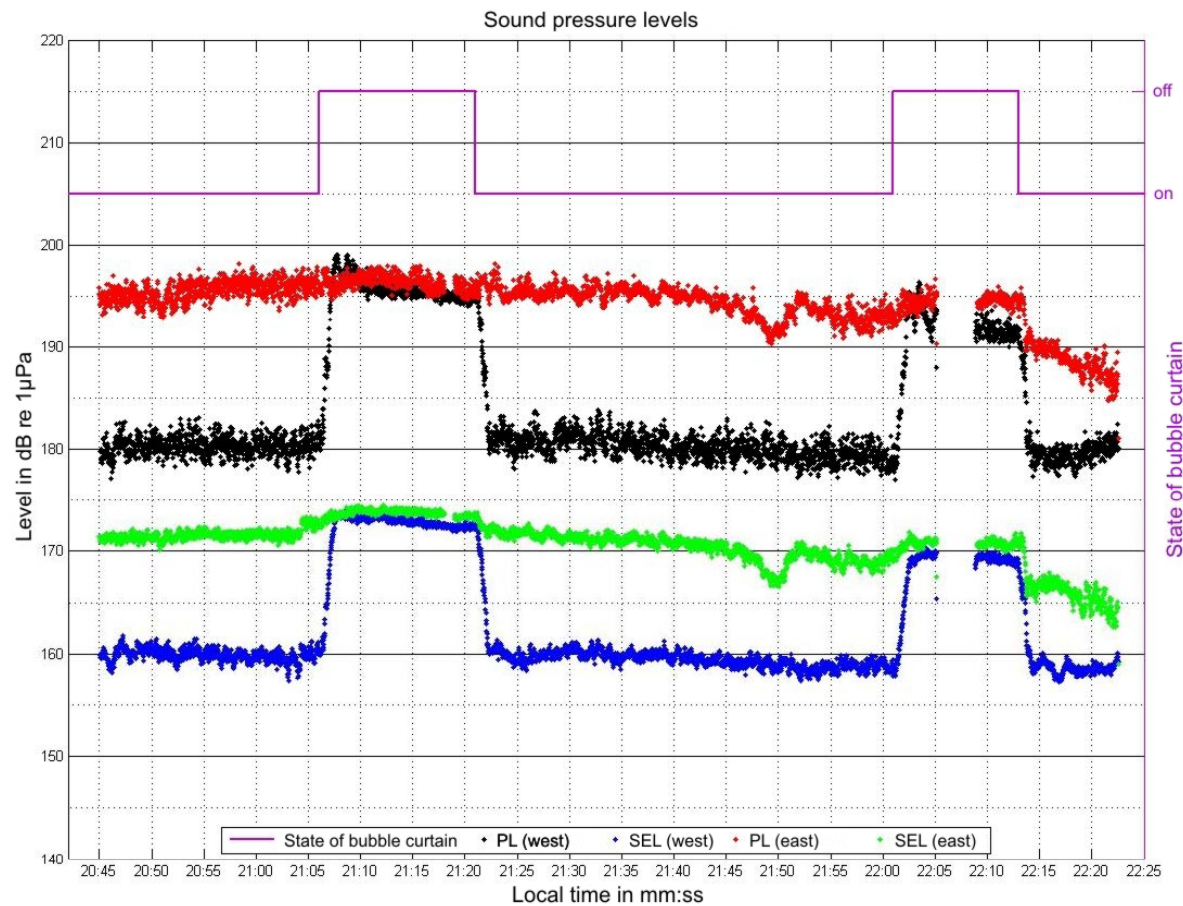
- 500 m west
- 500 m east



Alpha ventus



Alpha ventus



Sound pressure levels and state of bubble curtain

Sound reduction:

