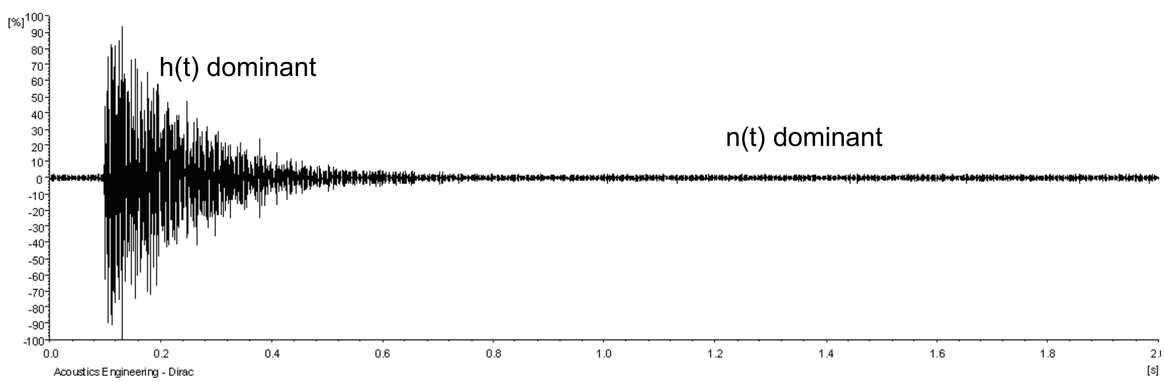
Acoustics Engineering

TN007

Technical Note

IMPULSE RESPONSE TO NOISE RATIO INR

Qualification Parameter For Acoustical Impulse Response Measurement



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TN007 Impulse Response To Noise Ratio INR

1 Introduction

The definition of the reverberation time presumes that the RMS value of a room acoustical impulse response follows a straight line when plotted on a dB scale. The reverberation time is then calculated from the slope of the regression line over the largest useful range of this plot. This regression range is directly related to the decay range, which in turn is limited due to measurement noise, as depicted in figures 1 and 2.

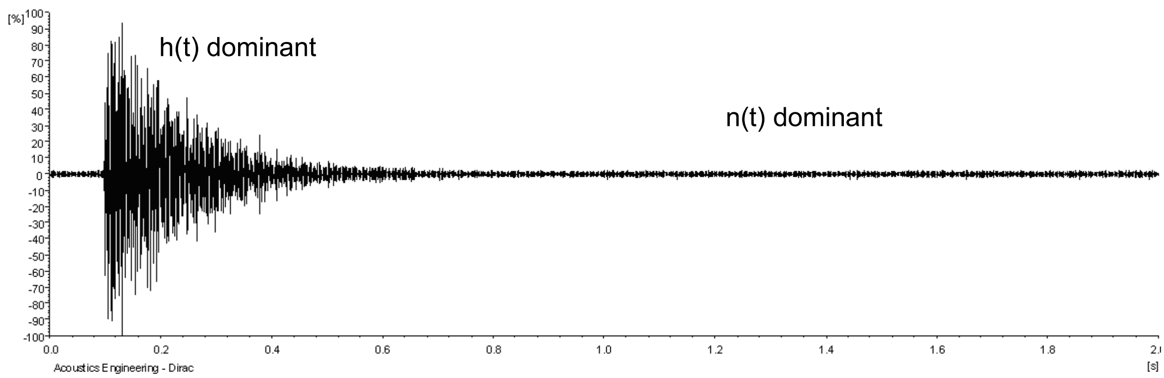

Figure 1. Measured impulse response p(t), including actual system response h(t) and noise n(t).

