MECH6066 HW#2

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10.05.25

Problem 1

(a)

Yes, this matches my expectations. A quiet room is typically quoted around 25–30 dB, and my air conditioning was running during the measurements so it makes sense to be slightly high.


22:39
Quiet whisper
1643 Hz
74 Hz
Upgrade
AVG
34.5
41.0
MAX
41.0
12s
Camera
Dosimeter
Meter
Data
Settings

(b)

At 50%, the FFT showed 62dB. At 75%, it showed 65dB. At 100%, it showed 68dB. I felt like 75% was not that much louder, but 100% felt much louder than 50%. I think the increase between 50%–75% and 75%-100% felt like the same difference.

(c)

I had measured S1 at 62dB, and set S2 to 61dB. Together, I measured them at 64dB. Since these are uncorrelated sources, we can sum the intensity. Using an online calculator to convert each to intensity, then summing and getting SIL we calculate that the measured value should be 64.55dB. This is very close to the 64dB I measured, and a number of setup issues could cause the slight discrepancy.

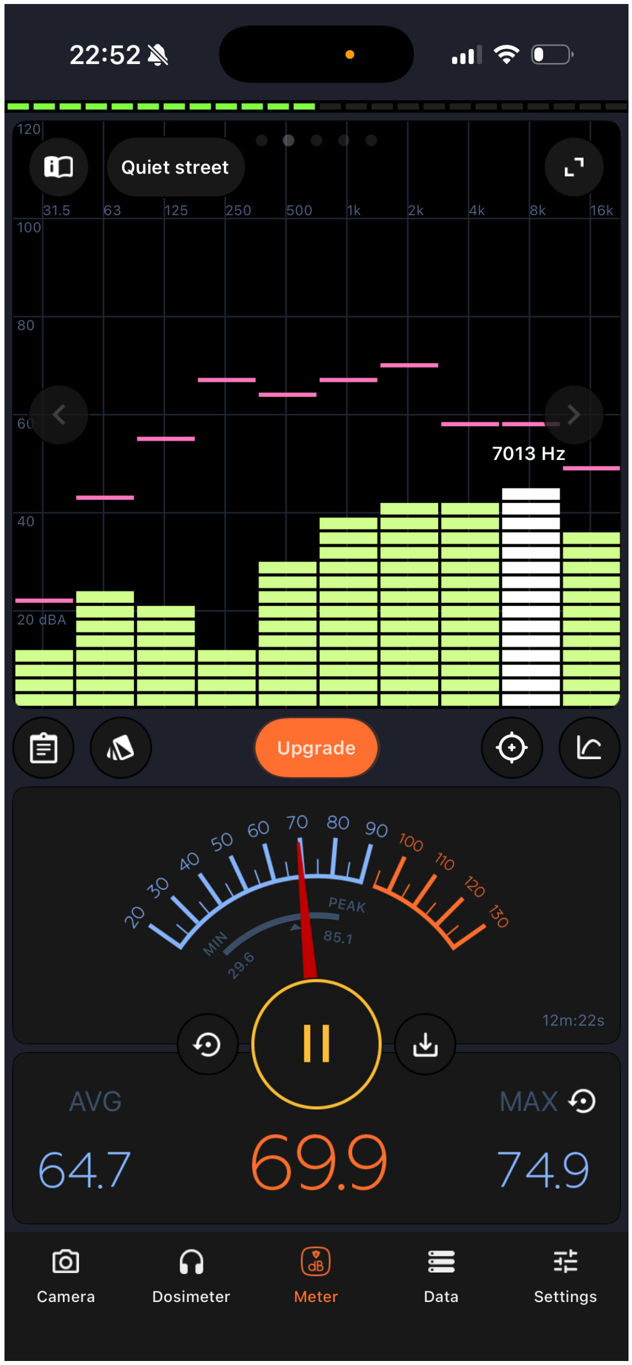
(d)

I ended up with both S1 and S2 measuring 62dB. The fluctuation in the time history could be caused by phasing. Since the sources are not necessarily in phase, the total measured can fluctuate. In theory, the maximum is two in phase which would be 68dB and the minimum would be 180deg out of phase which would totally cancel out and measure only the background level of 41dB. I measured a maximum of roughly 72dB and a minimum of 59dB. I measured a little bit higher than this, but my background noise was changing a little bit so this may be an increase in background during the measurement. The two signals clearly never went completely out of phase, as I always heard a tone, which means my minimum will be higher than the background.

(e)

The spectrum is pretty close, but not exact. There is a fairly flat band from 1kHz–10kHz, but there are visible peaks and valleys within that range. The average value appears to be constant. The white noise will not show an exactly flat response due to the speakers response, and the fact that we have A-weighting applied. It is unlikely to ever be a perfect flat frequency output.

The SPL at the 125Hz band is roughly 20dBA. This would be 36.2dB unweighted based on the conversion table. This would be much closer to the value measured at the other frequency bands, and the full unweighted conversion may show a flatter response for the white noise.



I ended up getting both sources to measure 70dB individually. Together, I measured them at 73dB. The calculated value for the sum, since they are uncorrelated noise, is the sum of intensities, which would give 73dB. My measurement was very accurate to the expected value.

(f)

The white noise is much more comfortable. While it is still loud and you can feel how loud it is, it is much more pleasant to hear white noise. The single tone is incredibly annoying and it gets stuck in your head even after it ends. The white noise can reach an unpleasant volume, but it does not stick in your head or bother me as much as a single tone does. This makes a lot of sense as people typically enjoy white noise, but hearing a constant tone like a buzzing sound would be super annoying.

Problem 2

(a)

I would select the Teledyne TC4038 for measuring the transducer output. Firstly, we want a hydrophone capable of at least double the frequency we are interested in. Teledyne only had 2 options that measured over 500kHz. I selected the TC4038 because while it is rated for less depth and does not have a built-in pre-amp, it is described as a standard reference hydrophone that is "traceable to national standards". It is also described as ideal for near-field measurements. Overall, it seems perfect for characterization of a transducer. The other option, the TC4035, appears to be a more applied version of the hyrdophone. It is rated for high depth and has an integrated pre-amp, so it would be much more useful in a real application. The TC4038 that I selected has a sensitivity of -228 dB re. 1Vrms/μPa, which is equal to $3.981 \cdot 10^{-6}$ V/Pa.

(b)

$$V_{out} = S \cdot p_{hyd} = 3.981 \cdot 10^{-6} (55000 + j389000) = 0.219 + j1.549 \text{ V}$$
$$|V_{out}| = \sqrt{0.219^2 + 1.549^2} = \boxed{1.564 \text{ V} = |V_{out}|}$$
$$\phi_{out} = \arctan(1.549/0.219) = \boxed{81.95^\circ = \phi_{out}}$$

(c)

$$p_{rms} = |p_{hyd}|/\sqrt{2} = \left(\sqrt{55^2 + 389^2}\right)/\sqrt{2} = 277.8 \text{ kPa} = 277800 \text{ Pa}$$

$$p_{SPL} = 20\log_{10}\left(\frac{277800}{1 \cdot 10^{-6}}\right) = \boxed{228.9 \text{ dB} = p_{SPL}}$$

(d)

$$S = \frac{\sqrt{55000^2 + 389000^2}}{10} = \boxed{39287 \text{ Pa/V} = S_{trans}}$$

(e)

I do not believe enough information is given to calculate the speed of sound. Assuming the phase shift is from propagation time gives a speed of sound of over 100000 m/s, which is clearly wrong for water. I also attempted to solve for k in the V_{out} equation, but without knowing the measured voltage at some time, there is not enough information. I also attempted to solve using SIL, but that requires assuming a reference intensity for water based on a specific speed of sound. Using an internet value for speed of sound, we can see that the speed of sound is roughly 1500 m/s. This gives a wavelength of 0.003 m at 500kHz in water.

