SAND2022-16682C

Optimization-based Designs for Communicating Through Barriers with Mechanical Waves

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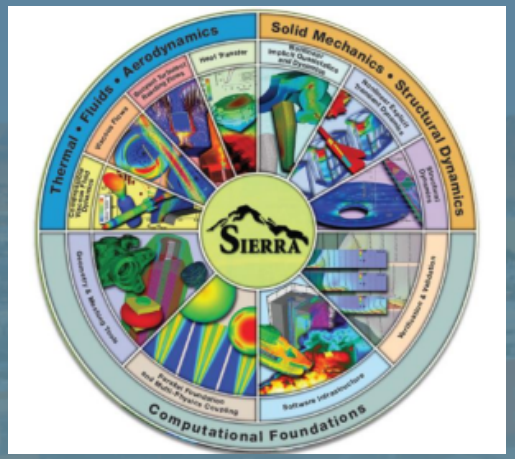

PRESENTED BY

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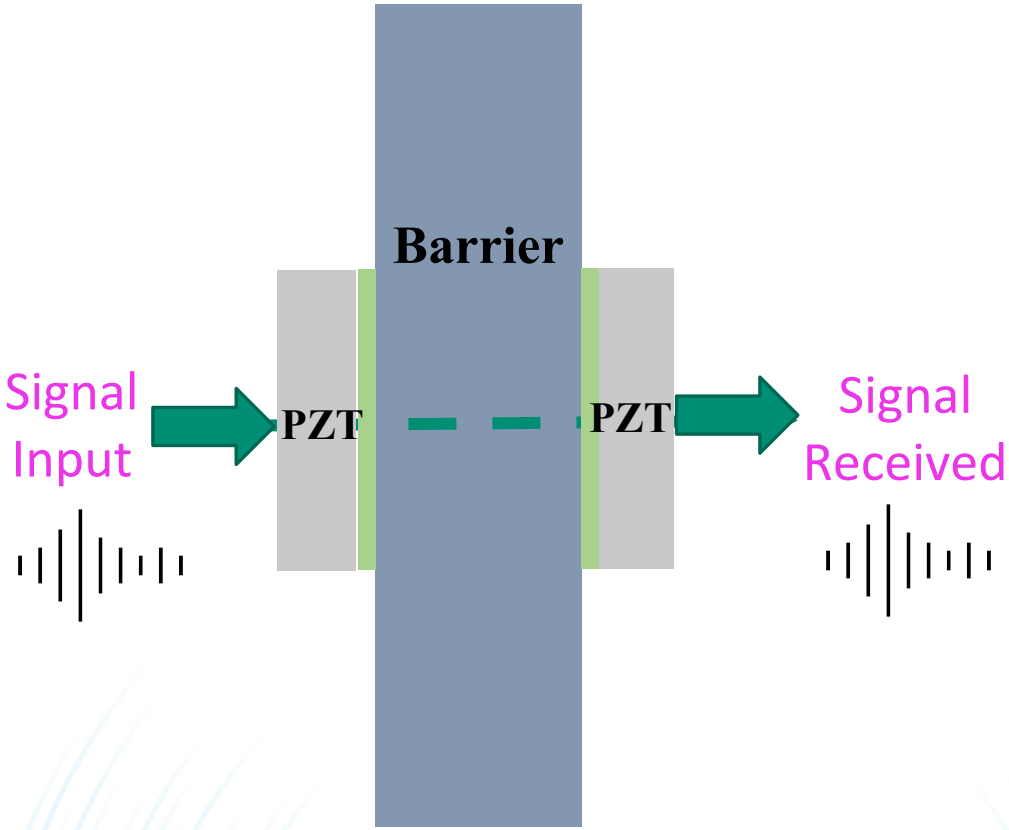
Piezoelectric-based Megasonic Communication

