

Noise from offshore wind turbines and effects on the marine environment

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Introduction

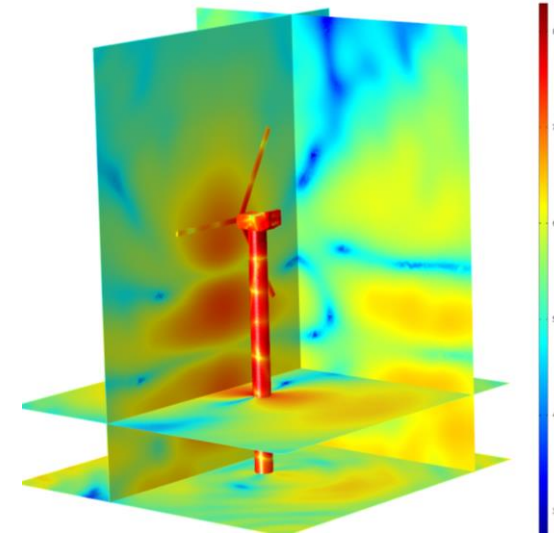
- Offshore wind farms produce noise that enters the marine environment.
- This noise can be heard by marine species and it may affect their behaviour
- Marine Scotland are the regulatory authority for building wind farms in Scottish waters and must consider their environmental impact
- Turbines are placed on a variety of foundations – how does this affect noise output and environmental impact?



Xi Engineering Consultants

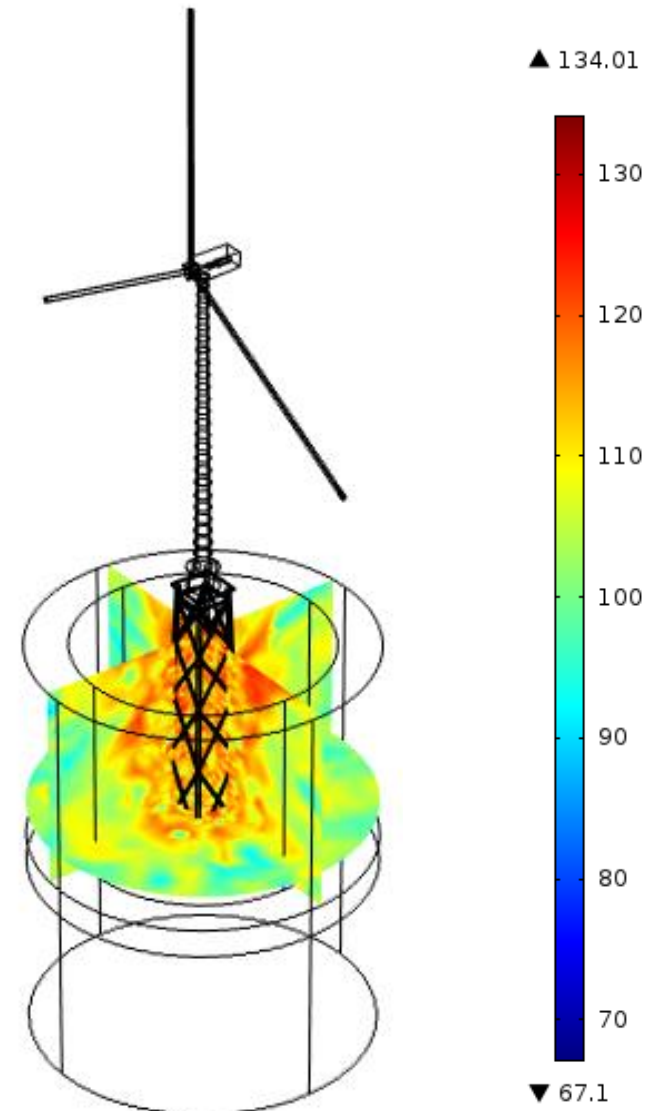


- Xi are based in Edinburgh and have clients throughout Europe and North America
- Our focus is vibration. We have provided vibration solutions to many sectors including:
 - Onshore wind and tidal stream turbines
 - Oil and gas
 - Superconductor industries
 - Health and occupational safety
 - Residential planning and construction
 - Military
- Xi are COMSOL Certified Consultants

