H. REVERBERATION TIME

H.1. Introduction

If an impulsive sound is generated in a room with reflecting boundaries, repeated reflections at the boundaries result in the rapid establishment of a more or less uniform sound field. This field then decays as the sound energy is absorbed by the bounding materials. The rate at which the sound energy decays is determined by the absorptive properties of the reflecting surfaces and the distances between them. The time taken for the sound intensity or the sound pressure level to decay by 60 dB is called the **reverberation time** (RT). The values of RT may range from fractions of a second to a few seconds and depend upon the size of the room and the nature of the materials used in its construction.

The graphs below present the reverberation time nature (in the case when only one frequency is emitted):

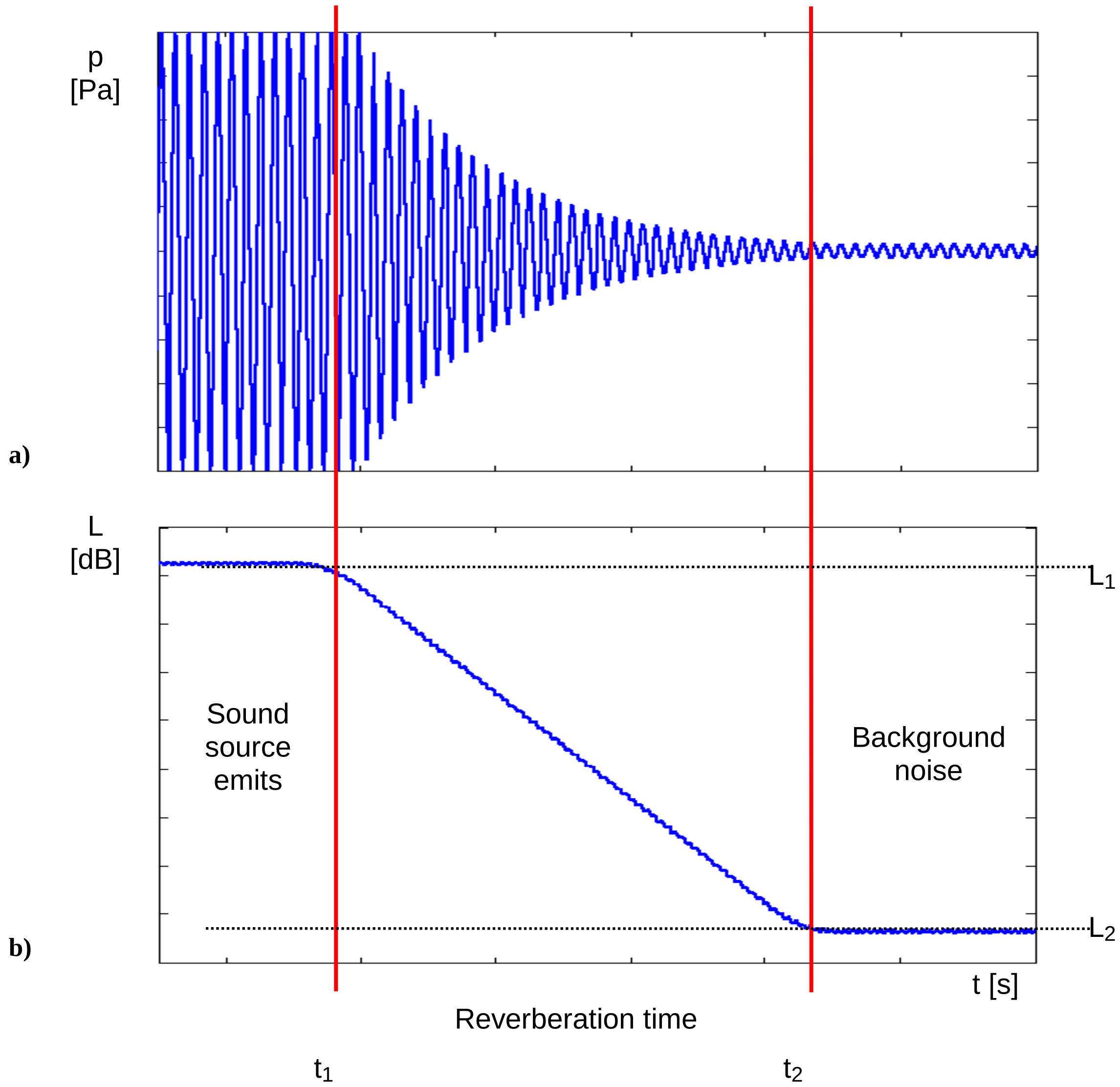

Fig 1. The acoustic pressure versus time (a) and the value of the sound pressure level versus time, so-called decay curve (b)

