

Modeling Sound Dispersion of a 3D Gyroid Lattice Structure

by Nikolas Gianulis and Shaunjae Suarez

Abstract

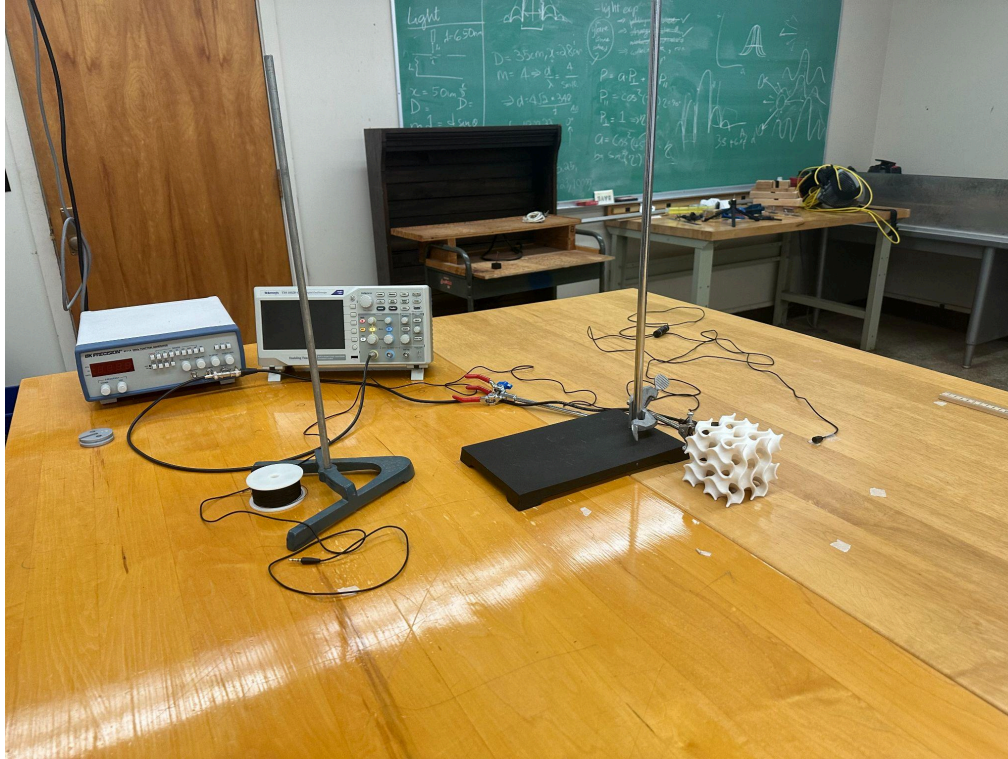
This experiment investigates the sound absorption behavior of a gyroid lattice structure placed between a speaker and a microphone at various frequencies and angular orientations. The gyroid lattice, known for its high surface area and complex pattern, is commonly used in speakers and headphones for sound quality improvement and noise reduction. The experiment also aims to test an inverse square relationship between distance and sound amplitude. Measurements are taken at 3 angular orientations relative to the speaker using a 3D-printed gyroid lattice obstructing the sound path. Fourier transforms of the recorded sound data are analyzed to observe frequency variations and amplitude changes. The experiment plan includes setting up the apparatus, conducting experiments with incremental frequency changes, and analyzing the collected data. Our results first disproved our predicted model of an inverse square relationship between distance and sound amplitude. One reason we believe this model to be incorrect is due to the saturation in the data collection room. Saturation in that room would lead to sound amplitude to not drop off as our model predicted. We ended up observing that as the angle went closer to 0° , there was more dampening for most frequencies of sound. Compared to our observations without the lattice that was more consistent between angles, the lattice's amplification of the sound depended on the angle at which the microphone was located.