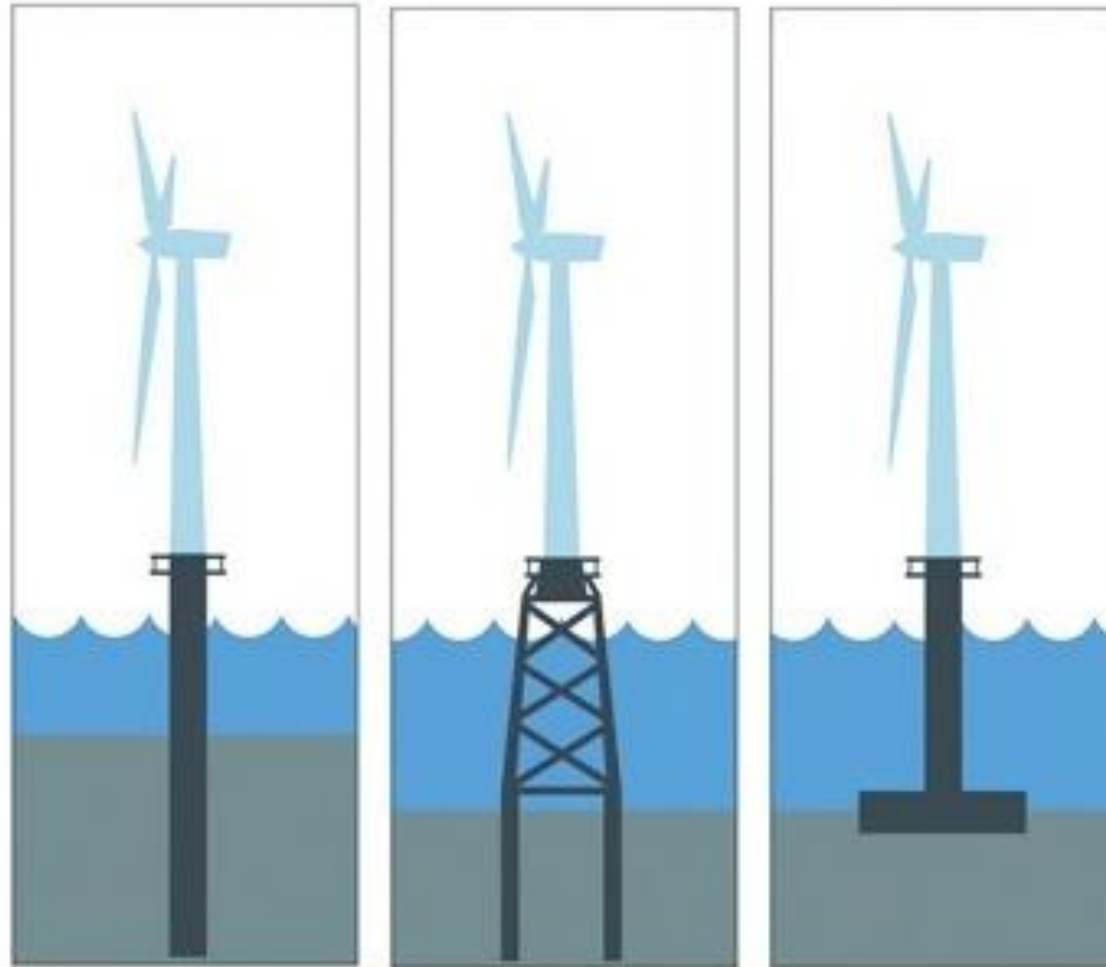


Modelling strategy

- Model vibration using coupled solid-shell domains in the structural mechanics module
- The foundation is surrounded by an acoustic domain which is coupled to the structural domain.
- The COMSOL model gives the near-field sound-field
- Use the near-field as a source-term in a gaussian beam trace model to extrapolate to the far field

