Developing a Resource for Determining Ideal Soundport Size

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Our team explored two different approaches to finding the ideal size of a guitar's sound port. Our initial approach was to pursue physical testing by recording how a guitar sounded when the hole was covered with various amounts of tape. We later switched gears to focus more on computer simulations as we felt this data would be easier to manage and the work could be transferred to another team more easily by passing on the simulation we created.

Physical Testing

For physical testing, we looked at the physical frequency response of an acoustic guitar as we closed the sound port as well as the relative volume at different points around the body of the guitar as the size of the sound port changed. We looked at this using quantitative decibels as well as the qualitative timbre.

For these tests we used a ¾ guitar and repeated the same 2 minute sequence with different amounts of the soundport being covered each time. To record the sound, we used an Array of Shure SM57s and an EarthWorks m23 microphones. The SM57s were placed around the guitar at the neck, port, bottom of the body, and side of the body. Gaff tape was used to cover the soundport. Our first recording used no tape, then in each subsequent recording 25% more of the soundhole was covered.

While one team member played the guitar sequence, we used Audacity and a Midas M32R as an audio interface to record the audio into wav files. We then individually analyzed the audio tracks using Max MSP, Excel, and R to get quantitative data about how the guitar performed. We used Max MSP for audio filtering and metering to convert the audio data into a CSV that gives a raw read out of the median volume of various frequencies when the volume was above a certain threshold every 10ms. Then we used Excel to organize all this data into averages for each sound port size grouped by mic type then we created graphs to help us visualize the data.

Our observations found that as we closed up the sound port on the guitar the instrument got quieter overall. We also found that the timbre of the acoustic guitar noticeably changes as coverage increases, with the lower frequencies becoming more prominent. At 100% coverage, the timbre of the acoustic guitar sounds similar to an unplugged solid body electric guitar.

	10 hz	50 hz	100 hz	500 hz	1000 hz	5000 hz
open	N/A	-2.89872 db	0.673718 db	2.443509 db	-0.35645 db	0.137947 db
¼ closed	N/A	N/A	-1.40054 db	1.816717 db	-0.74822 db	0.332038 db
½ closed	N/A	N/A	-1.32805 db =	2.353587 db	-1.36769 db	0.342157 db
¾ closed	N/A	N/A	0.322701 db	1.034792 db	-1.45372 db	0.096228 db
closed	N/A	N/A	N/A	0.876421 db	-1.59425 db	0.717831 db

Figure: chart of differences from the average volume based on frequency and Port Size based on the port microphone.

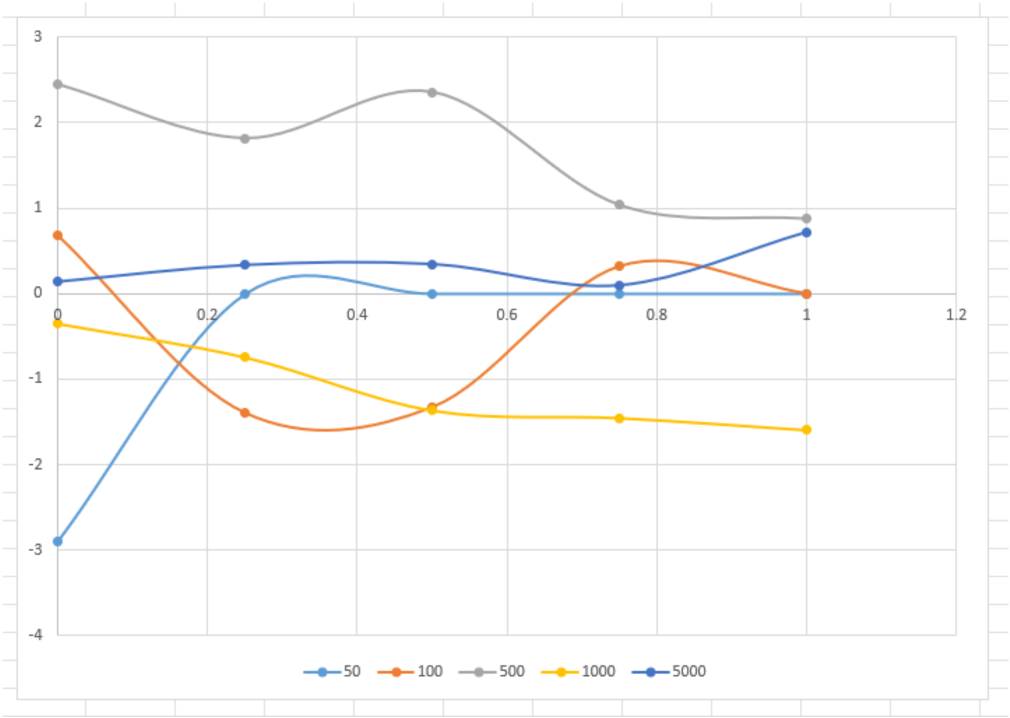
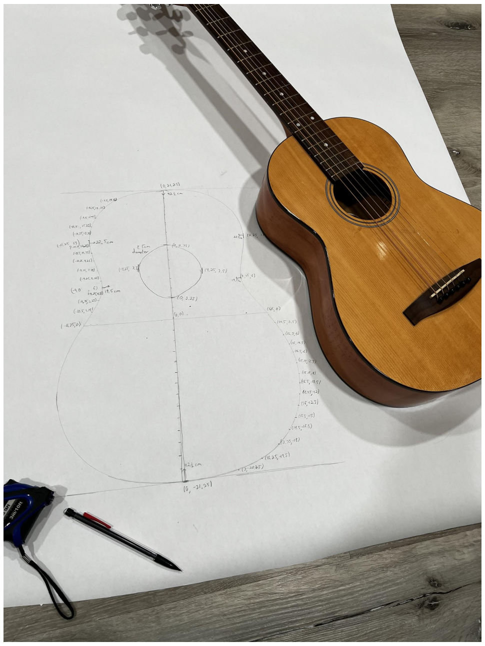


Figure 3: graph of table above.

Through our analysis tools we found that the lower frequencies of a guitar come from the body of the guitar. We also found that lower frequencies tend to be quieter then higher frequencies

In Future iterations of this experiment one factor to consider changing would be the size of the guitar. This experiment was done with a ¾ guitar and it would be interesting to see if the results of this experiment hold or change if you were to use a full size guitar or a ½ size guitar. Another area to consider changing up is by physically changing the location of the sound port. This is something we were not able to do since cutting up a guitar with a router or sawzall and still having it work is outside our area of expertise. Finally changing the analysis parameters on Max audio tool may be beneficial to find better results at lower volumes and also making the max patch less spaghetti.

Computer Simulations



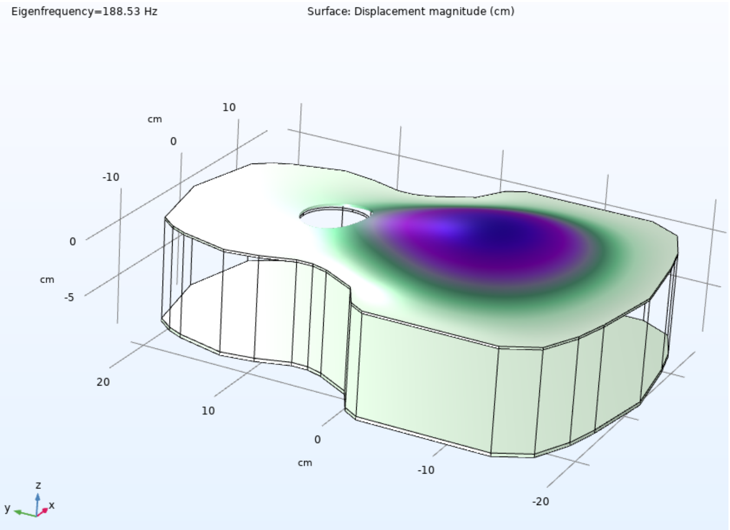
We created a simulation of a guitar body to get a better understanding of the resonance at different frequencies and how it is affected by changing the size of the soundport. We then ran calculations in the simulation software to obtain the eigenfrequencies for the guitar body for each soundport size and created a visual representation of this data. This simulation was developed based on an existing similar COMSOL simulation that modeled the resonance and airflow of a violin, which is linked below in the references section.

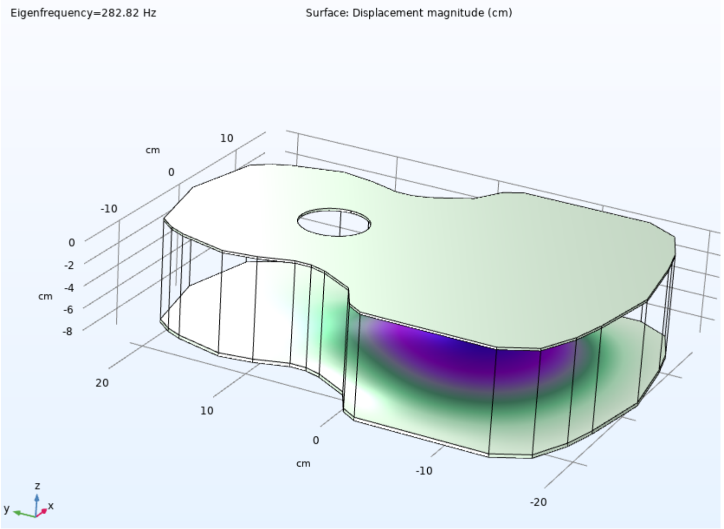
To make the geometry of the guitar body, we used a group member's ¾ length guitar and traced it onto a large sheet of poster paper. Then, a coordinate system was created with the origin being placed in the center of the face of the guitar. For each 1.5 cm down the length of the guitar, a new measurement was taken from the middle line to the edge of the guitar's face, creating a new set of coordinates. The diameter of the soundhole was measured and recorded as 8.5 cm, making the radius 4.25 cm. Measurements were also taken to find the exact location of the sound port on the coordinate system and the distance between the back and front faces of the guitar. This data was used to create the shape of the guitar body in our simulation which was created in COMSOL. We chose to set our simulation's material as mahogany wood since it is one of the most common materials for acoustic guitars. We ran three studies in COMSOL on the initial guitar body simulation including surface displacement, acoustic pressure, and sound pressure level. Then, we ran these studies again when the radius of the sound hole was approximately 50% larger (6.3 cm) and approximately 50% smaller (3.1 cm).