(f)

$$u = \omega\delta$$

$$p = \rho c u$$

$$\delta = \frac{p}{\rho c \omega} = \frac{392868}{1000 * 1500 * 2\pi(250000)} = \boxed{1.67 \cdot 10^{-7} \text{ m} = \delta}$$

(g)

One big assumption is that the transducer generates a plane wave. This may be accurate over small distances and is probably resonable for the experimental setup pictured. Another assumption is that there is no reflections. This is unlikely to be true if the scale of the diagram is accurate. A very large tank would be required to have "no" reflections, although technically having 0 reflections is never actually possible. This may change the accuracy of the measurements. We are also assuming a perfect sinusoid is generated, only with frequency content at the desired frequency, which is typically a reasonable assumption but may not be true depending on the system performance. We also make some reasonable implicit assumptions such as that the medium is completely homogenous and is at standard temperature and pressure and behaving normally.

(h)

For part a, ChatGPT selected a Teledyne-style hydrophone it made up with a sensitivity of -200 dB. This is already a problem as it has estimated well, but selected a completely nonexistent device. The sensitivity choice also creates 2 orders of magnitude difference between its sensitivity and what is actually quoted by the company.

ChatGPT got a much different answer for part b. Since it assumed an incorrect sensitivity, it calculated the output voltage magnitude at 39.3V. I believe my answer is more correct since it was based on a real device. It did have the same phase as me at 81.95°.

In part c, ChatGPT calculated the SPL to be 231.9dB, which is very similar to my answer. I believe the only difference is some rounding error.

For part d, ChatGPT got the exact same answer as me.

In part e, ChatGPT tried to estimate the speed of sound based on the phase of the measured signal and the distance between the transducer and hydrophone. It got the speed of sound was 110000 m/s, and noted that this does not make sense and the phase change is likely due to other sources. It gives up and uses 1480m/s for the speed of sound in water to determine the wavelength is 3 mm at 500kHz, which agrees with my answer. With more prodding, ChatGPT said that it is not given enough information to determine the speed of sound in the tank, which I think may be correct.

ChatGPT got the same answer as me for part f.

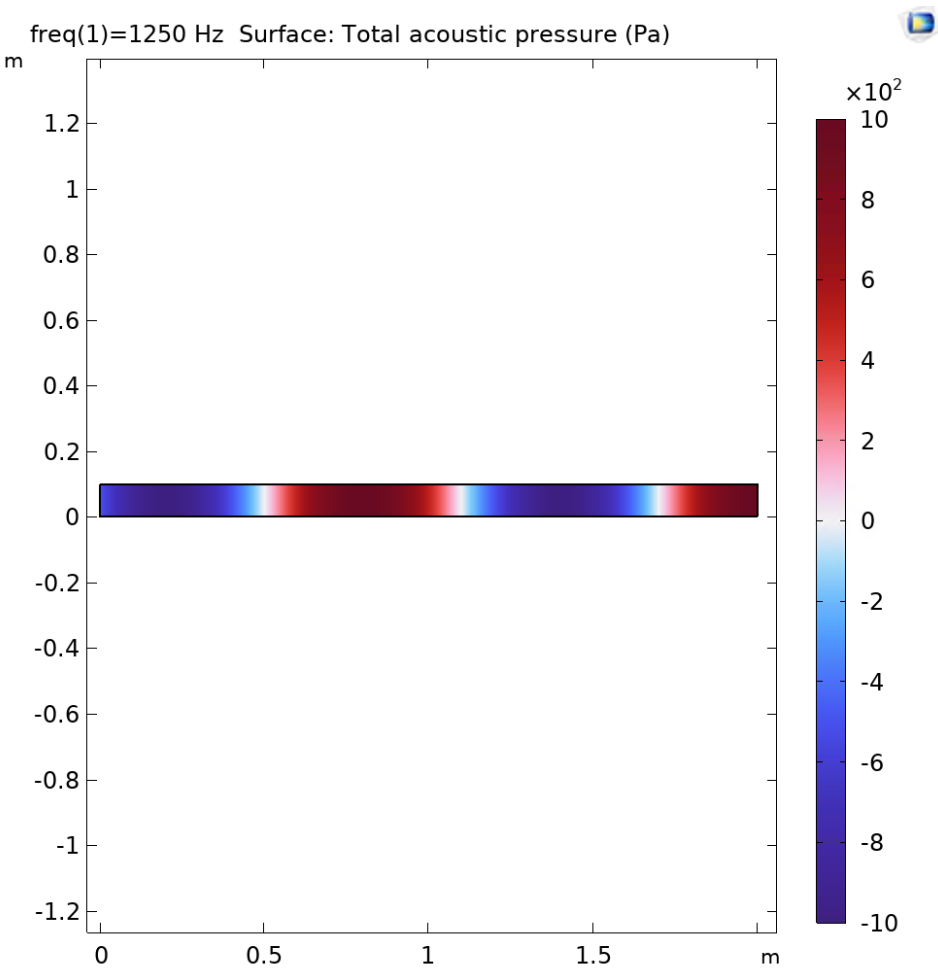
For part g, ChatGPT included some assumptions I did not think about. First, we implicitly assumed that the hydrophone sensitivity is not frequency dependent. It says that this is only ok for an example, although I think for a flat-response hydrophone it is a reasonable assumption. It agreed with my plane wave assumption. It also agreed that we are neglecting reflections and attenuation, which may lead to a poor approximation.

Problem 3

(a)

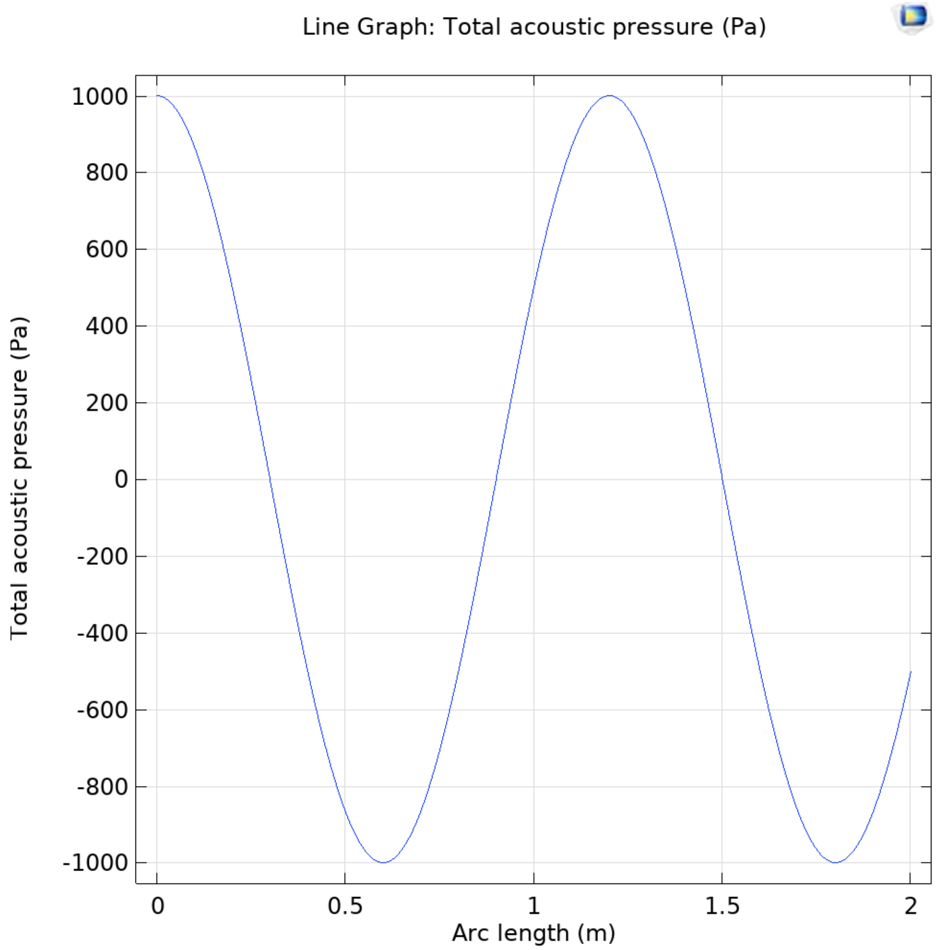
i

The color in the plot represents the acoustic pressure in Pascal.



