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# Study of the Effect of Pink Noise, White Noise, Sinusoidal, and Real Audio Signals with MATLAB-based Sound Pressure Level

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A B S T R A C T

This study presents a comprehensive methodology for measuring Sound Pressure Level (SPL) utilising MATLAB software. Through analysing four distinct categories of audio signals—Pink Noise, White Noise, Sinusoidal, and Real Audio—this research aims to investigate the fundamental acoustic properties associated with each signal type. The SPL measurement process employs specialised MATLAB functions tailored to each specific signal. The results are meticulously analysed to better understand the acoustic responses regarding energy and frequency spectrum. Furthermore, visual representations of the audio signals are provided to facilitate a clearer understanding of the structure and patterns inherent in each signal type. The outcomes of this study contribute valuable insights into SPL measurement within diverse audio contexts while also advancing the understanding of MATLAB's role in exploring acoustic characteristics. The analysis is expected to offer a refined perspective on the application of MATLAB in acoustic research, thereby showcasing its broader potential within the field of audio engineering. Consequently, this research makes a significant scientific contribution and paves the way for future advancements in the domain.

## INTRODUCTION

Auditory acoustics and psychophysics focus on understanding how the human ear responds to different sound signals [1]. Research in this area explores how various sounds influence auditory perception and response [2,3]. This article will discuss the relevance, objectives, research landscape, and experimental methods used, including sound-signal production, SPL measurement, and data analysis with MATLAB [4,5].

Understanding how the human ear processes sounds is essential, as it has implications across various fields [6]. This research provides insights into human auditory perception from psychological and physical perspectives [7] , laying the groundwork for new theories in acoustics and auditory psychophysics [8].

Additionally, the research has practical applications in technology. Understanding how different sounds affect communication quality is essential for digital signal processing, audio technologies, and communication systems. This study could inform the development of better audio technologies [9].

Moreover, the findings could be valuable in audiology, helping to diagnose and treat hearing loss or communication disorders [10].

This research aims to better understand how the human ear responds to different sound signals. Specifically, it examines the ear's sound processing, the brain's response to sound, and how these processes influence the perception of acoustic environments [11]. The research also seeks to explore the technical applications of these findings, such as sound signals in communication technology and digital signal processing [12] Additionally, it aims to investigate potential healthcare applications, particularly in audiology, and the development of algorithms or models predicting auditory responses to sound [13]. Previous studies in acoustics and auditory psychophysics have analysed various sounds and human responses [14], but gaps remain, especially regarding the interaction between specific sound signals and SPL [15].

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This study will use experimental methods, including producing different sound signals, measuring SPL with advanced acoustic equipment, and analysing data using MATLAB [16]. This approach will provide a thorough assessment of how sound signals impact SPL. This background provides a clear overview of the relevance, objectives, research landscape, and experimental methods. It focuses on how sound signals influence SPL within acoustic science and auditory psychophysics using MATLAB modelling [8].

## METHODS

### *Research Design*

This study adopts a computational experimental design to analyze the characteristics of Sound Pressure Level (SPL) from various audio signals [1]. The entire experiment was conducted using MATLAB to ensure consistency in signal generation, processing, measurement, and visualization [9]. The study does not involve human participants or physical measurements but relies on digitally generated and recorded audio signals to simulate real-world sound conditions. The main objective is to understand how different types of audio signals—namely, pink noise, white noise, sinusoidal signals, and real audio recordings—differ in their SPL profiles when analyzed under the same technical conditions [17], [18] This study involves some steps, as can be seen in Figure 1.

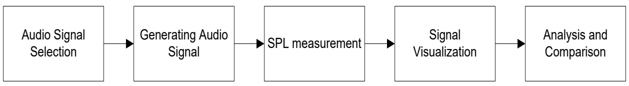

Figure 1. Block diagram of research flow

### *Audio Signal Types*

The types of audio signals used in this study include pink noise, white noise, sinusoidal signals, and real audio [19], [20]. Pink noise represents a signal with equal power per octave, making its energy distribution more concentrated in the lower frequencies [19]. White noise, in contrast, has equal power across all frequencies, resulting in a flat spectral density [21], [22], [23]. The sinusoidal signal is a pure tone, characterized by a single frequency component, and is useful in isolating system responses to specific frequencies [24], [25]. Meanwhile, real audio refers to recordings from the surrounding environment that reflect the complex and unpredictable nature of actual acoustic conditions [20], [26]. These four types of signals were chosen to represent a broad spectrum of acoustic behaviors, ranging from synthetic and controlled signals to realistic, complex recordings [33].

