The walls are thin: measuring sound transmission through different thicknesses of plywood

Patricia Angkiriwang, Winnie Peng
Science One Program[1]
The University of British Columbia
Vancouver, Canada
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The relationship between frequency of sine waves and sound transmission through plywood was explored. Frequencies in the range of 100 to 1000 Hz were transmitted through birch plywood of three thicknesses. We conclude that the resonant frequency of our setup is centered around 700 Hz.

Introduction

Sound transmission through a medium depends on the acoustic properties of the material. When sound energy comes in contact with a surface, it is converted into other forms of energy (heat, mechanical), reducing the sound energy that propagates through. Some sound is absorbed, dissipated, or reflected [1]. Factors that affect acoustic energy loss include porosity (interlocking fibres or pores in the material), thickness, and surface area of the material. Three general types of sound absorbers are used for varying purposes: porous materials, membrane absorbers, and Helmholtz resonators. Porous materials are most commonly used in sound absorption, and in most cases have some degree of absorbance at wide ranges of frequencies as opposed to excellent absorption in narrow, specific regions [1]. These are materials such as insulation blankets, mineral wools, fibreboard, etc., and their absorption depends on the thickness of the material [1]. Helmholtz resonators are another type of sound absorber. They are air-filled cavities with a small opening and have a much narrower band of absorption frequencies [2]. At its resonance frequencies, Helmholtz resonators convert areas of high acoustic pressure into regions of high particle velocity, which are then absorbed; in other words, resonance frequencies indicate the frequencies at which absorption occurs the most [3]. Finally, membrane absorbers also have a narrow frequency range of absorption [1]. These are typically made with flexible sheets of plywood, or rubber stretched over supports at some distance away from a solid wall [2]. At its resonance frequencies, the membrane is forced into oscillation [3], turning the sound energy into heat.

Methods

In this experiment, varying thicknesses of birch plywood were tested for differences in sound transmission. The sound was generated by a multimedia speaker connected to a computer to produce tones of sine waves of frequencies in the range of 100 to 1000 Hz. The speaker was placed in a cavity, boxed in by two 55 x 55 x 13 cm foam walls of density 27 kg/m^3 on either side. The back wall of the box was made of material similar to the foam walls, and the top was covered by a down cover filled with polyester batting. Holding the cover in place in place was a 1.1 cm thick piece of plywood. Thinner boards of plywood, each 0.635 cm thick, were placed one by one to cover the opening of the box. A decibel meter placed 50 cm away from the box opening measured the intensity of sound transmission through the plywood medium as the speaker emitted tones of sine waves at the different

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[1] University of British Columbia, 1961 East Mall, Irving K. Barber Learning Centre, Room 361

frequencies. A control of no plywood was used as a basis of comparison. Five trials were conducted with measurements taken at 50 Hz intervals. Additional measurements were taken around 700 Hz, for example at 675 and 725 Hz.

A note on our measurements

Sound intensities are typically scaled logarithmically and are measured in decibels, where

$$1\text{dB} = 10\text{ dB}\log\left(\frac{I}{I_0}\right),\ I_0 = 1\text{ x }10^{-12}\text{ W/m}^2.$$

I indicates the sound intensity, and I_0 is a reference intensity indicating the limit of sensitivity of the human ear. A decibel reading of zero indicates the human threshold of hearing. Our decibel meter expressed the sound intensity readings in dBC, decibels that are measured through a C-contour filter. This means that sound levels measured (dB) at very low and high frequencies were scaled down by the decibel meter to yield a value in dBC [4]. However, this adjustment is inconsequential for our experiment since sound level measurements in our frequency range of 100 to 1000 Hz are essentially unaffected by this filter. That is, for our measurements we assume that 1 dBC = 1 dB.

Discussion of Results

We obtained the difference between sound intensities measured with and without the plywood barrier. The results from our five trials were averaged to yield Figure 1 below, a graph of sound transmission loss (dB) plotted against frequency (Hz).

