MEASUREMENTS METHODS AND ANALYSIS FOR ROAD AND RAILWAY NOISE

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1 – INTRODUCTION

The noise can be measured in various ways. Depending on the type of information that it is desired to obtain, it is necessary to “prepare” preventively the measurement by performing a survey that supplies you with the relevant information needed for that purpose.

In fact it is to be considered the need of repeating the measurements, and in that case extra expenses and organizational problems must be avoided.

2 – SCOPE OF THE MEASUREMENTS

Before proceeding to any measurement, it is indispensable to clarify what it is exactly expected from its execution.

In fact, there are different approaches to be followed for the verification of the noise emitted from an installation, for the measurement of the sonorous power, for the evaluation of the disturbance to the community, for the surveying aimed at the resolution of a problem or the improvement of a product.

Finally, it is necessary to verify the existence of technical and/or legal norms which prescribe the way to proceed, determine instrumentation requirements, microphone positioning, measurement period, etc.

3 – TECHNICAL NORMS FOR THE EXECUTION OF THE MEASUREMENTS BASED ON THE BASE OF ITALIAN LEGISLATION

The measurement of the Equivalent continuous A-weighted sound pressure level in the period of reference ($L_{Aeq,TR}$) can be executed:

a) By continuous integration

$L_{Aeq,TR}$ is obtained by measuring ambient noise during the entire period of reference, with exclusion of periods in which anomalous, not representative conditions in the examined area take place;

b) With sampling technique

$\mathbf{L_{Aeq,TR}}$ is calculated as the mean of the values of the Equivalent continuous A-weighted sound pressure level relative to time observation intervals $\mathbf{(To)_i}$.

The measuring methodology finds values of $\mathbf{L_{Aeq,TR}}$ which are representative:

- of the ambient noise in the reference period
- of the examined zone
- of the typology of the source and
- of the propagation of the sonorous emission.

The measure must be rounded off to 0.5 dB.

Free-field microphone must be oriented towards the noise source; in the case in which the source is not locatable or more sources are present, it must be used a Random Incident Microphone.

The microphone must be installed on an appropriate support and must be connected to the phonometer with a cable of length such as to permit the operators to place themselves at a distance not lower than 3 meters from the microphone.

Outdoor measurements

In the case of buildings with façade close to the street, the microphone must be placed at 1 meter from the same façade.

In the case of buildings detached from the street or in case of open areas, the microphone must be placed inside the space usable by persons or communities and not less than 1 meter from the façade of the building, anyway.

The height of the microphone for measurements either in built up areas or in other sites, must be chosen according to the effective or presumed position of the receiver.

The measurements must be executed in absence of atmospheric precipitations, of fog and/or snow.

Wind speed must not exceed 5 m/s. The microphone must be equipped with anti-wind cap, anyway.

The measuring chain must be compatible with the meteorological conditions of the period in which the measurements are carried out and in accordance with EN Technical Standards.

4 – METHODOLOGY OF MEASUREMENTS OF ROAD NOISE

Being the road traffic a random or pseudo-random phenomenon, monitoring of the produced noise must be executed for a time of measurement not below one week.

During such period the equivalent continuous A-weighted sound pressure level must be measured for every hour in the space of 24 hours.

Field data are then elaborated to obtain:

a) equivalent diurnal and nocturnal levels for every day of the week;

b) diurnal and nocturnal weekly mean values.

The microphone must be placed at a distance of 1 m from the façades of buildings which are exposed to most high noise levels.

The height from ground floor of the measuring point must be equal to 4 m. In absence of buildings the microphone must be placed in the position of sensitive receptors.

