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Modeling the Acoustic Scattering from Objects Buried in Porous Sediment Using COMSOL Multiphysics

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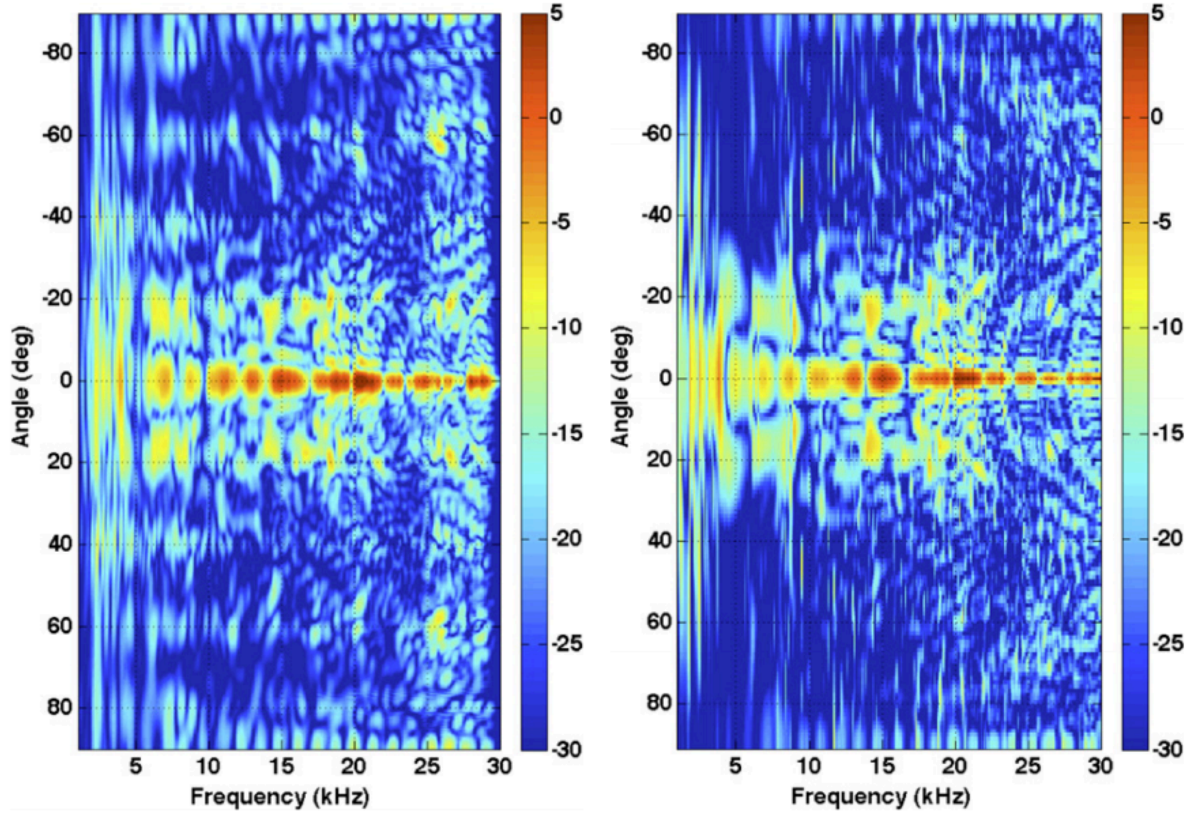
Outline

- Motivation
- Problem
- Modeling Approach
- Implementation
- Results
- Conclusions

Motivation

- Goal: development of automatic target recognition (ATR) algorithms for the detection of unexploded ordnances (UXOs) buried in ocean sediments.
- ATR algorithms are trained using "acoustic templates" generated from physical acoustics models and numerical simulations.

Motivation



(a) (b)

Fig. 5. Data/model comparison of the absolute target strength as a function of frequency and aspect angle for an aluminum pipe proud on a sand sediment. (a) Shows the experimental results acquired during the pond experiment (PondEx10), and (b) is the result of the finite element simulation with geometry matching that of the pond experiment. Note the 5 dB change in scale relative to Fig. 4.

