Standard ECMA-425

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Statistical background correction for information technology and telecommunications equipment noise measurements

Standard

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Introduction

This standard describes a statistical background correction (SBC) for removing background noise contributions from measured noise levels. Measured source levels include a background contribution because background noise is present during source measurement. Since the source is of interest, there is motivation to remove the background contribution. The background must be estimated from background samples obtained when the source is not operating. Background estimation and measured source level correction become increasingly difficult as background fluctuation increases and confidence in the background contribution decreases.

The formulation of the SBC addresses this situation with an explicit description of time-varying background noise. The statistics of the background noise are assumed to be time-invariant (stationary) and are estimated from samples of the background noise. Application of the SBC to a measured source level produces a background corrected source level that upper bounds the true source level with known confidence. The magnitude of the SBC increases with background steadiness and with background proximity to the measured source level, as confidence in the measured background increases.

The description of background variation distinguishes the SBC from the legacy background correction (LBC) K_1, which has no such description. Use of the SBC is permissible only for adequately steady backgrounds, but the legacy correction may be used for any background, regardless its fluctuation. The nature and values of SBC and LBC maxima also contrast. The SBC maximum is determined by considerations of background fluctuation and sampling, while heuristic caps limit the legacy correction according to the standard—ISO 3741, ISO 3744, ISO 3745, and ISO 11201—and measurement grade being followed. The various legacy caps produce different corrections that obscure source comparisons and introduce a 0.8 dB “grade penalty” such that background-corrected source levels for engineering grade are lower than for precision grade, thereby discouraging precision grade measurements.

The SBC avoids the grade penalty by its uniform use of background noise statistics. The SBC depends on measured source-background level difference, like the LBC, and on background steadiness, unlike the LBC. Dependencies on grade and standard like the heuristic caps of the LBC are avoided.

For steady backgrounds close in level to the measured source the SBC is larger than the LBC and provides lower background corrected source levels. Minimized background corrected source levels are often desired for precision grade 1 and engineering grade 2 measurements. For grade 1 the legacy correction is capped at 0.46 dB for source-background level differences ΔL below 10 dB; for grade 2 it is capped at 1.26 dB for ΔL below 6 dB. For steady backgrounds within 6 dB of the measured source ($\Delta L < 6$ dB) the SBC is as much as 3 dB greater than the LBC when used for grade 1, and up to 2 dB greater than the LBC when used for grade 2, with correspondingly lower background corrected source levels.

At the publication of this standard, no other standard tied the SBC to measurement grade. No future standard should impose such an association because the SBC is independent of and unaffected by measurement grade.

Since the statistical and legacy background noise corrections produce different source corrections, it is envisioned that future noise emission standards allow test directors to choose between the two corrections. SBC implementation involves a modest increase in processing of background samples, to figure not only the measured mean but also the measured variance of background noise. The additional effort is justified when accuracy is needed, and the measured source level is within 6 dB of a steady background.

It should be noted that, while the SBC described in this standard applies to acoustic decibel levels like sound pressure level and sound power level obtained with one or more sensors and spanning narrow or broad frequency bands, the SBC framework may also be applied to other dynamic signals like acceleration, velocity, and displacement.

For the 2nd edition, the independence of the SBC and measurement grade was emphasized in the Scope, while also noting that the relative magnitudes and advantages of the SBC versus the LBC often depend on measurement grade. Guidance on background sampling was clarified in Clause 7. Clarifications and corrections were made in Annexes A and B.

This Ecma Standard was developed by Technical Committee 26 and was adopted by the General Assembly of December 2025.

Statistical background noise correction for information technology and telecommunications equipment noise measurements

1 Scope

This standard describes a statistical background noise correction by which background noise contributions may be removed from measured noise levels. The statistical background noise correction is an alternative to the legacy background noise correction found in ECMA-74 and ISO 7779, ISO 3741, ISO 3744, ISO 3745, and ISO 11201.

Background noise corrections are used to obtain the background corrected source level, which is an estimate of the level radiated by the source or device under test. The background corrected source level is obtained by subtracting the background noise correction from the measured noise emission or source level, which contains both source and background contributions.

The statistical background correction (SBC) is independent of and unaffected by measurement grade. No present or future standard should link the SBC to measurement grade since the SBC is applied in the same manner regardless of measurement grade, unlike the legacy background correction (LBC) whose caps vary by measurement grade according to the standard calling the LBC.