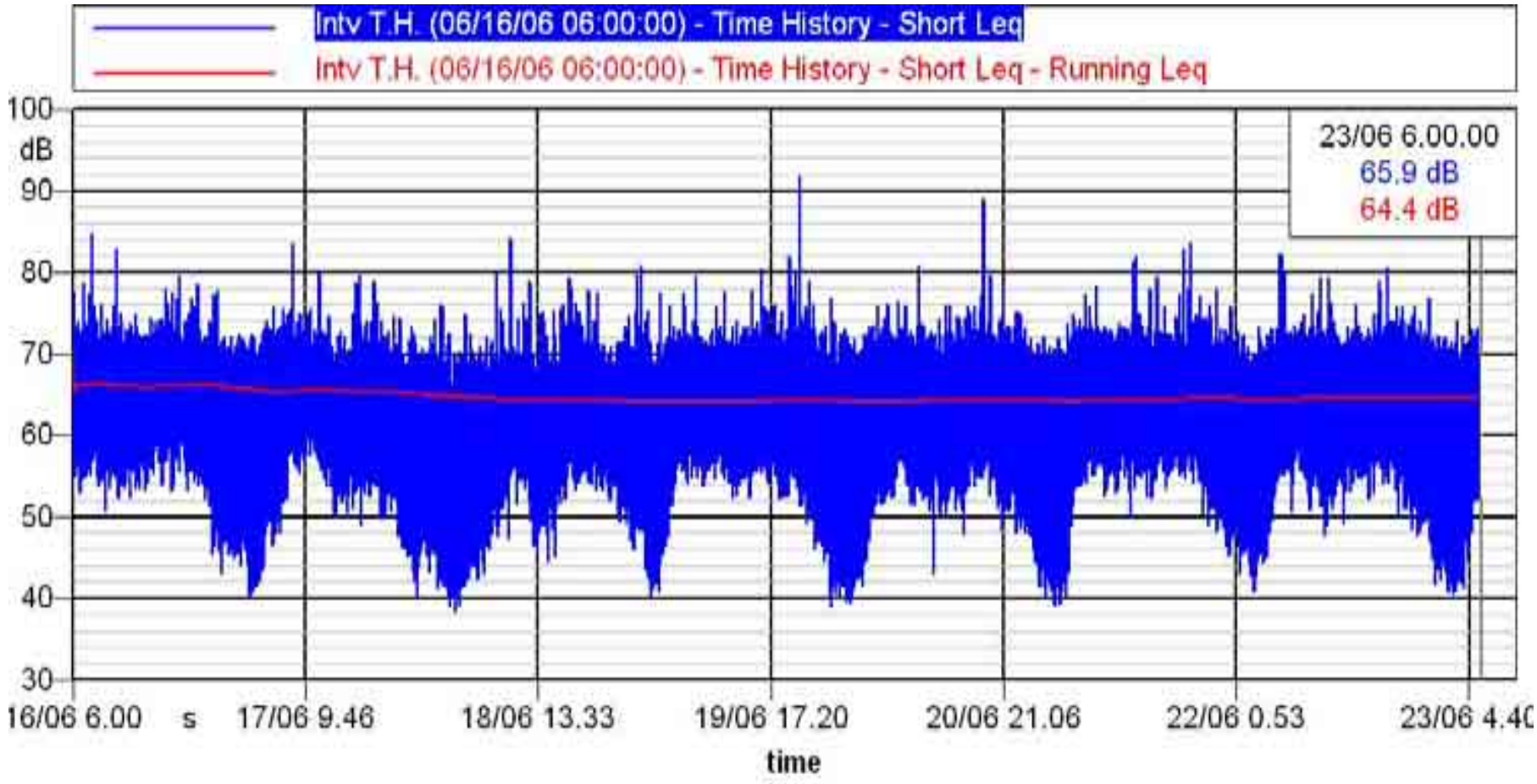
From such hourly $\mathbf{L_{Aeq}}$, the diurnal (06.00-22.00 hr) and nocturnal (22.00-06.00 hr) mediated equivalent levels are determined, for each of the 7 days of monitoring and from these, the weekly medium levels, through the following relationship :

$$L_{Aeq,Tr\_\ \textbf{weekly}} = 10\,log_{10}\left[\frac{1}{7}\times\left(\sum_{i=\ \textbf{mon}}^{\textbf{sun}}\left(10^{0,1\times(\mathrm{LAeqTr})i}\right)\right)\right]\ dB(A)$$

With:

Tr = Time of reference
LAeq,Tr i = Daily diurnal (06.00-22.00 hr)
or nocturnal (22.00-06.00 hr) equivalent level

Example of monitoring of street noise carried out during one week



According to the Ministerial Decree 16 March 1998, the level of environmental noise (L_A) is the equivalent continuous A-weighted sound pressure level produced by all the existing sources of noise in a fixed place and during a fixed term.

The ambient noise is constituted by the residual noise and by that produced by the specific disturbing sources, with exclusion of the exceptional sonorous events, singularly identifiable in regard to the ambient value of the zone.