Zampolli et al., *J. Comp. Acoust.*, **20**(2), 1240007 (2012)

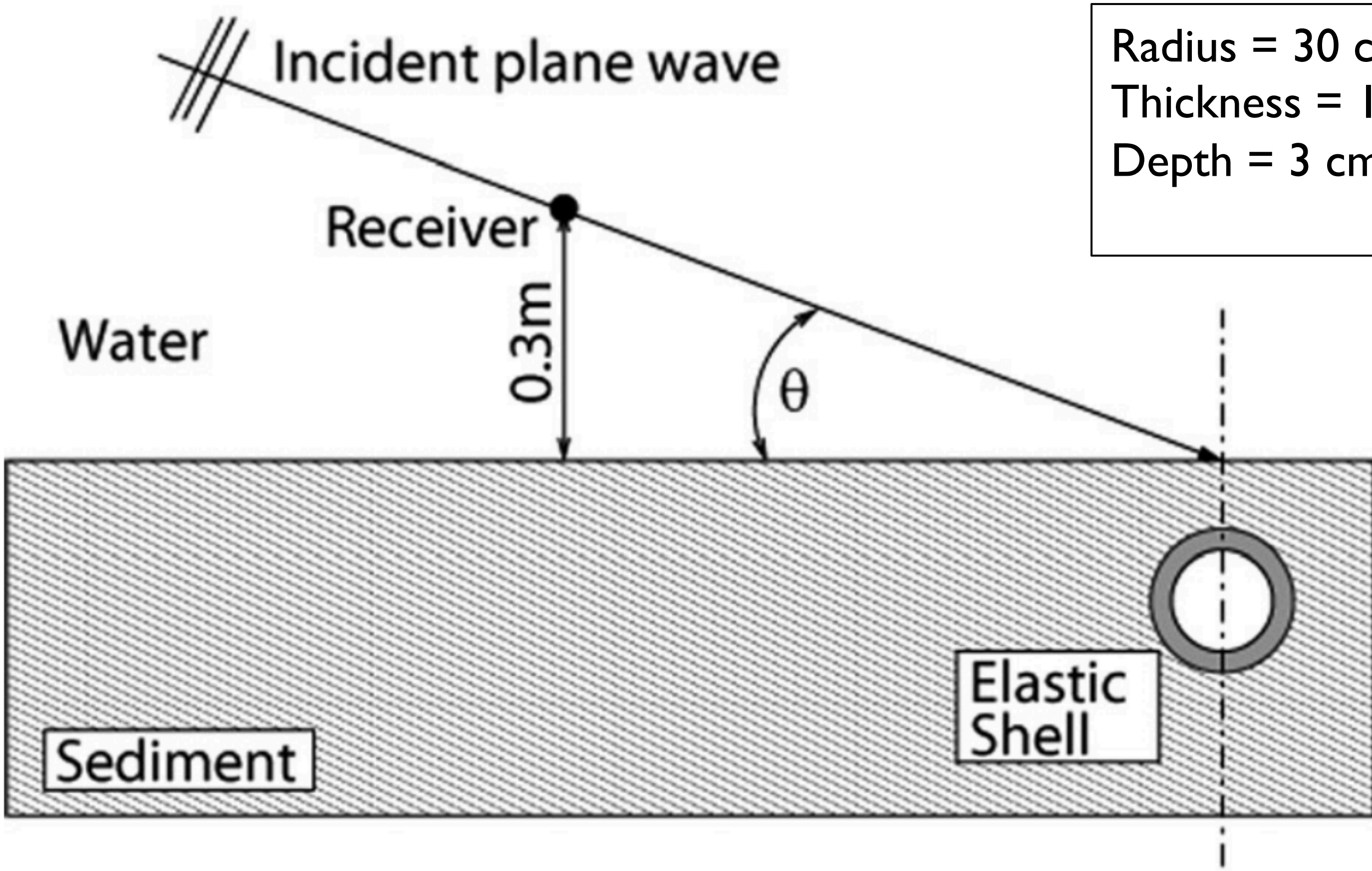
Motivation

- In vast majority of related literature, ATR algorithms trained with assumption that sand behaves as a simple acoustic fluid.
- This assumption is often employed to reduce computational cost.
- Two questions:
  - How do results from fluid models compare to poroelastic models?
  - How can computational cost be reduced?

