Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

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Sub-wavelength acoustic liner via “metamaterials”

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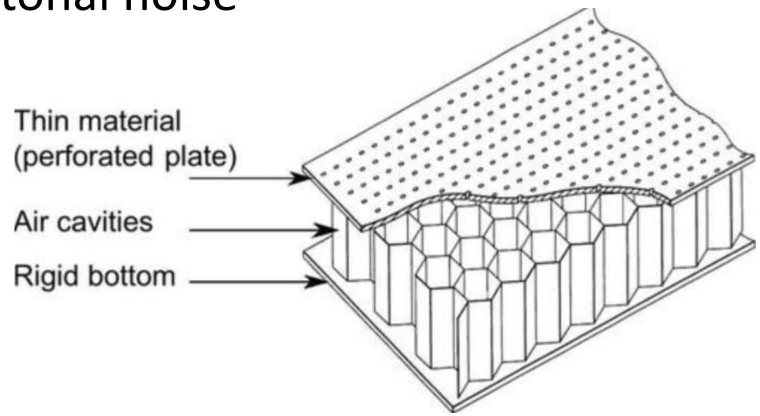
AERIALIST

AdvancEd aircRaft-noIse-AlLeviation devIceS using meTamaterials

- To disclose the potential of metamaterials to envisage innovative devices for the mitigation of the civil aviation noise
- Achieve the noise reduction targets foreseen by the Advisory Council for Aeronautics Research in Europe (ACARE) Flightpath 2050
  - **Reduce perceived noise emission of flying aircraft by 65%.**
- Focus on the reduction of the noise propagating outside turbofan nacelles

Acoustic Liners

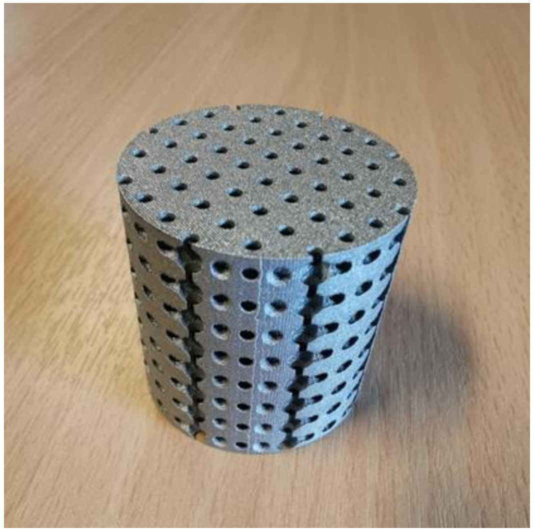
- In modern aircraft, most of the engine noise attenuation is provided by liners, in the internal walls of the nacelle, designed to reduce both broadband and tonal noise

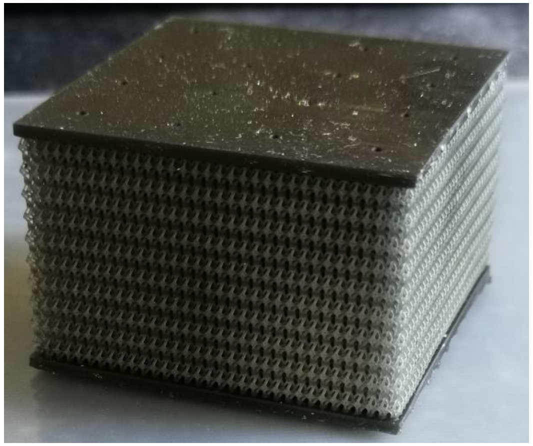


- Design Limitations
  - Frequency response is dependant on resonator depth
  - High depths result in narrow peaks for low and high frequencies
  - Shallow depths result in broader peaks at higher frequencies

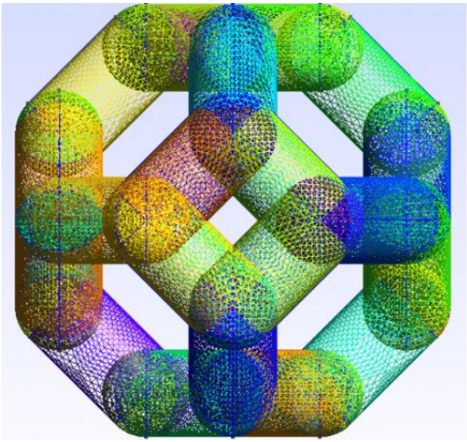
Acoustic Metamaterials

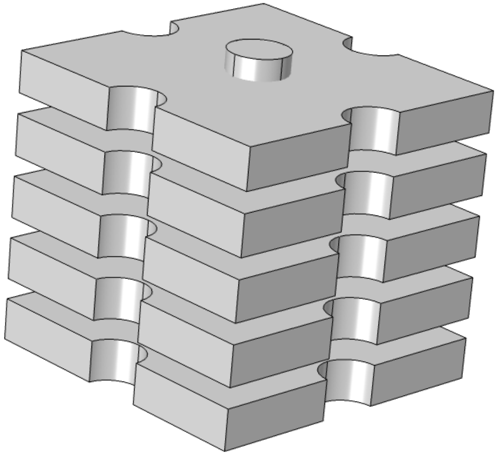
- Synthetic material that exhibits global mechanical properties beyond natural behaviour
  - Often represented by a structure with a periodic pattern
- Proposed Acoustic metamaterial classification depending on the type of acoustic response
  - energy absorption (subtraction of the energy associated to the acoustic pressure perturbations in the field by “trapping” and/or dissipation effects)
  - energy redistribution (directivity pattern distortion of the total acoustic field by scattering)

