UNIVERSITY OF BATH

Development of novel, light-weight and multifunctional acoustic metamaterials/metasurfaces for aeronautical applications using 3D Boundary Element Method (BEM3D)

Project: AERIALIST - AdvancEd aicRaft-noIse-AlLeviation devIceS using meTamaterials

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Presentation overview

- Aim and objective
- Introduction and Development of BEM3D
- Testing and validating BEM3D
- Benchmark study
    - Flat plate
    - Duct
- Experimental data
- Conclusions

Objective: Mitigation of the civil aviation noise

- Low cost airlines have significantly increased the air transport, thus increase in aviation noise.
- Conventional noise attenuation techniques cannot mitigate civil aviation noise.
- The aim of this work is to design innovative configurations, which are capable of absorbing, dissipating and redirecting the aero-noise at the source.
- To achieve this, the light-weight multi-functional acoustic metamaterials and metasurfaces those have already been proven in room acoustics and noise attenuation are being studied to test their performance in flow and modify their design to be suitable for aeronautical applications.

Aerialist

Horizon 2020

AERIALIST

AdvancEd aicRaft-noIse-AlLeviation devIceS using meTamaterials

Development of BEM3D for simulation of Aeroacoustics problems

- BEM3D is an open source package to simulate aero-acoustic problems.
- BEM3D is a standard collocation technique which can optionally use the in-house Fast Multipole Method (FMM) library of Greengard and Zimbutas.
- Sound propagation through aero-engines which involves moving sources in moving media provides a significant challenge in predicting as conventional methods are not applicable.
- The work presented here considers the development and re-formulation of existing techniques to incorporate the aeroacoustic environment and to validate results with experimental data.

Developed by Dr Michael Carley, University of Bath, UK

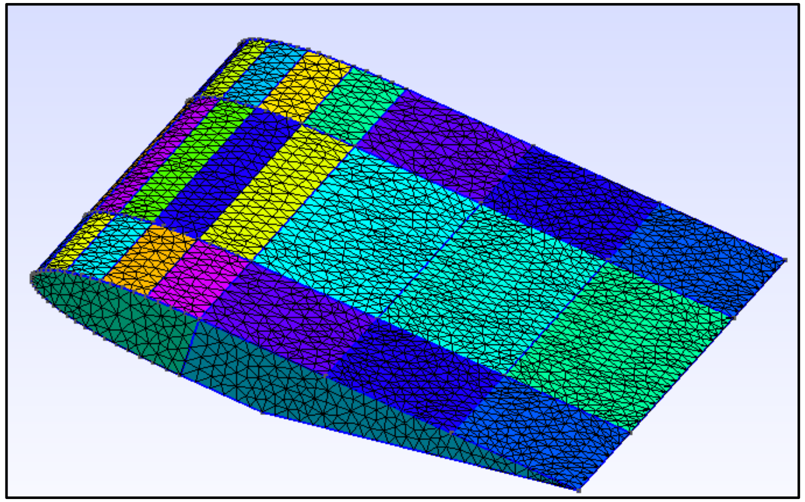
BEM3D development: Simulation of metamaterials in Aeroacoustics environment, the ultimate aim

- BEM3D solves the sound propagation in mean flow by using the Taylor Transformation.
- Scattering problems are solved by applying Taylor's transformation to the solution for the total field in the zero-flow case and given by the solution of the Helmholtz equation
- The effect of low-Mach number homentropic potential flows on acoustic scattering problems obtained by solving Laplace problem.
- This technique is being use as a basis to develop methods for the simulation of metamaterials, which is the ultimate goal of the AERIALIST project.

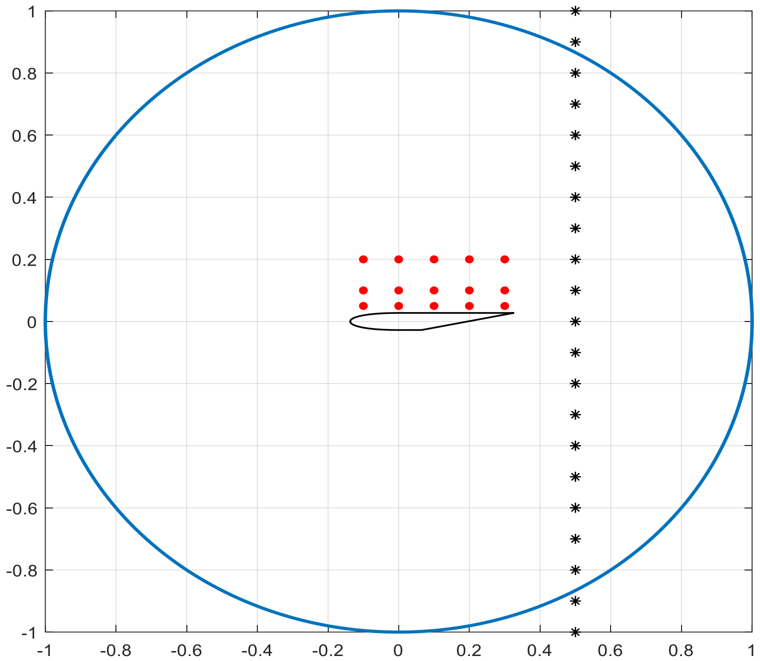
Benchmark study: A step towards implementation of Metamaterials in BEM3D

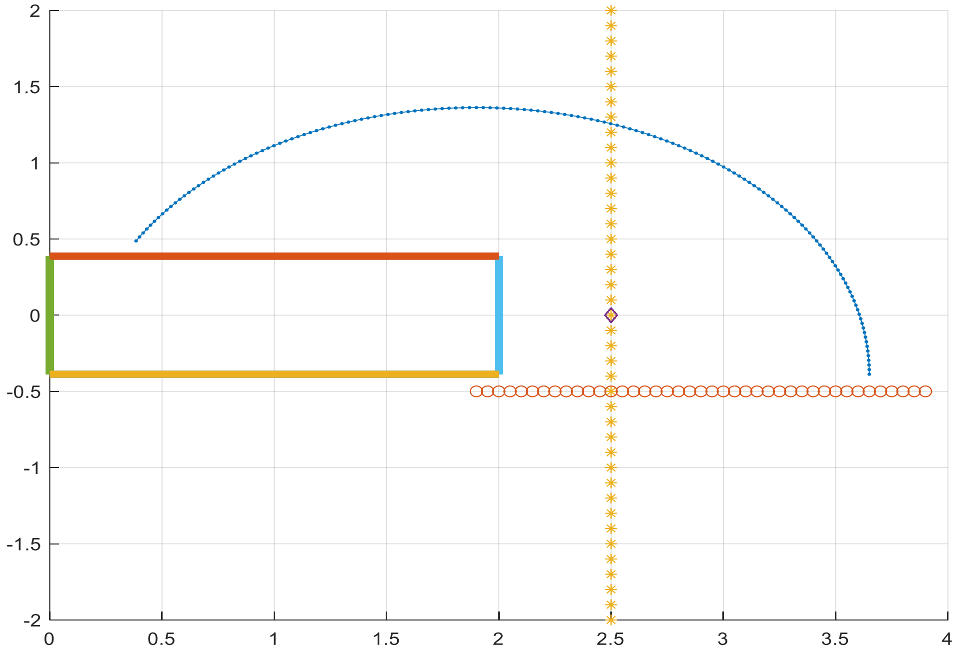
- The benchmark problems are designed to represent aero-acoustics environment in terms of geometrical and operating conditions.
- Simplified geometries have been selected on which metamaterials are embedded to simulate and test their acoustical performance with and without mean flow.
- Two fundamental geometries has been selected for benchmark case studies,
    - A flat plate model, representing a wing of aircraft
    - A rectangular duct model
- A comparative study has been carried out between BEM3D, AcouSTO and COMSOL for validation purposes.