Introduction

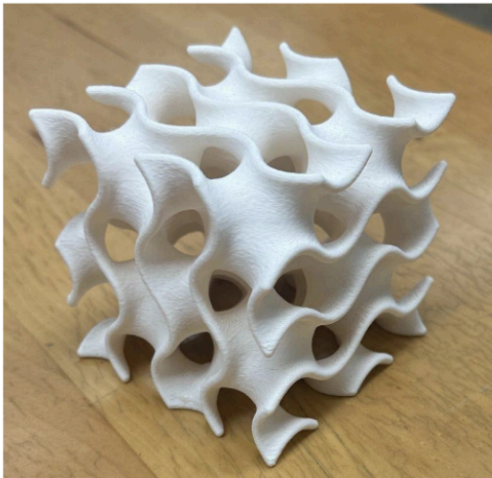
Reducing noise pollution is a common endeavor in day-to-day functions such as class lectures that use speakers or music festivals. Headphones and speakers implement lattices to provide exceptional sound quality, reduce the intensity of noise, and reduce vibration within the speakers. The gyroid lattice is one of these lattice structures that is commonly used for those purposes. What makes the gyroid lattice special is its high surface area combined with its complex pattern that makes it useful for energy absorption and dispersion. The lattice was discovered in 1970 by American physicist Alan Schoen with many interesting properties arising from its infinite connections. Its surface can be graphically defined by this equation: $\sin(x)\cos(y) + \sin(y)\cos(z) + \sin(z)\cos(x) = 0$. In past semesters, the metal lattice microwaves and sound transmission projects were our motivation for exploring the intersection between lattice structures and how sound is transmitted. In the sound transmission project, they explored how sound travels through materials of different densities. The authors- Hu, Kaplan, and Kong- found a relationship between amplitude versus material density, where denser materials dampened sound the most. Flint, Bensadoun, and Hagi in "Impact of Metal Lattice Patterns on Microwave Transmission," explored metal lattices with various slits and Microwave transmissions. They discovered increasing the number of superimposed lattices decreased transmission. We opened our experiment with the question: What is the impact of a gyroid lattice positioned between a

speaker and a microphone if we measured decibels across different frequencies by the microphone situated at different angular orientations relative to the speaker?

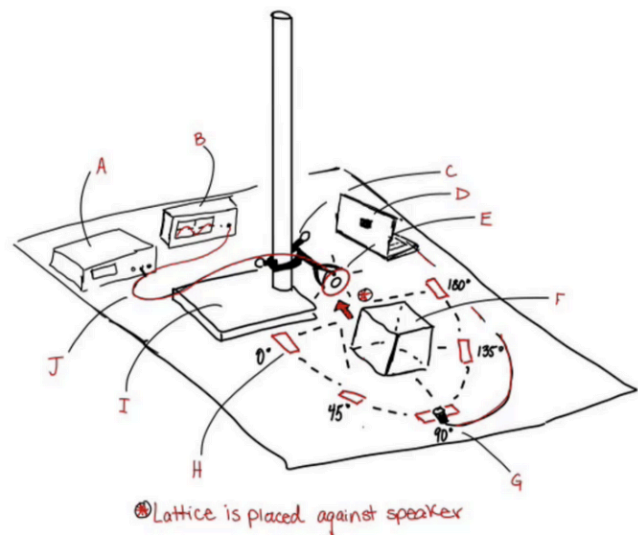
Experiment Design and Materials



(Image of the 3D printed lattice below)



Experiment Plan



(Figure of the apparatus with letters corresponding to the equipment list)

We utilized several pieces of equipment to achieve this experiment: Function Generator (A), Oscilloscope(B), Coax to Alligator Clip Cable(F), Speaker of diameter 5.5 cm(E), Audacity Computer Software(D), 3D printed gyroid lattice structure (83mm cube, see above)(F), Ring stand and clamp(I), Protractor and string, Microphone(G), Tape, and Marking Tape(H). (Image of the 3D printed lattice below) The speaker was clamped to a ring stand and connected to a function generator.

An oscilloscope was connected to the function generator to ensure that the amplitude remains constant. We used a 20 cm piece of string in conjunction with a protractor to measure the angles 0, 45, and 90 degrees. We measured distances of 20, 50, 80, 100, 150, and 200 cm with a meter stick. A Boya BY-M1S microphone recorded the speaker's sound output from each marked location. Data was recorded using Audacity which outputs a Fourier transform that describes the frequencies the microphone was detecting and the amplitude of these frequencies. We tested the frequency values of 500, 1000, 2000, 3000, 4000, 5000, 7500, 10000, 12500, 15000 Hz. At each increment, we recorded the sound at a single angle around the speaker coming through the lattice and relocated the microphone to begin the process again from 500 Hz. The same process was repeated with the lattice absent and the two cases were compared with their Fourier transforms. We graphed a frequency vs. dB graph to observe the peaks of frequency to show how the lattice absorbed and reflected different frequencies.

