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On the effects of derivation method on statistical data in environmental noise measurement

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Statistical Levels (percentiles or Lns) are widely employed for analysis and interpretation of large sets of noise data, and can be obtained either from implementations in Sound Level Meters or by post- processing. The type of source data and the sampling rate are often not specified. Samples can either be regular instantaneous snapshots of time weighted sound pressure level, or short samples of integrated sound level. The choice of sampling rate can vary. Due to the statistical nature of Lns the sample size should be an important consideration in determining the quality of the resulting data. In cases where the noise level distribution is bimodal or multimodal, a simple 'bin-counting' algorithm may result in significant differences in Ln values compared to a more sophisticated algorithm using interpolation. Analysis is presented on the effect on Ln data of different choices of source data and sampling rate, with input data including a range of different 'real-world' noise climates and regular electrical signals of varying impulsivity. The inverse relationship between sample size and uncertainty is investigated. The paper describes the test procedure for Lns described in DIN 45657:2005 and suggests alternative tests intended to provide better coverage of potential variation in results due to differences in implementation.

Introduction

Statistical Levels, commonly known as 'Lns', are used in many noise measurement regulations around the world. In short, an Ln value represents the decibel level exceeded for a given percentage of the measurement duration. For example 'L10' is the level exceeded for 10% of the measurement time.

Ln values are calculated internally by many Sound Level Meters, but this function is not described within the International Standard IEC 61672:2002 [1].

International Standard ISO 1996-2:2007 [2] states that the Leq sampling rate should be less than 1 second, or if time weighted sound pressure level is used the sampling time should be less than the time constant (0.125 s for Fast). However, in modern Sound Level Meters and software post-processing, many choices of data type and sampling rate may be available, leading to a potential lack of clarity and consistency. This paper investigates the effects of the choice of source data type and sampling rate on resultant Ln values.

DIN standard 45657:2005 [3] includes specifications and test methods for Ln data. The source data type and sampling rate are not referred to, and the recommended tests involve signals that vary in level only gradually over time. This work is intended to be a starting point for research into test methods with comprehensive coverage of these aspects of Ln derivation.

1 Theory

Sound Level Meters typically calculate and store several simultaneous noise metrics. Typical data types are LAF (1), LAFMax (2) and LAeq (3).

$$L_{AF} = 10\ \log_{10}\left(\frac{p_A^2}{p_0^2}\right) dB \tag{1}$$

$$L_{AFMax,T}(t) = MAX\left[L_{AF}(\tau)\right]_{t-T}^{t}\ dB \tag{2}$$

$$L_{Aeq,T} = 10\ \log_{10}\left[\frac{1}{T}\cdot\int_{t-T}^{t}\left(\frac{p_A^2}{p_0^2}\right)\right] \tag{3}$$

Lns can be calculated either internally in the Sound Level Meter during the measurement, or by post-processing of downloaded time-history data. The duration (i.e. sampling rate) of stored time history values can typically be selected by the operator, between a few milliseconds to several seconds.

To derive Ln values, samples of a particular metric are fed at a regular sampling rate into 'counting bins' during the measurement period. At the end of the measurement period, the count values in these 'bins' are accumulated into histograms from which specific Ln values are derived.

2 Experiments

Three noise sources were chosen:

a) 'Background' - the typical noise climate in a quiet rural residential garden, comprising slight wind noise with occasional birdsong and distant traffic.

b) 'Constant noise above Background' - quiet rural background noise with an intermittent continuous louder noise, such as that from a cental heating boiler or industrial motor. (The louder noise was simulated using a radio tuned between stations). The louder noise was present for 10% of the measurement duration.

C) 'Hammering' – rural background noise with multiple loud impulsive banging noises (created by repeatedly hitting a hammer on a wooden board).

Each sound source was recorded then played back into a Sound Level Meter several times, with the meter set to different time history logging rates. Time history data was then downloaded to a PC and Statistical Levels derived using post-processing software.