Such level is confronted with the maximum limits of exposure:

- in the case of differential limits, it is related to T_M;
- in the case of absolute limits, it is related to T_R

Example of post-elaboration data obtained from monitoring of street noise carried out for a week (DAY/NIGHT).

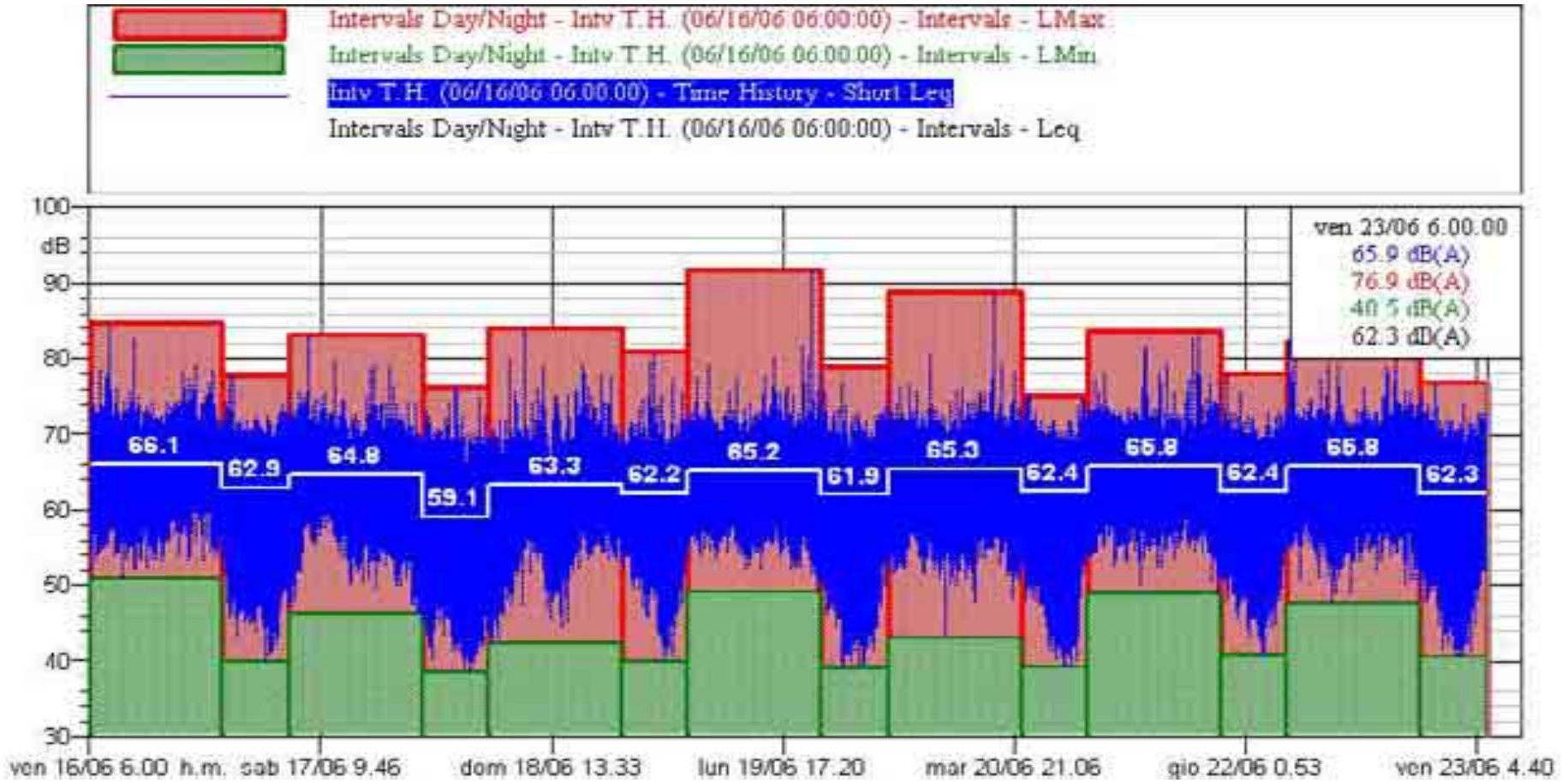


Table of elaborated Equivalent Levels (Daily and Weekly Average)

