PD CEN/TS 16272-5:2014

BSI Standards Publication

Railway applications — Track — Noise barriers and related devices acting on airborne sound propagation — Test method for determining the acoustic performance

Part 5: Intrinsic characteristics — In situ values of sound reflection under direct sound field conditions

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National foreword

This Published Document is the UK implementation of CEN/TS 16272-5:2014.

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A list of organizations represented on this committee can be obtained on request to its secretary.

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Bahnanwendungen - Oberbau - Lärmschutzwände und verwandte Vorrichtungen zur Beeinflussung der Luftschallausbreitung - Prüfverfahren zur Bestimmung der akustischen Eigenschaften - Teil 5: Produktspezifische Merkmale - In-situ-Werte zur Schallreflexion in gerichteten Schallfeldern

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Foreword

This document (CEN/TS 16272-5:2014) has been prepared by Technical Committee CEN/TC 256 “Railway applications”, the secretariat of which is held by DIN.

This Technical Specification is one of the series EN 16272 “*Railway applications – Track – Noise barriers and related devices acting on airborne sound propagation – Test method for determining the acoustic performance*” as listed below:

- *Part 1: Intrinsic characteristics – Sound absorption in the laboratory under diffuse sound field conditions*
- *Part 2: Intrinsic characteristics – Airborne sound insulation in the laboratory under diffuse sound field conditions*
- *Part 3-1: Normalized railway noise spectrum and single number ratings for diffuse field applications*
- *Part 3-2: Normalized railway noise spectrum and single number ratings for direct field applications*
- *Part 4: Intrinsic characteristics – In situ values of sound diffraction under direct sound field conditions*
- *Part 5: Intrinsic characteristics – In situ values of sound reflection under direct sound field conditions*
- *Part 6: Intrinsic characteristics – In situ values of airborne sound insulation under direct sound field conditions*
- *Part 7: Extrinsic characteristics – In situ values of insertion loss*

It should be read in conjunction with:

EN 16272-1, *Railway applications – Track – Noise barriers and related devices acting on airborne sound propagation – Test method for determining the acoustic performance – Part 1: Intrinsic characteristics – Sound absorption in the laboratory under diffuse sound* field conditions

EN 16272-3-1, *Railway applications – Track – Noise barriers and related devices acting on airborne sound propagation – Test method for determining the acoustic performance – Part 3-1: Normalized railway noise spectrum and single number ratings for diffuse field* applications

EN 16272-3-2, *Railway applications – Track – Noise barriers and related devices acting on airborne sound propagation – Test method for determining the acoustic performance – Part 3-2: Normalized railway noise spectrum and single number ratings for direct field applications*

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to announce this Technical Specification: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

This Technical Specification describes a test method for determining the intrinsic characteristics of sound reflection of noise barriers and claddings designed for railways in non-reverberant conditions (a measure of intrinsic performance). It can be applied *in situ*, i.e. where the noise barriers are installed. The method can be applied without damaging the surface.

The method can be used to qualify products to be installed along railways as well as to verify the compliance of installed noise barriers to design specifications. Regular application of the method can be used to verify the long term performance of noise barriers.

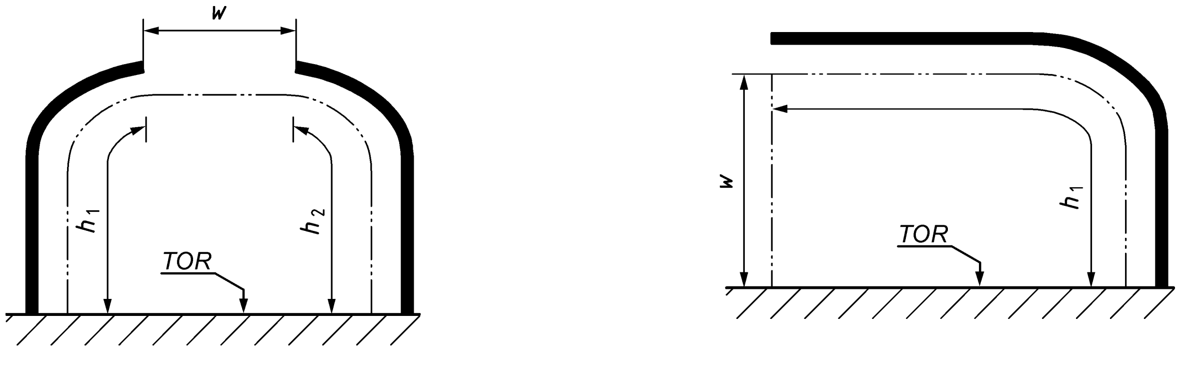
The method requires the average of results of measurements taken in different points in front of the device under test and/or for specific angles of incidences. The method is able to investigate flat and non-flat products.