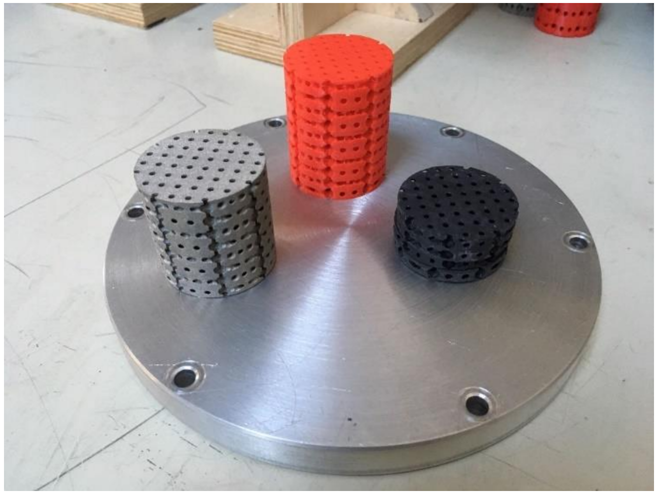


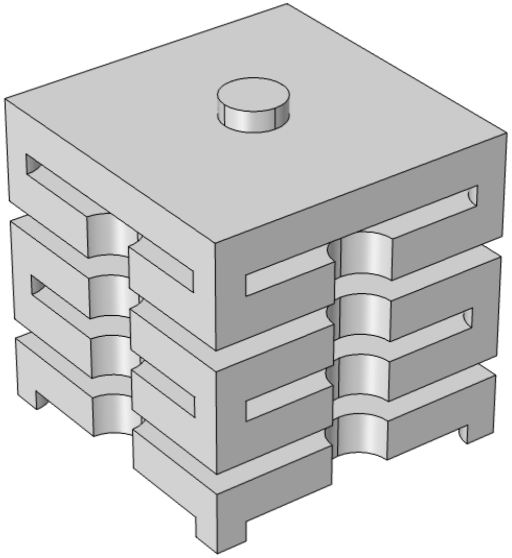


Explored designs



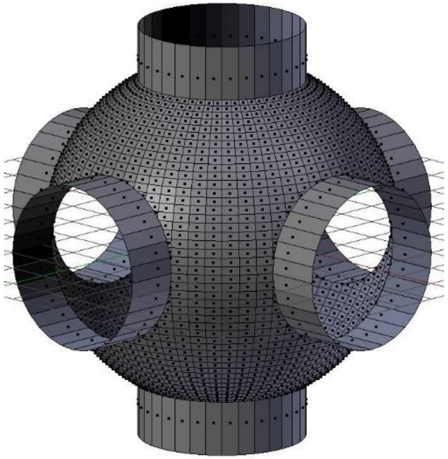




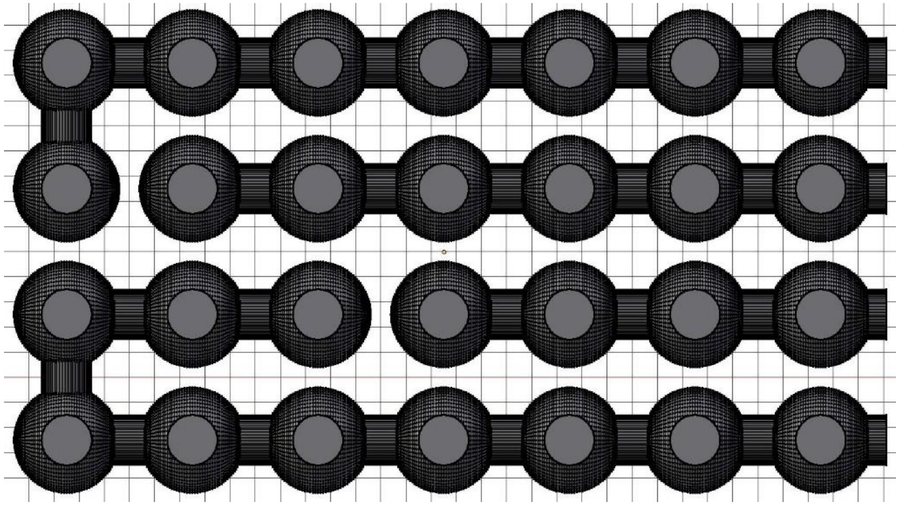


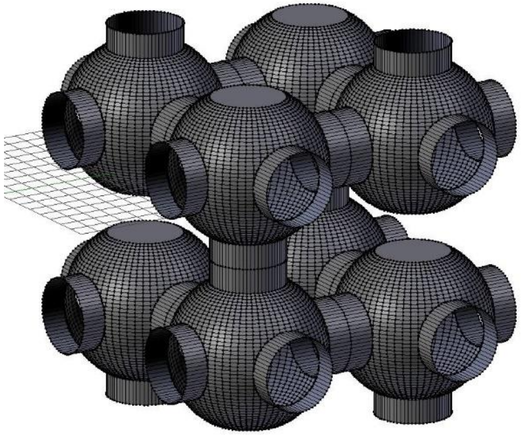
DENORMS design

- Benchmark design proposed by the DENORMS COST Action consists of a periodic structure of cubes with a spherical internal cavity connected through cylindrical openings on each face of the cube.

