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A SUPPLEMENT OF SOUND MEASUREMENT TECHNIQUE BY AN ONLINE QUALITY TEST PROCEDURE FOR THE INDICES L_{EQ} AND $L_{X\%}$

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As is well known every measured sound index like L_{eq} and $L_{x\%}$ has limited accuracy due to the usually occurring stochastic level fluctuations. This limitation can be taken into account adequately by calculating the confidence limits from the signal's microstatistic structure. The basic theory and its preconditions close to measurement practice have been established formerly by the author. An overview is given here. The method provides to work quality controlled in a flexible way. A PC-software for online performance is now available. Tested by field measurements this technique is applicable on the quality-monitored short-term separation of level components of different sound sources in the outdoor environment. The final results are the L_{eq} of the source of interest, the confidence limits of the L_{eq} and its resolution level. Resolution limits down to 10 dB below the residual sound level are practicable. This kind of application has already been introduced and used in Germany to some extent. At the present state of the art the tool also can be applied on sound transfer measurements, especially with relatively high background level in a receiver room, and on examining the influence of a small absorption model area for in-room damping, to be extended later to full scale.

1. INTRODUCTION

Environmental noise generally occurs in the form of continuous random signals. It is also well known that those signals are described quantitatively by evaluation indices as the energy equivalent sound level L_{eq} and the $L_{x\%}$ percentile level. The accuracy achievable within the measurement performance of environmental random signals is of interest when application is considered such that it is sensitive against uncertainties of the primary observations. This is the case if there are performed combinations of single measured index values within an evaluation algorithm which, for example, provides an interesting magnitude like L_{eq} of a sound source in the presence of inevitable background noise. It is evident that the precondition for this kind of quality monitoring is that the accuracy of the primary random sound level index is measured. This can be conveniently and is performed by a bracket confidence interval [1, 2].

The confidence interval is directly related by the cumulative distribution function (c.d.f.) to the variance of the excess fraction. This excess fraction is identical to the partition of the signal's instantaneous amplitudes with respect to a fixed level, say the expectation value of an interesting kind of percentile index. The variance of the partition is quite straightforward and accessible. The basic theory for calculation of the confidence limits have already been presented in references [2–4]. In further development of the methodology a software for the

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online monitoring of the confidence limits was established [5] from which two examples of application are presented in section 4. This was recently extended by a software for some types of sound level separation [4] due to a corresponding demand of the permitting practice and control of industrial plants by environmental authorities, also taking into account the background noise situation. An overview on the basic concept and on the features of the tool now available for more sophisticated sound evaluation in measurement practice are given here.

2. SOME REMARKS ON THEORY OF PERCENTILE VARIANCE AND SOUND LEVEL CONFIDENCE LIMITS

The goal in general is to describe the fluctuation range of a percentile which is calculated from the instantaneous values of an observable continuous random variable occurring during a definite time interval. As a special field of application this variable can be the sound pressure level as is considered within this context. The basic features of the system to be considered here are given in Figure 1.

The fraction q, $(0 \leqslant q \leqslant 1)$ of time during which a fixed given level noted by L_q is exceeded is determined by

$$q(L_q) = \frac{1}{T} \sum_{i=1}^{n} w_i(L_q) := \frac{W}{T}. \tag{1}$$

The notations used in this expression and illustrated by Figure 1 are: T is the measurement time interval, n in T observed number of the time intervals w_i, the "crossing up" intervals, created by the immediately successive crossing up and crossing down of the time-dependent sound pressure level relative to L_q. W denotes the sum of the crossing up intervals, here presupposed to be mutually independent. The number n should not be less than about 7.

