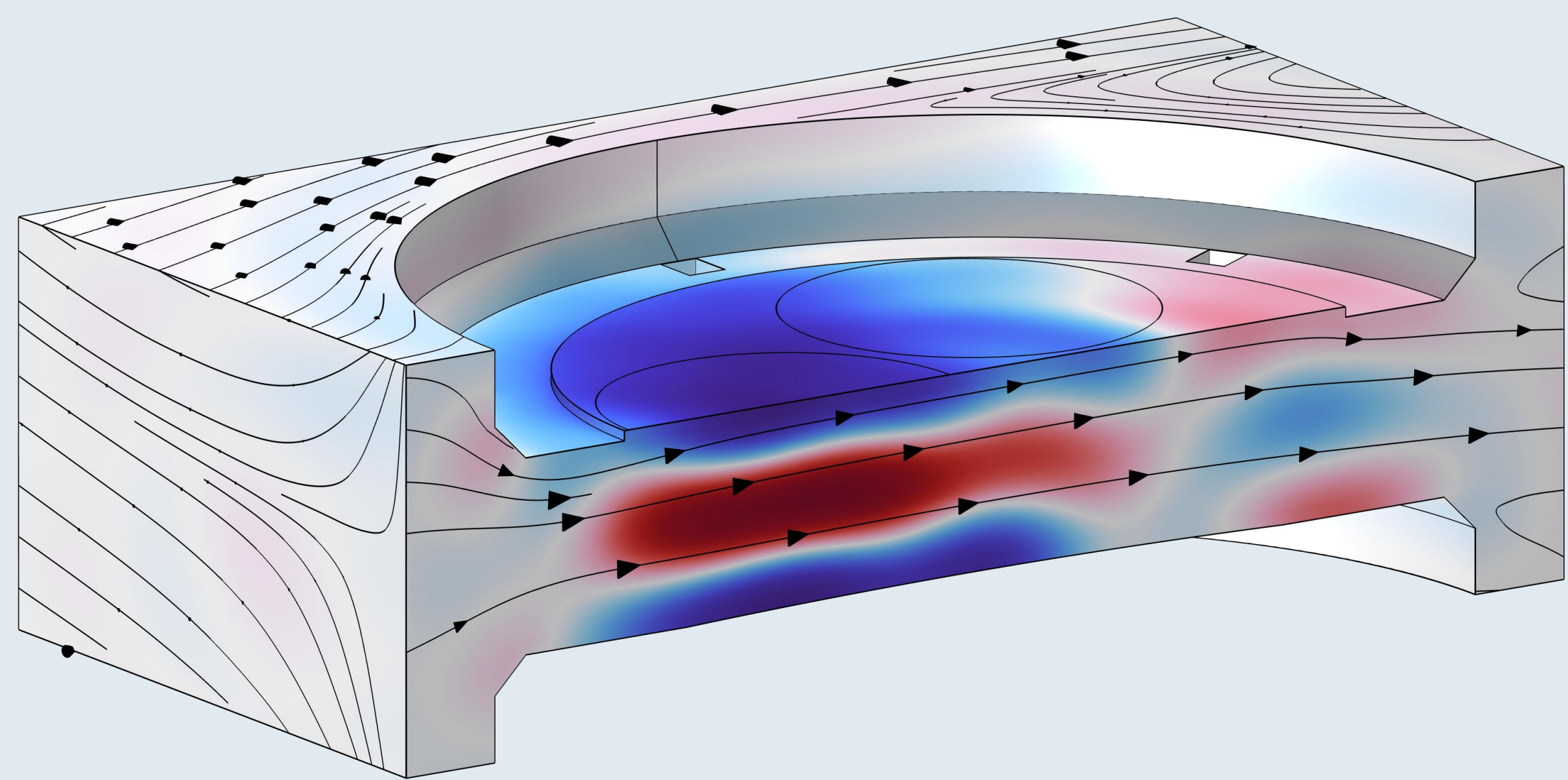


Convected Acoustic Physics Interfaces for Acoustic Resonance Technology



A robust and validated simulation framework is essential for a true understanding of the complex coupling between acoustics and aerodynamics. At the same time, rapid and efficient simulations are vital to meet industrial demands and enable the development of advanced machine learning tools.

