FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE DE COIMBRA

DEPARTAMENTO
DE ENGENHARIA
CIVIL

Erasmus Mundus WAVES / MEAECS

Practical work 2

Viktoriia Boichenko, UC student n.º2022190966

Work developed in the scope of the course

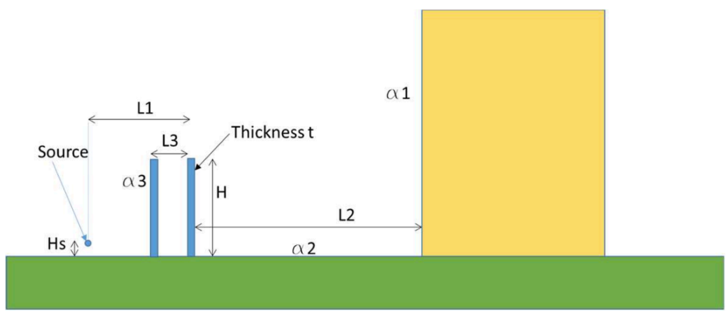
Computational Modelling

2022/2023

1 Problem

Consider a 2D practical acoustic problem, in the frequency domain, in which it is intended to compute the Insertion Loss of a noise barrier system, next to the façade of a tall building. The following scenario with input values:

A1 = 6, A2 = 6;
t=0.1m
L1=2.0+(A1+A2)/10.0 = 3.2
L2=7.0+|A1-A2|/10.0 = 7
L3=1.0+A1/10.0 = 1.6
H=1.5+A2/10.0 = 2.1
H2=2xH = 4.2
Hs=0.5m



b) For A1=3, A1=4, A1=5 or A1=6

Figure 1: Scenario for a 2D practical acoustic problem

Consider that the acoustic wave propagating problem is governed by the Helmholtz equation $\frac{\partial^2 p}{\partial x^2} + (\frac{\omega}{c})^2 p = 0$, in which p is the acoustic pressure, c the sound propagation velocity and ω the angular frequency.

The physical surfaces are rigid (Neumann condition with v_n=0), except those indicated with α1, α2 or α3. For those, consider:

$$\alpha 1 = (0.002 * f + 0.04 * log10(f) - (0.0008 * f)^2)/(2 * \sqrt{(A1 + 10)});$$

$$\alpha 2 = (0.002 * f + 0.04 * log10(f) - (0.0008 * f)^2)/(2 * \sqrt{(A1 + 5)});$$

$$\alpha 3 = (0.002 * f + 0.04 * log10(f) - (0.0008 * f)^2)/(2 * \sqrt{(A1 + 1)});$$

All absorbing surfaces can be assumed to be locally reactive (thus absorption conditions can be approximated from surface impedance $Z = p/v = \rho c \frac{1+\sqrt{1-\alpha}}{1-\sqrt{1-\alpha}}$).

At the indicated point, a 2D sound source excites this system.

Establish a Finite Element Model for this problem using Matlab's pdeModeler application.

a) Considering an excitation frequency of 500+A1*10+A2 (Hz):

a1) parametrize (and explain the different parameters you use) pdeModeler to solve the given problem (including PDE and boundary conditions).

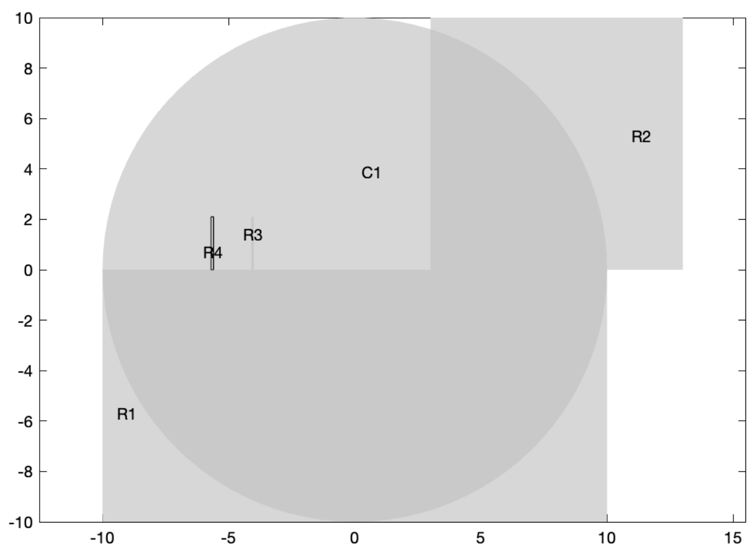


Figure 2: pdeModeler with initialised figures

Following manipulations were performed in the file modeler_problem_b.m in pdeModeler.