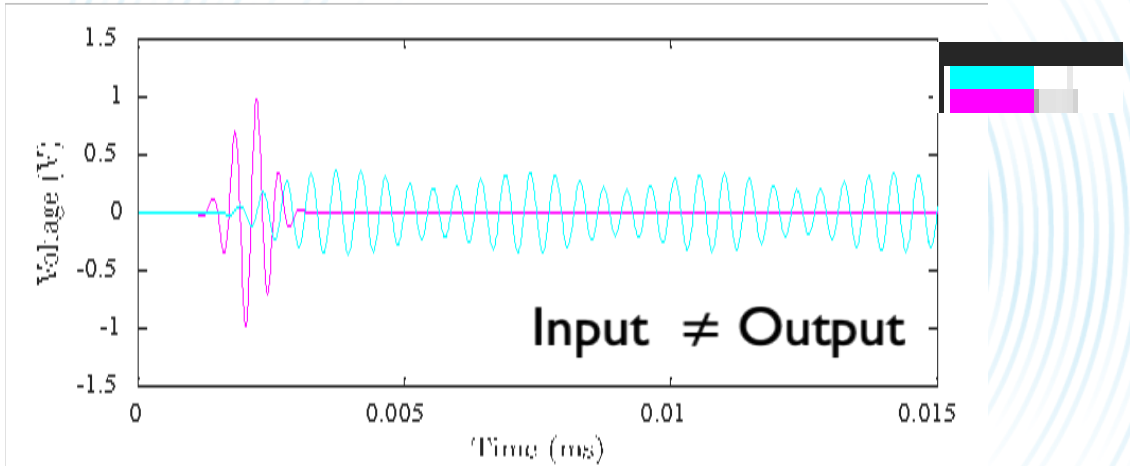
Motivation: High bit rate communication across barrier without wires, feedthroughs or penetrations

Approach: Use piezoelectric transducers to transmit electrical signals via megasonic mechanical transduction

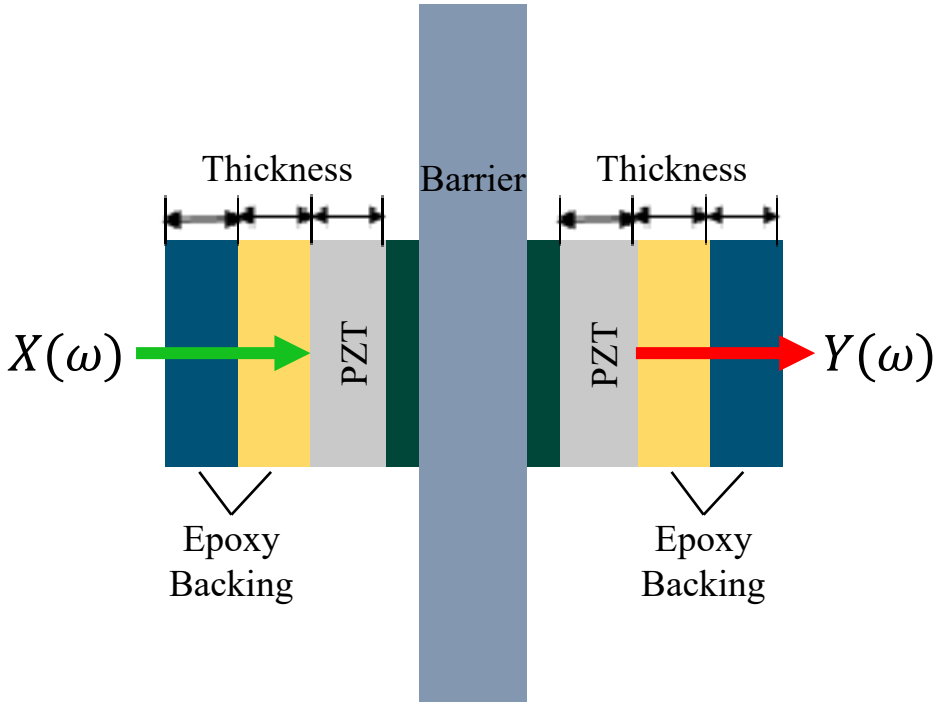
Challenge: Communication channel creates unwanted modification to signal