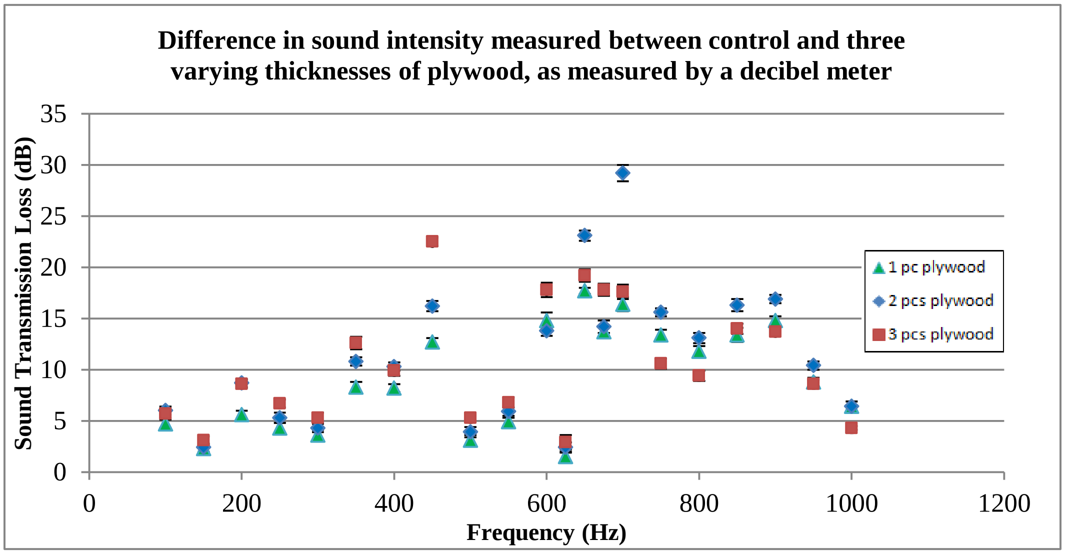

Figure 1. Sound transmission loss at various frequencies, in decibels (10 dB $\log_{10}(I_1/I_2)$), where I_2 is intensity with plywood barrier, and I_1 is the control).

In most cases, there is least transmission in sound through three sheets of plywood and most transmission in sound through one sheet. In all three cases, there is no clear trend in sound transmission loss with respect to frequency.

However, an interesting phenomenon occurs when we plot sound transmission loss (dB) divided by the sound intensity of the control (W/m^2), as in the following formula,

$$T = \frac{10 \log\left(\frac{I_1}{I_2}\right)}{I_1}$$

where I_2 denotes sound intensity with plywood barrier (W/m^2) and I_1 denotes sound intensity without plywood barrier (W/m^2). The numerator here represents sound transmission loss (dB). We will call this coefficient T the Transmission Loss Index, with implied units dB·m^2/W.