Three sampling rates were chosen for analysis:

- 10 ms (1/100th second)
- 62.5 ms (1/16th second)

- 2 s (2 seconds)

Three metrics were chosen for analysis:
1 LAeq: integrated sound level
2 LAeq Fast: Fast-time-weighted level calculated by applying an exponential time-weighting filter to LAeq samples before passing to the Ln bins.
3 LAFMax: the Maximum, Fast-time-weighted sound level during each sampling period.

Charts of the time history data for each source are shown in Figures 1, 2 and 3.

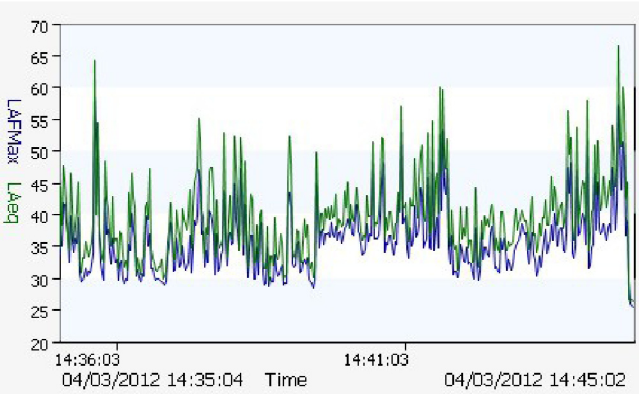

Figure 1: Background, 62.5 ms

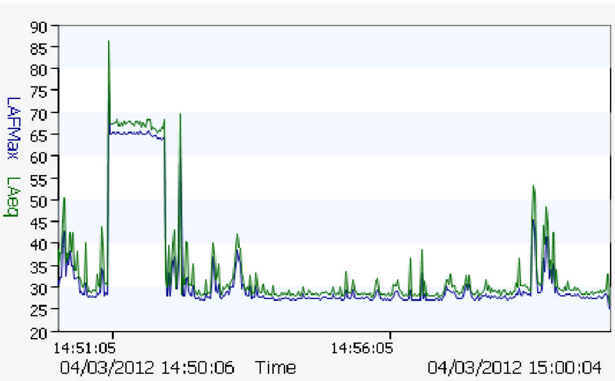

Figure 2: Constant noise above Background, 62.5 ms

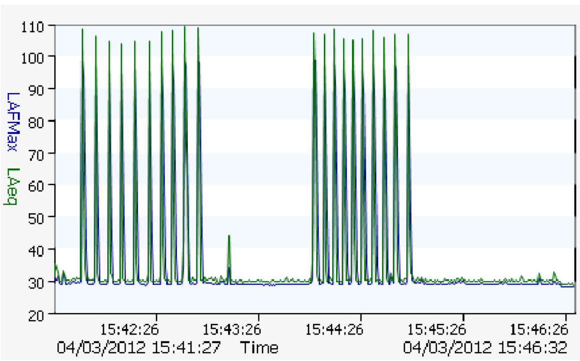

Figure 3: Hammering 62.5ms

3 Results

The three noise sources were measured at each of the three time history rates, then the data downloaded into PC software and processed to produce Ln values and histograms.

3.1 Background

Results for the Background noise in common Ln values are given in Table 1:

		L1	L5	L10	L50	L90	L95	L99
10 ms	LAeq	44.2	38.5	36.6	31.3	28.5	28.0	26.2
	LAF	45.0	38.9	36.8	32.0	28.9	28.4	27.6
	LAFMax	45.1	39.0	36.9	32.1	28.9	28.5	27.6
62.5 ms	LAeq	44.2	38.5	36.7	31.7	28.7	28.3	27.7
	LAF	44.8	39.0	36.9	32.1	28.9	28.5	27.8
	LAFMax	45.6	39.6	37.3	32.4	29.1	28.6	27.9
2 s	LAeq	44.6	40.0	37.5	32.8	29.2	29.0	28.2
	LAF	44.6	40.0	37.5	32.8	29.2	29.0	28.2
	LAFMax	53.0	47.2	44.4	36.2	30.7	29.7	29.1

Table 1: Ln results for Background

Figure 4 shows the histogram of level against normalized count rate for the different source types and sampling rates. It can be seen that the 10 ms and 62.5 ms sampling rates show similar distributions, but the 2 second rate contains a higher proportion of higher levels.

