

# **Xi** Engineering Consultants





# Boundary element method simulation of tonal noise from a wind turbine

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# Introduction



- Xi use COMSOL Multiphysics as virtual rapid prototype tool for a range of applications
- One application where we have had great success is simulating the acoustic performance of wind turbines
- The geometry of wind turbines makes these simulations very challenging using conventional finite element analysis
- The introduction of boundary element method (BEM) to the acoustics module provides a tool whereby we can reduce the modelling time by an order of magnitude

# Overview



- Why is tonal noise from wind turbines important and how to mitigate?
- FEA and BEM approaches to simulation wind turbine acoustics
- How do FEA and BEM simulations compare?
- Some wind turbine applications that can now be tackled with COMSOL Multiphysics



# Introduction to Tonal Noise

- Tonal noise is easily perceivable
- Tonal noise caused by wind turbines is more likely to cause complaint
- Strict regulatory penalties
- Tonal noise can be caused by frequency matching between tower and rotating components in drive train
- Tonal noise can be amplified through modal responses of the tower and/or blades



# Tonal Noise Solutions



## Free Layer Damping (FLD)

- Attach visco-elastic material tiles to tower
- Part of vibration energy is dissipated through material extension and compression



## Advanced Particle Damping

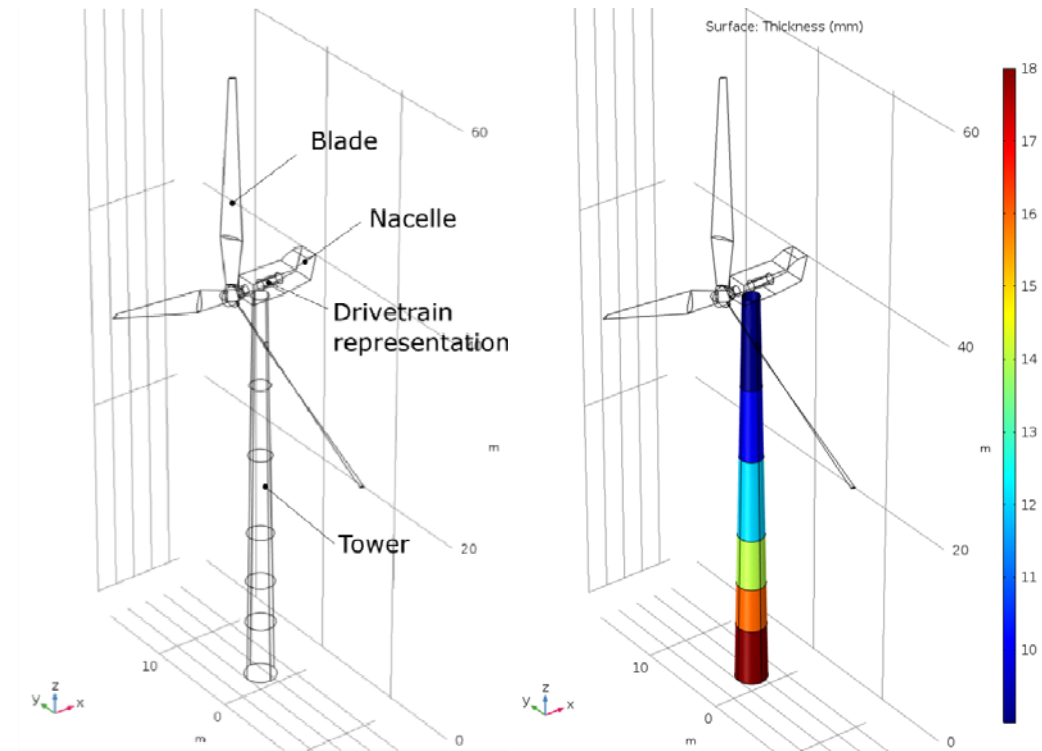
- Custom granulated elastomer, different shapes and sizes; optimised for broadband damping of wind turbines
- Material housed in a soft or hard-shell container magnetically attached