Similarly, we recorded the peak value of each distance marker and graphed it against its distance from the speaker with and without the lattice present at a constant 0.2V and 1000Hz. The system contained many moving pieces, thus all unchanging positions were marked with tape and kept as consistent as possible by eye. The speaker and clamp position will be marked. The lattice was placed with the speaker resting upon its center. The position of the microphone was carefully moved after every frequency was recorded at a given angle, both with and without the lattice obstructing the sound.

Results and Analysis

The data in all cases showed a significant amplification of sound with the lattice present at each angle (and similarly at each distance an amplification was present). At the 90° and 45° degree positions, we observed a much more consistent amplification. The most notable difference between the two figures being that at 45° there was less amplification. In comparison, the 0° position lacked a definitive difference at several frequencies (such as 2kHz, 5kHz, and 12.5KHz). Additionally, the former two angles observed a much larger amplification in sound at the larger frequencies. The 0° angle obtained a much weaker correlation between frequency and amplification (defined here as the difference between recorded decibels with the lattice and without). It instead saw a larger amplification at the median frequency value - 7.5kHz. Notably,

the drop in recorded decibels was constant without the lattice in each angle's readings as the frequency increased. This could imply a limitation of the microphone being used.

Furthermore, we noticed the inverse square model was not satisfied in our distance versus decibels measurements because of the lack of a consistent 3-decibel drop as distance increased as we expected from a spherical sound model. The inverse square law was an assumption we made for how the sound should drop off as the speaker was moved away from the speaker. In this model, we assumed that amplification would decline inversely to the square of the radius assuming a spherical distribution of sound from the speaker. However, the rough model was not observed in the recorded data and seems to increase instead at the farthest distance. Initially, for the angular orientation at 90° we measured uncertainty solely through instrumental uncertainty. Our tools of Audacity and the Oscilloscope have very insignificant uncertainties. In all following data collections, we collected data multiple times over and used the standard deviation formula to get a more accurate uncertainty.