- Acoustic multipath
- Ringing
- Reflections



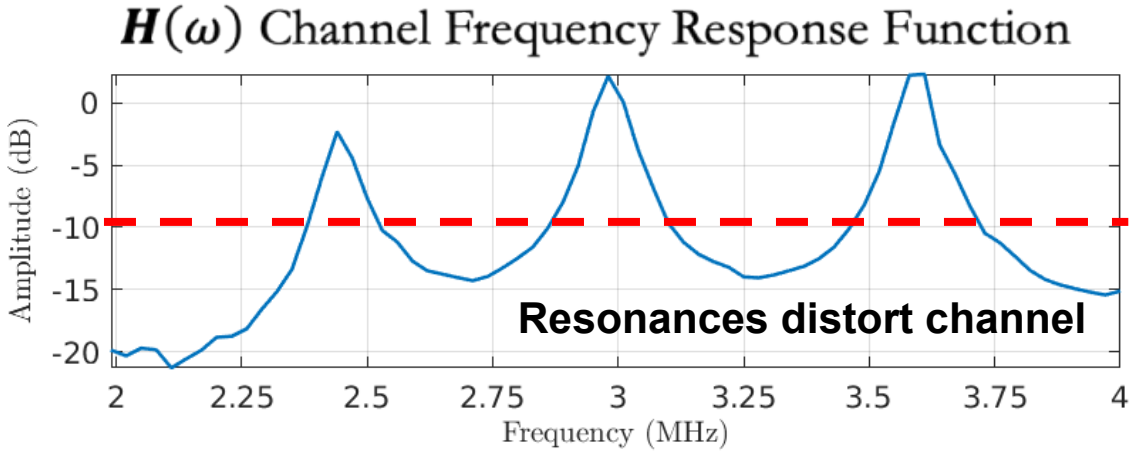


Piezoelectric-based Megasonic Communication



Single Input Single Output System

$$Y(\omega) = \boldsymbol{H}(\omega)X(\omega)$$



Existing Methods: Advanced signal processing (OFDM), backing materials

Proposed Approach: Optimize backing properties and thicknesses using a Finite Element Model to achieve **desired channel characteristics**