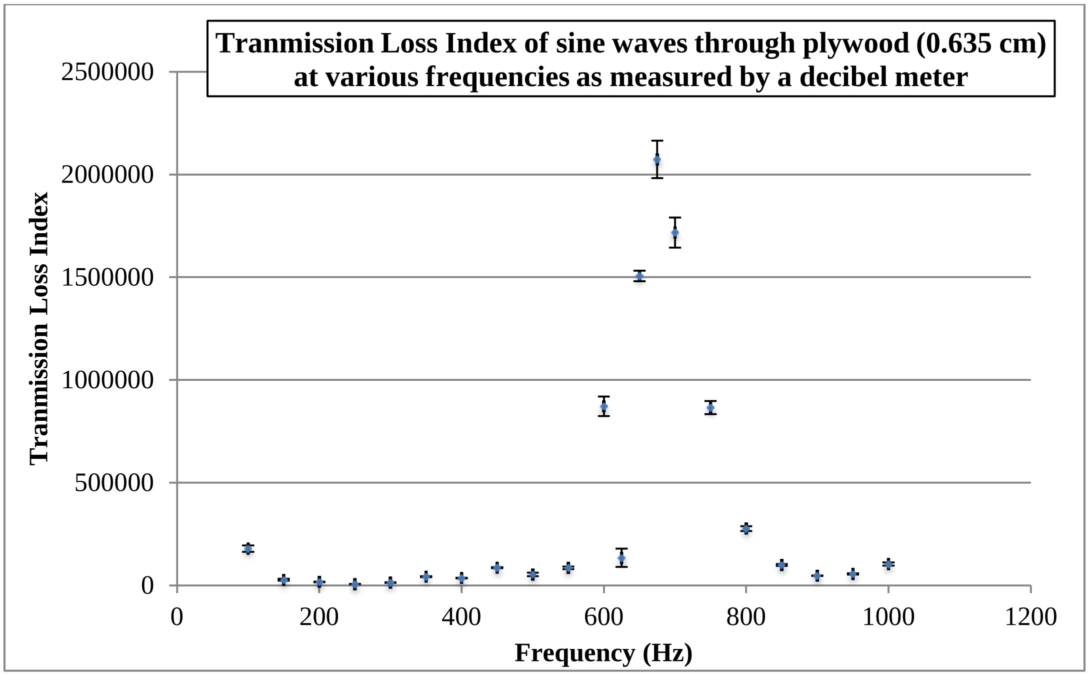

Figure 2. Sound transmission loss at various frequencies through 0.635 cm plywood (dB), divided by the sound intensity of the control (W/m^2).

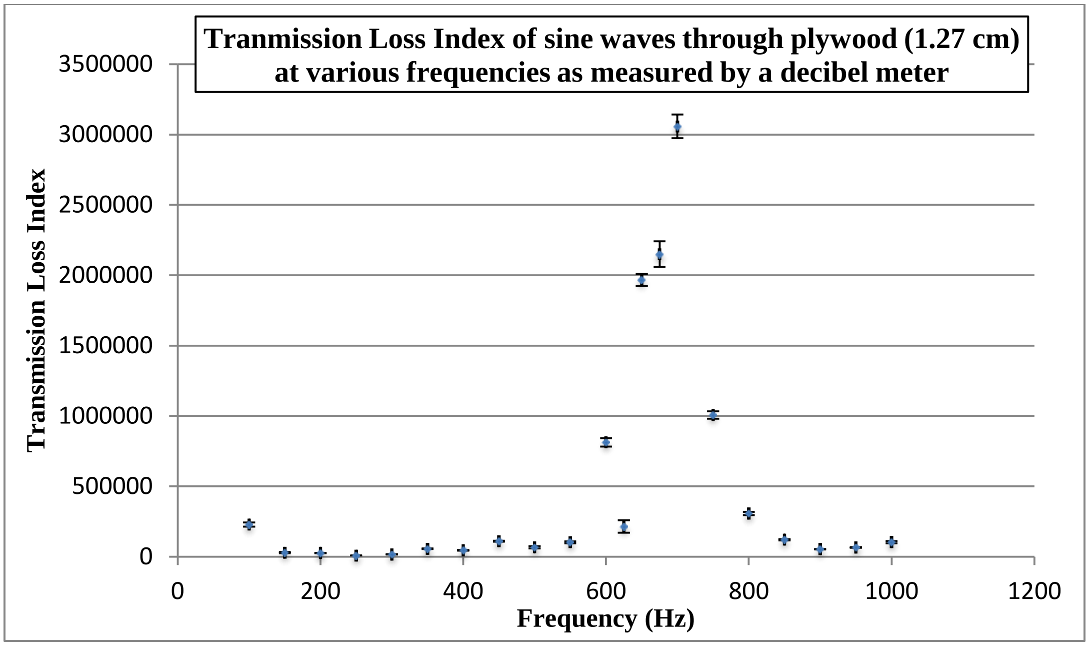

Figure 3. Sound transmission loss at various frequencies through 1.27 cm plywood (dB), divided by the sound intensity of the control (W/m^2).