Among used parameters were L1, L2, L3,

The height of building (rectangular R2) was chosen with dimensions 10×10 at position (3,0).

Circle (C1) for discretisation of our problem was chosen with radius 10 and centre at (0,0).

Rectangular R1 has dimensions of 20×10 with left bottom corner (-10,-10).

Rectangulars R3, R4 have dimensions of $0.1\times$ 2.1.

Distance between building and closest obstacle R3 is 7. Distance between R4 and R3 is 1.5. Distance between R3 and point source is 3.2.

After locating all the figures on the plane following formula was applied: C1-R1-R2-R3-R4.

Point source has coordinates of (-7.3,0.5)

a2) define a uniform mesh that you consider to be adequate (justify) to solve this problem for the given frequency.

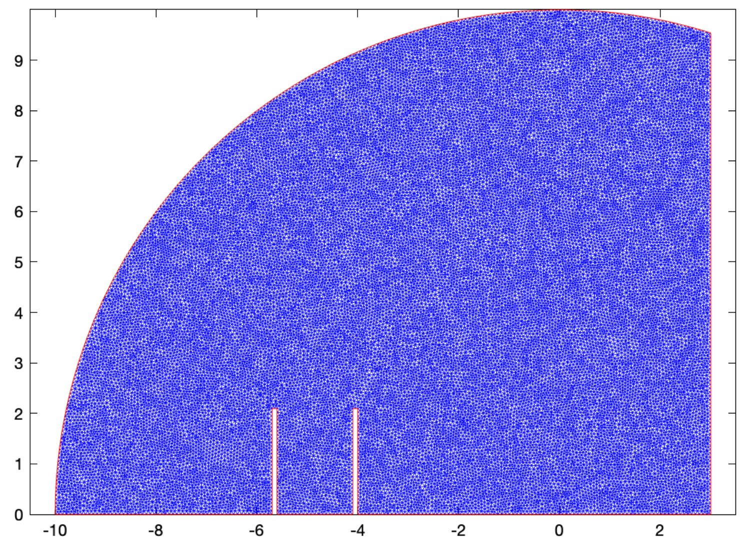


Figure 3: pdeModeler figure with a defined uniform mesh

$f = 500 + A1 * 10 + A2 = 566Hz$

$$h = \frac{c}{8f} = \frac{343}{8 \cdot 566} = 0.0758 - \text{for defining the adequate discretization}$$

a3) compute the sound pressure distribution in this system, and present plots for its real, imaginary and absolute values, as well as for the Sound Pressure Level (ref 2E-5Pa).

Following manipulations were performed in the file modeler_problem_test.m in pdeModeler.

We use the Helmholtz equation, where $\frac{\partial^2 p}{\partial x^2} + K^2 p = 0$

$$K = \frac{\omega}{c} = \frac{2\pi f}{c} - \text{wave number}$$

At first we have to specify Neumann conditions for all lines as for $n*c*grad(u)+qu = g$ where $g = 0, q = 0$.

For excitation point (in this case I have introduced a small circle with 0.01 radius). It's boundary condition has Neumann type

$g = 1i * rho * 2 * \pi * f = 1i * 1.22 * 2 * \pi * 566,\ q = 0$

For semi-circle we use boundary of Neumann type

$g = 0, q = -1i * K = -1i * 2 * \pi * 566/343$

For parts with the given alpha we use boundary of Neumann type

$g = 0, q = -1i * K * Z^{-1} = -1i * 2 * \pi * 566/343 * \frac{1-\sqrt{1-\alpha}}{1+\sqrt{1-\alpha}}$

PDE specifications

For $-c\nabla^2 u + au = f$ are:
$c = -1$, $a = K^2 = (2 * \pi * freq/c)^2 = (2 * \pi * 566/343)^2$, $f = 0$