Relative to the legacy background correction K_1, the SBC is often larger and provides lower background corrected measured source levels when steady backgrounds are close in level to the measured source. The SBC advantage applies to both low and high background levels for steady backgrounds, since the SBC depends on the measured source-background level difference and not absolute background noise level.

While the application of the SBC is independent of measurement grade, the SBC advantage over K_1 often depends on measurement grade because K_1 depends on measurement grade for background levels approaching the measured source.

The measurement of noise emissions generated by Information Technology and Telecommunications Equipment (ITT) is described in ECMA-74 and ISO 7779.

2 Normative references

The following referenced documents are indispensable for the application of this Standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ECMA-108 Determination of High-frequency Sound Power Levels Emitted by Information Technology and Telecommunications Equipment

NOTE ISO 9295[3] is ISO counterpart of ECMA-108. It is noted that, after the revision in 2015, the scope of ISO 9295 covers machinery and equipment in general, not limited to information technology and telecommunications equipment.

ISO 3741 Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Precision methods for reverberation test rooms

ISO 3744 Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Engineering methods for an essentially free field over a reflecting plane

ISO 3745 Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Precision methods for anechoic test rooms and hemi-anechoic test rooms

ISO 11201 Acoustics — Noise emitted by machinery and equipment — Determination of emission sound pressure levels at a work station and at other specified positions in an essentially free field over a reflecting plane with negligible environmental corrections

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
background noise level, L_B
the measured level of background noise in decibels (dB).

3.2
background corrected source level, $\hat{L}$
an estimate of the true source level obtained by subtracting a background correction from the measured source level, in decibels (dB).

3.3
measured source level, L
a sound level in decibels (dB) measured for operating equipment containing source and background noise contributions.

3.4
background correction K
an adjustment that removes the background contribution in a measured source level.

3.5
legacy background correction K_1
LBC

a background correction involving the measured source-background level difference.

3.6
legacy background correction cap K_C
the maximum allowable legacy background correction.

3.7
measured source-background level difference ΔL
the difference in decibels (dB) between the measured source level and the measured background level.

3.8
statistical background correction K_S
SBC

a background correction involving not only the measured source-background level difference but also the steadiness of the background noise.

3.9
minimum measured source-background level difference $\Delta L_{\min}$
the smallest measured source-background level difference at which the statistical background correction may be applied.

3.10
background steadiness M
a statistic describing the consistency and repeatability of the background taken over samples of the background.

3.11
measured background standard mean m_{b^2}
the average of background noise (not background noise level) over several samples of the background.

3.12
measured background standard deviation s_{b^2}
a statistic describing the consistency and repeatability of background noise (not background noise level) over several samples of the background.

3.13
background noise b^2
the time-average of the square of sound pressure generated by all sources other than the noise source under test.

3.14
background noise sample b_i^2
a sample of background noise with sample index i.

3.15
background sample count N
the number of background samples used to form the mean, standard deviation, and steadiness of the background.

3.16
enveloping percentile z_e
the standard normal percentile in the statistical background correction that serves to upper bound the true source with specified confidence.

3.17
physical source percentile z_p
the standard normal percentile in the minimum measured source-background level difference that assures with specified confidence a source description due to the equipment noise source under test, as opposed to a fictitious source arising from background fluctuation.

3.18
relative percentile error θ
the error in the realized (actual) enveloping percentile relative to the enveloping percentile arising from the formulation of the statistical background correction due to a non-stationary background or departure from the theoretical statistical distribution of the background sample difference.

3.19
background correction error δK
the maximum allowable decibel (dB) error in the statistical background correction.

3.20
nondimensional ratio x
a unitless quotient of a power or energy quantity relative to a reference quantity used to form a decibel (dB) level.

3.21
mean square sound pressure p^2
the time average of squared sound pressure.

3.22
sound pressure reference p_0
the reference quantity used to form a sound pressure level.

3.23
sound power W
the time rate of sound energy radiation by a sound source.

3.24
sound power reference W_0
the reference quantity used to form a sound power level.

