An Acoustic Metamaterial Cloaking By Topology Optimization

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Abstract

Multiphysics Acoustics is increasingly used to design novel products. Underwater acoustic cloaking is an emerging field, after the electromagnetic cloaks. Numerous approaches to develop acoustic cloaking have been reported. Multiphysics modelling of Acoustic Metamaterial Cloaking by Topology Optimization is the focus of this paper.
Acoustic Metamaterial Cloaking involves pressure acoustic modelling and topology optimization. The acoustic wave propagation in cloak is governed by the wave propagation equation. The pressure acoustics interface in frequency domain in COMSOL was used for this investigation. The sound wave propagation was modelled with the appropriate boundary conditions and material properties. The typical material properties used for the simulation will be detailed. The objective of the numerical design of experiments was to explore the acoustic wave propagation and the effects of various parameters on the cloaking performance.
Topology optimization method involves, objective functions, design space, constraints and minimization variable. Topology optimization method are used to design feasible and efficient acoustic cloak. The optimality criterion is defined by the objective function, which is chosen to be the acoustics scattering. The objective is to minimize the average sound pressure level in the circular receiver domain. The optimization is allowed to distribute material in cloak domain. The gradient-based optimization solver, Density Model feature in the Optimization Module are used for optimal cloak. The topology optimization achieves a large reduction of the average sound scatter pressure level in the objective domain by moving a pressure node into the domain. The topology optimization result is further transferred to a new component using a Filter dataset. In this step a solid geometry is generated from the optimized cloak solution.
Fig 1 to 4 show typical simulation results, at initial condition and after optimized cloak.
The Simulation methodology used for acoustic cloak development, parameterization and optimization will be described. Governing Equations, boundary conditions, meshing are also detailed. The COMSOL Models developed, as a parametric CAD model, to enable design of experiments (DoE) and optimization. The 3D printing and experimental details will also be outlined.