Benchmark studies

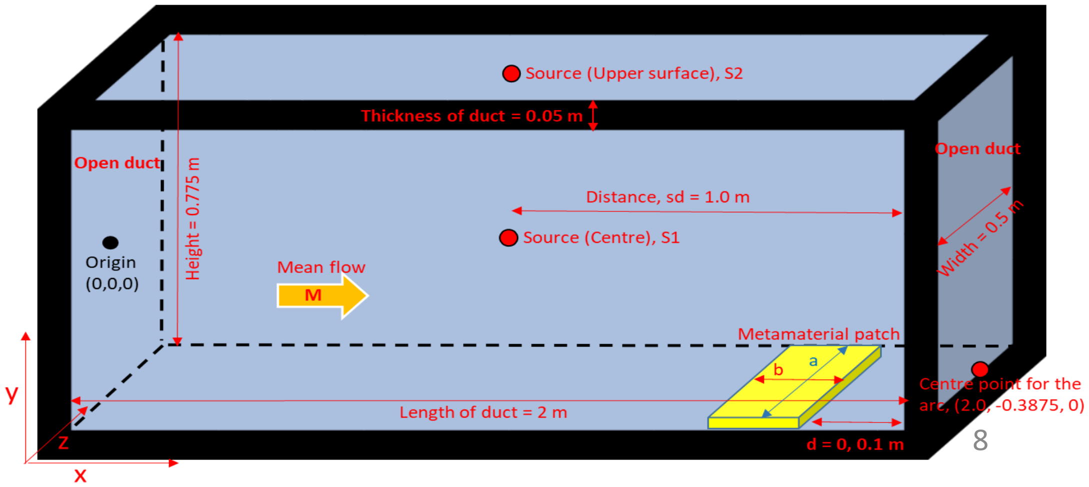


Flat plate

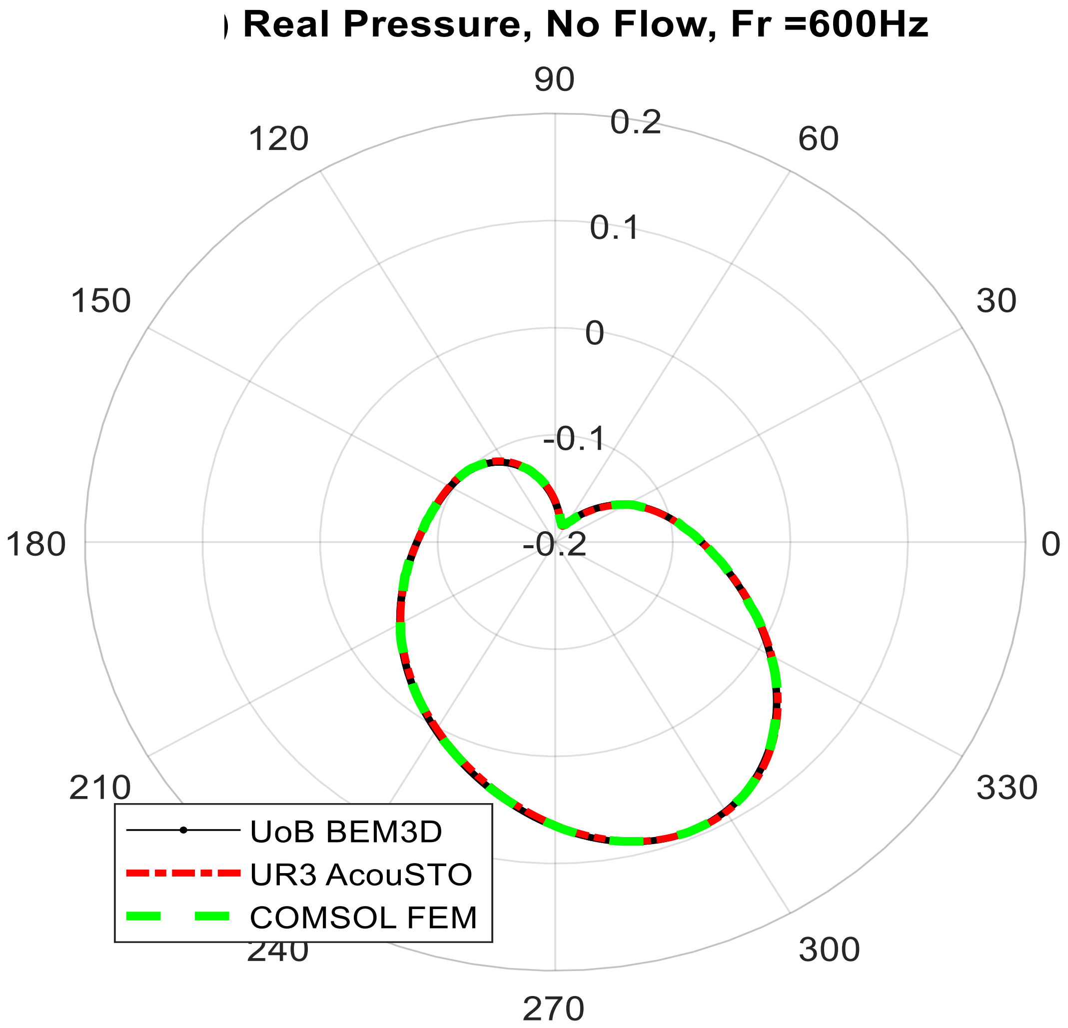


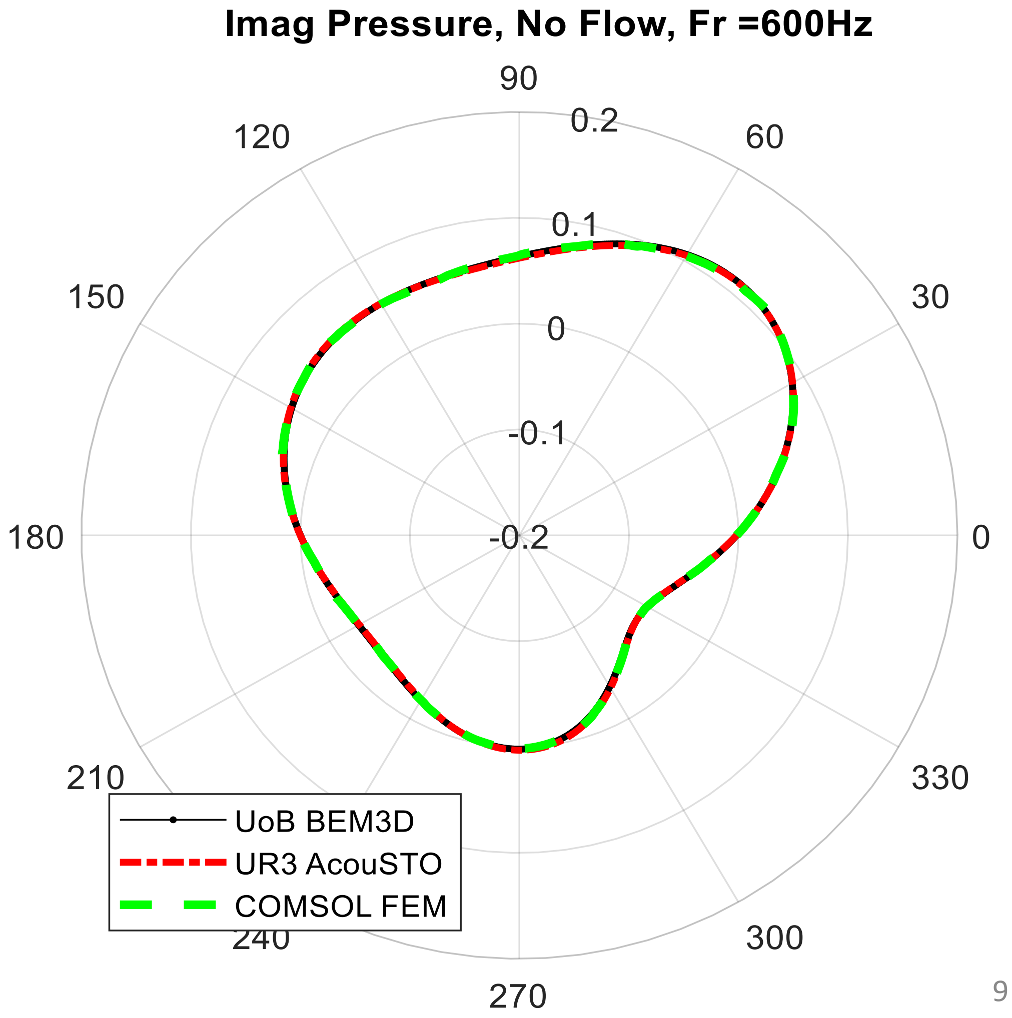


Duct

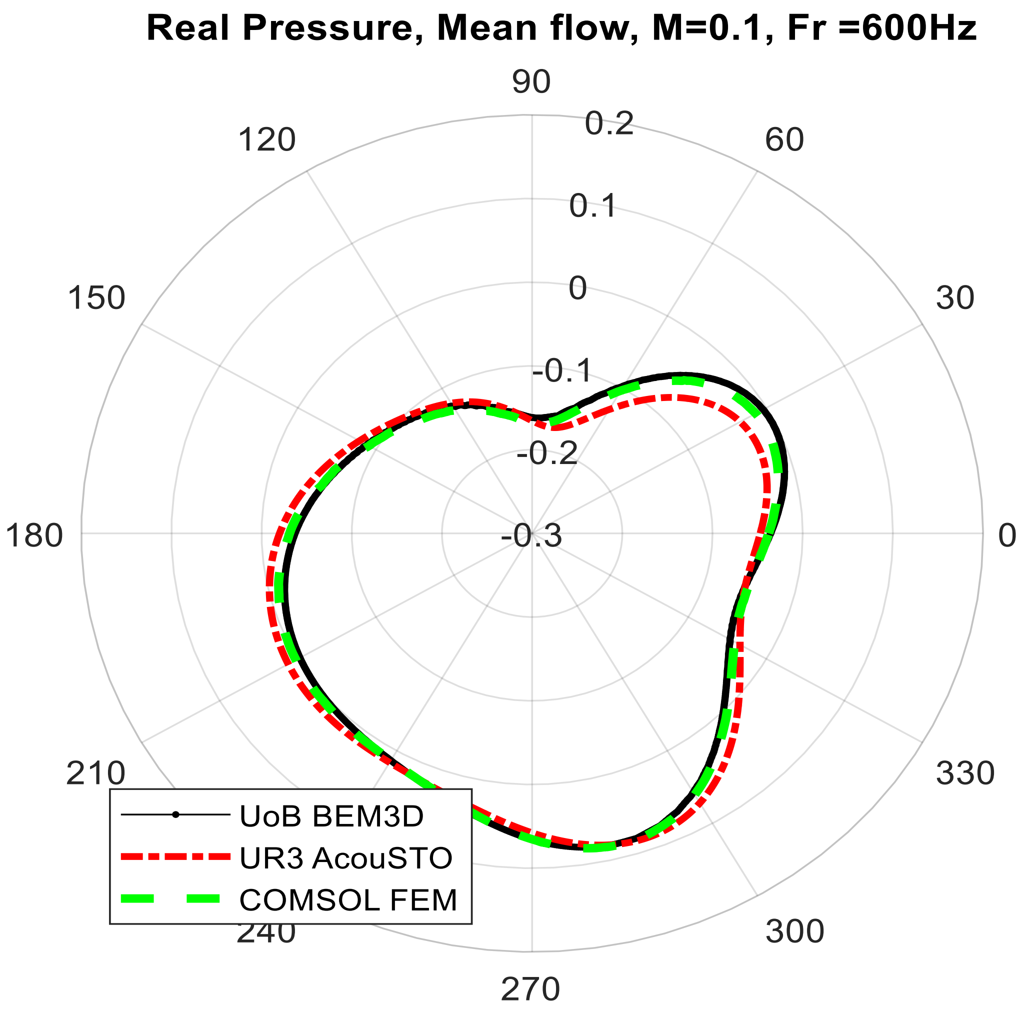


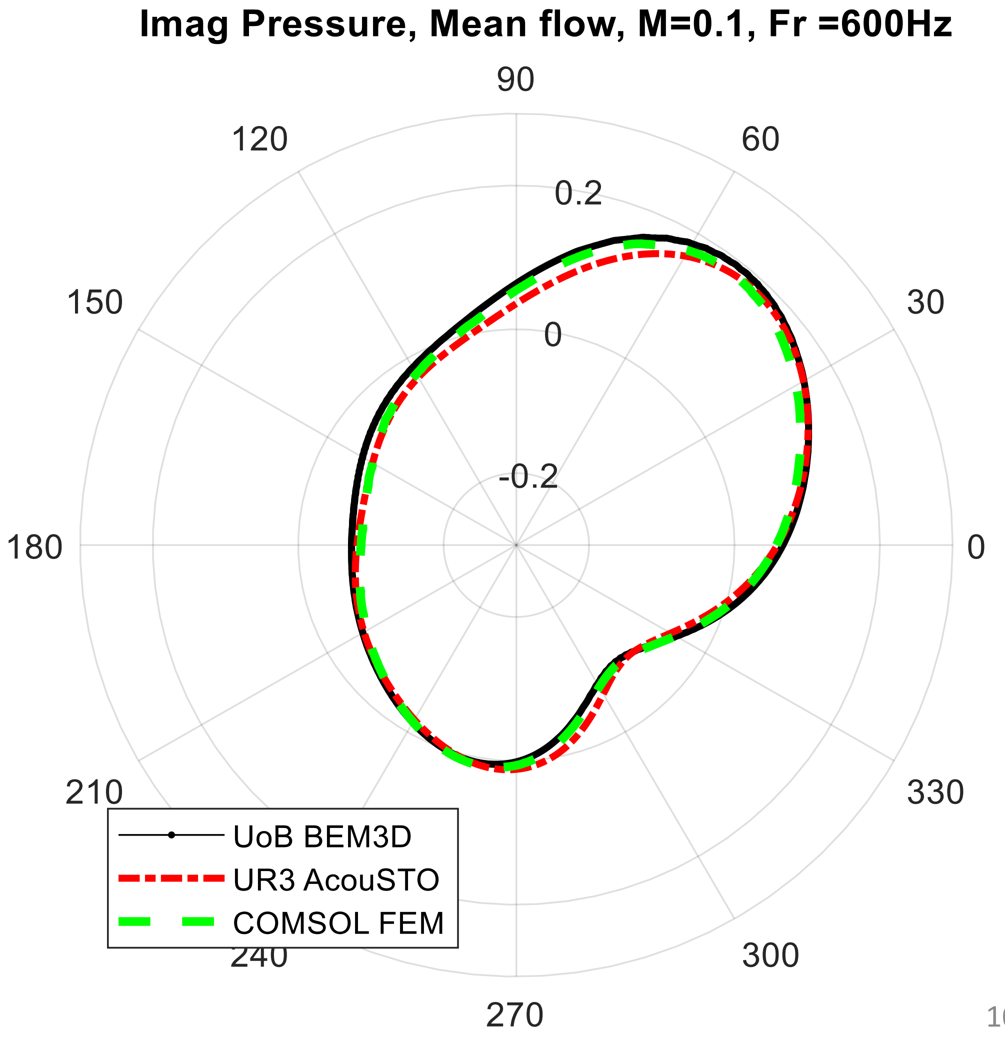