### *Signal Generation*

The generation of the signals was performed using MATLAB with standard audio signal processing libraries [27]. Each signal had a sampling rate of 44.1 kHz and a duration of five seconds. White noise was generated by creating a normally distributed random sequence using the standard randomization function, while pink noise was synthesized using a filtered noise method that introduces a 1/f frequency decay [19]. The sinusoidal signal was created using a sine wave formula where parameters such as frequency (set at 1000 Hz), amplitude, and phase were defined explicitly in the script [26]. Real audio was obtained by loading existing audio recordings in .wav format using MATLAB's audioread function, which allowed for the extraction of amplitude-time data from environmental audio recordings [29], [30].

### *Sound Pressure Level (SPL) Measurement*

After generating or loading the audio signals, SPL measurements were performed on each [31], [32]. The SPL value was computed by first calculating the Root Mean Square (RMS) of the signal, which provides an effective measure of its average amplitude. This RMS value was then inserted into the standard SPL formula, as can be seen in Equation 1.

$$SPL\ (dB) = 20 \cdot log_{10} \left(\frac{p}{p0}\right) \tag{1}$$

Where p denotes the RMS of the signal and $p_0$ is the reference sound pressure of 20 µPa [1], [17], [18]. This formula converts the linear amplitude into a logarithmic decibel (dB) scale, which more accurately reflects human auditory perception [1], [12]. MATLAB's built-in functions, such as rms and log10, were used to automate this computation [9], [28]. The SPL values were stored for further analysis and comparison. This method ensures consistency in measurement across signal types and simplifies the evaluation process by relying on digital signal processing rather than physical measurement equipment [38].

### *Signal Visualization*

Visualization was an important part of this research, as it provided insight into the temporal behavior of each audio signal [39]. Each signal was plotted in the time domain using MATLAB's visualization functions. The waveform of each signal was displayed with appropriate labeling for time and amplitude, allowing for easy identification of amplitude variation over time [35], [36]. Adjustments were made to graphical parameters such as line thickness and color to improve visual clarity. To support comparative analysis, multiple signal plots were either placed in sequence or grouped using subplot arrangements. These visualizations helped to highlight the unique characteristics of each signal type, especially in terms of waveform regularity, noise complexity, and signal density [40].

### *Data Analysis*

The final stage of the methodology involved analyzing and comparing the SPL values of the different signal types [41]. The comparison focused on identifying which signal type produced higher or lower SPL levels under the same conditions, and how the structure of the signal affected the resulting SPL. Visual inspection of the time-domain plots supported the interpretation of SPL measurements by providing a clearer picture of each signal's behavior. These results were then used to draw conclusions about the relationship between signal type and sound pressure characteristics, and to evaluate the effectiveness of MATLAB as a platform for acoustic signal analysis.

## RESULTS AND DISCUSSION

### *SPL Measurement on Pink Noise, White Noise, and Sinusoidal Signal*

Sound Pressure Level (SPL) is crucial for understanding noise distribution, especially in pink noise and white noise. White noise has an even energy distribution across frequencies, leading to a flat SPL curve and consistent loudness, which can mask other sounds in environments like intensive care units [42]. In contrast,