The marker t_1 indicates the moment when the sound source was switched off. From this moment the acoustic sound pressure / acoustic power (reflected waves propagate in the room) decreases till the moment indicated by the marker t_2. The lower graph presents so-called the **decay curve**. The reverberation time value is equal to $t_2 – t_1$ when the difference between sound pressure levels L_1 and L_2 is 60 dB. The 60 dB dynamic condition is impractical in real measurements (very difficult to fulfil) hence the reverberation time (RT 60) is obtained using the slope coefficient of the decay curve. The type of the definition from which slope coefficient is calculated (EDT, RT 20, RT 30 or user defined) depends on the difference between levels L_1 and L_2 (the difference between background noise level and sound source level) of the decay curve and it depends on significantly from the acoustic source ability. If the level difference is larger than 45 dB, the RT 60 parameter can be calculated using three definitions: EDT, RT 20 and RT 30.

The real measurement results are not as smooth as the curves presented on graphs in Figure 1. In order to point out the interesting decay curve region (the position of the markers t_1 and t_2) some measurement data processing (in general signal smoothing by averaging) need to be applied.

H.2. The definition and the calculation process of the RT 60 reverberation time

- **EDT (early decay time):**

The EDT decay curve region is pointed out by markers t_1 and t_3 (cf. Fig. 2). It is checked whether the selected decay curve region has proper dynamics for the EDT calculation:

$$L_1 – L_2 >= 10 \text{ dB}$$

$$L_2 – L_3 >= \text{noise margin}$$

It is recommended by the ISO-3382 standard to set 10 dB value for noise margin.

In the case of the **impulse method**, the sound pressure level values between points t_1 (with L_1 level) and t_2 (with L_2) are approximated with the straight line ($y = a \cdot x + b$) by the linear regression. Before approximation the EDT value is calculated using the slope coefficient ‘a’ according to the formula:

$$EDT = – 60.0 / a$$

In the case of the **decay method**, the EDT value is calculated according to the formula:

$$EDT= 6 \cdot (t_2 – t_1)$$

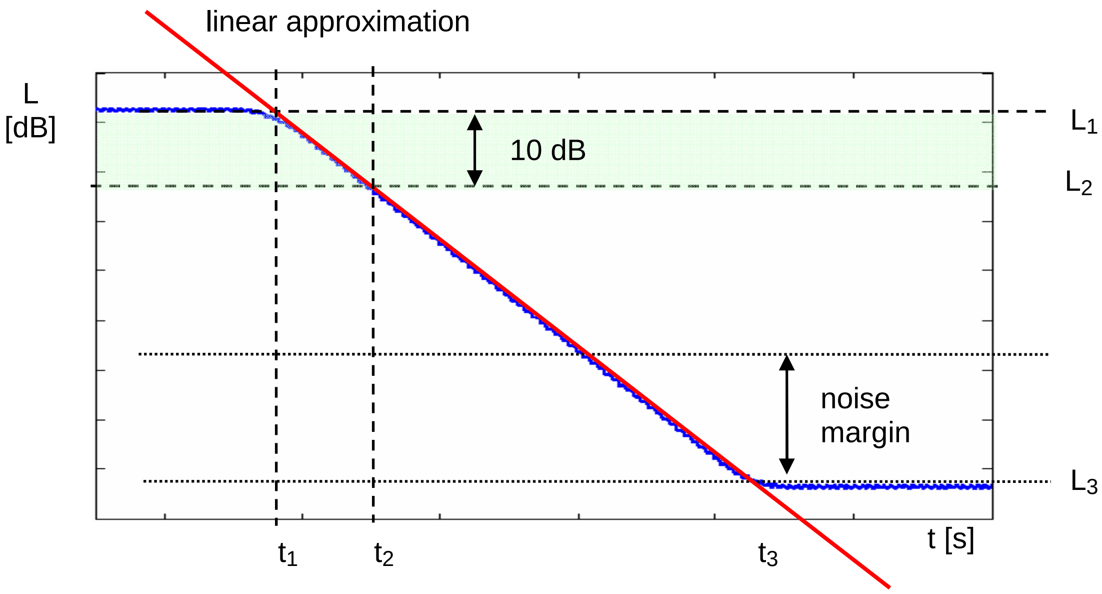

Fig 2. The EDT evaluation

- **RT 20 (reverberation time calculated with 20 dB dynamics):**

The RT 20 decay curve region is pointed out by markers t_1 and t_4 (cf. Fig. 3). It is checked whether the selected decay curve region has proper dynamics for the RT 20 calculation:

