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Article

Experimental study of sound wave propagation patterns

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Abstract. The present study compares the behavior of different sound types and their sources concerning distance. Experimental findings demonstrate a consistent reduction in noise levels with increasing distance from the sound origin, aligning with anticipated sound propagation patterns. Median noise level reductions are quantified, showing decreases from 72.7 dB at the source to 54.8 dB at a distance of 3 m. Pulsed sounds exhibit pronounced fluctuations and peaks at close distances, while steady and blended sounds maintain more uniform levels. An exponential model accurately characterizes the noise reduction phenomenon ($R^2 = 0.8664$), underscoring its applicability for construction noise control. These results offer valuable insights into sound propagation dynamics and provide a basis for developing effective noise control strategies.
Keywords: sound waves, sound propagation, noise levels, acoustic engineering, measurement.

1. Introduction

The study of sound wave propagation patterns is important for both basicscience and applied fields such as acoustics, structural engineering and ecology [1,2]. Understanding the mechanism of sound wave propagation contributes to improving the quality of sound environments, developing more effective noise insulation materials and technologies, and optimizing the acoustic performance of rooms and open spaces [3–6].

In the modern world, the level of noise pollution is constantly increasing, which negatively affects the health and well-being of people [3,6]. Problems related to excessive noise are becoming more and more relevant in urban and industrial areas, and construction sites [2,4,7]. In this regard, accurate data on the behavior of sound waves in different environments are needed to develop effective noise control methods and improve acoustic comfort in living and working spaces [8].

Despite a significant amount of research in acoustics, there is a lack of data concerning the behavior of sound waves in different environments and conditions. Frequently arising questions are related to the influence of different types of sound sources and distances on noise levels, which requires additional experimental studies and validation of theoretical models [9].

A pulsed sound is a sound that occurs in individual rhythmic bursts or pulses. These bursts can vary in intensity and frequency, creating a characteristic pattern [10,11].

Steady sound, means a constant and unchanging sound without fluctuations or variations in amplitude or frequency, which often come from mechanical or environmental sources [12,13].

A blended sound is a mixture or combination of different sounds occurring simultaneously, resulting in a complex auditory experience [14].

Choosing these types of sounds to experiment with allows us to explore different aspects of auditory perception and cognition. Impulsive sounds allow precise timing and synchronization of events, sustained sounds provide a stable background for comparison, and mixed sounds reflect the complexity of actual auditory experience. These diverse types of sounds allow the experiment to be designed to reflect the variability of auditory stimuli encountered in everyday life.

The purpose of this study is to investigate the propagation patterns of sound waves of various types under controlled conditions. The study aims to obtain quantitative data on the behavior of sound waves and their variation as a function of distance from the sound source.

In order to achieve the set goal, the following tasks should be solved:

– Develop and manufacture experimental racks for equipment placement.
– Prepare and set up measuring devices for fixing the sound level.
– Conduct a series of experiments with different types of sound sources (pulsed, steady and blended).
– Collect and analyze data on sound levels at different distances from a source.
– Draw conclusions about the patterns of sound wave propagation based on the data obtained.

This study will contribute to the knowledge of sound wave propagation mechanisms and the development of effective methods for controlling and managing noise in different environments, including construction sites.

2. Methods

2.1 Preparation of experimental racks

The preparation of experimental racks is a critical step to ensure accurate and consistent data collection. For this experiment, specialized racks were designed (Figure 1) and constructed following a specific layout to meet the requirements of the study. The racks were crafted from wooden material, selected for its durability and ease of manipulation. Each board connection was reinforced using four screws on each side, ensuring structural stability and rigidity. The schematic drawing of the racks provided precise dimensions for each component (Figure 1). These dimensions were meticulously adhered to during the manufacturing process to ensure uniformity across all racks used in the experiments. To minimize the influence of external vibrations, particularly from the ground, the surfaces of the racks were covered with a 10 mm layer of sponge (Figure 2).