# Example study



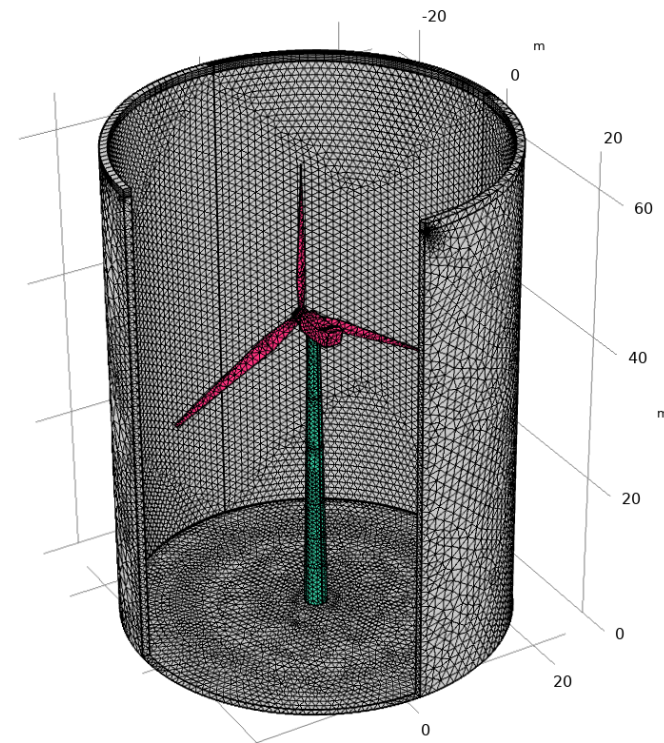
- Compare the modelling of a small/medium scale wind turbine
- 20 m blades, 40 m tower
- 500 kW
- Shell-solid-acoustic
- In this model we have deliberately kept the structural part of the model simple



# Typical approach - FEA



- Build an acoustic-structural interaction model
- Excite in the frequency domain
- Use a cylindrical perfectly matched layer
- Use a far-field analyser to calculate SPL at some distance
- Requires a very large mesh
- *Mesh size is frequency dependent*