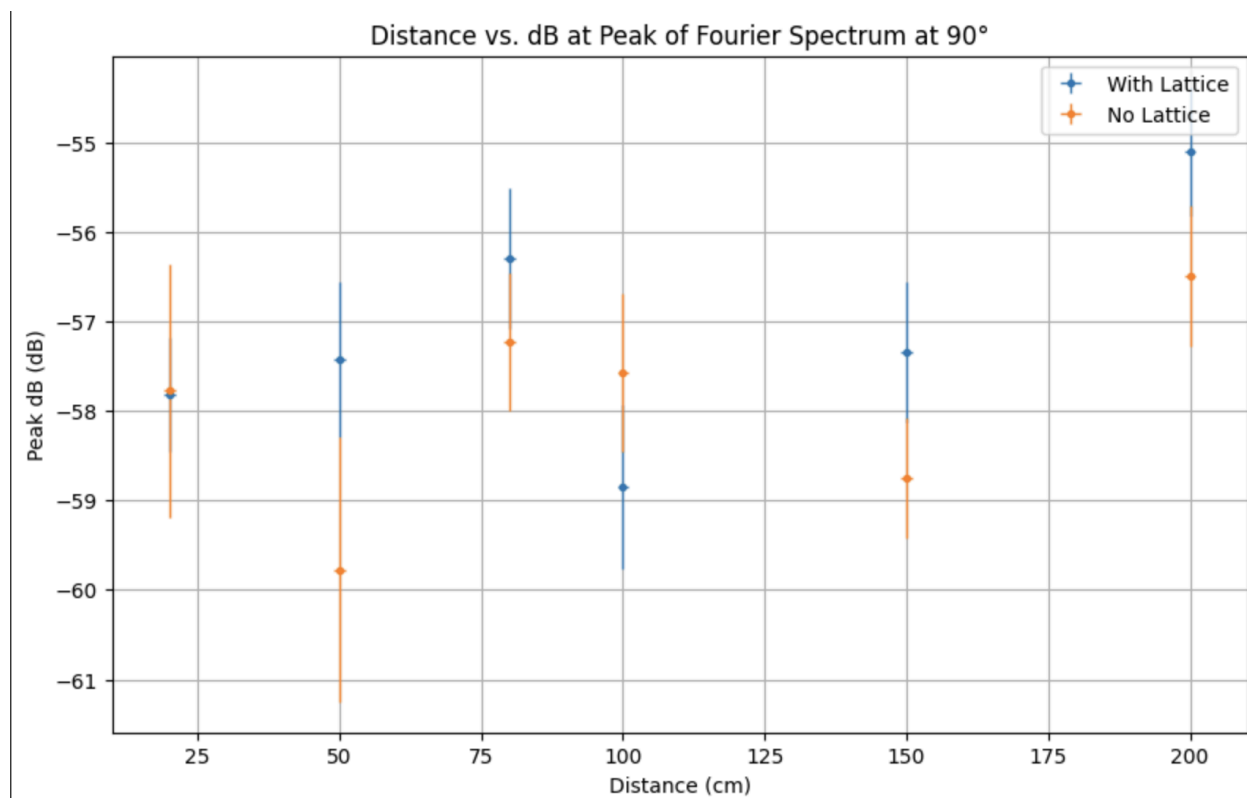


Figure 1.1 Sound was almost consistently shown to be amplified by the lattice (in blue), however the expected trend without the lattice was not present, making the abnormal trend with the lattice obsolete (as the abnormality stems from the environment not the introduction of the structure)

