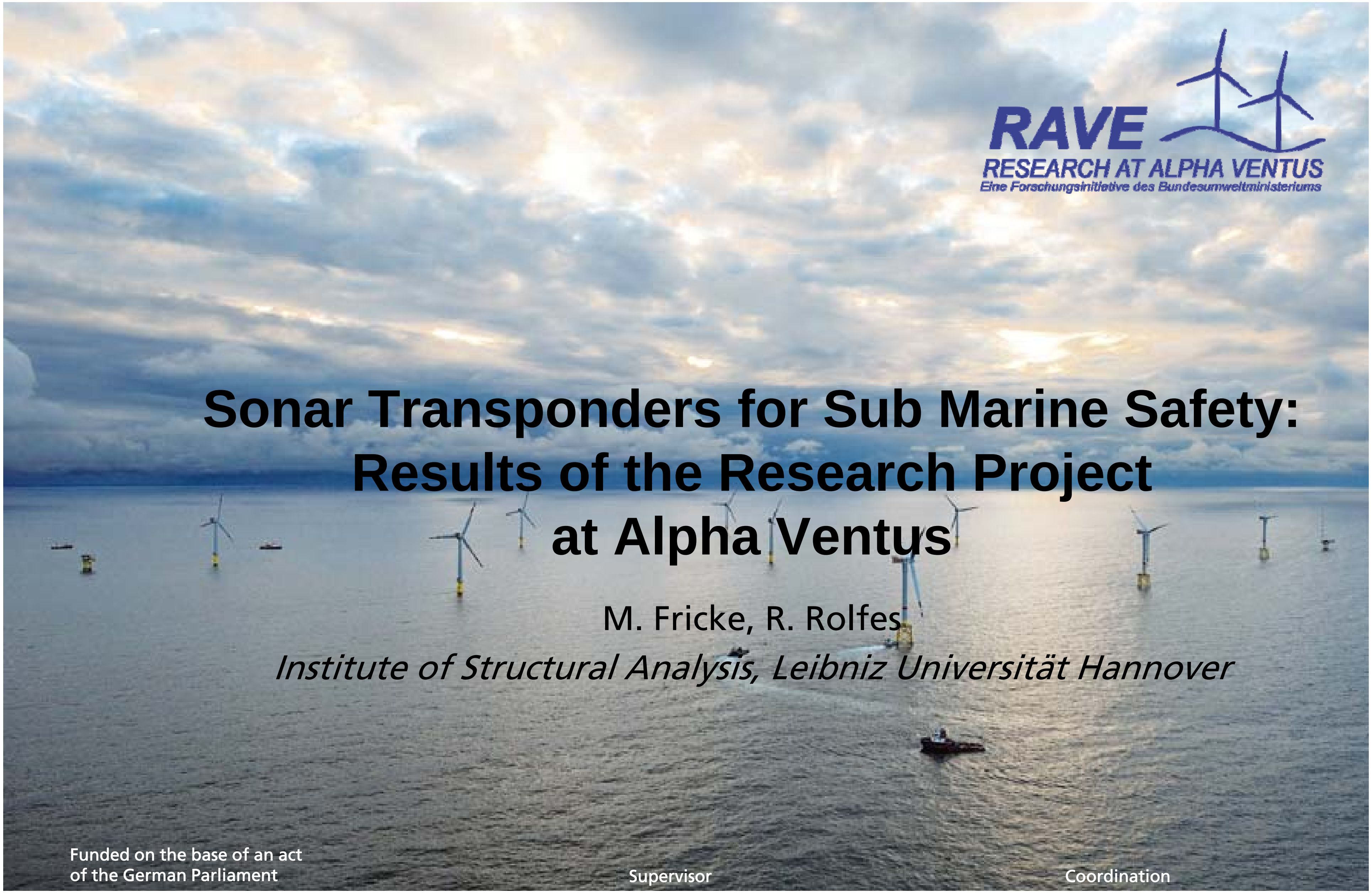

Sonar Transponders for Sub Marine Safety: Results of the Research Project at Alpha Ventus

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Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit

Supervisor

PtJ Projektträger Jülich Forschungszentrum Jülich

Coordination

Fraunhofer IWES

Projekt Outline

- **Project Title:** „Investigation of Sonar Transponders for Offshore Wind Farms and Technical Integration to an Overall Concept“
- **Duration:** 01/2009 - 03/2011
- **Coordination:** Institute of Structural Analysis (ISD), Leibniz Universität Hannover
- **Project Partners:**