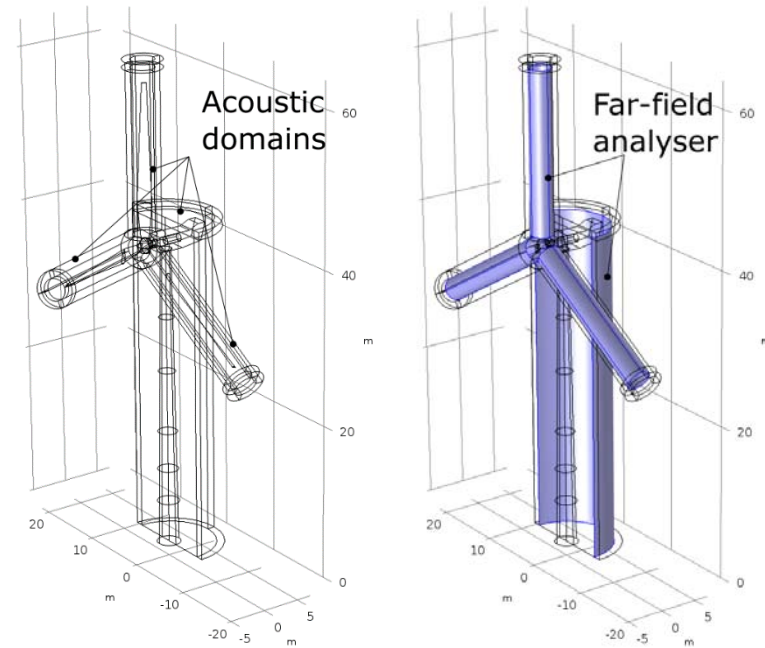






# Modified FEA

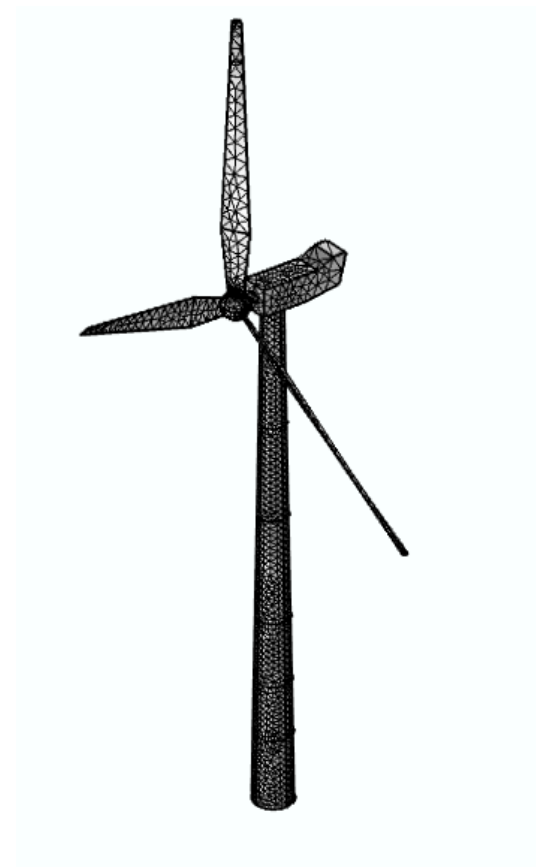
- Series of far-field analysers
- One for each blade
- One for the tower
- Sum to get far-field pressure
- Perfectly matched layers



# BEM - approach



- Couple a BEM to the surface of the structure
- No need to mesh the far-field

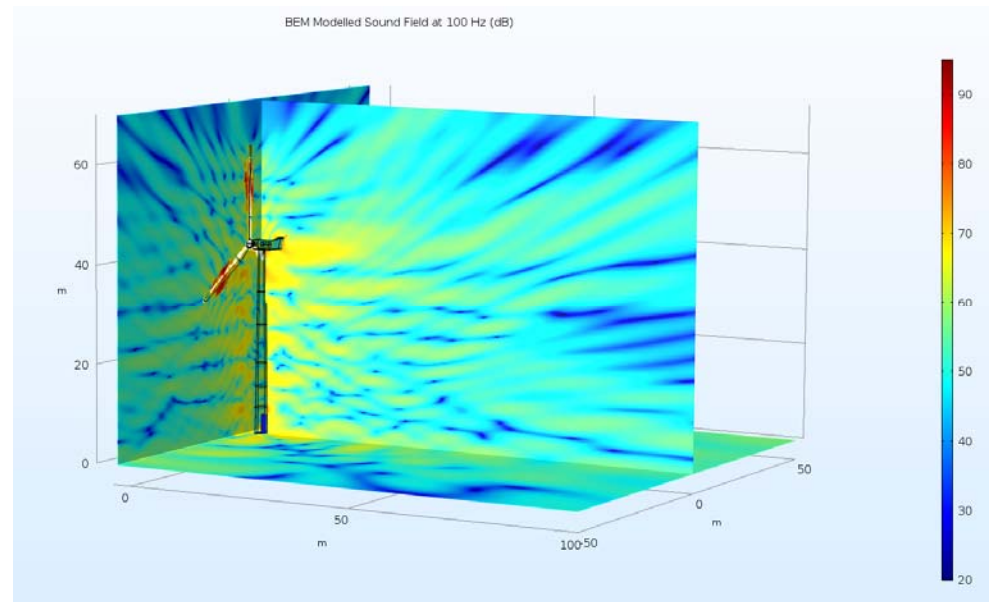
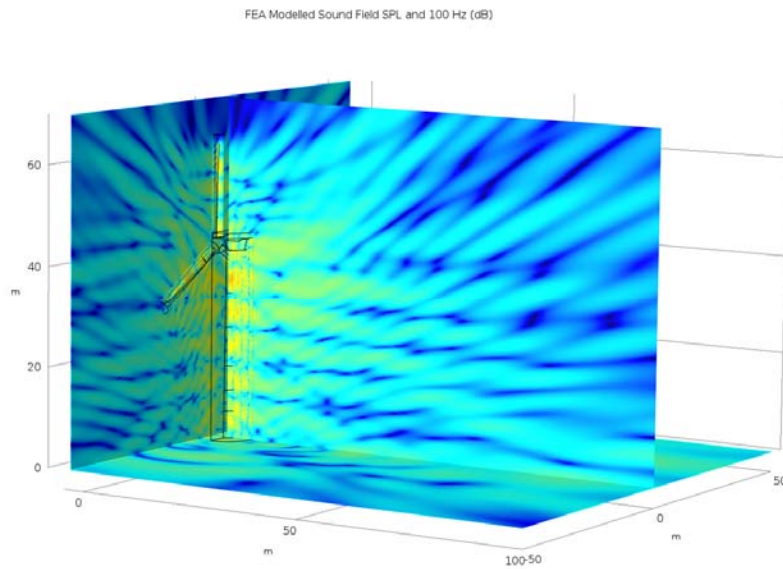