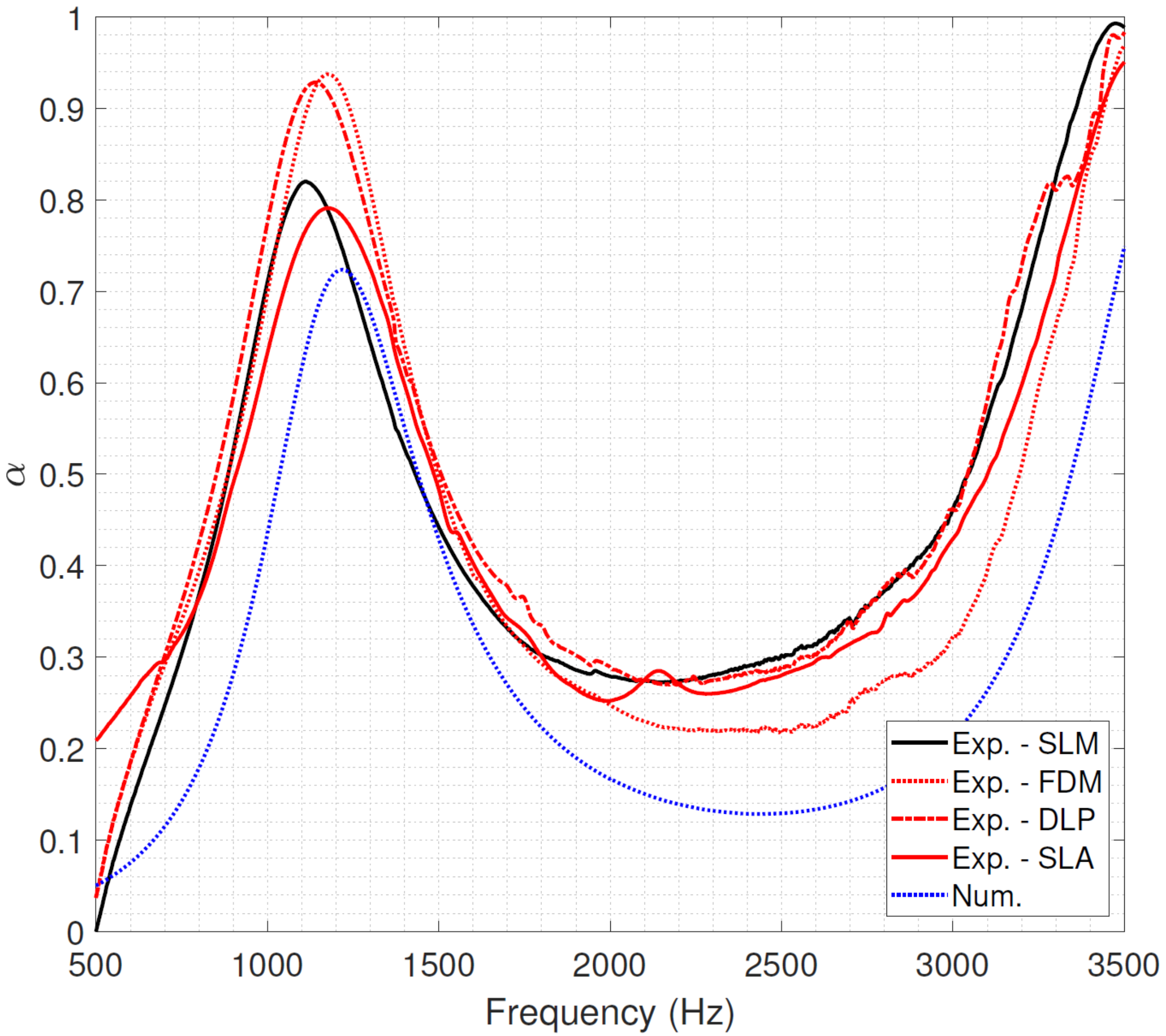


- Design variations





Influence of printing technology on acoustic performance



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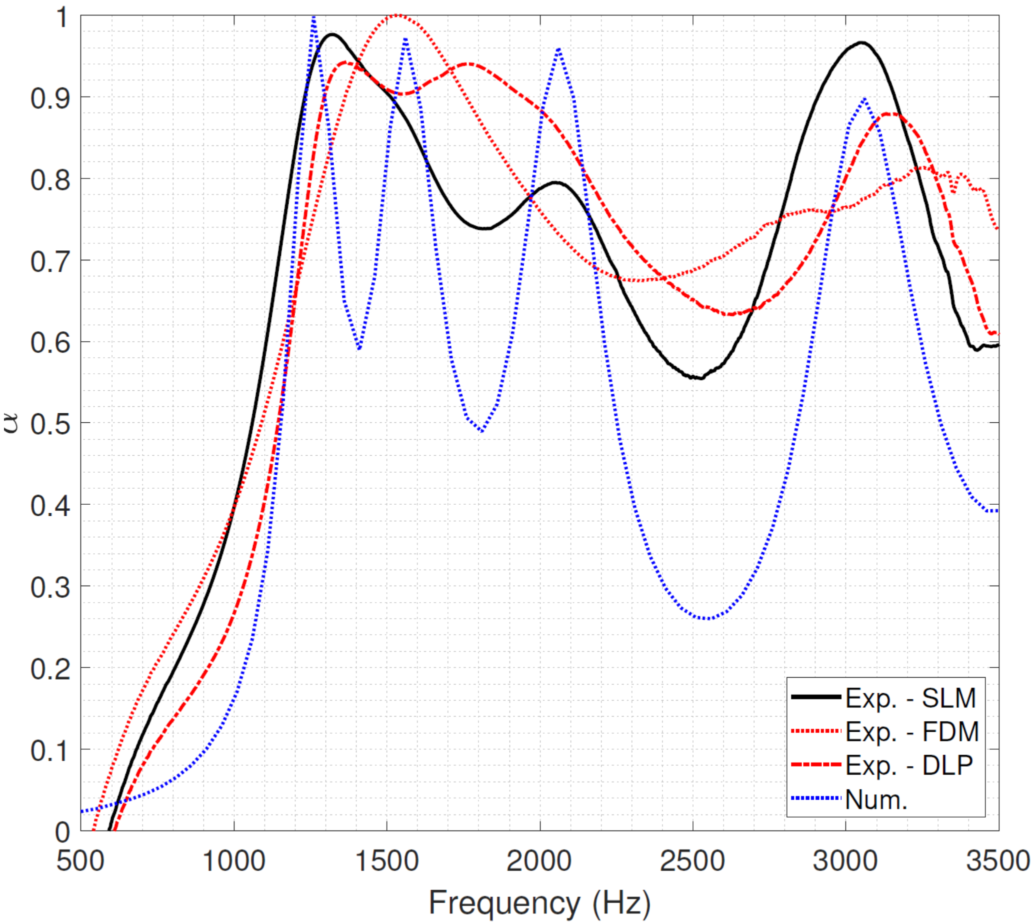
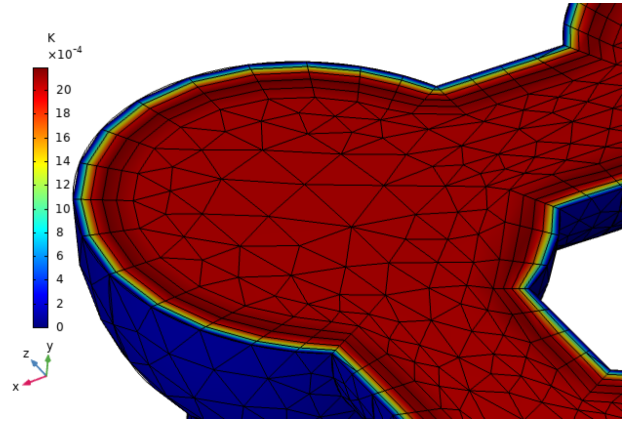
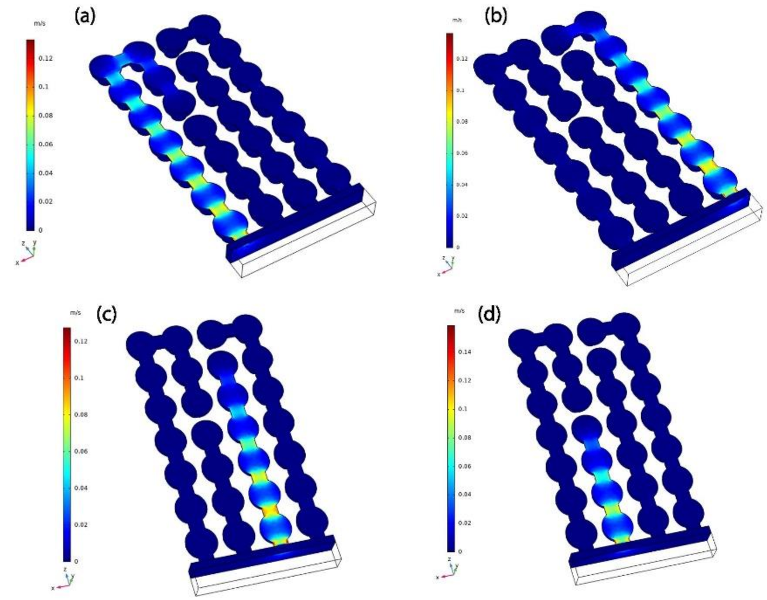
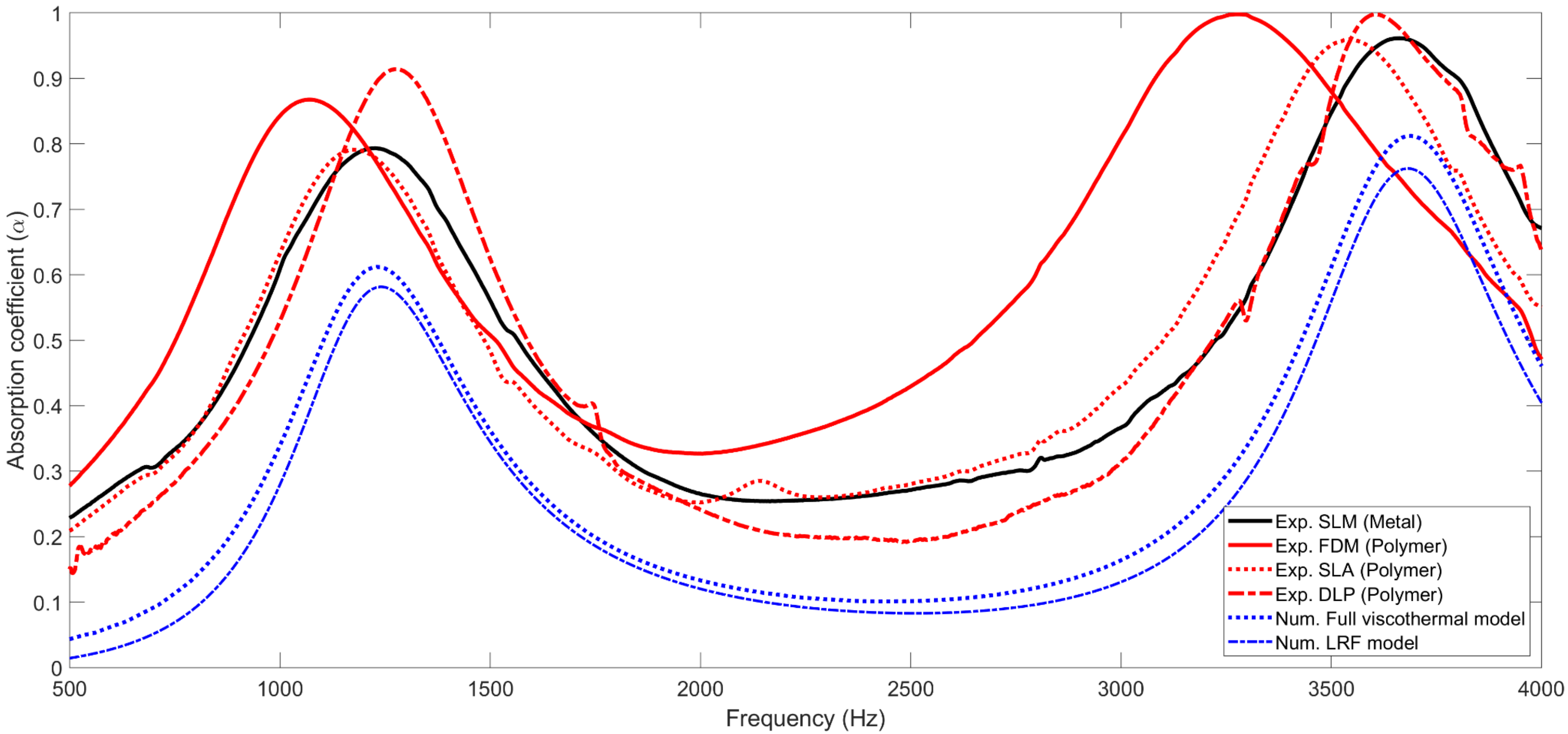