Daily Equivalent Level dB(A)		
	Diurnal (06.00-22.00 hr)	Nocturnal (22.00-06.00 hr)
Monday	65.2	61.9
Tuesday	65.3	62.4
Wednesday	65.8	62.4
Thursday	65.8	62.3
Friday	66.1	62.9
Saturday	64.8	59.1
Sunday	63.3	62.2
Weekly Average	***65.5***	***62.0***

Summarizing schedule of results

ABSOLUTE VALUES OBTAINED (Weekly Average)		ABSOLUTE LIMIT VALUES According to Attachement 1 – Table 2 of the D.P.R. n° 142 of 30 March 2004		Difference Obtained Absolute Values minus Absolute Limit Values (DPR 3/30/2004 n. 142)	
$L_{Aeq, TR}$ dB(A) DIURNAL	$L_{Aeq, TR}$ dB(A) NOCTURNAL	$L_{Aeq, TR}$ dB(A) DIURNAL	$L_{Aeq, TR}$ dB(A) NOCTURNAL	$L_{Aeq, TR}$ dB(A) DIURNAL	$L_{Aeq, TR}$ dB(A) NOCTURNAL
65.5	**62.0**	**70.0**	**60.0**	**-4.5**	**+2.0**

Exceeding of the absolute limit values has resulted only during the nocturnal period of reference.

5 – METHODOLOGY OF MEASUREMENT OF RAILWAY NOISE

The measurements must be executed in conditions of normal railway traffic and in favorable meteorological conditions.

The microphone, equipped with anti-wind cap and oriented towards the noise source, must be placed at a distance of 1 m from the façades of buildings exposed to more elevated sonorous levels and to a level from ground equal to 4 m.

The sonorous level meter must be set for the acquisition of levels of sonorous pressure with time constant "Fast“ and to allow the determination of the starting time, of the value of the sonorous exposure level $\mathbf{L_{AE}}$ and of the temporal profile $\mathbf{L_{AF}(t)}$ of the individual transit of the trains.

For a correct determination of the exposure levels, it is necessary for the $\mathbf{L_{AFmax}}$ values to be at least 10 dB(A) higher than the residual sonorous level.

$\mathbf{T_M}$ (measuring time) must not be less than 24h.

The determination of the $L_{Aeq,TR}$ values must be carried out based on the following relationship :

$$L_{Aeq,TR} = 10 \log\left(\sum_{i=1}^{n} 10^{0,1(L_{AE})i} \right) - k$$

where:

TR is the diurnal or nocturnal period of reference;

n is the number of transits during the TR period;

k = 47.6 dB(A) in the diurnal period (06.00-22.00 hr)

= 44.6 dB(A) in the nocturnal period (22.00-06.00 hr).

L_{AE} **(SEL)** is the Single Event Level, evaluated according to the following relationship:

$$SEL = L_{AE} = 10\log\left[\frac{1}{t_0}\int_{t_1}^{t_2}\frac{p_A^2(t)}{p_0^2}dt\right]dB(A)$$

SEL (Single Event Level) is the event energy related to 1 second.

t2 - t1 is an interval of time sufficiently long to include the event;

t0 is the reference time (1 second)

On the base of the time during which the event has taken place and from the examination of the temporal profiles, the sonorous events not attributable to the transit of trains or determined by accidental phenomena must be individuated.

The values of $\mathbf{L_{AE}}$ corresponding to transits of railway convoys invalidated by exceptional events, must be substituted by arithmetic medium value of $\mathbf{L_{AE}}$ calculated for all the remaining transits.

In order $\mathbf{L_{Aeq,TR}}$ to be valid, the number of invalidated railway convoys transits by other noisy phenomena must not exceed 10% of the number of transits n.

If the residual noise does not permit the right determination of $\mathbf{L_{AE}}$ values in the measurement point, or if the number of invalidated transits is more than 10% of the total number n, a methodology must applied based on measurement in a reference point $\mathbf{P_R}$ placed in proximity of the railway infrastructure characterized by free sonorous field conditions.

In the point $\mathbf{P_R}$ the measurements must be performed for a time $\mathbf{T_M}$ not less than 24 hours and the $\mathbf{L_{AE}}$ values measured in $\mathbf{P_R}$ must be correlated to the correspondent values measured in the reception point for at least 10 transits for each rail line.

