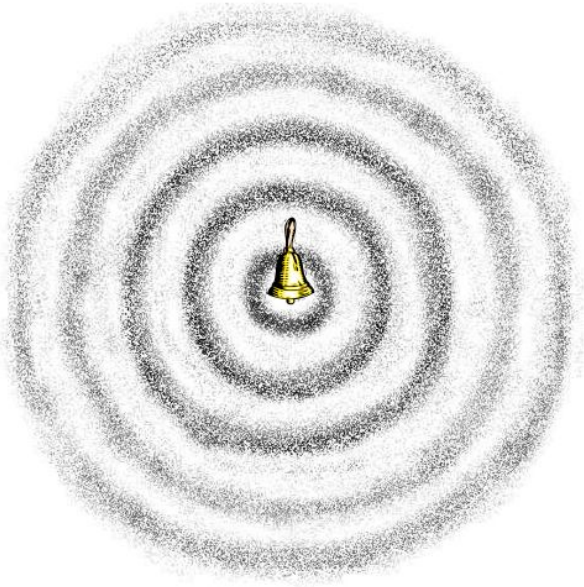
Sound Travel Simulation

Diana Korotun, Harshita Gupta

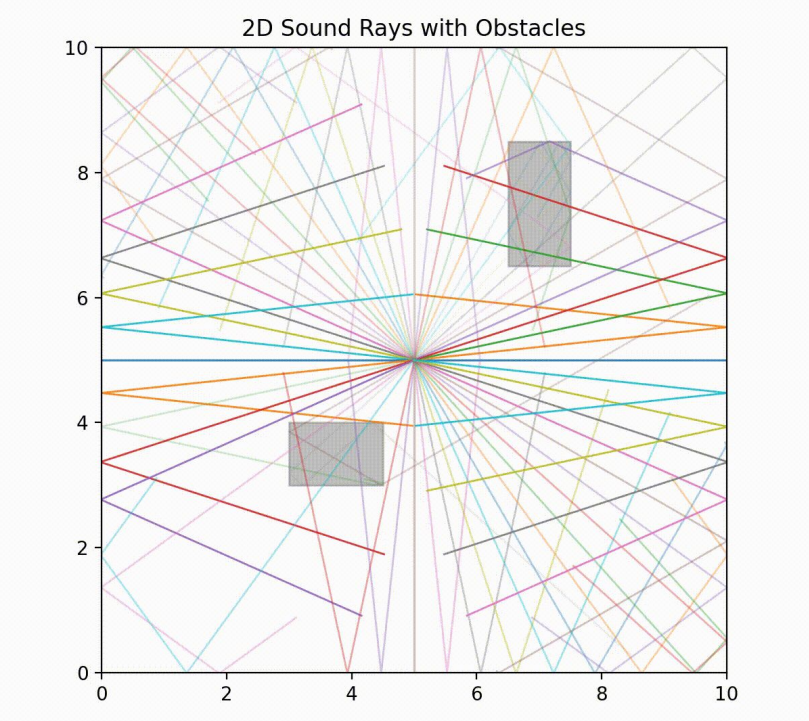
Advanced Simulation in the Natural Sciences. ESC203
June 2, 2025