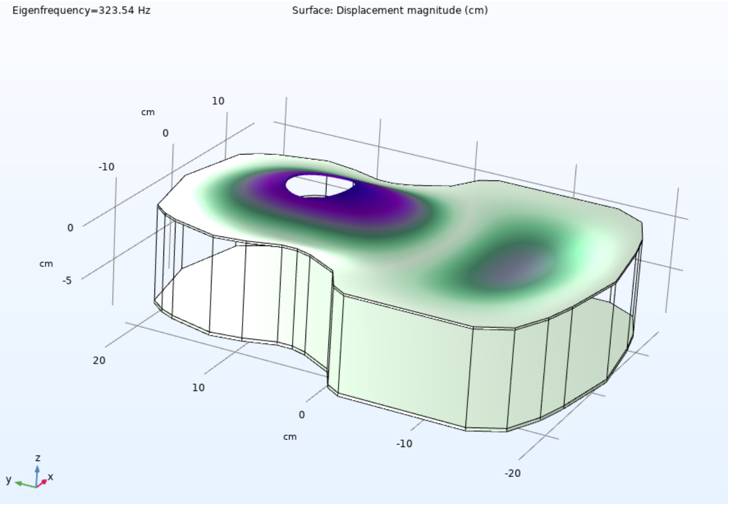
The data we discovered from conducting these studies can be found in the images below. Some key trends to note are that, as the area of the port increased the intensity of the guitar's physical deformation decreased but the area which was being displaced increased. Additionally, as the soundport's radius decreased, the sound pressure level became more concentrated around the port whereas with a large soundport, the sound pressure would radiate more equally around the body.

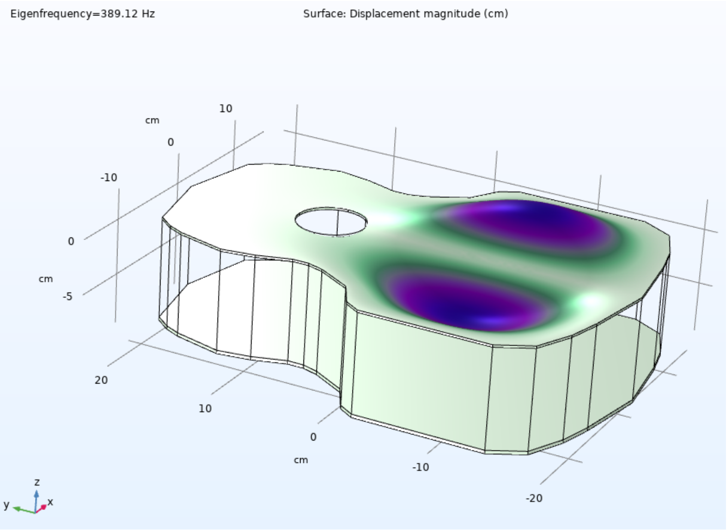
In future iterations of this project, a deeper analysis of the studies produced from our simulations could be performed to draw some conclusions from the data. More studies could also be conducted from the same guitar geometry with different sizes of the radius. Additionally, a more complex simulation of the guitar body that includes the wooden supports inside of the guitar could be created. The guitar we used was ¾ size of a typical guitar so another simulation could be created with geometry that is closer to a typical guitar as well. Finally, a simulation could be created with a different shape or placement of the sound hole.