Figures used in the abstract

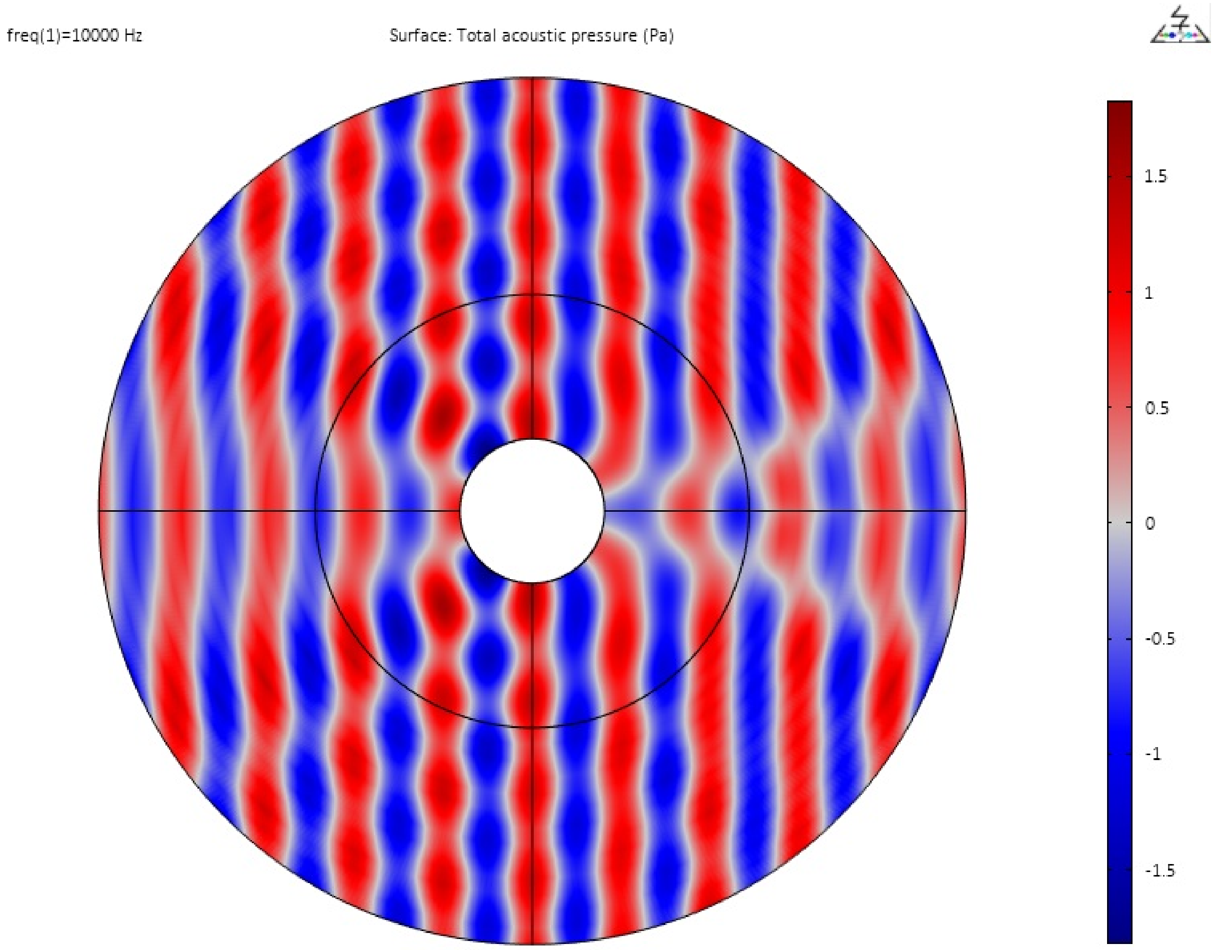

Figure 1 : Total acoustic pressure (Pa) of the domain without cloak

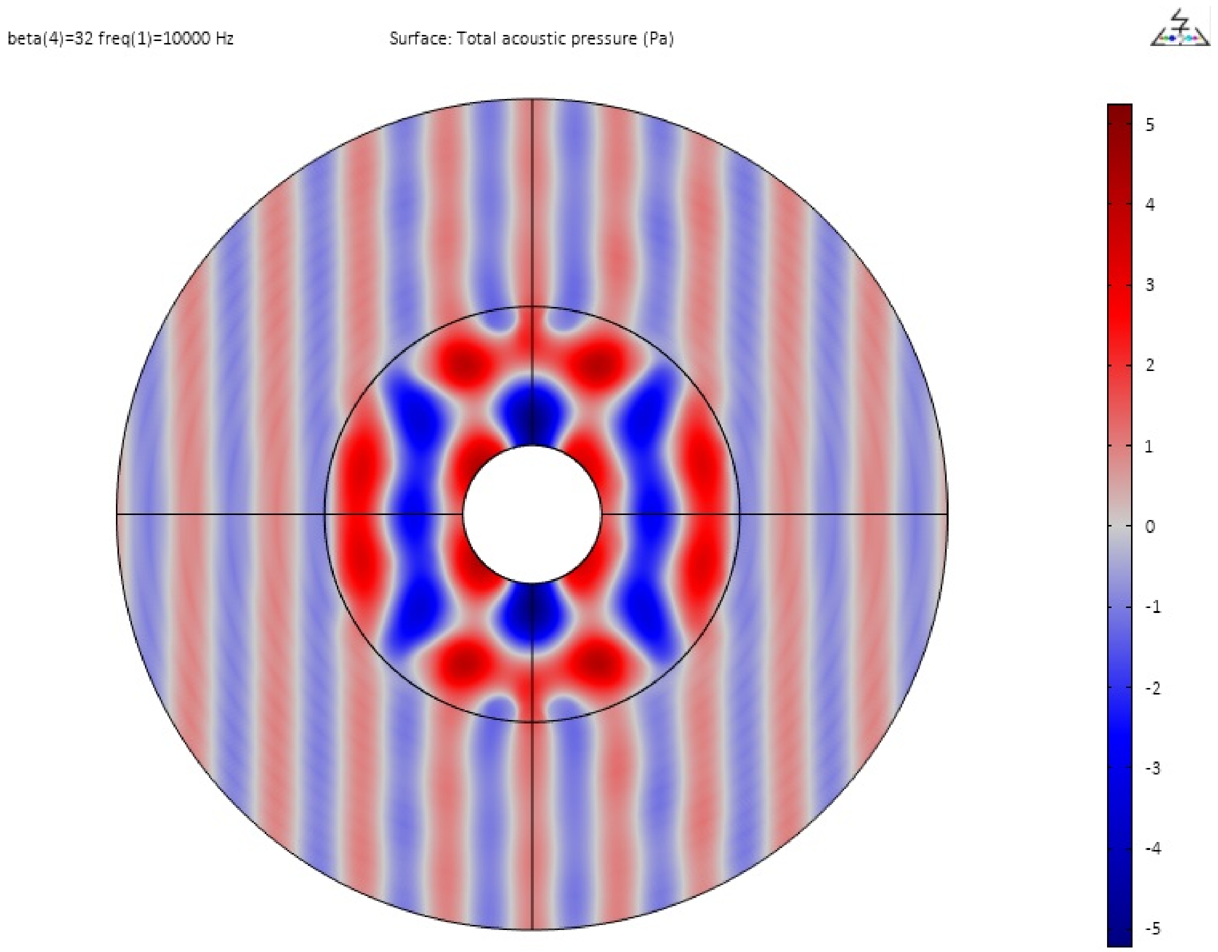