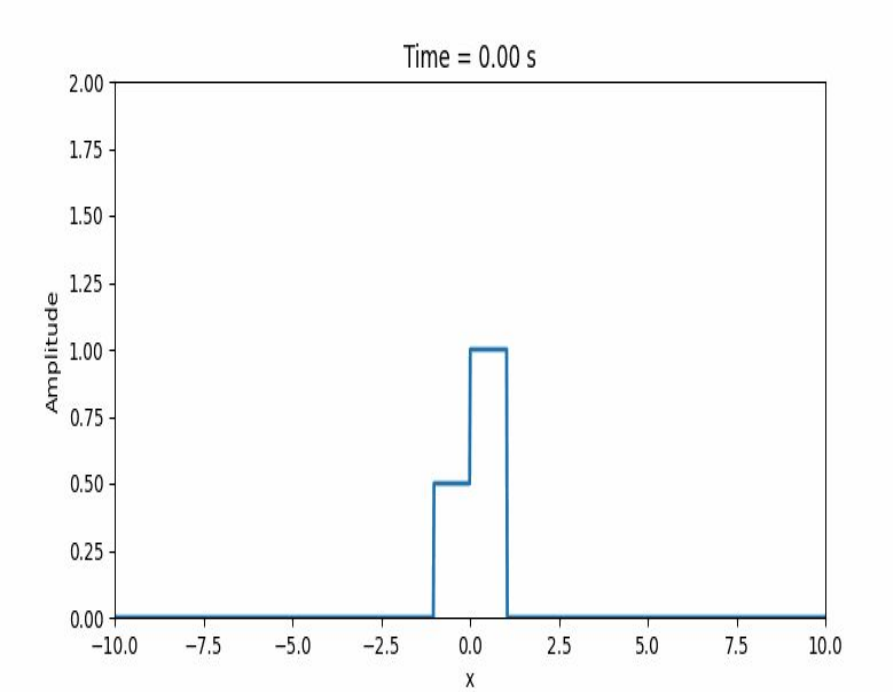
Set Up

- Simulating Sound
- Single Pulse
- At 440 Hz frequency
- Through Water and air
- Including reflections and absorptions
- Methods:
  - Wave equation solution
  - Ray Tracing



Early Iterations





Finite differences for 2D wave equation

$$\frac{\partial^2 u}{\partial t^2} = c^2 \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} \right)$$

$$c_{\text{air}} = 0.373 \text{ km/s}$$
$$c_{\text{water}} = 1.48 \text{ km/s}$$

$$u_{i,j}^{n+1} = s_x(u_{i+1,j}^n + u_{i-1,j}^n) + s_y(u_{i,j+1}^n + u_{i,j-1}^n) + 2(1 - s_x - s_y)u_{i,j}^n - u_{i,j}^{n-1}$$

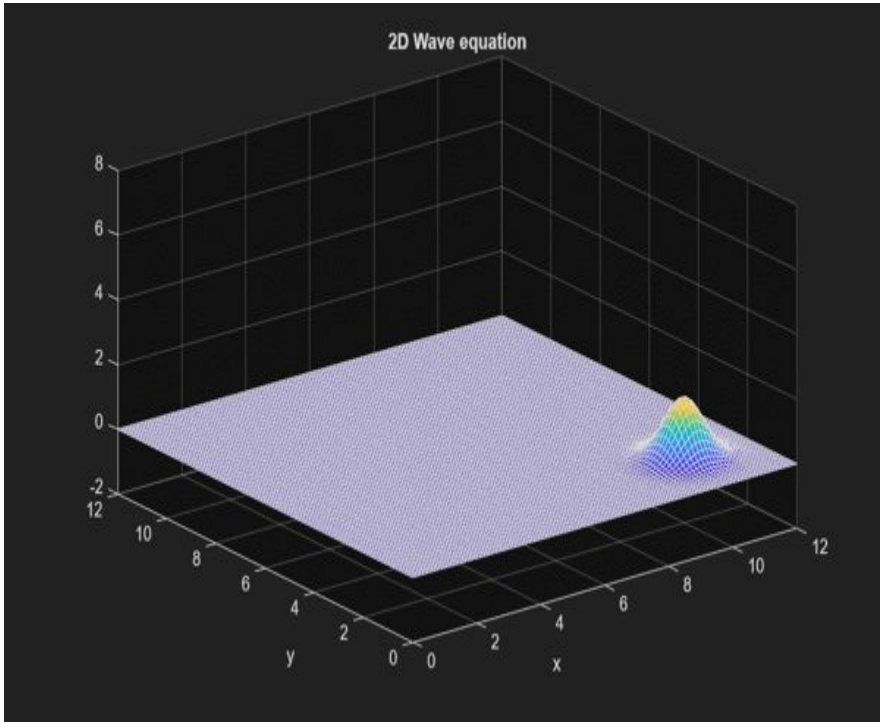
Courant–Friedrichs–Lewy (CFL) number:

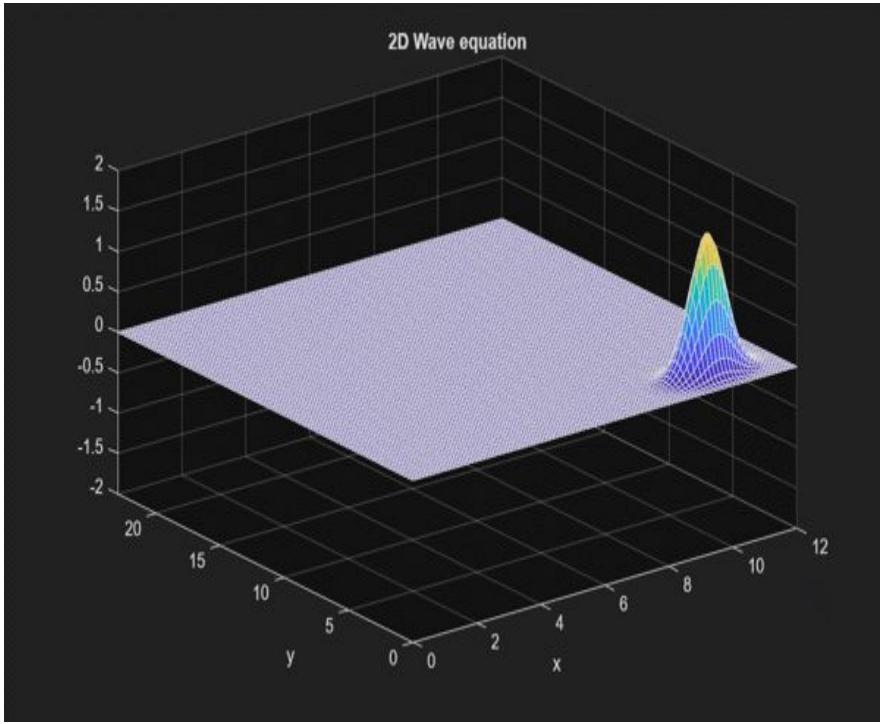
$$s_x = c^2 \frac{\Delta t^2}{\Delta x^2}, s_y = c^2 \frac{\Delta t^2}{\Delta y^2}$$

CFL condition for stability:

$$s_x + s_y \leq 1$$

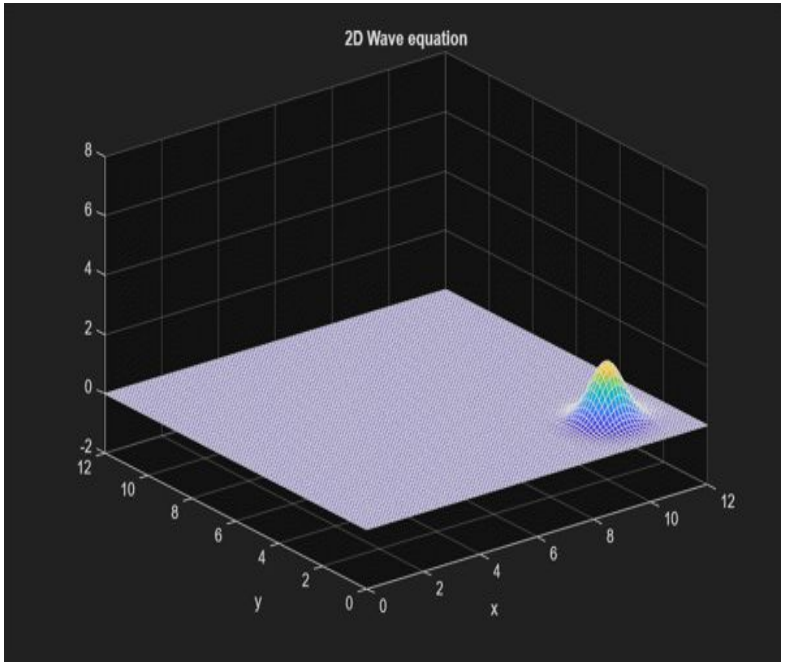
Wave Equation – Different Space



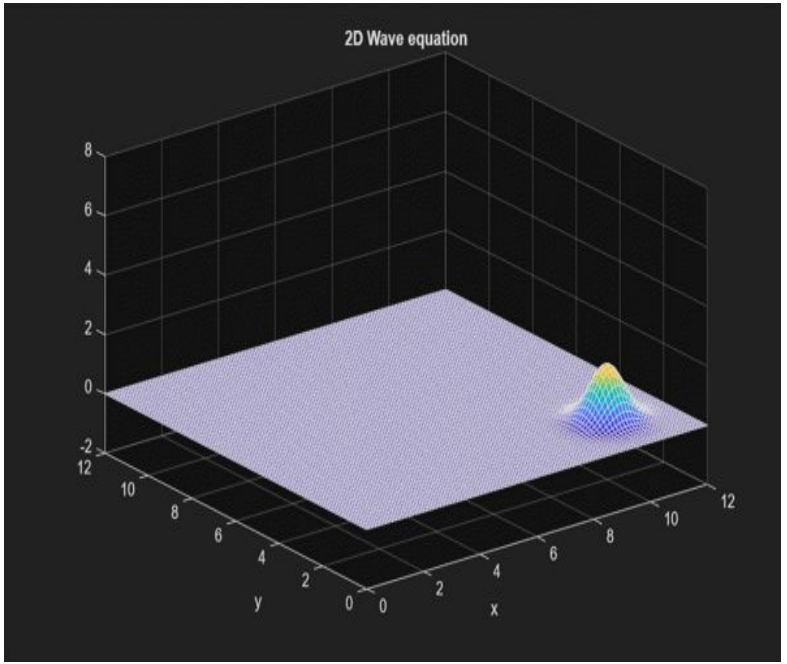


Wave Equation - Different Material

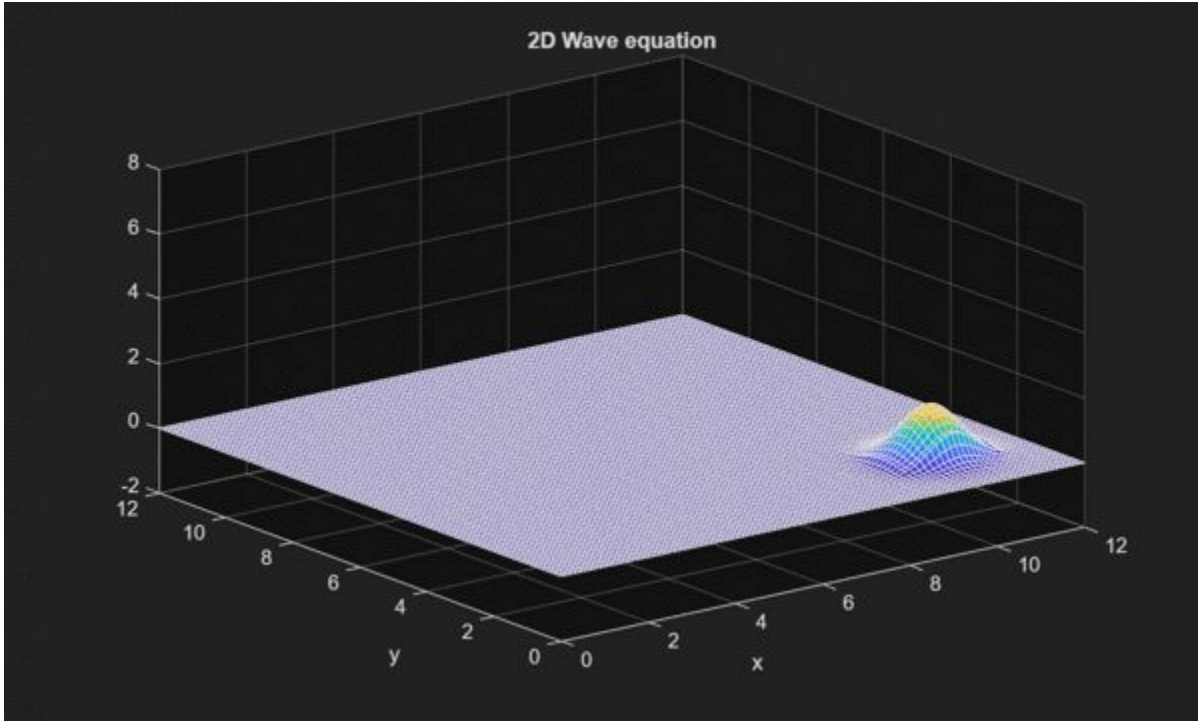
Room Full of water
With source in a bubble of air



