

**Supervisor:** t.b.d.

**Deadline 1 (present first results):** February 2nd, 2021

**Deadline 2 (submission):** February 9th, 2021

**Presentation:** February 11th, 2021 during lecture class.

## Project 5: Acoustics – Diffraction at an Aperture Plate

When acoustic waves hit an aperture plate (deutsch: Lochblende), the waves get partially reflected and partially move through the holes inside the plate. Those transmitted waves are affected by diffraction (deutsch: Beugung) and, thus, act as sources of secondary waves which are emitted from the holes. The size of the aperture plate and the diameter of the holes play a critical role to the shape of the resulting acoustic field beyond the plate. In this project you shall investigate on those relations by applying Finite Element simulation.

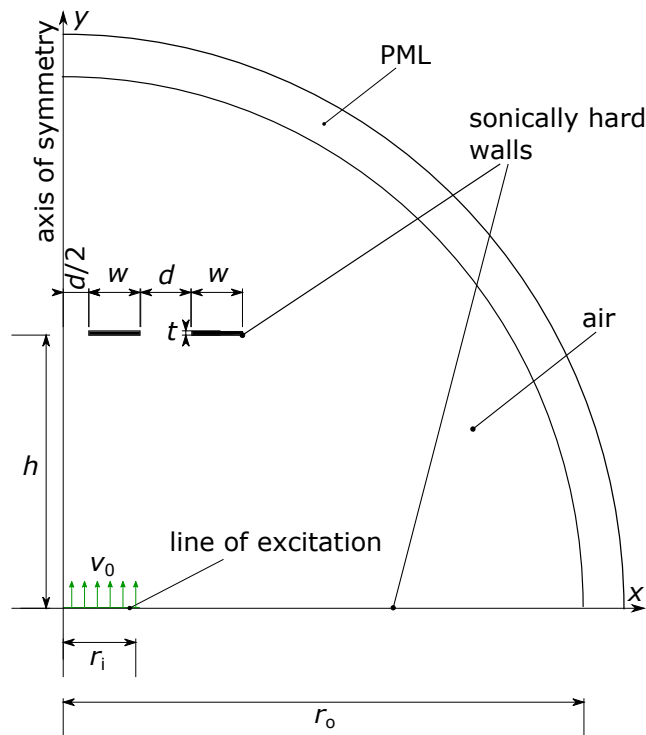


Figure 1: Plane geometry for the investigation of acoustic diffraction.

Figure 1 shows the **plane** geometry which shall be investigated (not axi-symmetric!). It consists of an air region in the form of a half circle of radius  $r_o$  and is enclosed at its curved outer boundary by a perfectly matched layer (PML). At a distance  $h$  from the bottom of the air domain, the aperture plate is located. It consists of four sonically hard walls of width  $w$  which are separated by three holes of diameter  $d$ . The system is excited by an excitation line of width  $r_i$ . Note that due to symmetry with respect to the  $y$ -axis only half of the geometry is depicted.

## 1 Modeling

1.1. For your investigations consider the following parameters:

- material properties air:  $c_0 = 343$  m/s,  $\rho_0 = 1$  kg/m<sup>3</sup>
- investigation frequency:  $f_0 = 1000$  Hz
- normal velocity on exciting line:  $v_0 = 1$  m/s
- dimensions in terms of the wave length  $\lambda$ :
  - $h = 5\lambda$
  - $r_i = \lambda/4$
  - $w = \lambda/2, \lambda, 2\lambda$
  - $d = \lambda/4, \lambda/2, \frac{3}{4}\lambda, \lambda, \frac{5}{4}\lambda, \frac{3}{2}\lambda, \frac{7}{4}\lambda$
  - $t \rightarrow 0$

1.2. The circular outer boundary of the setup shall be modeled as a perfectly matched layer (PML) and has to be placed at a proper distance from the obstacle. Add an appropriate domain for the PML to the geometry as indicated in the Fig. 1.

**Important:** Make sure that the circular PML domain is centered at the **origin** of the coordinate system or otherwise specify the center point in the PML node. Comsol requires this in order to be able to perform an appropriate coordinate scaling for the PML.

1.3. Choose an appropriate sinusoidal burst with *Hanning* window as input signal. Plot its magnitude spectrum in Matlab and determine its  $-6$  dB bandwidth. What is the minimum and maximum frequencies contained in the burst signal? What are the corresponding minimum and maximum wave lengths that will be excited?

1.4. Model the geometry such that the dimensions can easily be adapted. Mesh the geometry with an appropriate element size.

## 2 Analysis

2.1. For each parameter combination above, perform a transient simulation. The time step size  $dt$  has to be chosen according to the rule of thumb for transient simulations. Remember to specify a strict time stepping to the solver. The total simulation time should be sufficiently large for the emitted acoustic pulse to reach the boundaries of the domain. The input is provided to the system by prescribing the normal velocity on the excitation line.

2.2. Evaluate the results of your simulations by comparing the acoustic pressure field at appropriate time steps during your simulations. As you have varied multiple parameters, try to find a proper grouping to allow comparisons. You could for example keep all parameters but one fix to display the effect of that parameter.

## 3 Presentation

Prepare for a **ten minutes** presentation followed by a **five minutes** discussion. Your presentation should consist of the following blocks:

- 3.1. Introduce yourselves (names, fields of studies).
- 3.2. Motivate and introduce the topic, i.e., what is this project about, how does the shown sensor/actor/assembly work in practice, what is it used for, what are the main objectives.
- 3.3. Present the major aspects of your modeling and analysis, i.e., what quantities were analyzed, are there any analytic estimates, what major difficulties had to be solved, how did you overcome these difficulties, etc.
- 3.4. Show and discuss your results in a descriptive way using graphs, screenshots, videos, etc.
- 3.5. Give a short conclusion.

## Some remarks

- Brainstorm a concept on how to proceed and think about the desired goals and how you can achieve them. Focus on the relevant aspects of the project.
- Start early with your project and meet regularly to work together and/or exchange ideas. You might be able to distribute some tasks inside your group.
- The task description is rather vague on purpose and has room for your own interpretations. If you face uncertainties, e.g., regarding the choice of some parameter, discuss in the group first and think about reasonable choices. Only if this does not help, contact your supervisor.
- Present your project milestones to your supervisor **twice or thrice** during the course of the project. Discuss your “almost” final slides with your supervisor **before the first** deadline. Keep in mind, that you might need to make substantial changes and/or more simulations after this discussion.
- You can/should use Matlab where you deem it useful.
- When making animations, make sure to fix the color range of surface plots.

## Submitting your project

Hand in your

- .mph file (clear all meshes and results beforehand, see the COMSOL Tutorial),
- plots (as .png files) and
- Presentation in PowerPoint or PDF format

before the final due date (second deadline) by copying everything into your home directory inside an **project5** folder (name the folder **exactly** this way!).