Simulation results: Flat plate hard wall, No flow, BEM3D vs AcouSTO vs COMSOL



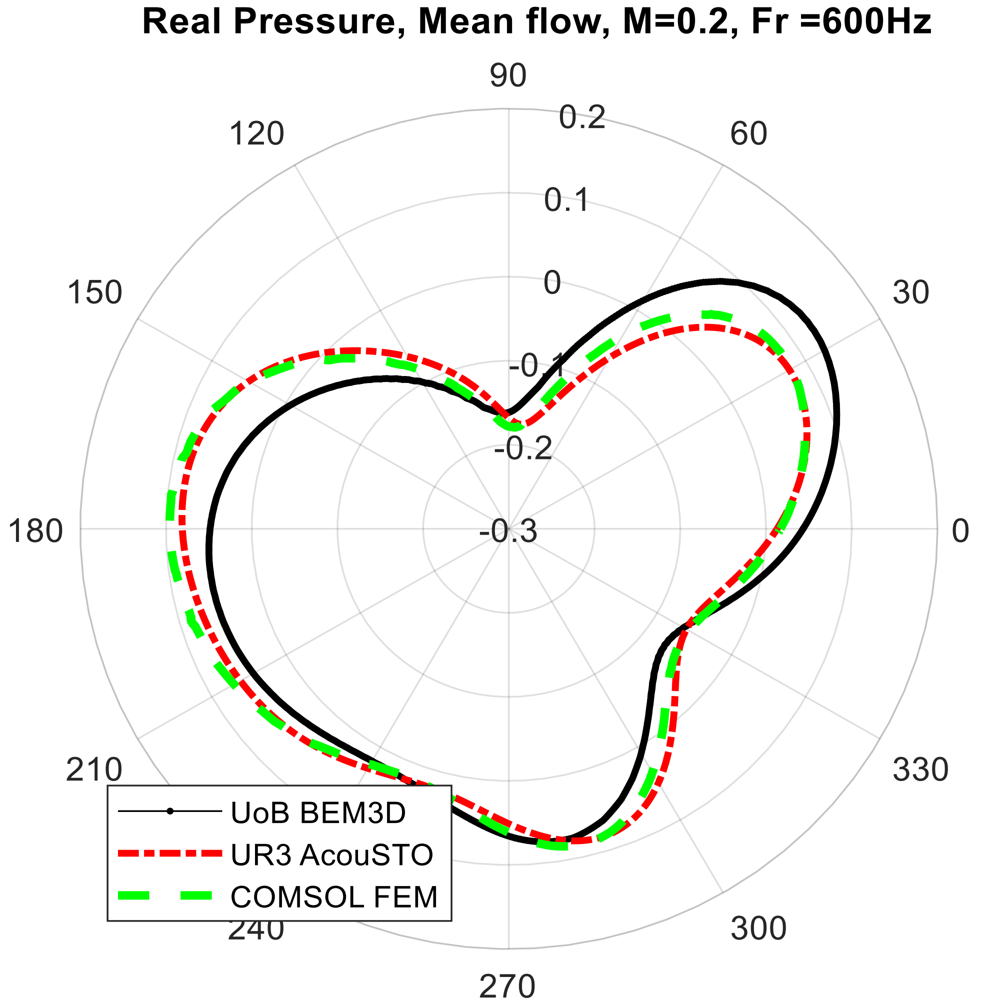


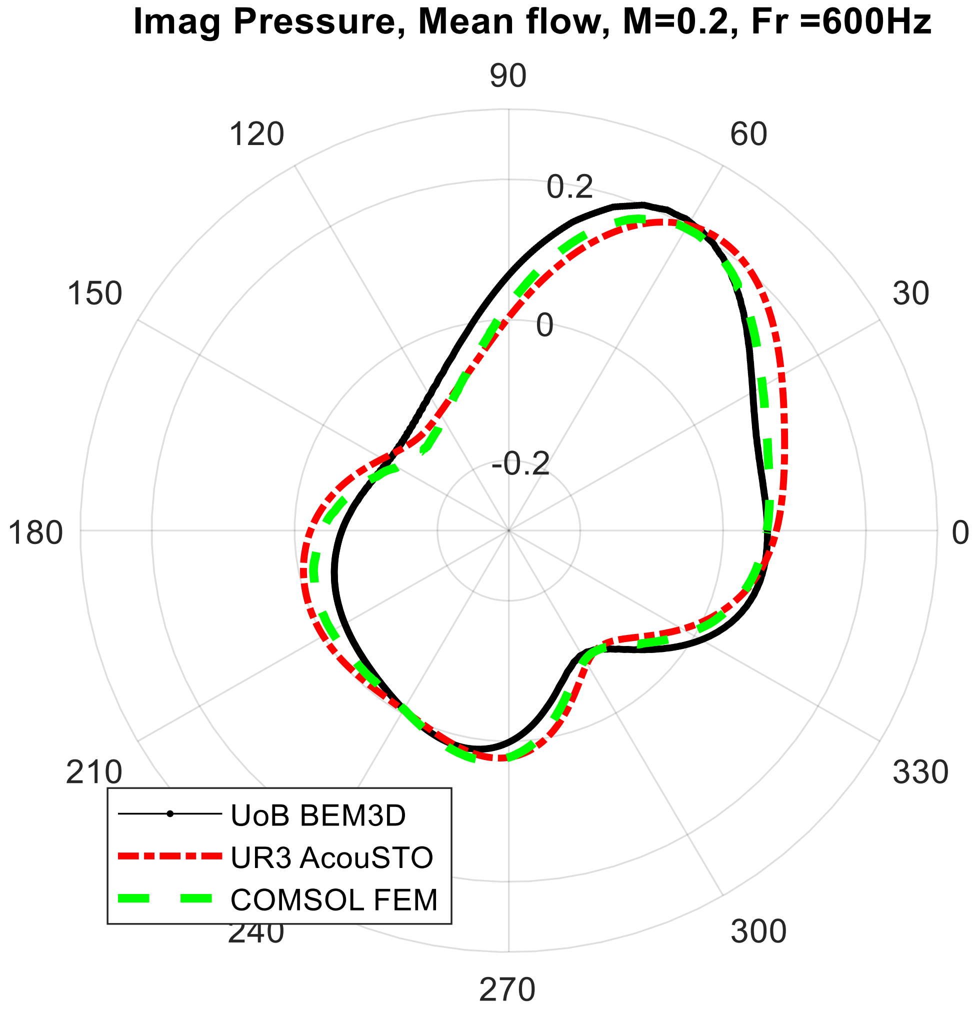
Simulation results, Flat plate hard wall, with flow M = 0.1, BEM3D vs AcouSTO vs COMSOL