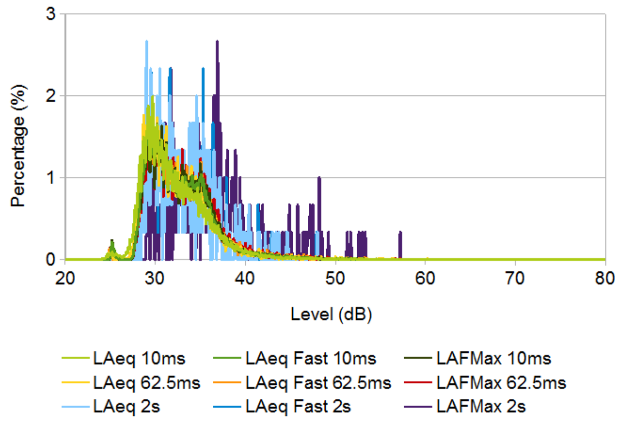

Figure 4: Background normalized histogram

Figure 5 shows the corresponding cumulative histograms. It can be seen that most source types and rates show very similar results, except for the 2 second LAFMax.

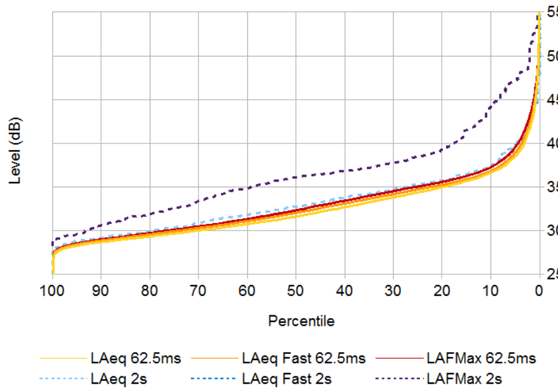

Figure 5: Background cumulative histogram

3.2 Constant Noise above Background

Results for common Ln values are shown in Table 2:

		L1	L5	L10	L50	L90	L95	L99
10 ms	LAeq	65.6	64.0	43.4	27.4	26.4	26.2	25.6
	LAF	64.8	64.3	54.9	27.3	26.8	26.7	26.6
	LAFMax	64.8	64.4	54.9	27.3	26.8	26.7	26.6
62.5 ms	LAeq	65.0	64.3	45.4	27.3	26.7	26.6	26.3
	LAF	64.8	64.3	54.0	27.3	26.8	26.7	26.6
	LAFMax	64.9	64.5	56.4	27.4	26.9	26.8	26.7
2 s	LAeq	64.6	64.4	51.2	27.3	26.8	26.7	26.6
	LAF	64.6	64.4	51.2	27.3	26.8	26.8	26.6
	LAFMax	65.4	65.0	63.7	28.0	27.1	27.0	26.9

Table 2: Ln results for Constant noise above Background

The histograms at 62.5 ms and 2 s sampling rates, Figures 6 and 7, show the bimodal distribution - with no samples between about 50 and 60 dB.