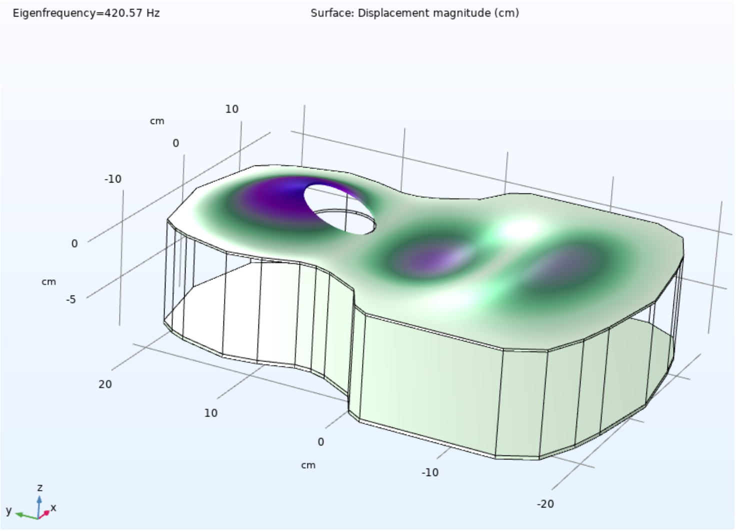
COMSOL data
Soundport radius = 31.5 mm

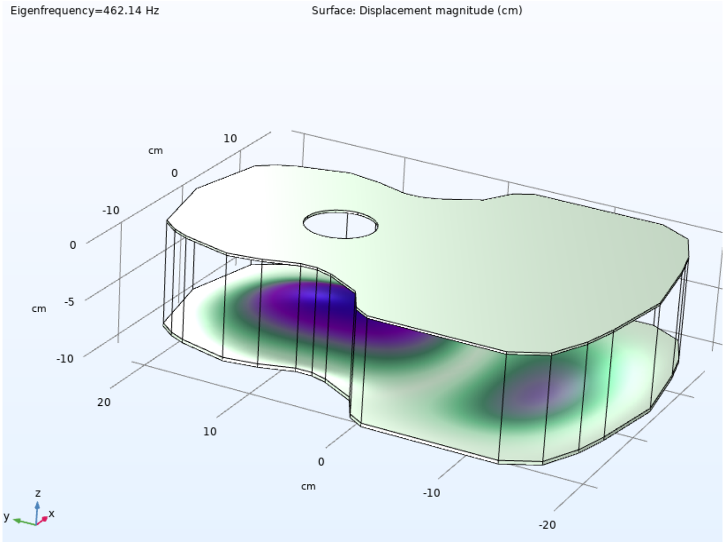




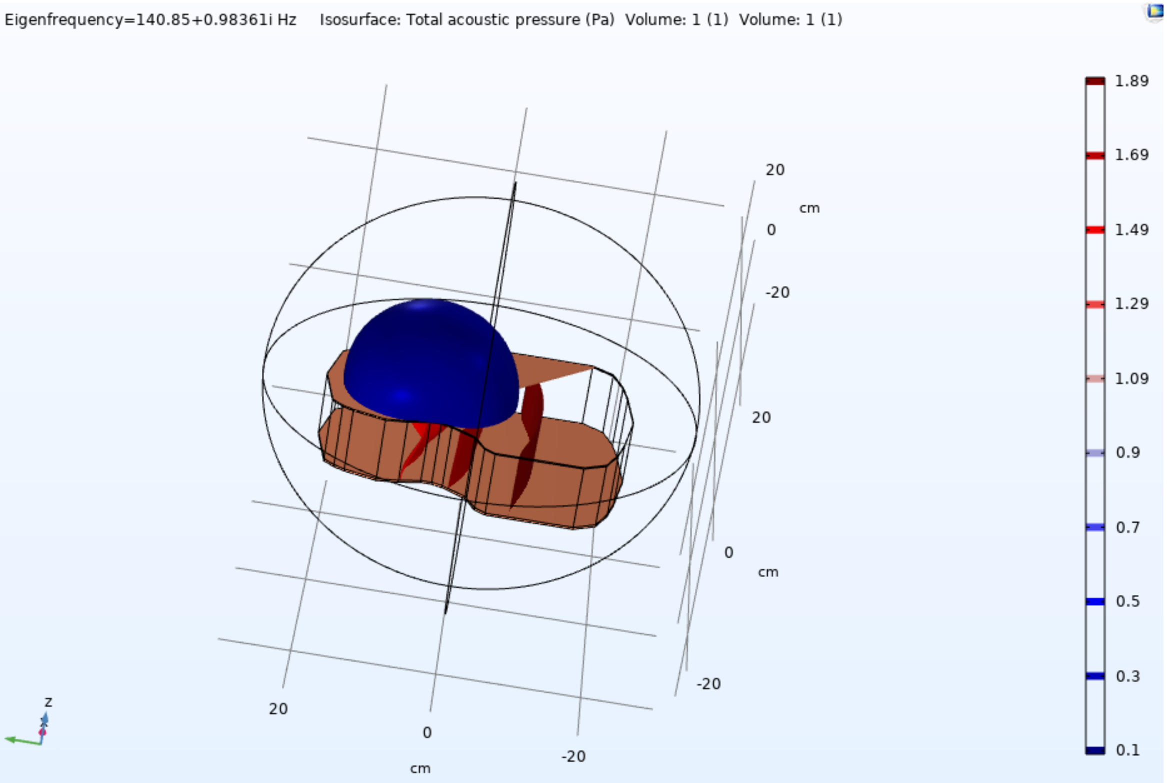


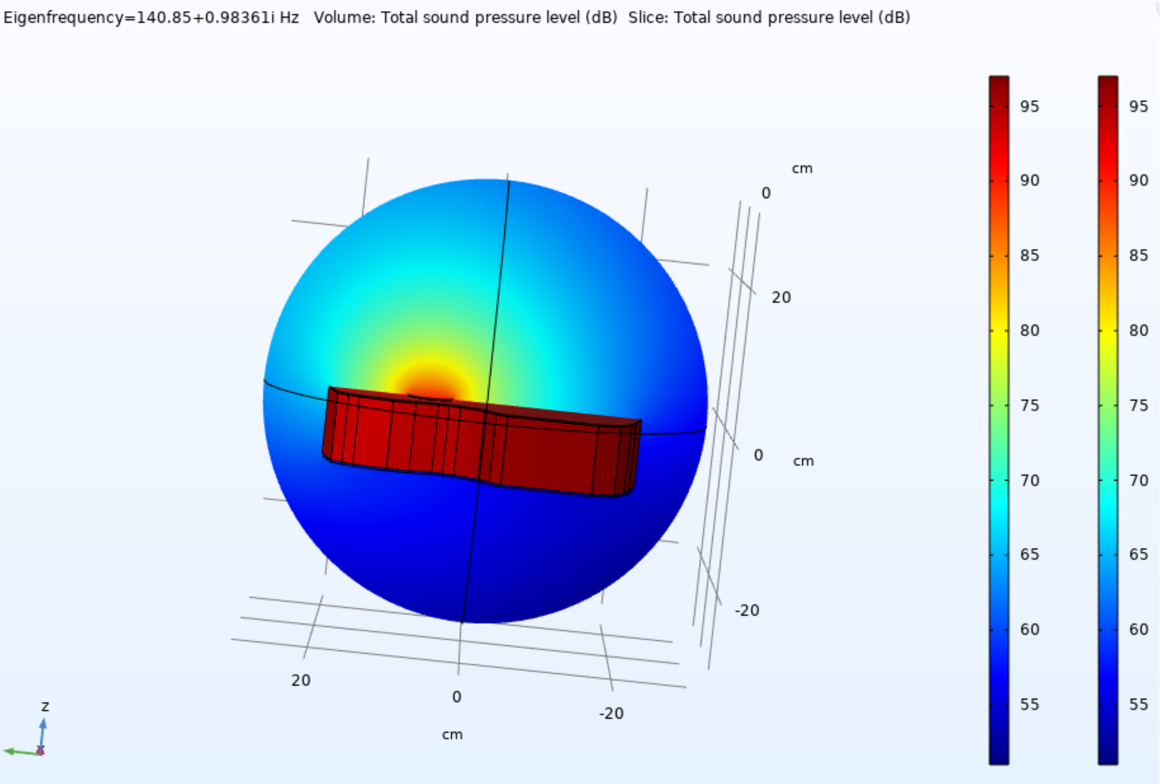




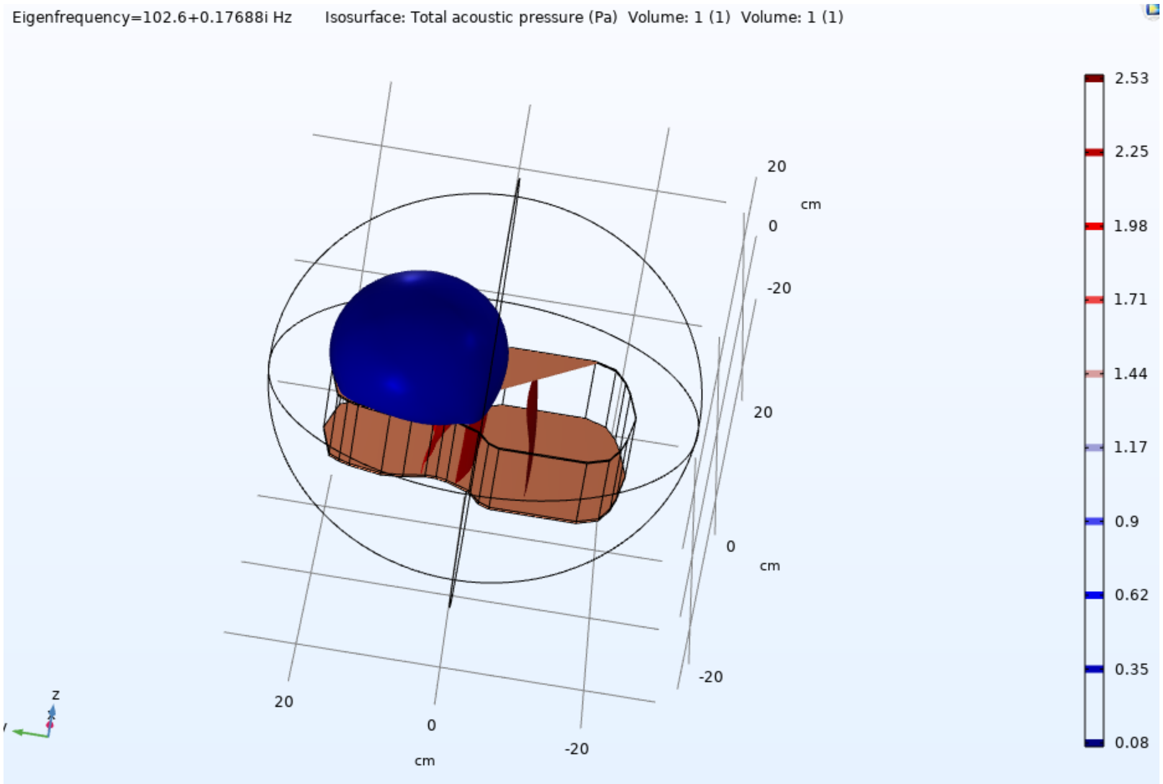


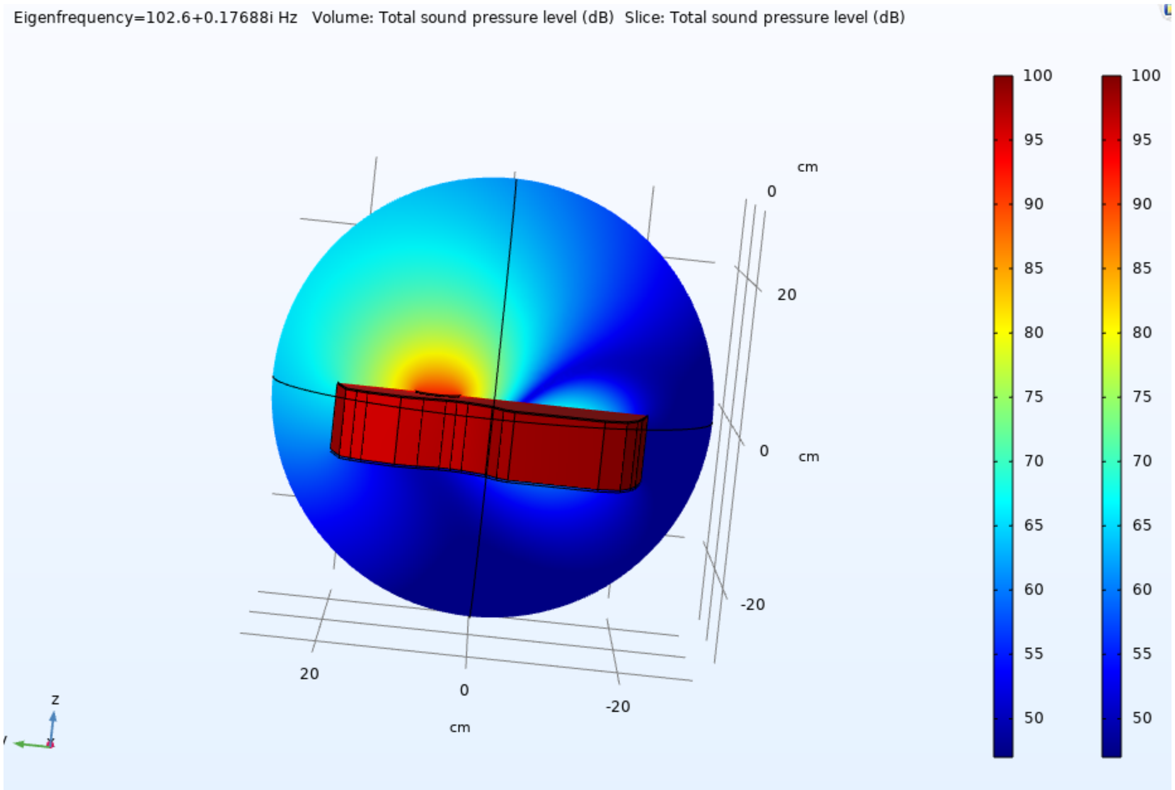
Study 2


Eigenfrequency=140.85+0.98361i Hz   Isosurface: Total acoustic pressure (Pa) Volume: 1 (1) Volume: 1 (1)
1.89
1.69
1.49
1.29
1.09
0.9
0.7
0.5
0.3
0.1
20
cm
0
-20
20
0
cm
-20
20
0
-20
cm
z