# Results – frequency response

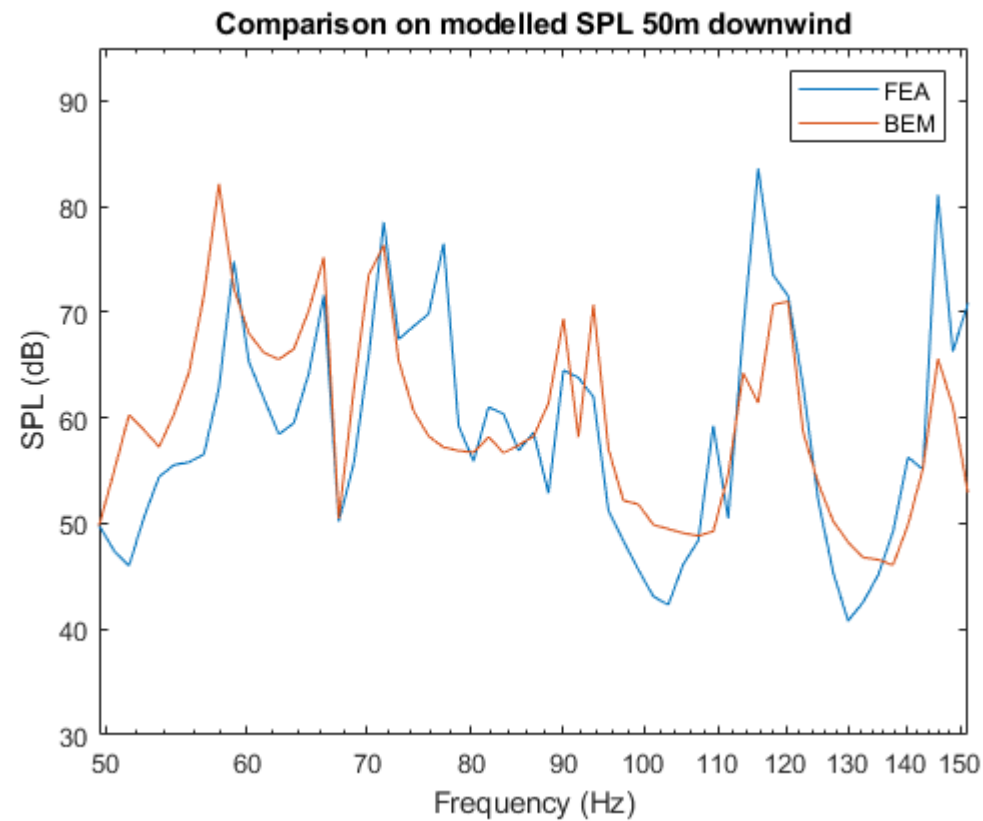


- FEA

BEM



# Results – frequency response



# Compare FEA and BEM approaches

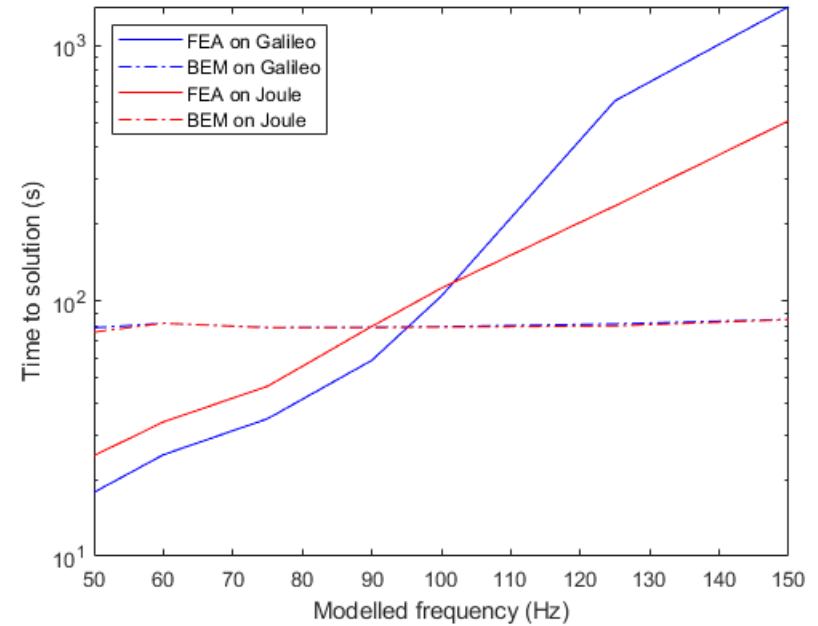


	Galileo	Joule
Processor	Intel 8th Gen i5	AMD 1st Gen Threadripper
Cores	6	16
RAM	16 GB	128 GB

# Results – time to solution



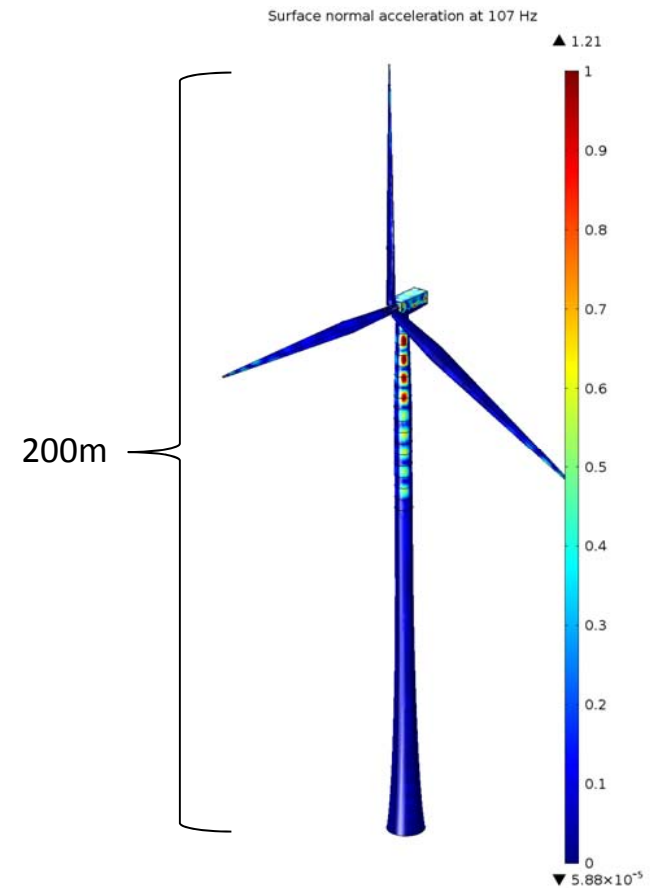
Frequency (Hz)	Degrees of freedom		Run time (s)			
			Galileo		Joule	
	FEA	BEM	FEA	BEM	FEA	BEM
50	277,799	50,054	17.8	78.6	24.8	75.6
60	324,695	50,054	25	81.8	33.6	81.9
75	440,984	50,054	34.6	78.8	46.4	78.6
90	646,004	50,054	58.6	79	79.6	78.6
100	805,614	50,054	104.6	79.4	112.4	79.1
125	1,343,395	50,054	609.6	81.4	236.2	79.9
150	2,126,706	50,054	1424.8	84.8	509.4	84.6
200	4,360,077	50,054		90.2	1892.2	93.6
300		50,054		102.8		102.4
400		50,054		108.6		113.6