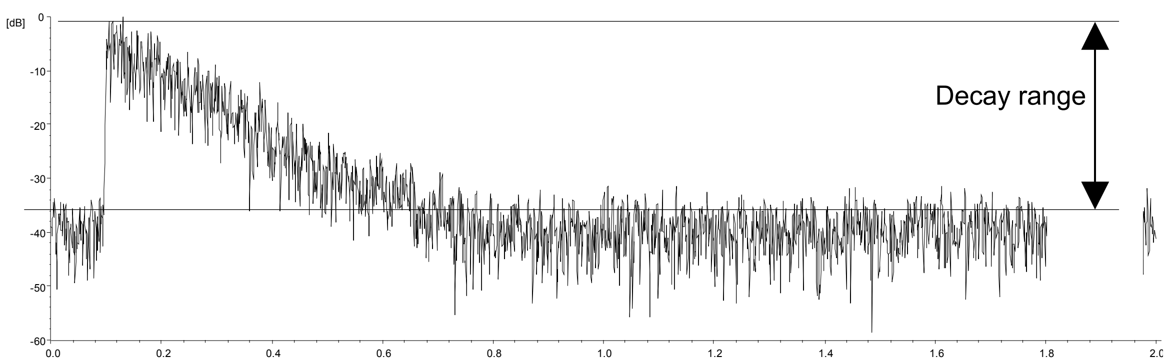

Figure 2. RMS plot: logarithm of lowpass filtered version of $p^2(t)$.

The ISO 3382 standard prescribes a decay range of 35 dB for the measurement of T_{20} (regression range -5...-25 dB) and of 45 dB for the measurement of T_{30} (regression range -5...-35 dB). Although the term decay range is conceptually clear, no definition is given. Hereafter a parameter to denote the decay range is defined, called INR (Impulse response to Noise Ratio).

2 Definition

The INR [dB] is defined as: $INR = L_I - L_N$ (1)

where L_I is the maximum RMS level in dB of p(t) and L_N is the noise level in dB. To define L_I, the backward integration method by Schroeder is as useful as it has already proven to be for the accurate determination of the slope. Indeed, the maximum of the Schroeder plot in figure 3 is easy to find, but its exact relation with L_I is not obvious.

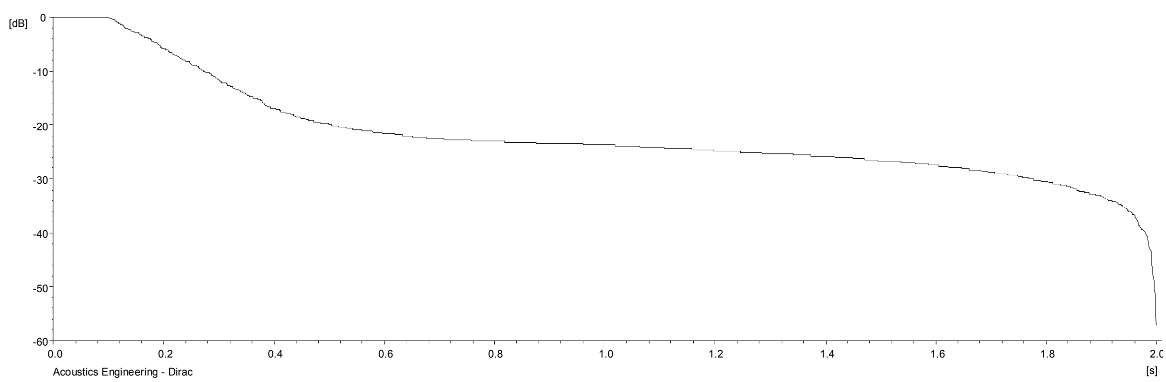

Figure 3. Schroeder plot of p(t) (without noise compensation).

Although there is no simple relation that is valid for all impulse responses, a good approximation can be made under the above-mentioned assumption that the RMS value of a room acoustical impulse response is essentially exponential with a decay rate of $60/T_{60}$ dB/s:

$$h(t) = h_0 \cdot U(t - t_d) \cdot C(t - t_d) \cdot 10^{-\frac{3(t-t_d)}{T_{60}}}$$

where h_0 is the maximum impulse response value, t_d is the time for the direct sound to travel from source to receiver, U(t) is the unit step function (0 if t < 0, 1 if t ≥ 0), C(t) is any carrier signal with unit RMS value, and T_{60} is the reverberation time. The maximum RMS level is:

$$L_I = 10 \cdot \log\left(h_0^2\right) \tag{2}$$

Backward integrating h(t) according to Schroeder and substituting (2) results in:

$$S(t) = 10 \cdot \log\left[\int_t^\infty h^2(t)\right] \quad \text{and} \quad S(0) = 10 \cdot \log\left[\frac{T_{60}}{6 \ln 10} \cdot h_0^2\right]$$

Hence, starting from this type of impulse response, we can define:

$$L_I = S(0) + 10 \cdot \log\left[\frac{6\ln 10}{T_{60}}\right] \qquad [dB] \qquad (3)$$

In words: L_I is defined as the level of the total impulse response energy normalized to the decay time T_{60}.