For every rail line it will be determined the arithmetic average of the differences between the $\mathbf{L_{AE}}$ values measured in $\mathbf{P_R}$ and those detected in the reception point. Such medium value must be subtracted to the $\mathbf{L_{Aeq,TR}}$ value determined in the $\mathbf{P_R}$ point, in order to obtain the correspondent value in the reception point.

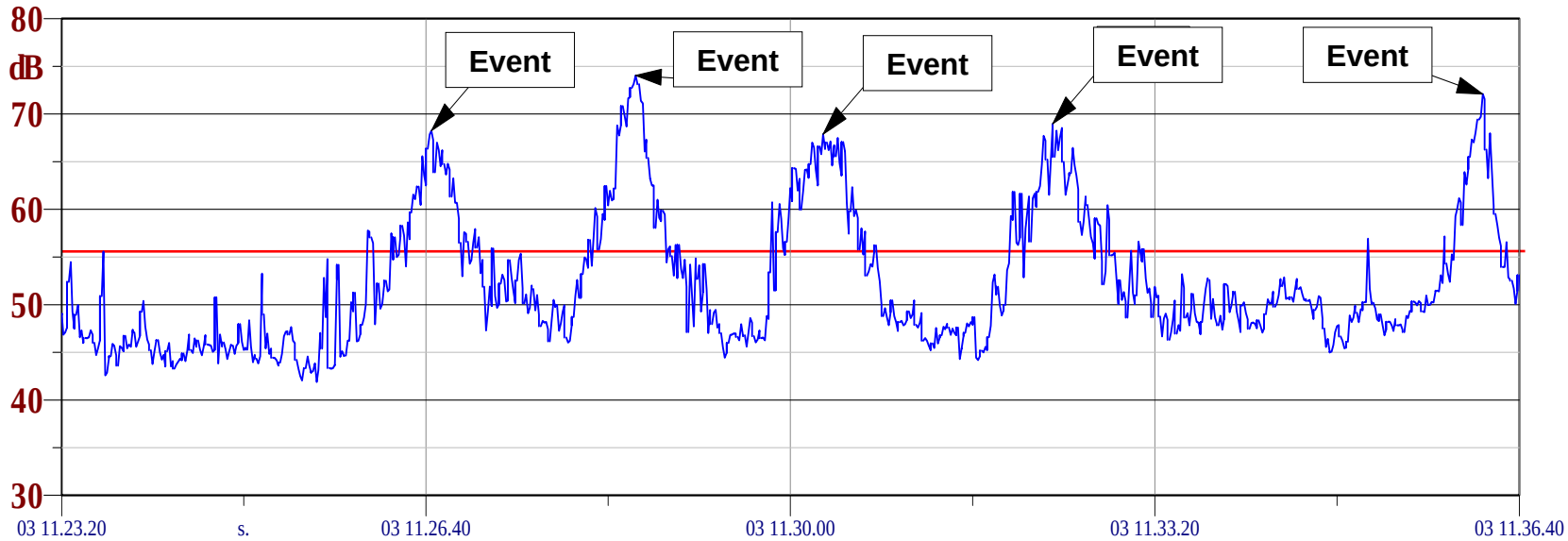
The total continuous equivalent level in the reception point is determined by means of the relationship :

$$L_{Aeq,TR} = 10 \log \left[\frac{1}{T_R} \sum_{k=1}^{n} 10^{0,1(L_{Aeq,TR})k} \right]$$

being ***n*** the number of railroad tracks (rail lines)