4 Background corrected source level

The background corrected source level $\hat{L}$ is an estimate of the true source level and is given by:

$$\hat{L} = L - K \qquad (1)$$

where L is the measured source level which contains a background noise contribution, and K is a background noise correction. The measured source level is obtained by measuring the sound level of an operating device under test and contains source and background noise contributions. The source contribution is due to the sound radiated by the device. The background noise contribution is due to ambient and instrumentation noise. The source levels L and $\hat{L}$ may be sound pressure levels, sound power levels, sound energy levels, or any power or energy quantity that can be expressed in decibels, gathered by one or more microphones or other sensors, and may span a narrow, one-third octave, or broad (e.g. overall) band of frequency.

NOTE Because the scope and focus of this Standard is background noise correction, corrections for other systematic errors producing bias in measured source levels are omitted in Equation (1). Other systematic error sources include sound reflections, associated with the environmental correction K_2 of ISO 3744 and ISO 3745, as well as sound absorption, sound incidence angle, and instrumentation.

5 Statistical background noise correction

The statistical background correction is given by:

$$K_S = -10\log_{10}\left[1 - 10^{-\Delta L/10}\left(1 - \frac{2.33}{\sqrt{M}}\right)\right] \qquad \text{for} \qquad \Delta L \geq \Delta L_{\min} = 10\log_{10}\left[1 + \frac{39}{\sqrt{M}}\right] \qquad (2)$$

in which M is the steadiness of the background noise given in Equation 4 in Clause 6, ΔL is the measured source-background level difference, and $\Delta L_{\min}$ is the minimum allowable source-background level difference. A background corrected source level obtained using Equations (1) and (2) produces a background corrected source level that upper bounds the true source level with 95% confidence. The measured source-background level difference ΔL is the amount by which the measured source level L exceeds the measured background level L_B:

$$\Delta L = L - L_B \qquad (3)$$

The measured background level L_B is obtained by measuring the background noise while the source under test is not generating sound. The measured source and background levels L and L_B are averages over time of a power or energy quantity, expressed in decibels, and pertain to identical frequency bands, sensors, sensor locations, and spatial averaging schemes over sensors when spatial averaging is employed.

As Equation (2) implies, the statistical background noise correction is permitted only when the measured source-background level difference ΔL is greater than or equal to $\Delta L_{\min}$. The SBC shall not be used to adjust a measured source level when the measured source-background level difference is less than $\Delta L_{\min}$.

The statistical and legacy background corrections are compared in Annex A.

A spreadsheet implementing the SBC is available at https://ecma-international.org/publications-and-standards/technical-reports/ecma-tr-107/.

NOTE 1 The general form of the statistical background correction is $K_S = -10\log_{10}\left[1 - 10^{-\Delta L/10}\left(1 - z_e\sqrt{2/M}\right)\right]$ for $\Delta L \geq \Delta L_{\min} = 10\log_{10}\left[1 + z_p\sqrt{2/M}(1 + 4.34|\theta|/\delta K)\right]$ [1,2,3]. The standard normal percentile z_e specifies the confidence of the upper envelope applied by the background corrected source level on the true source. The standard normal percentile z_p specifies the confidence of obtaining a description of the source under test, not background fluctuation, from the background corrected source level at the minimum measured source-background level difference $\Delta L_{\min}$. Parameter δK is allowable background noise correction error. Parameter θ is the relative error of the upper envelope percentile z_e that arises when the realized background distribution departs from the background distribution underlying the K_S formulation.

NOTE 2 In Equation 2 the SBC is obtained with $z_e = 95\%$, and the minimum measured source-background level difference is obtained with $z_p = 99\%, |\theta| = 25\%$, and $\delta K = 0.1$ dB [4,5]. The latter three parameter values impose a more restrictive limit on the magnitude of K_S for backgrounds near the measured source than the $z_p = 95\%, |\theta| = 5\%$, and $\delta K = 0.2$ dB used in [1].

NOTE 3 The legacy background noise correction, when not capped, is equally likely to understate or overstate the true source level. This is seen from the equality of uncapped legacy background noise correction (upper right-hand side of Equation A-1) and the general form of the K_S correction in NOTE 1 when evaluated for 50% confidence at which $z_e = 0$.