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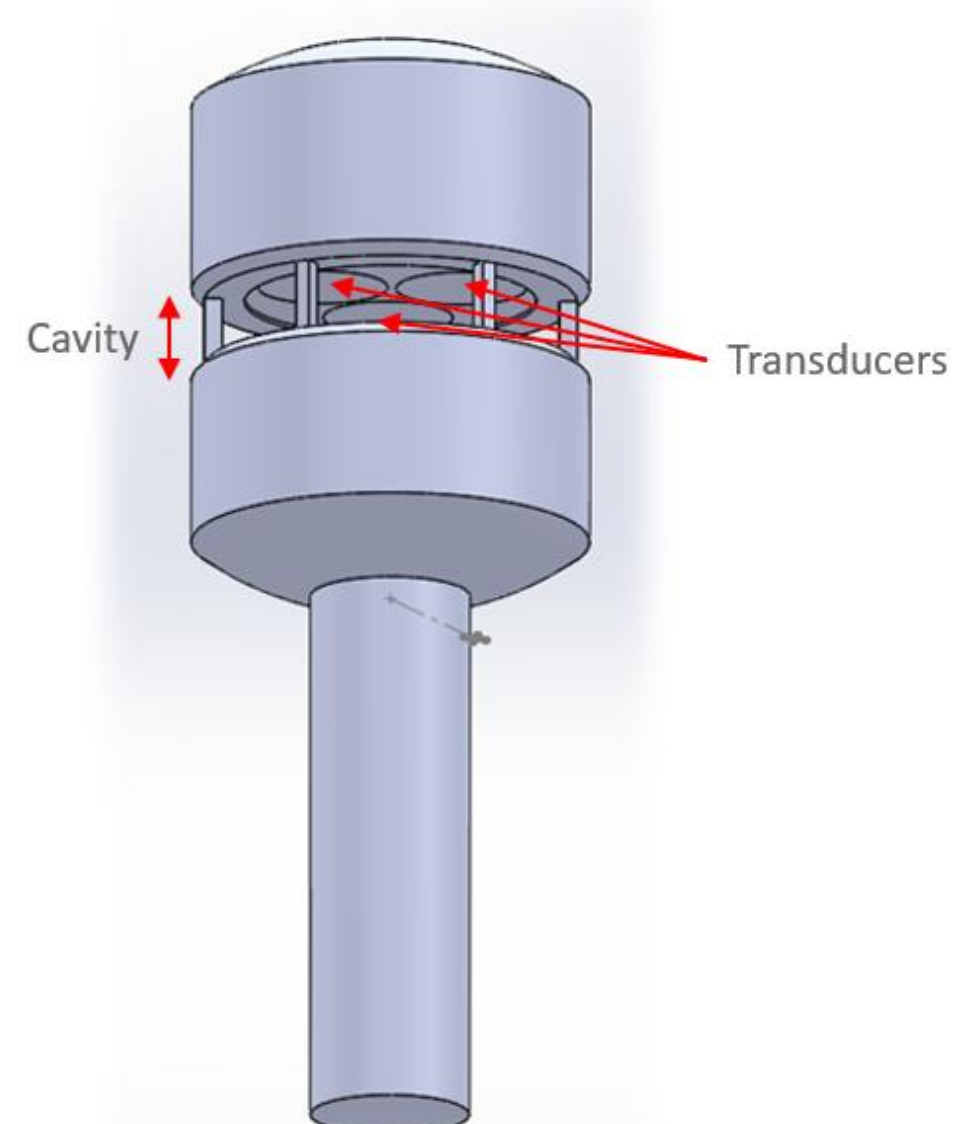
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Abstract