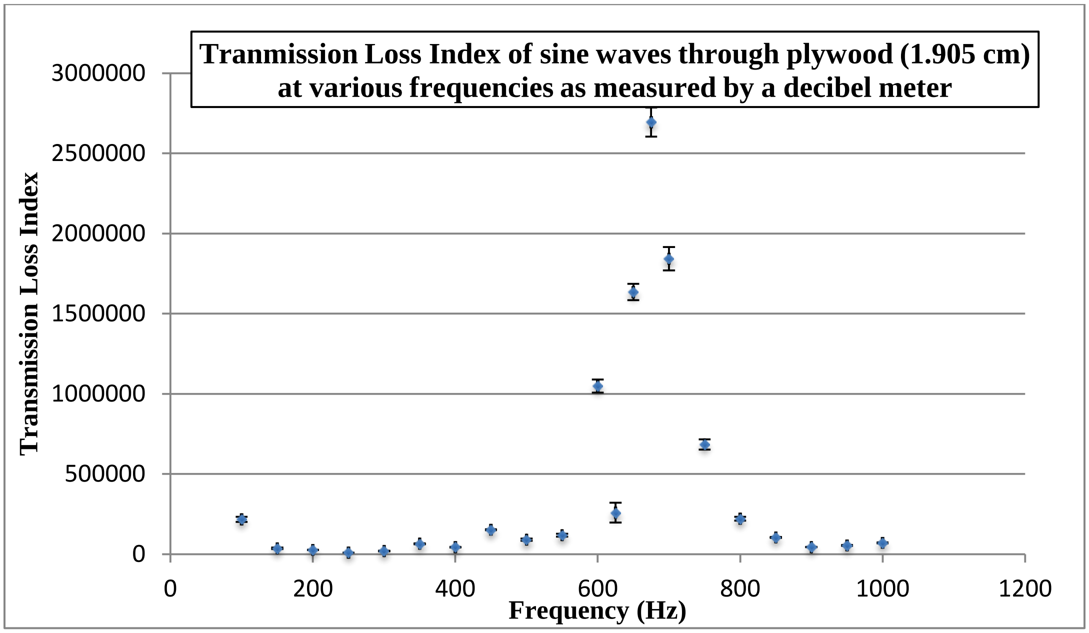

Figure 4. Sound transmission at various frequencies through 1.905 cm plywood, divided by the sound intensity of the control (W/m^2).

Figures 2, 3, and 4 show a region of roughly 600 to 800 Hz of higher transmission loss through the plywood, consistent in all three thicknesses.

If transmission loss through plywood were frequency independent, the graphs of Transmission Loss Index in Figures 2, 3, and 4 would be horizontal lines, assuming constant sound intensity output by the speaker. However, this is not the case. A positive spike in the Transmission Loss Index implies a particular frequency range in which the plywood material is especially absorbent. This range appears to be centered around 700 Hz. We deduce that these peaks in absorption occur because our apparatus forms a membrane or Helmholtz resonator with resonant frequency centered around 700 Hz. Further investigation is needed to determine the type of resonance occurring. One possibility is that the resonance may have occurred due to the construction of our setup. Upon a closer look, we found that our setup resembles a Helmholtz resonator, which consists of a cavity of air with a small opening.

Sources of error

The greatest source of error in our experiment was our inability to keep the sound intensity output constant. At certain frequency ranges, a speaker will consume less current and decrease the output intensity [6]. In addition, the multimedia speaker used was designed to soften or strengthen sound intensities at specific frequencies so as to best fit within the comfort range of the human ear. To account for this possible source of error, we conducted a side experiment in an attempt to keep sound intensity constant: we adjusted the volume at each frequency until the decibel meter read 69.5 dB, and recorded the sound transmission after adding 1, 2, and then 3 pieces of plywood. However, we found that restricting the decibel meter reading even to an intensity of 69.5 ± 0.2 dB was difficult. Given better equipment, we may have been able to keep intensity constant, which we predict would improve the accuracy of our experiment.

Additionally, although initial measurements of surrounding noise indicated that the experiment was conducted under relatively constant conditions (30 ± 0.5 dB), a completely soundproof room would have eliminated uncertainty by allowing the decibel meter to pick up only sound emitted by the speaker. Fluctuations in ambient noise between readings may have been picked up by the decibel meter and affected our data.

Finally, better insulating materials in the construction of the setup may have resulted in more accurate results. Sound reflection and transmission through the foam walls certainly affected our data. However, our methods account for imperfect insulating materials, so this factor may have dulled, but would not have skewed, our data.

Concluding remarks

It was found that the birch plywood in our setup absorbed more sound within a particular frequency range centered around 700 Hz. This is plausibly due to resonance effects.

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