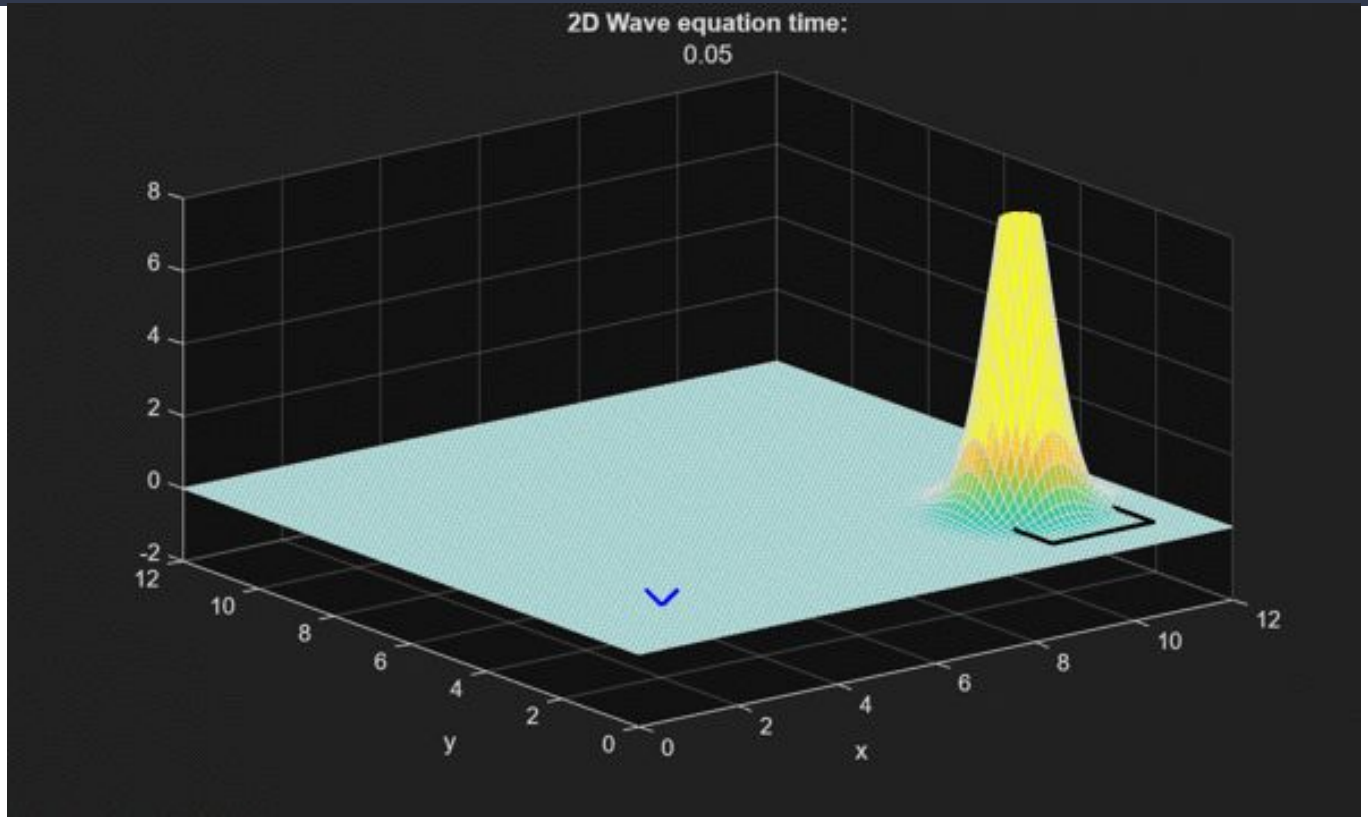
Room Full of air
With source in a bubble of water



