Abstract:

The Acoustic Shadow Effect refers to the phenomenon in which sound waves are blocked, absorbed, or refracted, resulting in zones where sound is notably weakened. This study aims to approximate and analyse this effect within an indoor setting. By strategically placing various materials between a sound source and a recording device, changes in sound intensity and frequency content were captured and examined using audio analysis software. The experiment highlights how different materials influence sound propagation and contributes to the formation of acoustic shadows. Observations revealed a reduction in amplitude and high frequency components when obstacles were introduced, aligning with theoretical principles of wave diffraction, absorption, and sound path disruption. Although conducted in a noncontrolled environment, this simple setup offers a practical demonstration of the acoustic shadow effect and its potential applications in areas such as acoustic design, soundproofing, and noise management.

Introduction:

"Sound is the vocabulary of nature." – Pierre Schaeffer

Sound shapes the way we experience the world around us. It communicates, warns, comforts, and connects, all through vibrations traveling through air. While sound generally radiates uniformly from a source, its journey can be interrupted, altered, or even silenced by the environment it moves through. One such intriguing phenomenon is the Acoustic Shadow Effect, where sound waves are weakened or entirely blocked, creating quiet zones despite the presence of a nearby sound source.

Unlike atmospheric effects like temperature inversion, which also contribute to sound distortion, this study focuses on the material-based aspect of the phenomenon, i.e. how solid barriers influence sound propagation. In nature, this can affect how animal calls are heard across a forest, how predators locate prey, or how sound travels through a canyon or valley. Similar principles apply in human-made environments, from concert halls to urban planning, but the foundation lies in how materials interact with sound. Some examples of this effect in nature are:

Examples of the Acoustic Shadow Effect in Nature:

1. **Forests and Dense Vegetation**
In thick forests, tree trunks, branches, and leaves scatter and absorb sound waves. This can create zones where animal calls or rustling sounds become faint or completely inaudible, especially if a large tree or dense underbrush lies between the source and the listener.

2. **Rock Formations and Cliffs**
When sound travels in mountainous or rocky areas, large boulders or cliff faces can block direct sound paths. A person behind a rock wall might not hear someone speaking or shouting, even if they are very close.

3. **Caves and Valleys**
Inside caves or deep valleys, sound can be trapped, reflected, or shadowed depending

on the surface geometry. Certain spots may seem unusually quiet due to the way sound waves are blocked or redirected by the terrain.

4. **Snowbanks and Natural Ice Formations**

   In snowy regions, thick snowbanks absorb sound rather than reflect it. This makes the environment feel quieter, and sounds from behind these natural barriers can be greatly muffled—creating a noticeable acoustic shadow.

5. **Large Trees or Fallen Logs in Animal Habitats**
   In wildlife habitats, a fallen tree or large animal burrow may block the call of an animal from reaching others nearby. This can influence communication or detection of predators/prey.
6. **Hills and Natural Mounds**
   Even small hills or mounds can create acoustic shadows. For instance, a person or animal standing on the opposite side of a hill might not hear what's happening on the other side because the curvature blocks the direct sound path.

Though also relevant in human contexts, such as battlefields, concert halls, or urban soundscapes, this study focuses on a basic indoor simulation of the acoustic shadow effect to reflect how natural barriers might influence sound. Using a digital piano as the sound source and common materials to mimic natural obstructions, changes in sound intensity and frequency were observed using audio software. While the experiment was conducted in a non-controlled environment, it offers a practical exploration of how sound behaves around obstacles, reflecting patterns found in the natural world and offering insight into the physics of acoustic shadows.

Methodology:

This experiment was designed to simulate the Acoustic Shadow Effect in a basic indoor setting using accessible materials and audio analysis software. The aim was to observe how different physical barriers affect sound transmission by blocking or absorbing sound waves.

1. Equipment Used

- **Sound Source:** Digital piano (C major chord played consistently)
- **Recorder:** Laptop with a built-in microphone, placed at a fixed distance from the keyboard
- **Obstacles:** Common materials including cardboard (books), cotton (folded blankets and thick books), and foam panels
- **Software:** Audacity for waveform and frequency analysis and Python for observing trends.