THALES Instruments GmbH, Oldenburg

BioConsult SH GmbH & Co.KG, Husum

ITAP GmbH - Institut für technische und angewandte Physik GmbH, Oldenburg

DEWI GmbH - Deutsches Windenergie-Institut, Wilhelmshaven

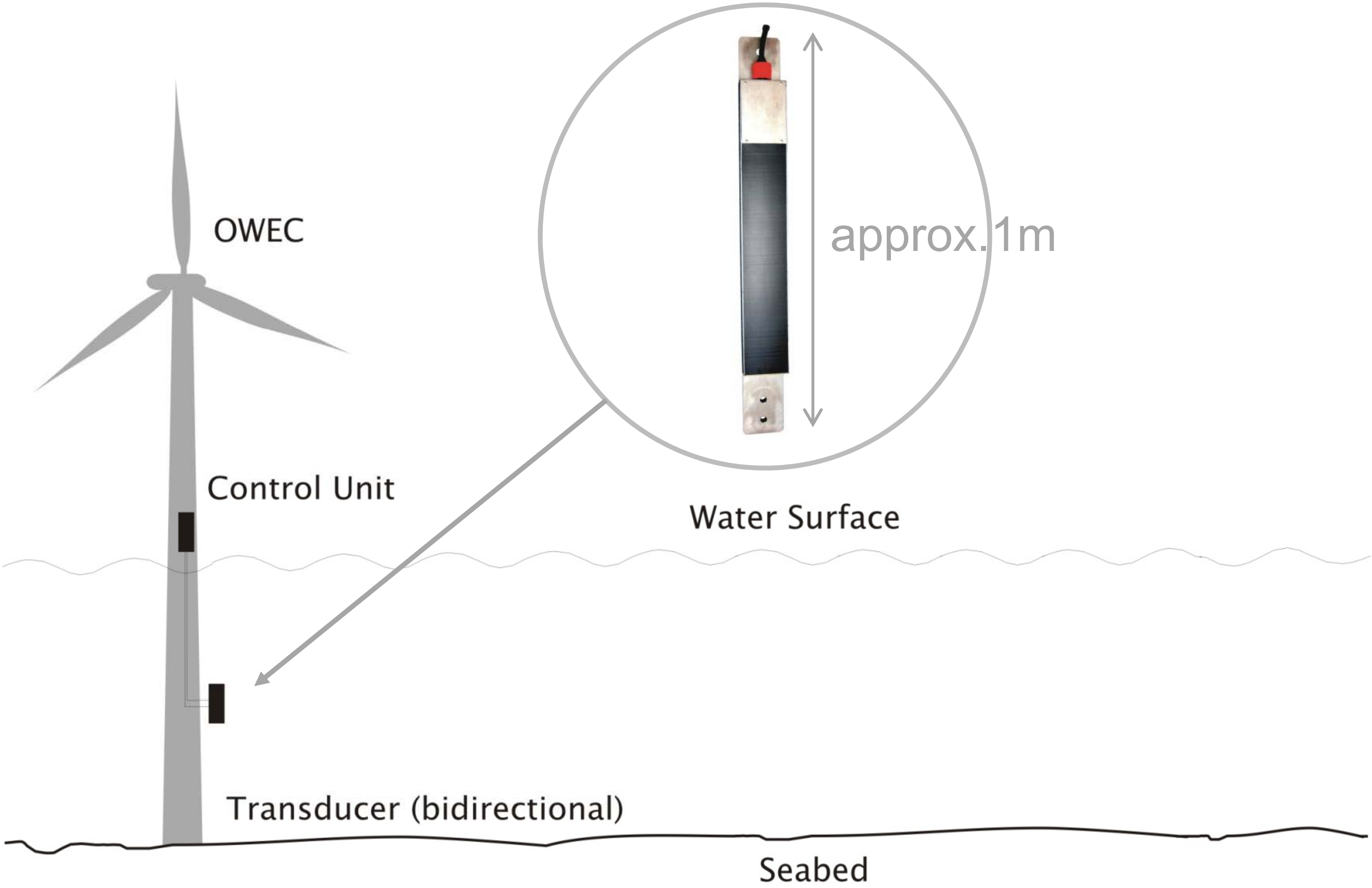
Overview

- Background / motivation
- System design and operating principle
- Signal characteristics of the warning signal
- Acoustic source and propagation modeling
- Measurements at alpha ventus
- Evaluation of results