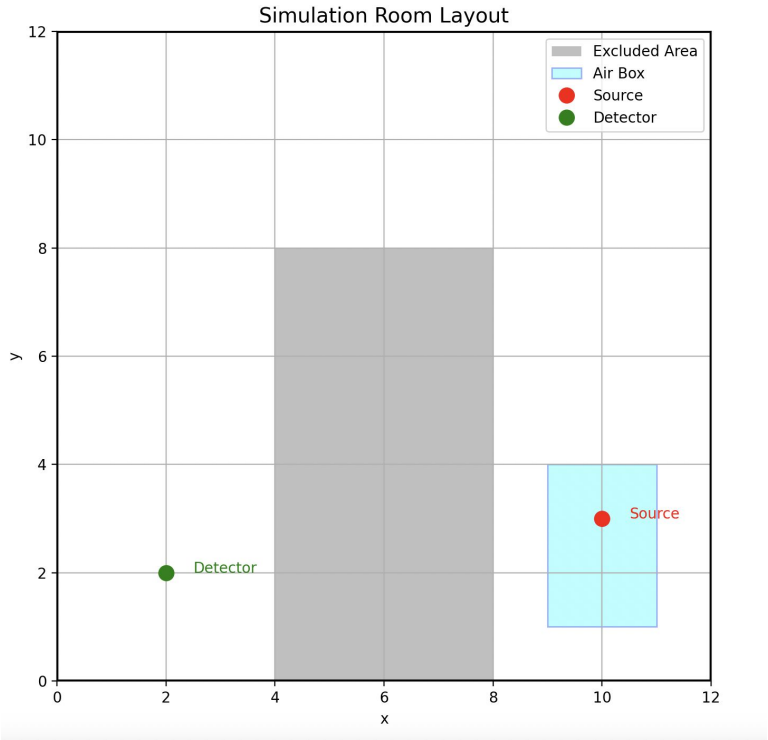
Wave Equation - Broken CFL condition



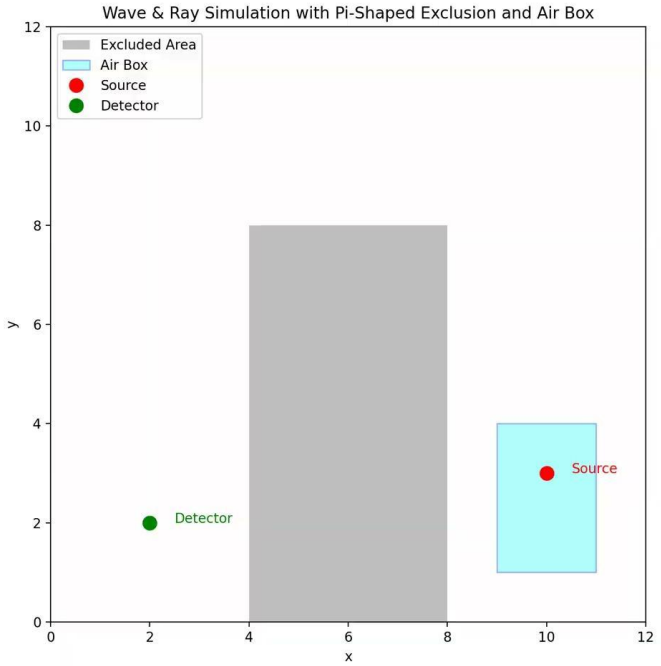
Wave Equation - Final



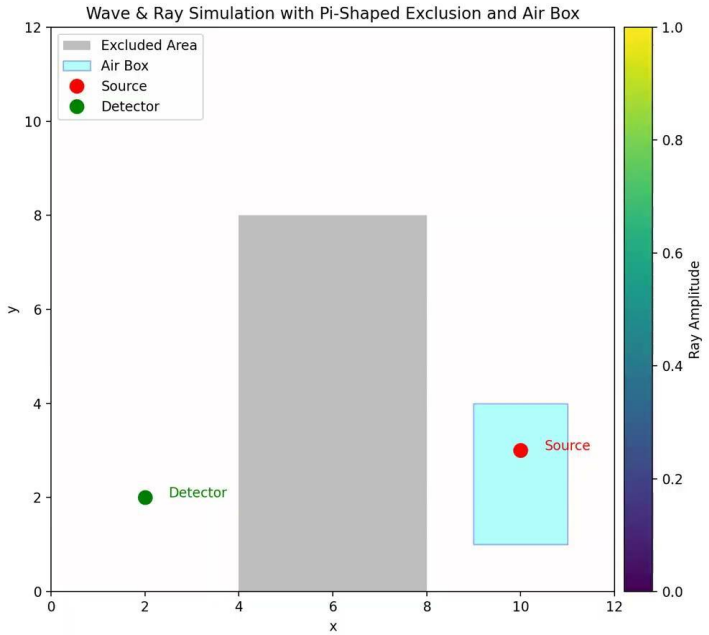
Ray Tracing


Simulation Room Layout
Excluded Area
Air Box
Source
Detector
Source
Detector
x
y
0
2
4
6
8
10
12

Ray Tracing