Practically, the INR can be obtained as follows:

1. Determine L_N from the initial part or from the tail of p(t), defined as the part of p(t) where the energy level of p(t) is essentially constant in time.
2. Determine the Schroeder curve S(t) in the usual way, with or without noise compensation.
3. Estimate T_{60} from the initial decay of the Schoeder curve.
4. Calculate L_I according to equation (3)
5. Calculate INR according to equation (1)

3 Evaluation

The INR is calculated for three kinds of impulse responses, measured respectively:

1. in the diffuse sound field, using an omni-directional microphone ("normal")
2. close to the source, using an omni-directional microphone ("stage")
3. in the diffuse sound field, using a bi-directional microphone ("lateral")

The RMS and Schroeder plots are shown with the corresponding calculated INR values in figures 4 through 6.

As could be expected, the INR of the "normal" impulse response can be estimated quite easily by visual inspection of the RMS plot.

The INR of the "stage" impulse response is clearly affected by the direct sound peak and is much more difficult to determine unambiguously from the RMS plot.

The INR of the "lateral" impulse response is hardly affected by the slow attack and can also be estimated quite easily from the RMS plot.

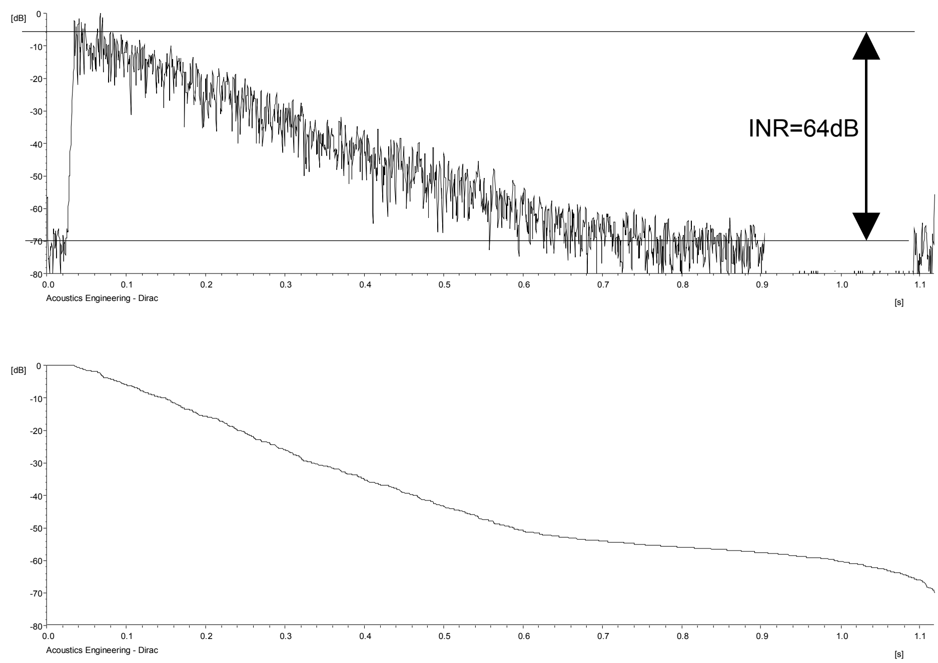

Figure 4. RMS and Schroeder plot of ”normal” impulse response.