ii

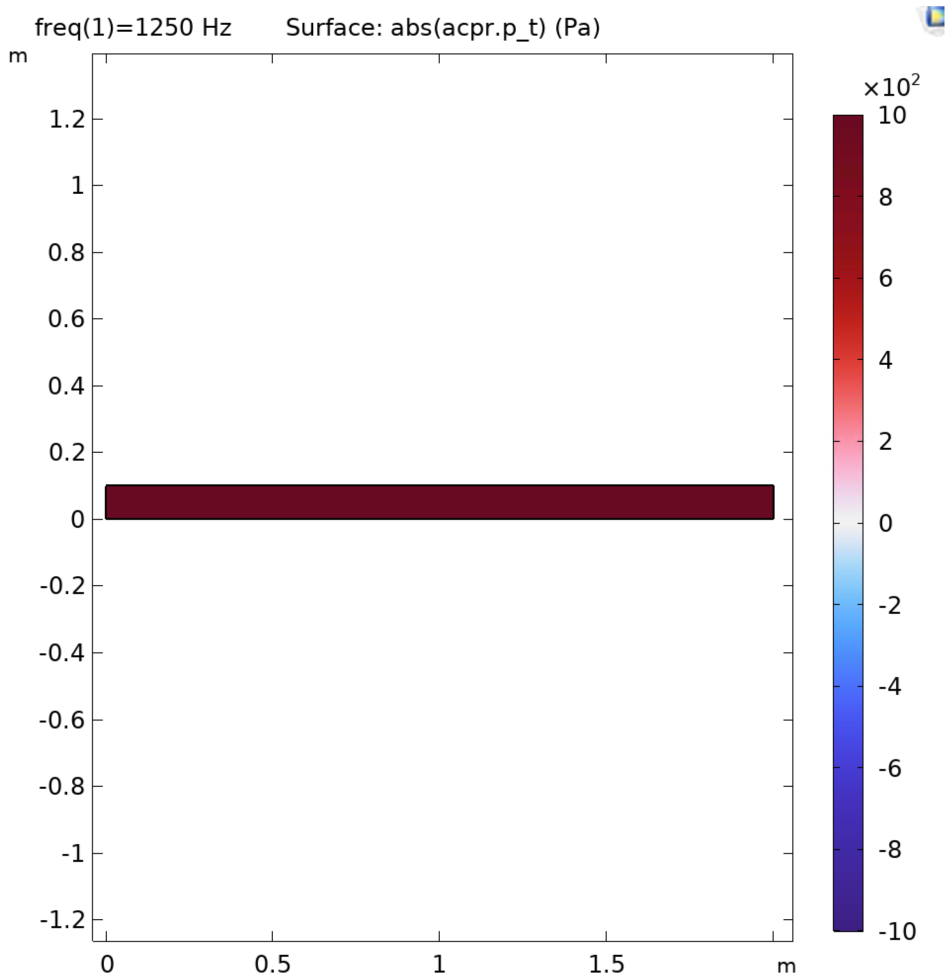
The wavelength is roughly 1.25m from trough to trough on the plot. The aanlytical wavelength should be 1.2m, so this makes sense.



(b)

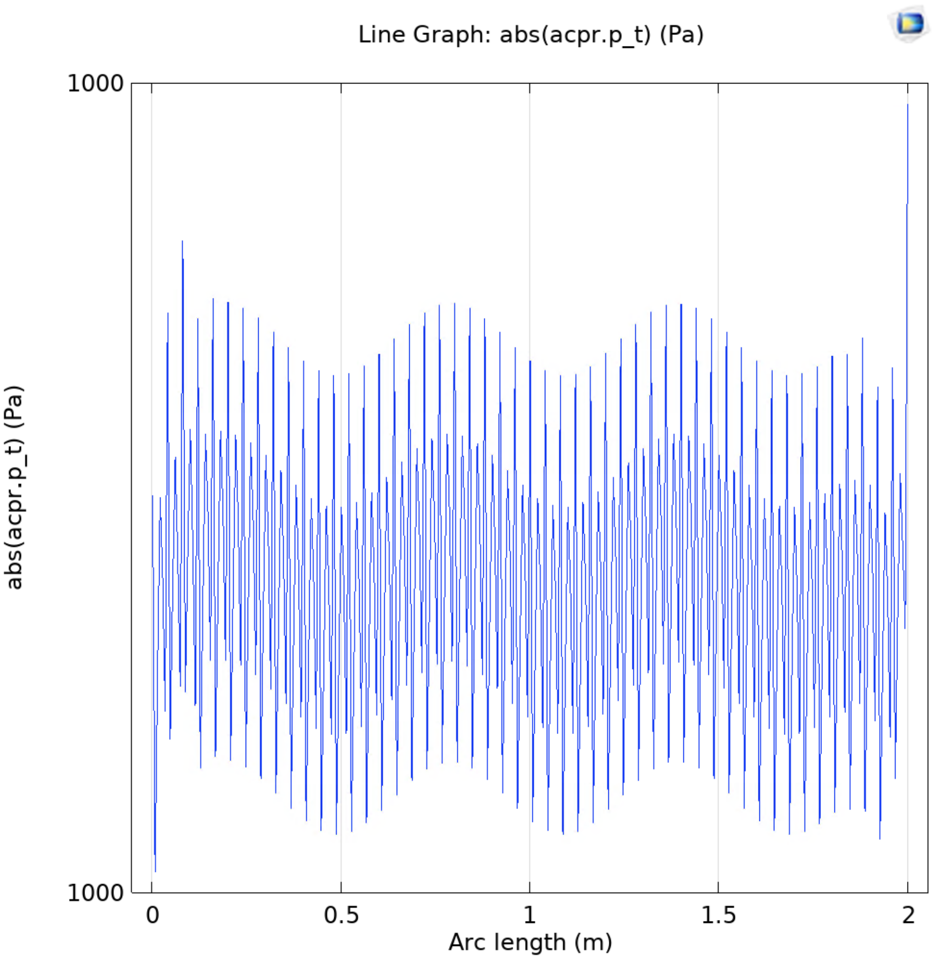
i

This plot is one color because the amplitude should be equal to the input amplitude, and the absolute value of the wave should be that value everywhere.



ii

This is also a constant line (despite not looking like it), as the range is from 1000 to 1000 and the shape is weird comsol plotting. This also makes sense for the same reason as part bi. When taking the absolute value of a wave, we should see the magnitude everywhere.