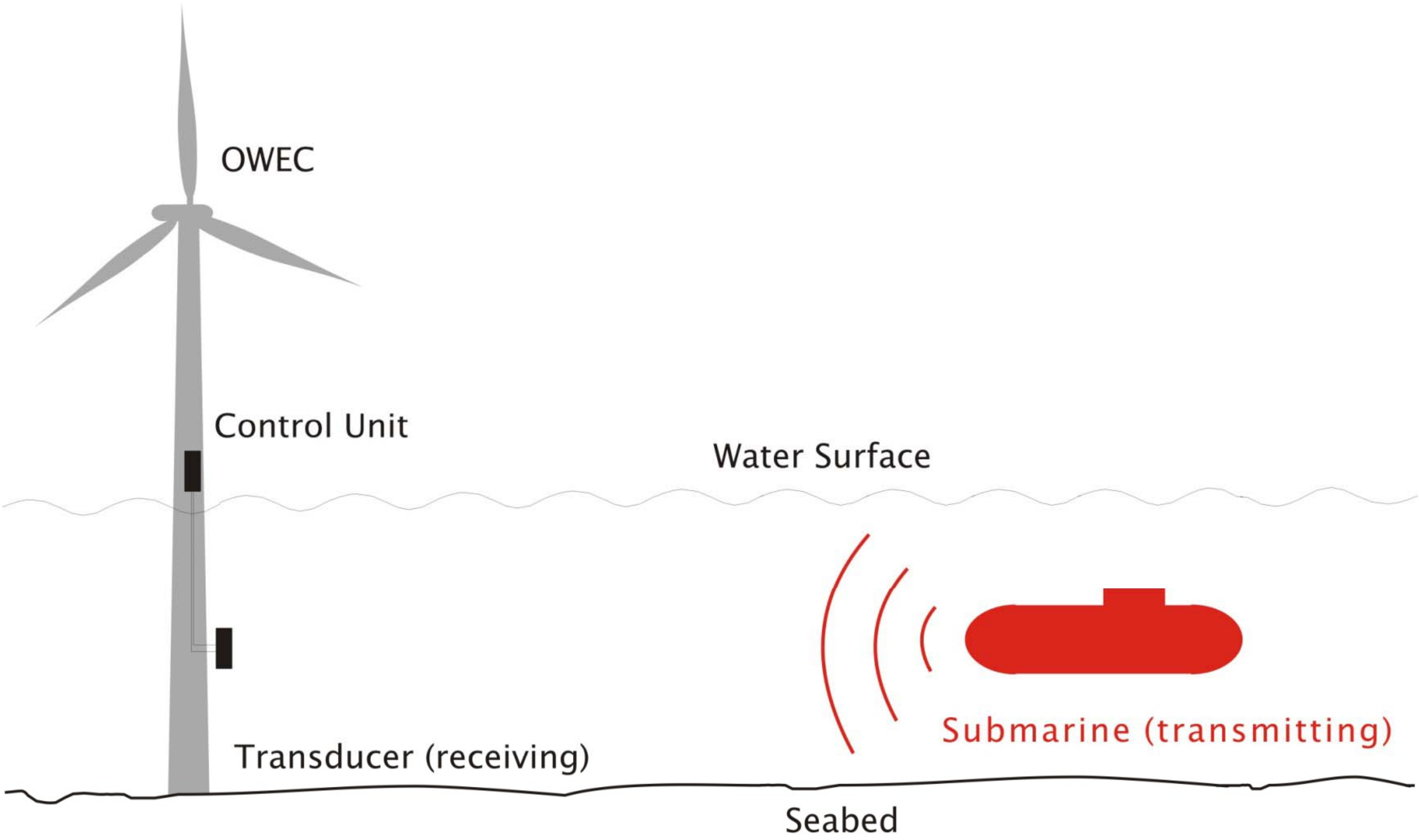
Background / Motivation

- Offshore wind energy converters (OWECs) are artificial underwater obstacles for submarines.
- The large number of projected OWECs in the German Exclusive Economic Zone (EEZ) implicates an increasing risk of collisions between submarines and OWECs .
- Therefore the approval procedure of offshore wind farms implies the operation of sonar transponders for acoustic underwater identification.
- The deployment of sonar transponder allows for
  - *availability even in case of a radar malfunction,*
  - *an event-driven acoustic warning of submarines,*
  - *minimization of the impact on marine mammals.*