If the variance of W the total of crossing up intervals is accessible, then according to equation (1) the variance of the partition q is also known. The variance of W dependent on the system's parameters is by its well-known basic definition [1] the mean square of the deviation from the expectation value of W (the average indicated by a bar): i.e.,

$$Var\, W = \overline{(W - \bar{W})^2} = \overline{W^2} - \bar{W}^2. \tag{2}$$

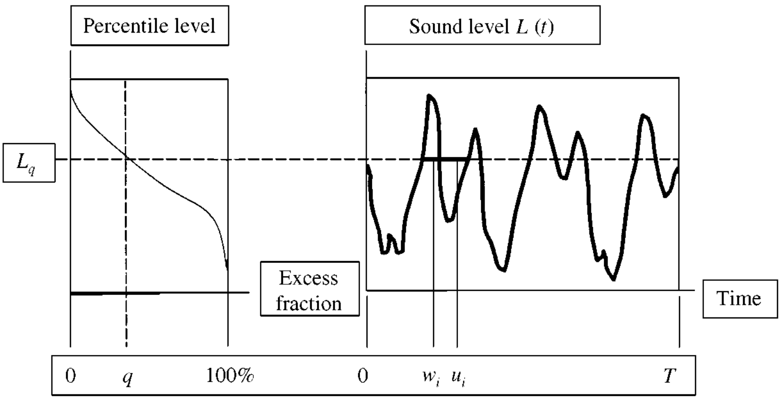

Figure 1. Definition of parameters used in equation (1) to estimate the excess fraction, denoted by q, with $0 \leqslant q \leqslant 1$, if the percentile is given, by summing the single crossing up intervals which occur within the given measurement time interval T. The crossing down intervals are denoted by u_i.

To calculate *Var W* the probability density function (p.d.f.) of W is to be expressed by observable statistical parameters related to the signal structure. The structure of this p.d.f. and its terms are determined by the following aspects.

(a) Within the evident constraint $W + U = T = \text{const.}$ the probability density functions for W and the analogous total U of the crossing down intervals u_i are still mutually independent as there are many possible variations in separately adding up the w_i- and u_i- elements to a fixed value of W and U respectively. As a consequence, one element of the p.d.f. for W occurring within $W + U = T$ must be the product of the p.d.f. for the free sums W and U respectively.
(b) Evidently, a fixed W or U value also principally can be established for every number of crossings. Hence, a further independent p.d.f. denoted by $f(n, T)$ has to be taken into account for the crossing number which also depends on T.

Hence, the final p.d.f. for W can be expressed by equation (3), in which $\varphi(W, n)$ and

$$\begin{aligned} \mathrm{d}^2 P(W, n, T) &:= P\{W \leqslant W' \leqslant W + \mathrm{d}W; n \leqslant n' \leqslant n + \mathrm{d}n \,|\, W + U = T\} \\ &= a(n, T)\,\varphi(W, n)\,\psi(T - W, n)\,\mathrm{d}W\, f(n, T)\,\mathrm{d}n. \end{aligned} \tag{3}$$

$\psi(U, n)$ denote the probability density functions for crossing up and crossing down if there are n stochastic periods within the interval T. The function $a(n, T)$ denotes a factor which normalizes $\varphi(W, n)\,\Psi(T - W, n)$ to unity over the parameter space $S_W = \{W: 0 \leqslant W \leqslant T\}$. The p.d.f. of the crossing number $n \in \mathbf{R}^+$ is denoted by $f(n, T)$.

For a treatable evaluation of equation (3) to a final expression containing only observable quantities and parameters given by measurement requirements, like the measurement time interval T, the Central Limit Theorem of Statistics [1] is used. Then the sum in equation (1) can be approximately presented as a normal distribution (1, Chapter 5.3) with the mean value parameter

$$\bar{W} = \bar{n} \cdot \bar{w} \tag{4}$$

and the variance

$$\sigma_W^2 = \bar{n} \cdot \sigma_w^2. \tag{5}$$

Hence, the p.d.f. $\varphi(W, n)$ in equation (3) can be denoted as

$$\varphi(W, n) = N(n\bar{w}, n\sigma_w^2) \tag{6}$$

and the corresponding $\psi(U, n) = \Psi(T - W, n)$ by

$$\psi(T - W, n) = N(T - n\bar{u}, n\sigma_u^2). \tag{7}$$

From these two equations after some algebraic rearrangement, one obtains

$$\begin{aligned} &\varphi(W, n)\,\psi(T - W, n) \\ &\quad = v_P N_W\left[\frac{n\bar{w}\sigma_u^2 + (T - n\bar{u})\sigma_w^2}{\sigma_u^2 + \sigma_w^2},\quad n\frac{\sigma_u^2\sigma_w^2}{\sigma_u^2 + \sigma_w^2}\right] N_n[n, \sigma_n^2], \end{aligned} \tag{8}$$