2. Setup

- The digital keyboard was placed on a table in a quiet indoor room.

- The microphone (laptop) was positioned approximately 1 meter in front of the keyboard to record the baseline sound.
- Obstacles were then placed directly in front of the speaker on the digital piano.
- The experiment was repeated with different materials used as barriers, in order to observe their individual impacts on the recorded sound.

3. Procedure

1. A baseline recording of the C major chord was made without any obstacles in place.
2. Each material was individually placed between the sound source and the microphone, and the chord was played and recorded again.
3. Care was taken to minimize background noise and maintain consistent timing and pressure while pressing the chord to ensure comparability.
4. Each recording was imported into *Audacity*, where waveform amplitude was examined.
5. Key observations included:
    - Amplitude reduction (drop in loudness) ○
    - High-frequency attenuation (loss of sharpness or brightness)
    - Changes in waveform shape or clarity

4. Limitations

- The room was not acoustically treated, so echoes and background noise may have slightly affected the results.
- Manual playing of the chord introduced small variations in volume and duration.
- The experiment provides a rough approximation of the acoustic shadow effect rather than precise quantitative measurements.
- For simplicity, elements, such as thickness and shape of the material were not considered.

Observations:

1. Direct (No Obstacle):

- **Amplitude:** Highest among all, the raw signal (RMS=-23.092dB)

- **Waveform:** Sharp and complex, containing both high and low-frequency components.
- **Observation:** This is the reference waveform without any barrier. It represents the undisturbed signal and serves as a baseline to compare how different materials absorb or alter sound.

Figure 1: Waveform of sound recorded without any obstacle.

2. Cardboard:

- **Amplitude:** Very low, shows significant damping (RMS=-34.4675dB)
- **Waveform:** Smooth, with very little variation.
- **Observation:** Cardboard absorbs a large portion of the sound energy, reducing both amplitude and higher frequency components. This indicates good sound absorption and low reflection.

Figure 2: Waveform of sound recorded with cardboard as obstacle.

3. Plastic:

- **Amplitude:** Higher than cardboard, with noticeable sharp peaks.(RMS=-26.9898dB)
- **Waveform:** More irregular and jagged, with sudden rises and dips.
- **Observation:** Plastic reflects more sound compared to cardboard. The jagged waveform suggests multiple reflections and some resonance. Plastic is a poor absorber and likely reflects mid to high frequencies.

Figure 3: Waveform of sound recorded with Plastic as obstacle.

4. Cotton Cloth:

- **Amplitude:** Moderate, more than cardboard but less than plastic. (RMS=-25.1007dB)
- **Waveform:** Smoother than plastic, showing noticeable damping.
- **Observation:** Cotton cloth absorbs sound energy fairly well but not as effectively as cardboard. It likely damps high frequencies more and is good for reducing echo and reverb.

Figure 4: Waveform of sound recorded with Cotton as obstacle.

Results and Discussion:

Python was used to analyse the sound absorption characteristics of the different materials, by comparing their effects on the amplitude and waveform of a sound signal against a Direct (unobstructed) control signal.

Results:

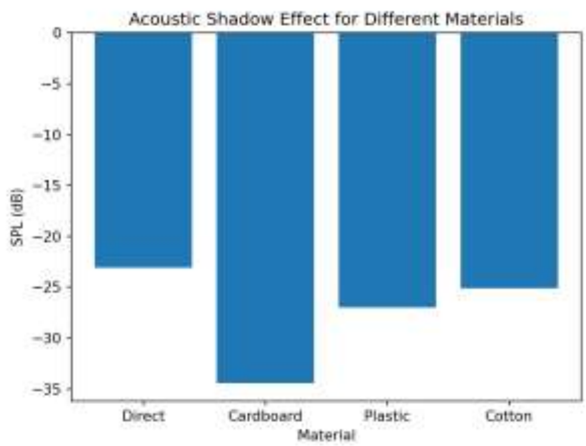

Figure 5: RMS in dBFS

The waveforms captured reveal distinct variations in amplitude and frequency content depending on the material placed between the sound source and the receiver:

- **Cardboard** significantly reduced amplitude and flattened the waveform, indicating high absorption and minimal reflection.
- **Cotton Cloth** moderately reduced amplitude and smoothed the waveform, especially in the high-frequency range, suggesting decent damping capability.
- **Plastic** maintained relatively higher amplitude with jagged waveform features, pointing toward low absorption and higher reflectivity.
- **Direct** signal (no obstacle) had the highest amplitude and full-frequency richness, serving as a benchmark for comparison.