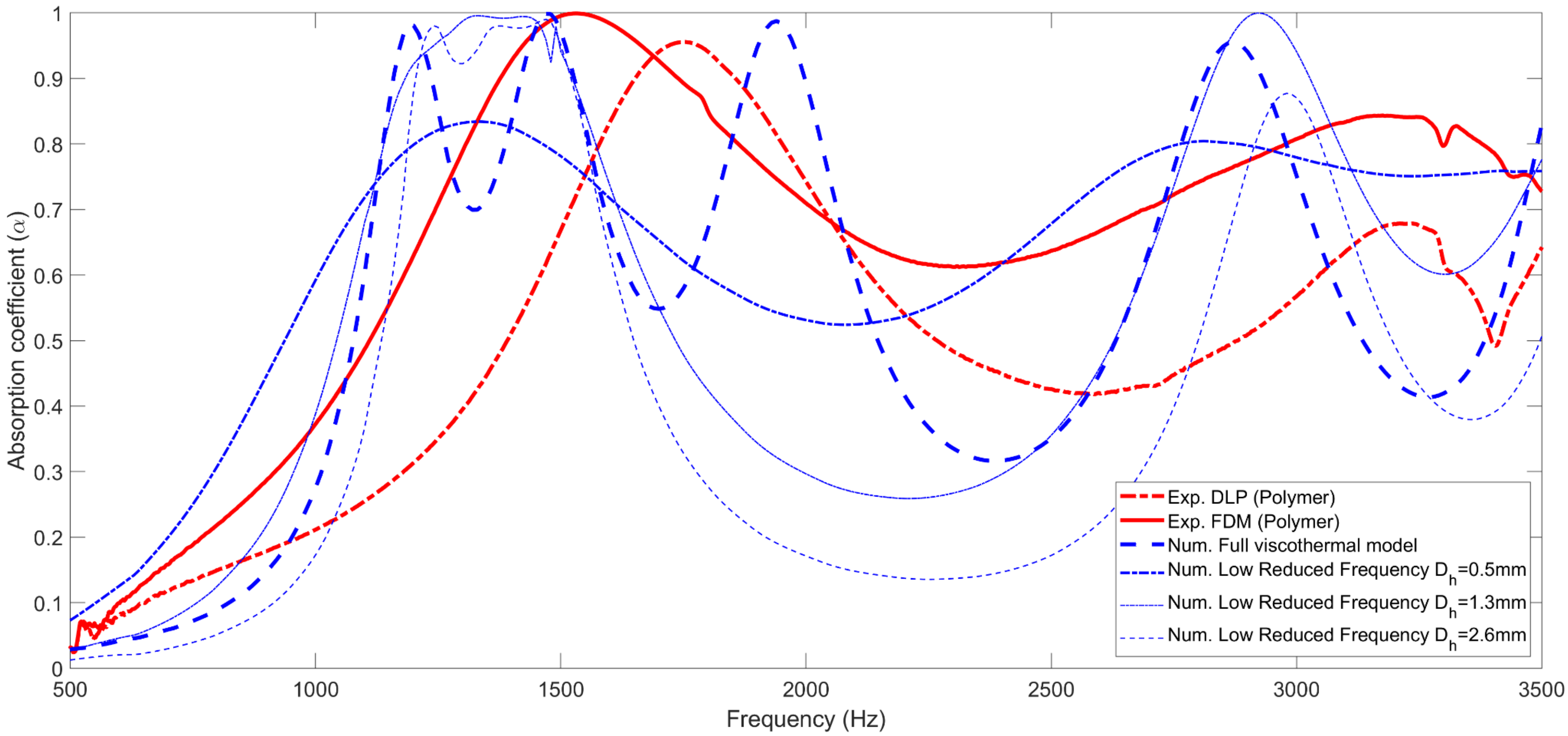
Reduced-order Models

10 layer deep DENORMS cell



Reduced-order Models

combined 4, 6, 8 and 10 layer depths of the DENORMS cell



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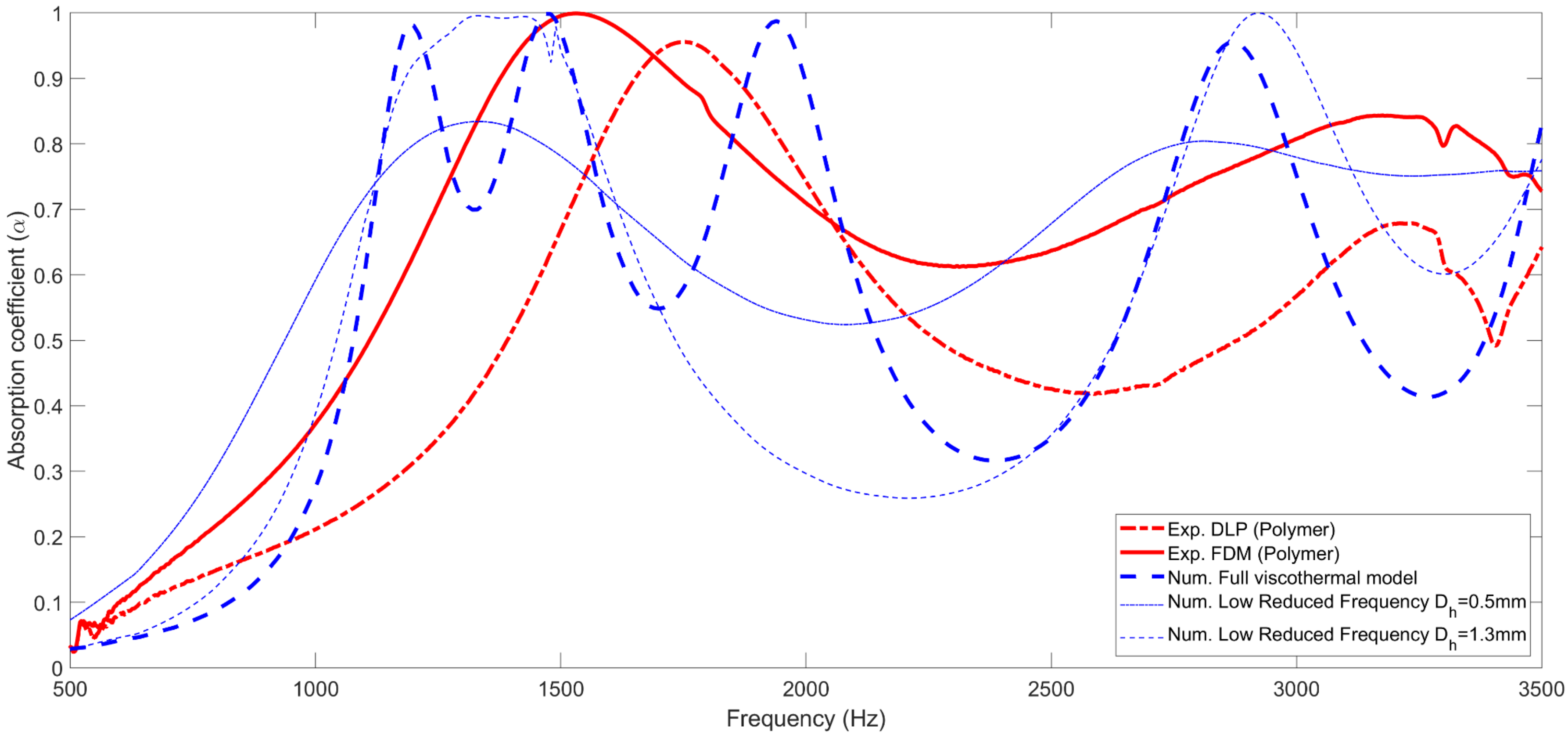
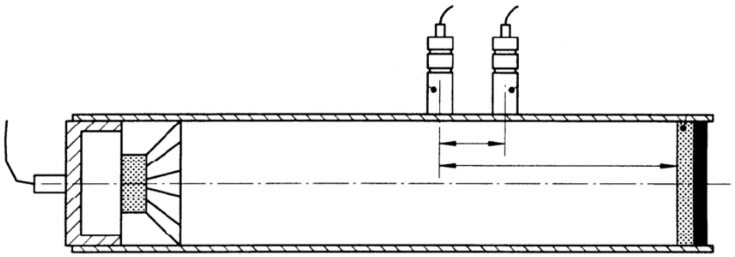
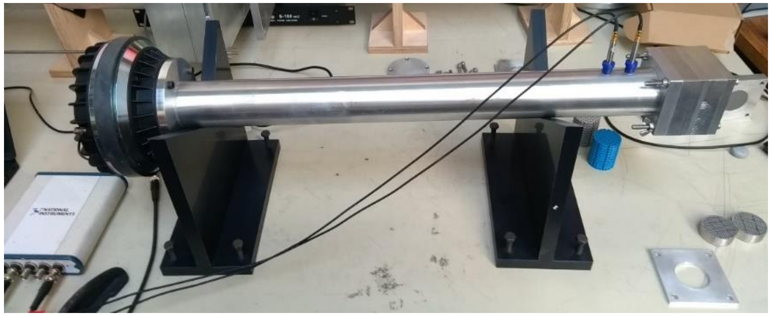
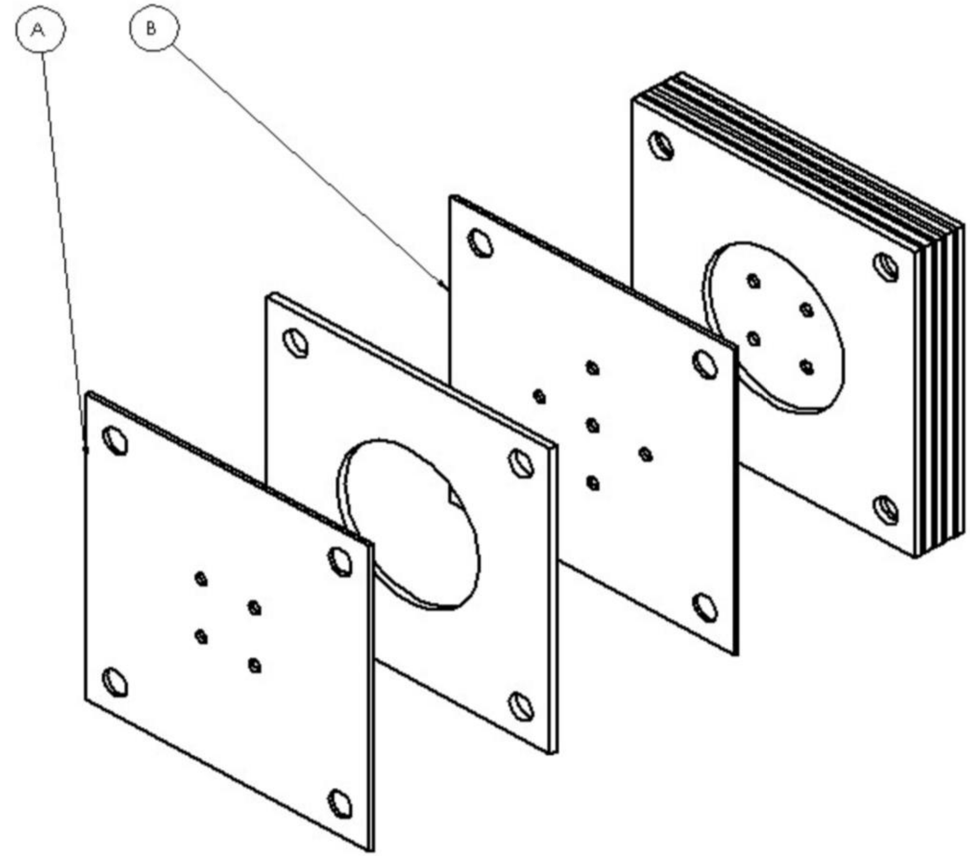