where

$$v_P := 1/(\bar{u} + \bar{w}) \quad \text{and} \quad \sigma_n^2 = n\frac{\sigma_u^2 + \sigma_w^2}{(\bar{u} + \bar{w})^2} \tag{9a, b}$$

are the mean frequency of crossing up and crossing down intervals, respectively (equation (9a)), and the number variance of the crossing intervals within the chosen measurement interval T (equation (9b)). The number n is still a freely varying parameter. Taking into account the usual normalizing requirement for a p.d.f., here for $\phi(W, n, T)$ one arrives at

$$\phi(W, n, T) = N_W f(n, T). \tag{10}$$

As is shown in reference [6] the p.d.f. $f(n, T)$ can be expressed as

$$f(n, T) = -\frac{\partial \Phi(T, n)}{\partial n} = -\int_0^T \frac{\partial N_{t'}(t' - n\cdot(\bar{u} + \bar{w}))}{\partial n}\,\mathrm{d}t' = N_n(\bar{n}, \sigma_n^2), \tag{11}$$

where $\Phi(T, n)$ denotes the c.d.f. of the sum of n stochastic periods, calculable by a $(2n - 1)$-fold convolution. Thus, the final form of $\phi(W, n, T)$ is

$$\phi(W, n, T) = N_W\left[\frac{n\bar{w}\sigma_u^2 + (T - n\bar{u})\sigma_w^2}{\sigma_u^2 + \sigma_w^2},\quad n\frac{\sigma_u^2\sigma_w^2}{\sigma_u^2 + \sigma_w^2}\right] N_n[\bar{n}, \sigma_n^2]. \tag{12}$$

Inserting equation (12) into the variance definition for W and integrating over n finally yields, also by account of equation (1),

$$Var\, q = \frac{\bar{n}}{T^2}\left[\left(\frac{\bar{u}}{\bar{u} + \bar{w}}\right)^2 \sigma_w^2 + \left(\frac{\bar{w}}{\bar{u} + \bar{w}}\right)^2 \sigma_u^2\right], \tag{13}$$

and finally, due to the relations

$$\frac{\bar{w}}{\bar{u} + \bar{w}} = q_w, \qquad \frac{\bar{u}}{\bar{u} + \bar{w}} = q_u, \qquad \bar{v} := \frac{\bar{n}}{T}, \tag{14–16}$$

one arrives at formulas suitable for practical application purposes in measurement;

$$Var\, q = \frac{\bar{v}}{T}(q_u^2 s_w^2 + q_w^2 s_u^2) = \frac{1}{T}\frac{q_u^2 q_w^2}{\bar{v}}(v_u^2 + v_w^2) = \frac{q_u^2 q_w^2}{\bar{n}}(v_u^2 + v_w^2). \tag{17a–c}$$

Here $\bar{v}$ is the Ratio $\bar{n}/T$; $\bar{u}$ and $\bar{w}$ are the average of the u_i and w_i respectively, s_u, s_w the standard deviations, and v_u, v_w the coefficients of variation ($v_u := s_u/\bar{u}$, etc.). All quantities in equation (17) are either known or observables. The parameters q_u and q_w ($q_u + q_w := 1$) and T are constants to be chosen according to the type of measurement task. Equation (17) is to be understood as an estimation-type relation. For this reason σ is replaced by the standard deviation s.

Equation (17) is valid if there are at least approximate stable conditions, i. e., v_u, v_w are about unity or less. A bracket confidence interval of the partition q is

$$q_u - q = q - q_l = t_{f;1-\alpha/2}[Var\, q]^{1/2}. \tag{18}$$

In equation (4) q_u, q_l are the upper and lower limit of the confidence interval, t the quantile of Student's distribution [1], and $f = n - 1$; and $1 - \alpha$ the confidence coefficient [1]. Equation (18) can be derived by transforming equation (1) into $q = (n/T)(\Sigma w_i/n)$ and applying analoguously—extended by the constant factors q_u and q_w—the well-known calculation procedure for the confidence limits of a mean value.