Problem

- Target strength from buried elastic shell calculated using COMSOL.
  - Three sand models: simple fluid, EDFM, Biot-Stoll
- Problem configuration follows NRL experiment.
  - Ref: Simpson et al., *J. Acoust. Soc. Am.*, **113**(2) (2003).
- FEM predictions compared to NRL backscattering data.
  - Grazing angle of 20 degrees
  - Frequencies: every 250 Hz from 1 to 5 kHz

Problem



Radius = 30 cm
Thickness = 1.5 cm
Depth = 3 cm

Figure from Dey et al., *J. Acoust. Soc. Am.*, **129**(5), 2979 (2011)

Modeling Approach

- For axisymmetric geometry, Fourier decomposition allows full 3D physics to be obtained from 2D simulations.

$$u(r,\theta,z) = \sum_{m} u_m(r,z)e^{im\theta}$$

Modeling Approach

- First, determine Fourier terms of incident field (either analytically or numerically).
- Next, solve series of scattering problems with background field set to each Fourier term.
- Finally, assemble solution through summation.
  - See associated conference paper for more detail.

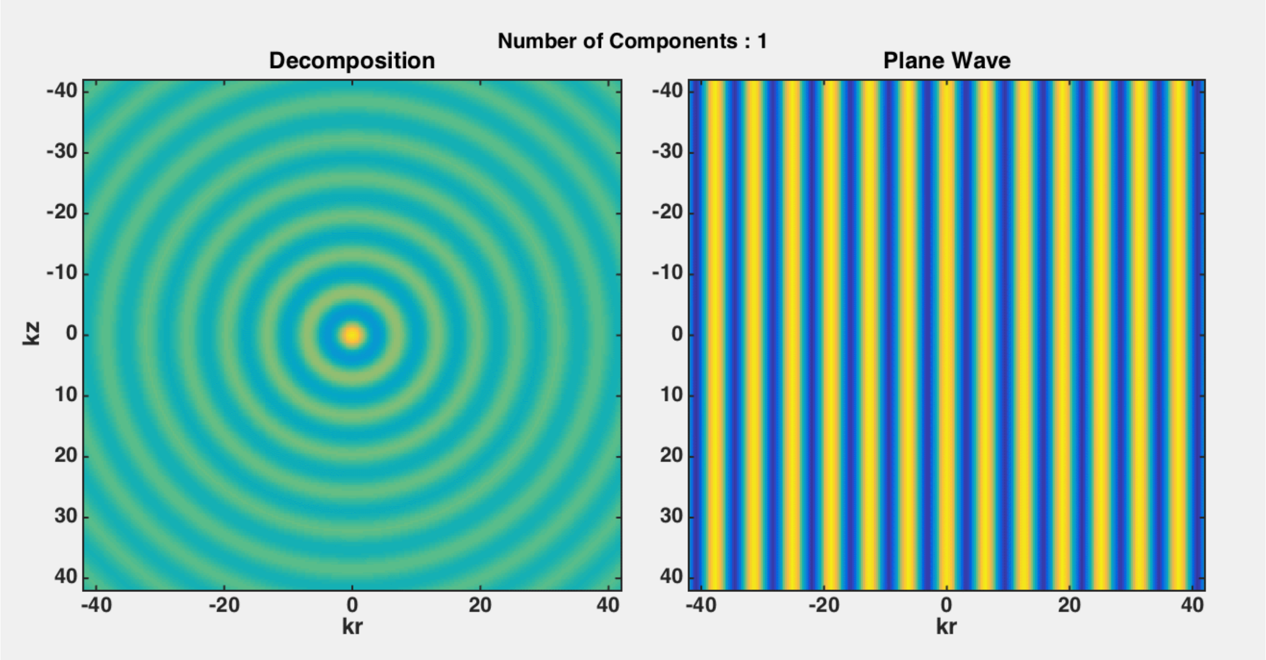
Modeling Approach

Example: Plane Wave decomposed into a Fourier Series

$$p^{inc}(r,\theta,z) = \sum_{m=0}^{\infty} \epsilon_m p_m^{inc}(r,z)\cos(m\theta)$$