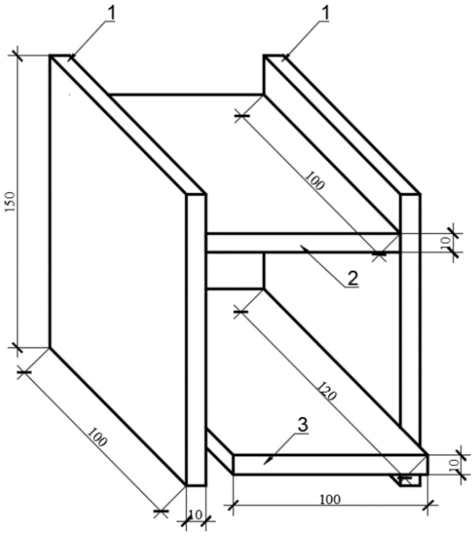

Figure 1 – Schematic drawing of the stand for the experiment. Board dimensions:
1 – 150x100x10 mm; 2 – 100x100x10 mm;
3 – 120x100x10 mm

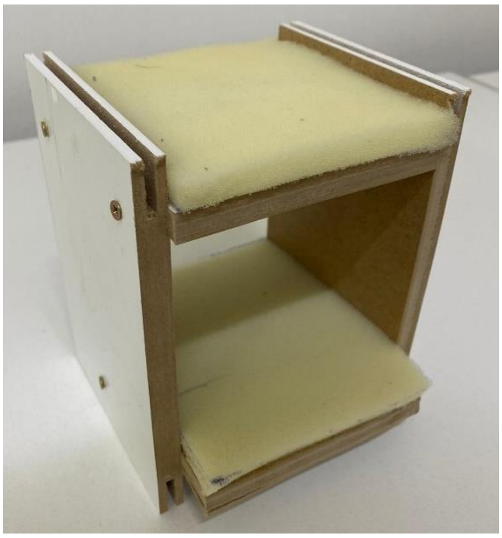

Figure 2 – Experiment stand

This cushioning material was chosen for its effectiveness in dampening vibrations, thereby ensuring that the measurements taken were not affected by extraneous movement or noise. Four identical racks were produced for use in the experiments.

2.2 Placement of racks and equipment

Proper placement of the racks and equipment was essential to maintain the integrity of the experiment. The first rack was strategically positioned directly at the sound source (Figure 3). This placement was crucial for capturing the initial sound intensity and variations at the point of origin. The remaining racks were placed at intervals of one meter from the sound source, forming a linear arrangement. This linear sequence allowed for the systematic measurement of sound intensity at increasing distances from the source, providing a clear gradient of sound propagation.

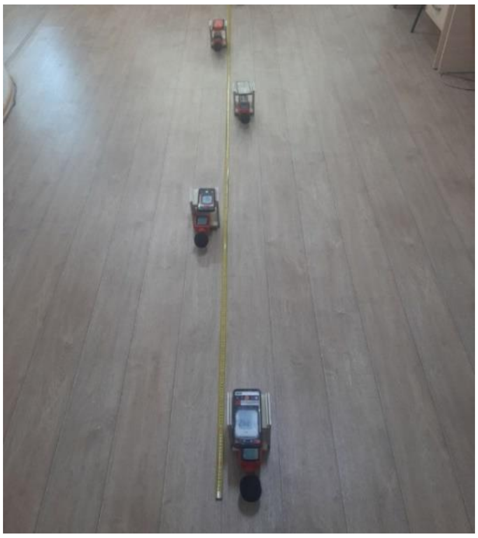

Figure 3 – Placement of racks

Each rack was equipped with two key pieces of equipment:

1. Video Fixation Devices: The upper part of each rack was designated for mounting video fixation devices (Figure 4). These devices, fixed on phones, were used to visually document the experiment and ensure the precise timing of measurements.

2. Noise Level Meters: The lower part of each rack was designed to hold UT352 (Figure 4) noise level meters. These meters, manufactured by UNI-T, were chosen for their reliability and accuracy. They are certified and listed in the Register of Standard Measuring Instruments of the Republic of Kazakhstan, ensuring compliance with measurement standards.