A sub-wavelength test configuration



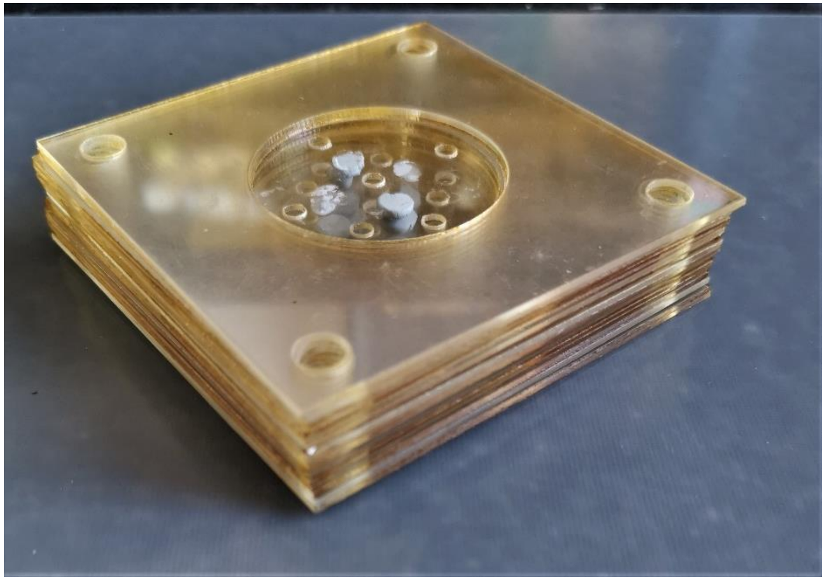




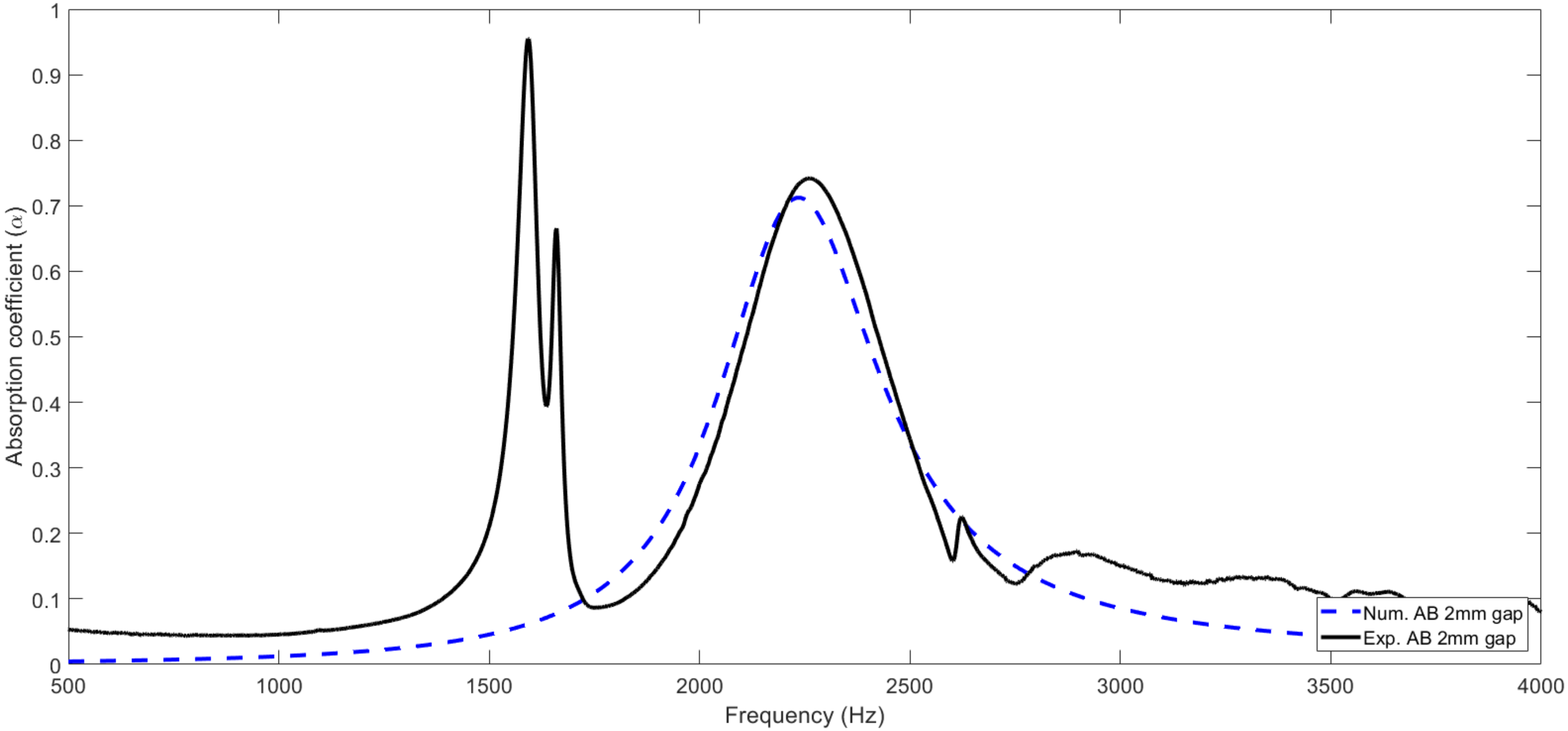
- Staggered perforations alternated between patterns A and B
- Air gap of 2 mm
- Direct patterns of A or B