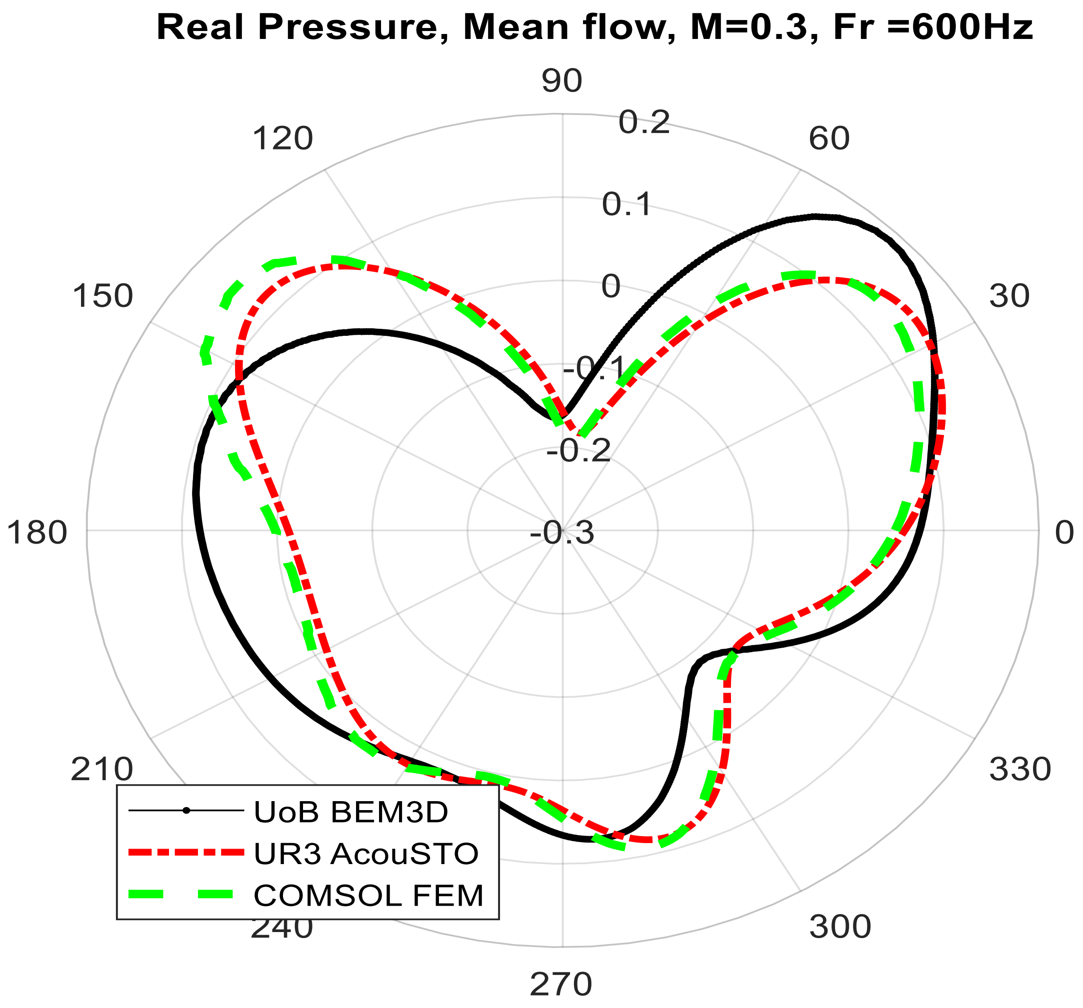


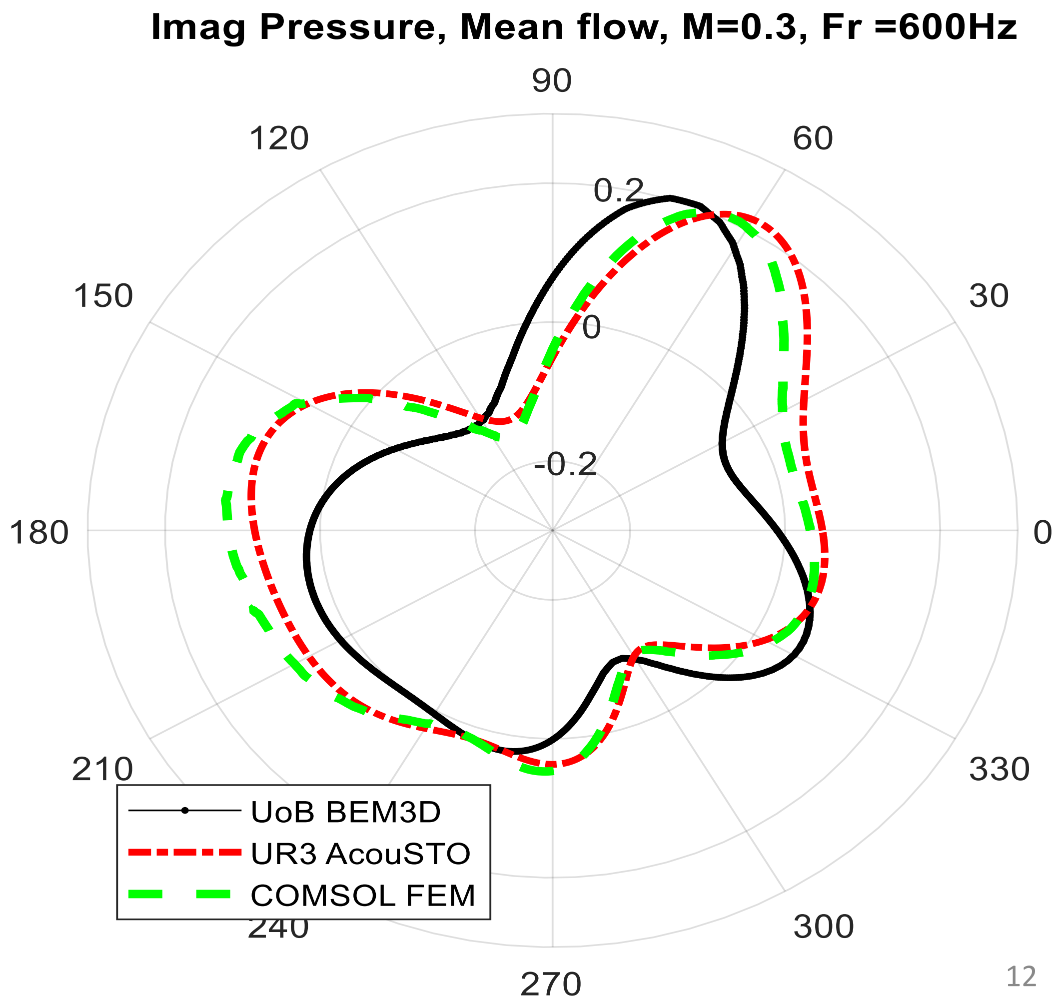
Simulation results, Flat plate hard wall, with flow M = 0.2, BEM3D vs AcouSTO vs COMSOL





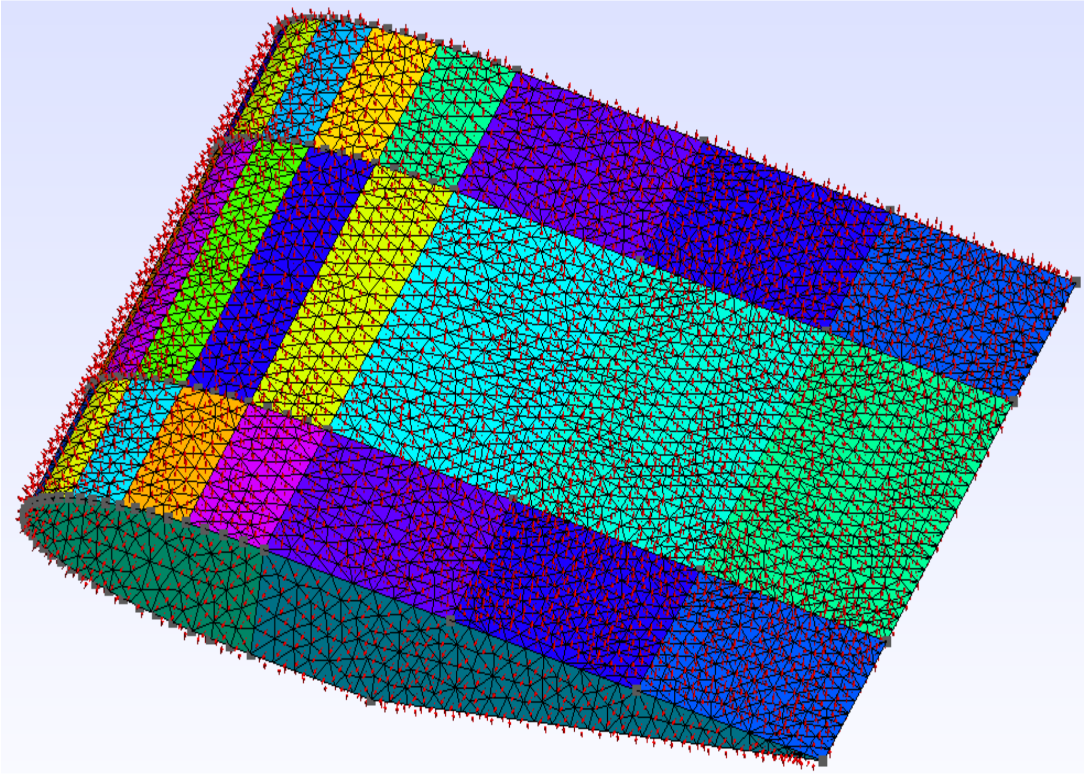
Simulation results, Flat plate hard wall, with flow M = 0.3, BEM3D vs AcouSTO vs COMSOL