NOTE 4 The requirement $\Delta L \geq \Delta L_{\min}$ statistically assures a physical source description by minimizing the difference of background noise sampled during source and background measurements for specified maximum errors δK in the statistical background noise correction and θ in the background noise difference percentile [1,2,3]. The measured source-background level difference ΔL contains background sample difference, since the measured source level and the measured background level each contain a background sample. It is possible for the background sample difference to be large enough that the time-varying background masquerades as a source, particularly when an unsteady background approaches the measured source level. In this case the background fluctuates high during source measurement and low during background measurement. To assure a physical source description of the equipment under test with high probability, the background sample difference is minimized to the 1st percentile of its statistical distribution, below the mean background sample difference. The percentile $z_p = 99\%$ is allowed by the symmetry of the distribution of the background sample difference and assures a physical source description 99 out of 100 times on average.

6 Background noise steadiness

To determine background steadiness at least three (3) samples of background noise shall be used. The following calculations are to be performed without numerical rounding.

Background noise steadiness M describes the consistency of the background noise and is given by

$$M = \left(\frac{m_{b^2}}{s_{b^2}}\right)^2 \tag{4}$$

in which m_{b^2} and s_{b^2} are the measured mean and measured standard deviation of the background noise b^2, which is the time-average of the square of background sound pressure. The measured mean and measured standard deviation of the background noise are obtained by:

$$m_{b^2} = \frac{1}{N}\sum_{i=1}^{N} b_i^2 \tag{5}$$

$$s_{b^2} = \left[\frac{1}{N-1}\sum_{i=1}^{N}(b_i^2 - m_{b^2})^2\right]^{1/2} \tag{6}$$

where $i = 1 \ldots N$ is sample index, and the b_i^2 are background noise samples and are related to samples of background noise level L_{Bi}:

$$b_i^2 = p_o^2 10^{L_{Bi}/10} \tag{7}$$

The 20 micro-Pa reference pressure p_o has no effect on steadiness because of cancellation in the numerator and denominator of Equation 4.

An example of the calculation of background steadiness is given in Annex B.

Uncertainty for background corrections and background corrected source levels are described in Annex C.

NOTE 1 Rounding is prohibited because it introduces numerical noise and reduces background steadiness.

NOTE 2 The SBC may be applied to any decibel level $L = 10\ \mathrm{lg}_{10}(x)$ in which the nondimensional ratio x follows the type of level. For sound pressure level, $x = p^2/p_0^2$ in which p^2 is the time average of squared pressure in Pascals and the reference quantity $p_0 = 20$ micro-Pa. For sound power level, $x = W/W_0$ is the ratio of sound power W in Watts to the reference quantity $W_0 = 1$ pico-Watt. The reference quantity cancels in the numerator and denominator of Equation 4 and therefore does not affect the SBC.

7 Background noise sampling

Background noise shall be measured while the equipment under test is configured not to generate noise.

Background noise shall be measured with the same microphone(s), at the same fixed or traversing position(s), and data acquisition system as for the equipment under test.

At least three (3) background samples, each measured not more than 36 hours apart, before or after the equipment noise measurement of interest, shall be used to form the SBC. The background samples are candidate background noise samples for forming the SBC according to Clauses 5 and 6.

The candidate background noise samples selected for SBC formation must be confirmed as statistically stationary relative to previously measured background data before using them to form the SBC.

NOTE 1 There are many ways to satisfy the background sampling requirement. The required minimum three (3) background samples may be measured over a period much less than 36 hours, for example before, after, and in between source measurements spanning a 1- to 8-hour period. Moreover, an on-going workflow involving one (1) background sample measured at the start and end of a work period, for example 8am and 5pm, satisfies the background sampling requirement, even on non-successive days like the first day of the workweek, since the background samples measured on the first day and the following day are within 36 hours of any equipment noise measurement on the first day.

NOTE 2 Ambient phenomena producing background noise include but are not limited to foot and vehicle traffic, HVAC and machinery operations, and instrumentation noise due to electromagnetic radiation from these operations. Listening to recordings can confirm that ambient events in outlier noise samples are absent from non-outlier background and equipment noise measurements.

NOTE 3 Visual inspection of background data may be used to confirm stationarity of background samples relative to previously measured background data. Augmented Dickey-Fuller (ADF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests may also be used [8,9].

NOTE 4 Outlier removal can restore stationarity of candidate background samples relative to previously measured background data. Outlier removal can also introduce competing effects on the SBC. Outlier removal increases background steadiness, thereby increasing the SBC. When a high background outlier is removed, the measured background level decreases, increasing the measured source-background level difference ΔL and decreasing the SBC. See Equation 3 and Figure B.1.