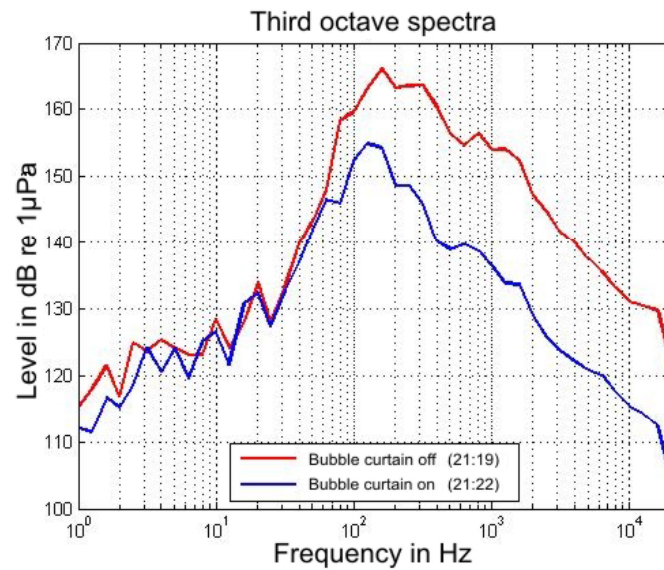
➤ 21:19 – 21:24

	<u>west</u>	<u>east</u>
PL:	14 dB	0 dB
SEL:	13 dB	2 dB

➤ 22:11 – 22:15

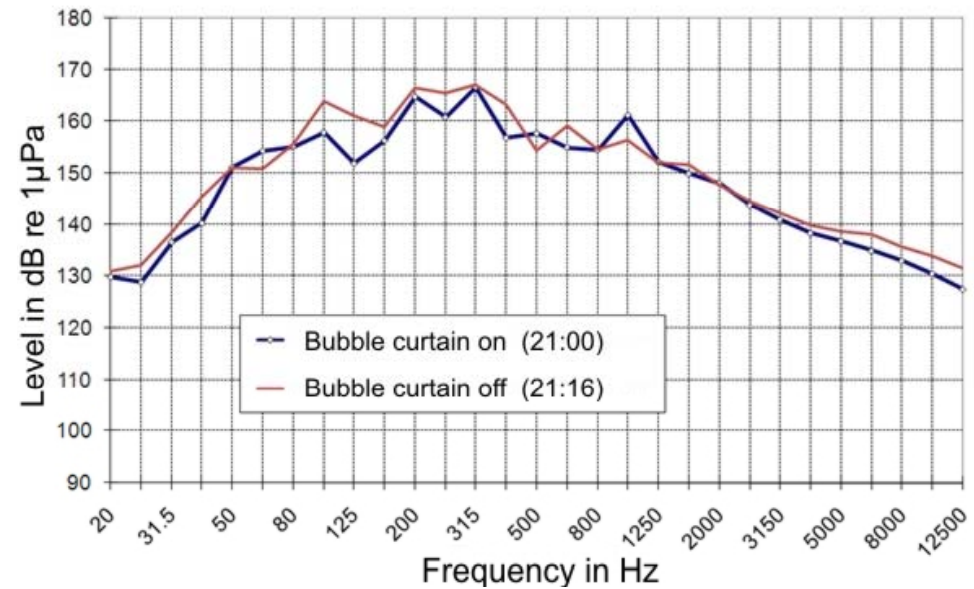
	<u>west</u>	<u>east</u>
PL:	12 dB	5 dB
SEL:	10 dB	4 dB