$$L_1 - L_4 > 5\text{ dB} + 20\text{ dB} + \text{noise margin}$$

It is recommended by the ISO-3382 standard to set 10 dB value for noise margin.

In the case of the **impulse method**, the sound pressure level values between points t_2 and t_3 are approximated with the straight line ($y = a \cdot x + b$) by the linear regression. The RT 20 value is calculated using the slope coefficient 'a' according to the formula:

$$RT\ 20 = -60.0 / a$$

In the case of the **decay method**, the T 20 value is calculated according to the formula

$$RT\ 20 = 3 \cdot (t_3 - t_2)$$

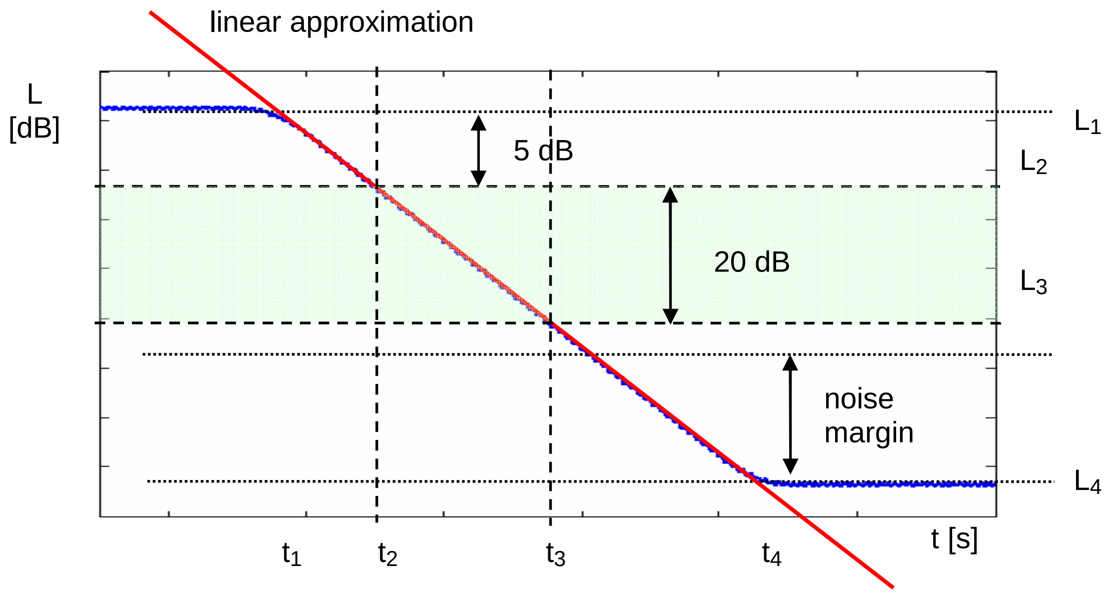

Fig 3. The RT 20 evaluation

- **RT 30 (reverberation time calculated with 30 dB dynamics):**

The RT 30 decay curve region is pointed out by markers t_1 and t_4 (cf. Fig. 4). It is checked whether the selected decay curve region has proper dynamics to the RT 30 calculation:

$$L_1 - L_4 > 5 + 30\text{ dB} + \text{noise margin}$$

It is recommended by the ISO-3382 standard to set 10 dB value for noise margin.