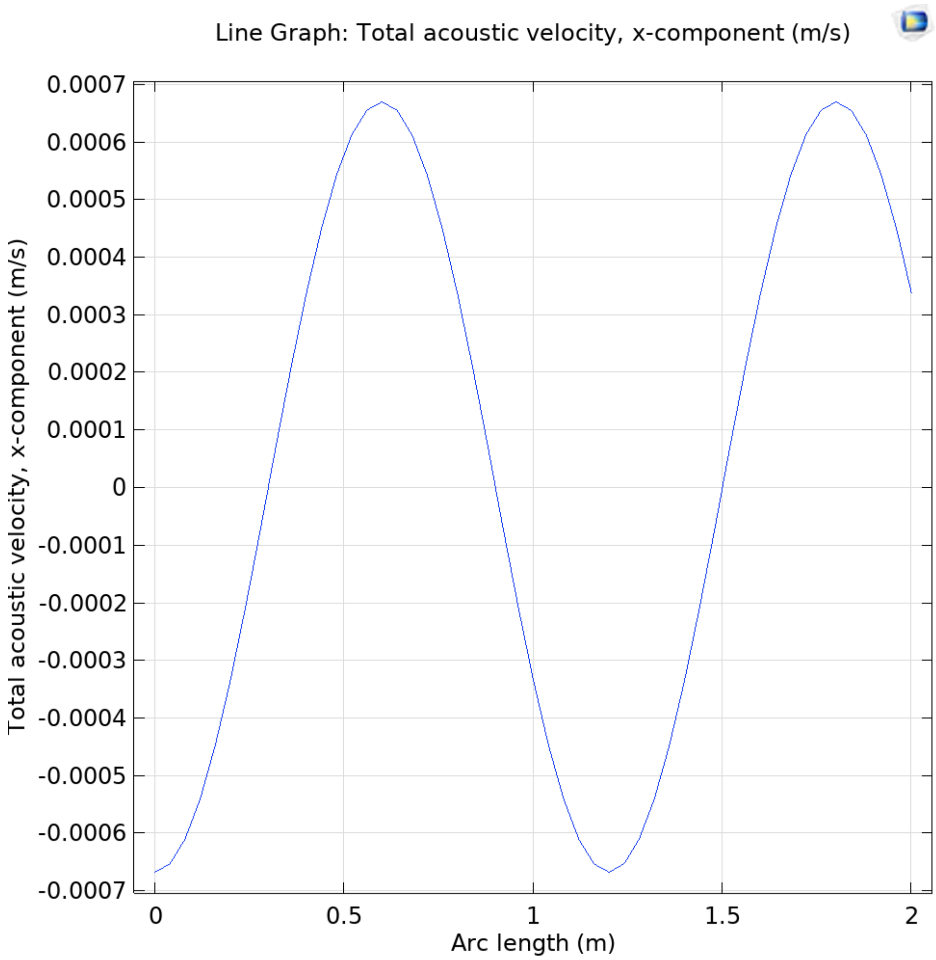


(c)

This generated an animation with left-moving pressure waves.

(d)

The value of the plot makes sense. The input pressure divided by the impedance gives a maximum velocity of 6.7E-4 m/s, which appears to be the maximum of the plot.


Line Graph: Total acoustic velocity, x-component (m/s)
Total acoustic velocity, x-component (m/s)
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
-0.0001
-0.0002
-0.0003
-0.0004
-0.0005
-0.0006
-0.0007
0
0.5
1
1.5
2
Arc length (m)

HW2

Report date	Oct 5, 2025, 10:01:20 PM

Contents

1 Global Definitions

Date	Oct 5, 2025, 9:19:44 PM

GLOBAL SETTINGS

Name	Untitled.mph
Version	COMSOL Multiphysics 6.3 (Build: 420)

USED PRODUCTS

COMSOL Multiphysics

COMPUTER INFORMATION

CPU	Intel64 Family 6 Model 198 Stepping 2, 28 cores, 63.46 GB RAM
Operating system	Windows 11

1.1 PARAMETERS

PARAMETERS 1

Name	Expression	Value	Description
W	2[m]	2 m	
H	0.1[m]	0.1 m	
f	1250[Hz]	1250 Hz	
pin	1[kPa]	1000 Pa	
r	1000[kg/m^3]	1000 kg/m^3	
a	1500[m/s]	1500 m/s	

2 Component 1

SETTINGS

Description	Value
Unit system	Same as global system (SI)

2.1 DEFINITIONS

2.1.1 Coordinate Systems

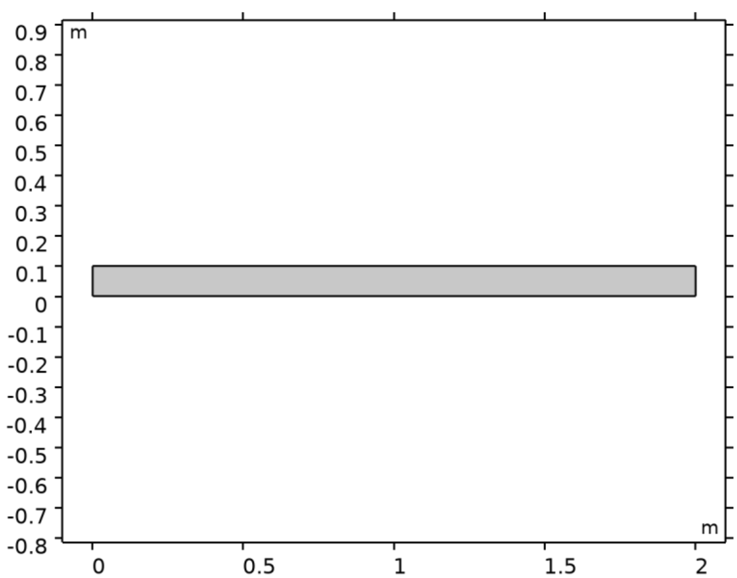
Boundary System 1

Coordinate system type	Boundary system
Tag	sys1

COORDINATE NAMES

First	Second	Third
t1	n	to

2.2 GEOMETRY 1



Geometry 1

UNITS

Length unit	m
Angular unit	deg

GEOMETRY STATISTICS

Description	Value

Description	Value
Space dimension	2
Number of domains	1
Number of boundaries	4
Number of vertices	4

2.2.1 Rectangle 1 (r1)

SIZE AND SHAPE

Description	Value
Width	W
Height	H

POSITION

Description	Value
Position	{0, 0}

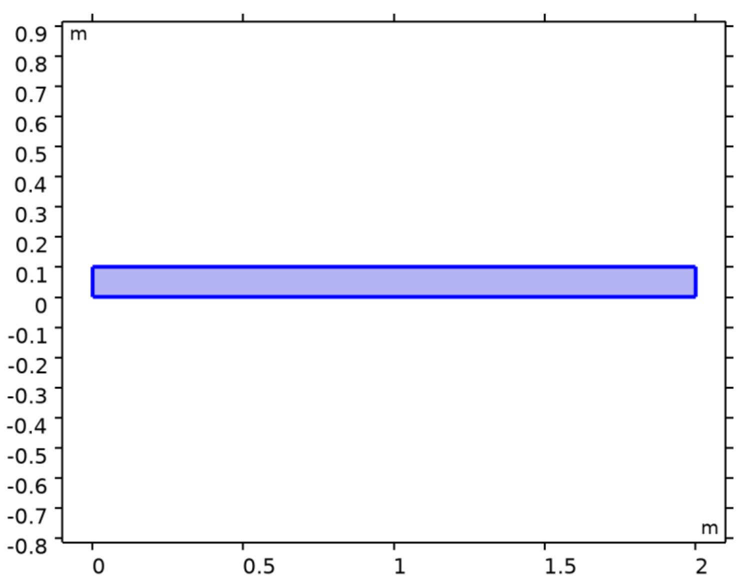
2.2.2 Form Union (fin)

INFORMATION

Description	Value
Build message	Formed union of 1 solid object. Union has 1 domain, 4 boundaries, and 4 vertices.