Alpha ventus



Third octave spectra, position: west

Sound reduction up to 20 dB
at frequencies > 300 Hz
only at west position

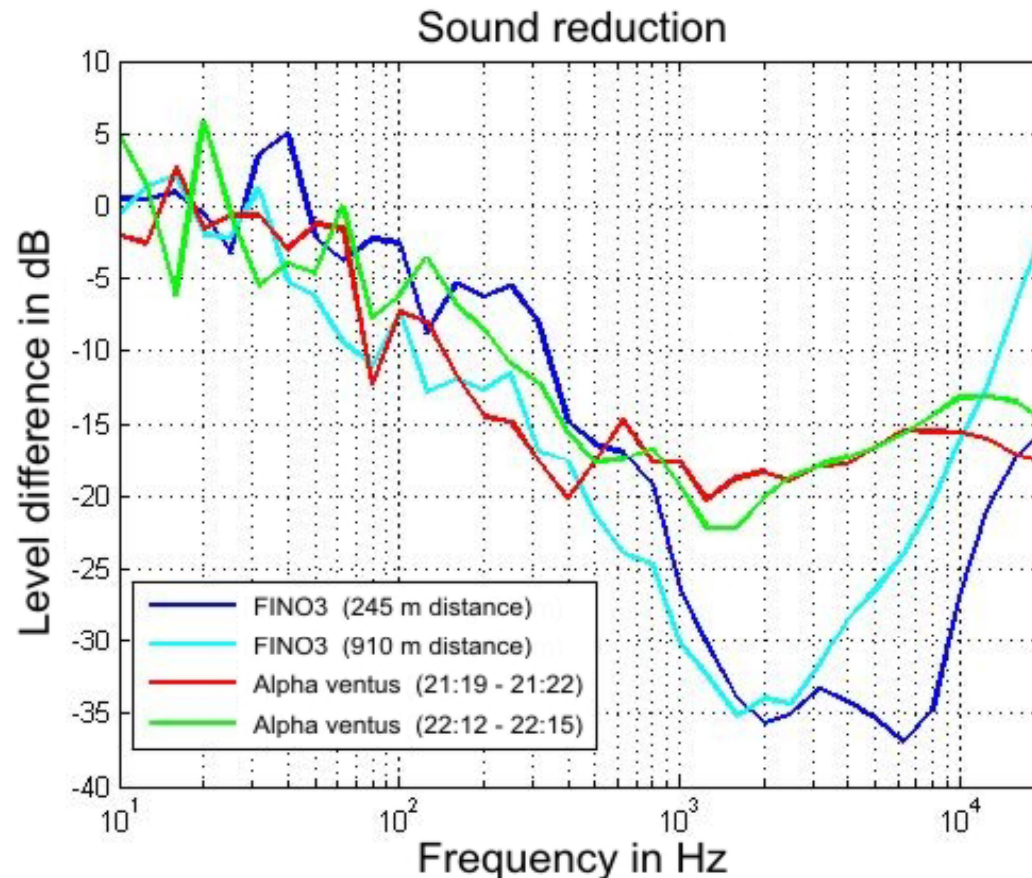


Third octave spectra, position: east (DEWI)

No sound reduction at east position



Comparison of both attempts



Sound reduction at FINO3 and alpha ventus (only west position)

Best mitigation effect
of the bubble curtains
at frequencies > 1000 Hz

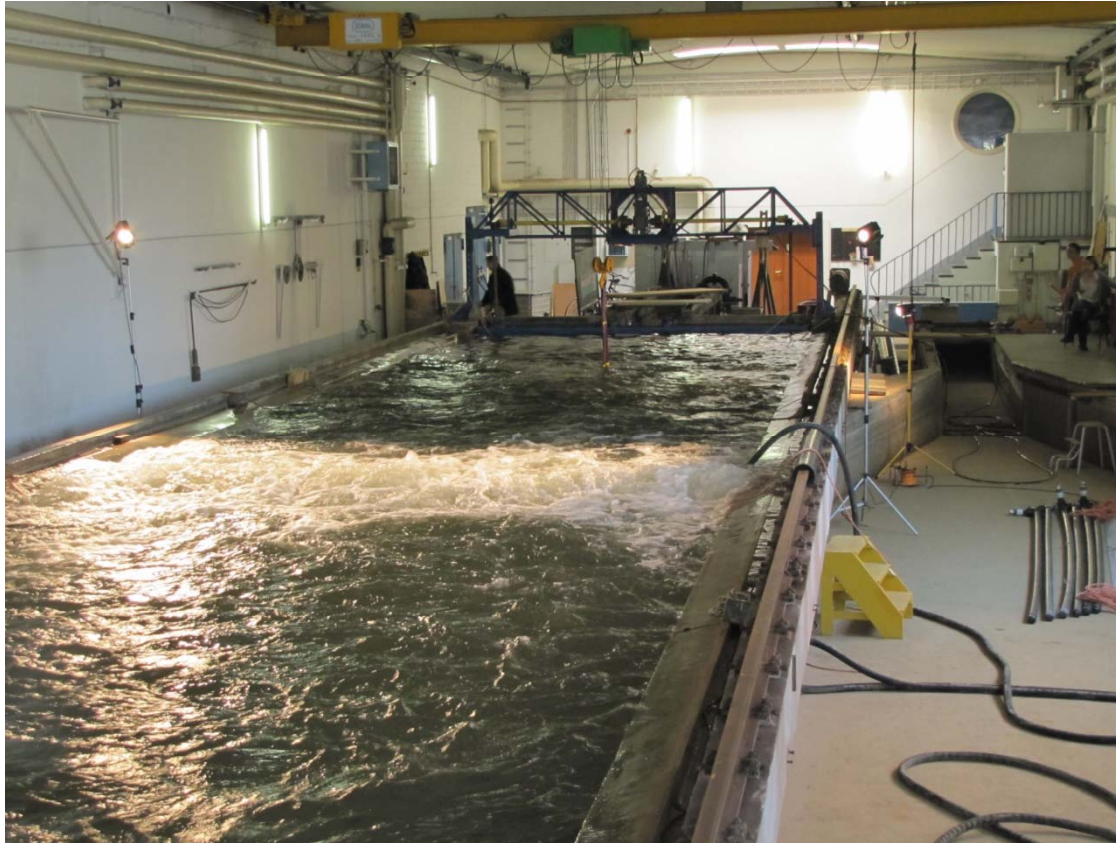
Maximum energy of unmitigated
sound wave
at about 200 Hz

⇒ Shift the range of
highest efficiency
to lower frequencies by:

- creating bigger bubbles
- increasing the air volume



Schall 3



Testing of different pipes to vary the air volume fraction and bubble sizes by varying

- the nozzle size
- the nozzle spacing
- the air pressure

Testing of different membranes which were put on the pipes

Testing of a double bubble curtain (using 2 pipes)

Bubble curtain tests at the Hamburg Ship Model Basin (HSVA)