In the case of the **impulse method**, the sound pressure level values between points t_2 and t_3 are approximated with the straight line ($y = a \cdot x + b$) by the linear regression. The RT 30 value is calculated using the slope coefficient 'a' according to the formula:

$$RT\ 30 = -60.0 / a$$

In the case of the **decay method**, the T 30 value is calculated according the formula

$$RT\ 30 = 2 \cdot (t_3 - t_2)$$

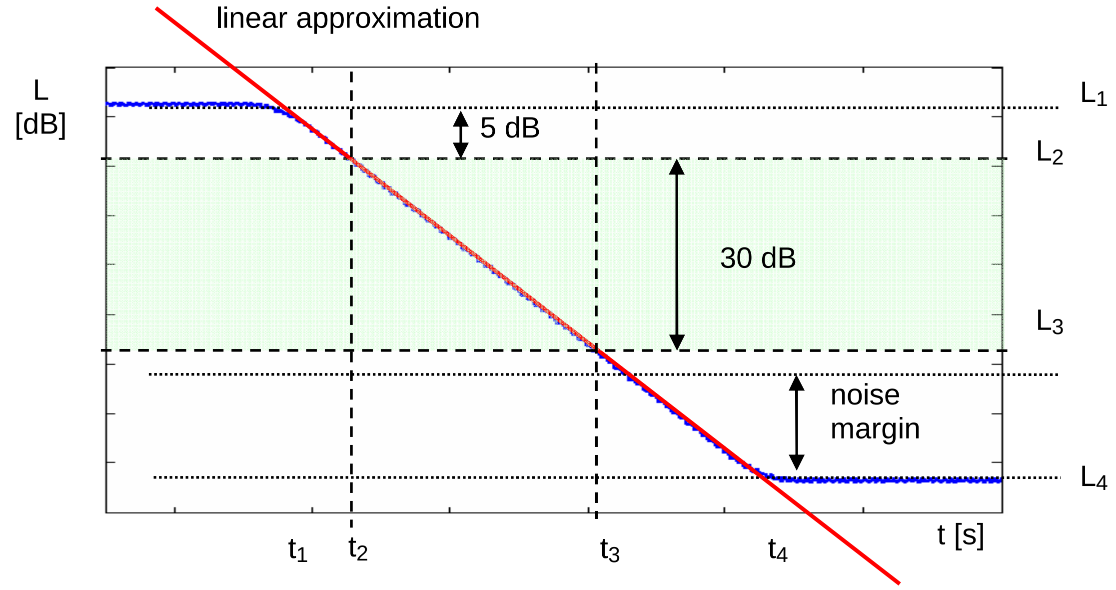

Fig 4. The RT 30 evaluation

H.3. Description of the decay curve recording in different measurement methods

➢ **DECAY method**

This RT 60 measurement method requires omnidirectional sound source which emits pink noise in appropriate frequency band. The most critical parameter of the omnidirectional sound source is emitted sound pressure level as it was mentioned in the beginning of the appendix.

The graphical illustration of the data recording in this method is presented in Figure 5.

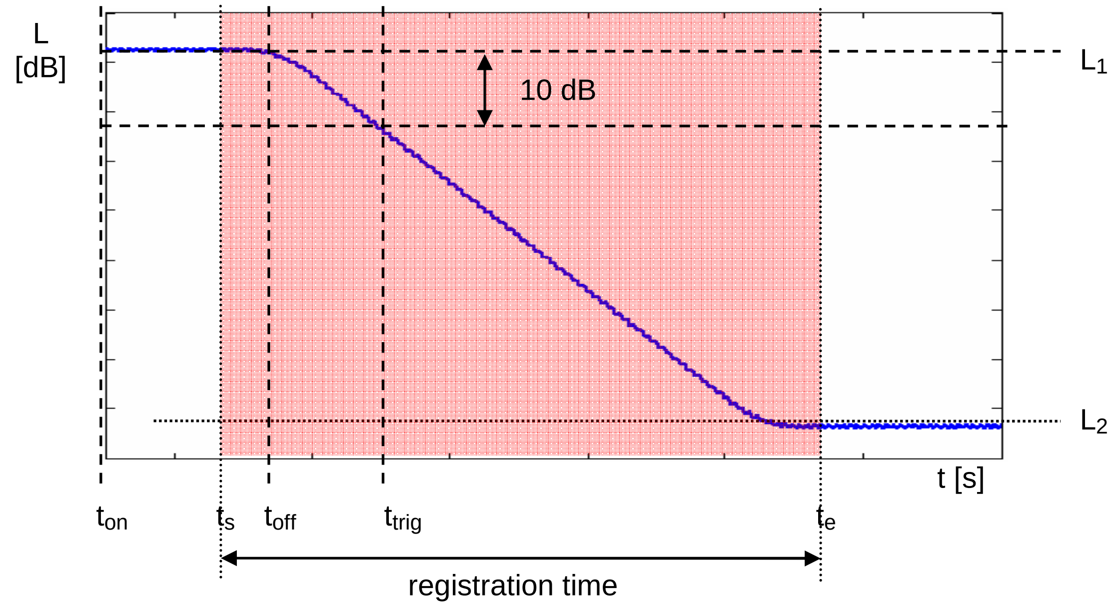

Fig 5. Data recording in the decay method of the reverberation time evaluation

The measurement time in this method consists of:

- The time between markers t_{on} and t_{off} in which the omnidirectional sound source emits acoustic power and the SVAN xxx analyser measures the actual sound pressure level.
- The time between markers t_{off} and t_{trig} in which the omnidirectional sound source is switched off and the SVAN xxx instrument waits for trigger condition fulfilment.
- The time between markers t_s and t_{trig} registered since the trigger condition fulfilment back till point t_s to allow recognising the beginning of the decay region. In the SVAN xxx instruments this time is equal to the **TIME STEP** (*path: MENU / INPUT / MEASUREMENT SETUP*) parameter value multiplied by 20.
- The time between markers t_{trig} and t_e registered since t_{trig} forward to record whole decay curve together with significantly long period of the noise level. This time in SVAN xxx instruments is adjusted by the **RESPONSE TIME** (*path: MENU / INPUT / MEASUREMENT SETUP*) parameter.

The above graph shows that the proper setting of the **RESPONSE TIME** value is very important. The registration time has to be long enough to acquire sufficient number of background noise level values. In other case the decay curve region could not be properly analysed or decay region could not fulfil the dynamic condition mentioned above. It is recommended to set the **RESPONSE TIME** parameter two times longer than expected reverberation time.

➢ IMPULSE method

In the Impulse method, Reverberation Time is computed by using the reverse-time integrated impulse response. This way of measuring sound decay was introduced firstly by M. R. Schroeder in two historical articles:

- New Method of Measuring Reverberation Time, *Journal of Acoust. Soc. Am.1965*
- Integrated-Impulse Method Measuring Sound Decay without Using Impulses, *Journal of Acoust. Soc. Am. Vol. 66(2) 1979*

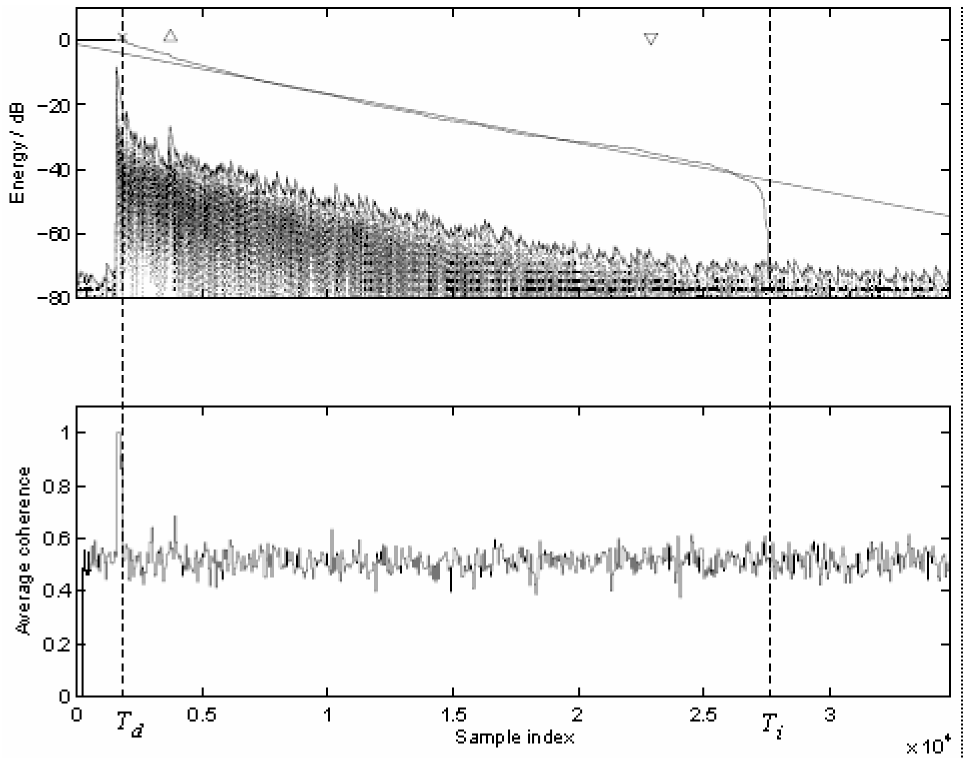

Fig. 6 An example of Schroeder integration with the limits Ti and Td

This RT 60 measurement method requires impulse sound source like pistol, petard or other sound source which emits impulse signal with very high sound pressure level.