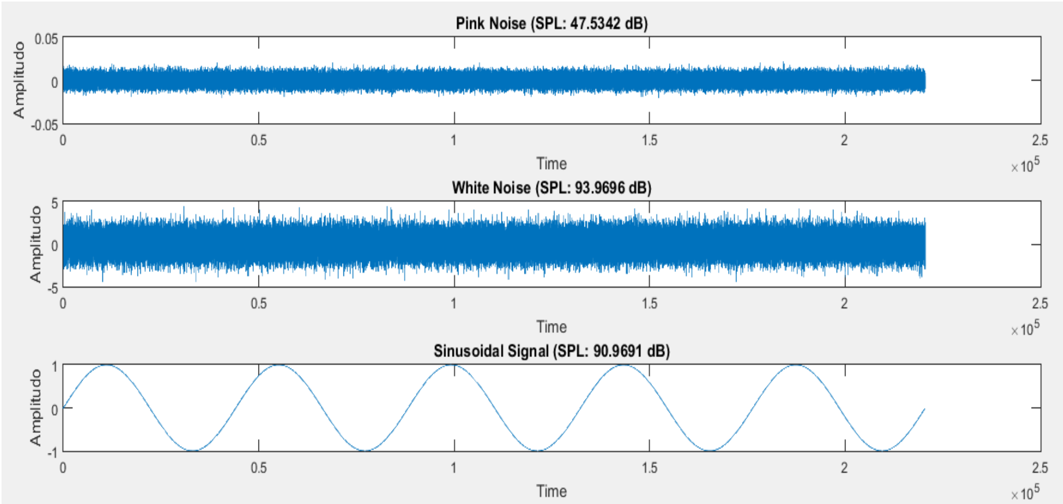


Figure 2. Visualisation of the generated Signal

pink noise has an energy distribution that decreases with frequency, resulting in a higher SPL at lower frequencies and a more balanced sound perception [43]. The random nature of both noises impacts their acoustic behavior, with white noise masking sounds and pink noise mimicking natural environments [44]. Compared to sinusoidal signals, pink noise and white noise show less distinct SPL peaks [45]

Figure 2 illustrates the results of the SPL analysis, validating the observation that each type of audio signal has unique SPL characteristics. The SPL curves for Pink Noise and White Noise display a relatively flat or evenly distributed pattern across the frequency spectrum, meaning that the energy in these signals is spread out evenly across different frequencies. This is consistent with the nature of these noises, where the power is distributed across a wide range of frequencies, resulting in a uniform SPL. Pink noise is characterized by a spectral power density that decreases with increasing frequency, following a 1/f distribution [39]. This results in equal power within each octave, making it sound more balanced to human ears, as it reflects how many natural sounds distribute energy across frequencies [46]. In contrast, white noise has a flat spectral density, meaning it possesses a constant power level across the frequency spectrum. This gives it a sharp, hissing sound that is perceived as less natural compared to pink noise [39], [46]. The differing SPL patterns, where pink noise exhibits a gradual decline while white noise remains stable, illustrate how energy is distributed uniformly across frequencies in white noise, whereas pink noise prioritizes lower frequencies, reflecting the logarithmic characteristics of human auditory perception [39], [46].

### *SPL Response to Real Audio*

Figure 2 illustrates that Sound Pressure Level (SPL) measurements on accurate audio signals yield a more complex response compared to modeled noise signals, such as Pink Noise and White Noise. This complexity arises from significant variations in noise levels associated with the intrinsic properties of authentic audio, including varying dynamics and diverse frequency complexity. Authentic audio is dynamic in nature, meaning that sound amplitude and intensity can fluctuate significantly over time. These fluctuations often manifest as variations between quieter and louder sections of the audio, creating a more dynamic and varied SPL response. Consequently, SPL measurements for real audio signals are not as consistent or straightforward as those for noise signals. The human auditory system is highly sensitive to these changes, enabling the perception of the sound envelope in complex auditory environments [47]. In contrast, modeled signals exhibit consistent energy distributions, with Pink Noise showing a flat SPL and White Noise evenly distributed. The varying SPL in real audio, influenced by quieter and louder sections, enhances perceptual engagement [48].

The frequency structure of real audio signals differs significantly from uniformly modeled noise signals. Real audio, such as music and speech, has a non-uniform energy distribution across frequencies due to its harmonic and rhythmic components, with most energy concentrated in low frequencies. This is linked to the physical properties of sound sources [49].