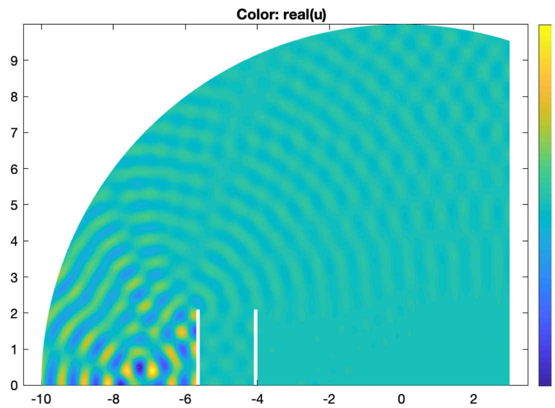


Figure 4: Frequency 566 Hz with BC configured in pdeModeler, real(P)

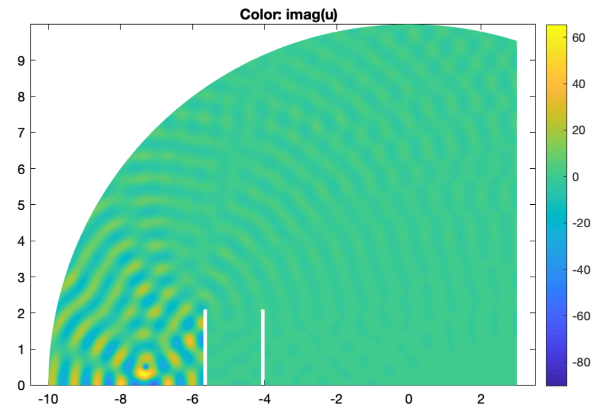


Figure 5: Frequency 566 Hz with BC configured in pdeModeler, imag(P)

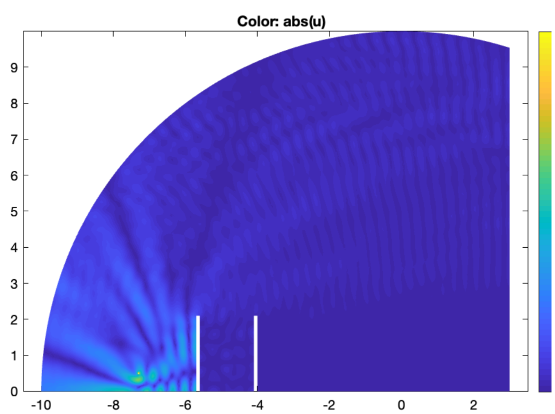


Figure 6: Frequency 566 Hz with BC configured in pdeModeler, abs(P)

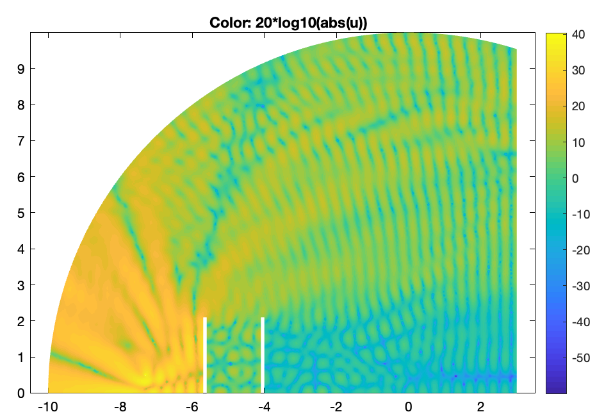


Figure 7: Frequency 566 Hz with BC configured in pdeModeler, SPL(dB ref 1Pa)

In comparison to the view from programmed in Matlab *Figure 8* to *Figures 4-7* it is visible that those plots are similar which indicates that program works correctly.

b) Setup the same problem using the provided Matlab code, specific for acoustic problems. Check your model comparing the real and imaginary parts of pressure