Figure 4 – Placement of the noise meter on the rack

The careful positioning of these devices was critical for capturing accurate sound levels at each specified distance.

2.3 Conducting the experiment

Three different types of sound sources were used during the experiment:

– Pulsed sound: this involved brief, pulsed sounds designed to simulate sudden noise bursts.

– Steady sound: this type involved a steady, uninterrupted sound, representing a constant noise source.

– Blended sound: This included complex sounds with varying frequencies and time characteristics, simulating more natural and varied noise environments.

For each type of sound source, measurements were taken over a specific time interval of 5 seconds. During this interval, the noise level meters recorded the sound intensity at a high sampling rate, capturing 8 values per second. This high temporal resolution ensured that even small fluctuations in sound intensity were recorded, providing a detailed dataset for analysis. The measurements were taken at four different distances from the sound source: at the source (0 meters); 1 meter from the source; 2 meters from the source; 3 meters from the source. This setup allowed the researchers to observe how sound intensity diminished with distance, a fundamental aspect of sound wave propagation. The data collected from these measurements were then analyzed to identify patterns in sound propagation and to understand how different types of sounds behave over distance.

The overall methodology ensured that the experiment was conducted in a systematic and controlled manner, allowing for the collection of reliable and accurate data on sound wave propagation. The results of this experiment are expected to provide valuable insights into noise control and management.

3. Results and Discussion

The experiment was conducted to measure the Sound Pressure Level (SPL) of pulsed, steady, and blended sound in decibels (dB) at four posts located at different distances from the sound source. Figure 5-7 presents the results of these measurements.

0: a stand that is directly at the sound source; 1: a stand that is 1 meter away from the source; 2: a stand that is 2 meters away from the source; 3: a rack that is 3 meters away from the source.

3.1 Pulsed sound in decibels (dB)

The graph (Figure 5) shows the variation in noise level for each of the 40 measurements:

– 0 m: noise level varies from 59.7 to 73.3 dB;

– 1 m: noise level varies from 43.4 to 66.0 dB;

– 2 m: noise level varies from 40.3 to 65.4 dB;

– 3 m: noise level varies from 39.6 to 59.9 dB.

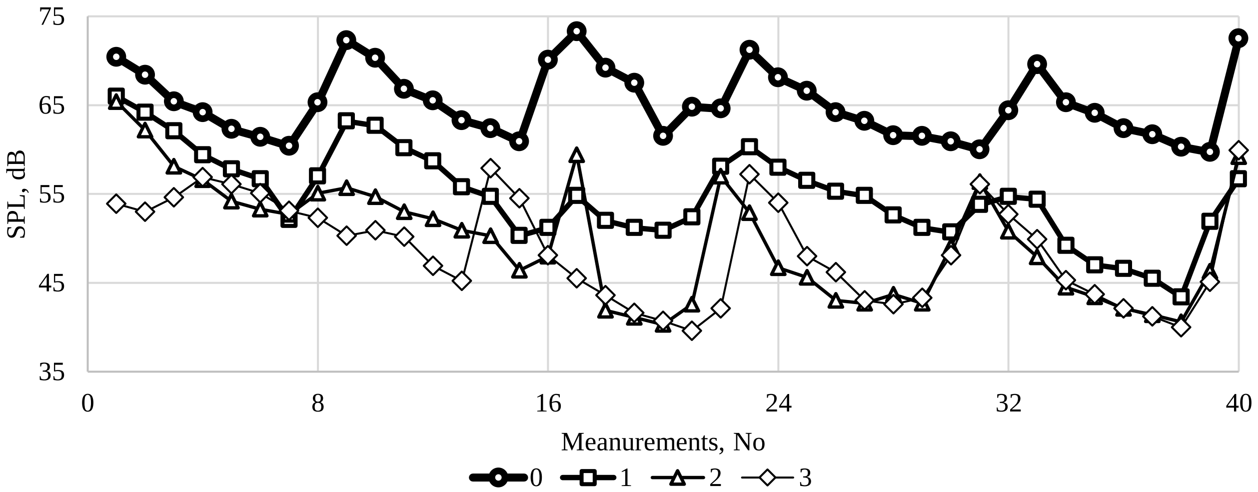

Figure 5 – Pulsed sound

The noise level decreases as the distance from the sound source increases. In all cases, there is a general tendency for the noise level to decrease from the beginning to the end of the measurements. More pronounced fluctuations and peaks in noise level are observed at the post located at the sound source (blue line) compared to the rest of the posts.