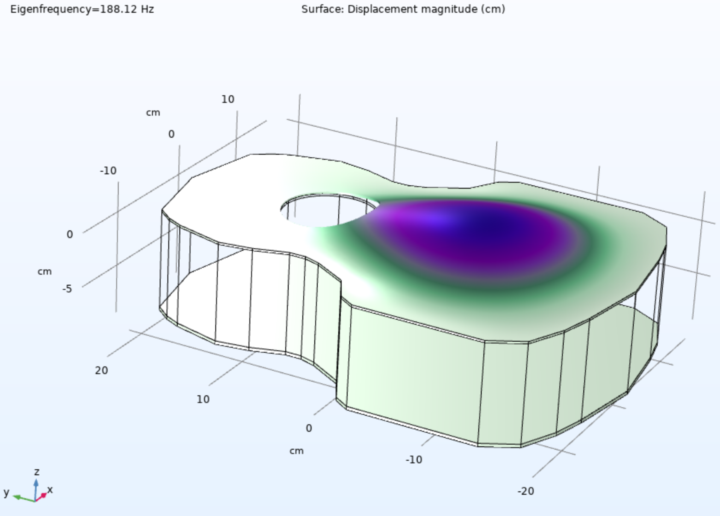

Eigenfrequency=140.85+0.98361i Hz   Volume: Total sound pressure level (dB) Slice: Total sound pressure level (dB)
95
90
85
80
75
70
65
60
55
95
90
85
80
75
70
65
60
55
cm
0
20
0
cm
-20
20
0
-20
cm
z

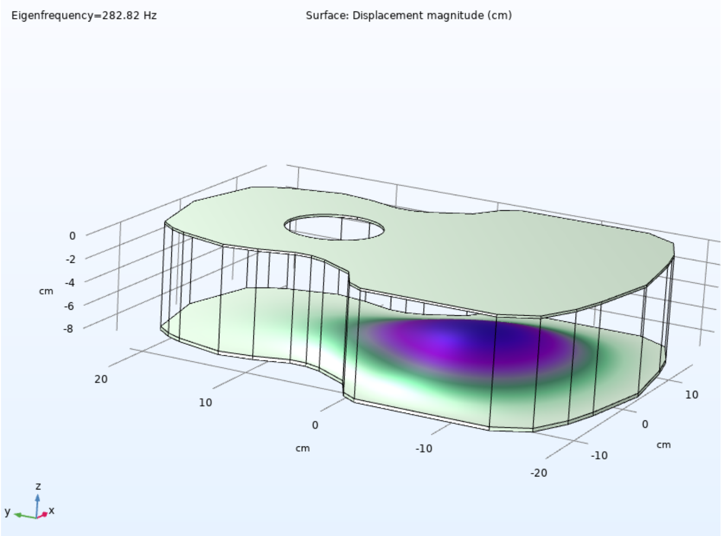
Study 3

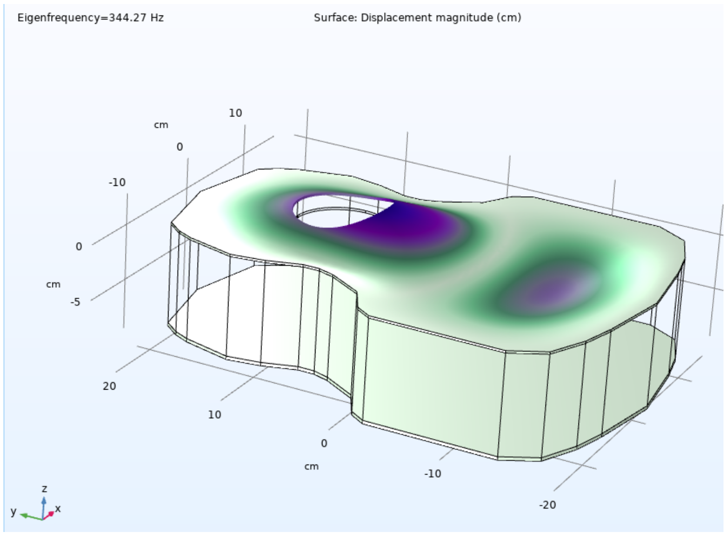

Eigenfrequency=102.6+0.17688i Hz
Isosurface: Total acoustic pressure (Pa) Volume: 1 (1) Volume: 1 (1)
2.53
2.25
1.98
1.71
1.44
1.17
0.9
0.62
0.35
0.08
20
cm
0
-20
20
0
cm
-20
20
0
-20
cm
z


Eigenfrequency=102.6+0.17688i Hz Volume: Total sound pressure level (dB) Slice: Total sound pressure level (dB)
100
95
90
85
80
75
70
65
60
55
50
100
95
90
85
80
75
70
65
60
55
50
cm
0
20
0
cm
-20
20
0
-20
cm
z

42.5mm


Eigenfrequency=188.12 Hz
Surface: Displacement magnitude (cm)
10
cm
0
-10
0
cm
-5
20
10
0
cm
-10
-20
y
z
x


Eigenfrequency=282.82 Hz
Surface: Displacement magnitude (cm)
0
-2
-4
cm
-6
-8
20
10
0
cm
-10
-20
10
0
-10
cm
z
y
x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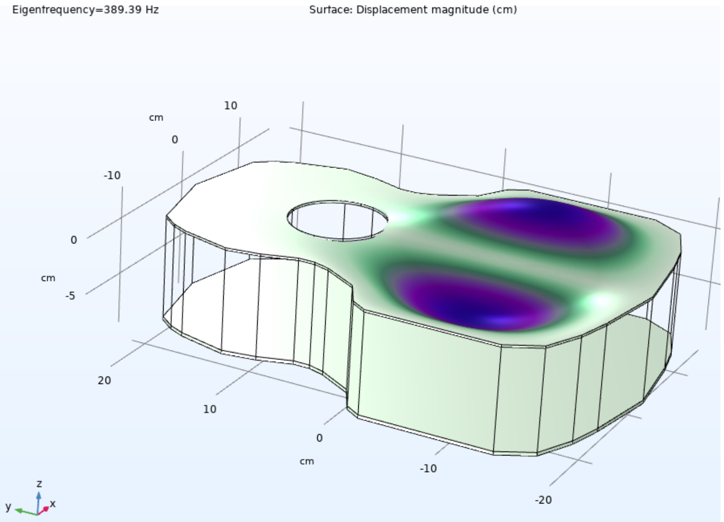
10
cm
0
-10
0
cm
-5
20
10
0
cm
-10
-20
z
y
x


Eigenfrequency=389.39 Hz
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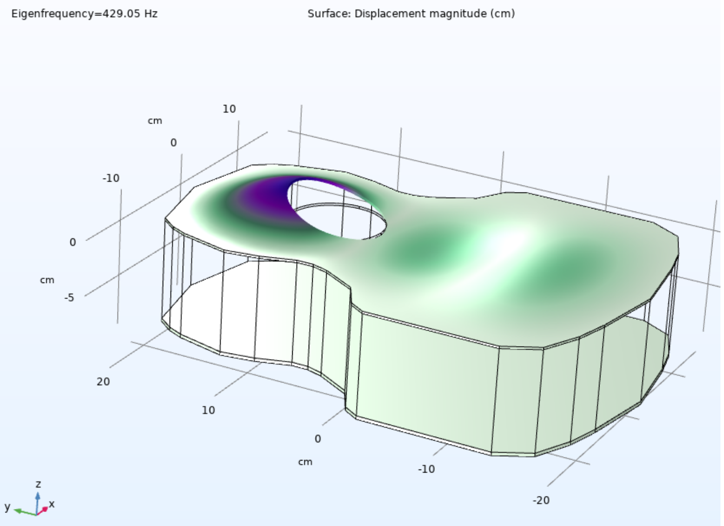
10
cm
0
-10
0
cm
-5
20
10
0
cm
-10
-20
z
y
x