The measurements results of this method for sound reflection are not directly comparable with the results of the laboratory method (EN 16272-1), mainly because the present method uses a directional sound field, while the laboratory method assumes a diffuse sound field. The test method described in the present document should not be used to determine the intrinsic characteristics of sound reflection of noise reducing devices to be installed in reverberant conditions, e.g. claddings inside tunnels or deep trenches.

For the purpose of this Technical Specification reverberant conditions are defined based on the envelope, *e*, across the rail formed by the barriers, trench sides or buildings (the envelope does not include the railway surface) as shown by the dashed lines in Figure 1. Conditions are defined as being reverberant when the percentage of open space in the envelope is less than or equal to 25 %, i.e.:

Reverberant conditions occur when $w/e \leq 0{,}25$, where $e = (w + h_1 + h_2)$

This criterion is applied also to the open space between the train body and the barrier surface.

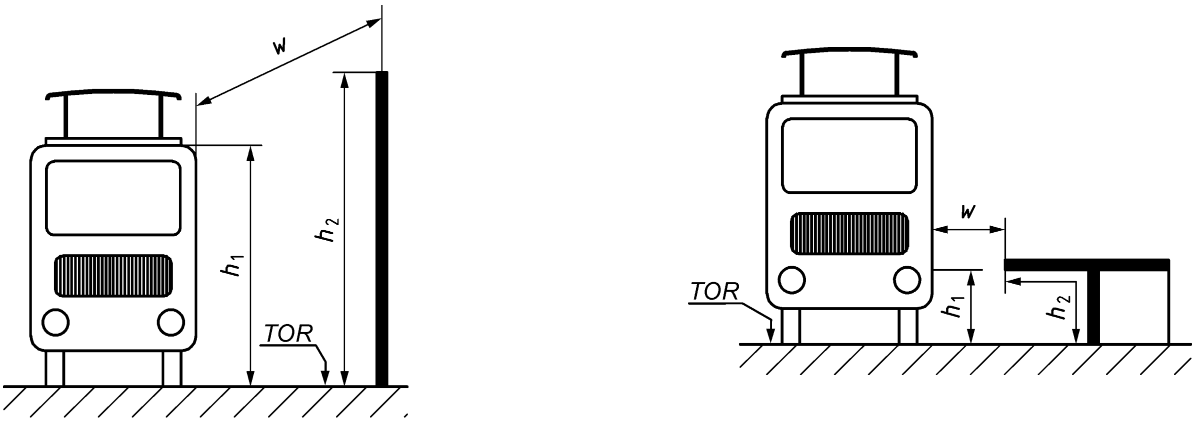


(a) Partial cover on both sides of the railway; envelope, $e = w + h_1 + h_2$

(b) Partial cover on one side of the railway; $e = w + h_1$

(c) Deep trench envelope, $e = w + h_1 + h_2$

(d) Tall barriers or buildings; envelope, $e = w + h_1 + h_2$



(e) Train passing close to a noise barrier envelope, $e = w + h_1 + h_2$

(f) Train passing close to a platform at the station, $e = w + h_1 + h_2$

Key

TOR top of rail

w width of open space

Figure 1 — (not to scale) Sketch of the reverberant condition check in six cases.

This method introduces a specific quantity, called reflection index, to define the sound reflection in front of a noise barrier or cladding, while the laboratory method gives a sound absorption coefficient. Laboratory values of the sound absorption coefficient can be converted to conventional values of a reflection coefficient taking the complement to one. In this case, research studies suggest that a quite good correlation exists between laboratory data, measured according to EN 16272-1 and field data, measured according to the method described in the present document.

This method may be used to qualify noise reducing devices for other applications, e.g. to be installed along roads or nearby industrial sites. In this case the single-number ratings should be calculated using an appropriate spectrum.

1 Scope

This Technical Specification describes a test method for measuring a quantity representative of the intrinsic characteristics of sound reflection from railway noise barriers: the reflection index.

The test method is intended for the following applications:

- determination of the intrinsic characteristics of sound reflection of noise barriers to be installed along railways, to be measured either on typical installations alongside railways or on a relevant sample section;
- determination of the *in situ* intrinsic characteristics of sound reflection of noise barriers and claddings in actual use;
- comparison of design specifications with actual performance data after the completion of the construction work;
- verification of the long term performance of noise barriers and claddings (with a repeated application of the method).