3.2 Steady sound in decibels (dB)

The graph (Figure 6) shows the variation in noise level for each of the 40 measurements:

– 0 m: noise level varies from 74.3 to 85.5 dB;
– 1 m: noise level varies from 65.0 to 69.1 dB;
– 2 m: noise level varies from 62.7 to 65.6 dB;
– 3 m: noise level varies from 61.0 to 63.4 dB.

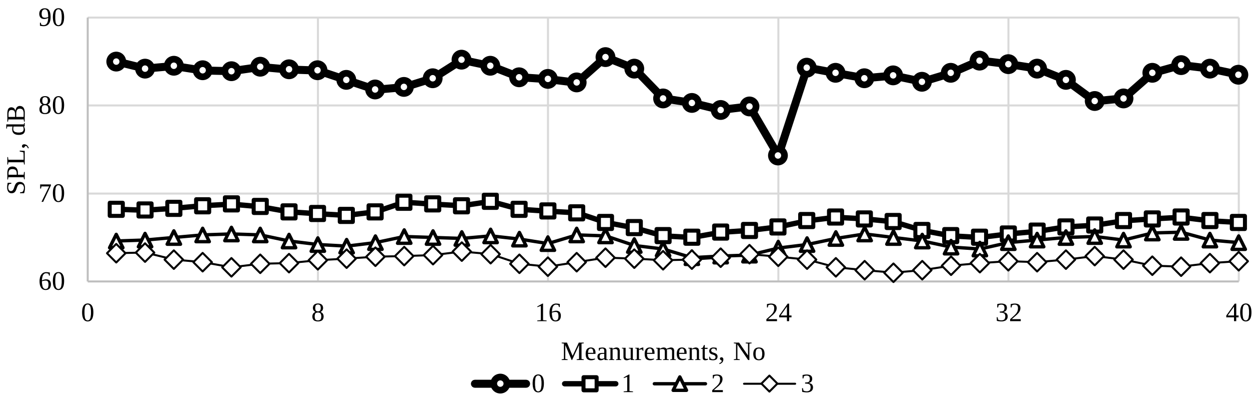

Figure 6 – Steady sound

The noise concentration decreases as the distance from the sound source increases. The rack located directly at the sound source (orange line) shows significant fluctuations in the noise level in the middle of the measurements, while at the other racks the noise level remains almost uniform.

3.3 Blended sound in decibels (dB)

The graph (Figure 7) shows the variation in noise level for each of the 40 measurements:

– 0 m: noise level varies from 74.3 to 85.5 dB;
– 1 m: noise level varies from 65.0 to 69.1 dB;
– 2 m: noise level varies from 62.7 to 65.6 dB;
– 3 m: noise level varies from 61.0 to 63.4 dB.