Acoustic Resonance (Acu-Res[®]) Technology [1] is the foundational principle behind FT wind sensors, enabling the measurement of wind speed by detecting phase shifts between paired transducers within an acoustic resonator. This technology inherently couples acoustics with aerothermal fields, making precise modelling essential for optimal sensor performance. This study presents a comprehensive modelling framework for convected acoustics using COMSOL Multiphysics[®] [2], focusing on Acoustic Resonance Technology applications. Two physics interfaces are evaluated to determine

the best compromise between computational accuracy and efficiency. The study systematically explores mesh density, computational domain boundaries, solver types, and computational power, aiming to enhance the design lifecycle of Acu-Res[®] Technology through state-of-the-art simulation strategies and SciML-based methodologies.



caseID	Sym	rbc	rbc _y	elem/λ	BC
00-03	Yes	0.5,1,2,3	0.5	6	IMP
04-09	Yes	0.5	0.5	4-10	IMP
10	Yes	0.5	1	7	IMP
11	No	0.5	0.5	7	IMP
12-15	Yes	0.5,1,2,3	0.5	6	PML
16-21	Yes	0.5	0.5	4-10	PML
22	Yes	0.5	1	7	PML
23	No	0.5	0.5	7	PML

Figure 1. Simplified geometry of FT wind sensor (on the left); table with the cases run to assess the computational domain, mesh, and boundary conditions, when using LPF physics interface in COMSOL Multiphysics[®] (on the right).

Methodology

This study followed multiple steps to define the computational domain, mesh, and boundary conditions that would provide the best compromise between computational cost and accuracy, using the LPF model in COMSOL[®]. After establishing these parameters, both direct and iterative solvers within COMSOL Multiphysics[®] were assessed to determine whether computational time could be reduced further without compromising the accuracy of the results. Subsequently, the simulation was executed on a higher-performance machine to evaluate the benefits of increased CPU cores and memory. Finally, the focus is shifted to the LNS model to assess the improvements that it brings to the acoustic solution, studying also the effects of the mesh density on the accuracy of the solution.

The accuracy of the simulations was assessed by analysing the magnitude and phase of acoustic pressure recorded on the transducers acting as receivers. This method aligns with how FT wind sensors detect wind speed and direction, making it a Key Performance Indicator (KPI) for evaluating simulation reliability.

Results

The study demonstrated that carefully selecting mesh parameters and domain settings enables substantial reductions in CPU time without compromising the fidelity of the solutions. Specifically, for the LPF physics interface, a mesh density of 7 elements per wavelength provided reliable results with lower computational cost (90 seconds), while the more demanding LNS simulations required 8 elements per wavelength to capture resonance accurately and keep phase uncertainty below 4°. A comparison of the LPF and LNS methodologies highlights the trade-off between computational efficiency and physical detail. The LPF approach, by resolving only the velocity potential, achieves substantial savings in computational resources, making it suitable for quick prototyping and development of surrogate models. In contrast, the LNS methodology provides a more comprehensive representation of the acoustics at the cost of longer computational times (more than half an hour). In summary, the strategic optimisation undertaken in this study underscores the importance of tailoring simulations to the chosen modelling approach and desired accuracy, enabling robust and efficient acoustic analysis across both LPF and LNS frameworks.