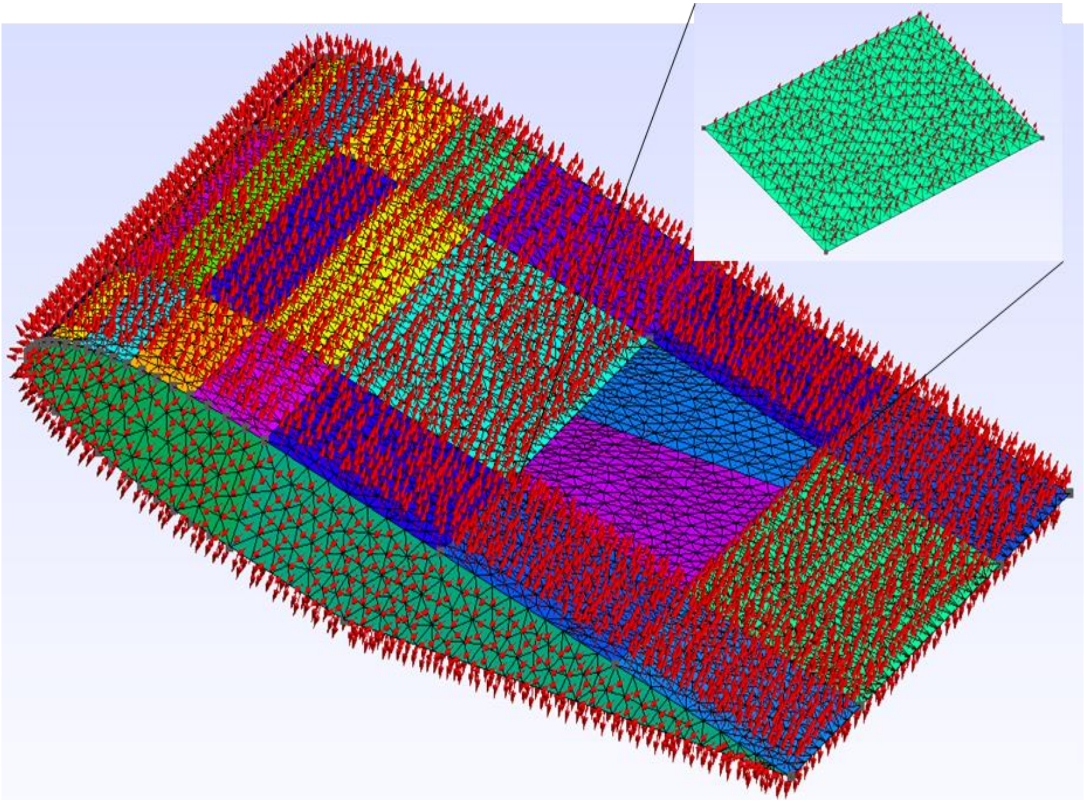




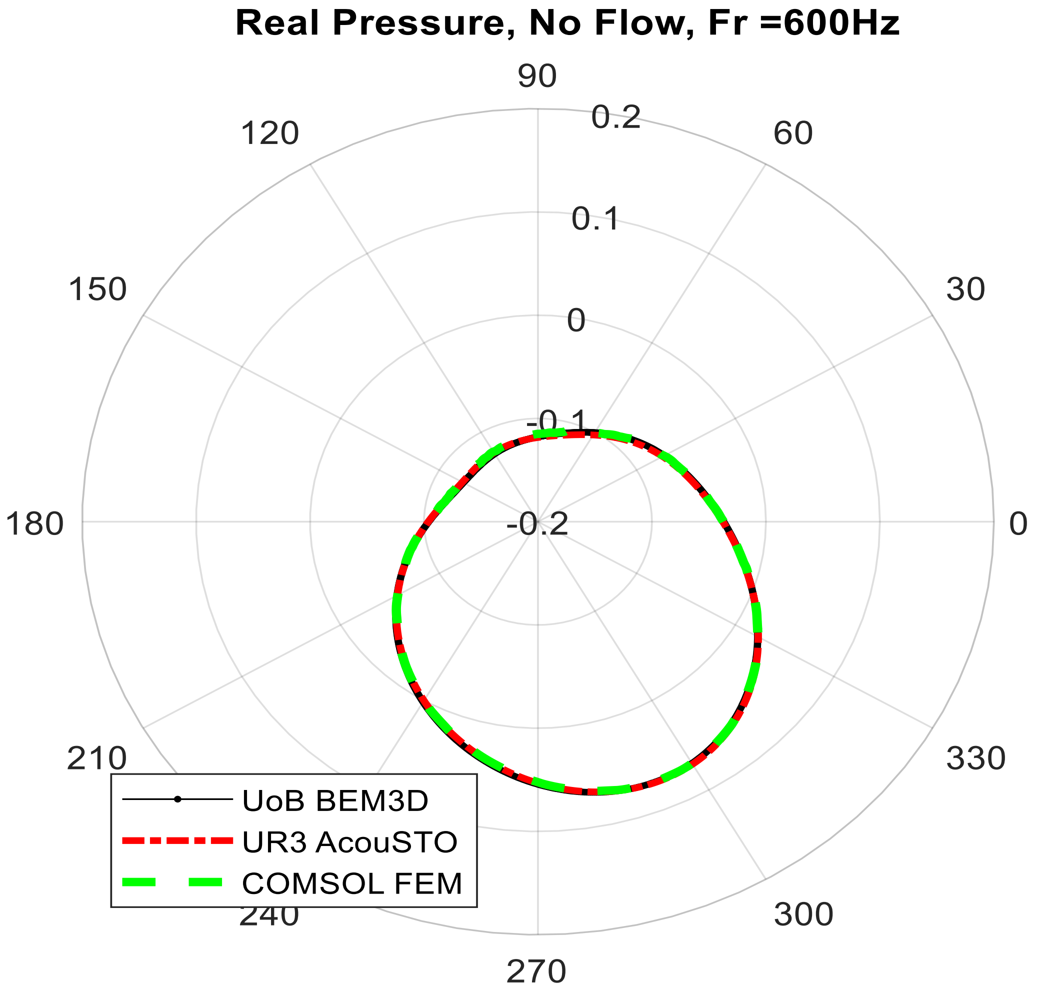
Flat plate with surface treatments

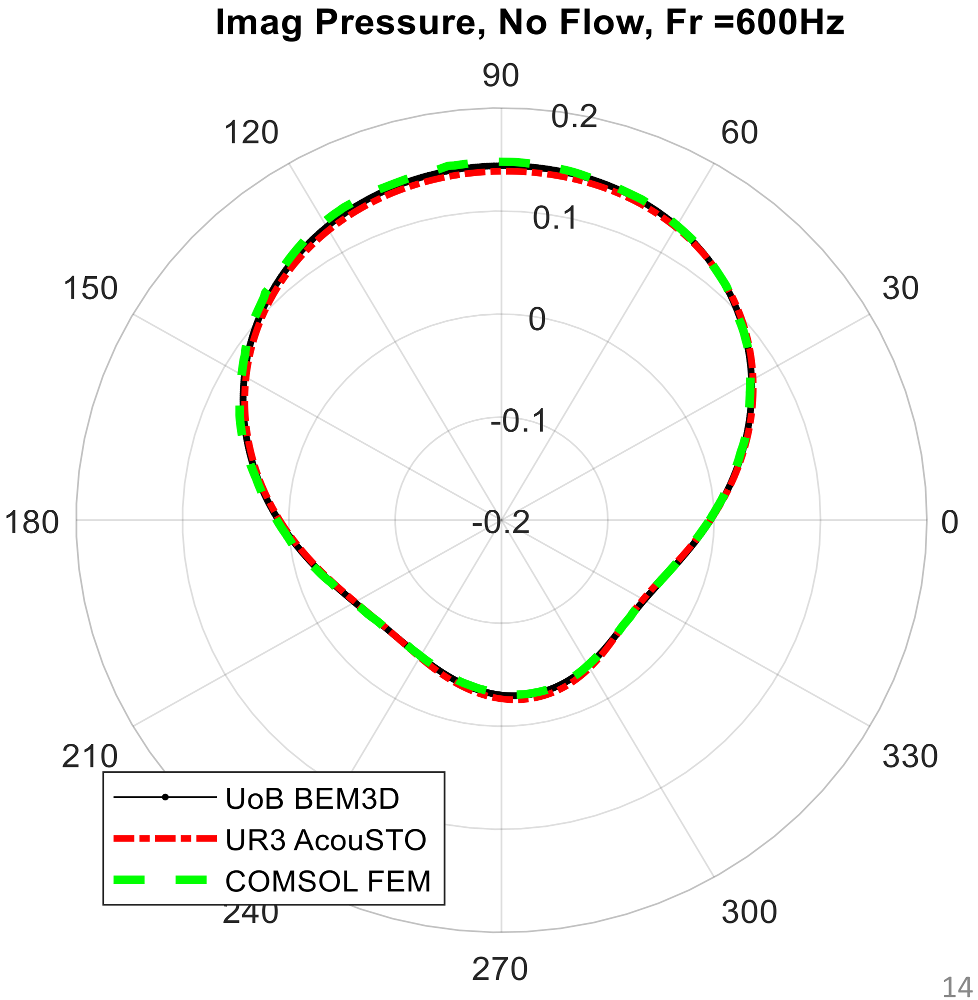
- Flat plate is implemented as surface treatments.
- This is a step forward to implement metamaterial in flat plate

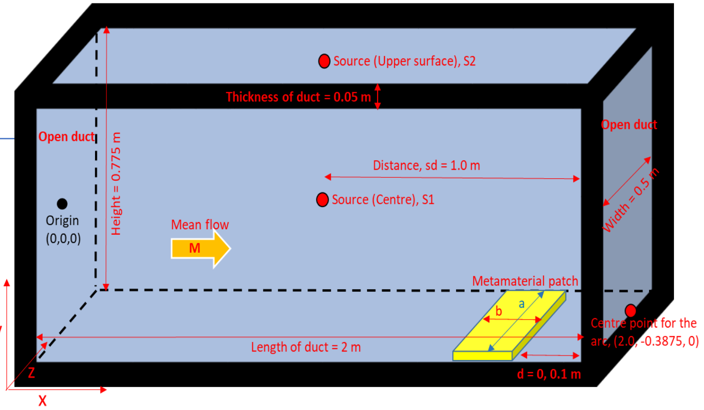




Simulation results: Flat plate with surface treatment, No flow, BEM3D vs AcouSTO vs COMSOL