# Application – Larger turbines



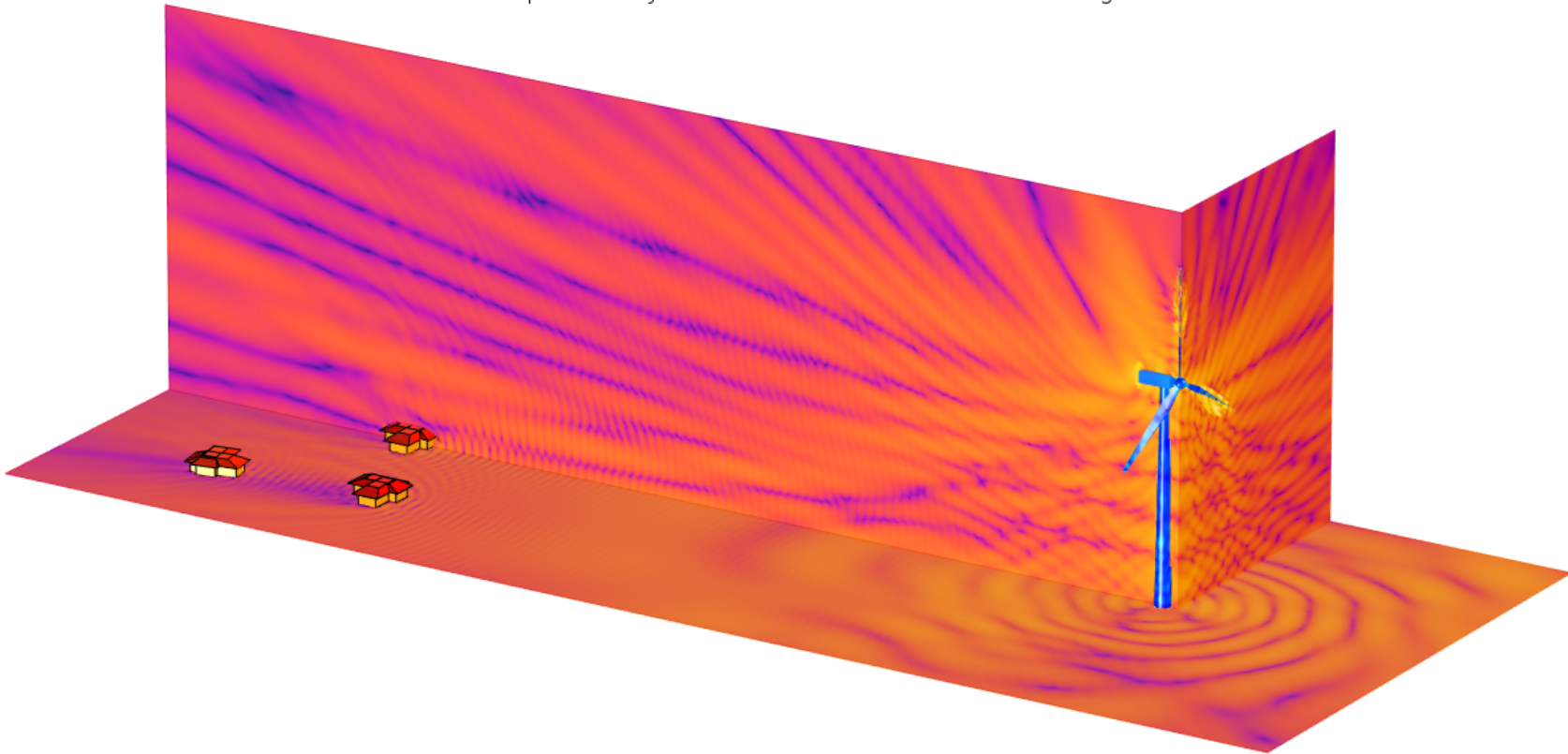
Solving for a single frequency on Joule: 100 Hz					
Tip height	Blade	Time to solve		Degrees of freedom	
		FE	BEM	FE	BEM
60	20	112 seconds	80 sec	800,000	50,000
120	40	23 min	2 min	4 million	164,000
200	60	4 hr 16 min	3 min 30 sec	12 million	217,000