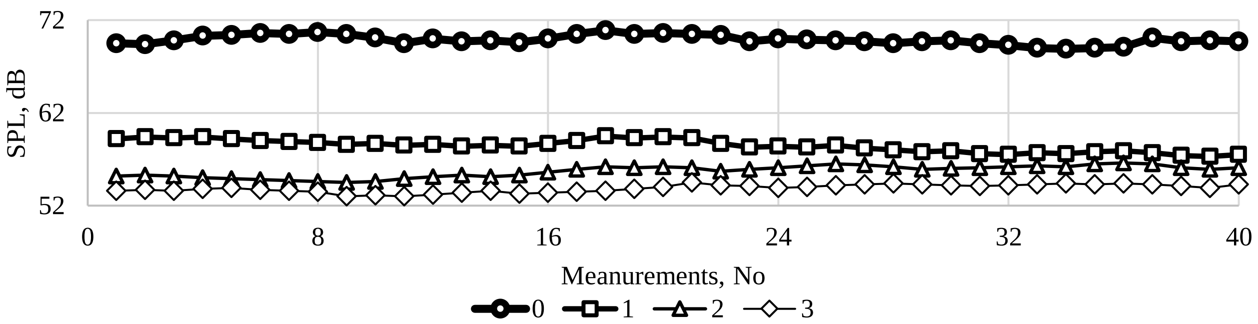

Figure 7 – Blended sound

Noise intensity decreases with increasing distance from the sound source. Nevertheless, the noise level at the measuring stand located directly at the source (orange line) is significantly higher than the values recorded at the other stands. In all cases, the noise level is almost evenly distributed.

The graph (Figure 8) shows a general trend of decreasing sound level with increasing distance from the source, based on median values. The pulsed sound starts at 64.5 dB at 0 meters and decreases to 48.1 dB at 3 meters. The steady sound starts at 83.7 dB at a distance of 0 meters and decreases to 62.4 dB at a distance of 3 meters. The blended sound starts at 69.8 dB at a distance of 0 meters and decreases to 53.9 dB at a distance of 3 meters. The average sound starts at about 70 dB at a distance of 0 meters and decreases to 55 dB at a distance of 3 meters. The exponential trend line follows the average sound points with a strong correlation (R^2 = 0.8664).

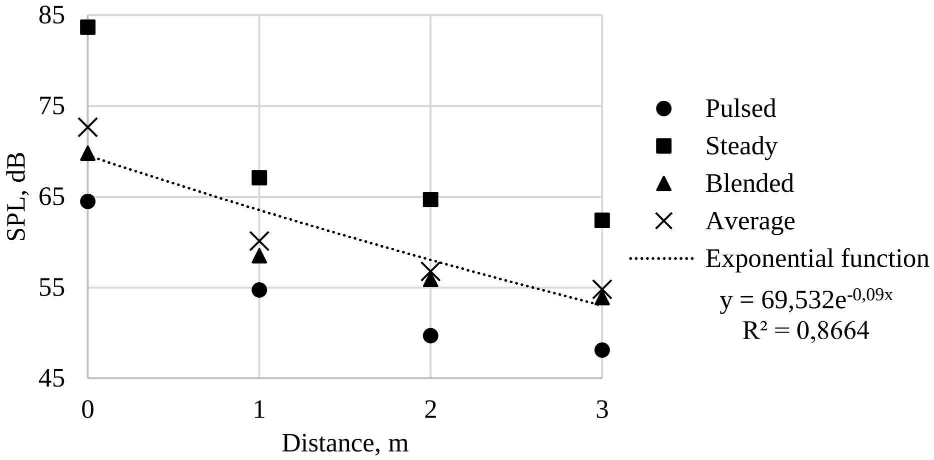

Figure 8 – Analysis of sound propagation

The sound level decreases as the distance from the source increases, which is consistent with the physical behavior of sound propagation in open space [15]. The exponential decay model agrees well with the average sound data, indicating that the decrease in sound level is exponential. The coefficient of determination (R^2 = 0.8664) indicates a good fit of the exponential model to the observed data. This analysis provides insight into how sound level decreases with distance, which can be useful in construction noise control.

4. Conclusions

In this paper, different types of sounds and their potential sources were investigated as a function of distance. Experimental results show a clear decrease in noise level with increasing distance from the sound source for pulsed, steady, and blended sounds, which is consistent with the expected physical behavior of sound propagation. Numerical values include a median noise level reduction from 72.7 dB at the source to 54.8 dB at a distance. Pulsed sounds are observed to exhibit greater fluctuations and peaks at close distances, with the median level starting at 70.4 dB and decreasing to 59.9 dB. Steady and blended sounds have more uniform noise levels, with steady sounds decreasing from 66 dB to 56.7 dB and blended sounds decreasing from 65.4 dB to 59.2 dB. The exponential model accurately describes noise reduction with a high coefficient of determination (R^2 = 0.8664), which emphasizes its applicability for construction noise control.

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