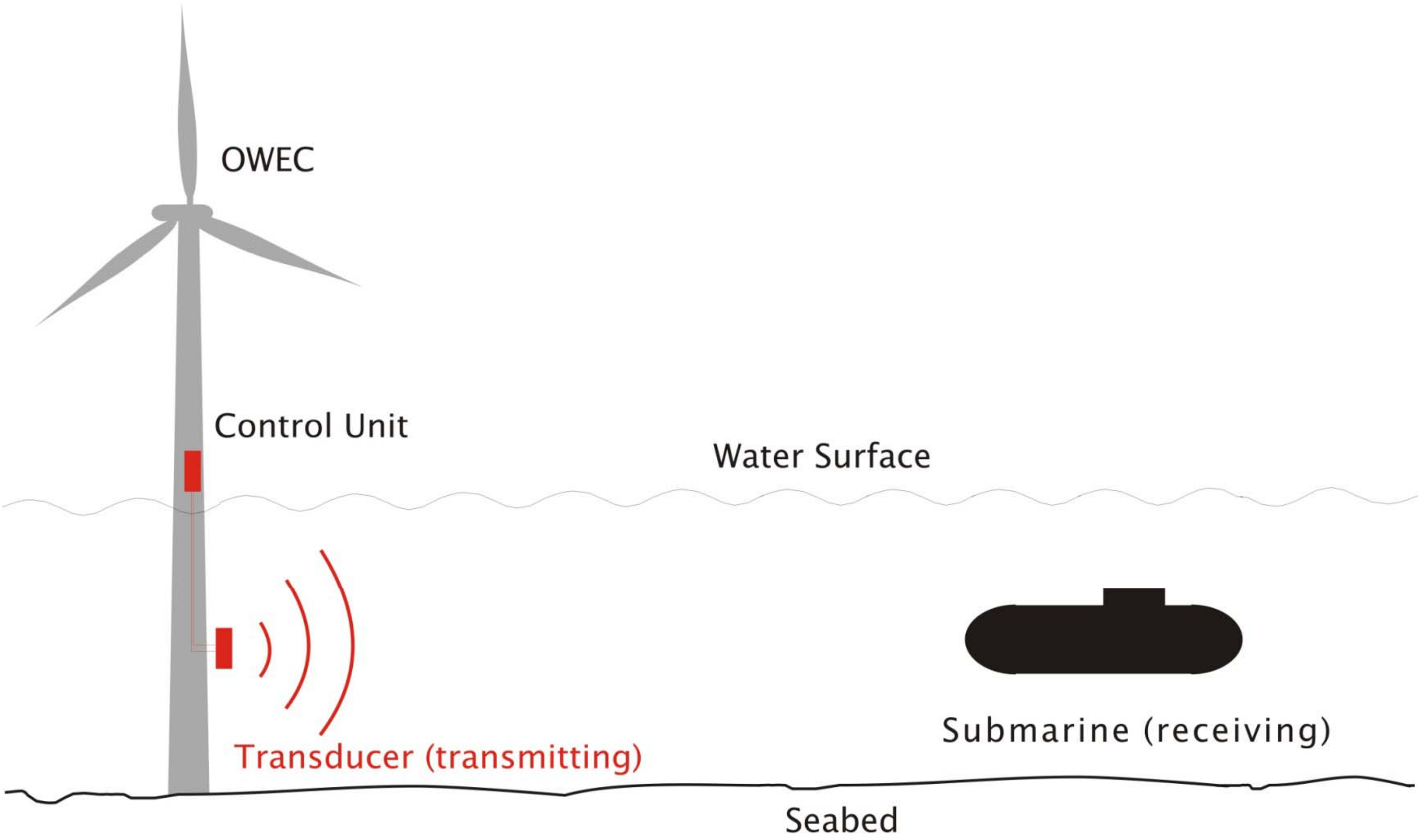
System design



Operating principle

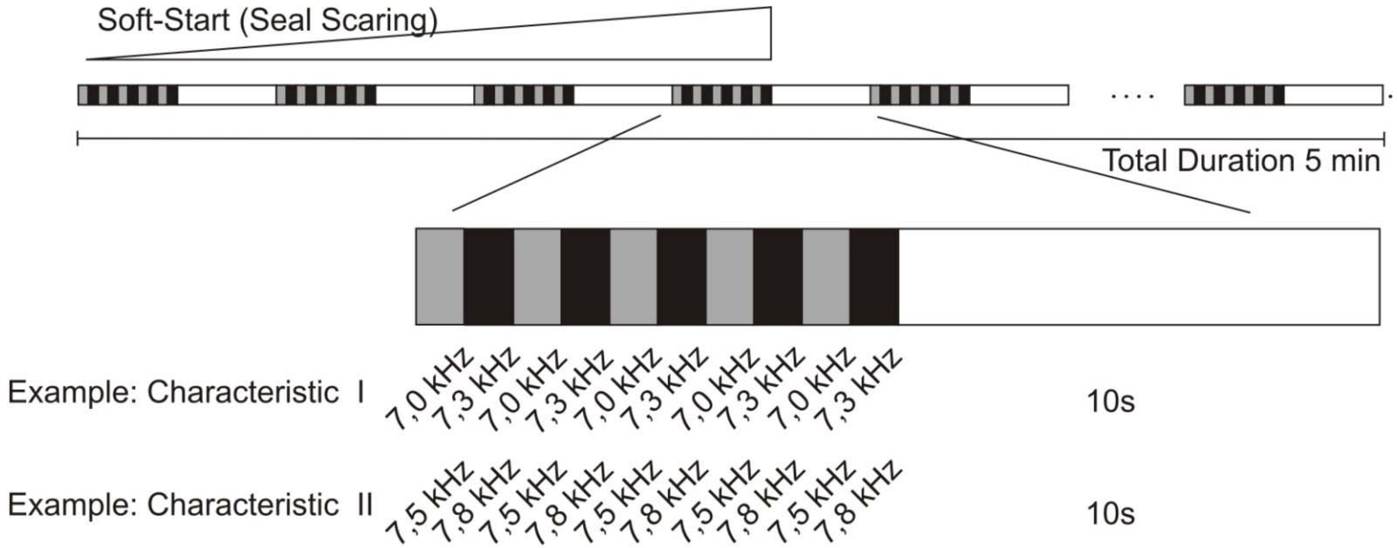


Operating principle



Signal characteristics

- Alternating continuous wave sequence at 7,0/7,3 kHz (characteristic I) and 7,5/7,8 kHz (characteristic II) respectively in 10s segments, each followed by 10s of silence [FWG 2004].
- Integration of a soft start period to allow for escape of marine mammals.



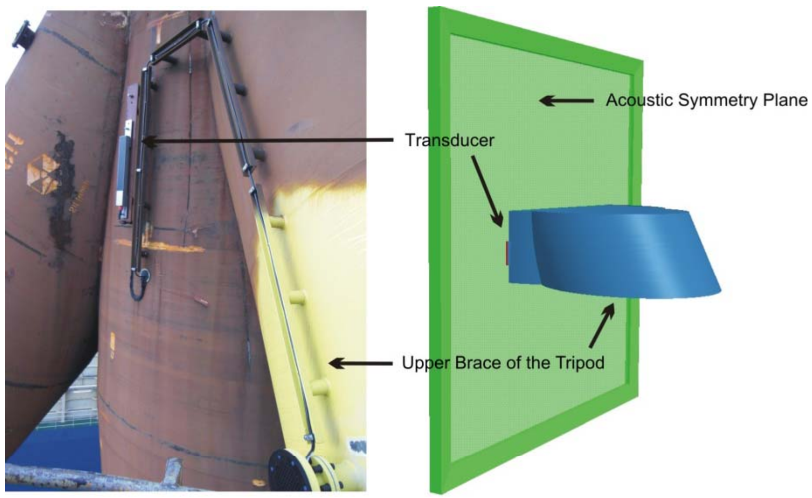
Acoustic source modeling

- Separate modeling of source and propagation path using a hybrid approach of the boundary elements method and ray tracing
- Modeling of both the transducer and the foundation to account for diffraction and reflection effects
- Symmetric modeling for computational efficiency