Eigenfrequency=429.05 Hz
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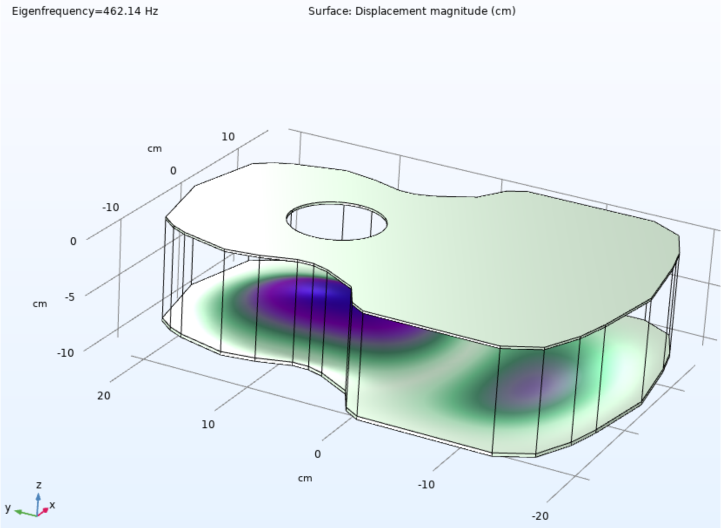
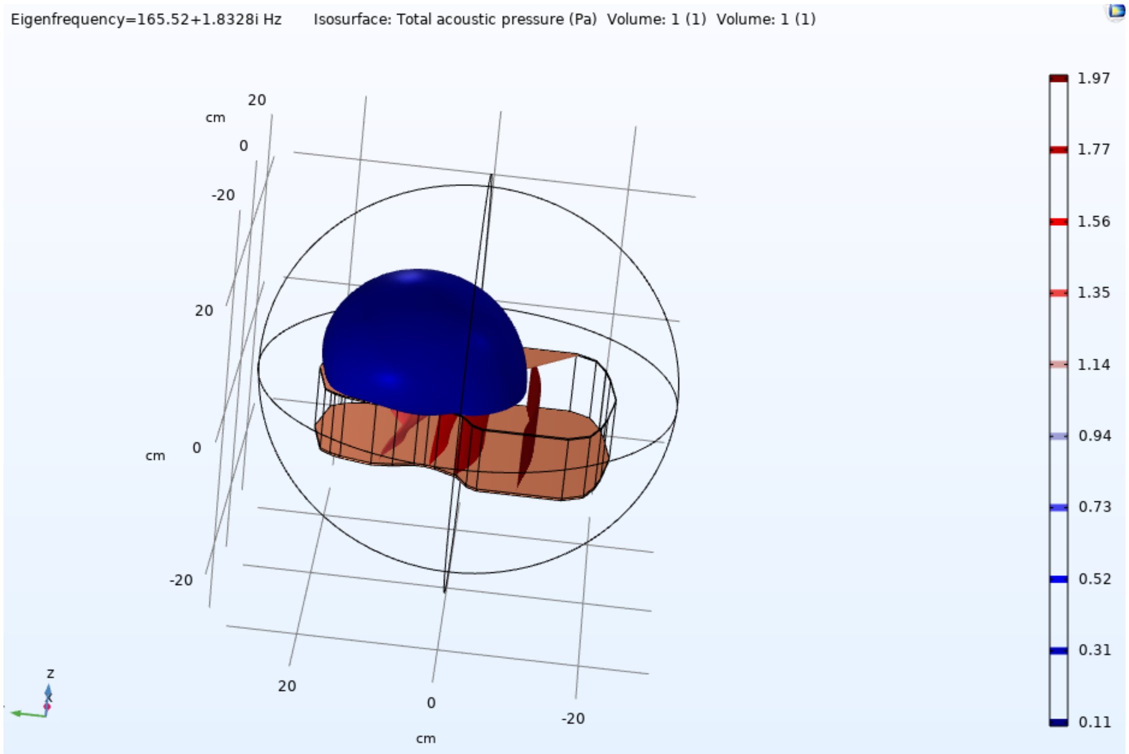
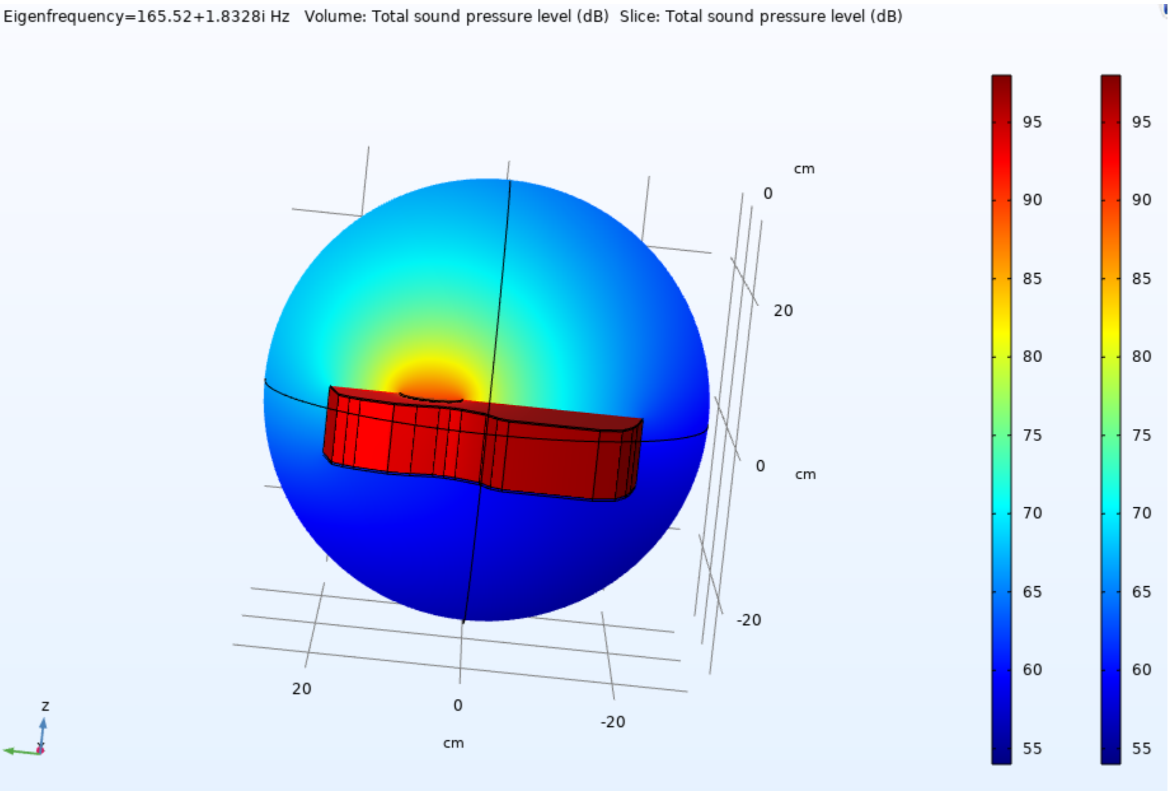
10
cm
0
-10
0
cm
-5
20
10
0
cm
-10
-20
z
y
x


Eigenfrequency=462.14 Hz
Surface: Displacement magnitude (cm)
10
cm
0
-10
0
cm
-5
-10
20
10
0
cm
-10
-20
z
y
x