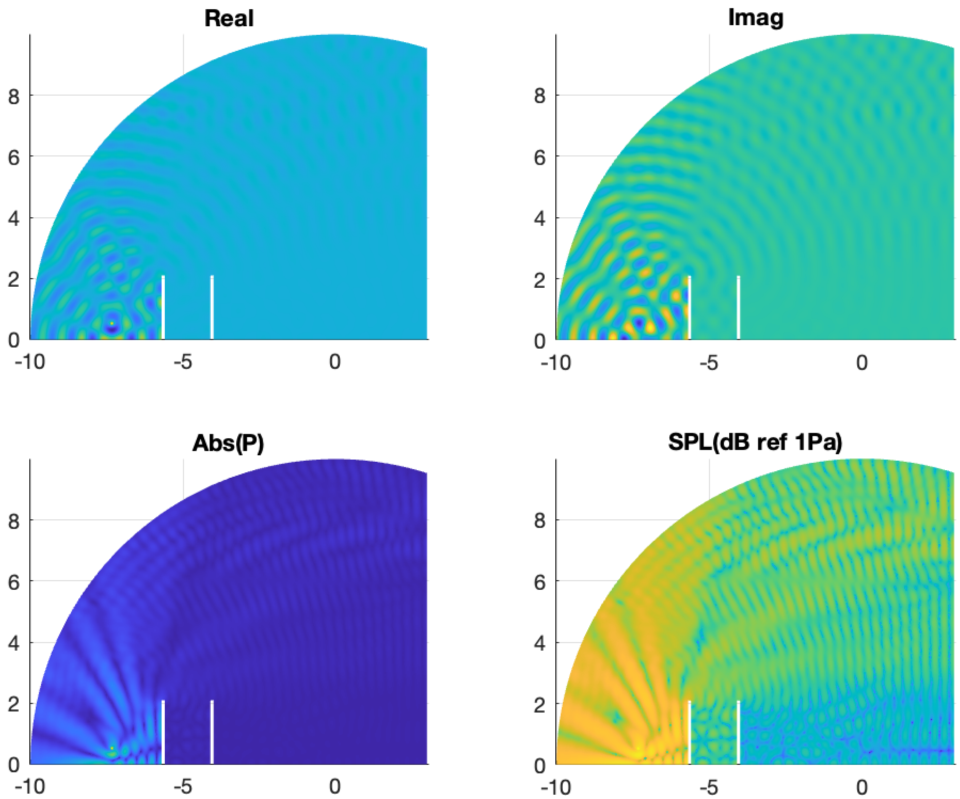


Figure 8: Frequency 566 Hz with BC configured in Matlab

distribution at the frequency defined above, comparing results obtained using this code and PDEModeler.

Figures 9-12 show the sound pressure distribution in this system in plots for its real, imaginary and absolute values, as well as for the Sound Pressure Level (ref 2E-5Pa).

Considering a frequency range from 100 Hz to 1000 Hz (with an interval of 10Hz), compute the Insertion Loss curve of this system (use an adequate mesh for the complete frequency range), considering the average of nodal points positioned at heights between 0.5 and 1.0m, and at distances between 1.0 and 1.5m from the building façade. Present these results also for octave bands and 1/3 octave bands.

$f = 500 + A1 * 10 + A2 = 566Hz$

$$h = \frac{c}{8f} = \frac{343}{8 \cdot 566} = 0.0758 - \text{for defining the adequate discretization}$$

Perform the same calculation considering completely rigid surfaces (Neumann conditions at all surfaces, with v_n=0).

Figures 13-15 present curves of Insertion loss in different octave bands. It can be seen