$$f \approx 7{,}5\,kHz \Rightarrow \lambda \approx 0{,}2\,m$$

$$a_{Transduer} \approx 1m \Rightarrow ka_{Transducer} \approx 30$$

$$a_{Tripod} \approx 6m \Rightarrow ka_{Tripod} \approx 190$$

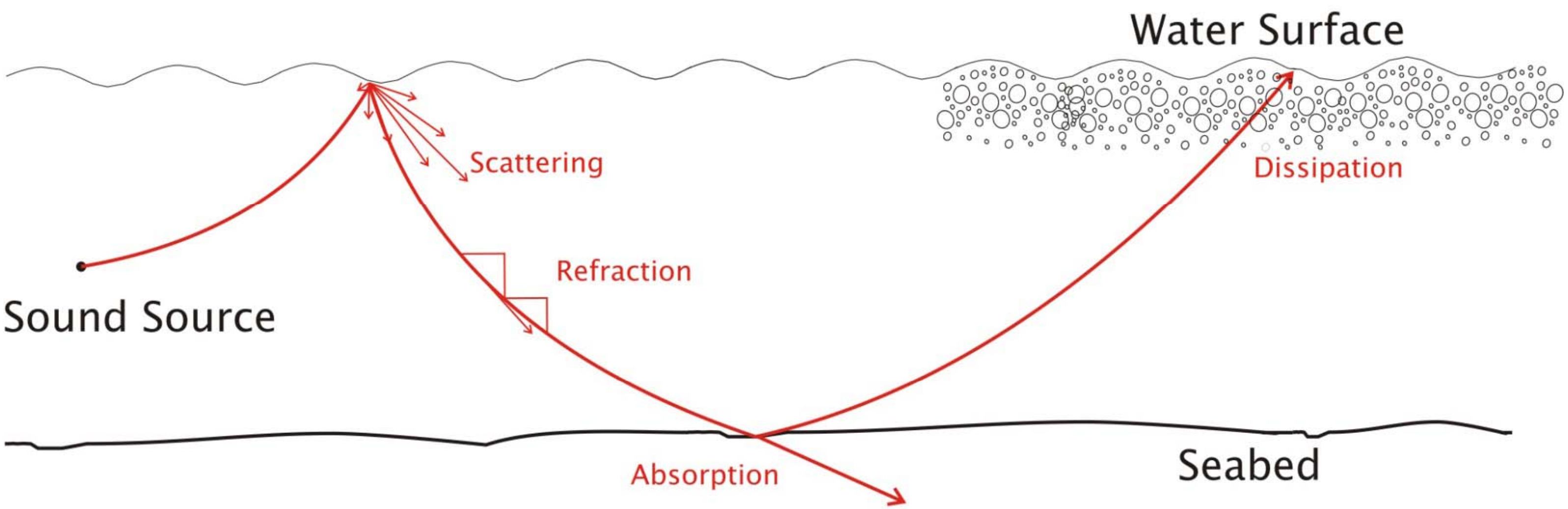


(a) (b)

OWEC AV10 (Tripod) (source: Thales 2009)

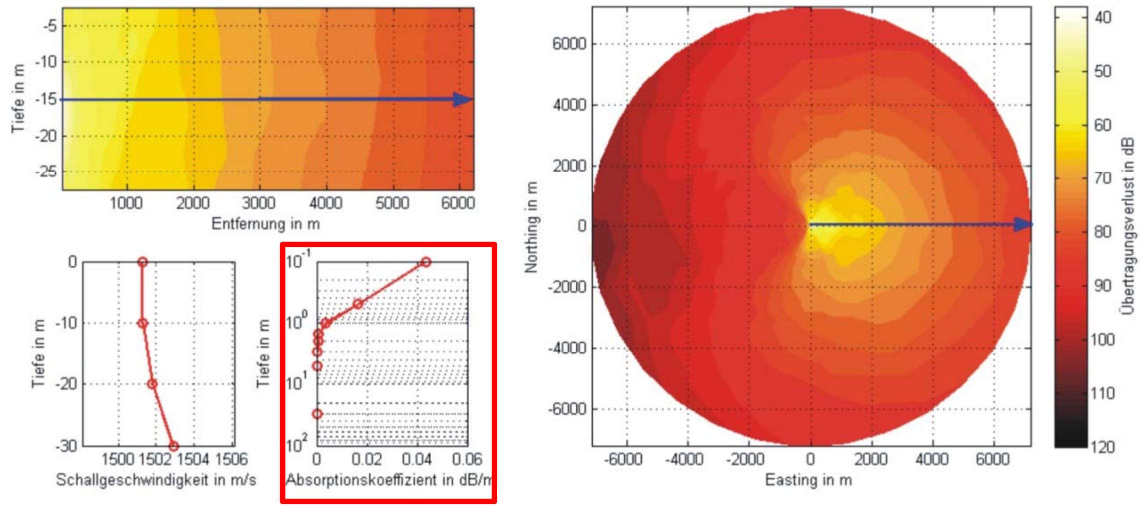
Acoustic propagation modeling

- Propagation modeling using 3D ray tracing including effects of
  - *Scattering due to swell (according to [Brekhovskikh et al. 1982])*
  - *Continuous refraction due to the layered sound speed profile (Runge-Kutta-Integration)*
  - *Absorption at the water-bottom-interface*
  - *Extinction/dissipation in the near-surface region caused by wind-driven air bubbles (according to [Ainslie 2005])*