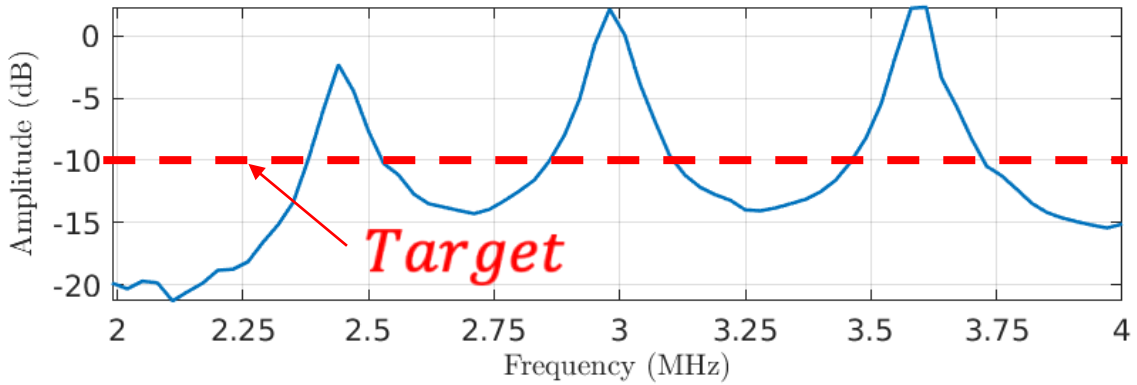
PDE-Constrained Optimization

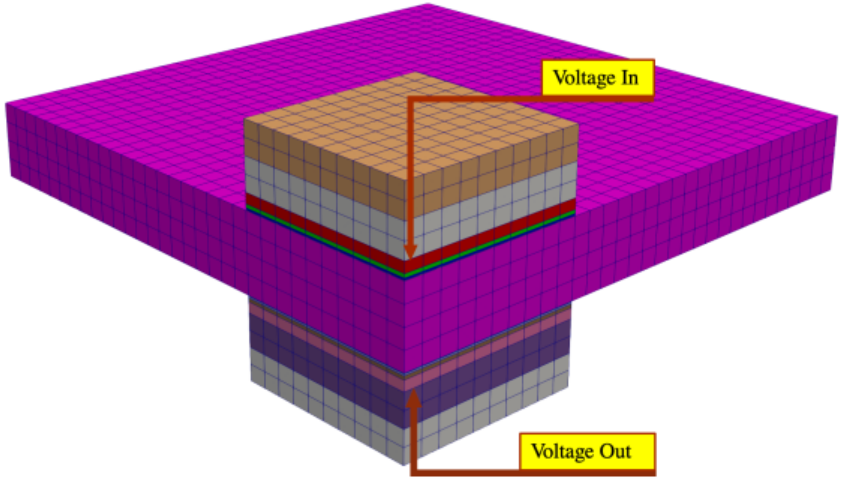
Objective Function

$$J(p,\omega) = \sum_{k=1}^{n_\omega} \left|\left|\bar{H}(\omega_k, p) - Target\right|\right|_2^2$$

- $\bar{H}$ is the magnitude of the transfer matrix
- $target$ is a user-defined constant

Parameters: Backing thickness, damping, density, shear and bulk moduli





Governing PDEs to FE Helmholtz

$$\rho \mathbf{u}_{tt} - \nabla \cdot \boldsymbol{\sigma} = 0 \text{ in } \Omega \quad \text{Elastodynamics}$$

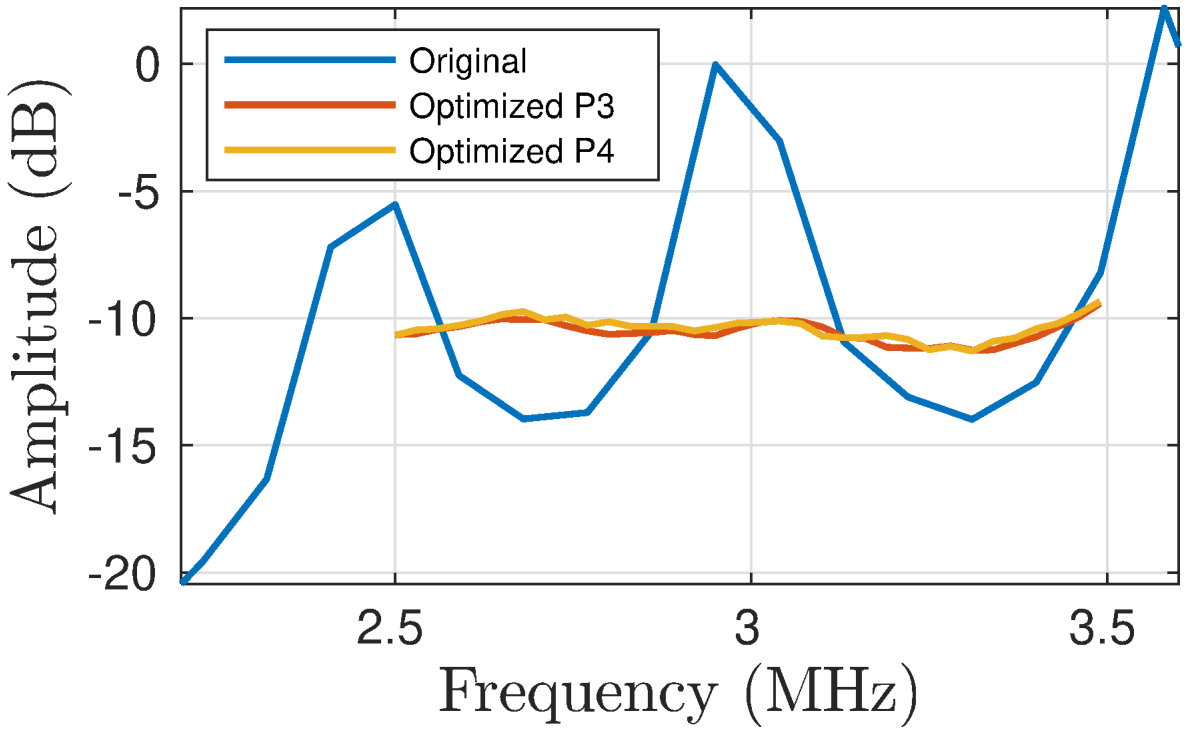
$$\nabla \cdot \mathbf{D} = 0 \text{ in } \Omega \quad \text{Electrostatics}$$