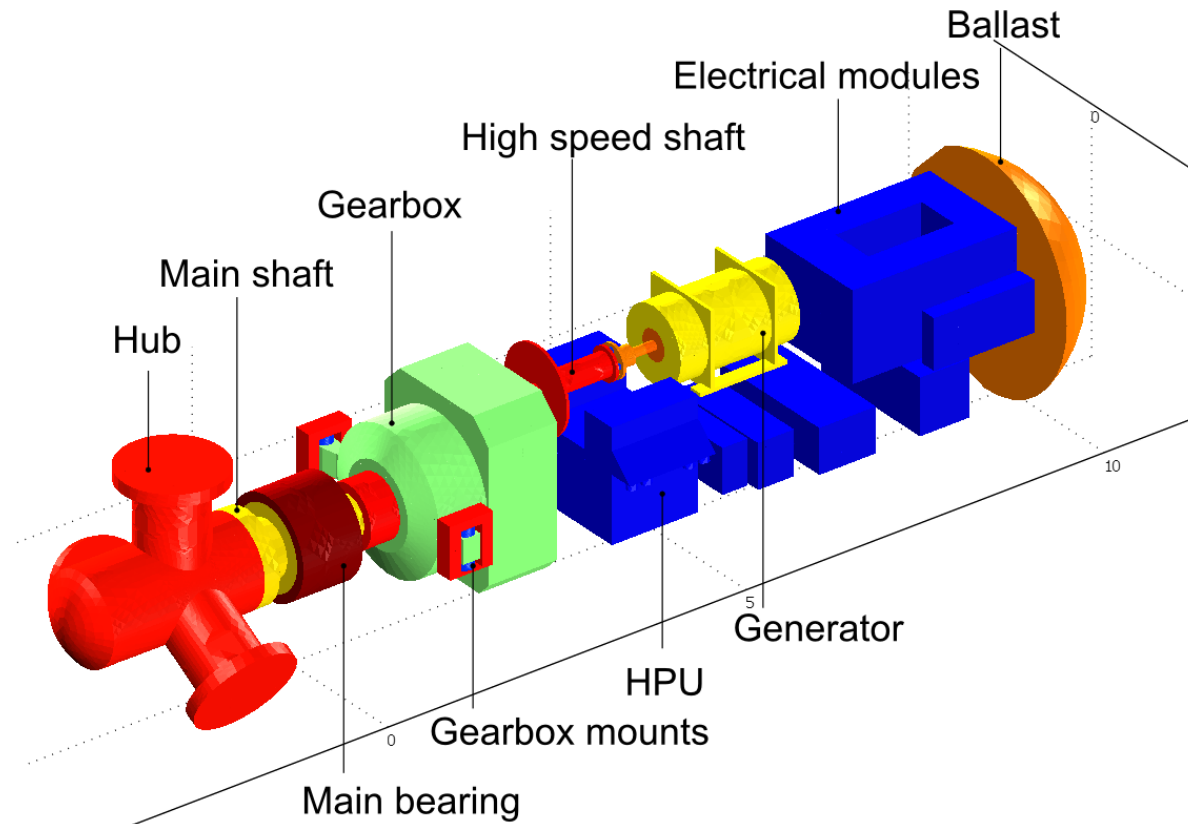


Foundation types



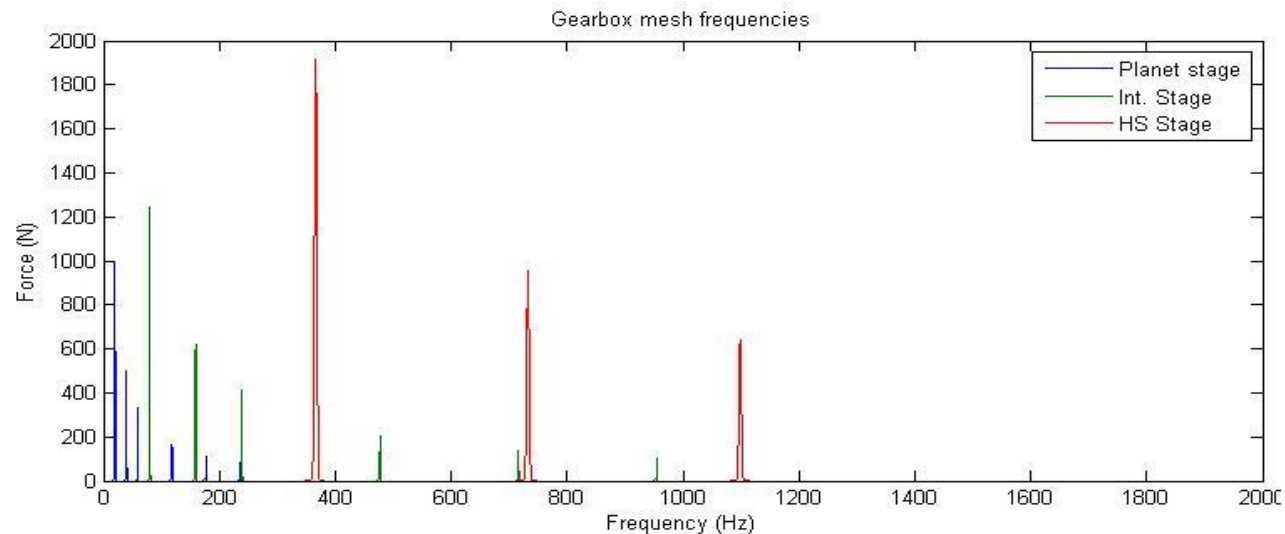
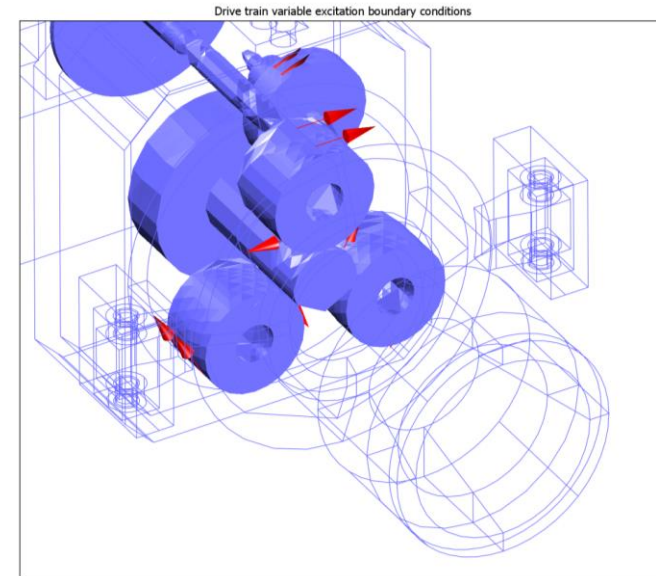
Noise Source – Drive train

- Rotational imbalances
- Blade pass
- Gear meshing in gearbox
- External grid
- Electromagnetic effects between poles and stators in the generator



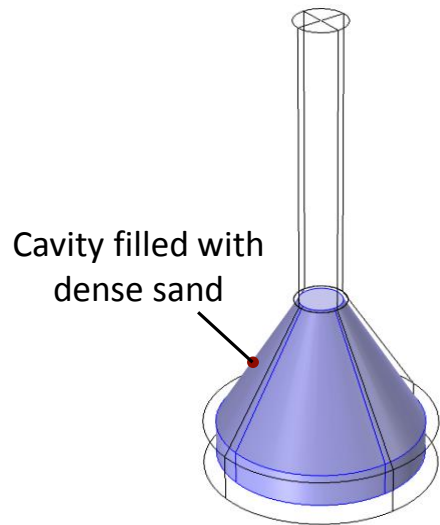
Vibration drivers – rotation dependent

- Gear meshing
 - Three stage gear box
- Gear meshing at:
 - 25 Hz
 - 80 Hz
 - 360 Hz
- Include multiples of gear-meshing (harmonics)
- Correct geometry position and orientation of excitation forces