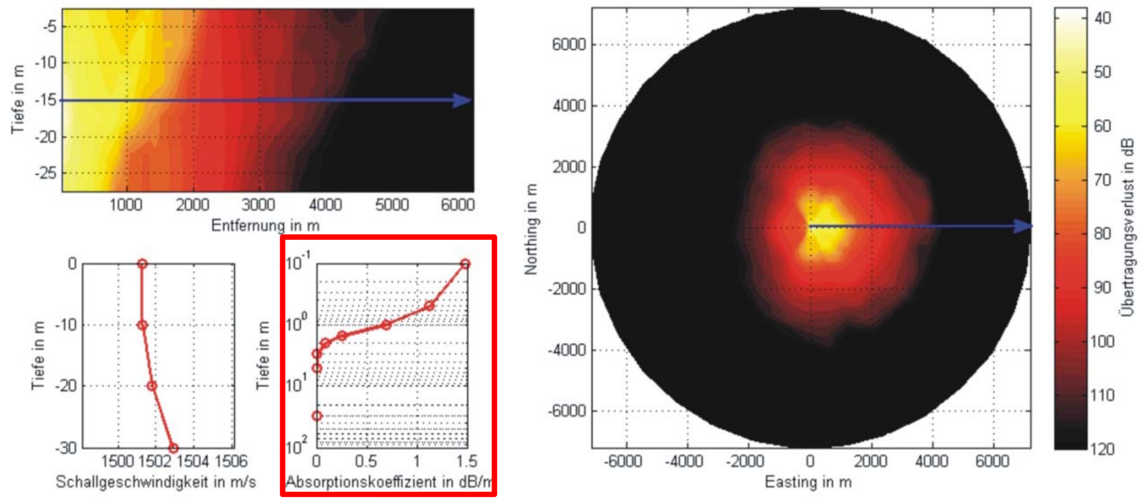


Exemplary results

- Wind speed: 5 m/s
- Typical sound speed profile „October“ [FWG 2004]

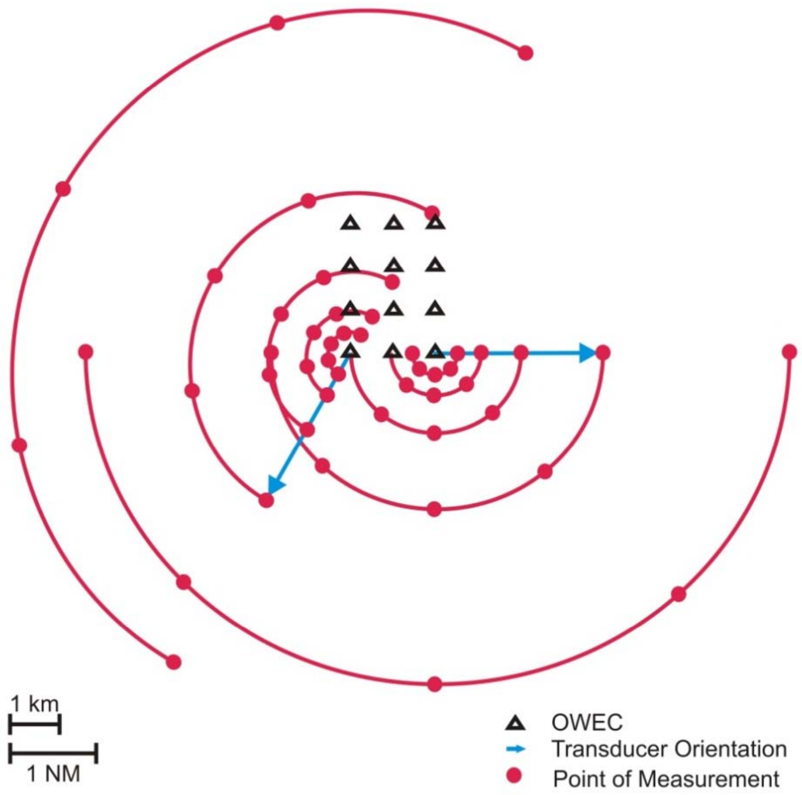


- Wind speed: 15 m/s
- Typical sound speed profile „October“ [FWG 2004]

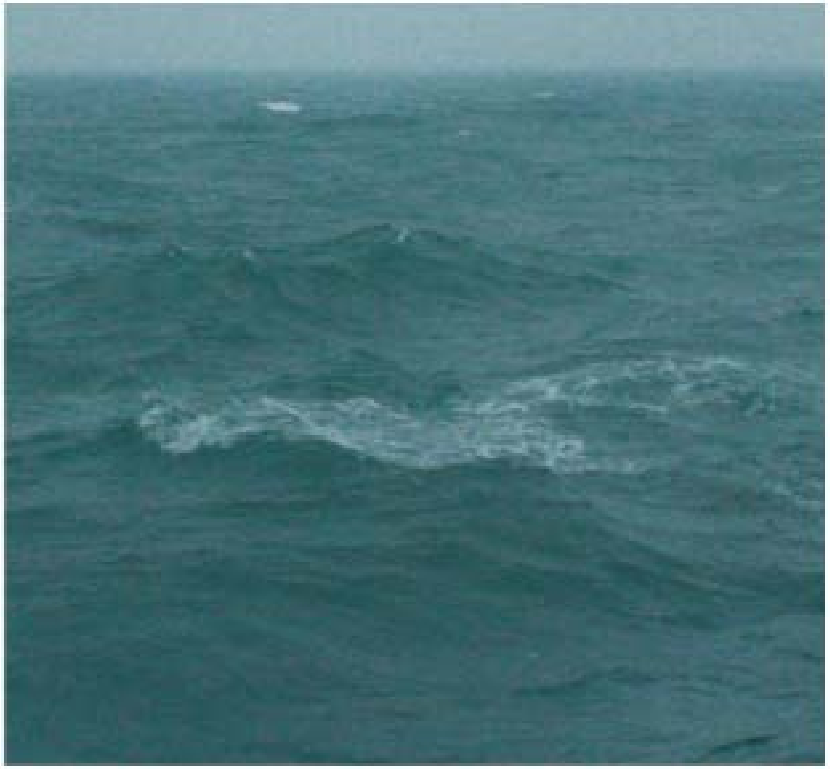


Measurements at *alpha ventus*

- Installation of 2 transponders at AV10 and AV12
- Measurements in 5 directions and 5 distances under 2 different weather conditions (wind speed <5m/s and ~10m/s respectively)
- R = 450, 900, 1800, 3600, 7200 m
- Φ = 0°, 45°, 90°, 135°,180°
- Use of the symmetry of the source to reduce the number of measurement points (semi circular arrangement of measurement points)