It should be ensured that the "true partition value", i.e., the partition of the signal's basic p.d.f. is in fact observed with a sufficient high probability. A reasonable criterion for this is established as follows. A position of any partition confidence limit outside the admitted q-variable space $S = \{q: 0 \leqslant q \leqslant 1\}$ makes no sense. Hence, the confidence limit which is located nearer to the edge of the q-space, denoted by q_{out}, must comply with the condition

$$q_{out} - q = t_{n-1;1-\alpha}\,[Var\, q]^{1/2} \leqslant q := 1 - q_{in}. \tag{19}$$

In equation (19) q_{in} denotes the greater (= inner) amount of the partition. Using equation (17c) one obtains the explicit minimum number condition

$$n \geqslant t^2_{n-1;1-\alpha}\, q^2_{in}(v^2_u + v^2_w). \tag{20}$$

For purely stochastic signals and confidence level 0·8 the minimum crossing number typically amounts between 5 and 10.

The spread of partition with regard to a fixed level L_q must be transformed into the level space to get the spread of the measured variable, here the percentile level. The partition and the physical variable, here the sound pressure level, per definition are interdependent by the c.d.f. From the practical point of view the transformation of the partition spread into the corresponding level's uncertainty can be accomplished in a relatively simple way: Numerous measurement evaluations already available show that for environmental noises the partition spread typically reduces down already after about 10 min to the order of magnitude of only a few percent. Thus the c.d.f. can be locally linearized without lack of relevant precision. Then by use of equations (18) and (17) the level distance V_L in dB of the upper and of the lower confidence limit (c. l.) from the measured L_x value itself can be determined by

$$V_L = (q_u - q)\frac{\mathrm{d}L}{\mathrm{d}q} = t_{n-1;1-\alpha}\left|\frac{dL}{dq}\right|\sqrt{\frac{\hat{v}}{T}(q^2_u s^2_w + q^2_w s^2_u)}. \tag{21}$$

In equation (21) $|\mathrm{d}L/\mathrm{d}q|$ denotes the inverse slope of the c.d.f. The numerical values of V_L occur typically between about 0·2 and 1·5 dB (A) for the most important types of environmental outdoor sound sources and measurement time intervals from about 5 min to 1 h.

V_L as a percentile related quantity depends on the partition parameter q. It can be used in a straightforward manner also to calculate the confidence limit of the level quantity L_{eq}. For this purpose the intensity values corresponding to the percentile quantities $L_x + V_{L,x}$ and $L_x - V_{L,x}$ are integrated separately across the interval $0 \leqslant q \leqslant 1$. Transformation of the two results into the level space yields the confidence limits of L_{eq}.

3. APPLICATION BY A MEASUREMENT SYSTEM DRIVEN BY SOFTWARE

For an online performed signal processing and representation of the L_x-accuracy according to equation (21) the neccessary software has been designed. For all kinds of L_x in steps of 1% from 1 to 99, the confidence limits are calculated by an online performance at confidence level 0·8 and given on to a screen and edited by a printer [7].

The reliability of this measurement technique was examined and confirmed by comparison of the results from equation (21) with the direct but much more time-expensive measurement of L_x-distributions from environmental (traffic) noise. It turned out that for outdoor noises the crossing up and down intervals are not mutually independent until about typically 2·5 further crossings in the mean [6]. By this the confidence interval is expanded by a "correlation factor" $b = 1{\cdot}6$.

4. MEASUREMENT EXAMPLES

In Figures 2 and 3 two measurement examples are shown. Example 1, presented by Figure 2, demonstrates the time-level diagram at 140 m distance from the edge of a chemical plant with sound emission in a stationary state. There is a superposition by the noise coming from nearby urban traffic. Example 2, presented by Figure 3, shows the time-level diagram at the edge of a highway with high-speed traffic.