2.3 MATERIALS

2.3.1 Material 1



Material 1

SELECTION

Geometric entity level	Domain
Selection	Geometry geom1: Dimension 2: All domains

MATERIAL PARAMETERS

Name	Value	Unit	Property group
Speed of sound	a	m/s	Basic
Density	r	kg/m³	Basic

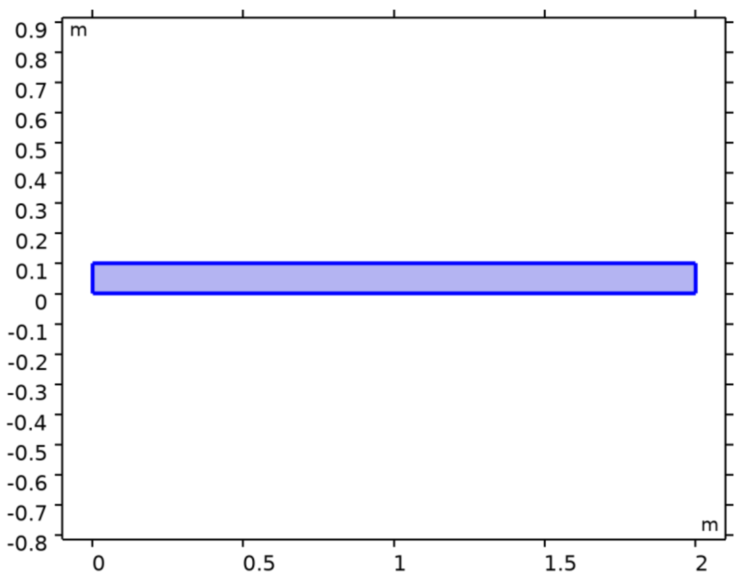
BASIC

Description	Value	Unit
Speed of sound	a	m/s
Density	r	kg/m³

2.4 PRESSURE ACOUSTICS, FREQUENCY DOMAIN

USED PRODUCTS

COMSOL Multiphysics



Pressure Acoustics, Frequency Domain

SELECTION

Geometric entity level	Domain
Selection	Geometry geom1: Dimension 2: All domains

EQUATIONS

$$\nabla \cdot \left(-\frac{1}{\rho_c}(\nabla p_t - \mathbf{q}_d)\right) - \frac{k_{eq}^2 p_t}{\rho_c} = Q_m$$
$$p_t = p + p_b$$
$$k_{eq}^2 = \left(\frac{\omega}{c_c}\right)^2 - k_z^2$$

2.4.1 Interface Settings

Physics Symbols

SETTINGS

Description	Value
Enable physics symbols	On

Discretization

SETTINGS

Description	Value
Element order	Quadratic Lagrange

Physics-Controlled Mesh

SETTINGS

Description	Value
Maximum mesh element size control parameter	From study
Number of mesh elements per wavelength	Automatic

Pressure Acoustics Equation Settings

SETTINGS

Description	Value	Unit
Out-of-plane wave number	0	rad/m

Global Port Settings

SETTINGS

Description	Value
Port sweep settings	No port sweep
Mode shape normalization	Amplitude normalization

Sound Pressure Level Settings

SETTINGS

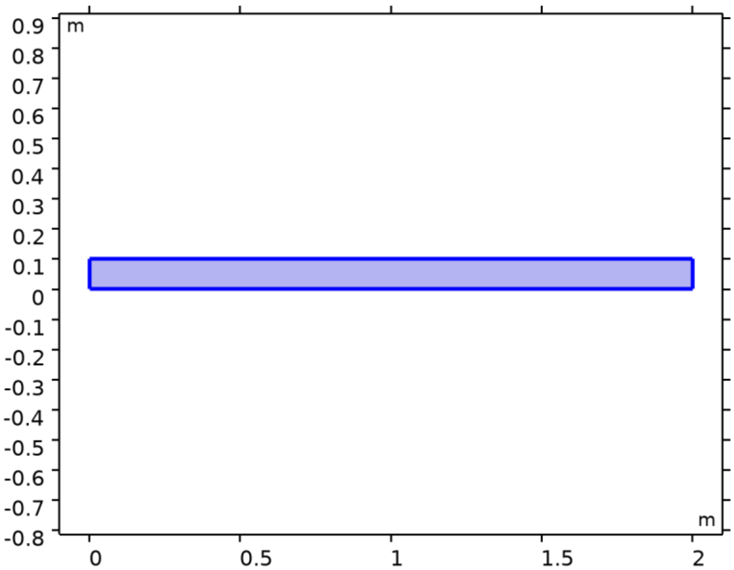
Description	Value
Reference pressure for the sound pressure level	Use reference pressure for water

Typical Wave Speed for Perfectly Matched Layers

SETTINGS

Description	Value	Unit
Typical wave speed for perfectly matched layers	real(acpr.c_c)	m/s

2.4.2 Pressure Acoustics 1



Pressure Acoustics 1

SELECTION

Geometric entity level	Domain
Selection	Geometry geom1: Dimension 2: All domains

EQUATIONS

$$\nabla\cdot\left(-\frac{1}{\rho_c}(\nabla p_t-\mathbf{q}_d)\right)-\frac{k_{eq}^2 p_t}{\rho_c}=Q_m$$

$$p_t=p+p_b$$

$$k_{eq}^2=\left(\frac{\omega}{c_c}\right)^2-k_z^2$$

$$c_c=c,\quad \rho_c=\rho$$

Pressure Acoustics Model

SETTINGS

Description	Value
Fluid model	Linear elastic
Specify	Density and speed of sound

Description	Value
Speed of sound	From material
Density	From material

Model Input

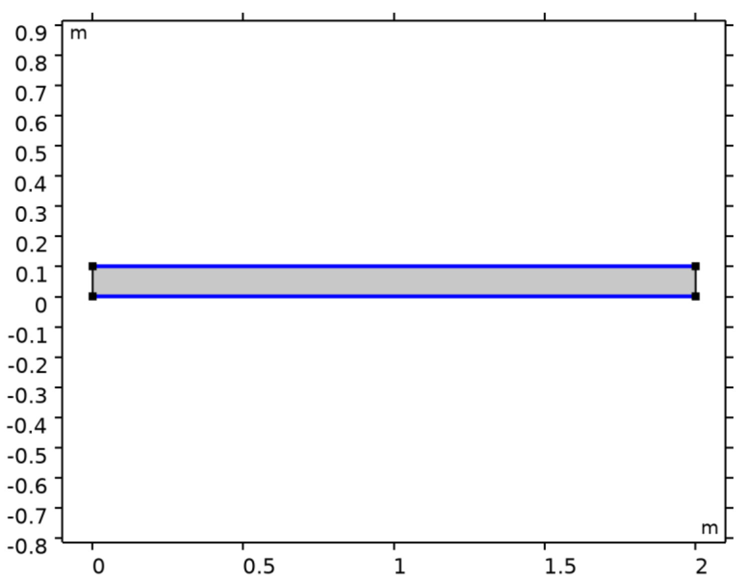
SETTINGS

Description	Value	Unit
Temperature	User defined	
Temperature	293.15	K
Absolute pressure	User defined	
Absolute pressure	1.0133E5	Pa

PROPERTIES FROM MATERIAL

Property	Material	Property group
Density	Material 1	Basic
Speed of sound	Material 1	Basic

2.4.3 Sound Hard Boundary (Wall) 1



Sound Hard Boundary (Wall) 1

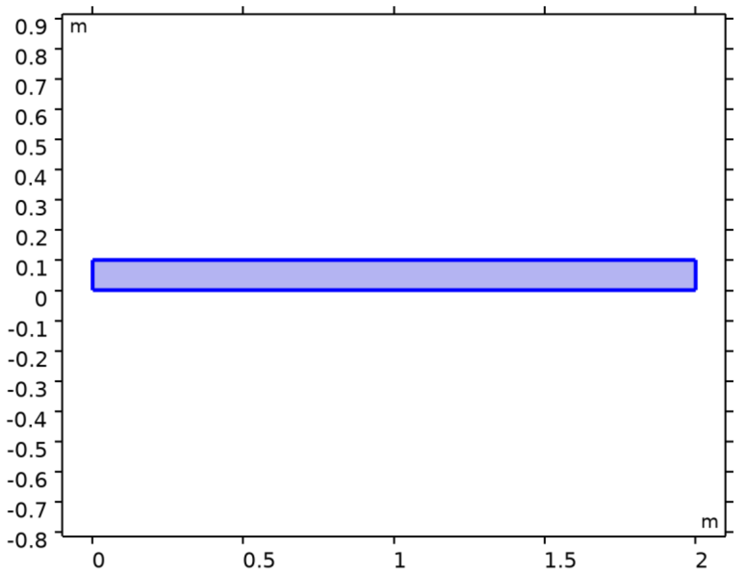
SELECTION

Geometric entity level	Boundary
Selection	Geometry geom1: Dimension 1: All boundaries