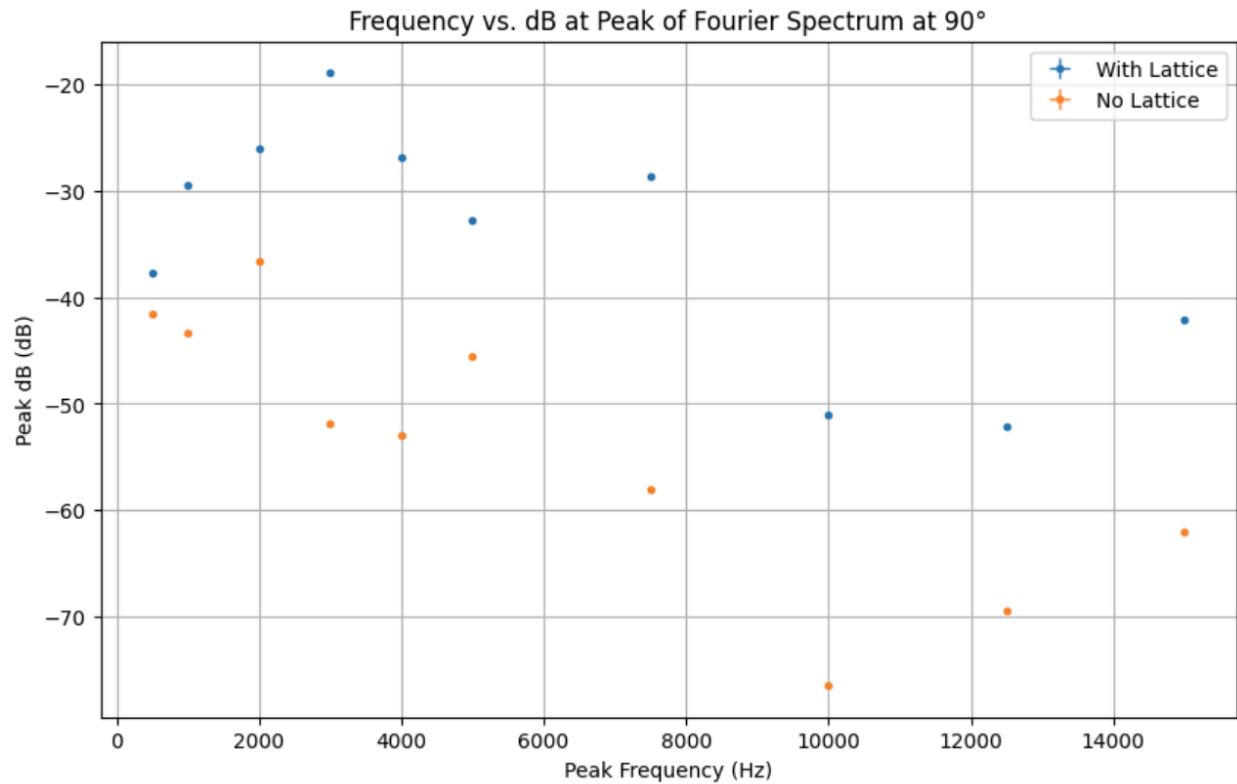


Figure 1.2 We lacked enough data points to add error margins, however; with the averages taken, amplitudes were greatly increased with the lattice at higher frequencies versus lower. We see a much more significant amplification at the 90 degree angle compared to others that we claim to be due to the structure of the lattice (its cavities tend to pierce straight through the structure).

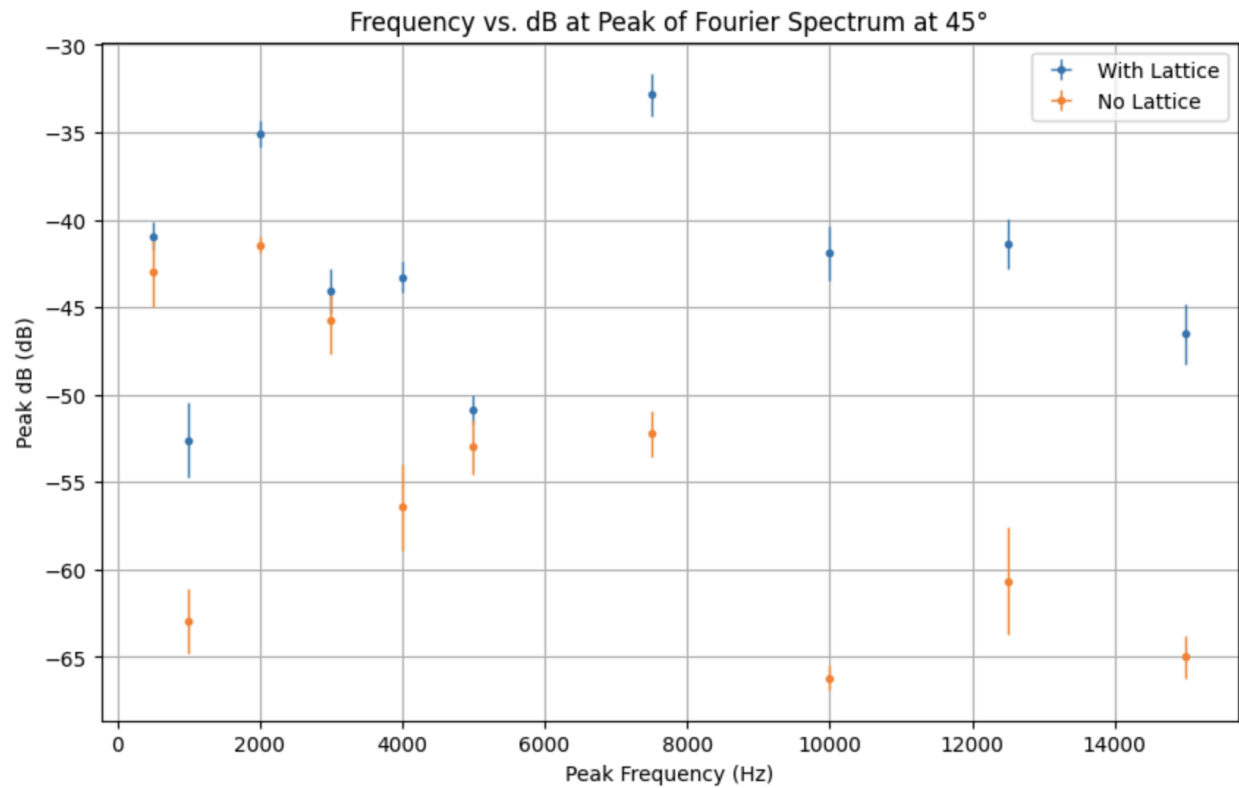


Figure 1.3 Similar to the data shown at 90 degrees, the data trends show consistently amplified sound measurements at all frequencies- larger disparities occurred at larger frequencies.

