Acoustical Cloaking using Metamaterials

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Literature Review

Acoustic Metamaterials (AMMs)

- Periodic artificially structured materials with very small units compared to the wavelength
- Offer unusual properties like negative refraction, bulk density, and bulk modulus
- negative parameters lead to phenomena such as as the Doppler effect reverse and super lens

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Application of AMMs

- Noise reduction through absorption and insulation
- Acoustic non-destructive testing
- **Invisible cloaking** for defense

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Literature Review

Types of AMMs

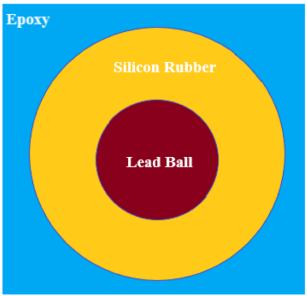

Figure: Locally resonating structure type AMM

Literature Review

Types of AMMs

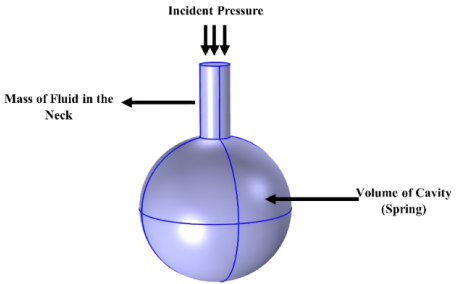

Figure: Conventional Helmholtz resonator

Literature Review

Types of AMMs

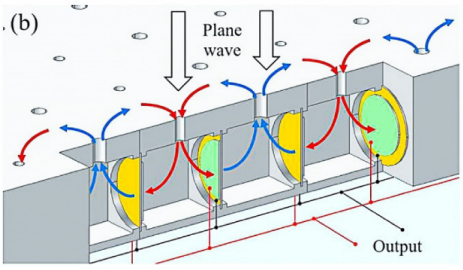

Figure: Helmholtz resonator type AMM

Literature Review

Types of AMMs

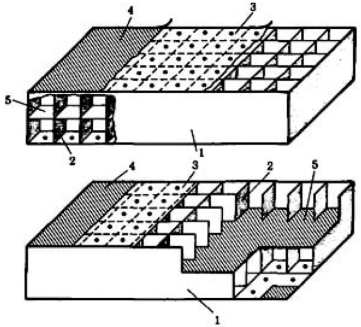

Figure: Membrane type AMM

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Types of AMMs

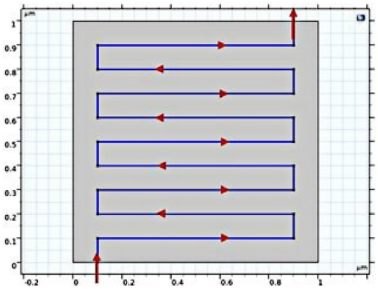
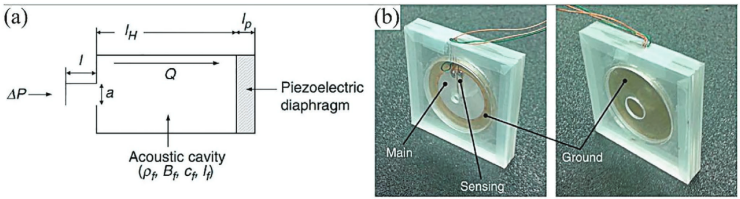


Figure: Space-coiled structure type AMM

Literature Review

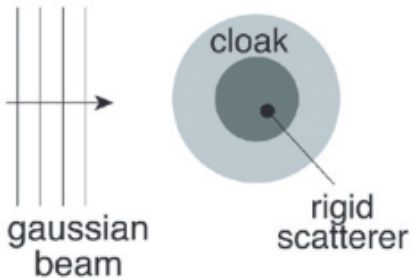
Active acoustic metamaterials



Literature Review

Previous studies on acoustic cloaking

- Cummer and Schurig (2007)



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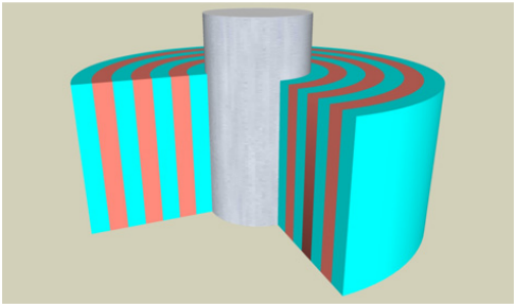
- Torrent and Sánchez-Dehesa (2008)



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Previous studies on acoustic cloaking

$$
\begin{aligned}
\rho_1 &= \frac{r + \sqrt{(2rR_1 - R_1^2)}}{r - R_1}\rho_\mathrm{b}, \\
c_1 &= \frac{R_2 - R_1}{R_2}\frac{r}{r - R_1}c_\mathrm{b}, \\
\rho_2 &= \rho_\mathrm{b}^2/\rho_1, \\
c_2 &= c_1 = c, \\
B_1 &= \rho_1 c_1^2, \\
B_2 &= \rho_2 c_2^2.
\end{aligned}
$$