ϕ = Angle with r-axis

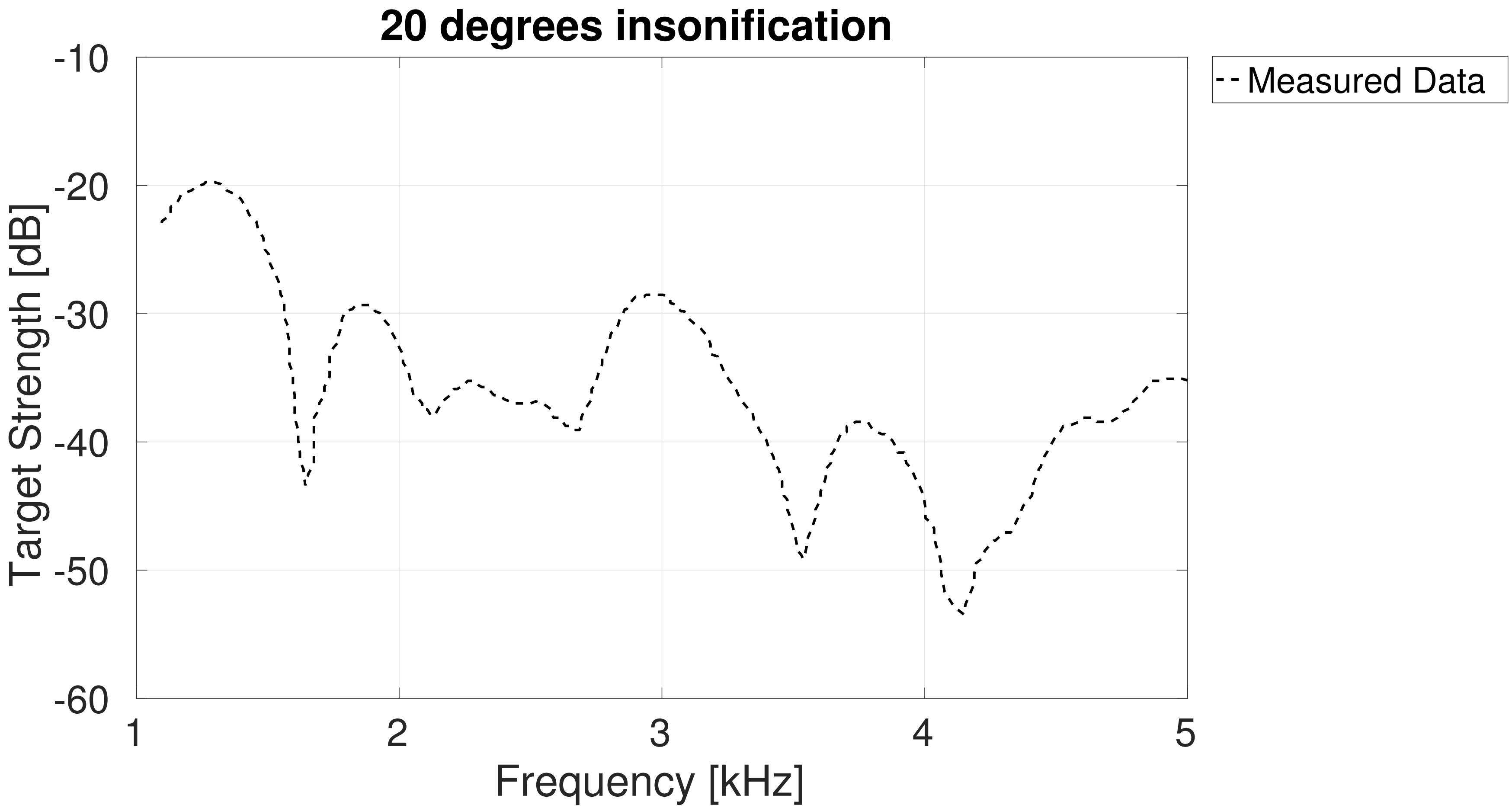
$$p_m^{inc} = i^m e^{(ikz\sin\phi)} J_m(kr\cos\phi)$$