Study 2

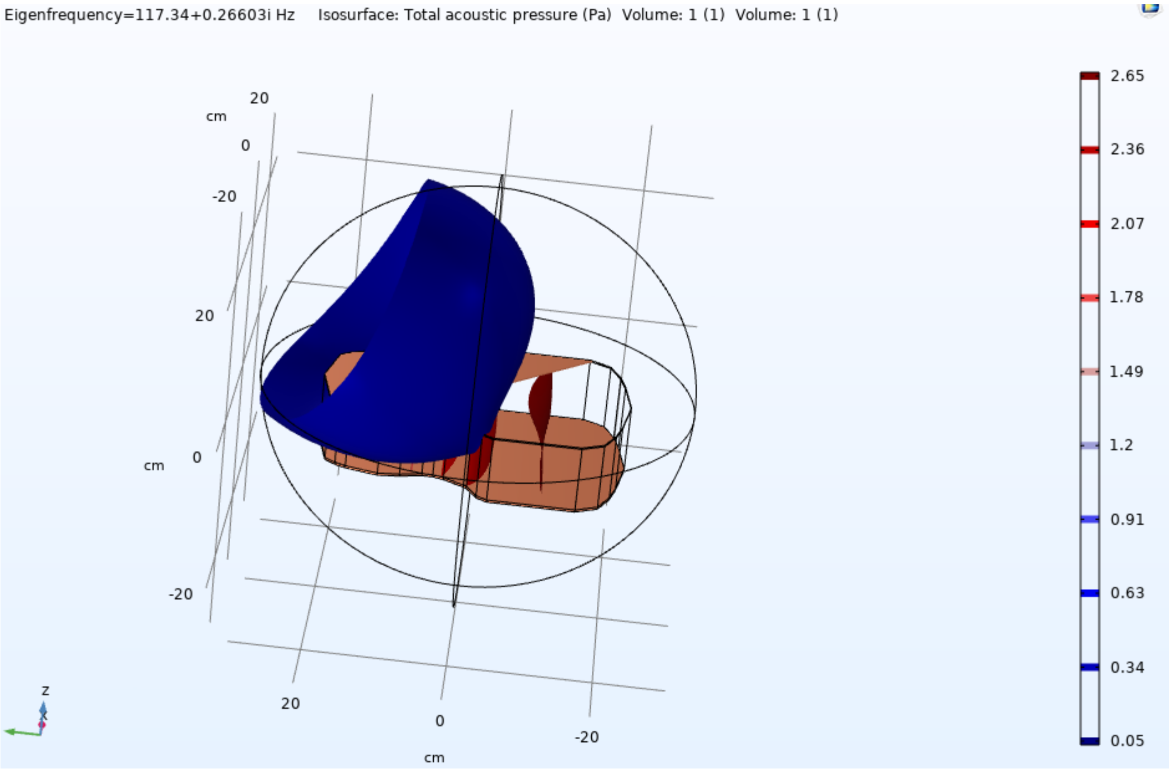


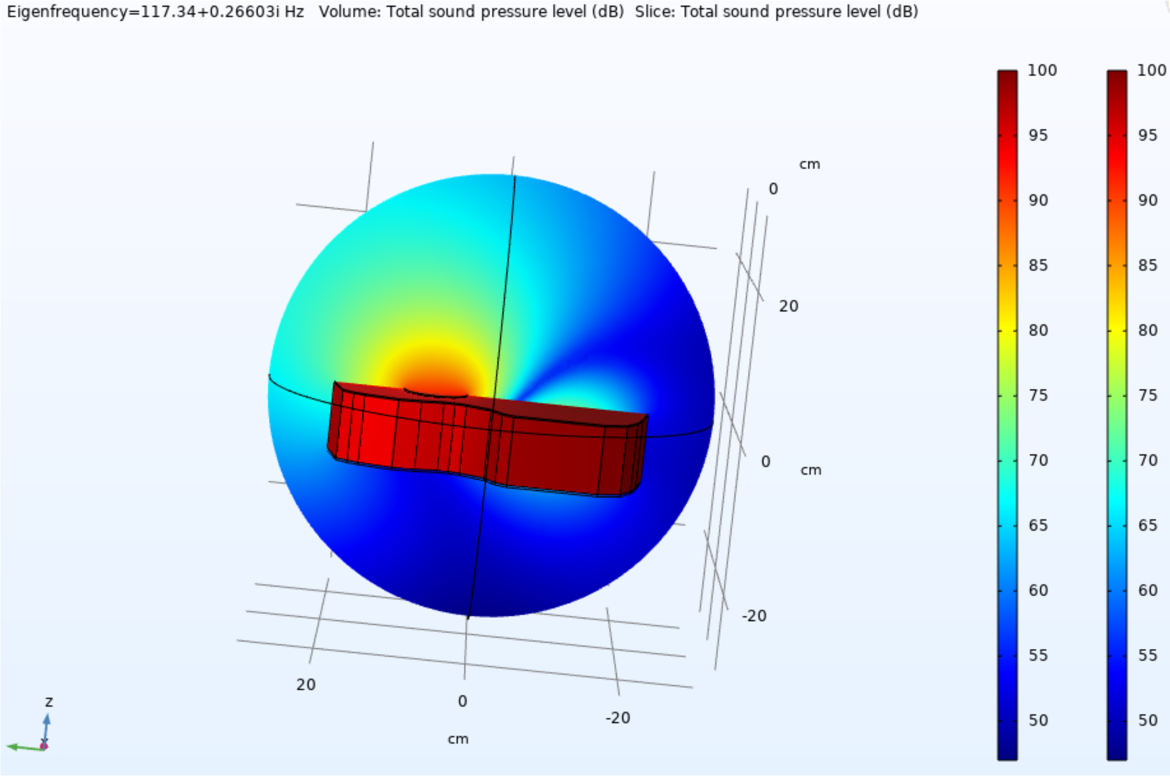
Eigenfrequency=165.52+1.8328i Hz
Isosurface: Total acoustic pressure (Pa) Volume: 1 (1) Volume: 1 (1)
1.97
1.77
1.56
1.35
1.14
0.94
0.73
0.52
0.31
0.11
20
cm
0
-20
20
0
cm
-20
20
0
-20
cm
z



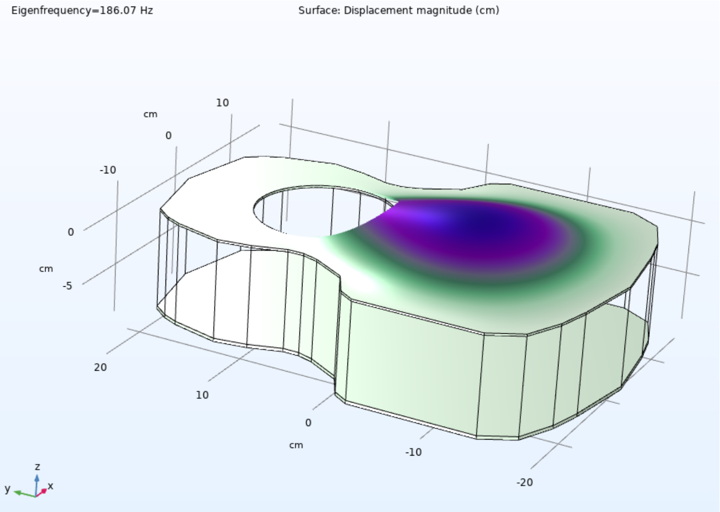
Eigenfrequency=165.52+1.8328i Hz Volume: Total sound pressure level (dB) Slice: Total sound pressure level (dB)
95
90
85
80
75
70
65
60
55
95
90
85
80
75
70
65
60
55
cm
0
20
0
cm
-20
20
0
-20
cm
z

Study 3


Eigenfrequency=117.34+0.26603i Hz Isosurface: Total acoustic pressure (Pa) Volume: 1 (1) Volume: 1 (1)
2.65
2.36
2.07
1.78
1.49
1.2
0.91
0.63
0.34
0.05
20
cm
0
-20
20
0
cm
-20
20
0
-20
cm
z
x


Eigenfrequency=117.34+0.26603i Hz Volume: Total sound pressure level (dB) Slice: Total sound pressure level (dB)
100
95
90
85
80
75
70
65
60
55
50
100
95
90
85
80
75
70
65
60
55
50
cm
0
20
0
cm
-20
20
0
-20
cm
z
x

63mm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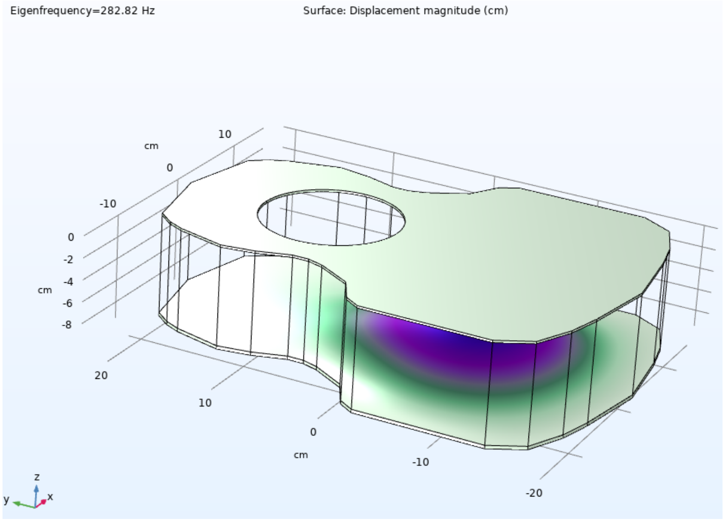
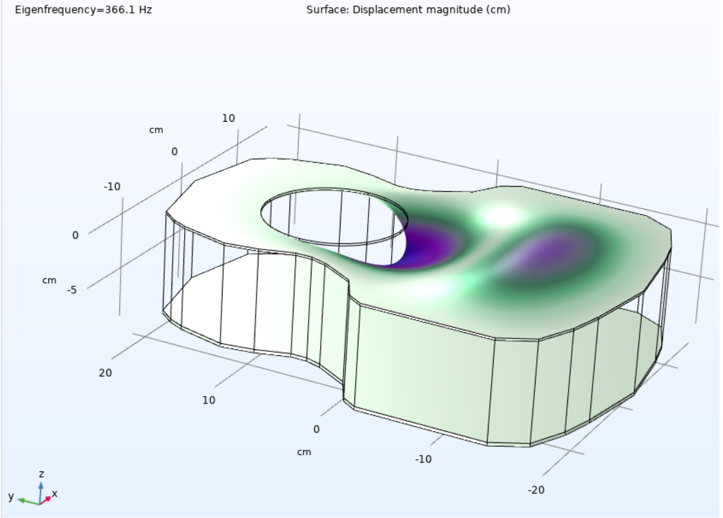
Surface: Displacement magnitude (cm)
cm
10
0
-10
0
cm
-5
20
10
0
cm
-10
-20
z
y
x