EQUATIONS

$$-\mathbf{n}\cdot\left(-\frac{1}{\rho_c}(\nabla p_t-\mathbf{q}_d)\right)=0$$

2.4.4 Initial Values 1



Initial Values 1

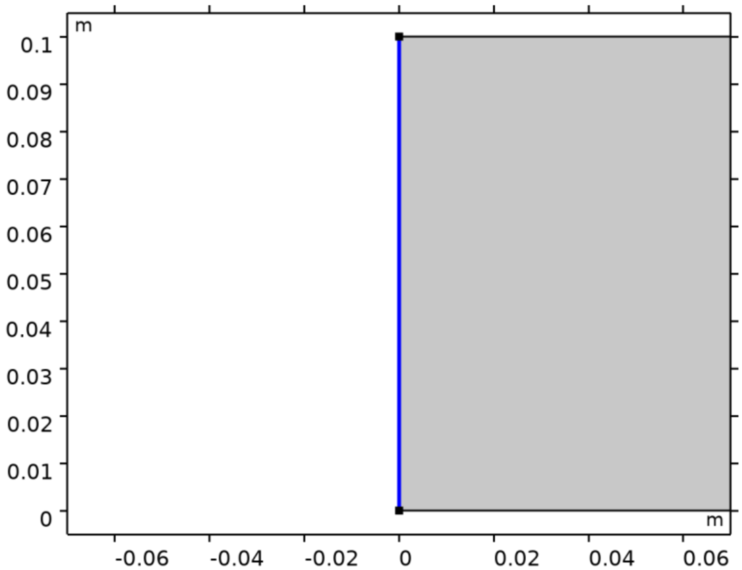
SELECTION

Geometric entity level	Domain
Selection	Geometry geom1: Dimension 2: All domains

SETTINGS

Description	**Value**	**Unit**
Acoustic pressure	0	Pa

2.4.5 Plane Wave Radiation 1



Plane Wave Radiation 1

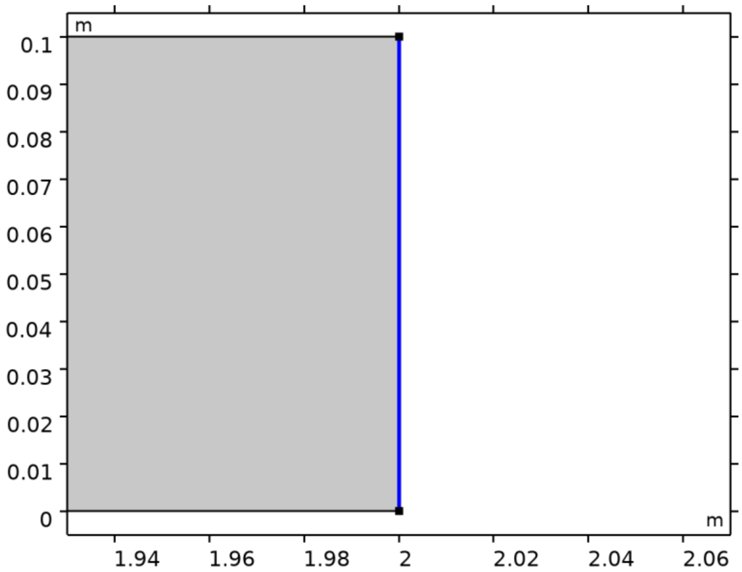
SELECTION

Geometric entity level	Boundary
Selection	Geometry geom1: Dimension 1: Boundary 1

EQUATIONS

$$-\mathbf{n}\cdot\left(-\frac{1}{\rho_{\mathrm{c}}}(\nabla p_{\mathrm{t}}-\mathbf{q}_{\mathrm{d}})\right)+i\frac{k_{\mathrm{eq}}}{\rho_{\mathrm{c}}}p+\frac{i}{2k_{\mathrm{eq}}\rho_{\mathrm{c}}}\Delta_{\parallel}p\ =Q_{\mathrm{i}}$$

2.4.6 Pressure 1



Pressure 1

SELECTION

Geometric entity level	Boundary
Selection	Geometry geom1: Dimension 1: Boundary 4

EQUATIONS

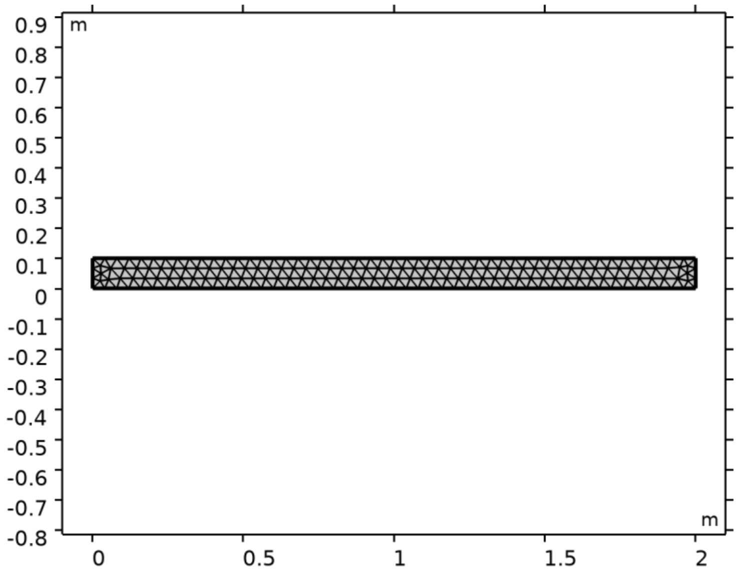
$$p_t = p_0$$

Pressure

SETTINGS

Description	Value	Unit
Pressure	pin	Pa

2.5 MESH 1



Mesh 1

2.5.1 Size (size)

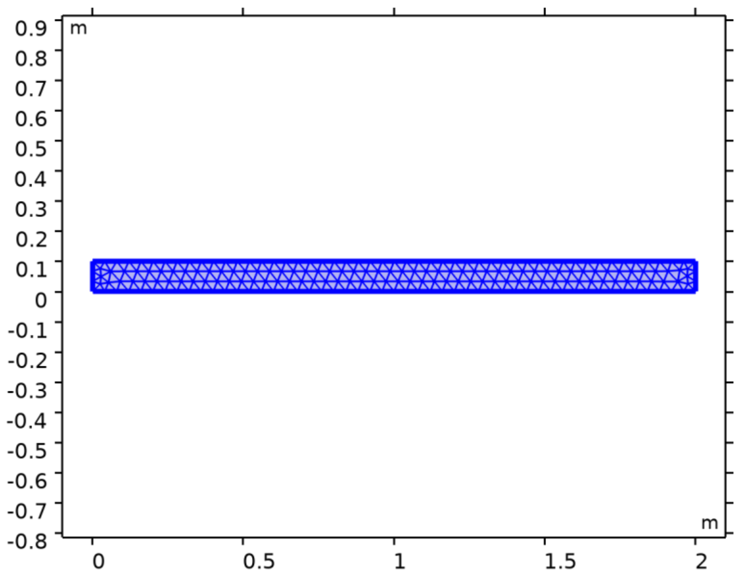
SETTINGS

Description	Value
Maximum element size	0.04
Minimum element size	2E-5
Curvature factor	0.25
Maximum element growth rate	1.2
Predefined size	Extra fine
Custom element size	Custom