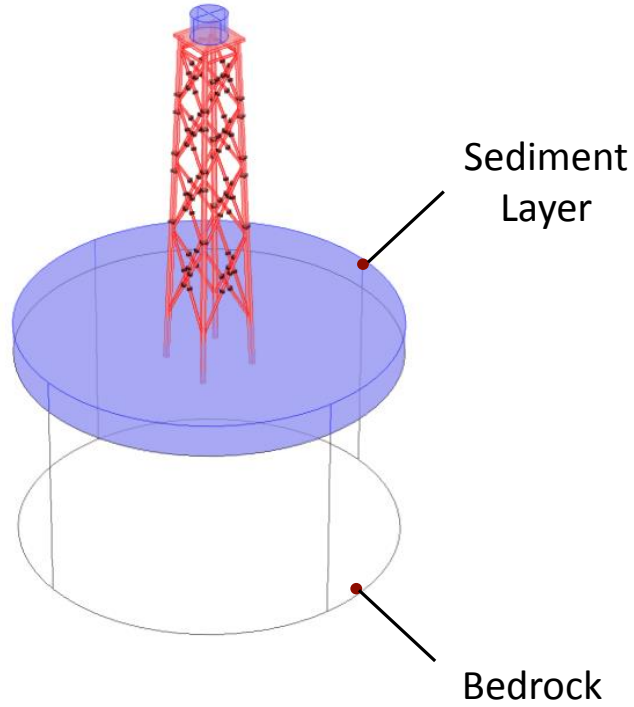


Off-shore foundations

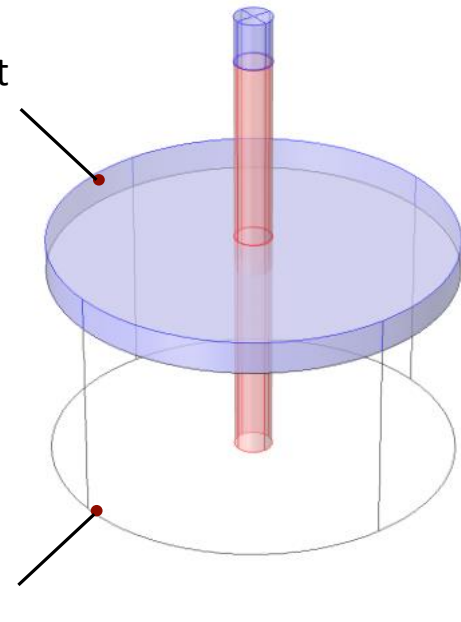
Gravity Base



Jacket

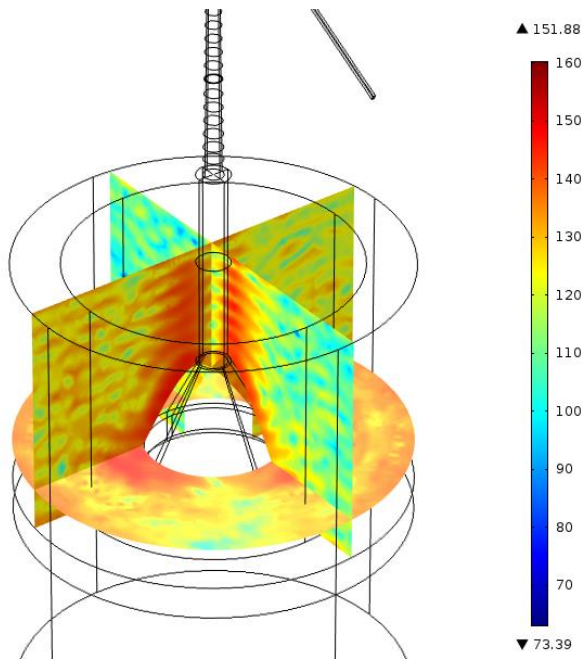


Monopile

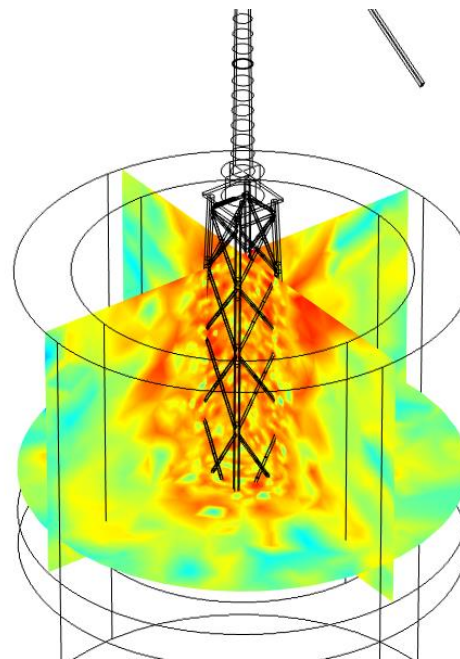


Sound Pressure Level Results

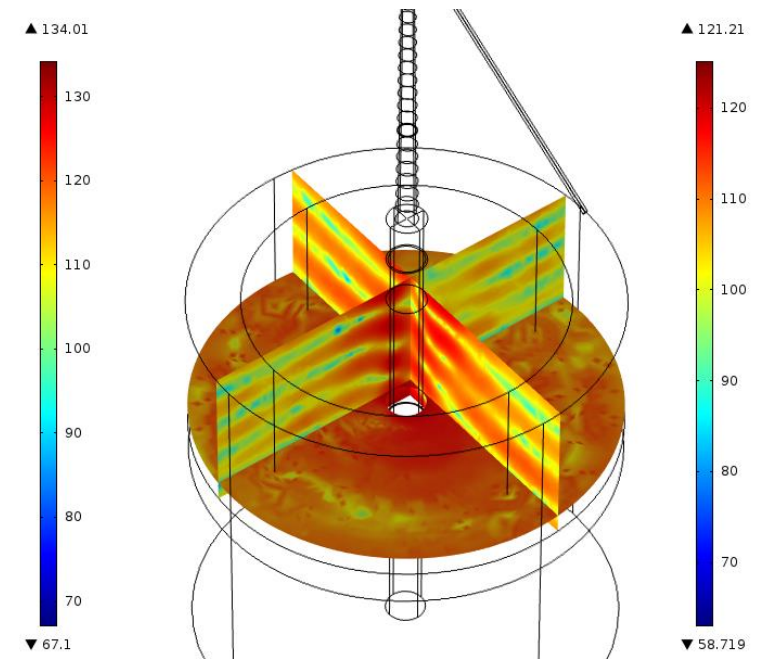
Gravity Base: 200 Hz