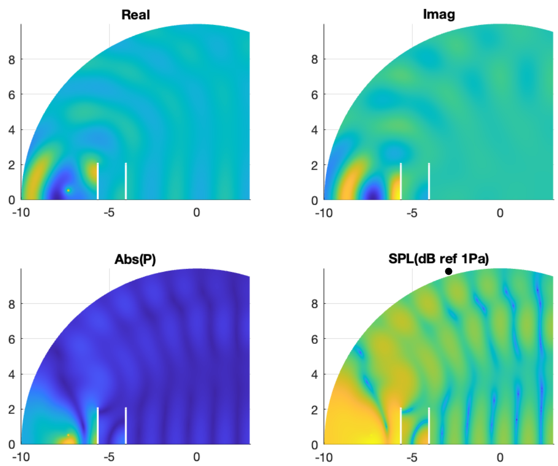


Figure 9: frequency 125 Hz with BC

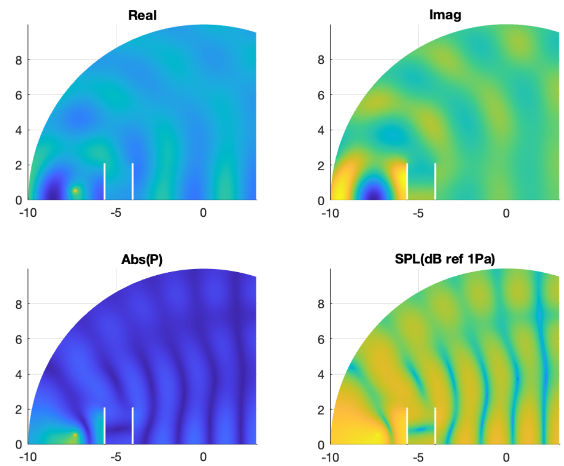


Figure 10: frequency 125 Hz with rigid surfaces

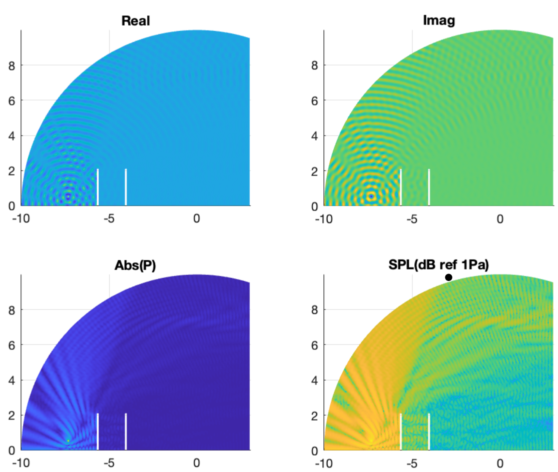


Figure 11: frequency 1000 Hz with BC

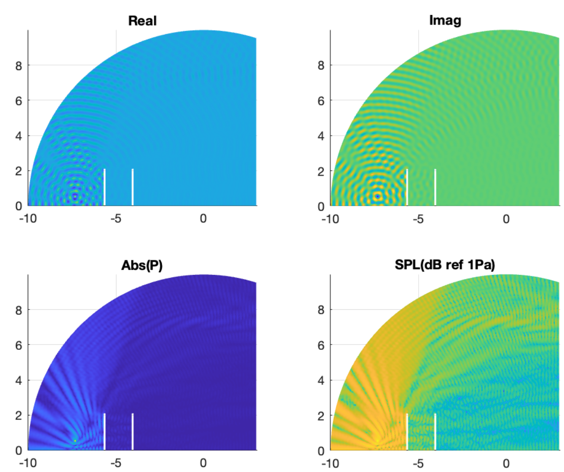


Figure 12: frequency 1000 Hz with rigid surfaces

that in case for rigid surfaces everywhere except for semi-circle this gives us a little higher loss overall, but curves tend to be in approximately the same values in each frequency.

Absorption of separate elements at low frequencies makes more interference on the plotting of waves, so when we have removed that boundary condition it has shown us more equally spaced intervals for waves. At higher frequencies waves behave almost the same way in both cases.