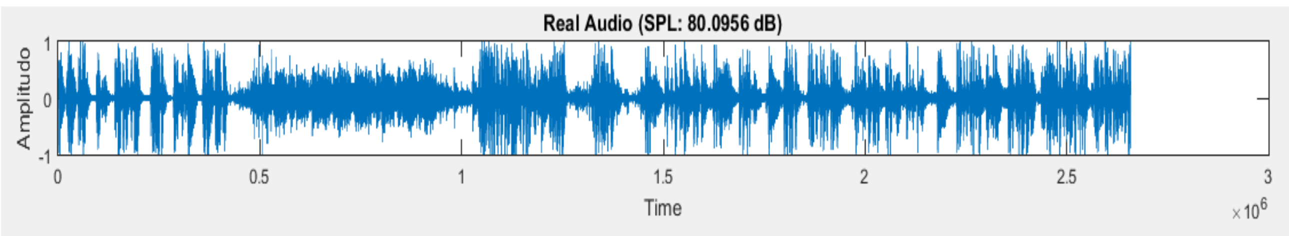

Figure 3. Real Signal Visualisation

In contrast, modeled noise signals like white noise have a flat spectral density, distributing energy evenly across all frequencies. This structured energy in real audio aids in applications like spectrogram analysis and improves audio quality, while noise signals remain unpredictable, making them less suitable for tasks requiring frequency-specific features, such as speech recognition [50]. Recent advancements in signal processing have harnessed these unique features to improve audio classification [51].

***SPL comparison between signal types***

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SPL Pink Noise: 47.5134 dB
SPL White Noise: 93.998 dB
SPL Sinusoidal Signal: 90.9691 dB
SPL Audio Nyata: 80.0956 dB
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Figure 4. SPL comparison between signal types

Figure 4 illustrates the comparison of Sound Pressure Level (SPL) across the different types of audio signals analyzed in this study. The results reveal that both pink noise and white noise exhibit a relatively even distribution of SPL across the frequency spectrum. This uniformity is a result of their spectral characteristics: pink noise distributes power equally across each octave, while white noise maintains constant power across all frequencies. These properties lead to a smooth and wide SPL response, making them suitable as reference signals in audio testing and system calibration.

In contrast, sinusoidal signals demonstrate a highly localized SPL pattern. The SPL curve for sinusoidal input is marked by distinct peaks that align with the signal's dominant frequency, while the SPL value outside that frequency band remains minimal. This is expected, given the single-frequency nature of sinusoidal waves, which concentrates energy within a very narrow band. This characteristic makes sinusoidal signals useful in isolating system responses and identifying frequency-specific behaviors in an acoustic system.

Real audio signals, on the other hand, show the most complex and irregular SPL patterns. The SPL variations in real audio are influenced by a combination of amplitude dynamics, frequency richness, and transient acoustic events inherent in natural environments. Unlike the synthetic signals, real audio contains speech, background noise, environmental reverberations, and temporal fluctuations that produce a more diverse SPL profile. These findings are consistent with the observations of Alkmim et al. [52], who emphasized the uneven energy distribution in authentic audio recordings compared to modeled signals. Similarly, Burke et al. [53] noted that fluctuations in SPL within real-world acoustic environments contribute to unique auditory experiences, which cannot be replicated by synthetic noise signals. Pohlhausen et al. [54] further supported this by demonstrating how SPL variability in natural settings significantly affects auditory perception and listener comfort.

The results of this analysis hold practical implications for various audio engineering and acoustic applications. In the context of audio system design, understanding how SPL behaves in response to different signal types allows for better calibration, tuning, and optimization of sound systems. For instance, systems used in concert halls might benefit from adjustments based on the behavior of real audio SPL, while noise control solutions in industrial environments may prioritize modeled signals like pink or white noise for simulation and testing. Moreover, recognizing the dynamic and transient nature of SPL in real-world recordings can aid in designing more adaptive systems that respond effectively to environmental changes.

Overall, this study demonstrates that SPL analysis is a valuable method for characterizing acoustic signal properties. The diversity in SPL responses across signal types highlights the importance of selecting appropriate audio test signals based on the specific goals and acoustic conditions of a given application. These insights provide a foundational understanding for further exploration in psychoacoustic modeling, signal processing, and audio system optimization.

## CONCLUSIONS

This study analyzed the Sound Pressure Level (SPL) characteristics of various audio signals using MATLAB, highlighting distinct acoustic patterns across pink noise, white noise, sinusoidal, and real audio. The results show that synthetic signals exhibit predictable and uniform SPL distributions, while real audio signals demonstrate dynamic and irregular SPL behaviors due to their complex structures and environmental variations.

The use of MATLAB proved effective for generating, measuring, and visualizing SPL, offering valuable insights for audio system analysis and design. These findings can inform future developments in audio calibration, signal processing, and adaptive acoustic technologies, reinforcing the importance of signal-specific analysis in modern audio engineering.

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