Jacket: 360 Hz

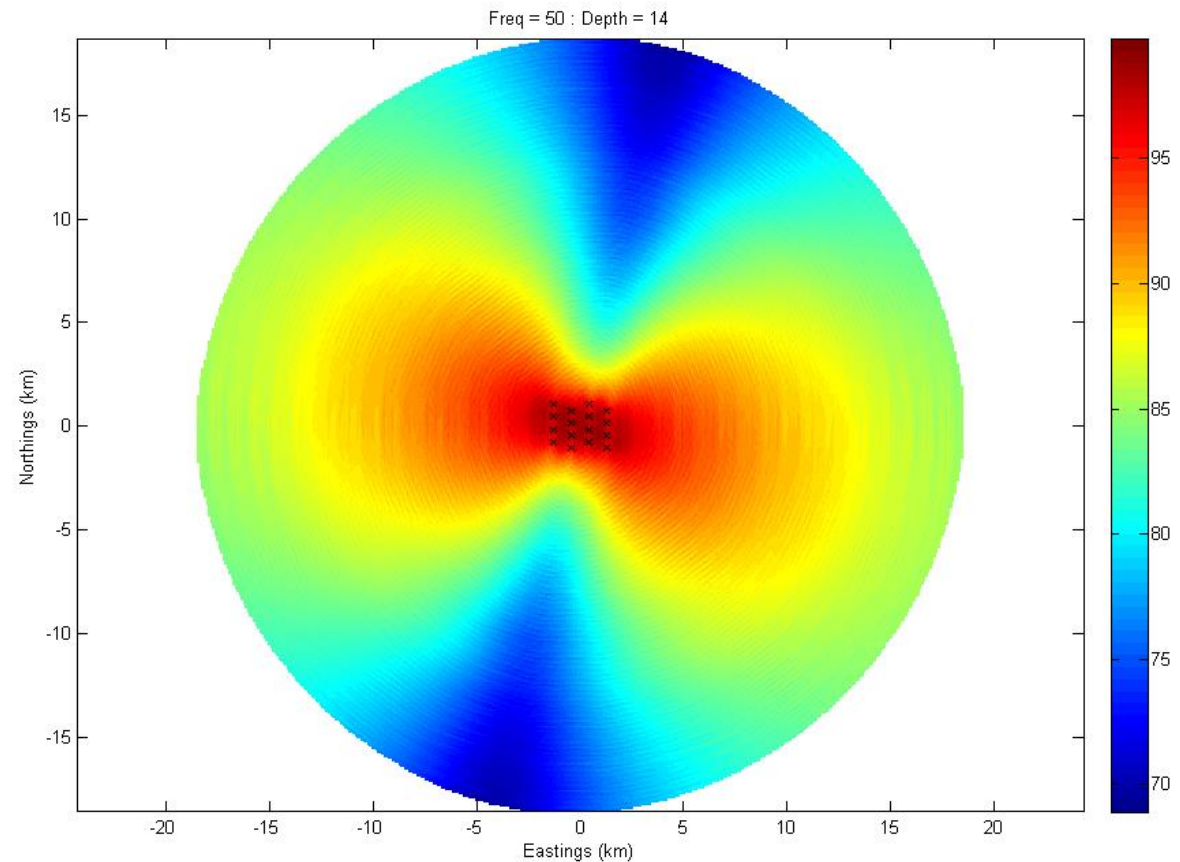


Monopile: 120 Hz



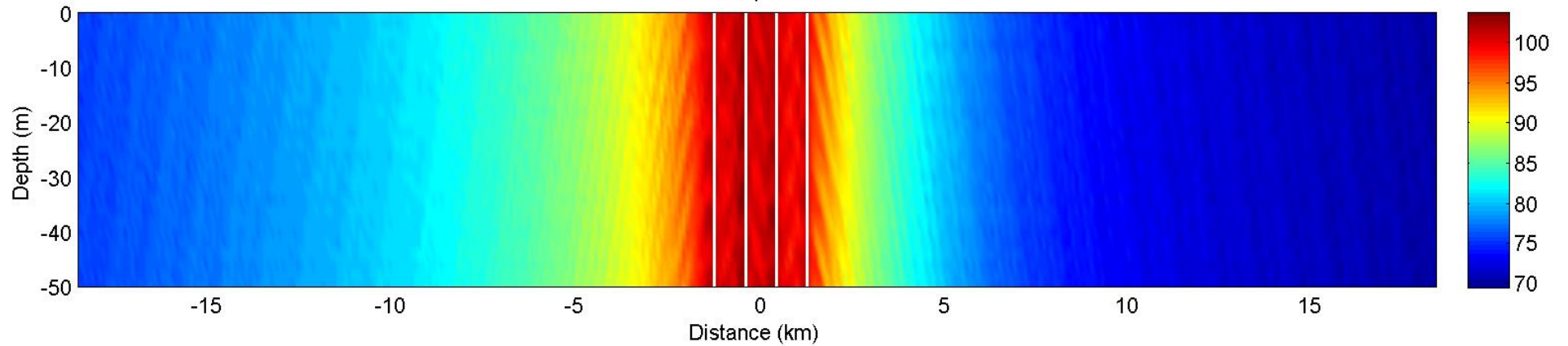
Far field models – horizontal section

- Use near-field results as source term in ray trace model
- Model vertical sections at different angular positions
- Collate results to produce a wind farm of 16 turbines