NOTE 5 Visual inspection and control charts may be used to identify outliers. The interquartile range (IQR) test and Carling's modified IQR test may also be used. The normal and Chi-square outlier tests are not recommended because the outlier effect on the measured mean and variance used in these tests tends to mask the outliers themselves [6,7].

NOTE 6 Statistical outliers among the candidate samples may be removed if and only if the ambient phenomena causing the outliers do not affect non-outlier samples and do not affect the equipment noise measurement of interest. Listening to recordings can confirm that ambient events in outlier noise samples are absent from non-outlier background and equipment noise measurements. Outliers generally indicate a change in the phenomena responsible for background noise.

NOTE 7 Instead of removing outliers, it is always preferable to repeat background and equipment noise measurements under controlled conditions.

NOTE 8 A library or baseline of background noise samples is needed to confirm that the background samples used to form the SBC are stationary relative to the previously measured background data. The background data library is also needed to identify outliers.

Annex A
(informative)

Statistical and legacy background noise corrections compared

The legacy background noise correction (LBC) K_1 is given by:

$$K_1 = \begin{cases} -10\,\lg_{10}(1 - 10^{-\Delta L/10}) & \Delta L > \Delta L_c \\ K_c & \Delta L \leq \Delta L_c \end{cases} \qquad \text{(A-1)}$$

in which ΔL is the measured source-background level difference, and the cap K_c limits the background noise correction to its value at a critical source-background level difference ΔL_c. Several measurement grade and frequency dependent caps are given in ISO 3741, ISO 3744, ISO 3745, and ISO 11201; apart from rounding there are two cap values: $K_c =$ 1.26 dB corresponding to $\Delta L_c =$ 6 dB and $K_c =$ 0.46 dB corresponding to $\Delta L_c =$ 10 dB. The two caps cause the “grade penalty” that produces background corrected source levels 0.8 dB lower for engineering grade than for precision grade methods [1,2,3].

Figure A-1 also shows the statistical background correction (SBC) K_S for background steadiness values of 30, 300, and 3000. The SBC increases with background steadiness and with decreasing measured source-background level difference.

Some features of the SBC:

- With sufficient background steadiness, the SBC can be 2 to 3 dB larger than the LBC at measured source-background level differences below 6 dB where caps limit the magnitude of the legacy correction.
- In the regime $\Delta L < 6$ dB where steady backgrounds approach the measured source level, steady backgrounds are rewarded with larger corrections, thereby incentivizing precision measurements and low noise chambers.
- When the LBC is capped, the SBC remains within 0.2 dB and below the uncapped legacy correction, approaching the LBC as background steadiness increases. This behaviour occurs because the SBC is sensitive to background steadiness, but the LBC is built on the assumption of a constant background.
- Unsteady backgrounds may be disqualified depending on the background steadiness variation and the measured source-background level difference parameters. The legacy background noise correction has no such restriction and may be applied for all backgrounds.
- The SBC produces background corrected source levels free of the grade penalty, which obscures source comparisons by 0.8 dB and perversely incentivizes measurement grade over precision grade.
- The SBC produces background corrected source levels that upper bound the true source with 95% confidence. When uncapped, the LBC bounds the true source with 50% confidence.