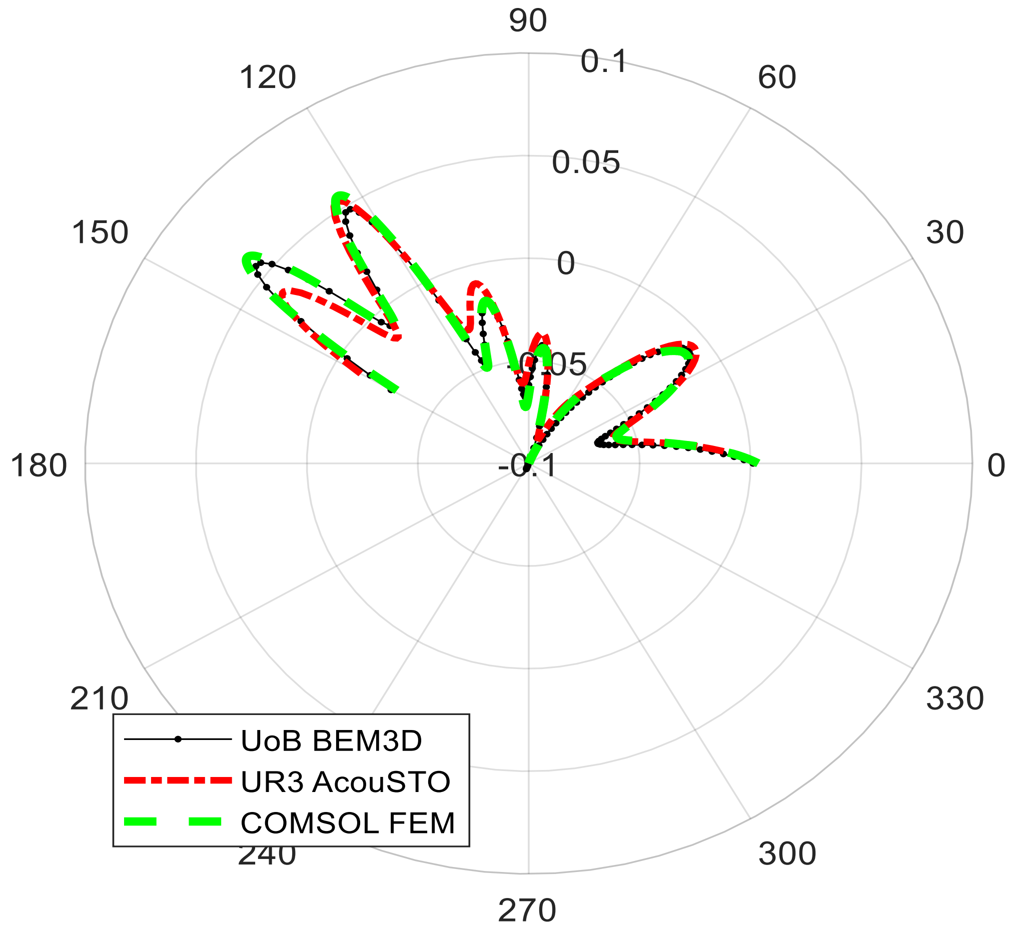




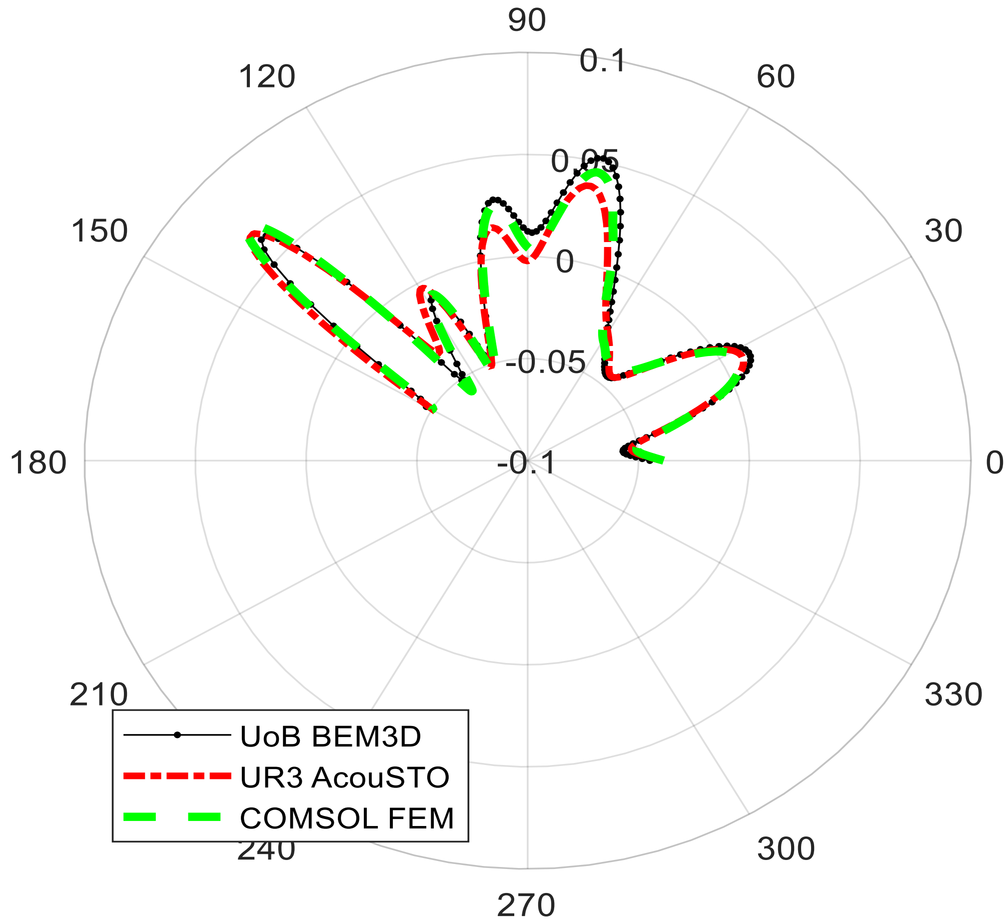


Simulation results: Duct hard wall, No flow, BEM3D vs AcouSTO vs COMSOL

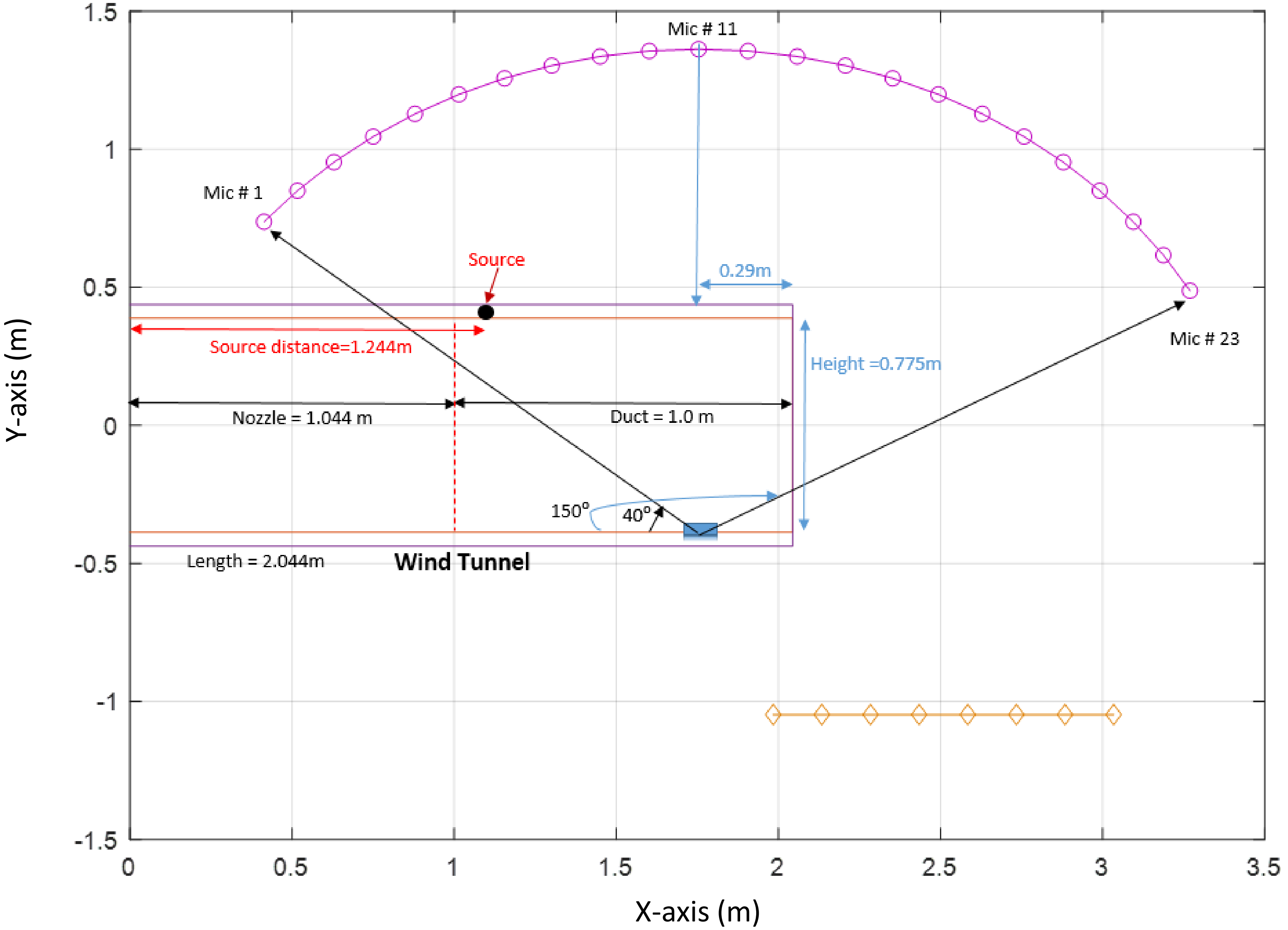
(a) Real Pressure, No Flow, Fr =600Hz

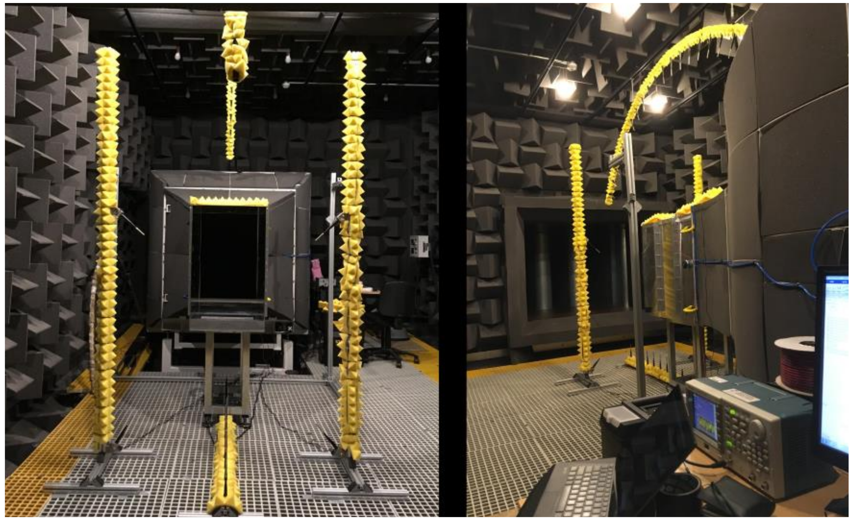


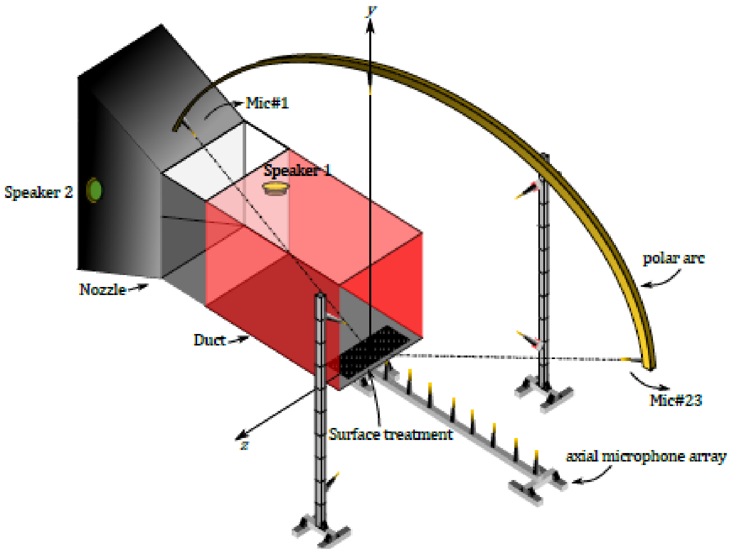