2.5.2 Size Expression 1 (se1)

SELECTION

Geometric entity level	Domain
Selection	Geometry geom1: Dimension 2: Domain 1



Size Expression 1

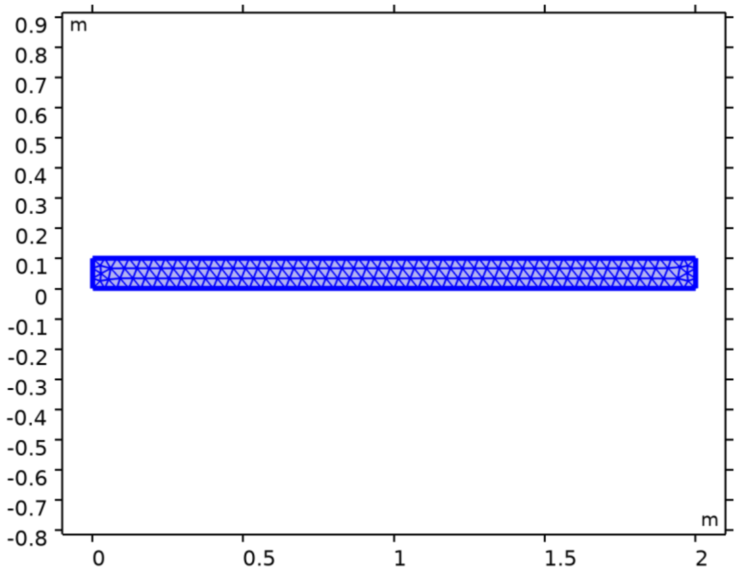
SETTINGS

Description	Value
Evaluate on	Initial expression
Study step	Study 1: Frequency Domain
Size expression	subst(real(acpr.c_c), acpr.freq, freqmax)/freqmax/5
Reevaluate with updated model	

2.5.3 Free Triangular 1 (ftri1)

SELECTION

Geometric entity level	Domain
Selection	Remaining



Free Triangular 1

SETTINGS

Description	Value
Number of iterations	4
Maximum element depth to process	4

INFORMATION

Description	Value
Last build time	< 1 second
Built with	COMSOL 6.3.0.420 (win64), Oct 5, 2025, 9:46:09 PM

3 Study 1

COMPUTATION INFORMATION

Computation time	0 s

3.1 FREQUENCY DOMAIN

Frequencies (Hz)
f

STUDY SETTINGS

Description	Value
Include geometric nonlinearity	Off

SETTINGS

Description	Value
Frequencies	1250

PHYSICS AND VARIABLES SELECTION

Key	Solve for
Pressure Acoustics, Frequency Domain (acpr)	On

STORE IN OUTPUT

Interface	Output	Selection
Pressure Acoustics, Frequency Domain (acpr)	Physics controlled	

MESH SELECTION

Component	Mesh
Component 1	Mesh 1

3.2 SOLVER CONFIGURATIONS

3.2.1 Solution 1

Compile Equations: Frequency Domain (st1)

STUDY AND STEP

Description	Value
Use study	Study 1
Use study step	Frequency Domain

Dependent Variables 1 (v1)

GENERAL

Description	Value
Defined by study step	Step 1: Frequency Domain

INITIAL VALUE CALCULATION CONSTANTS

Constant name	Initial-value source
freq	f

Acoustic Pressure (comp1.p) (comp1_p)

GENERAL

Description	Value
Field components	comp1.p

Stationary Solver 1 (s1)

GENERAL

Description	Value
Defined by study step	Step 1: Frequency Domain

RESULTS WHILE SOLVING

Description	Value
Probes	None

Advanced (aDef)

ASSEMBLY SETTINGS

Description	Value
Reuse sparsity pattern	On
Allow complex-valued output from functions with real input	On

Parametric 1 (p1)

GENERAL

Description	Value
Defined by study step	Step 1: Frequency Domain
Run continuation for	No parameter

PARAMETERS

Parameter name	Parameter value list	Parameter unit
freq	f	Hz

Fully Coupled 1 (fc1)

GENERAL

Description	Value

Description	Value
Linear solver	Direct

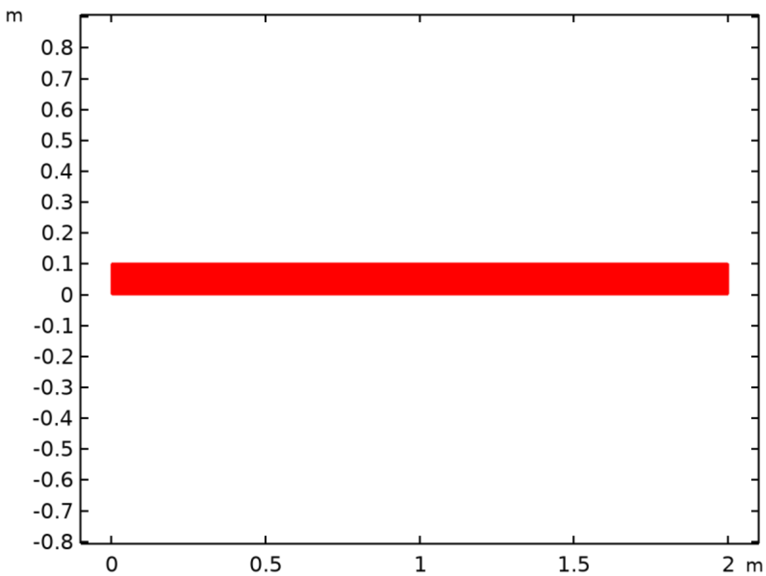
4 Results

4.1 DATASETS

4.1.1 Study 1/Solution 1

SOLUTION

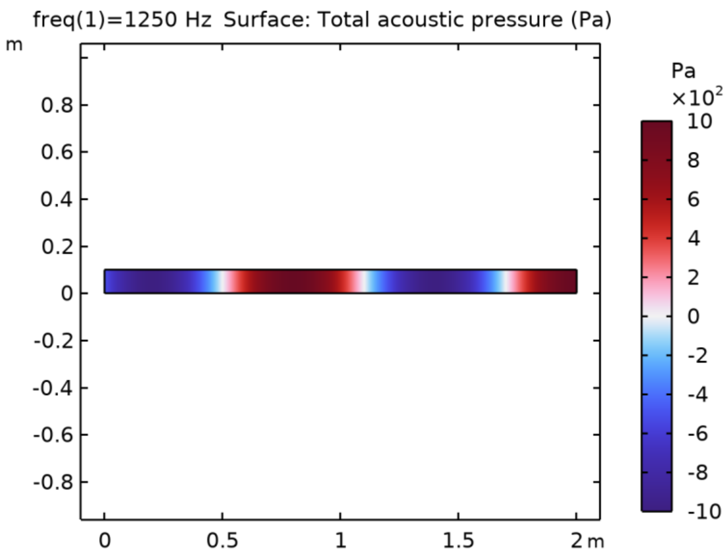
Description	Value
Solution	Solution 1 (sol1)
Component	Component 1 (comp1)