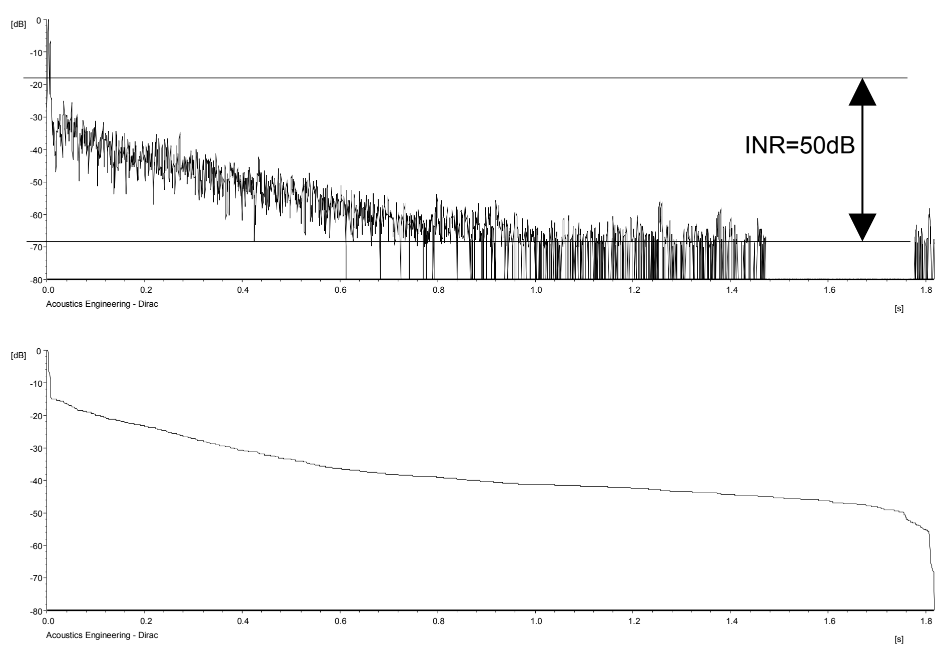

Figure 5. RMS and Schroeder plot of “stage” impulse response.

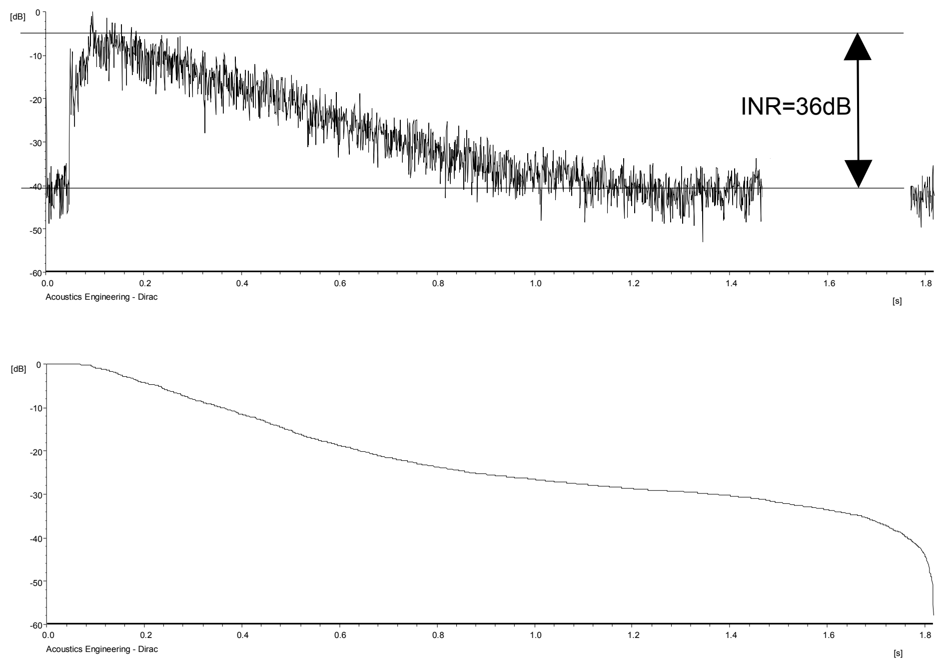

Figure 6. RMS and Schroeder plot of "lateral" impulse response.

4 Conclusion

The INR is an impulse response qualifying parameter that is closely related to the decay range, as mentioned in the ISO 3382 standard, which should be 35 and 45 dB for the accurate measurement of T_{20} and T_{30} respectively. The definition of INR, which is based on the RMS and Schroeder curves, makes the INR easy to calculate and useful for any practical acoustical impulse response.

Acoustics Engineering develops systems for the prediction and measurement of acoustical parameters, resulting in user-friendly tools that enable you to perform fast and accurate acoustical measurements and calculations.

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Acoustics Engineering	Email:	info@acoustics-engineering.com
	Phone/Fax:	+31 485 520996
	Mail:	Acoustics Engineering Groenling 43-45 5831 MZ Boxmeer The Netherlands
	Website:	www.acoustics-engineering.com

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