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# Assessment of environmental noise from long-term window microphone measurements

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ABSTRACT

Requirements for façade sound insulation against outdoor noise based on the assessment of environmental noise on building façades. For noise estimations now usually exploit an annual composite 24-h equivalent sound pressure level $L_{DEN}$, which is mandatory for noise mapping and may be measured. A one-year duration noise monitoring experiment with two microphones used simultaneously was done in the town of Vilnius near an arterial road with intensive road traffic, occurring mostly in the daytime. The first microphone with common all-weather protector was placed on a special support at a distance of 2 m apart the plate building façade, and the other microphone, in accordance with the ISO 1996-2 description, was simply directly glued to the façade window. Using represented in standard ISO 1996-2:2007 −3 dB correction between the window microphone and the microphone placed 2 m from the façade results, the traffic noise level expressed in $L_{DEN}$ were practically identical for both microphone positions. At the same time, results acquired on these both microphones at night, when the traffic abated and the dominant became the overall town background noise, demonstrated that the difference became smaller and varied from 1 dB to 2 dB. Additional statistical assessment of obtained during full year results shows that calculated the standard deviation of monthly $L_{DEN}$ values reaches 1.3 dB, while seasonal weather conditions give a 5 dB scattering in results. The experiment confirmed that the typical for Lithuanian climate seasonal traffic nose level variations (at winter time due to snow covering and impaired traffic conditions, at autumn due to wet road surface) must be taken into account applying short-term relatively to the annual determining $L_{DEN}$. When only representative whole-days (day selected to conform normal conditions under ISO 1996-2 standard requirement) measurements data are taken into account to assess annual value, the weekly (from 7 successive days) estimated $L_{DEN}$ values gave a standard deviation of 0.9 dB and the one whole-day estimated $L_{DEN}$ values gave the standard deviation of 1.3 dB.



## 1. Introduction

The annual average noise descriptor $L_{DEN}$ (Directive 2002/49/EC) [1] become mandatory looking to harmonize estimation of environmental noise pollution. The simplest approach is to calculate the $L_{DEN}$ from the traffic intensity or take it from available noise maps. However, remain cases when this descriptor evaluated using relatively to estimated time interval short-term measurements: e.g., when the noise maps for developed sites are not available and there is a need within a few days to design protection against outdoor noise in erected buildings.

Note, that in UK for annual LDEN assessment the measurement data acquired in one representative whole-day are used [2]. When the site noise pollution map is created by measurements, 24-h duration measurements are often replaced by shorter duration (15–60 min) measurements [3–7] made during a representative day. Unfortunately, reliable methods for such evaluation of the annual $L_{DEN}$ value still not recognized. The application of statistical methods for assessment the long-time equivalent sound levels from short-term measurements may be one of the ways to solve this aim. In [3], the statistical random choice model is used to reduce the number of measurement days to assess the annual $L_{DEN}$. In other works [4,5], specific types of sites were used for the purpose of statistically determining the similarity in results. In [4], at the sites investigated where the "road traffic is the principal noise generation source", it was shown that the 24-h interval in such sites was comprised of a stable noise segment during the day (14–15 h duration), a long (5–7 h) transition time segment from stable day noise to stable night noise, a short (1–3 h) stable night part and a very short conversion (1–2 h) from night to day.

The typical variations of one day $L_{Aeq,1h}$ values are shown graphically in Fig. 1.

In [5] the measurement data were grouped by the main roads of the town; in [6], site conditions were considered due to differences in road construction and the usage area, including the road

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gradient and reflecting surfaces. For the statistical model developed in [8], such input parameters for describing the outdoor noise level as "traffic volume, composition of traffic, traffic speed, number and width of lanes, approach width, horn-using effect, road slope, and pavement surface texture" were used.

In these investigations the measuring microphone positions was not the same. By EU directive recommendations [1] and according with standardization [9] for environment noise measurements, the microphone position usually selected apart from reflecting facades at a height of 4 m above local ground level. Such microphone positions were chosen in [3]. On the contrary, in [4] the microphone was placed at the sidewalk, 2 m away from the road and 5–6 m away from the building facade; in [5,6], the measurement points were located in the streets not far from the closest façade and at a height of 1.2 m.

The environmental noise measurements on building facades with the flush-mounted microphone are allowed by the standard ISO 1996-2:2007 [10] applying the appropriate sound reflection correction. Measurements with flush-mounted microphone were introduced else in the standard ISO 140-5 [11], where input from sound reflected at façade plane referred to 2 m distance was included in the calculation of façade sound insulation. Sound pressure level at 2 m distance due to incoherent phases of reflections approximates energy doubling (+3 dB), while very near to a reflecting surface pressure doubling (+6 dB) take place [12]. This correction with respect to microphone in a free-field conditions and ideal case is a 6 dB. In practice minor deviations from this value are possible, while deviation value not presented else.