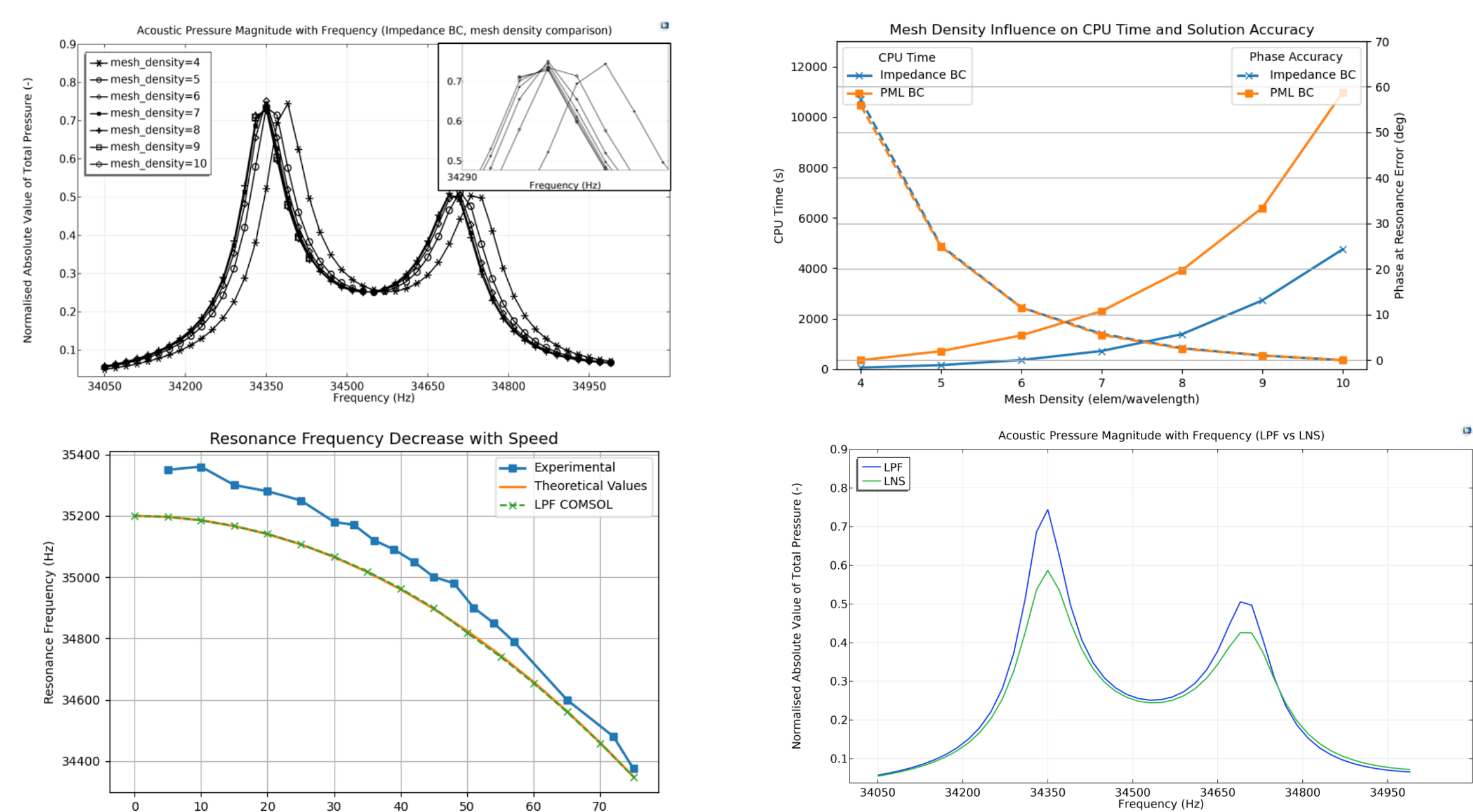


Figure 2. Normalised acoustic pressure magnitude at the receiving transducer as a function of different mesh densities (top-left); CPU time and solution accuracy as a function of the mesh density (top-right); comparison of the resonance frequency captured by simulations and theory against experimental data (bottom-left); comparison of pressure magnitude computed with LPF and LNS physics interfaces (bottom-right).

REFERENCES

[1] FT Technologies. Available: <https://fttechnologies.com/>. [Accessed September 8, 2025].

[2] COMSOL Multiphysics[®]. Available: <https://www.comsol.com/>. [Accessed September 9, 2025].



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