Dataset: Study 1/Solution 1

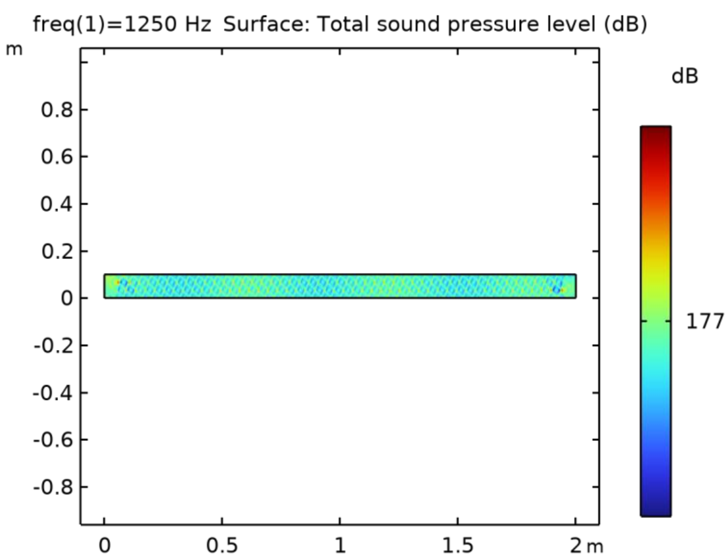
4.2 PLOT GROUPS

4.2.1 Acoustic Pressure (acpr)



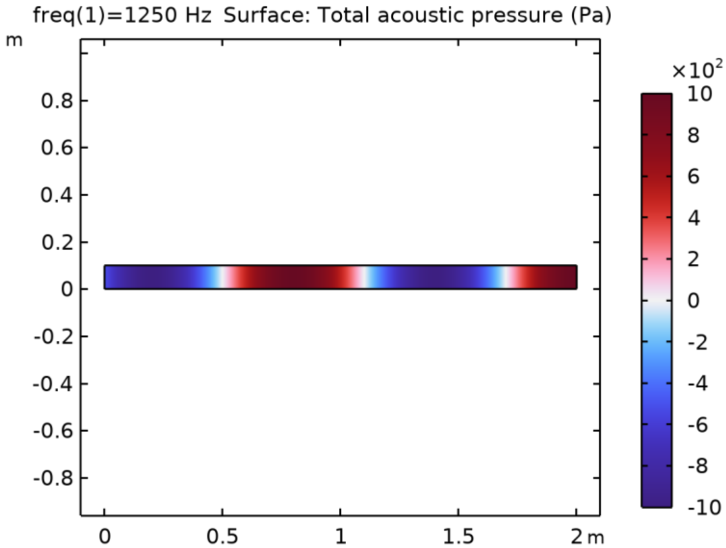
Surface: Total acoustic pressure (Pa)

4.2.2 Sound Pressure Level (acpr)



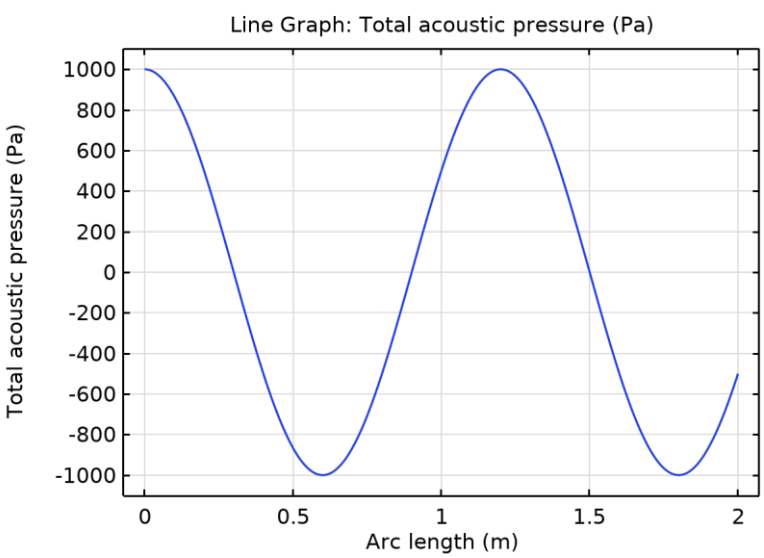
Surface: Total sound pressure level (dB)

4.2.3 ai



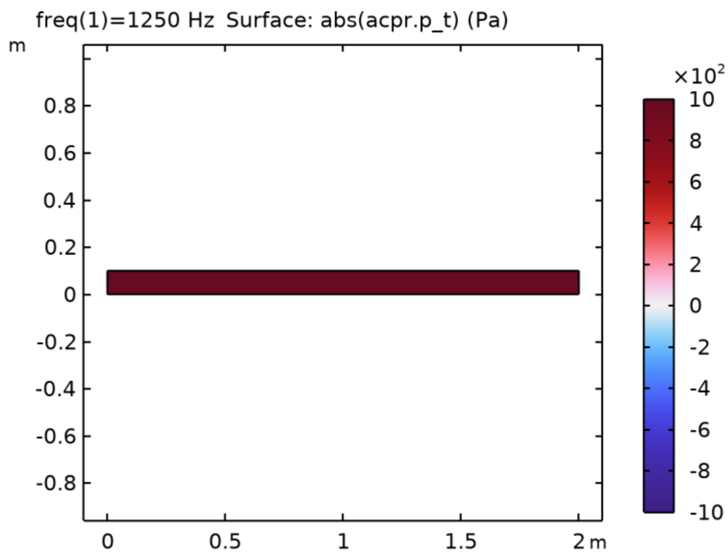
Surface: Total acoustic pressure (Pa)

4.2.4 1D Plot Group 4



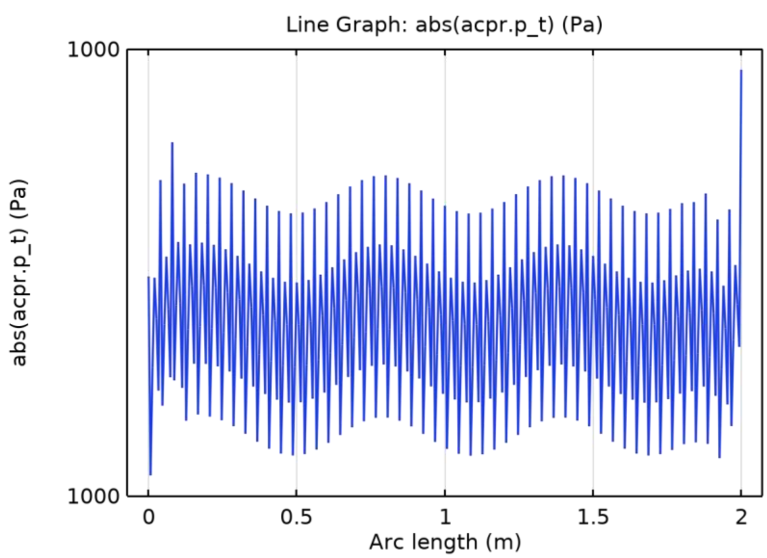
Line Graph: Total acoustic pressure (Pa)

4.2.5 2D Plot Group 5



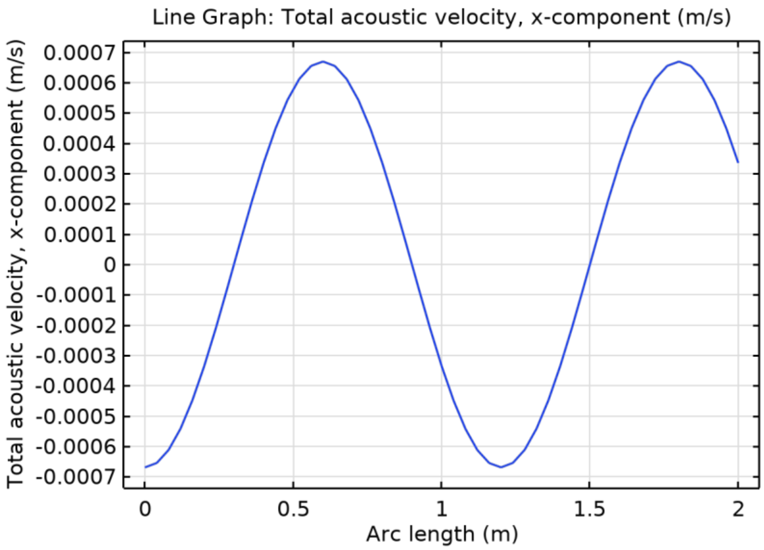
Surface: abs(acpr.p_t) (Pa)

4.2.6 1D Plot Group 6



Line Graph: abs(acpr.p_t) (Pa)

4.2.7 1D Plot Group 7



Line Graph: Total acoustic velocity, x-component (m/s)