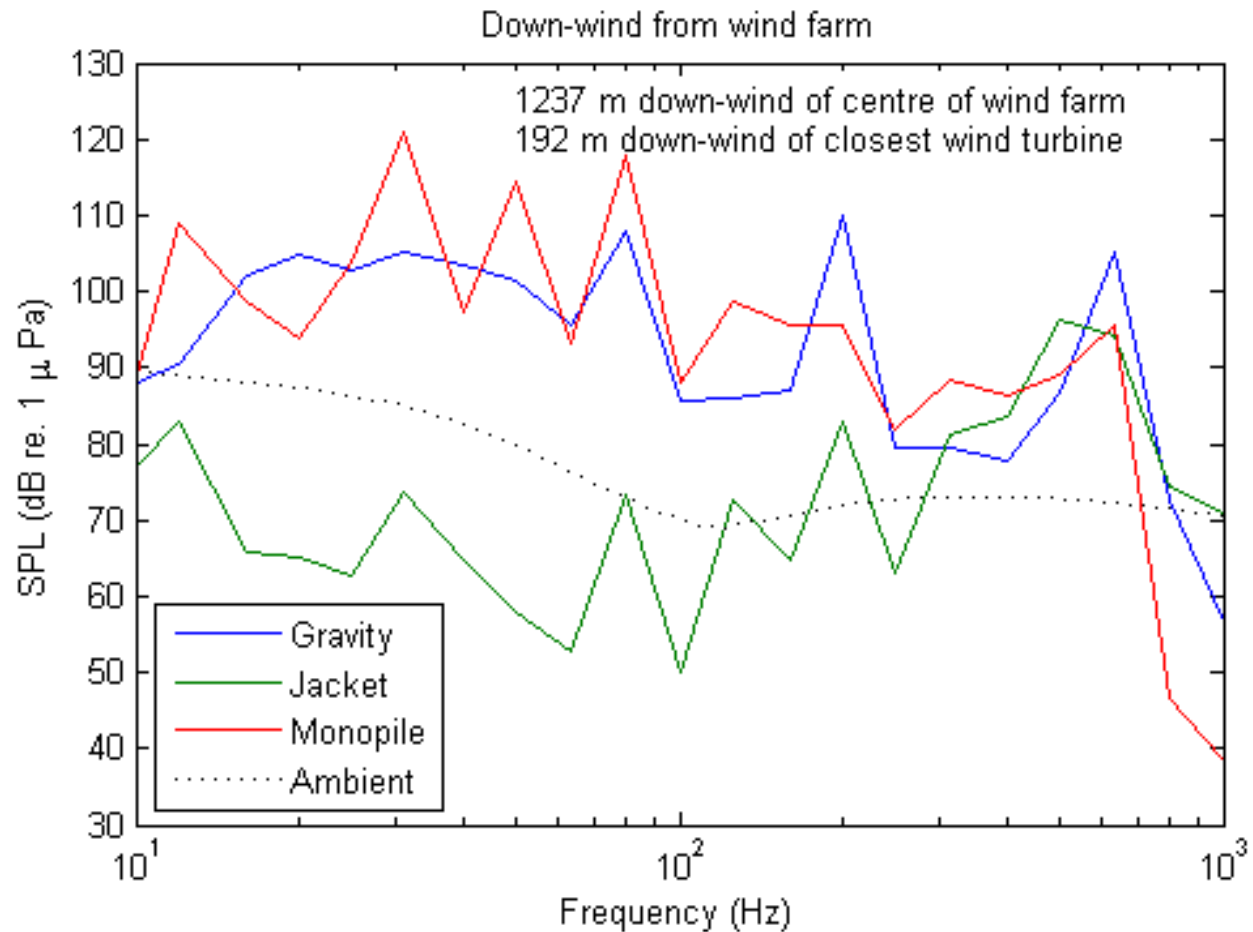


Far field models – vertical section

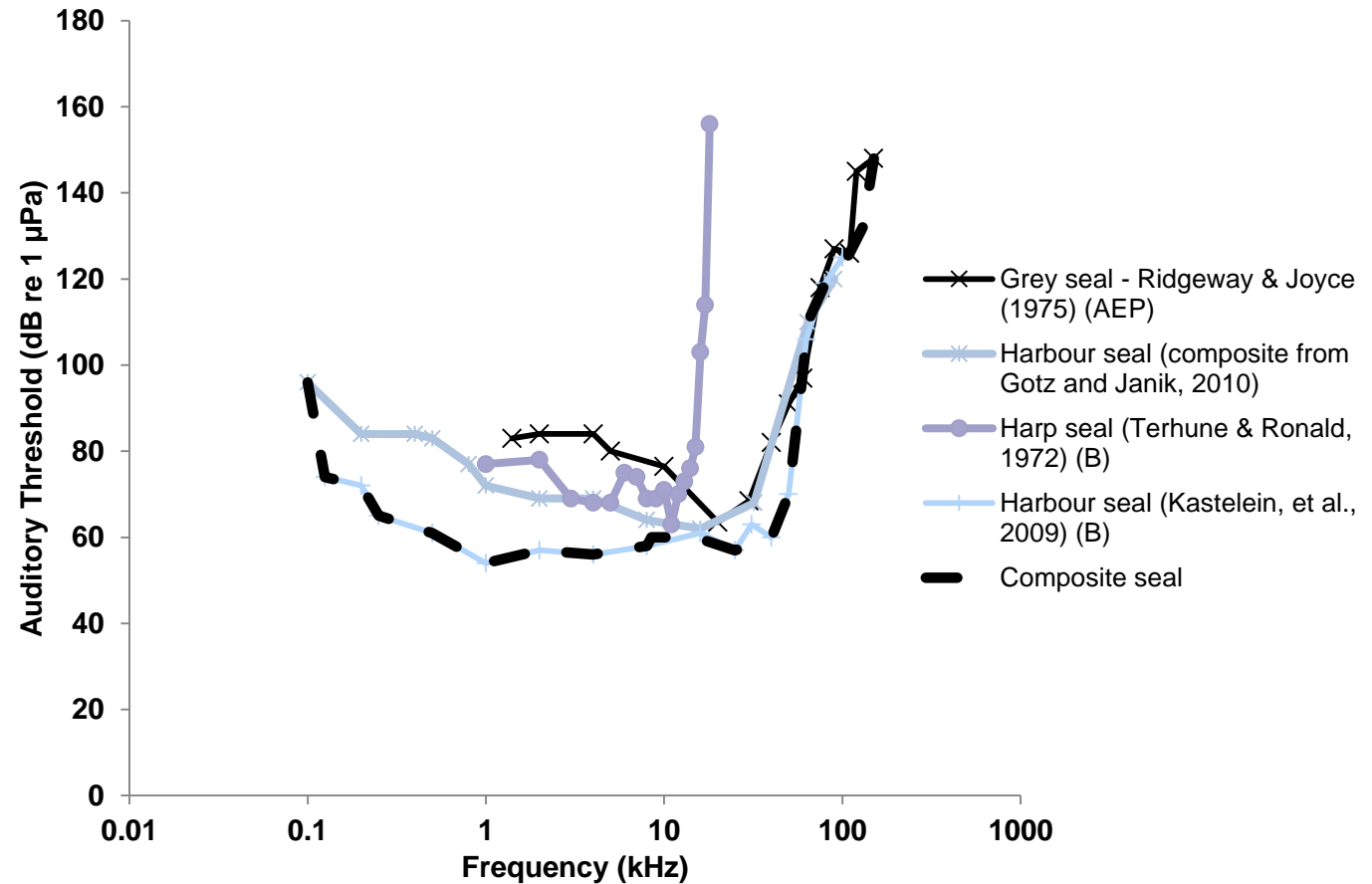
SPL with depth at 16 Hz



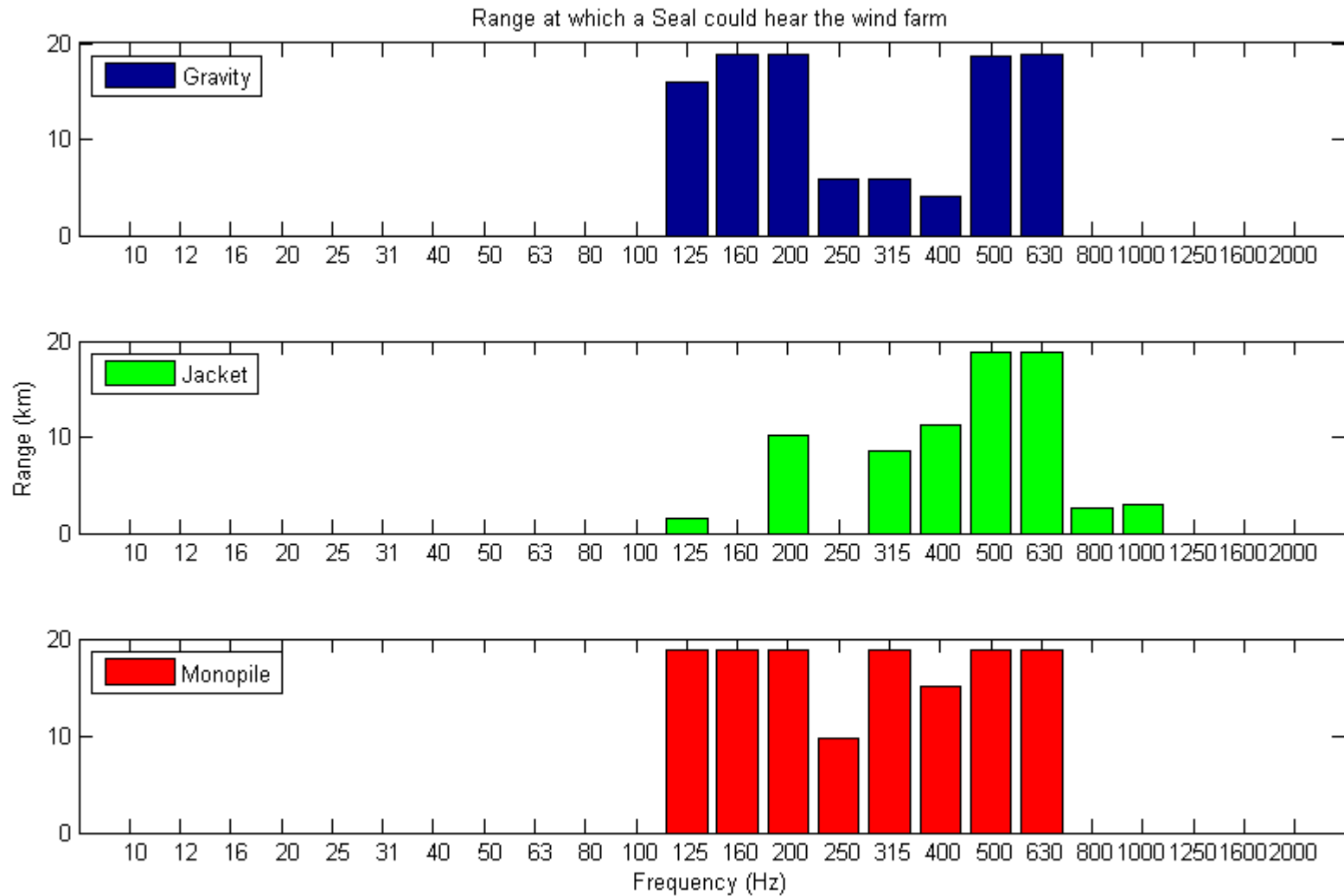
Comparison of foundation types



Foundation type and species hearing threshold



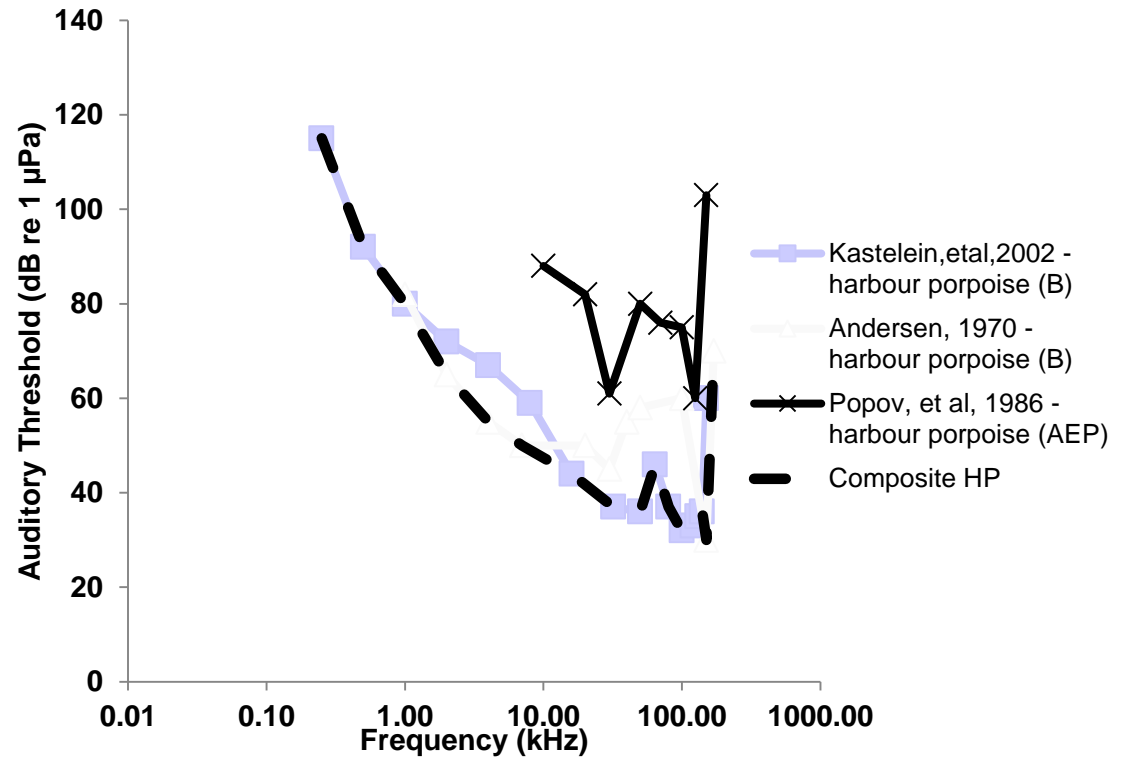