5. POSSIBLE APPLICATIONS

5.1. NOISE COMPONENT SEPARATION

The separation of noise components is a common necessity to meet legislation and regulations for environmental protection, primarily based on the polluter pays principle. In consequence, the separation in a qualified manner is indispensible to take well-founded noise-abatement measures. Since this problem is not new, there exist already a few related procedures but not performing an additional quality control to cover the advantageous

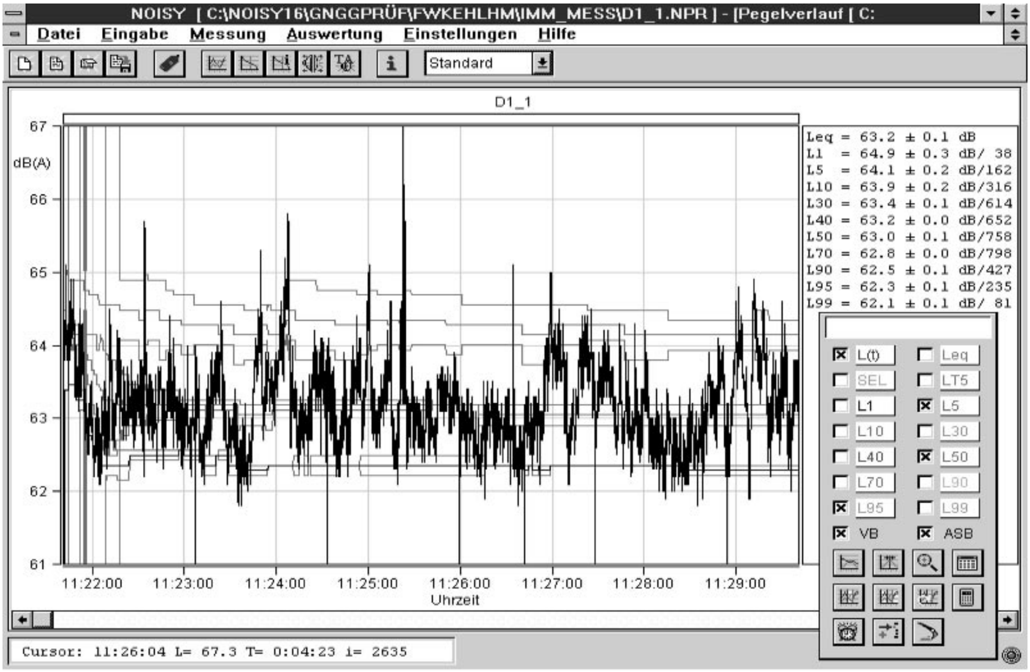

Figure 2. Sound pressure level and—with confidence intervals—the levels L_5, L_{50} and L_{95} in the vicinity of a chemical plant, slightly superposed by traffic noise. The last column in the table on the right above indicates twice the number of crossing intervals which occurred during the measurement. Translation of the german terms in the original computer print: Datei = File; Eingabe = Input; Messung = Measurement; Auswertung = Evaluation; Einstellungen = Adjustments; Hilfe = Help; Uhrzeit = Time.