Wave & Ray Simulation with Pi-Shaped Exclusion and Air Box
Excluded Area
Air Box
Source
Detector
Source
Detector
x
y
0
2
4
6
8
10
12

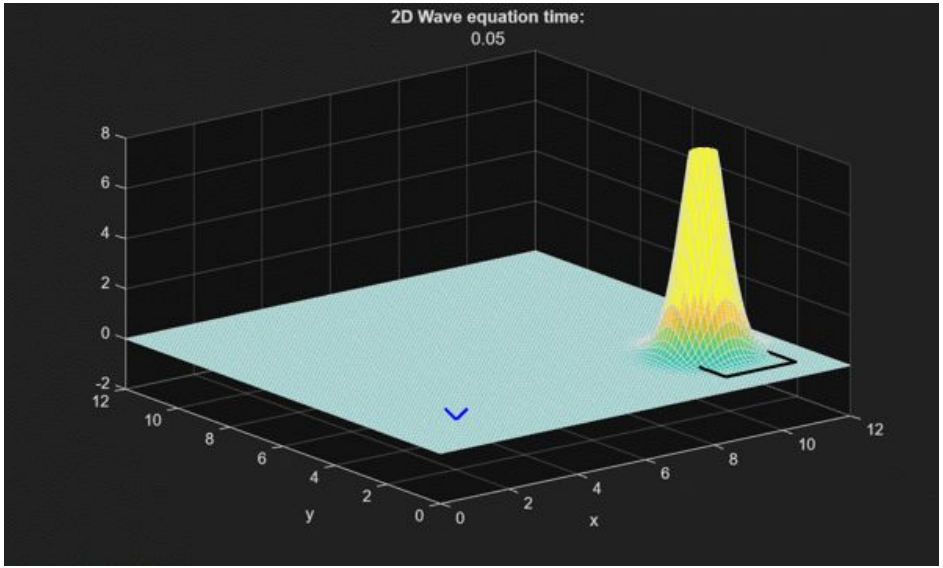
Ray Tracing – Final



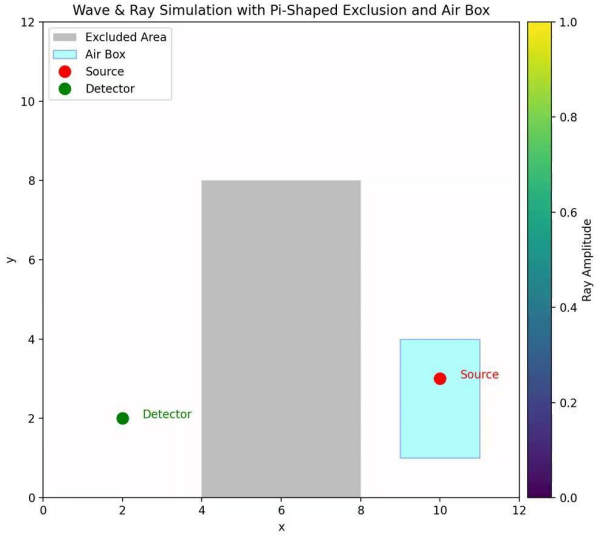
Ray Tracing – Audio

Final Results

Wave Equation



Ray Tracing




Thank
You!