How far away can a seal hear the wind farm



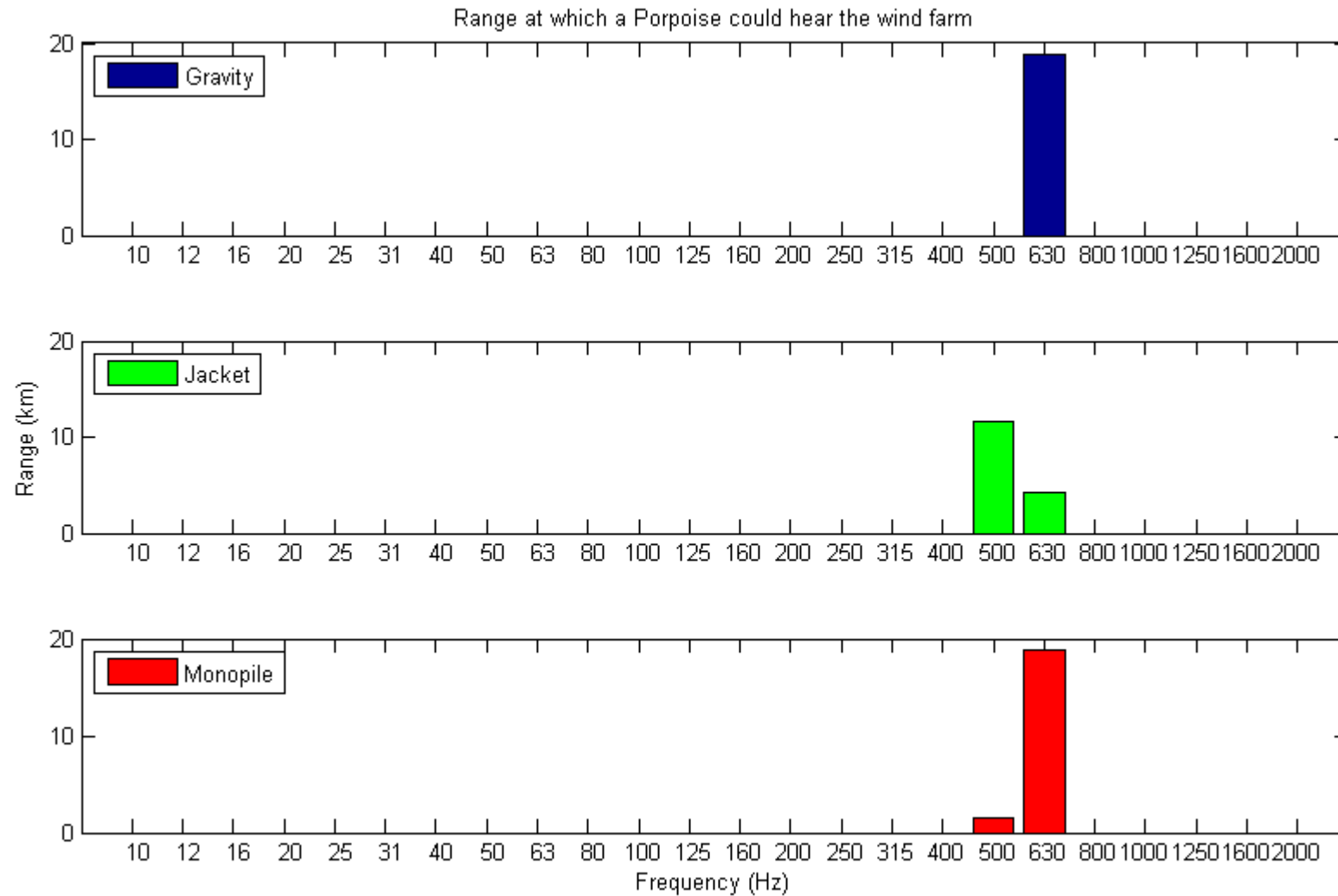
Hearing threshold of marine species



Audiograms of harbour porpoise



How far away can a porpoise hear the wind farm



Conclusion

- The modelling approach provided information on how foundations affect the environment
- It is not possible to measure this directly in the field
- This information is helping inform government policy on the installation of offshore wind farms
- The noise produced by wind farms was found to be within the hearing of marine mammals but at a level too low to cause harm