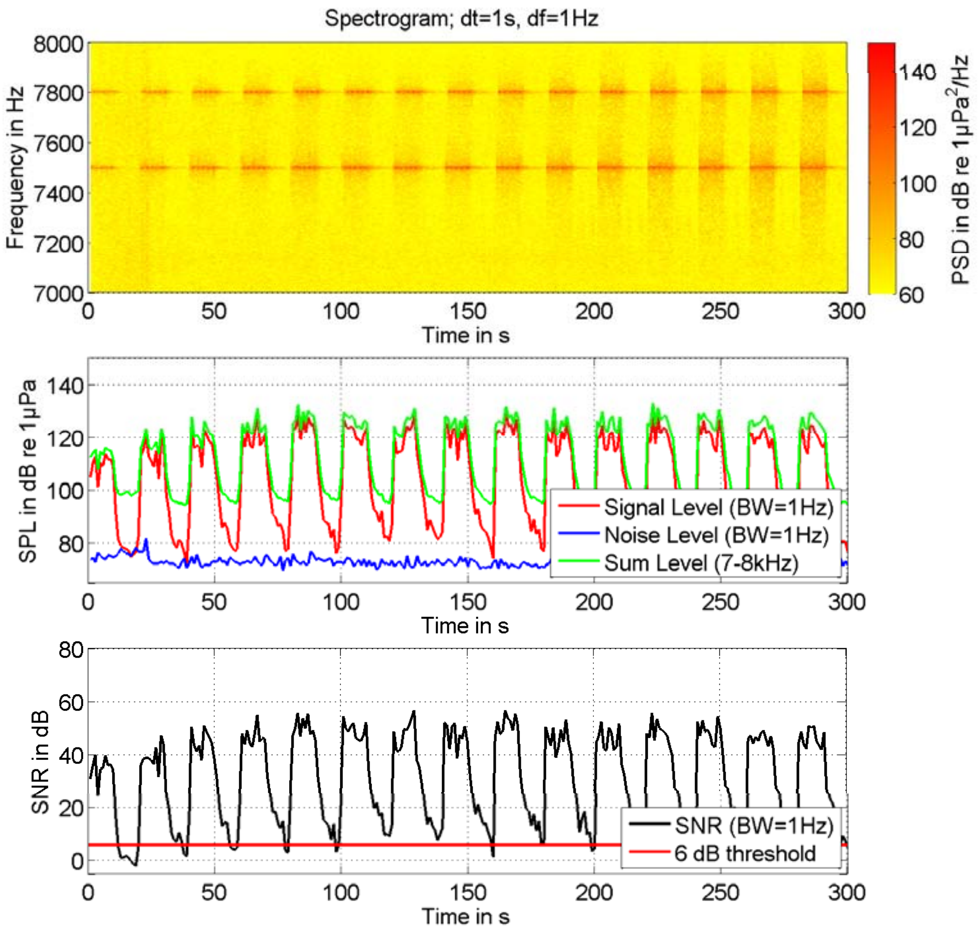
Measurements at *alpha ventus*



Measurement 10/2010: $v_{wind} < 5\ m/s$ Measurement 02/2011: $v_{wind} \approx 10\ m/s$

Signal post-processing

- Bandpass filtering in the range of [6.9...8.0 kHz]
- Extraction of the warning sequence using cross correlation analysis
- Shorttime-Fourier-Transformation with dt=1s und df=1Hz
- Level averaging for signal level, noise level and signal excess (SNR)