(b) Imag Pressure, No Flow, Fr =600Hz



Measurements – University of Bristol

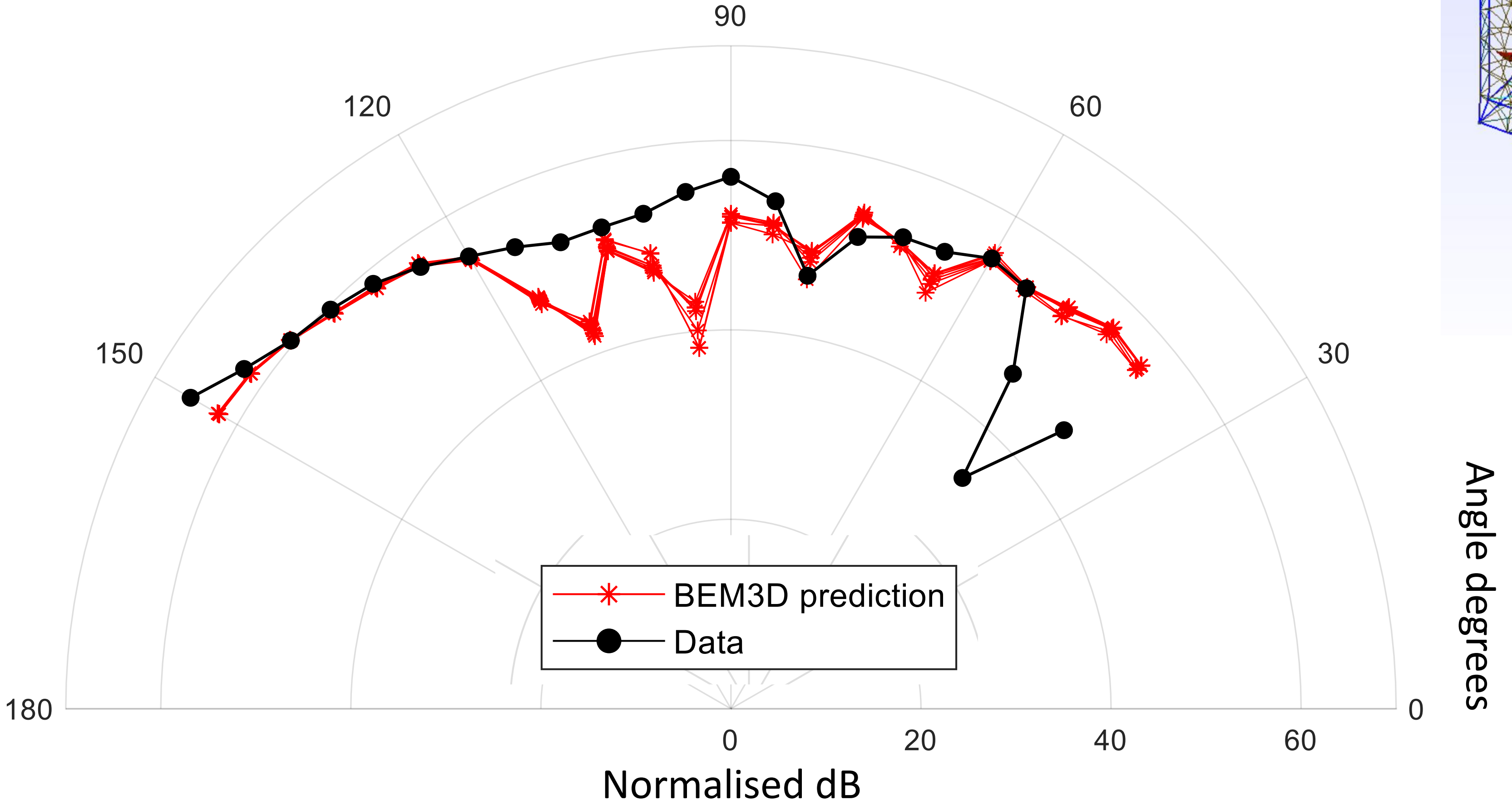


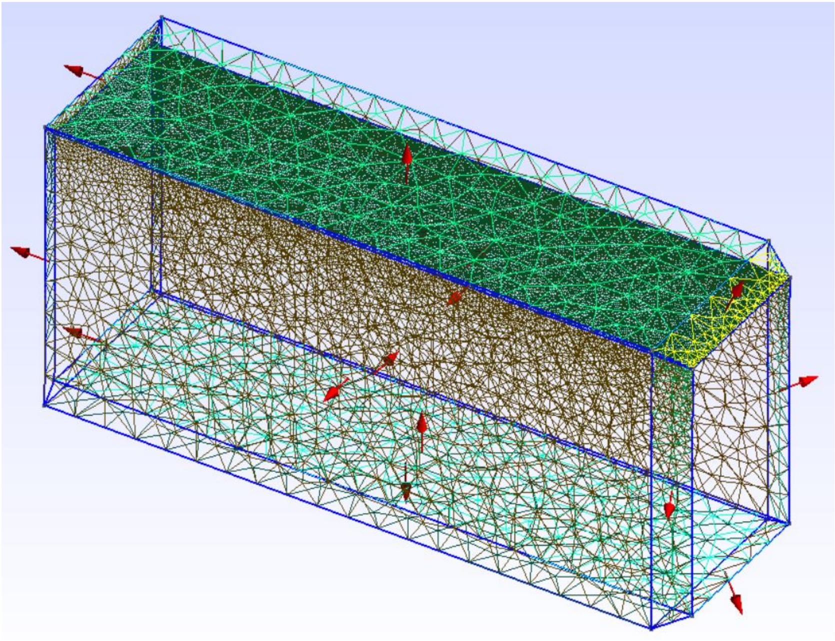




Comparison between data and predictions Rectangular Nozzle

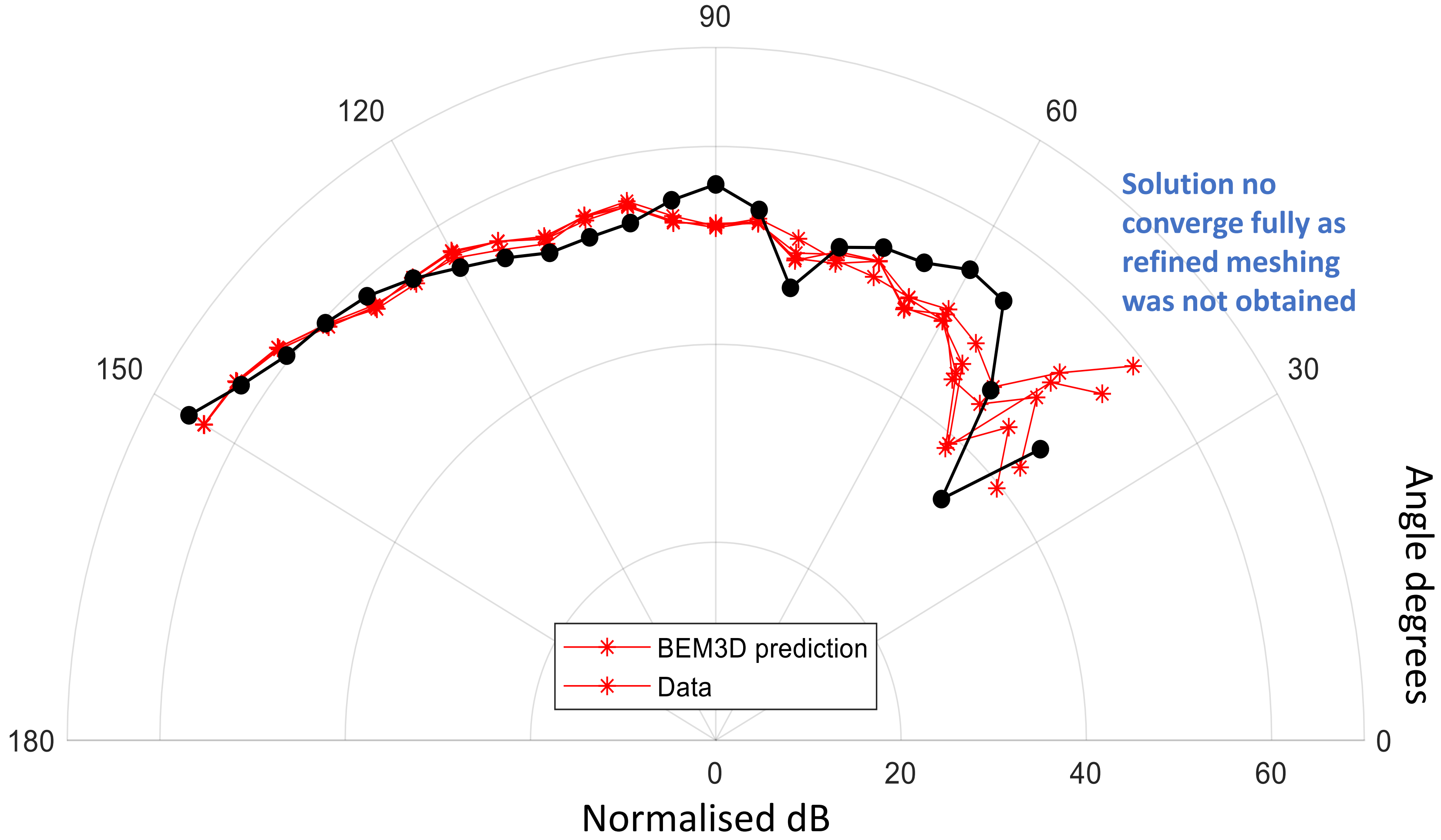
Frequency = 600 Hz (No flow) & Wall thickness = 50mm