Eigenfrequency=282.82 Hz
Surface: Displacement magnitude (cm)
cm
10
0
-10
0
-2
-4
cm
-6
-8
20
10
0
cm
-10
-20
z
y
x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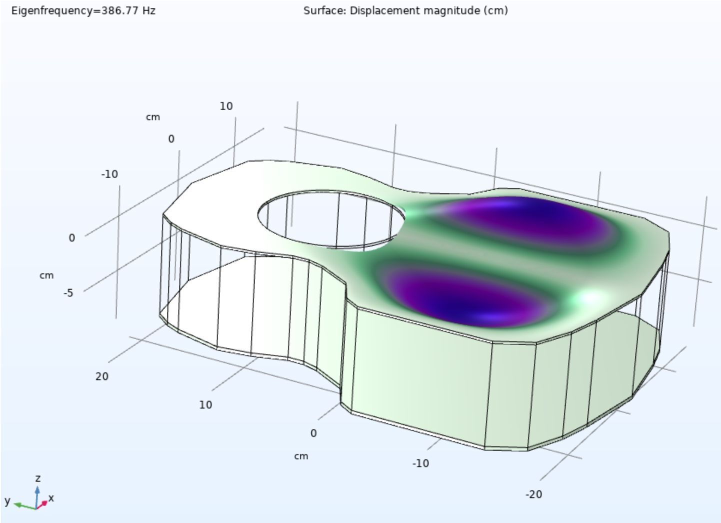
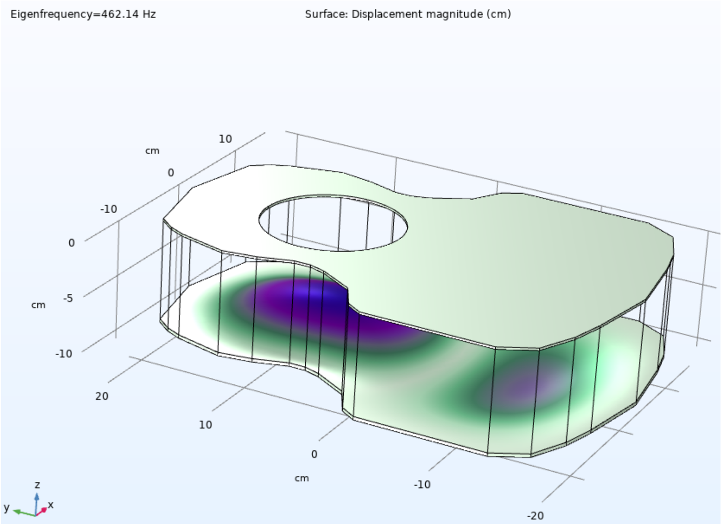
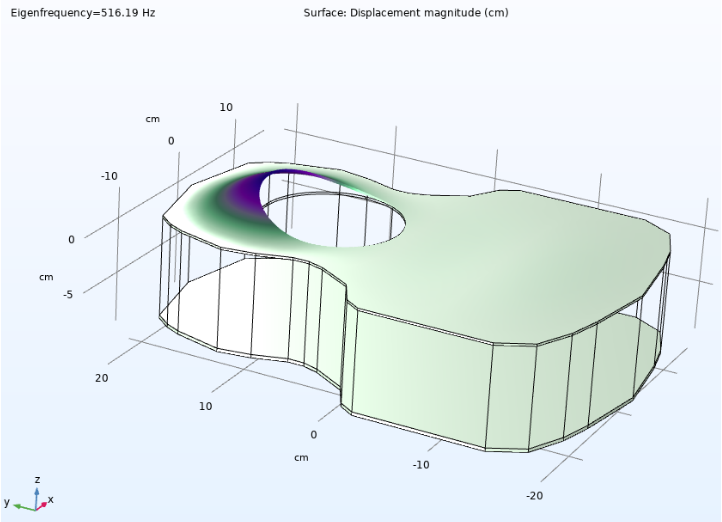
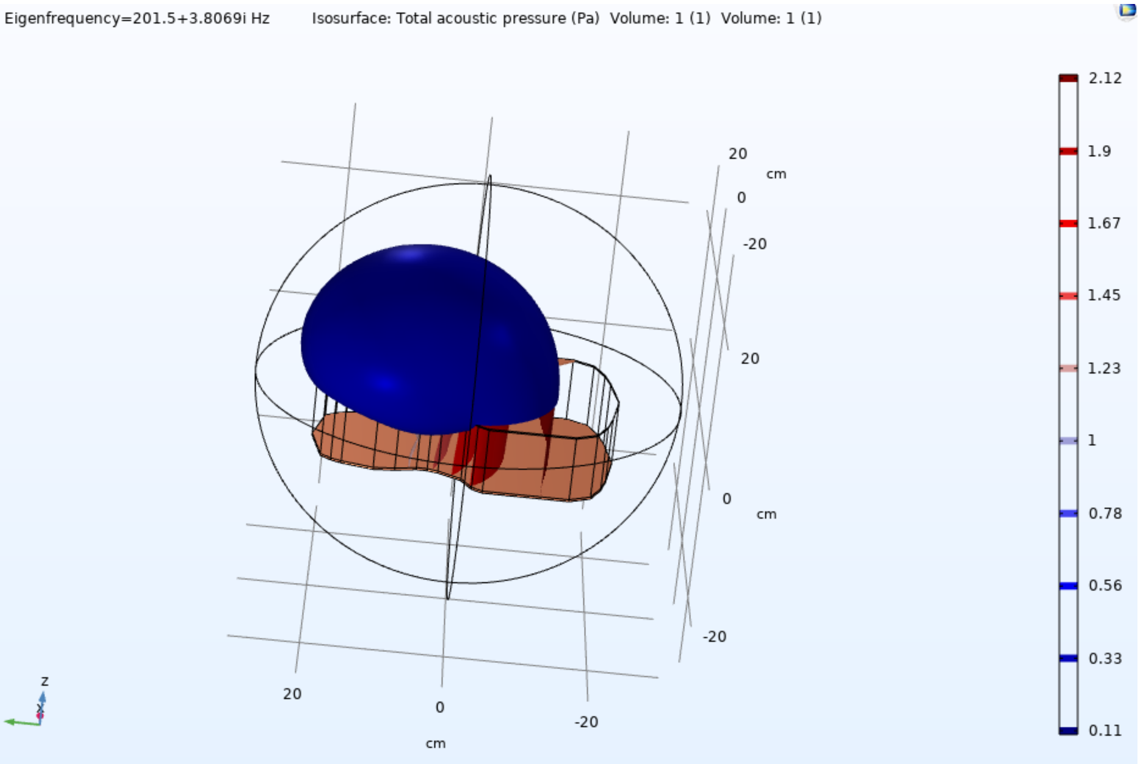
Surface: Displacement magnitude (cm)
cm
10
0
-10
0
cm
-5
20
10
0
cm
-10
-20
z
y
x

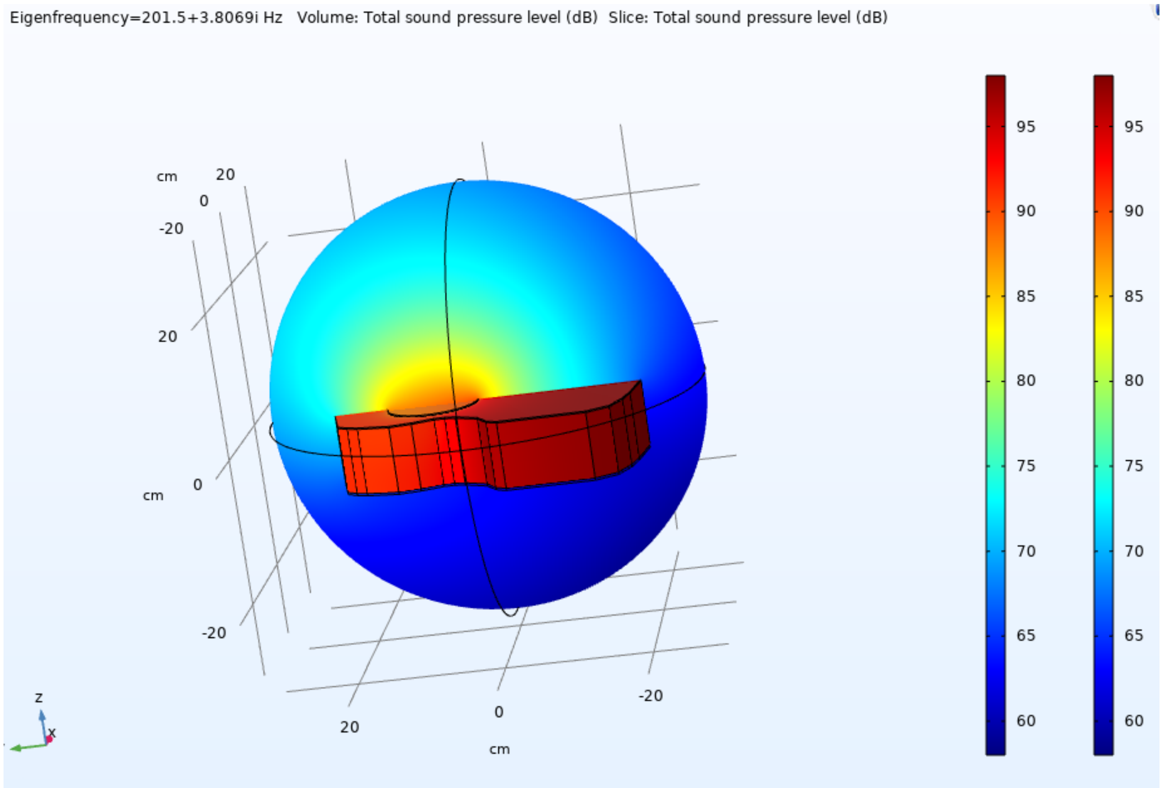

Eigenfrequency=386.77 Hz
Surface: Displacement magnitude (cm)
cm
10
0
-10
0
cm
-5
20
10
0
cm
-10
-20
z
y
x


Eigenfrequency=462.14 Hz
Surface: Displacement magnitude (cm)
cm
10
0
-10
0
cm
-5
-10
20
10
0
cm
-10
-20
z
y
x