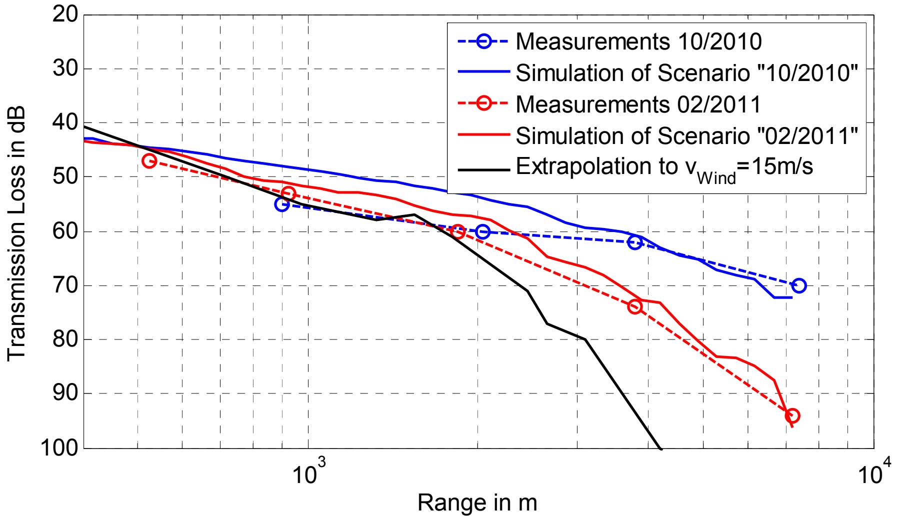


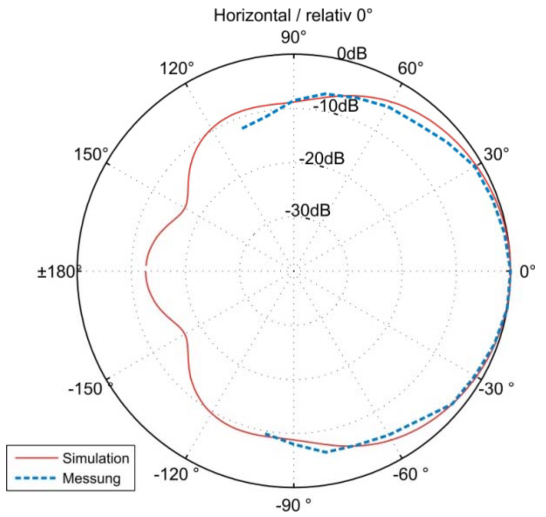
Relative Position: R = 843*m*; ϕ = 125°

Mean Values (BW=1Hz):
Noise Level NL = 73 dB re 1 µPa
Signal Level SS = 123 dB re 1 µPa
Signal Excess SNR = 50 dB

Validation

- Very good consistency between measured and simulated results concerning both range- and angle-dependency
- Extrapolation of the results to a wind speed of 15m/s based on the numerical model shows a transmission loss of 100dB at a distance of 4 km.
- Good approximation of the directivity of the transducer with respect to the forward half space

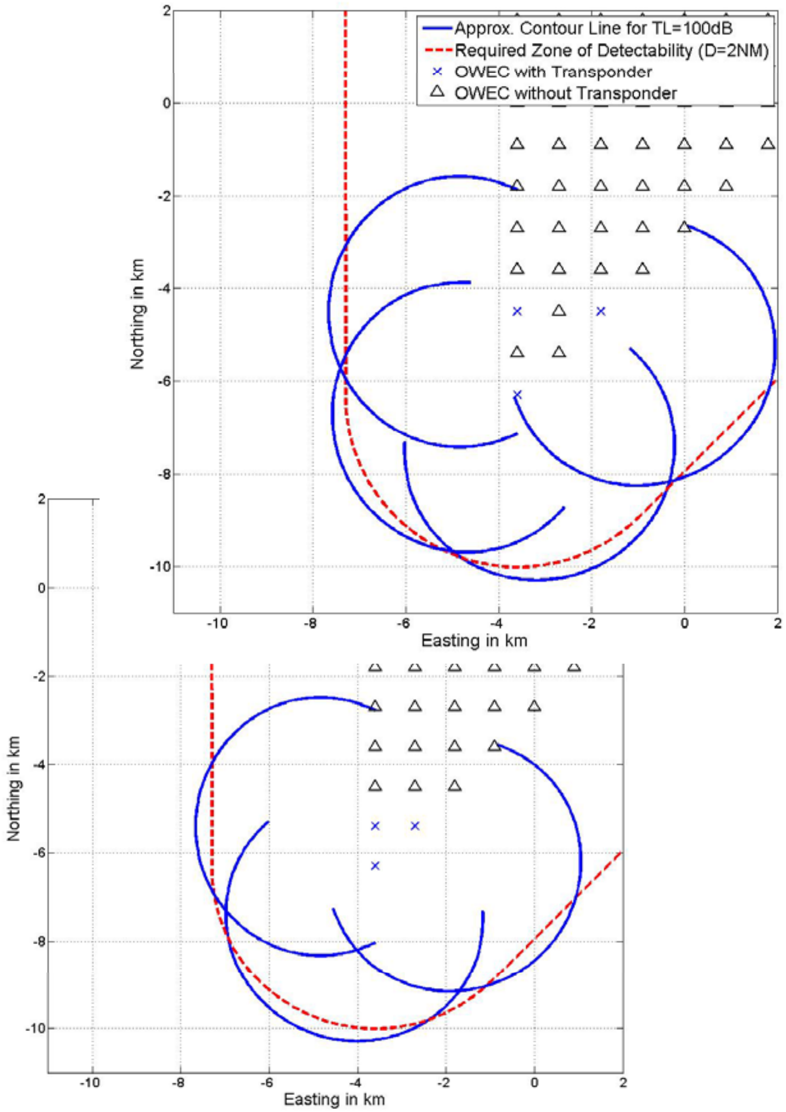




Exemplary setup

- Application of the results to an exemplary wind farm layout using the 100dB contour lines of each transponder (blue line)
- Examination of the coverage of the required zone of detectability (2NM, red line)
- Evaluation of different transponder setups and wind farm layouts

A general specification or instruction for the complete transponder configuration for an arbitrary wind farm layout is not possible; each wind farm has to be handled as an individual case.



Summary of results

- The comparison of measured and simulated results shows that the developed model is well-suited.
- A transmission loss of about 100 dB at a distance of 4 km is of realistic magnitude assuming a wind speed of 15 m/s and a wave height of 1.5m.
- A source level of 200dB re1µPa in 1m is required assuming a noise level of 90 dB re1µPa in the frequency range [7,0..8,1 kHz].
- A general specification or instruction for the complete transponder configuration for an arbitrary wind farm layout is not possible; each wind farm has to be handled as an individual case.
- Due to the event-driven and rare activation of sonar transponders it is likely that no negative impact on marine mammals will occur.

Thank you for your attention!

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