Discussion:

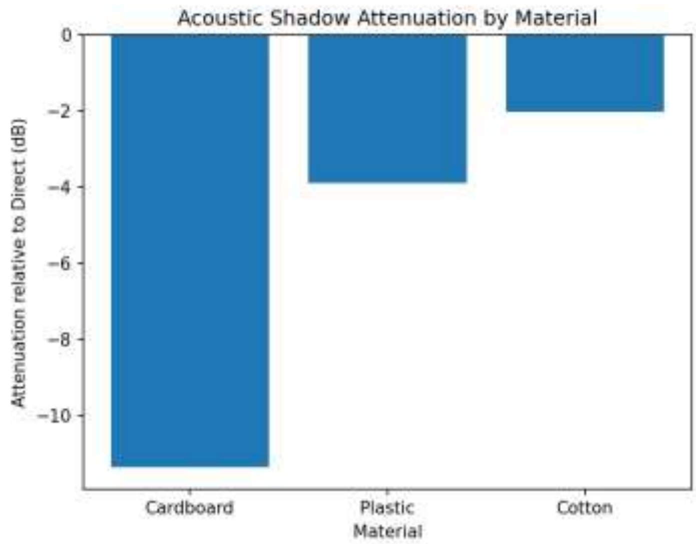

Figure 1: Attenuation Relative to direct

These observations highlight the impact of material properties on acoustic behaviour:

- **Cardboard**, being porous and fibrous, traps sound energy effectively within its structure, leading to significant attenuation. It demonstrates excellent potential as a low-cost sound-damping material, particularly for mid to high frequencies.
- **Cotton Cloth**, due to its soft and fibrous texture, partially absorbs sound, especially in the higher frequency range. Its performance suggests utility in applications where moderate absorption is sufficient, such as basic noise reduction or echo control.
- **Plastic**, a hard and non-porous material, reflects sound rather than absorbing it. The sharp waveform peaks indicate multiple reflections and poor damping capacity, making it unsuitable for soundproofing or absorption purposes.

The comparison with the Direct signal further validates the effectiveness of each material in altering the acoustic properties of the signal. Among the tested materials, cardboard emerged as the most effective absorber, highlighting its potential use in simple and cost-effective acoustic treatments. **Applications**

- **Cardboard:** Acts as an affordable sound absorber. Suitable for DIY acoustic panels, basic soundproofing, and noise-reducing packaging in homes, studios, and classrooms.
- **Cotton Cloth:** Useful for sound-absorbing curtains, wall hangings, and noise dampening partitions in studios, shared living spaces, or offices where moderate noise control is needed.
- **Plastic:** Due to its reflective nature, it can be used in speaker casings, auditorium walls, or as part of hybrid sound barriers where controlled reflections are required.

Further exploration involving less effects of background noise and including variables, such as thickness, density / surface impedance, frequency dependence, repetitions / uncertainty and more materials could lead to finding efficient substances for noise proofing.

Conclusion:

This study successfully demonstrated a basic indoor simulation of the Acoustic Shadow Effect using accessible, everyday materials. Through waveform analysis, it was evident that cardboard and cotton cloth significantly reduced the amplitude and high-frequency content of the sound, affirming their ability to absorb sound waves. In contrast, plastic exhibited reflective characteristics, with minimal absorption and greater waveform irregularity.

These results align with established acoustic theories on diffraction, absorption, and wave obstruction. Although conducted in a non-controlled environment, the experiment offers a practical and insightful glimpse into how different materials influence sound propagation. Such findings have meaningful implications in noise control, acoustic treatment, and environmental acoustic planning, especially for low-cost or DIY implementations.