Configurations

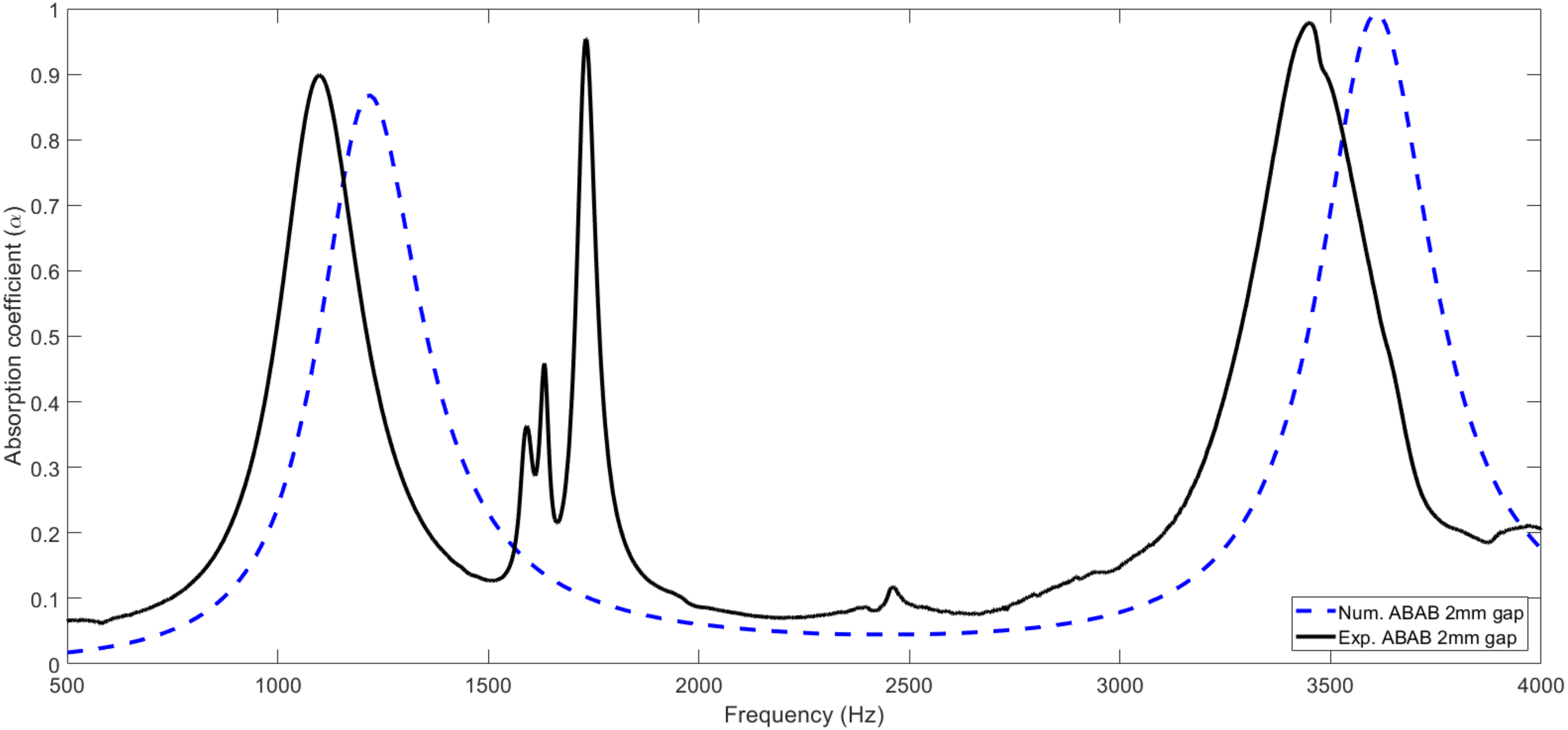
Configuration 1	**AB**
Configuration 2	**ABAB**
Configuration 3	**ABABAB**
Configuration 4	**AAA**