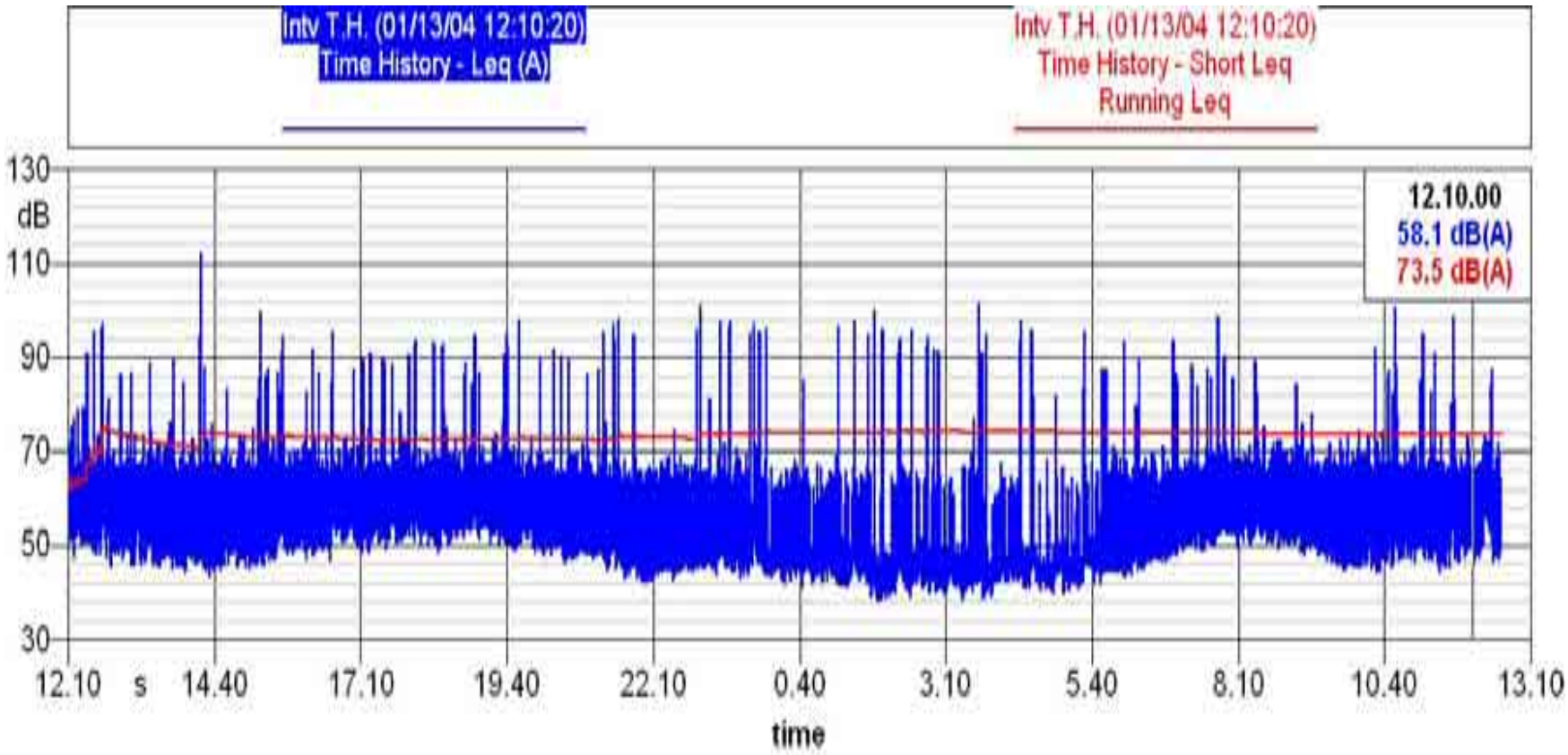
Identification of the sonorous events

Example of identification of the sonorous events based on the determination of a noise threshold (red line) and of a minimum time duration of the event