# Application – far-field effects and building acoustics

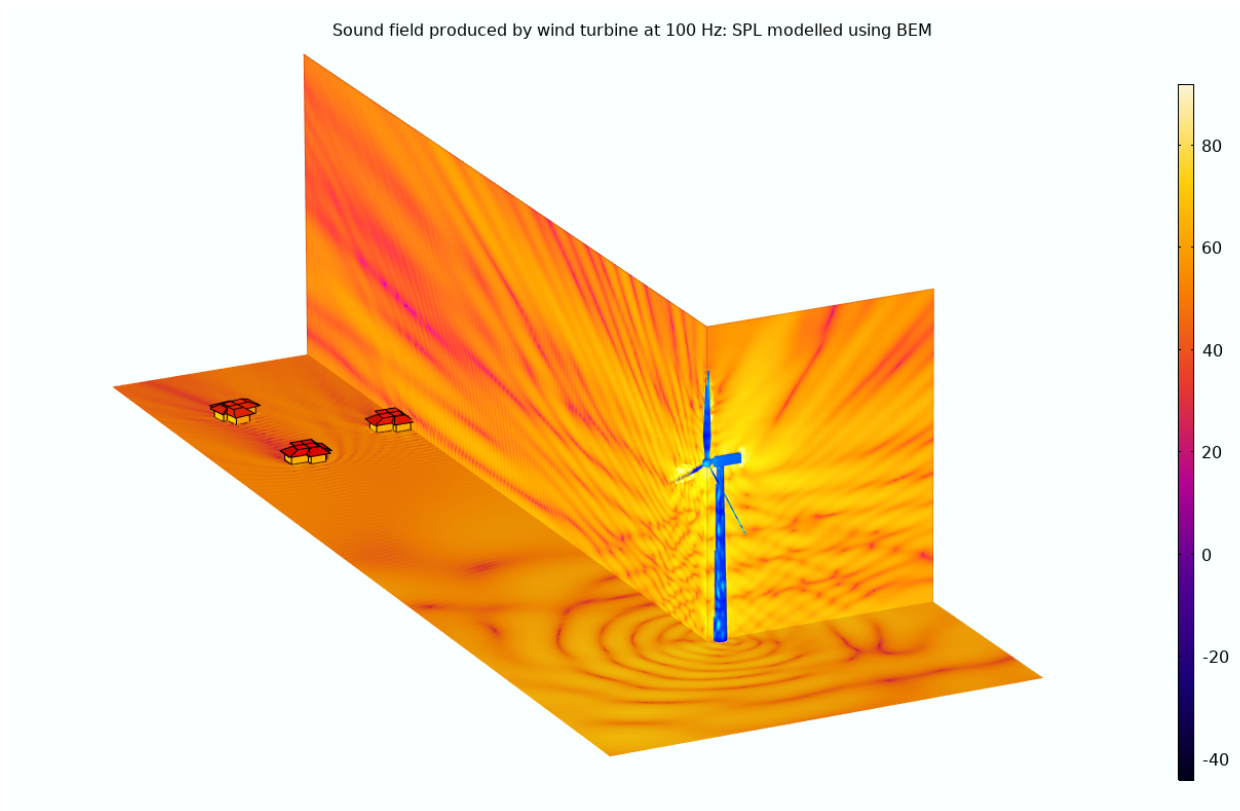
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Sound field produced by wind turbine at 100 Hz: SPL modelled using BEM