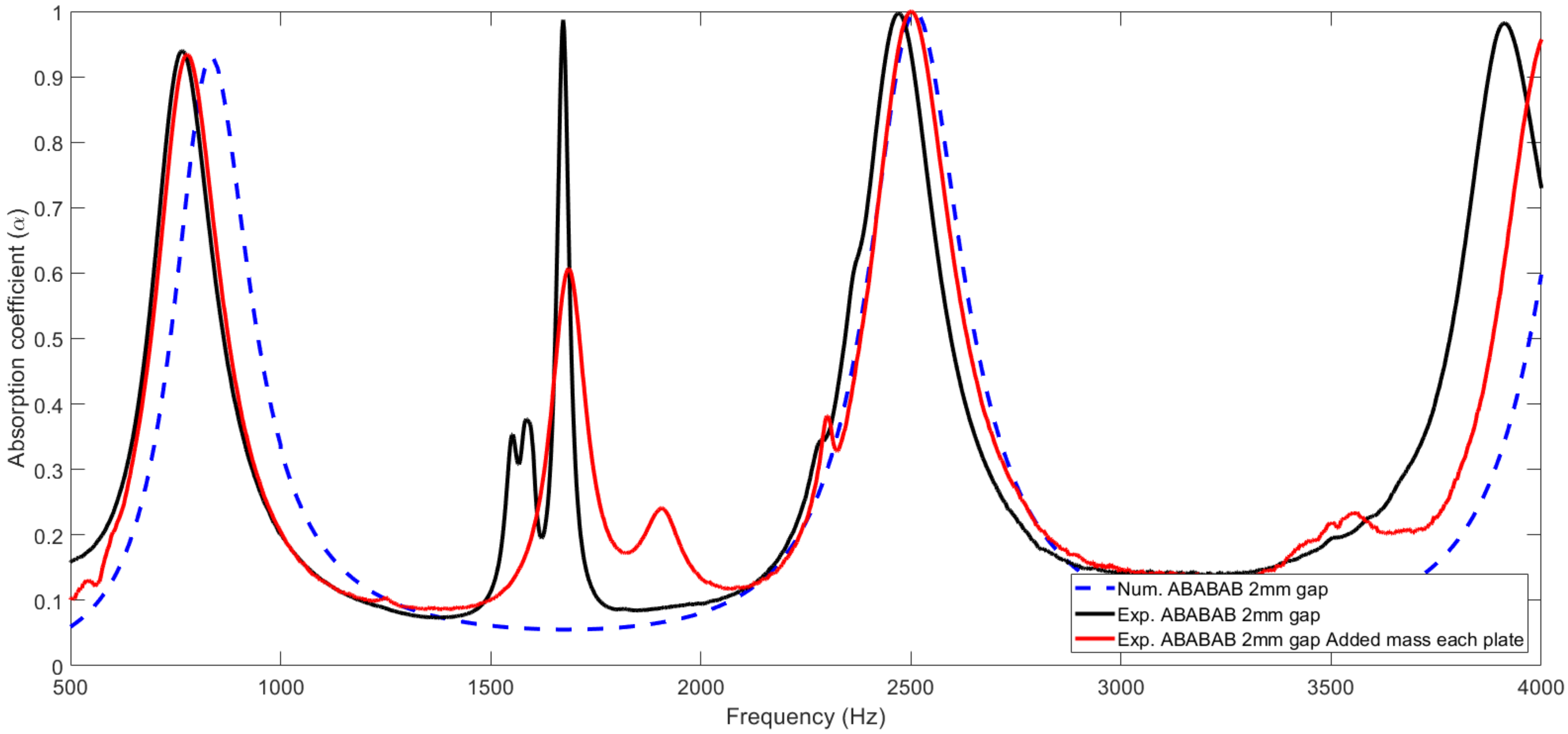
Configuration 1



Configuration 2



Configuration 3



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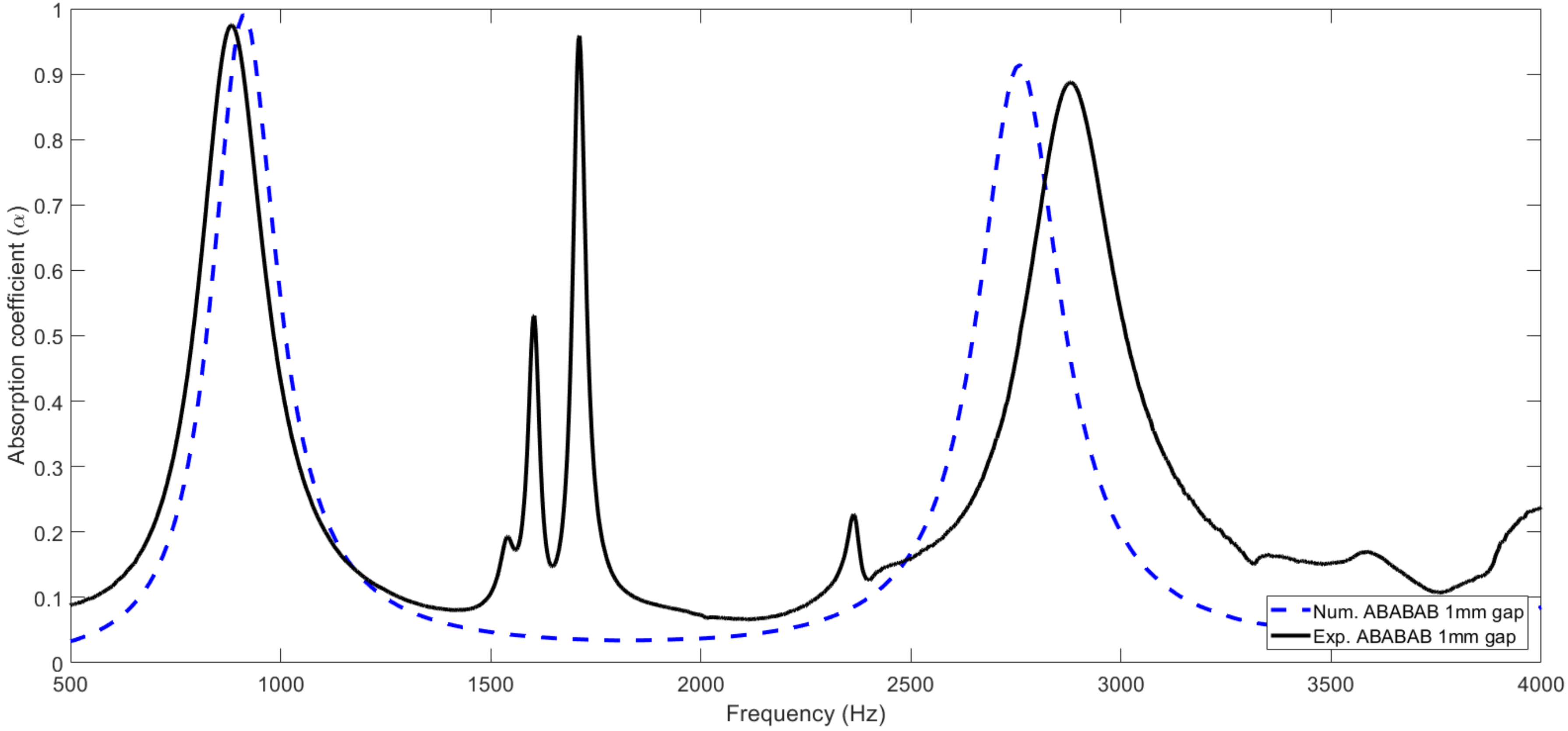