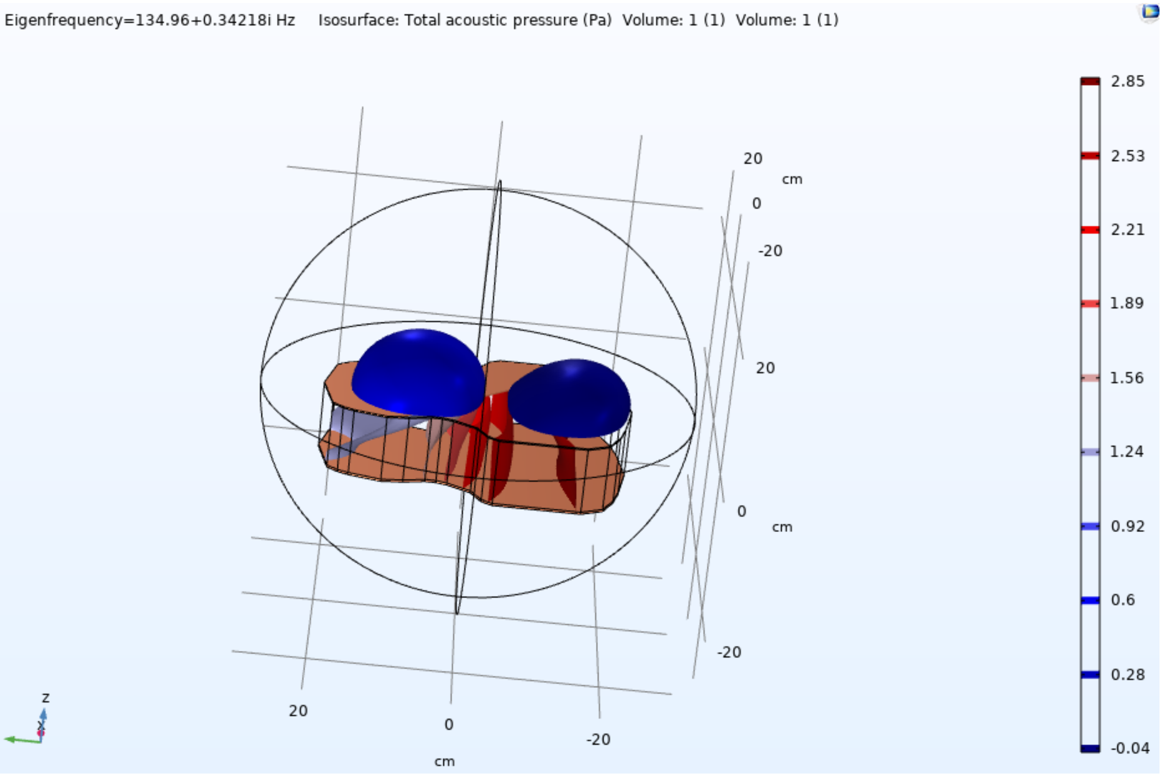

Eigenfrequency=516.19 Hz
Surface: Displacement magnitude (cm)
cm
10
0
-10
0
cm
-5
20
10
0
cm
-10
-20
z
y
x

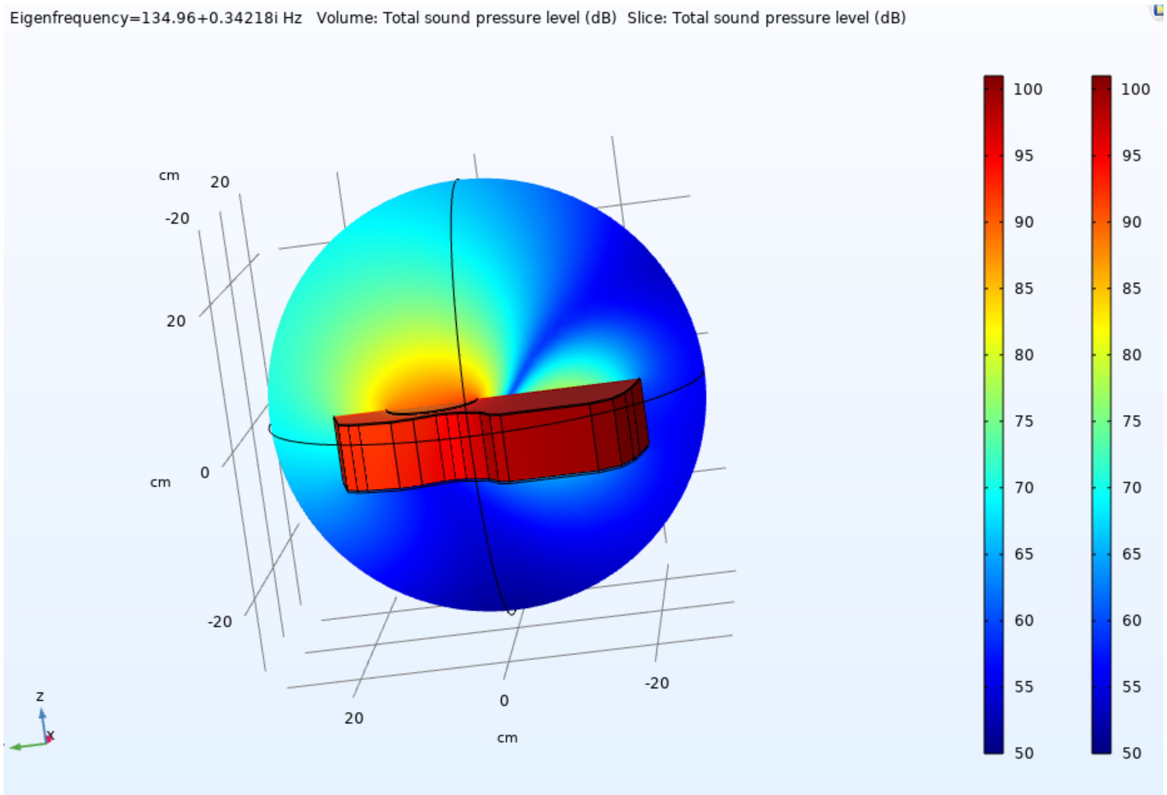
Study 2


Eigenfrequency=201.5+3.8069i Hz
Isosurface: Total acoustic pressure (Pa) Volume: 1 (1) Volume: 1 (1)
2.12
1.9
1.67
1.45
1.23
1
0.78
0.56
0.33
0.11
20
cm
0
-20
20
0
cm
-20
20
0
-20
cm
z
x

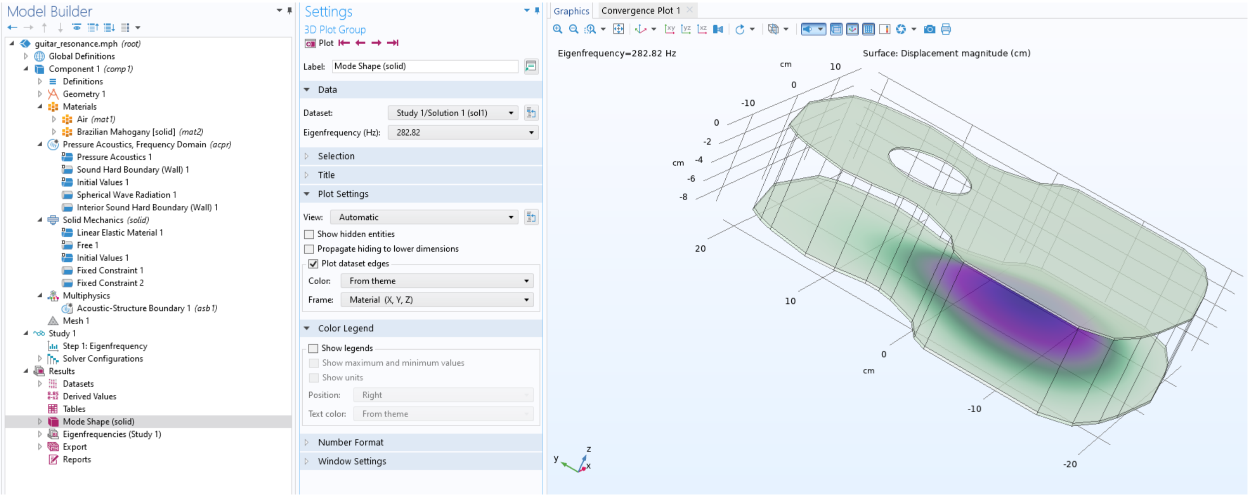

Eigenfrequency=201.5+3.8069i Hz Volume: Total sound pressure level (dB) Slice: Total sound pressure level (dB)
95
90
85
80
75
70
65
60
95
90
85
80
75
70
65
60
cm
20
0
-20
20
0
cm
-20
20
0
-20
cm
z
x

Study 3


Eigenfrequency=134.96+0.34218i Hz Isosurface: Total acoustic pressure (Pa) Volume: 1 (1) Volume: 1 (1)


Eigenfrequency=134.96+0.34218i Hz Volume: Total sound pressure level (dB) Slice: Total sound pressure level (dB)

COMSOL Interface



Label: Mode Shape (solid)

Data

Dataset: Study 1/Solution 1 (sol1)

Eigenfrequency (Hz): 282.82

Selection

Title

Plot Settings

View: Automatic

☐ Show hidden entities

☐ Propagate hiding to lower dimensions

☑ Plot dataset edges

Color: From theme

Frame: Material (X, Y, Z)

Color Legend

☐ Show legends

☐ Show maximum and minimum values

☐ Show units

Position: Right

Text color: From theme

Number Format

Window Settings

Eigenfrequency=282.82 Hz

Surface: Displacement magnitude (cm)

References:

Andersson, Linus. “Analyze Violin Tone and Volume with Multiphysics Modeling.” *COMSOL*, https://www.comsol.com/blogs/analyze-violin-tone-and-volume-with-multiphysics-modeling/.