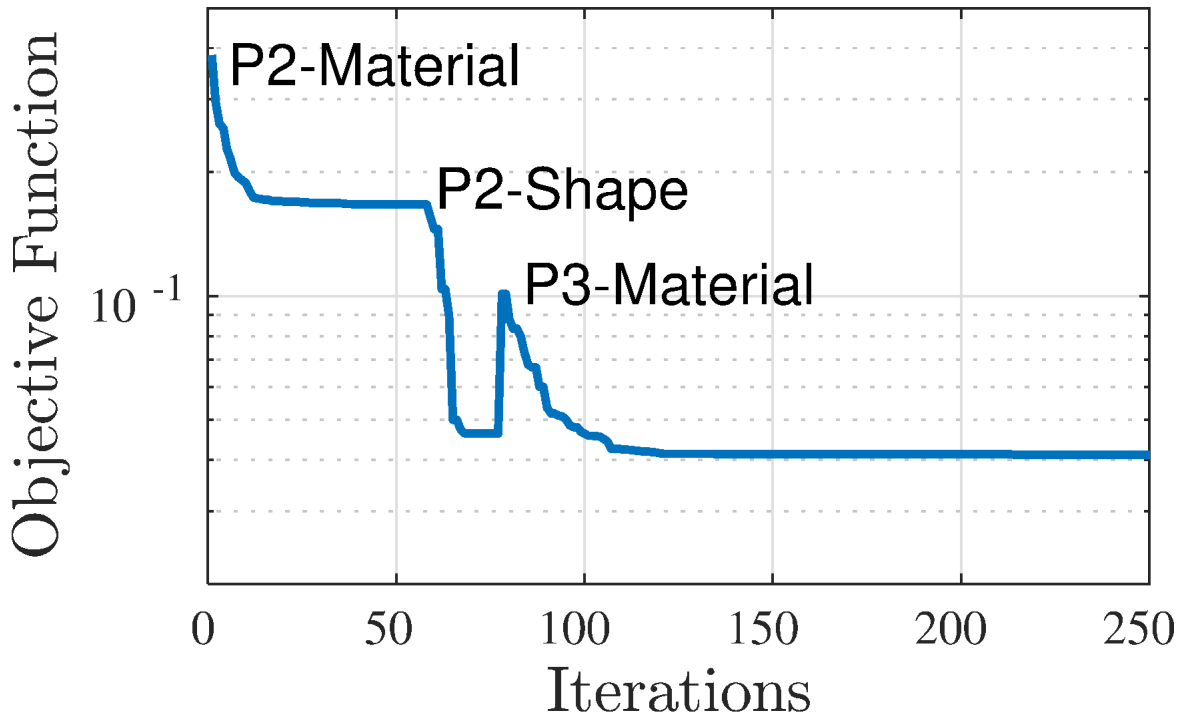
$$(-\omega^2 \mathbf{M} + j\omega \mathbf{C} + \mathbf{K})\hat{s} = \hat{f} \quad \text{Helmholtz}$$