The test method is not intended for the following applications:

- determination of the intrinsic characteristics of sound reflection of noise reducing devices to be installed in reverberant conditions, e.g. inside tunnels or deep trenches.

Results are expressed as a function of frequency, in one-third octave bands between 100 Hz and 5 kHz. If it is not possible to get valid measurements results over the whole frequency range indicated, the results should be given in a restricted frequency range and the reasons of the restriction(s) should be clearly reported.

All noise reducing devices different from noise barriers and related devices acting on airborne sound propagation, e.g. devices for attenuation of ground borne vibration and on board devices are out of the scope of this Technical Specification.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

prEN 16272-3-2:2012, *Railway applications – Track – Noise barriers and related devices acting on airborne sound propagation – Test method for determining the acoustic performance – Part 3-2: Normalized railway noise spectrum and single number ratings for direct field applications*

EN 61672-1, *Electroacoustics – Sound level meters – Part 1: Specifications (IEC 61672-1)*

ISO/IEC Guide 98-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

3 Terms and definitions

For the purpose of this document the following definitions apply.

3.1
acoustic element
element whose primary function is to provide the acoustic performance of the device

3.2
Adrienne temporal window
the composite temporal window described in 5.5.5

3.3
background noise
noise coming from sources other than the source emitting the test signal

3.4
cladding
noise reducing device, which is attached to a wall or other structure and reduces the amount of sound reflected

Note 1 to entry: Claddings are generally made of acoustic and structural elements (see 3.3 and 3.4).

3.5
impulse response
the time signal at the output of a system when a Dirac function is applied to the input

Note 1 to entry: The Dirac function, also called δ function, is the mathematical idealisation of a signal infinitely short in time that carries a unit amount of energy.

3.6
maximum sampled area
the surface area, projected on a front view of the noise reducing device under test for reflection index measurements, which shall remain free of reflecting objects causing parasitic reflections

3.7
noise barrier
noise reducing device, which obstructs the direct transmission of airborne sound emanating from railways; it may either span or overhang the railway

Note 1 to entry: Noise barriers are generally made of acoustic and structural elements (see 3.3 and 3.4).

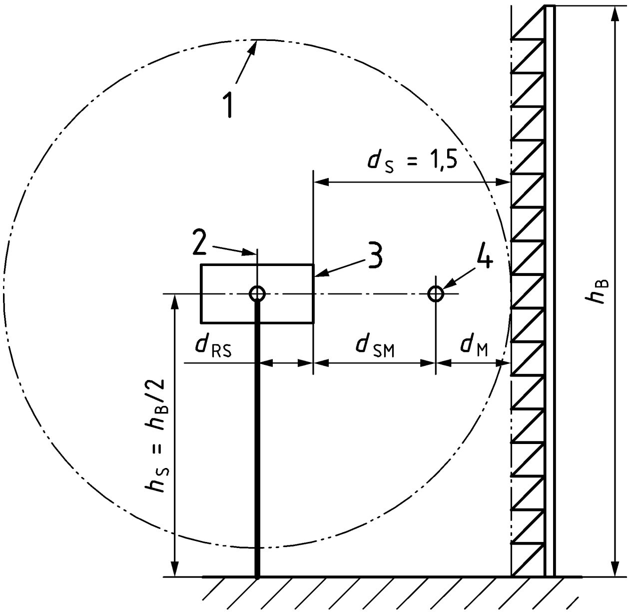
3.8
reference height
a height h_S equal to half the height h_B of the noise barrier or cladding under test: $h_S = h_B/2$ (see Figures 2 and 3)

3.9
rotation of the loudspeaker-microphone assembly
a set of nine measurement positions, including the reference position, reached rotating the loudspeaker-microphone assembly, around the axis of rotation R (see Figure 2), on the same plane in steps of 10° (Figures 5, 6 and 7)

3.10
signal-to-noise ratio, S/N
the difference in decibels between the level of the test signal and the level of the background noise at the moment of detection of the useful event (within the Adrienne temporal window)

3.11
sound reflection index
the result of a sound reflection test described by formula (1) (see 5.2)