The graphical illustration of data registering in this method is presented in Figure 7.

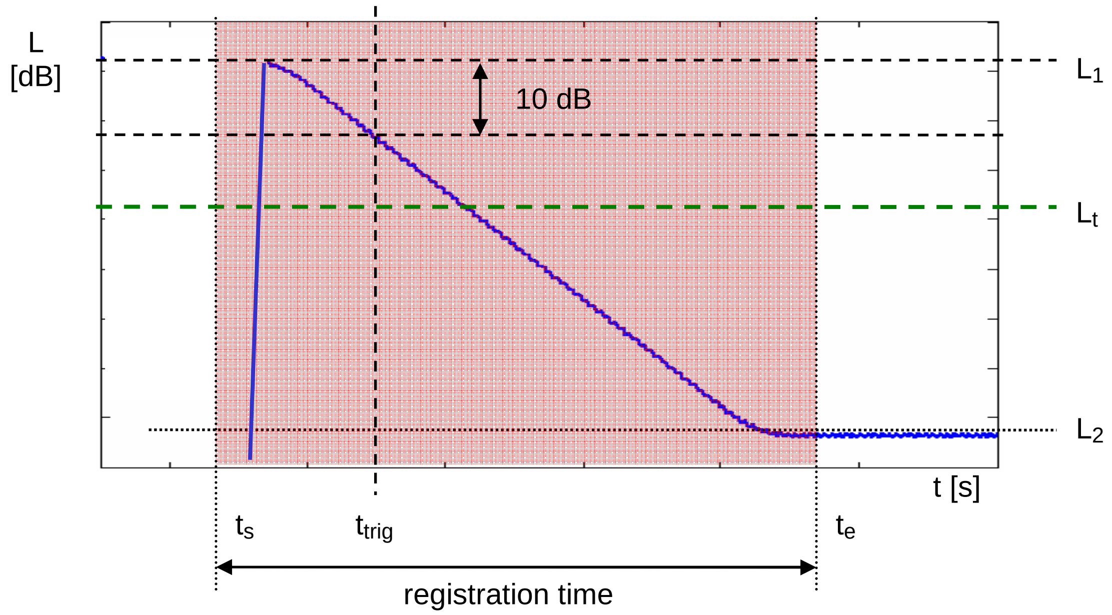

Fig 7. Data recording in the impulse method of the reverberation time evaluation

The measurement time in this method consists of:

- The time before marker t_{trig} in which the SVAN xxx analyser measures the actual sound pressure level and waits for the very high impulse sound pressure level which will fulfil the trigger condition. The trigger conditions will be fulfilled only when emitted impulse has maximal sound pressure level higher than L_t level (cf. Fig. 6). The L_t level in the SVAN xxx analyzer is adjusted by parameter **LEVEL** (*path: MENU / INPUT / TRIGGER SETUP*).
- The time between markers t_s and t_{trig} registered since the trigger condition fulfilment back till point t_s to allow recognising the beginning of the decay region. In the SVAN xxx instruments this time is equal to the **TIME STEP** (*path: MENU / INPUT / MEASUREMENT SETUP*) parameter value multiplied by 50.
- The time between markers t_{trig} and t_e registered since t_{trig} forward to record whole decay curve together with significantly long period of the noise level. This time in SVAN xxx instruments is adjusted by the **RESPONSE TIME** (*path: MENU / INPUT / MEASUREMENT SETUP*) parameter.

The above graph shows that the proper setting of the **RESPONSE TIME** value is very important. The registration time has to be long enough to acquire sufficient number of background noise level values. In other case the decay curve region could not be properly analysed or decay region could not fulfil the dynamic condition mentioned above. It is recommended to set the **RESPONSE TIME** parameter two times longer than expected reverberation time.