High Order Polynomial Elements

- Mitigate pollution effect
- Faster mesh convergence than linear elements

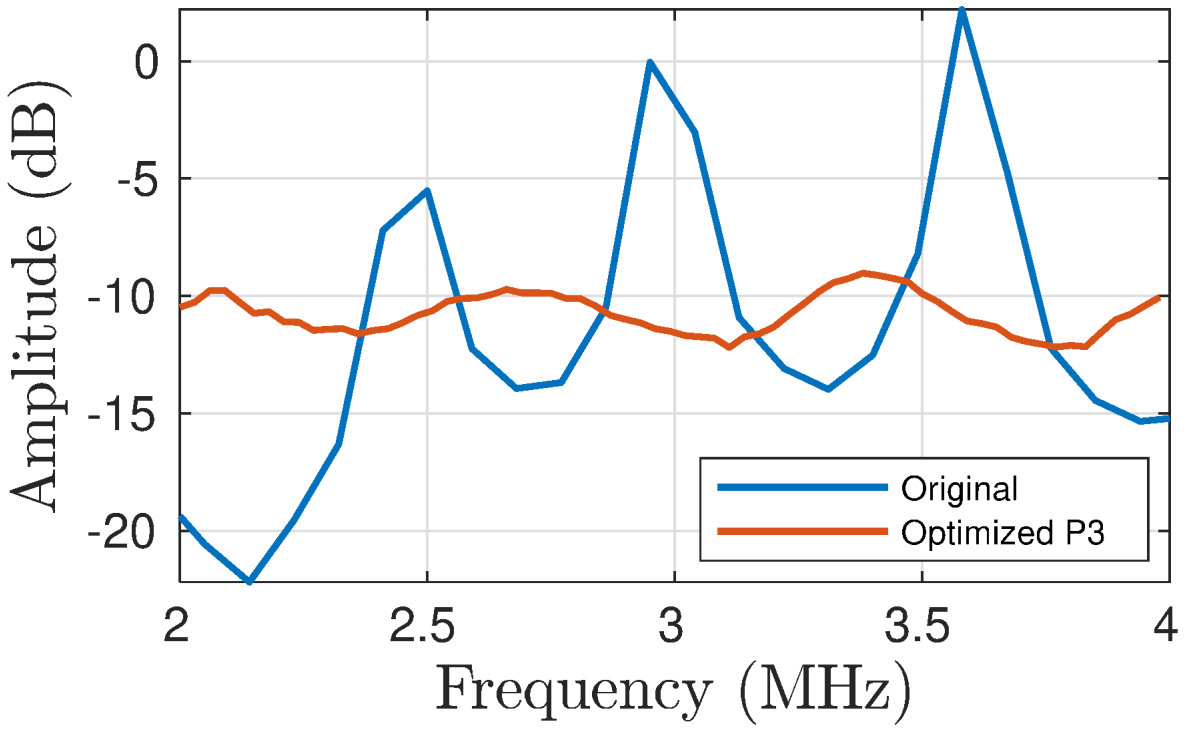
Optimization Results: One MHz Bandwidth

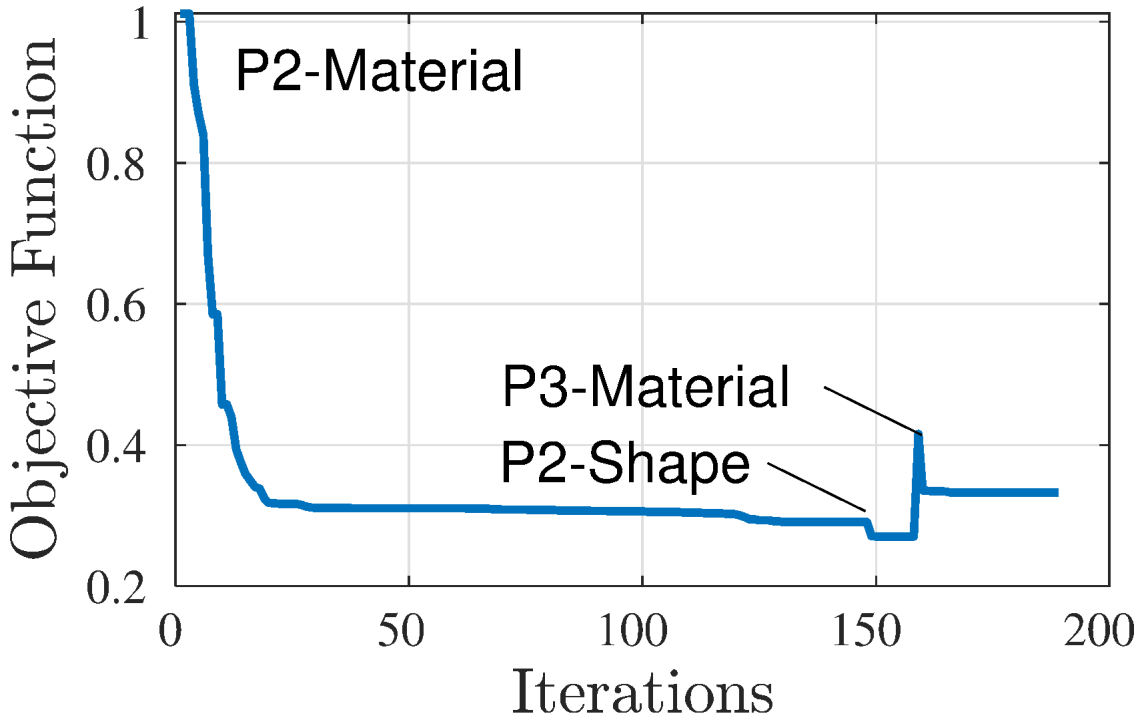




Alternating Directions / Discretization:
Sequentially refine mesh and change optimization parameter

Optimization Results: Two MHz Bandwidth





Alternating Directions / Discretization:
Sequentially refine mesh and change optimization parameter