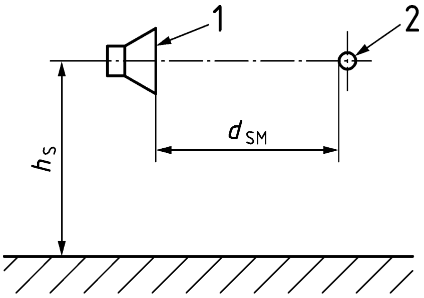
3.12
structural element
element whose primary function is to support or hold in place acoustic elements



Key

1	reference circle
2	axis of rotation
3	loudspeaker front panel
4	microphone

Figure 2 — (not to scale) Sketch of the loudspeaker-microphone assembly in front of the noise reducing device under test for reflection index measurements



Key

1	loudspeaker front panel
2	microphone

Figure 3 — (not to scale) Sketch of the set-up for the reference “free-field” sound measurement for the determination of the reflection index measurement

4 Symbols and abbreviations

For the purposes of this document, the following symbols and abbreviations apply.

Table 1 – Symbols and abbreviations

Symbol or abbreviation	Designation	Unit
a	Major axis of the ellipsoid of revolution used to define the maximum sampled area at oblique incidence	m
a_0, a_1, a_2, a_3	Coefficient for the expression of the Blackman-Harris window	-
c	Speed of sound in air	m/s
d_M	Horizontal distance from the microphone to the reference circle; it is equal to d_S = 0,25 m	m
d_p	Horizontal distance from the loudspeaker front panel to the microphone projected on a vertical plane, placed between the microphone and the noise reducing device under test, tangential to the reference circle when the loudspeaker-microphone assembly is horizontal	m
d_{RS}	Horizontal distance from the reference axis of rotation to the loudspeaker front panel; it is equal to: d_{RS} = 0,15 m	m
d_S	Horizontal distance from the front panel of the loudspeaker to the reference circle; it is equal to: d_S = 1,50 m	m
d_{SM}	Horizontal distance from the front panel of the loudspeaker to the microphone; it is equal to: d_{SM} = 1,25 m	m
DL_{RI}	Single number rating of sound reflection	dB
δ_i	Any input quantity to allow for uncertainty estimates	-
Δf_j	Width of the *j*-the one-third octave frequency band	Hz
f	Frequency	Hz
F	Symbol of the Fourier transform	-
f_{min}	Low frequency limit of sound reflection index measurements	Hz
f_s	Sample rate	Hz
f_{co}	Cut-off frequency of the anti-aliasing filter	Hz
h_B	Noise barrier height	m
h_S	Reference height	m
$h_i\ (t)$	Incident reference component of the free-field impulse response	-
$h_{rk}(t)$	Reflected component of the impulse response at the *k*-th angle	-
j	Index of the *j*-th one-third octave frequency band (between 100 Hz and 5 kHz)	-
k	Coverage factor	-
k_f	Constant used for the anti-aliasing filter	-
n_j	Number of angles on which to average	-
r	Radius of the maximum sampled area at normal incidence	m
RI_j	Sound reflection index in the *j*-th one-third octave frequency band	dB
t	Time	s or ms
$T_{W,BH}$	Length of the Blackman-Harris trailing edge of the Adrienne temporal window	ms

Symbol or abbreviation	Designation	Unit
$T_{W,ADR}$	Total length of the Adrienne temporal window	ms
u	Standard uncertainty	-
U	Expanded uncertainty	-
$w_i(t)$	Reference free-field component time window (Adrienne temporal window)	-
$w_r(t)$	Time window (Adrienne temporal window) for the reflected component	-

5 Sound reflection index measurements

5.1 General principle

The sound source emits a transient sound wave that travels past the microphone position to the device under test and is then reflected on it (Figures 2, 3, 5 and 6). The microphone placed between the sound source and the device under test receives both the direct sound pressure wave travelling from the sound source to the device under test and the sound pressure wave reflected (including scattering) by the device under test. The power spectra of the direct and the reflected components, corrected to take into account the path length difference of the two components, gives the basis for calculating the reflection index.

The measurement shall take place in an essentially free field in the direct surroundings of the device, i.e. a field free from reflections coming from surfaces other than the surface of the device under test. For this reason, the acquisition of an impulse response having peaks as sharp as possible is recommended: in this way, the reflections coming from other surfaces than the tested device can be identified from their delay time and rejected.