Figure 2 : Total acoustic pressure (Pa) of the domain with cloak

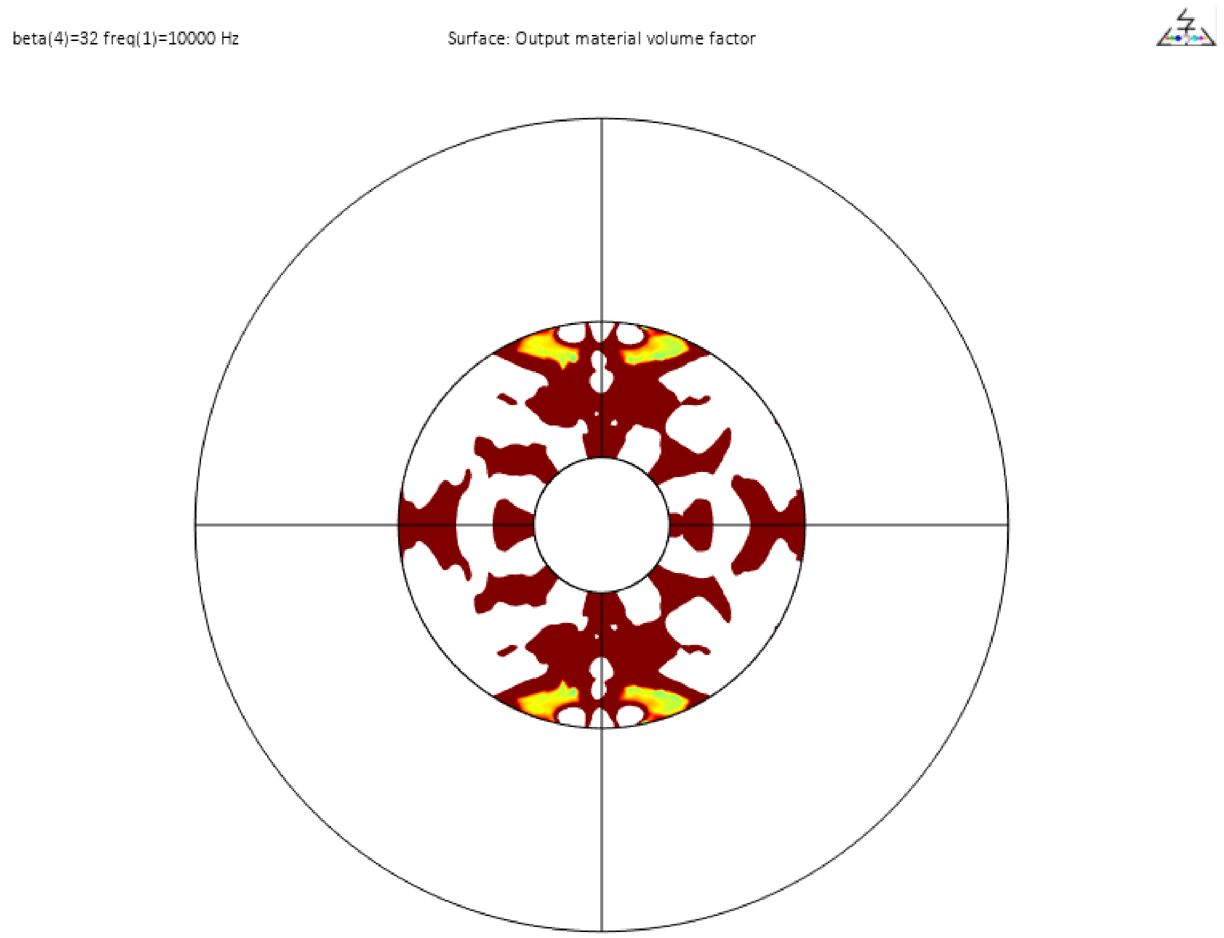

Figure 3 : Output material volume factor