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

Deadline 2 (submission): February 9th, 2021

Presentation: February 11th, 2021 during lecture class.

Project 6: Acoustics – Ultrasonic Distance Sensor

This axis-symmetrical sensor consists of a circular transmitter and a ring-shaped receiver. The transmitter launches Hanning-windowed ultrasonic sine bursts at 50 kHz with a total force F of 1 kN. The waves are reflected at obstacles of variable width w at different distances d and are afterwards detected by the receiver ring (see Fig. 1).

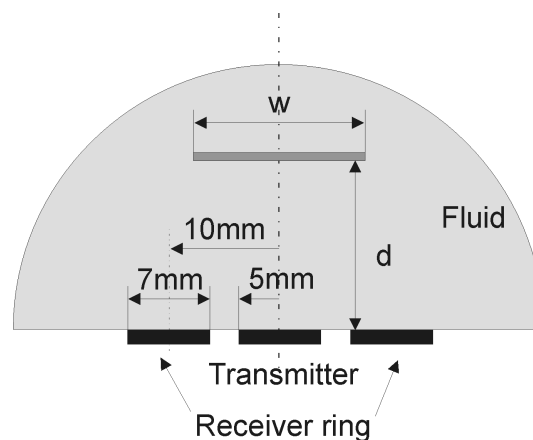


Figure 1: Ultrasonic distance sensor, principle and dimensions

The main objectives of this project are:

- How do the sine bursts propagate from transmitter to receiver? How does the frequency of the pulse influence this process?
- How do size w and distance d of the obstacle affect the received signals? Are there critical values of w and/or d for which the obstacle cannot be detected properly (i.e. nearly no signal is received)?

1 Modeling

- 1.1. Model the geometry as depicted in Fig. 1. Keep the width w and the distance d of the obstacle variable. The transmitter may be modeled as a pure boundary condition, i.e., the excitation signal can be applied directly to the interface line.
- 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.
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. The remaining lower boundary may be specified as a sonically hard wall.

- 1.4. You can model the obstacle as a simple line with thickness tending to zero. Specify an *interior* sound hard condition on this line (it is not a BC, as this line is in the interior of the domain).
- 1.5. The sensor operates in air.
- 1.6. 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?
- 1.7. Mesh the geometry with an appropriate element size.

2 Analysis

- 2.1. Simulate the reflection and reception process and investigate on the pressure at the center line of the receiver ring. Make a movie of such a process.
- 2.2. Vary the width w of the obstacle from 10 mm to 40 mm. Does this influence the strength of the received signal? How does the sensitivity change?
- 2.3. Vary the distance d of the obstacle from 20 mm to 50 mm. Evaluate the reception time as a function of the distance.
- 2.4. Finally, increase the excitation frequency from 50 kHz to 500 kHz (this will require a finer mesh size!) with $w=40$ mm at $d=30$ mm. Compare the results with those from the lower frequency excitation. How does the higher frequency influence the acoustic field between transmitter and obstacle? Does it improve the signal at the receiver ring or is there a decrease in amplitude?

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 **project6** folder (name the folder **exactly** this way!).