5.2 Measured quantity

The expression used to compute the sound reflection index RI as a function of frequency, in one-third octave bands, is:

$$RI_j = \frac{1}{n_j} \sum_{k=1}^{n_j} \frac{\int_{\Delta f_j} \left| F\left[t \times h_{rk}(t) \times w_r(t) \right] \right|^2 df}{\int_{\Delta f_j} \left| F\left[t \times h_i(t) \times w_i(t) \right] \right|^2 df} \tag{1}$$

where:

$h_i(t)$ is the incident reference component of the free-field impulse response;

$h_{rk}(t)$ is the reflected component of the impulse response at the k-th angle;

$w_i(t)$ is the incident reference free-field component time window (Adrienne temporal window);

$w_r(t)$ is the reflected component time window (Adrienne temporal window);

F is the symbol of the Fourier transform;

j is the index of the one-third octave frequency bands (between 100 Hz and 5 kHz);

Δf_j is the width of the j-th one-third octave frequency band;

n_j is the number of angles on which to average ($n \leq 9$ per rotation; see 5.5.2 and Table 1);

t is a time whose origin is at the beginning of the impulse response acquired by the measurement chain.

NOTE The reflections from different portions of the surface under test arrive at the microphone position at different times, depending on the travel path from the loudspeaker to the position of each test surface portion and back. The longer the travel path from the loudspeaker to a specific test surface portion and back, the greater the time delay. Thus, the amplitude of the reflected sound waves from different test surface portions, as detected at the microphone position, is attenuated in a manner inversely proportional to the travel time. In order to compensate for this effect, t is included as a factor in both numerator and denominator in Formula (1).

5.3 Test arrangement

The test method can be applied both *in situ* and on barriers purposely built to be tested using the method described here.

For applications on barriers purposely built to be tested using the method described here the specimen shall be built as follows:

— a part, composed of acoustic elements, that extends at least 4 m and is at least 4 m high.

The test specimen shall be mounted and assembled in the same manner as the manufactured device is used in practice with the same connections and seals between components parts.

For *in situ* applications the test specimen shall be constructed as follows:

— for *in situ* applications using single acoustic elements to achieve full height:

  - the test specimen shall be constructed as a single element which is representative of the *in situ* application;
  - where the test specimen cannot be constructed as a single element or where the *in situ* application is lower than 4 m, the test specimen shall be centred on the loudspeaker axis (at reference height h_S above the ground) and built up to 4 m high using smaller height acoustic elements at the base and top as appropriate;

— for *in situ* applications using stacked elements to achieve full height:

  - the test specimen shall be constructed as used *in situ*.

For the results to be valid on the full frequency range, the minimum dimensions of the sample shall be as follows (see Figure 4):

— a part, composed of acoustic elements, 4 m wide and 4 m high;

— two posts 4 m high at both sides (if applicable for the specific noise reducing device under test).

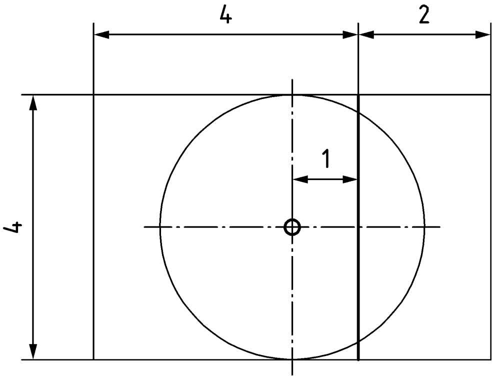
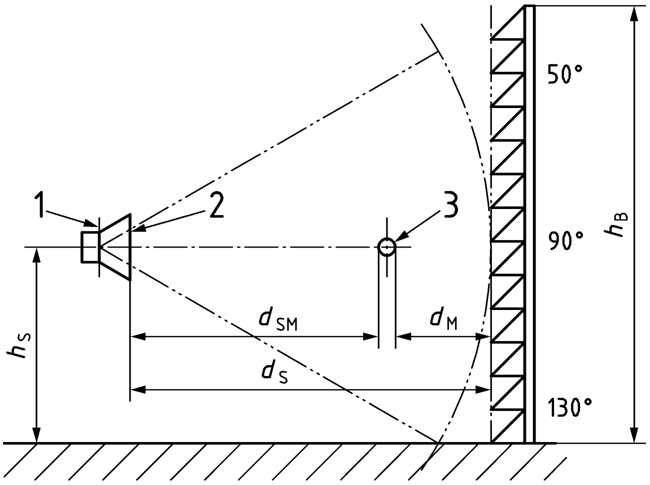
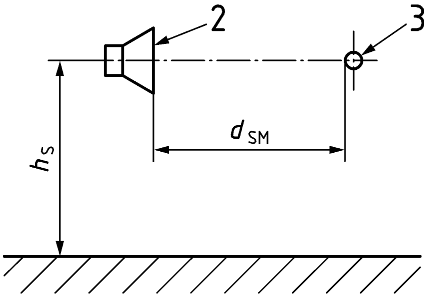