for the optimised cloak

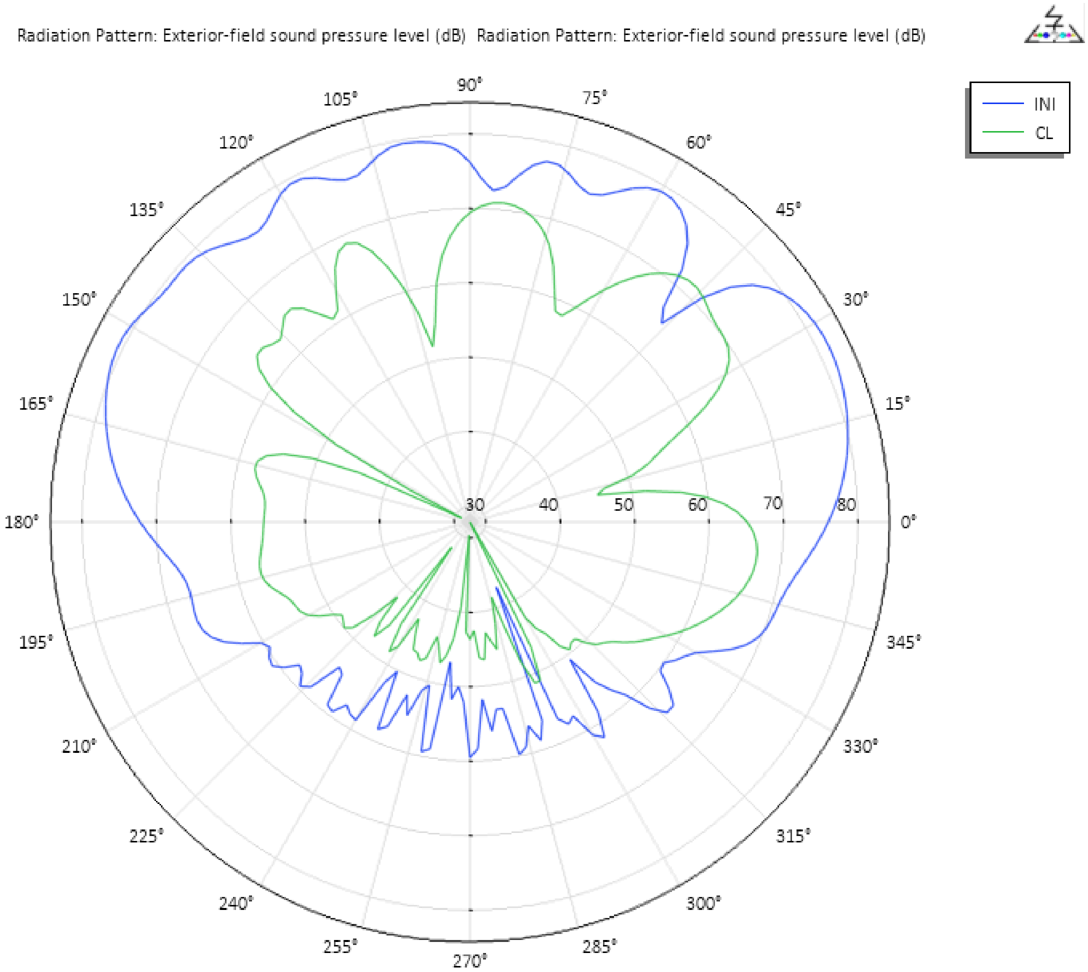

Figure 4 : Radiation Pattern of exterior-field sound pressure level (dB) of with and without cloak.