Conclusions

- Optimization successfully improves channel characteristics for communication
- Not enough parameters to optimize wider bandwidths
- Alternating optimization methods is suboptimal, but meets the goal of driving the objective down
- Future work needed to reduce computational time

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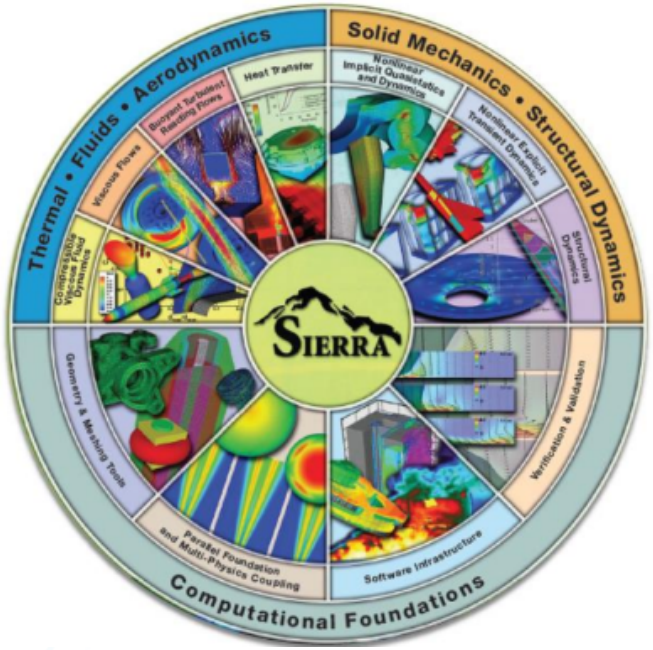

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