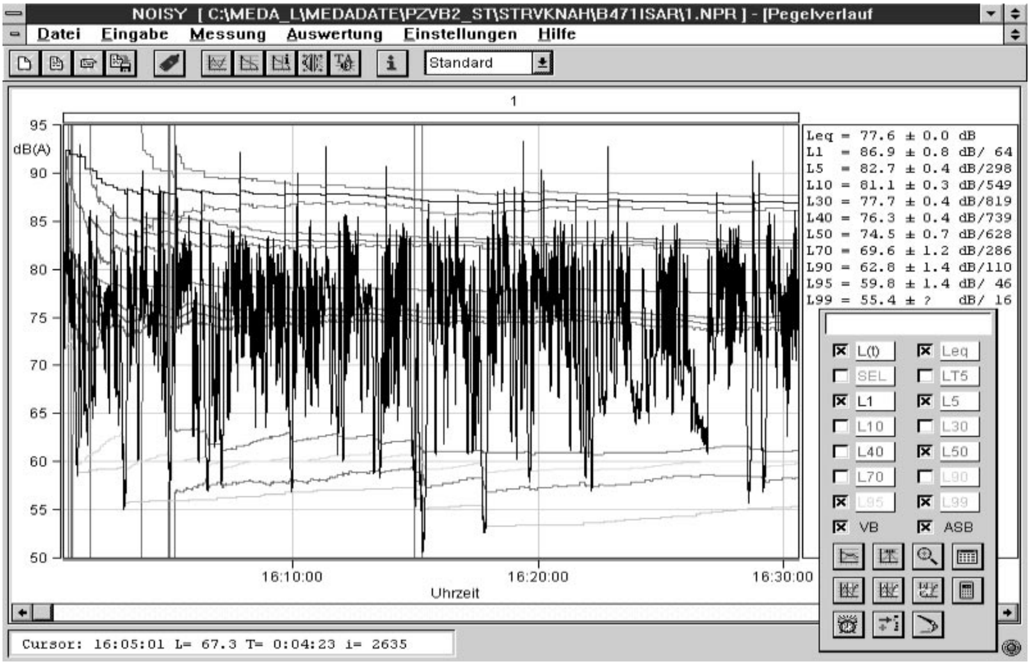

Figure. 3. Sound pressure level, L_{eq} and—with confidence intervals—the levels L_1, L_5, L_{50}, L_{95} and L_{99} at the edge of a highway.

high resolution, which is in fact achievable and translated into practice by the method presented here.

The noise impact caused by two different sources mostly occurs independent of each other. Then, as is well known, the cumulative distribution function $\Phi_G(x)$ of the superimposed sound components is, by convolution,

$$\Phi_G(x) = \int_{x'=0}^{x} \Phi_F(x - x')\, \varphi_Q(x')\, \mathrm{d}x', \tag{22}$$

where x denotes the sound intensity, $\Phi_F(x)$ the c.d.f. of the residual sound (noise) and $\varphi_Q(x)$ the probability density function of the noise component of interest, the "source". Its L_{eqQ} is accessible through a local linearization of the c.d.f. of the residual noise in equation (22) at $x' = \overline{x_Q} = 10^{0{\cdot}1 L_{eqQ}}$. Insertion of the linearized c.d.f. $\Phi_F(x - x')$ in equation (6) yields

$$1 - q_w := \Phi_G(x) = \Phi_F(x - \overline{x_Q}). \tag{23}$$

Hence, if one sets $q_w \equiv q$, the final result of this evaluation is

$$L_{eqQ} = 10 \log\,[10^{0{\cdot}1 L_{qG}} - 10^{0{\cdot}1 L_{qF}}], \tag{24}$$

with principally free choice of the parameter $0 < q < 1$. The validity of equation (24) was explicitly confirmed by field measurements and computer simulations of outdoor environmental noises. The *mean* systematic deviations of the L_{eqQ} results, calculated by equation (24) on the basis of, for example, L_{50} from their actual values, are about 0·2 dB. The standard deviation of these deviations themselves is approximately 0·5 dB. Their maximal spread is about 1 dB. It is self-evident that equation (24) also holds if the L_{eq}