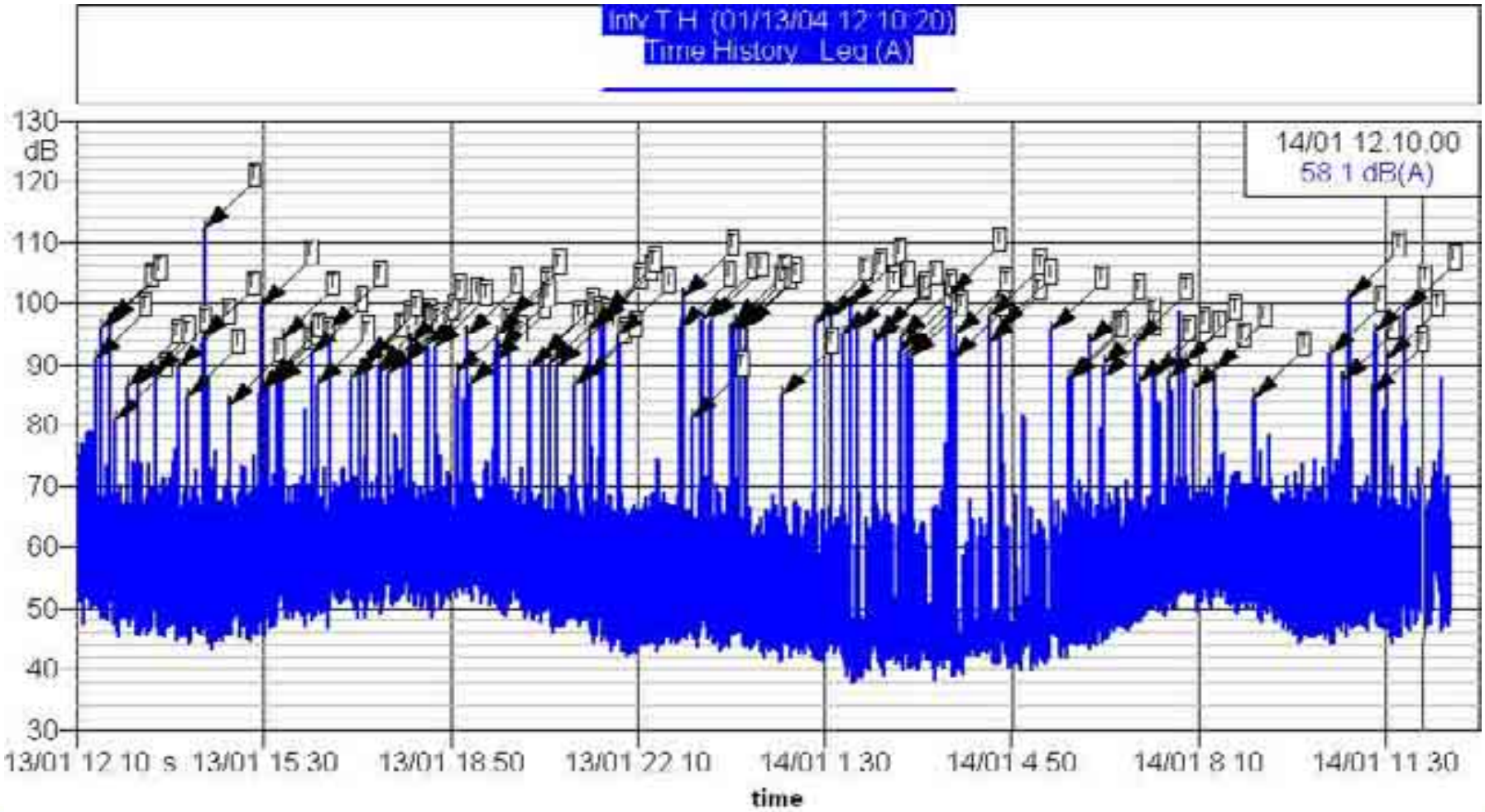


For every event the SEL value is obtained. All these events have contributed to the determination of an acoustic descriptor, $L_{Aeq,TR}$ ("equivalent continuous A-weighted sound pressure level in the reference period").