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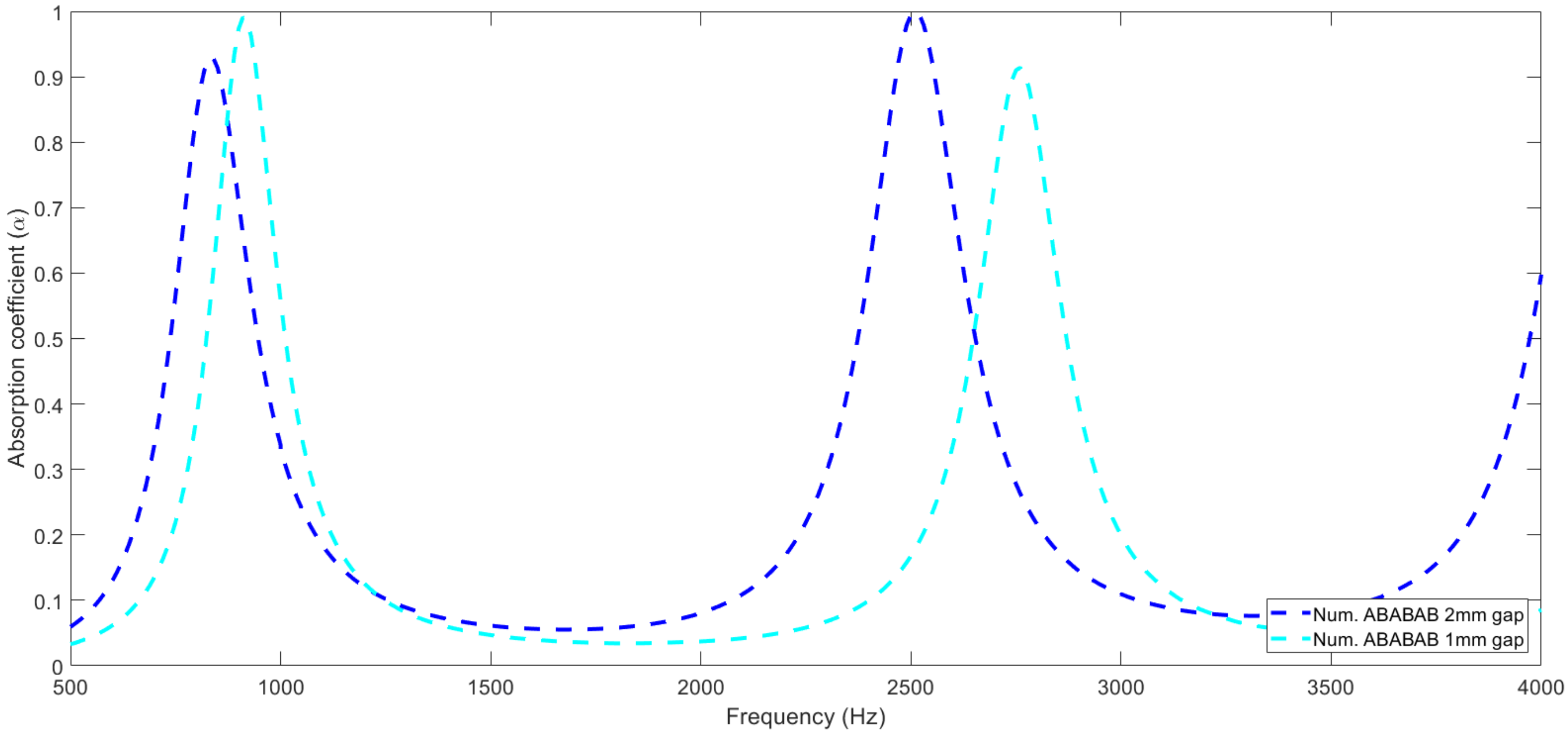
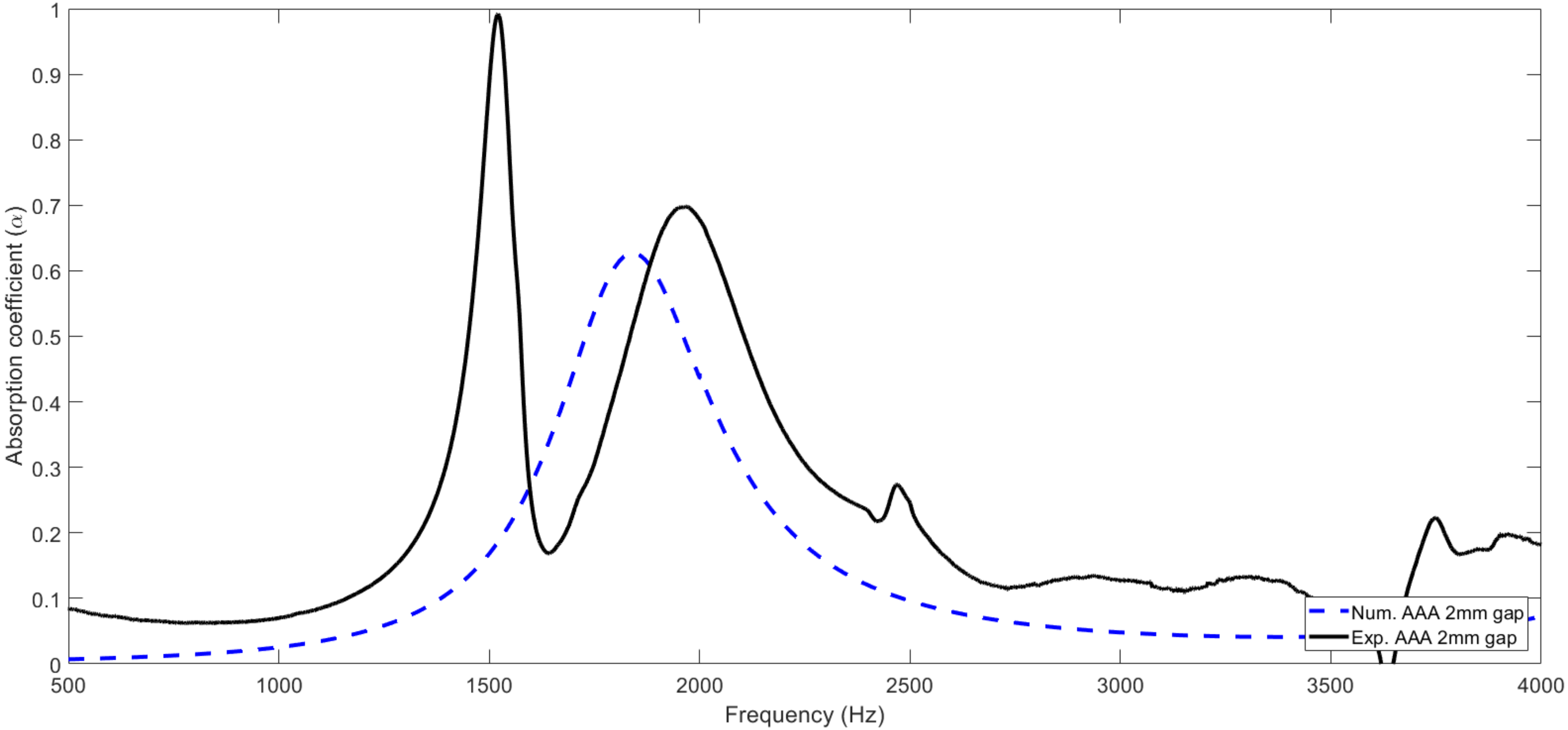
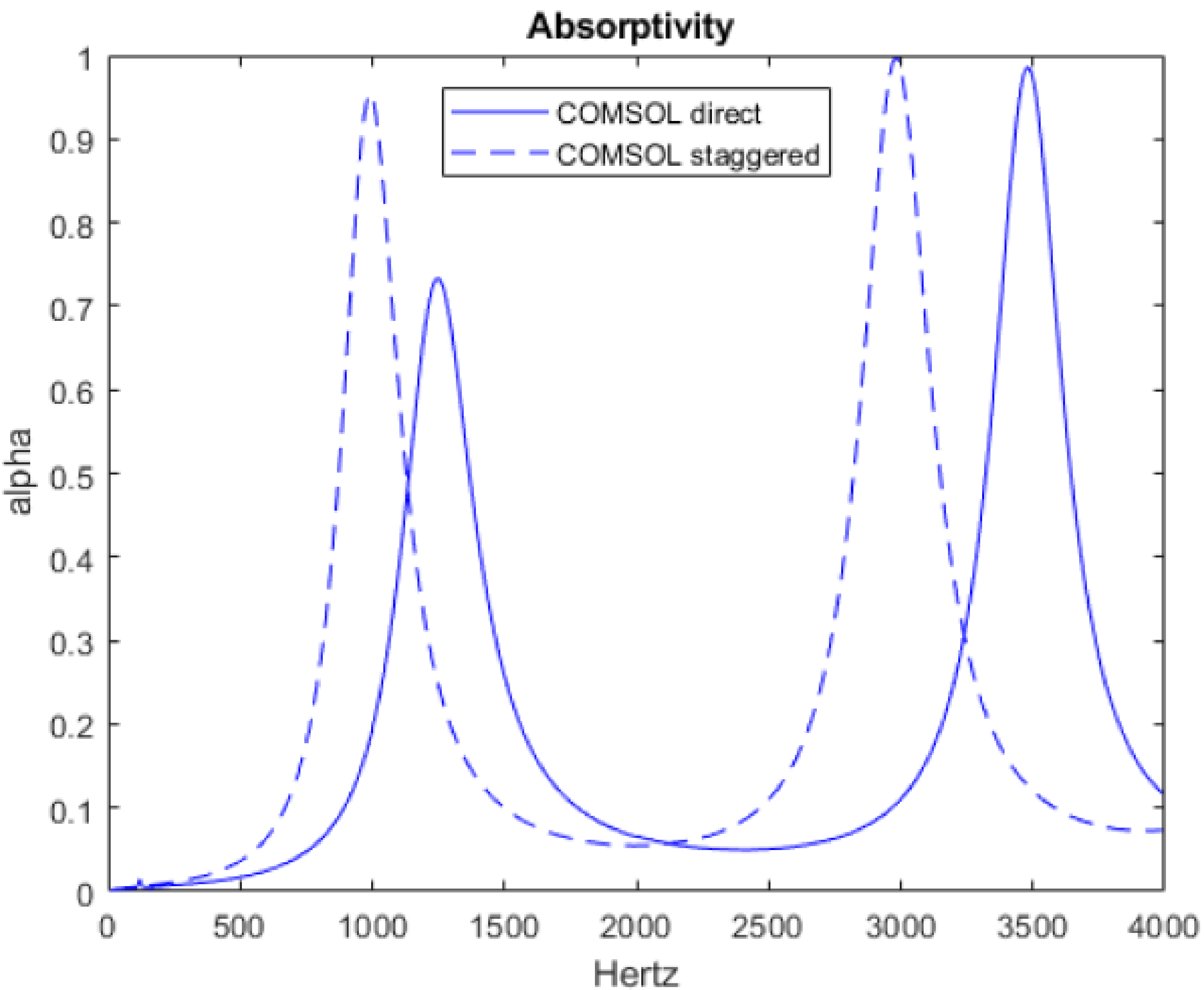
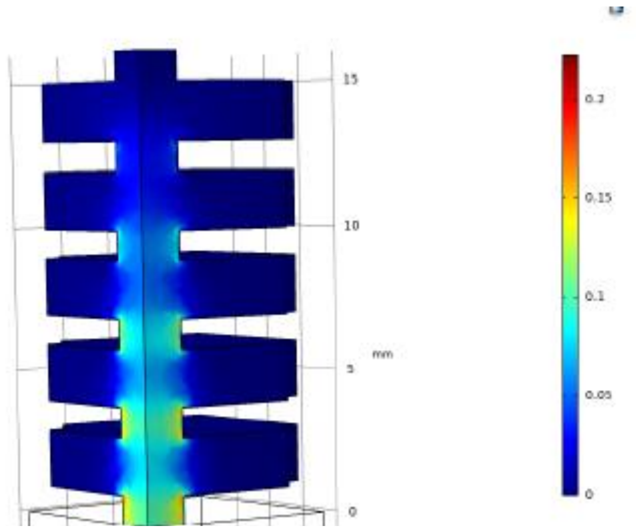


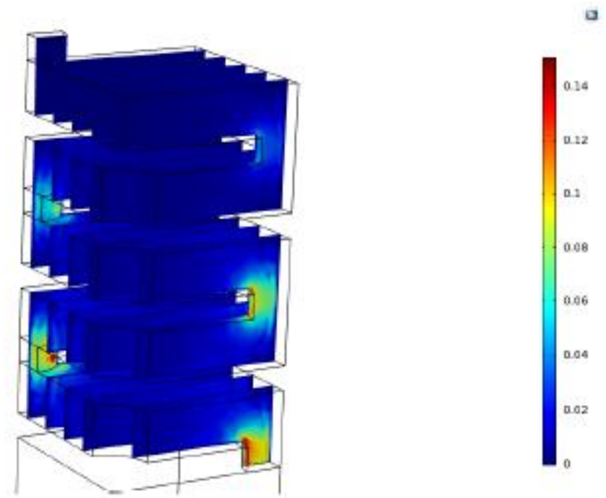
Configuration 4



Staggered vs Direct







Conclusions

- Experimental and numerical absorption in agreement
  - Plate resonances in experiments between 1250Hz and 2000 Hz
  - Mass added in an attempt to counter act this effect
- Configuration 3 possesses the best response over the range starting at the lowest frequency
  - Greatest cavity depth
- Dramatic subwavelength results
  - Thicknesses of cells of order 4mm, 3mm
- Optimise sub-wavelength modelling
  - Losses occur in gaps

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Thank You