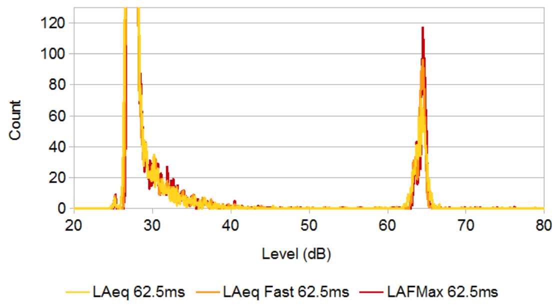

Figure 6: Constant noise above Background 62.5 ms histogram

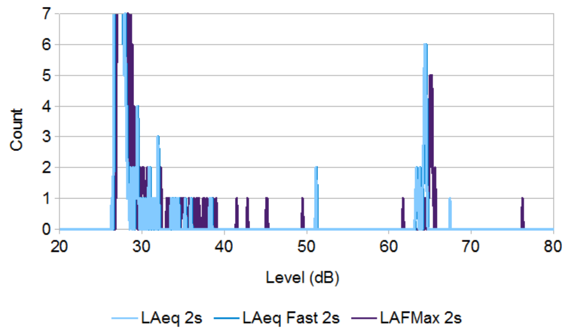

Figure 7: Constant noise above Background 2 s histogram

Figure 8 shows the entire cumulative histogram for all data types. Note the sharp vertical section in the region of the L10 percentile.

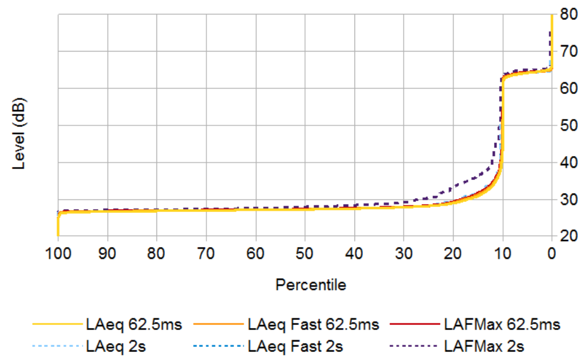

Figure 8: Constant noise above background Cumulative histogram

In Figure 9 the detail of the region around L10 is shown. From this it can be seen that small changes in the proportions of quiet and loud components can result in large changes in L90, even for the most consistent data types.

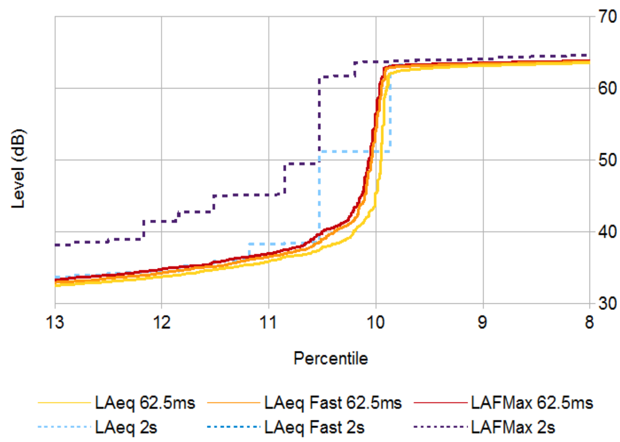

Figure 9: Constant noise above background Cumulative histogram, detail

3.3 Hammering

Results for commonly-used Ln values are in Table 3. Note the percentiles from L99 to L50 are similar but the L10, L5 and L1 show significant differences.

		L1	L5	L10	L50	L90	L95	L99
10 ms	LAeq	65.1	31.3	30.0	29.0	28.1	27.8	27.4
	LAF	92.4	72.2	46.8	28.9	28.6	28.5	28.0
	LAFMax	92.6	71.6	45.3	28.9	28.7	28.6	28.0
62.5 ms	LAeq	71.8	31.6	29.7	28.9	28.5	28.4	28.2
	LAF	92.6	71.8	45.6	28.9	28.7	28.6	28.5
	LAFMax	94.6	74.3	48.5	29.0	28.7	28.7	28.6
2 s	LAeq	87.6	86.4	84.3	28.9	28.7	28.7	28.5
	LAF	87.6	86.3	84.3	28.9	28.7	28.7	28.5
	LAFMax	98.9	97.5	95.5	29.3	29.0	29.0	28.9

Table 3: Ln results for Hammering

Figure 10 shows the histogram of level against normalized count rate for the different source types and sampling rates.