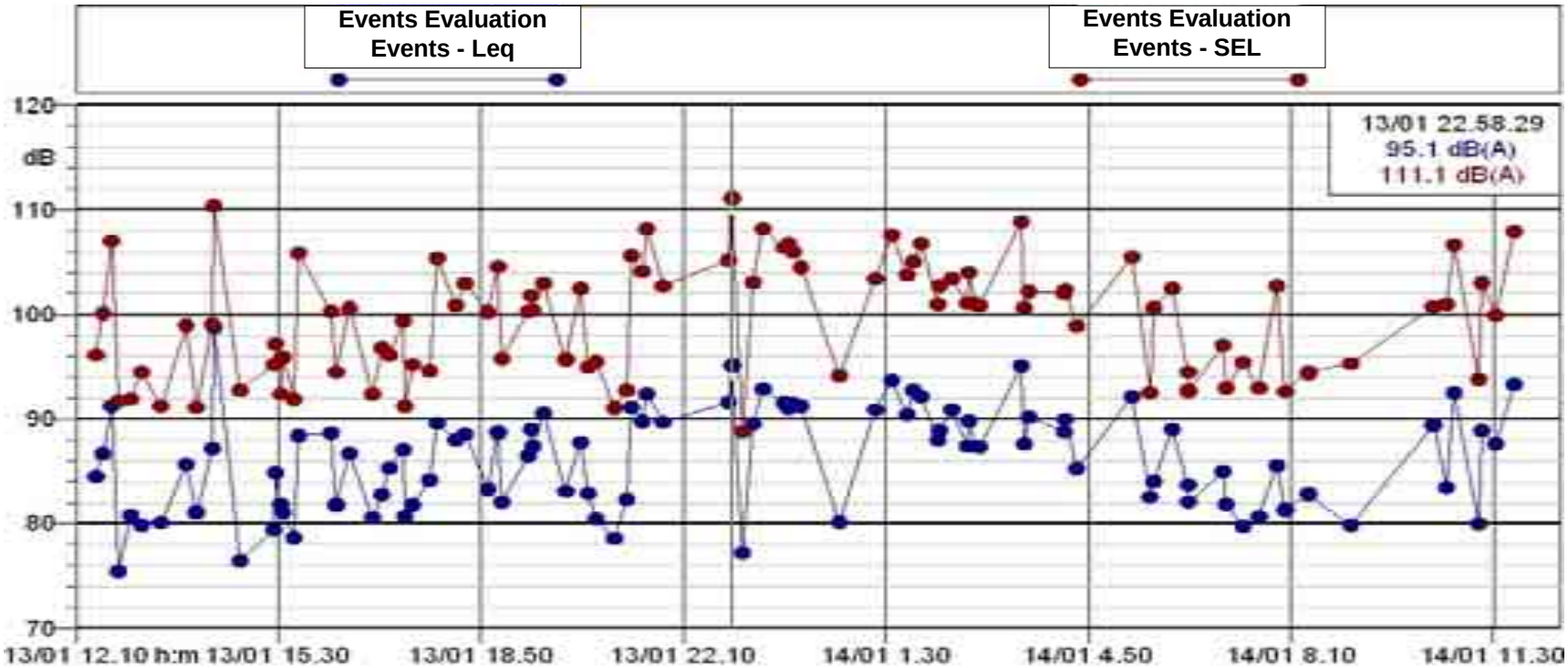
Example of monitoring of the railway noise carried out during 24 hours.



Post-elaboration example of data obtained from monitoring of the railway noise carried out during 24 hours and with the identification of the events



Post-elaboration example of data obtained from monitoring of railway noise carried out during 24 hours and determination of $L_{Aeq,TR}$.



Diurnal Events N. : 66 Nocturnal Events N. : 31 Total Events N. : 97

$L_{Aeq,TR\ (06.00\text{-}22.00\ hr)}$: 72.0 dB **$L_{Aeq,TR\ (22.00\text{-}06.00\ hr)}$: 75.0 dB**

Recapitulatory Schedule of results

MISURED DATA			ABSOLUTE LIMIT VALUES According to DPR n. 459 of 18 Nov. 1998 for "A" Zone		Difference of data measured with the Absolute Limit Values	
Site n.	$L_{Aeq, TR}$ dB(A) DIURNAL	$L_{Aeq, TR}$ dB(A) NOCTURNAL	$L_{Aeq, TR}$ dB(A) DIURNAL	$L_{Aeq, TR}$ dB(A) NOCTURNAL	$L_{Aeq, TR}$ dB(A) DIURNAL	$L_{Aeq, TR}$ dB(A) NOCTURNAL
1	72.0	75.0	70.0	60.0	+2.0	+15.0

The obtained values are greater than the absolute limit values either for the reference diurnal period and for nocturnal

6 – ITALIAN LEGISLATION IN THE FIELD

- Law n. 447 of 26 October 1995,– *"Frame Law on acoustic pollution";*
- Decree of the Minister of the Environment of 16 March 1998 - *"Techniques of survey and acoustic pollution measurement";*
- Decree of the President of the Republic n. 142 of 30 March 2004 - "*Provisions for the control and the prevention of acoustic pollution deriving from vehicular traffic, according to the article 11 of the Law n. 447" of 26 October 1995";*
- Decree of the President of the Republic n. 459 of 18 November 1998, - "*Provisions for the control and the prevention of acoustic pollution deriving from rail road traffic, according to the article 11 of the law n. 447 of 26 October 1995".*