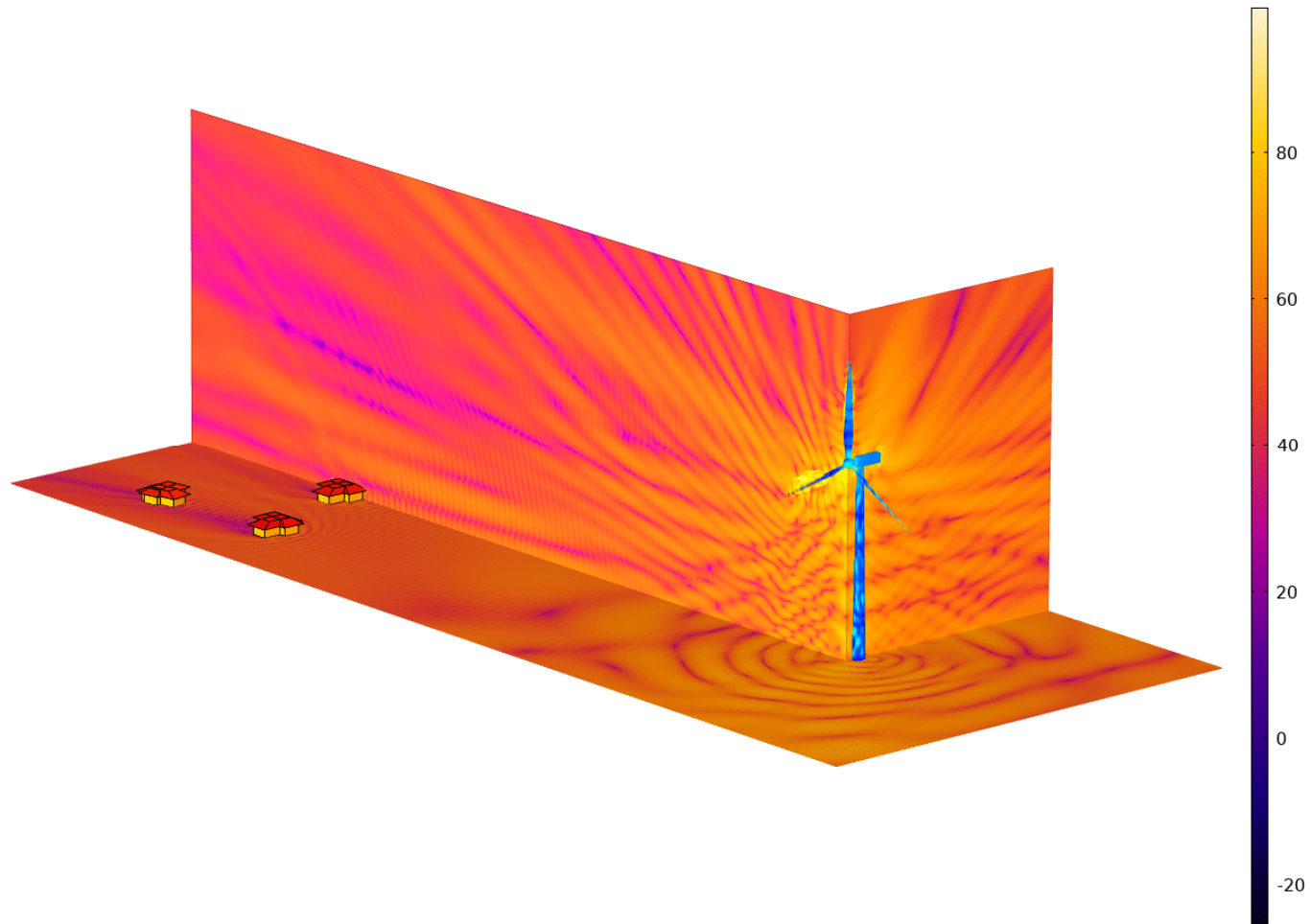
# Application – Amplitude modulation



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Sound field produced by wind turbine at 100 Hz: SPL modelled using BEM



# Concl usi on



- FEA and BEM produces comparable results with respect to sound fields and frequency response
- The modelling of large wind turbines and higher frequencies are now tractable with BEM in COMSOL Multiphysics
- Can use the BEM approach in increase our offering to the wind sector
  - Larger hybrid turbines
  - Coupled with building acoustics and calculate receptor levels
  - Amplitude modulation
- Thanks to COMSOL's engineers for provide the acoustic BEM