Schall 3



Testing of 4 pipes and a special hose

Bubble curtain tests with about 3 ms time without reflections

Use of CW-signals

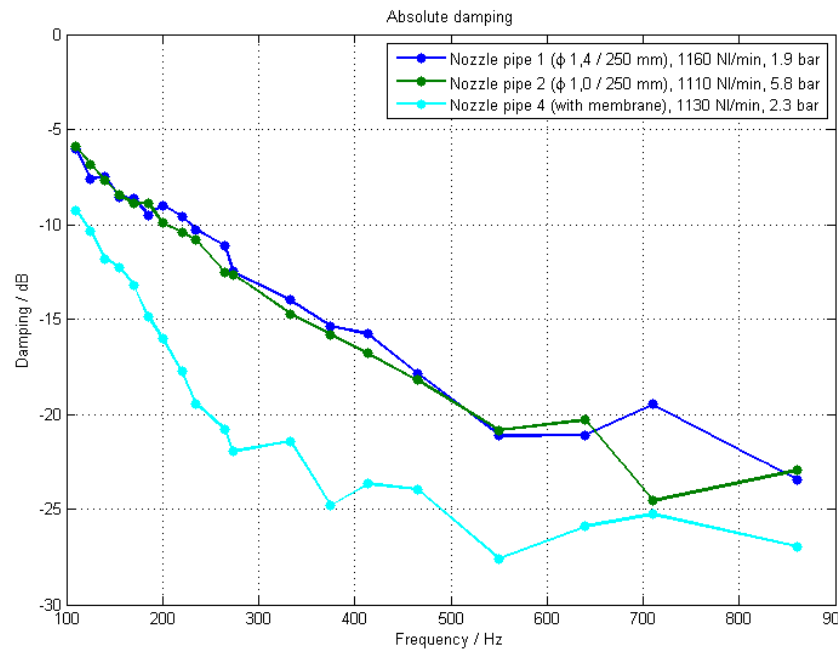
Variation of

- signal frequency
- air pressure and volume

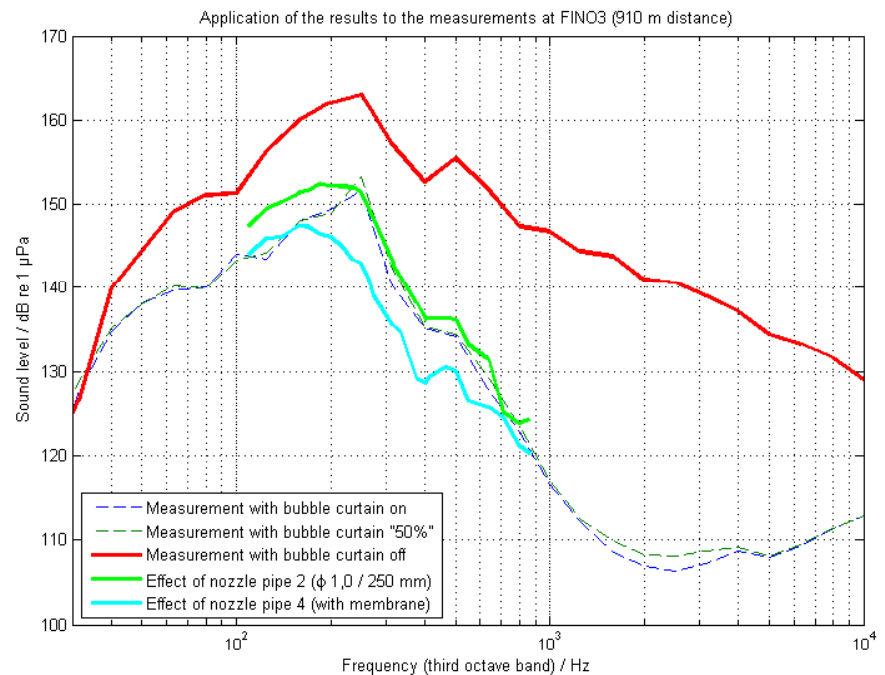
Bubble curtain tests in a lake near Bremen (Atlas Elektronik)



Schall 3



Results and comparison of systems



Application of the results to the measurements of FINO3



Summary and conclusions

FINO 3:

- Distance 910 m: Clear mitigation effect (12 dB for SEL, 14 dB for L_{Peak})
- Distance 245 m: reduced mitigation effect (6 dB for SEL, 9 dB for L_{peak})
- No time delay at construction site
- Prototype tested was too expensive

Alpha Ventus:

- Good results (13 dB for SEL, 14 dB for L_{Peak}) direction “with the current” (west position)
- At the same time: nearly no effect at east position
- Time delay at construction site
- Prototype tested needs to be improved and further developed for practical use

Schall 3:

- Promising results for a new tube system coated with a special membrane (test facility)
- Offshore tests needed to prove the results