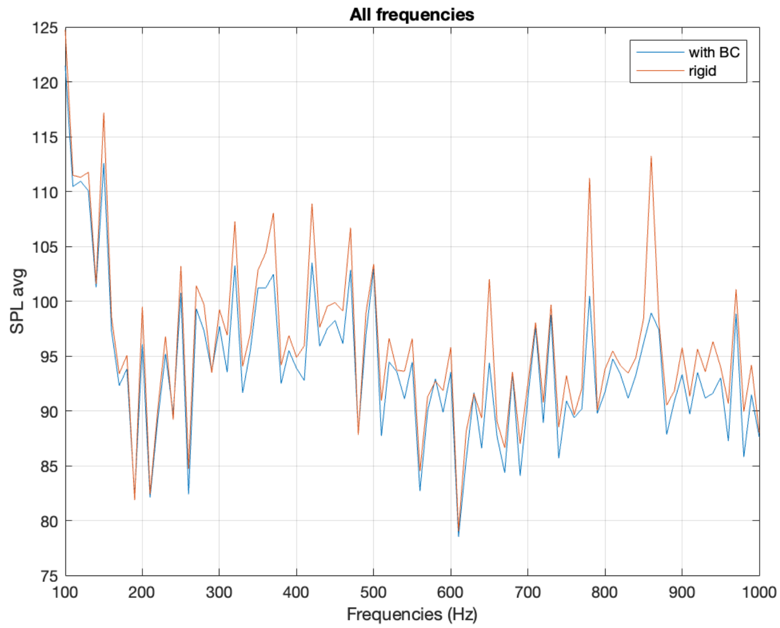


Figure 13: Insertion Loss curve of this system with given boundary conditions and rigid surfaces, 1-1000 frequencies

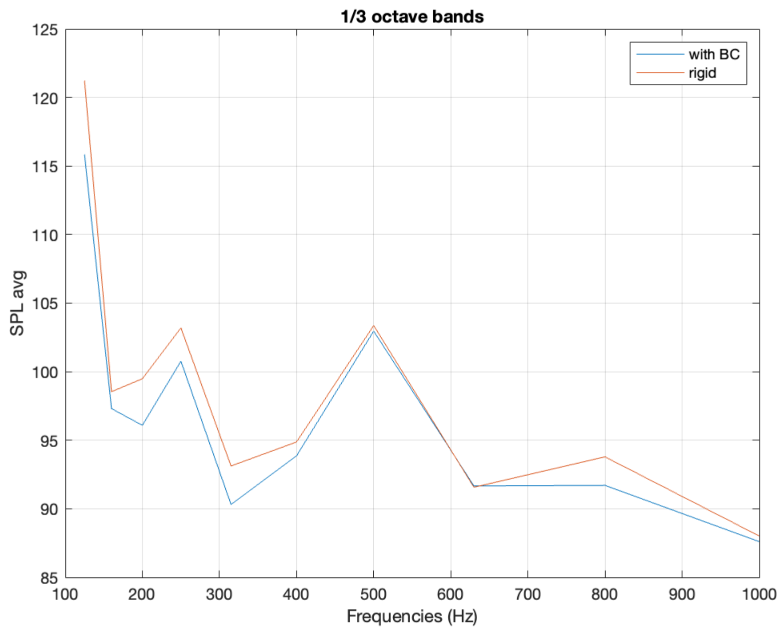


Figure 14: Insertion Loss curve of this system with given boundary conditions and rigid surfaces, 1/3 octave band frequencies

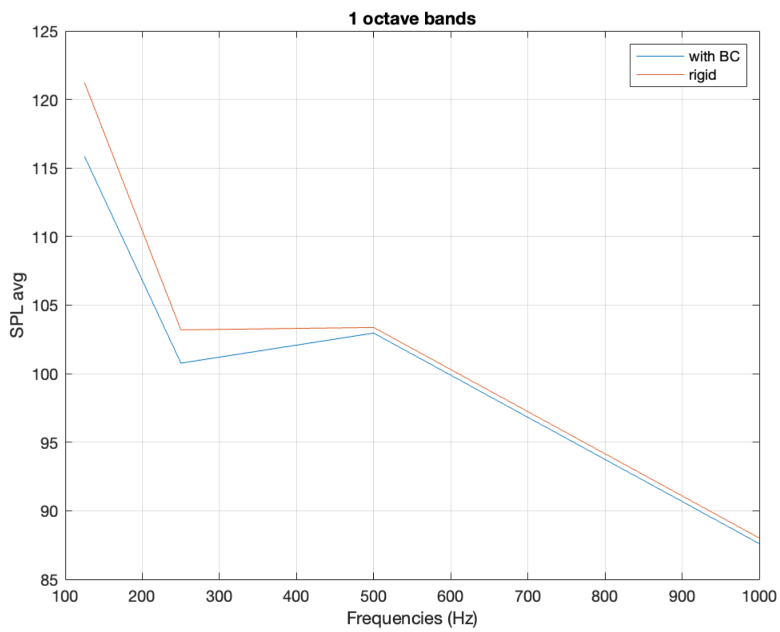


Figure 15: Insertion Loss curve of this system with given boundary conditions and rigid surfaces, 1 octave band frequencies