TABLE 1

Submodels for source level separation based on percentile measurement†

Variant number	Principle of operation and corresponding preconditions of applicability	Measurement sites and number of measurement cycles	Separation algorithm
1	Sound source is switched on and off. Background noise is stationary during the whole measurement cycle.	Measurement at the relevant immission site 1 Immission site 1 Measurement cycle	$Ia_x \equiv I_{G,x} = I_{eq,Q} + I_{F,x}$ $Ib_x = I_{F,x}$ (25a,b)
2	Choice of immission sites with different load by sound source. Sound source works continuously and cannot be influenced during the measurement cycle. Background noise is stationary during the whole measurement cycle.	Simultaneous measurements at the relevant immission site and at an auxiliary immission site within the "immission area" of the sound source. The values of sound level attenuation from source to immissions sites must be accessible in a reliable manner 2 Immission sites 1 Measurement cycle	$Ia_x = Ia_{eq,Q} + I_{F,x} * 10^{0 \cdot 1DF}$ $Ib_x = Ib_{eq,Q} + I_{F,x}$ $I_{eq,Q}/Ib_{eq,Q} = \gamma$ γ and DF known (26a–c)
3	Choice of measurement times with different load by background noise. Sound source works continuously and cannot be influence during measurement cycle. Background noise is strongly (i.e., $\geqslant 3$ dB) variable during the 24 h or an other period.	Simultaneous measurements at the relevant immission site and at an auxiliary immission site, there only with background noise of the same kind (traffic noise, level region arbitrary) 2 Immission sites At every immission site 2 measurement cycles: One during the higher and the other during the lower background level	$Ia_x = I_{eq,Q} + I_{F,x} * 10^{0 \cdot 1DF}$ $Ib_x = I_{eq,Q} + I_{F,x}$ $La_{F,x} - Lb_{F,x} = DF$ (27a–c)

† The left terms of the separation algorithms are known by measurement.
I denotes the sound intensity, $I := 10^{0 \cdot 1L}$.

values of the superimposed sound components and of the residual noise are inserted. In Table 1 quite a systematic overview of submodels for source level separation based on equation (24) is given.

For application all the equations in the fourth column of Table 1 are to be resolved with respect to the L_{eq} level of the sound source to be assessed—as the final result. In a second step, the accuracy of this result is to be expressed by the spread of the initially measured values Ia and Ib (see the left-hand sides of the equations). Variants no. 1 and 2 are already being introduced and executed in Germany to some extent. Variant 3 will be further examined in field operation and implemented to the system software as soon as possible.

Now one can consider, in a basic manner and on the most simple variant 1, the use of the confidence limits for quality control within level separation of different sources. In variant 1 the term to be separated is $L_{eq,Q}$. It is, by intensity terms, $I_{eq} = Ia_x - Ib_x$. If the half-width of the level's confidence interval is given by $V_{L,x}$, in dB, the confidence interval for the sound intensity I_{eq} is determined in terms of Table 1 by

$$V_{IQ} = 0{\cdot}23 \times 1{\cdot}6 \cdot [I^2_{a,x} V^2_{a,x} + I^2_{b,x} V^2_{b,x}]^{1/2}, \tag{28}$$

upon taking into account the correlation factor 1·6 and using the linear additivity of variances [1] and the general relation [8]

$$V_I = V_L \frac{\mathrm{d}I}{\mathrm{d}L} = 0{\cdot}1 \ln 10 \times 10^{0\cdot 1L} V_L = 0{\cdot}23 \times 10^{0\cdot 1L} V_L. \tag{29}$$

If the source to be assessed causes only weak intensity at the measuring site, i.e., $Ib_x \cong Ia_x$ and the lower confidence limit of intensity is set to zero, one obtains per definition the level $L_{res,Q}$, which is still evaluable together with confidence limits providing a definite significance by

$$L_{res,Q} = L_{b,x} + 10 \log (0{\cdot}23 \sqrt{2} \cdot 1{\cdot}6\, V_{b,x}) = L_{b,x} + 10 \log V_{b,x} - 2{\cdot}8 \text{ dB}. \tag{30}$$

Typical values of $V_{b,x}$ observable at short-term measurements (i.e., $\leqslant 1$ h) in the outdoor environment can reach 0·2 dB as a minimum. Hence, the resolution can be extended to about 10 dB below the background noise level, which itself already can be chosen relatively low, for example $L_{F,70}$.

5.2. LEVEL-BASED SOUND TRANSMISSION MEASUREMENTS

Consider a room with a switchable sound source (index S) and an adjacent receiver room (index R). To be measured is—for simplicity—the source-related level difference between the two rooms. Then variant 1 of Table 1 applies. The sound attenuation, denoted here by D_{SR}, is calculated as

$$D_{SR} = L_{x,S} - 10 \log (Ia_{x,R} - Ib_{x,R}) \pm V_D \text{ dB}. \tag{31}$$

The background sound intensity in the source room ($Ib_{x,S}$ in the terms used here) is usually of the same order of magnitude in comparison with the background within the receiver room. As the sound pressure level in the source room must be high to reach reasonable intensity in the receiver room, the background intensity in the source room can be neglected in comparison with the sound intensity $Ia_{x,S}$ in the source room.