Implementation

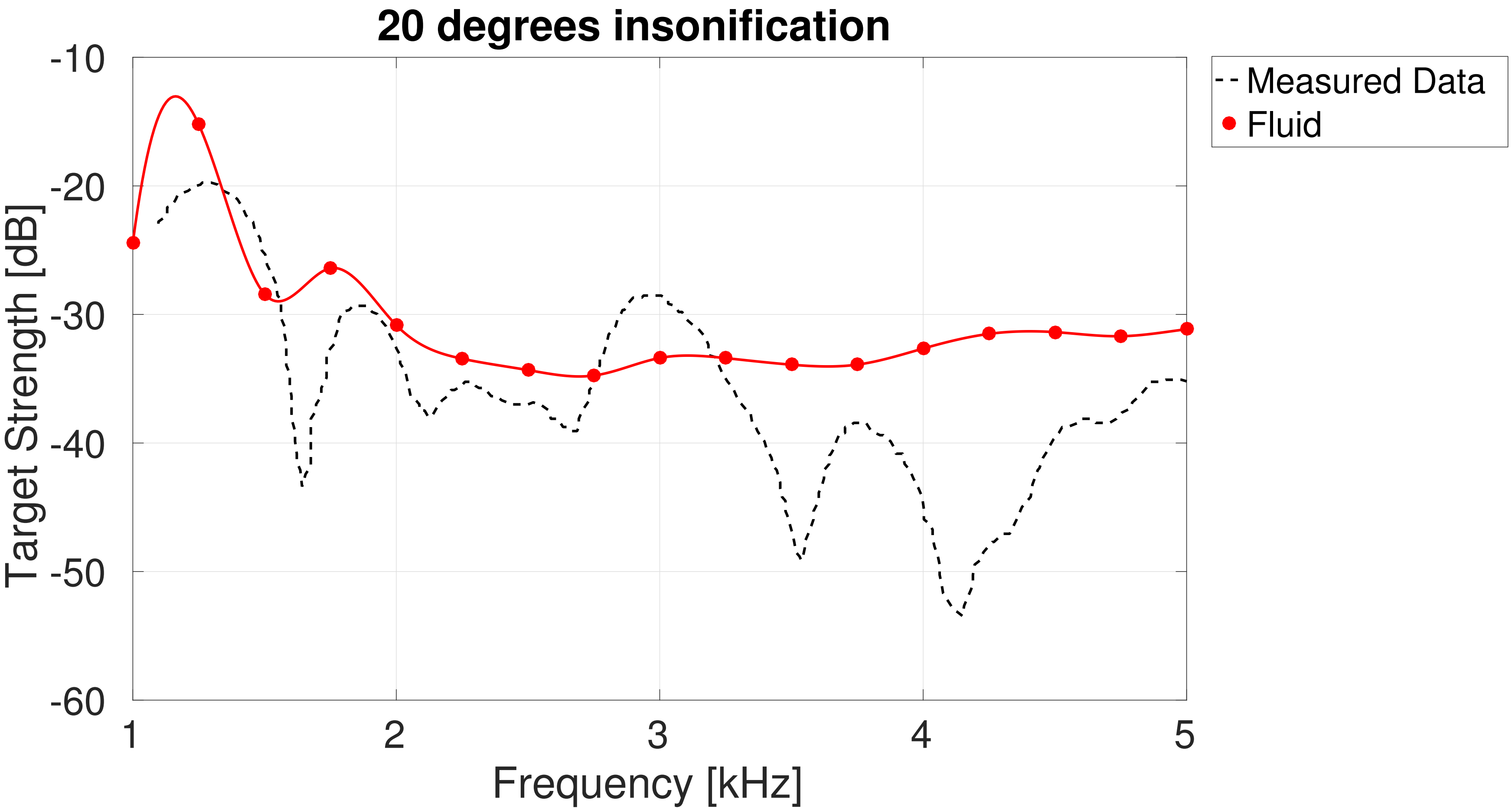
- Axisymmetric dimension chosen.
- Pressure Acoustics, Frequency Domain used for water/fluid sediment.
- Weak Form PDE interfaces used to implement governing equations for elastic shell and poroelastic sediment.
- Sommerfeld condition enforced using Perfectly Matched Layers.
- Tapered plane wave used to minimize edge effects.
  - Fourier terms found numerically.