Model setup

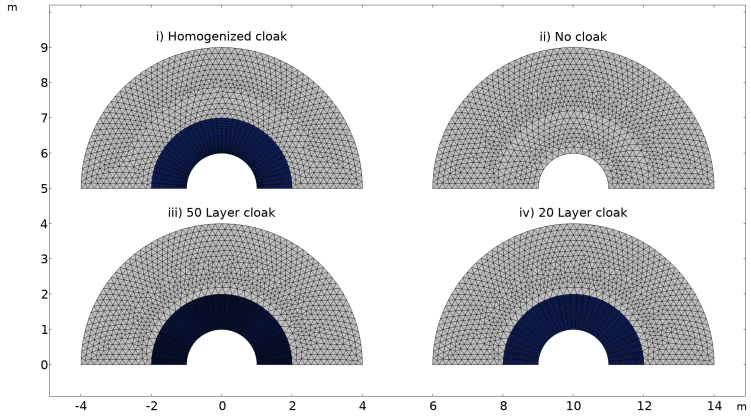

Figure: Geometry and mesh

Conservations laws

- Conservation of mass
- Conservation of momentum

$$\nabla \cdot (-\boldsymbol{\rho}^{-1} \nabla p_{\mathrm{t}}) - \frac{\omega^2}{B_{\mathrm{b}}} p_{\mathrm{t}} = 0$$

Results

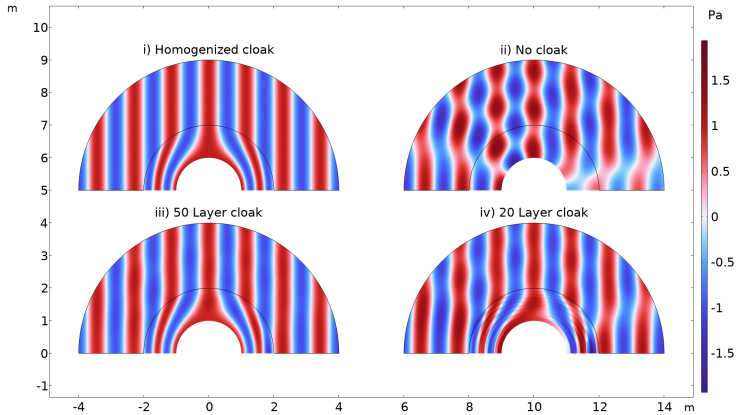

Figure: Total acoustic pressure, p_t (Pa)

Results

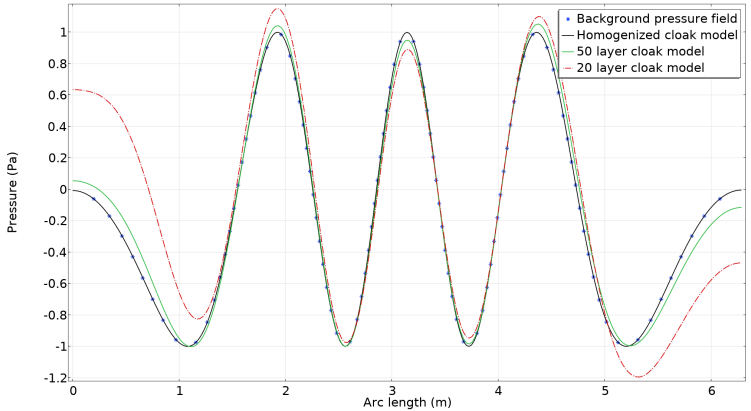

Figure: Total acoustic pressure along cloak boundary (Pa)

Results

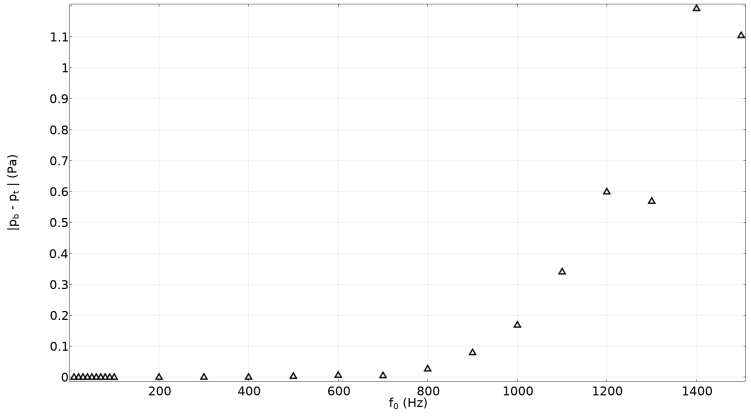

Figure: Effect of frequency on cloaking

Thank you!