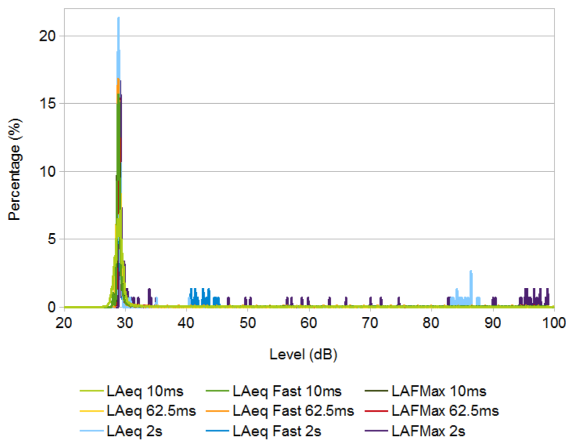

Figure 10: Hammering normalized histogram

Figures 11 and 12 show histograms for the Hammering noise at higher and lower sampling rates. At the 2 second rate there are very few samples between 45 and 85 dB.

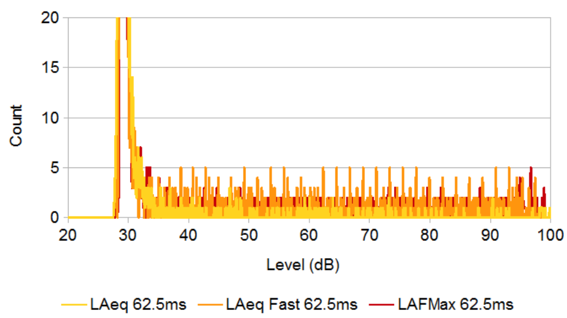

Figure 11: Hammering 62.5 ms histogram

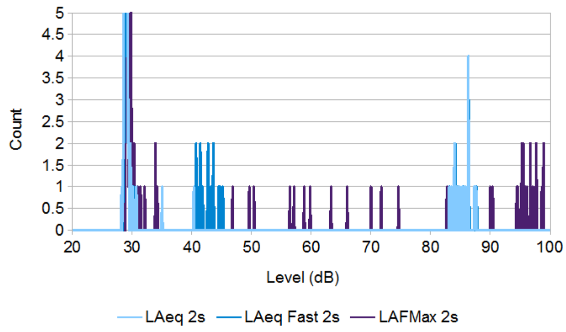

Figure 12: Hammering 2 s histogram

The differences in results between methods for the Hammering noise are illustrated in Figure 13.

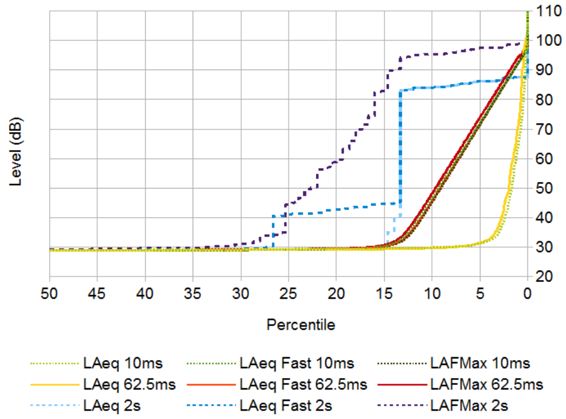

Figure 13: Hammering cumulative histogram, detail

4 Interpretation

In the 'Background' measurements, the source data type and sampling rate have a negligible effect - except for 2 second LAFMax data, which gives higher results. Over this relatively long sample duration – significantly longer than the Fast time constant of 0.125 s - each sample value represents the highest instantaneous LAF within the 2 second period. Thus samples are skewed toward higher levels.

In the 'Constant Level above Background' results, the source data type is seen to influence results by up to 20 dB dB for L10. The low data rate at 2 second sampling rate results in a wide gap between populated bins near the L90, and the specific algorithm used to derive the L90 value could produce widely varying results. The algorithm used in this work used a 'nearest higher bin' rule. A different algorithm, using interpolation between empty bins, may have produced a significantly different decibel value.