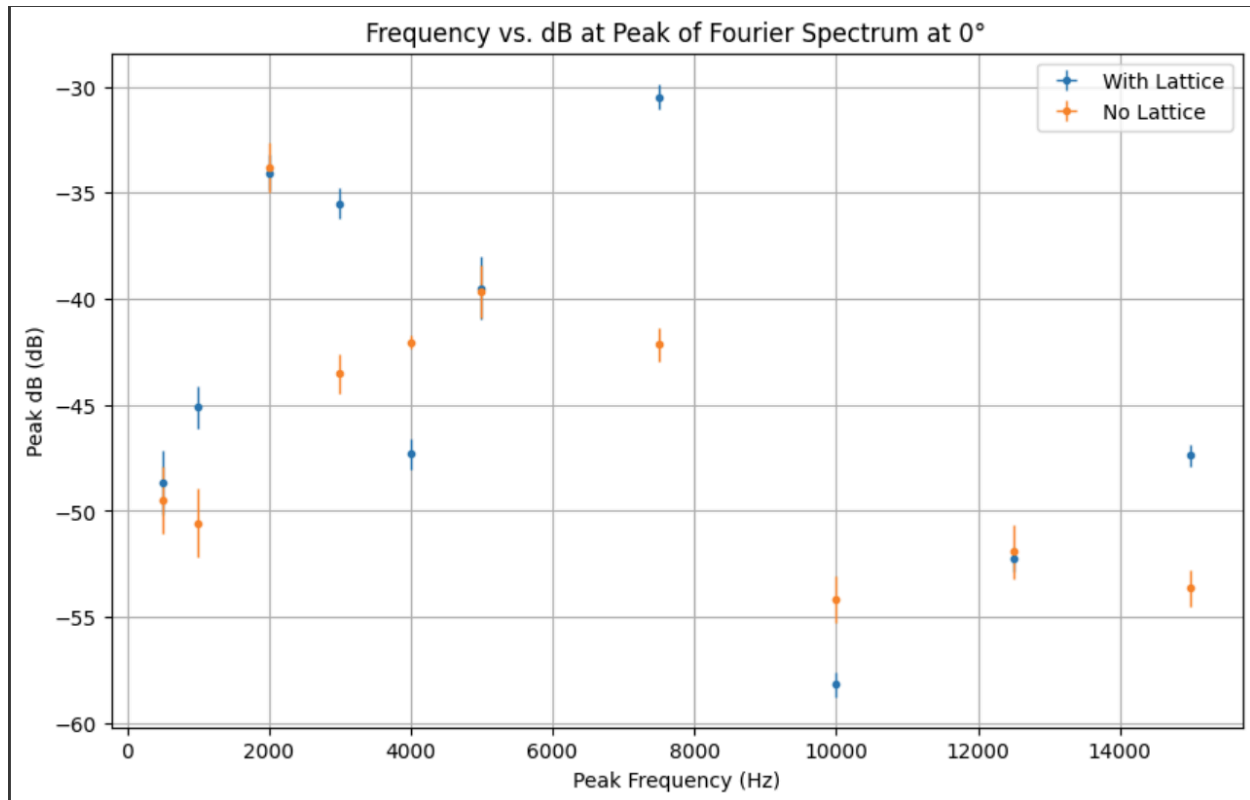


Figure 1.4 Unlike the previous two angular orientations, at 0° there is a lot more cross over between the two sets of data. We observed that the amplification of the sound is less than that of the 45° orientation in most frequencies.

Conclusion

In summary, the lattice quantitatively enhanced the volume of the speaker at carrying angles almost consistently throughout the range of frequencies. Lattice structures have been observed for their property to amplify sound, therefore our results matched those expectations. Furthermore, our second data set which included volume versus distance, did not seem to fit the model we anticipated. The model we expected to observe was an inverse square model that characterized the exponential decrease of volume as the distance from the speaker increased. With the peak being at the furthest distance, it is fair to assume that the room became saturated with sound causing an unusual dispersion relation between sound and distance. While our predicted model may work in an ideal setup, we have shown that this model is not practical for use in common spaces.