Hi-pass Pink Noise and Standard Volume for Auditory Experiments

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Abstract. This research analyzes the irrational acoustics of common reference sound source known as pink noise and proposes hi-pass pink noise by removing unnecessary pitch range. Compared to the original pink noise, 20Hz of hi-pass pink noise had a minimum of 20% unnecessary energy reduction and a marginal benefit of 0.7dBFS amplitude, while 40Hz of hig-pass pink noise had a 30% reduction and 1.6dBFS marginal benefit. Despite such physical features, hi-pass pink noise did not show audible difference, hence can replace pink noise regarding acoustic measurements and related research. Not only the frequency characteristics but also the variations in energy make the pink noise suitable for reference sound source. A reference sound source, the Comfortable Maximum Level (CML) is suggested to carry out sound comparison with other sound sources and can be used as a standard volume for pink noise.

Keywords: Pink Noise, Hi-pass Filter, A7B

1 Introduction

Unrelated to time, pink noise has constant energy, thus can exclude time factor and be used for audio systems or reference sound sources for analytical purposes. Furthermore, it is widely used for research purposes such as for summing noise. Despite its broad range of use, focused research as not been conducted on pink noise with the exception of its 1/f frequency characteristics that are similar to natural sounds; most of the studies are limited to the field of electromagnetism and physics. Therefore, it is necessary to find a reasonable reference sound sources for auditory aspects and to select experimental and standard volume[1][2].

<table>
<thead>
<tr>
<th>Category</th>
<th>Scale</th>
<th>Frequency Range [Hz]</th>
<th>Central Frequency[Hz]</th>
<th>Percentage of energy [unit: 100%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultra-low Frequency</td>
<td>~ 0 Octave C#</td>
<td>~ 17</td>
<td>-</td>
<td>20</td>
</tr>
<tr>
<td>Ultra Low Tone</td>
<td>~ A7WB</td>
<td>0 Octave C# ~</td>
<td>17 - 29</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>~ A7NB</td>
<td>0 Octave A# ~</td>
<td>29 - 49</td>
<td>38</td>
</tr>
<tr>
<td>Low Tone</td>
<td>1 Octave G ~</td>
<td>49 - 139</td>
<td>83</td>
<td>11.5</td>
</tr>
<tr>
<td>Mid Low Tone</td>
<td>3 Octave C# ~</td>
<td>139 - 392</td>
<td>233</td>
<td>11.5</td>
</tr>
<tr>
<td>Mid Tone</td>
<td>4 Octave G ~</td>
<td>392 - 1109</td>
<td>659</td>
<td>11.5</td>
</tr>
</tbody>
</table>
2 Problems of Pink Noise

Pink noise naturally occurs in wide ranges and is used for input/output data in various fields. There are notable noise differences between \( \alpha \) being close to 1 and \( \alpha \) being in an approximately wide range of .

\[
\begin{align*}
\text{White Noise} & : a = 0, S(f) = \frac{1}{f^0} = \frac{1}{1} = 1 \\
\text{Pink Noise} & : a = 1, S(f) = \frac{1}{f^1} = \frac{1}{f} \\
\text{Brown Noise} & : a = 2, S(f) = \frac{1}{f^2}
\end{align*}
\]

Fig. 1. Frequency spectrum of pink noise

Human’s audible range is commonly known to be between 20 to 20000Hz, but everyday use sound source contains inaudible pitch with energy. This inclusion is a natural phenomenon and does not cause any problems. However, all digital sound source as a limited domain of 9dBFS and is projected within the regenerative frequency of a speaker. Depending on the characteristics of a speaker unit, a specific signal can be played within the limited frequency domain, but when the input energy exceeds this advised limit various problems may occur[3][4].

3 Acoustic characteristics of High-pass pink noise

The definition of a Hi-Pass Pink noise is a sound source that has eliminated unnecessary energy below the pitch range in pink noise. A common “Hi-Pass Pink
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Noise is simply a pink noise that has hi-passed the frequency range of 20Hz. This research classified the hi-pass applied frequency into 6 subjects and analyzed its volume.

Fig.2 shows an enlarged hi-pass pink noise spectrum below a pitch range of 100Hz. The applied hi-pass filter of window function is Blackmann and the size of FFT is 16384. While current pink noise rapidly increases energy as frequency decreases, the hi-pass pink noise eliminates energy below certain frequency.

Fig. 2. Spectrum of existing pink noise and Hi-pass pink noise

3.1 Sound Level based on experiments of Pink Noise

This research defined the standard volume of pink noise as the suitable volume using CML. This is the maximum volume within the domains of comfort in the perspective of the auditor actively listening to a sound source (usually music).

CML can be interpreted as the advised, optimal standard volume and can relatively decide the effective volume from the optimal standard. The calculations of CML value was defined by the mean of MCL[5] and UCL which are relatively accurate. This applies within the range of 4th and 5th range shown in table 2. The equation of CML is as follows:

\[
\text{Comfortable Maximum Level (CML)} = \frac{\text{MCL} + \text{UCL}}{2}
\]

The experiment used the increase approach method with the assumption that the pink noise generated to the listener is the necessary sound. The listener understood the MCL as a sound too small to hear and UCL as a sound extremely uncomfortable giving displeasure.

The experiment results with 30 participants showed that the mean of CML was 62.8dB(A) and observed between 59.7dB(A) and 66.4dB(A). As mentioned above, the aim to elect the volume standard for pink noise using approximative and intuitive
decision making has brought out a final choice of 60dB(A) with decimals rounded down from the mean of the experiment results.

4 Conclusion

Although current pink noise is widely used as reference sound source for acoustic measurement and analysis, detailed research related to auditory characteristics. This study analyzed the irrational acoustics of existing pink noise and suggested the hi-pass pink noise as the solution.

Even though the hi-pass pink noise differs with the existing pink noise frequencies, waves, and energy characteristics, when audited they carry out similar auditory responses and volumes. Hi-pass pink noise excludes a frequency range that does not affect the auditory recognitions thus reduces the unnecessary energy load on amps and speakers.

Moreover, 60dB measured using CML can be effectively used as the standard volume for reference sound source and can be produced without technical difficulty which can be applied directly at the site.

References