Equation (31) is very conventional if the term V_D, due to limitation of the accuracy by stochastic fluctuations of measured sound, is neglected. The new aspect is, that the reliability of the result D_{SR} can be controlled immediately by the measured confidence limits, if they are taken into account within the evaluation procedure for D_{SR}. The half width V_D of the confidence interval assigned to D_{SR} is calculated as

$$V_D = \left\{ V_{x,S}^2 + \left[10 \log \left(1 - \frac{V_{IQ}}{Ia_{x,R} - Ib_{x,R}} \right) \right]^2 \right\}^{1/2}, \tag{32}$$

where V_{IQ} is determined according to equation (29). The attenuation which still can be evaluated *significantly* by measurement evidently can be defined by the condition $D_{res,SR} := V_D$. An example for magnitudes occurring at attenuation measurement, using white noise as testing sound, gives Table 2.

Evaluated source level $L_{eq,Q,R}$ in the receiver room 35·1 dB (A); half width of the confidence interval of source level $L_{eq,Q,R}$ 0·2 dB (A); attenuation 89·6 − 35·1 ⇒ 54·5 dB; halfwidth of the confidence interval of attenuation, and also resolution limit for attenuation measurement 0·5 dB.

TABLE 2

An example for sound transmission measurements using white noise; measured level values (*in* dB (A); *all measurement time intervals* 5 min

	First background measurement (source switched off)	Measurement in the source room	Measurement in the receiving room (source switched on)	Second background measurement (source again switched off)
Level L_{eq} in dB (A)	31·5	89·6	36·5	30·1
Halfwidth of confidence interval of measured level, in dB	0·1	0·3	0·1	0·4

This example shows that in fact a high resolution in attenuation measurement can be achieved although the white noise has fluctuations of the order of magnitude $L_1 - L_{99} \approx 6$ dB. An attenuation measurement using a strongly fluctuating source should be examined too.

5.3. SOUND MEASUREMENTS ON SPECIMENS FOR ACOUSTICAL MEASURES

From the preceding section it can be deduced that already a small increment of attenuation, caused by relatively small additional probe of a shielding construction can be resolved in a reliable procedure. A further evaluated example is the following. Between the sound pressure level L within a room, its effective absorption area A and the power level L_W of the sound source(s) creating the sound field there exists the well-known relation

$$\frac{1}{4} A\, 10^{0\cdot 1L} = 10^{0\cdot 1L_W}. \tag{33}$$

Let L_W be unchanged but the absorption area varied by an increment ΔA. Then by equation (34) the corresponding level change ΔL is simply determined by

$$10^{-0\cdot 1\Delta L} = 1 + \Delta A/A. \tag{34}$$

If by measurement the resolution of a level difference assigned to two states of a sound field is known, the minimum change of the corresponding acoustic parameter considered, here A, can be estimated. Upon setting $\Delta L \equiv V_L$, where V_L is the halfwidth of the confidence interval of the measured level L, from equation (34) the amount of a still significantly evaluable change, say $|\Delta A_{min}|$, can be derived as

$$|\Delta A_{min}| = 0\cdot 23 b\, 10^{0\cdot 1V_L} V_L A \cong 0\cdot 23 b V_L A. \tag{35}$$

For typical indoor values such as $V_L = 0\cdot 1$ and $b = 1\cdot 6$, due to the only partial correlation of crossing intervals one obtains

$$|\Delta A_{min}| = 0\cdot 04 A. \tag{36}$$

In general, a relation of the following type can be assumed

$$L = L_W - \Lambda(z_1, z_2, \dots z_i, \dots), \tag{37}$$

where L_W is a constant and the z_i are active variable parameters like area, spatial density of scattering bodies or similar. Then the equation

$$\Delta z_i = - V_L/(\partial \Lambda / \partial z_i) \tag{38}$$

provides the smallest variation of an acoustic parameter which can significantly be observed.

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