Results



Simpson et al., *J. Acoust. Soc. Am.*, **113**(1), 39 (2003).

Results



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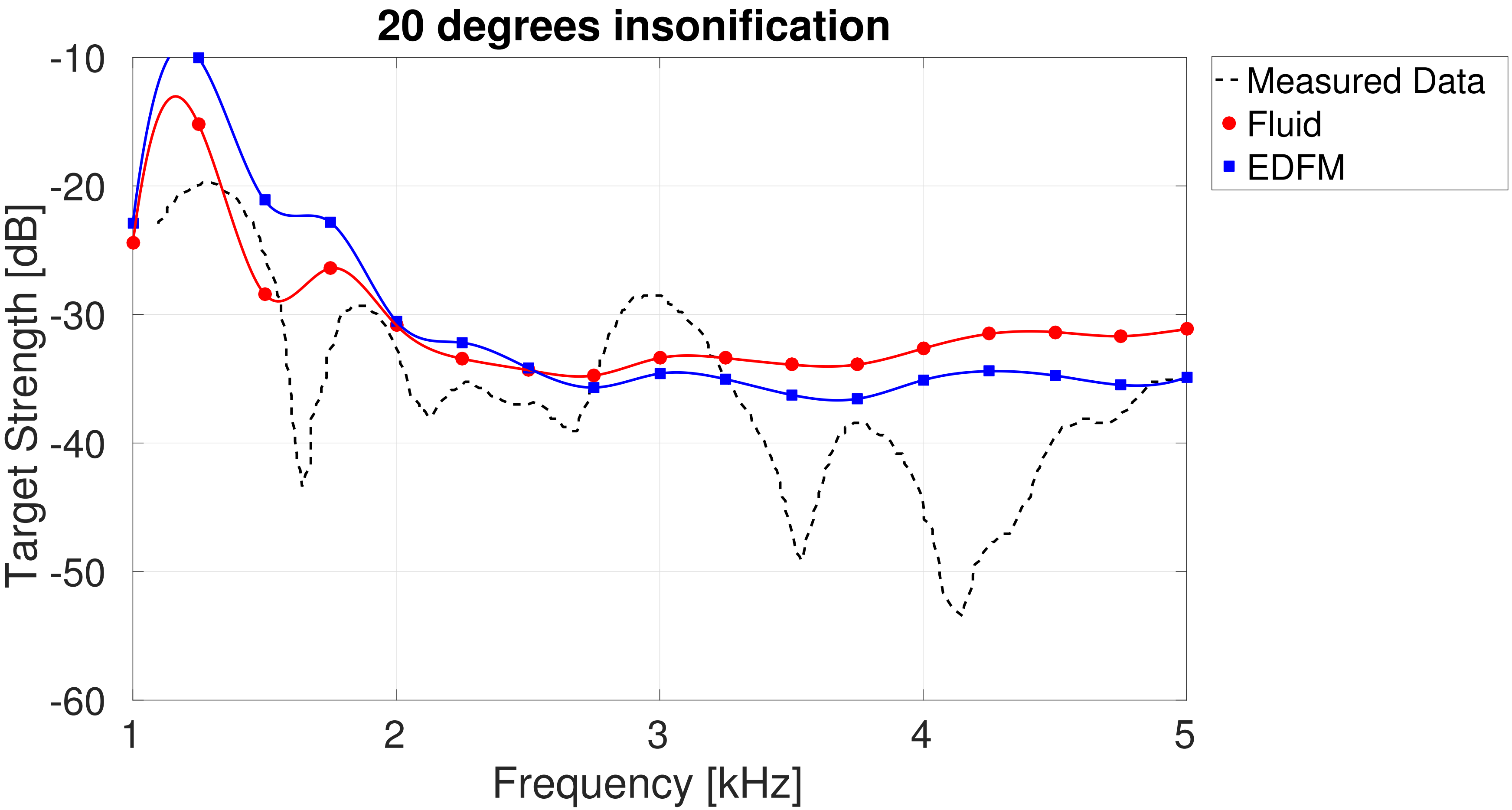
Results