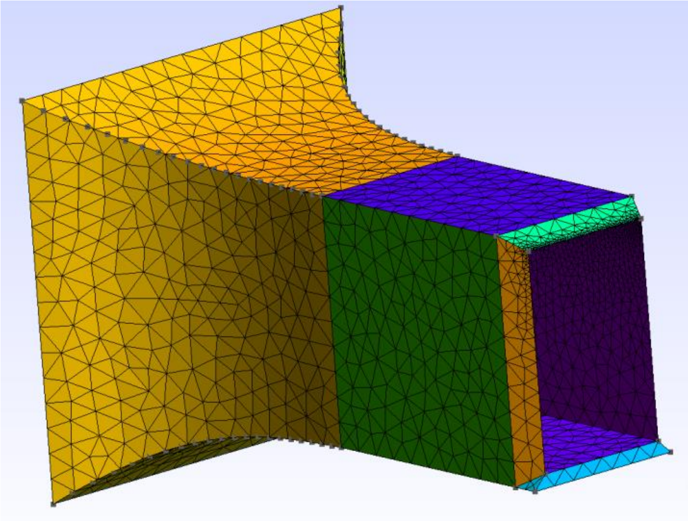


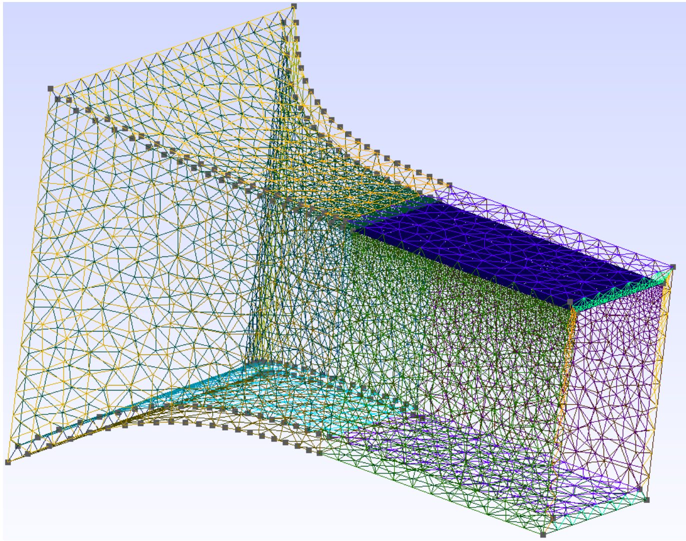
Comparison between data and predictions
Bespoke Nozzle

Frequency = 600 Hz (No flow) & Wall thickness = 50mm

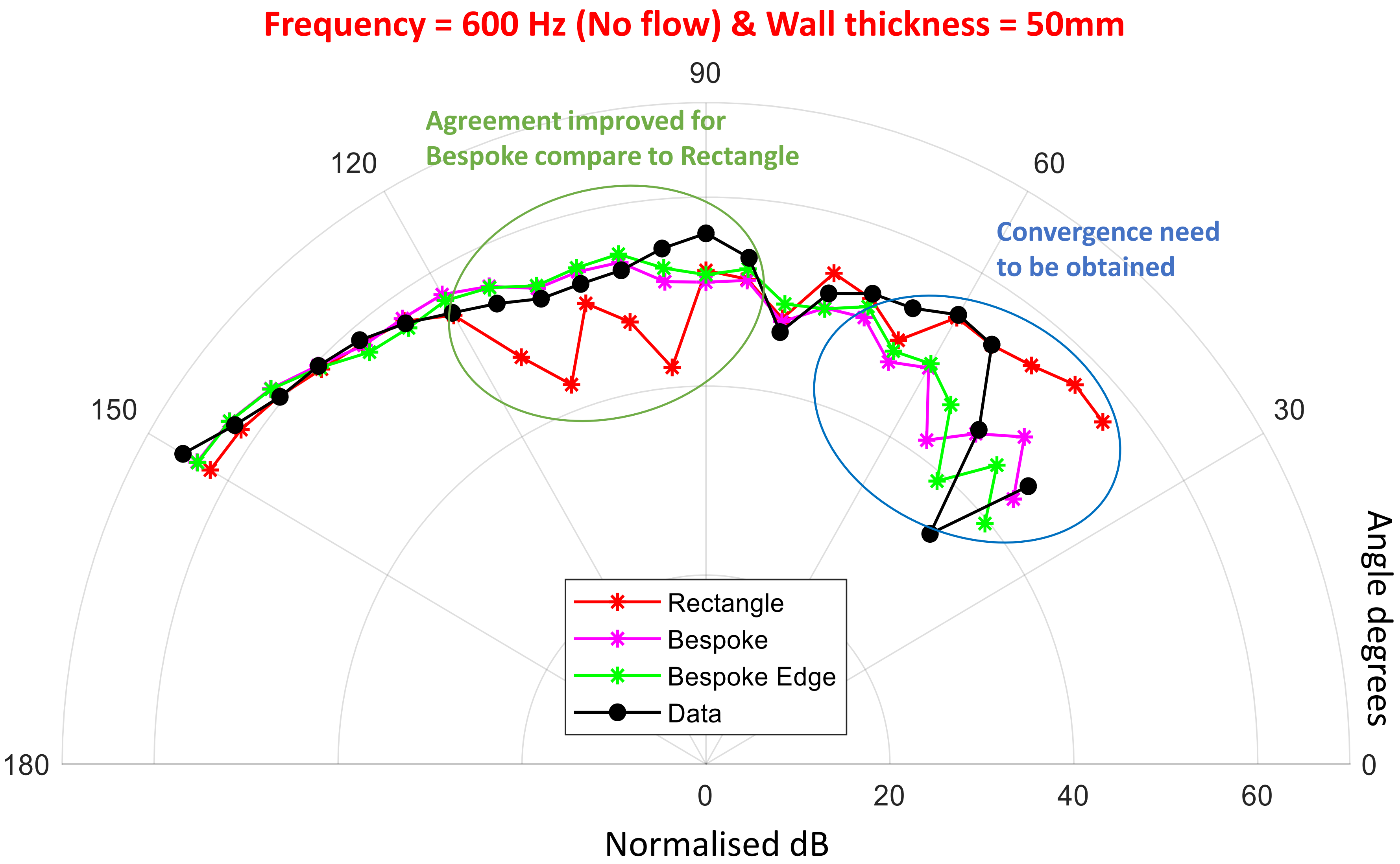


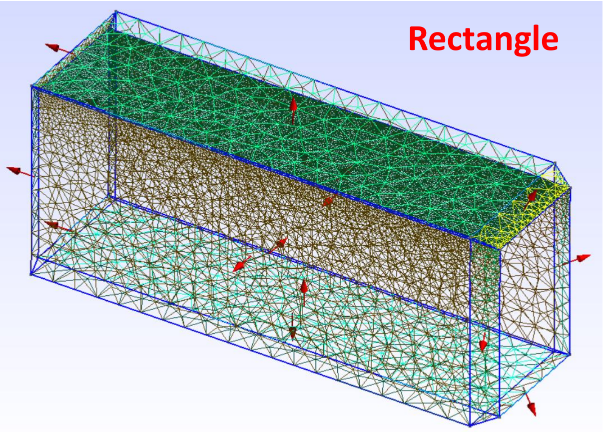
Solution no converge fully as refined meshing was not obtained

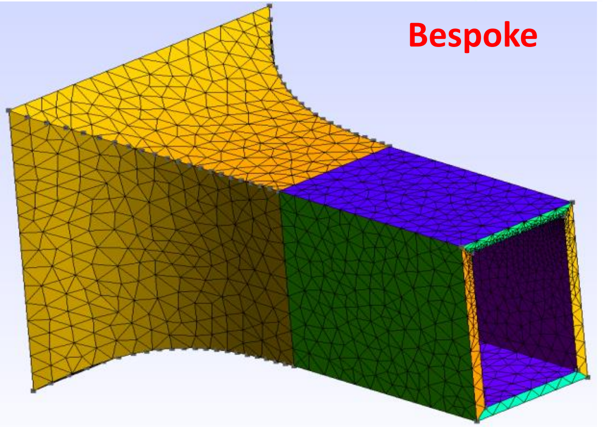


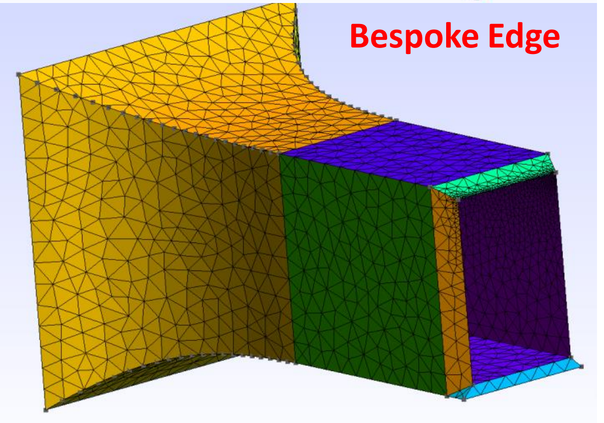


Comparison between data and predictions









Conclusions and future work

- A set of benchmark problems have been simulated intended to test the computational methods as developed at the University of Bath.
- The benchmark simulations carried out for flat plate and duct show a very good agreement between BEM3D, AcouSTO and COMSOL.
- Simulations with mean flow show good agreement at Mach number of 0.1 for three predictions techniques.
- For Mach number of 0.2 and 0.3, AcouSTO and COMSOL show very good agreement, however BEM3D simulations show some deviation as expected.
- Overall, good agreement has been found between experimental data and BEM3D predictions.
- Future work focused on the implementation of non-local boundary conditions.