The façade corrections for different special cases of street/road geometry configurations were investigated in [13], where 15 min acquired data from the microphones placed on distance of 0.5 m, 1 m, and 2 m from façade wall, mounted directly on the façade wall and also placed in hemi-free field were compared for by-passing road traffic noise sources for the purpose to estimate the reflection correction. Obtained results show a scatter depending on the distance from the noise source.

Common corrections now are presented in few standards [10,11,14,15] in different ways. When measuring microphones are mounted near reflected surface, the free field corrections to get the only incident sound field for microphones placed 0.5–2 m from the façade is a −3 dB, and a −6 dB for microphones flush-mounted on the plate façade surface [10].

The kit of endorsed by standards practically applicable free field corrections to measured environmental noise values concerning microphones position differently placed near reflecting surfaces are presented in Table 1.

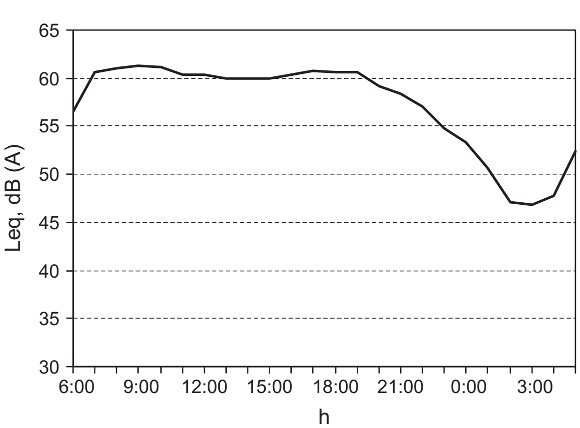


**Fig. 1.** Example of $L_{Aeq,1h}$ distribution during one full day (24 h).

The application of microphone mounted directly on window glass for annual $L_{DEN}$ assessment is not discussed in above presented investigations. Such microphone mounting gives practical advantages:

- Simple installation, do not requiring the high tripod or special supporting device to keep it 2 m from façade.
- Allow to substitute the special designed all weather microphone (comprising appropriate heating system and wind and rain protector).
- Equipment for measurements through the window sealing can be easy connected to the microphone amplifier using a short slim cable.

Note, that often there are cases where other possibilities of microphone position are practically not reasonable, e.g., when glazed facades of tall building are checked for façade insulation. By national Lithuanian building code (STR 2.01.07:2003) [16] the requirements for façade sound insulation of newly designed buildings are determined on the base on the annual $L_{DEN}$ value on this façade. When $L_{DEN}$ value vary from 55 dBA to 59 dBA the requirements for façade insulation described by standardized level difference is $D_{2m,nT,W} \geqslant 35$ dB. Those require carrying out environmental noise under long-term descriptor measurements in situ. Similar approach for façade insulation over the long time is used in Germany [17].

Environmental noise measurements on the façade are accomplished in [18] for investigation of the effects of the building facade and balcony design on the reduction of outdoor noise. In [7] the 24 h measurements in distance of 1 m from façade were accomplished to estimate the possibilities of assessment the $L_{DEN}$ value of community noise by data acquired in the shot-term (30 min) arbitrary chosen time periods. All measurements were carried out on dry weather conditions. Corrections due to sound reflections from surfaces are not discussed in these works.

In this work the possibility of applying a window microphone to assessment annual environmental noise descriptor will be studied. Simultaneous long term measurements of environmental noise produced mainly by urban road traffic are carried out with two microphones; one placed 2 m apart the façade and the other is flush-mounted on the window as described in [10] and shown in Fig. 2. Obtained data allows additionally done statistical calculations and investigate seasonal fluctuations in results. Assessing the annual $L_{DEN}$ value using measurement data acquired with window microphone allows apply results of the set of whole-days, selecting representative set of successive days or arbitrary chosen single days to investigate calculations uncertainty limits.

## 2. Measuring system and investigation strategy

The two-channel permanent noise monitoring station "OPER@" from 01 dB steel (now 01 dB-Metravib) comprised two acquisition modules "OPER@-Ex" and "OPER@-RF" was used for data storage, post-processing and analyses. The instantaneous A weighted sound pressure levels $L_{pA,F}$ from first channel and $L_{pA,S}$ from second channel were permanently recorded during full year. First channel was connected to 01 dB-Metravib preamplifier with heating Type

**Table 1**
Values of reflection correction.

| Microphone position | Noise source | Correction (dB) | |
|---|---|---|---|
| On façade surface | Road traffic | −6 | – |
| 0.5–2 m From façade | Road traffic | −3 | – |
| Free or hemi free field | Any | – | 0 |