It should also be noted that short-duration (10 ms) LAeq samples and Fast time-weighted values produce L10 results that differ by 11.5 dB. For this kind of short-duration impulsive noises, the decay rate of the Fast time-weighting has a significant effect on the statistical levels.

For the 'Hammering' noise, it can be seen that the shorter (10 ms and 62.5 ms) and longer (2 second) time histories show markedly different representations of the source data. Figures 14 and 15 show detail of two hammer blows over 11 seconds, with 10 ms and 2 second time history respectively.

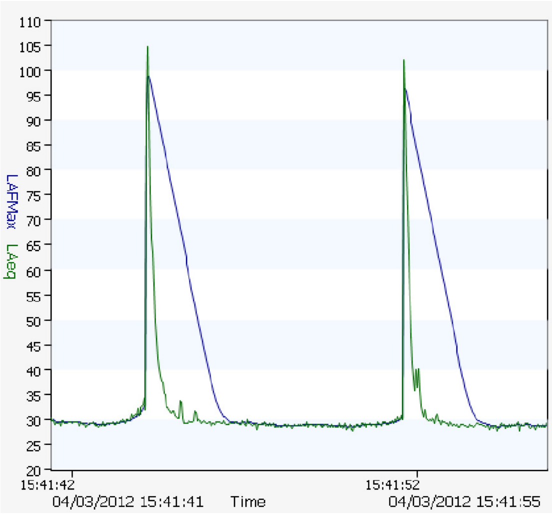

Figure 14: 'Hammering', 10ms time history detail

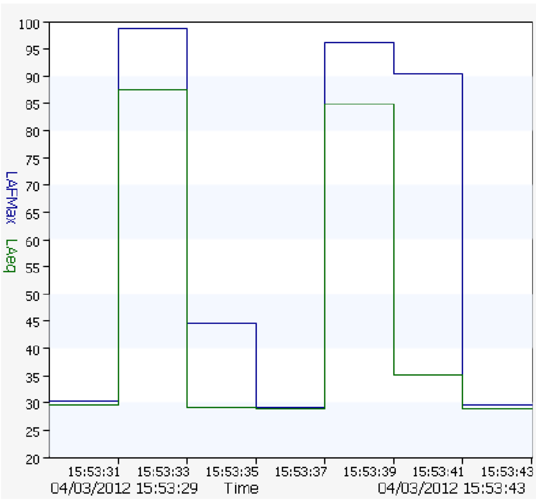

Figure 15: 'Hammering', 2 second time history detail

5 Discussion

The source data types and rates used in this work represent extremes which were selected in order to gauge whether these factors have the potential to affect results to a significant degree. The LAeq Fast 2 s rate and the LAFMax 2 s rate are not mandated by measurement standards and should not be used in practice. The intention of this work is to show how the accidental use of inappropriate source data and rate can produce results that differ by many decibels from that from appropriate sources. Research on comparisons of Ln source data types typically used in worldwide standards will form the basis of future work.

The DIN 45657 [3] test method uses continuous levels, changing in 0.5dB steps over relatively long time periods, and thus serves the purpose of testing bin resolution and correct statistical derivation - but not time weighting.

An enhanced test method could possibly be devised, using larger step-changes in level in order to incorporate the influence of time weighting into the tests. Research into such a test method will provide the basis of future work.

Conclusions

The results presented here suggest that the choice of source data type and sampling rate can have a large impact on resultant Ln values. The magnitude and nature of these variations is dependent to some extent on the impulsivity of the noise being measured. Sampling rate and time weighting are important factors.

International Standard ISO 1996-2:2007 [2] specifies that Ln results should be reported with the parameter basis, time weighting and class interval (i.e bin width) included. Such clarity is important in preventing invalid comparisons between Ln values derived using different methods.

References

[1] IEC 61672-1:2002, *Electroacoustics – Sound level meters – Part 1: Specifications*.

[2] ISO 1996-2:2007, *Acoustics – Description, measurement and assessment of environmental noise – Part 2: Determination of environmental noise levels.*

[3] DIN 45657:2005, *Sound Level Meters – Requirements for special applications.*