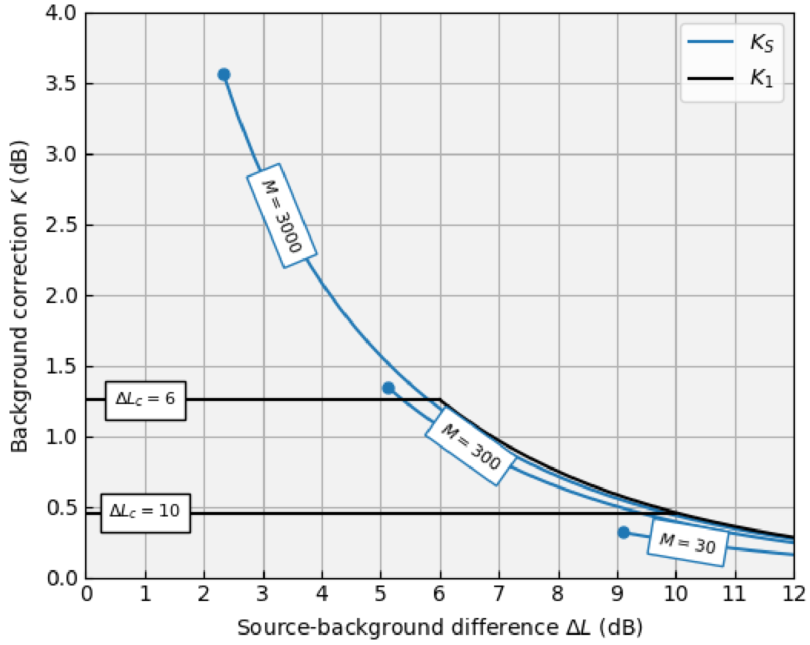

Figure A.1 – Statistical K_S and legacy K_1 background noise corrections

Annex B
(informative)

Background noise steadiness examples

Table B.1 gives examples of background noise steadiness are given using background noise data in acoustic rooms provided by three manufacturers, whose identity is withheld by request. The table shows four samples of background noise denoted as S1, S2, S3, and S4. Each sample of non-dimensional background noise, given by b_i^2/p_o^2, is related to the corresponding sample of background noise level L_{Bi} by Equation 7 and reference pressure $p_o = 20$ micro-Pa.

Table B.1 – Background noise for three chambers

Chamber	Background Noise Level (dB)				Nondimensional Background Noise				Statistics		Steadiness M
	S1	S2	S3	S4	S1	S2	S3	S4	Mean	Std. dev.	
Chamber A	6,9	7,0	7,5	7,3	4,9	5,0	5,6	5,4	5,2	0,33	250
Chamber B	16,56	16,75	16,56	16,57	45,0	47,0	45,0	45,0	45,8	0,975	2210
Chamber C	21,74	21,78	21,76	21,91	149	151	150	155	151	2,61	3360

Annex C
(informative)

Measurement uncertainty

The effect of background corrections on measurement uncertainty may be understood by recalling that background corrections remove the background contribution in measured source levels. During source measurement the background contribution combines with the source, upwardly biasing the measured source level relative to the true source. In the nomenclature of ISO/IEC Guide 98-3 [10] the measured source level contains “systematic error”. Removal of the systematic error by the legacy or statistical background correction is imperfect because the measured source-background level difference ΔL and background steadiness M parameters on which background corrections depend are estimates derived from background samples. It has been shown that background corrected source levels formed by the SBC and LBC are comparable in terms of overstating the true source level [5].

The uncertainty of a background corrected source level may be expressed using the methods of ISO/IEC Guide 98-3 [10]. The measured source level and measured background noise level have standard uncertainties given by the standard deviations s_L and s_{L_B} of the measured source and background noise levels, respectively. The sensitivity coefficient $c_{\hat{L}}$ of a background corrected source level $\hat{L}$ is given by :

$$c_{\hat{L}} = \begin{cases} 1 + \dfrac{1}{10^{\Delta L/10} - 1 + 2.33/\sqrt{M}} & \text{for } K_S \\ 1 + \dfrac{1}{10^{\Delta L/10} - 1} & \text{for } K_1 \end{cases} \quad \text{(C-1)}$$

in which K_S is the statistical background correction and K_1 is the legacy background correction. The sensitivity coefficient $c_{\hat{L}}$ describes the random error in the background corrected source level due to the random error in the measured source level L and measured background level L_B. See Equations (1) and (3).

NOTE 1 Source overstatement may occur because of the stochastic nature of background samples used to form background corrections. The source overstatement is defined as the excess of the background corrected source level above the true source. In reference [5] Monte Carlo methods are used to determine the envelopes that upper bound 95% and 99% of source overstatements for three background samples at the measured source-background level difference ΔL giving the largest overstatements, namely $\Delta L_{\min}$ for the SBC and ΔL_C for the LBC. The 95% envelope is 0.2 dB and constant over background steadiness for the SBC; for the LBC with $\Delta L_C = 6$ dB it increases to 1 dB with decreasing steadiness below the background steadiness of 250 where the 95% source overstatement envelopes for the SBC and LBC are equal and cross one another.

NOTE 2 Standard uncertainty is defined as the measured standard deviation in ISO/IEC Guide 98-3 [10].

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