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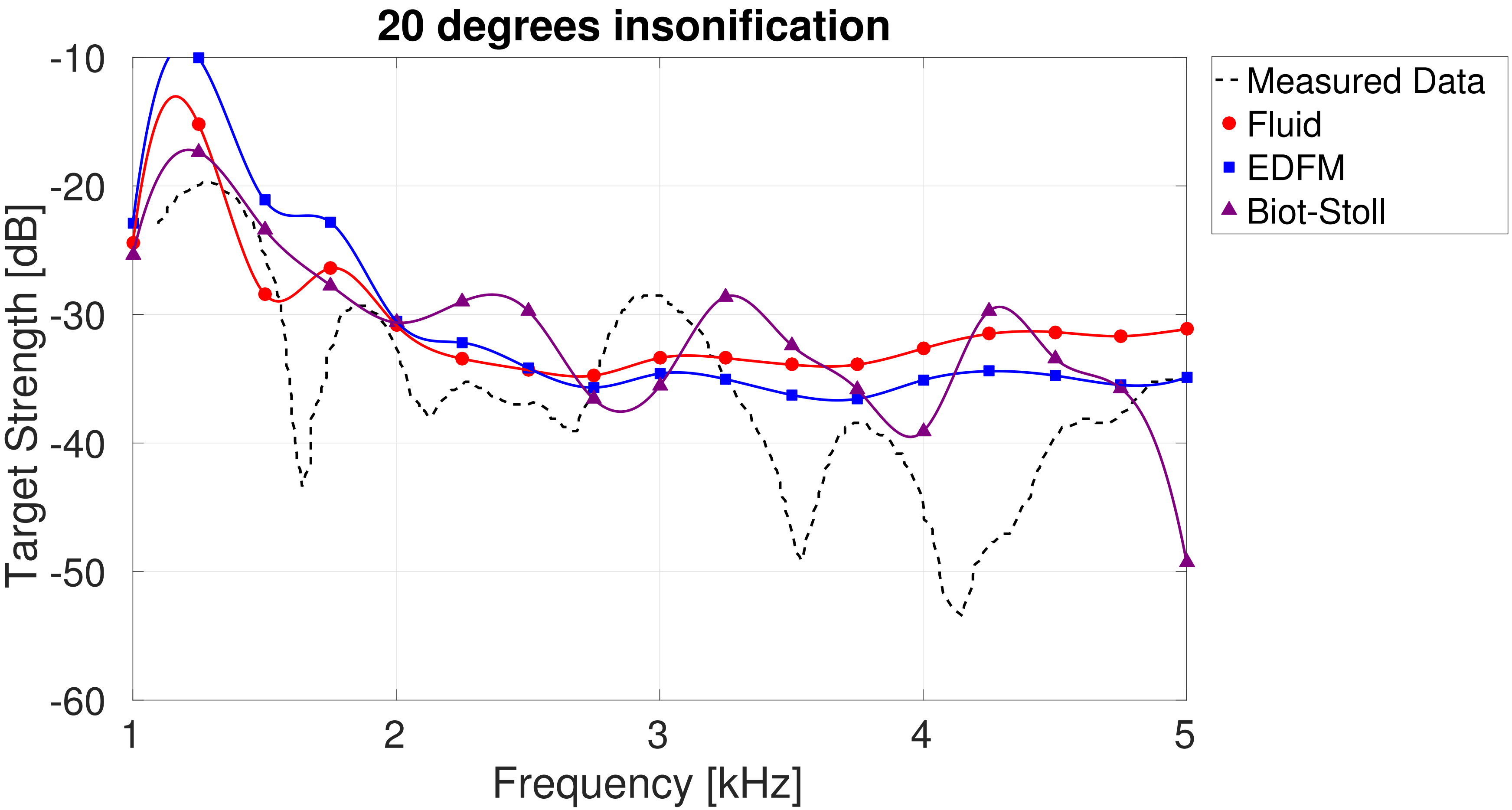
Results



Simpson et al., *J. Acoust. Soc. Am.*, **113**(1), 39 (2003).

Conclusions

- Target strength predictions for buried elastic shell compared for fluid and porous sediment models.
- To reduce computational cost, an axisymmetric Fourier decomposition technique is employed.
- Differences in target strength predicted whether fluid or porous sediment models are used.