Figure 4 — Sketch of the minimum flat sample required for reflection index measurements in the 200 Hz - 5 kHz frequency range (see 5.5.7). Thin circle: maximum sampled area (5.6.1)



(a) Reflected sound measurements, from 50° to 130° in step of 10° on the same rotation plane, in front of a non-flat noise reducing device



(b) Reference "free-field" sound measurement

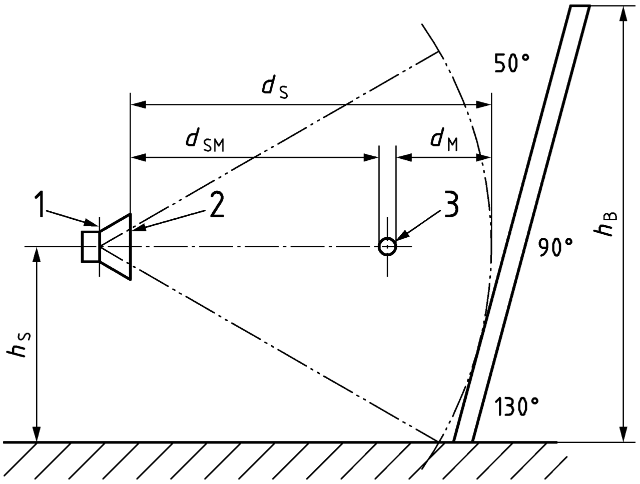
Key

1 axis of rotation

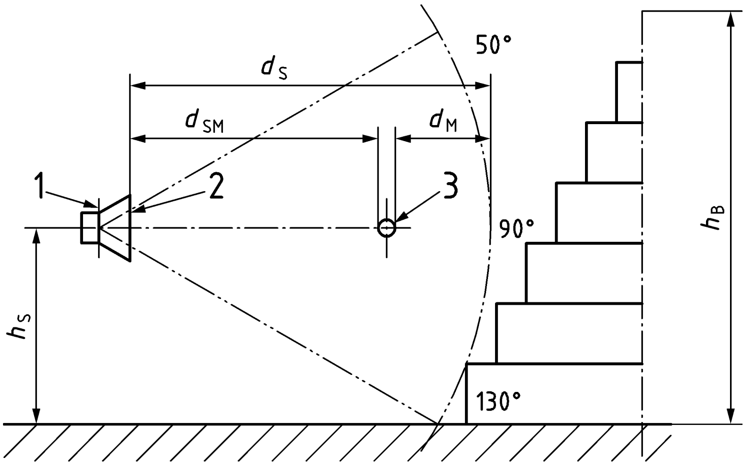
2 loudspeaker front panel

3 microphone

Figure 5 — (not to scale) Sketch of the set-up for the reflection index measurement (example for rotation in vertical direction)



(a) Reflected sound measurements, from 50° to 130° in step of 10° on the same rotation plane, in front of an inclined flat noise reducing device



(b) Reflected sound measurements, from 50° to 130° in step of 10° on the same rotation plane, in front of an inclined non flat noise reducing device

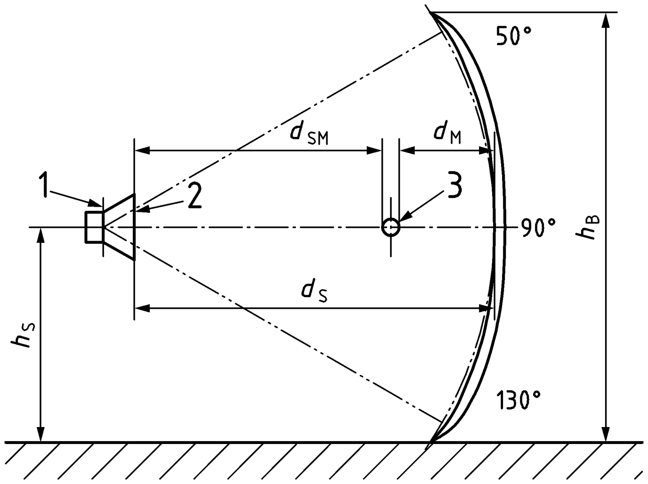
Key

1 axis of rotation

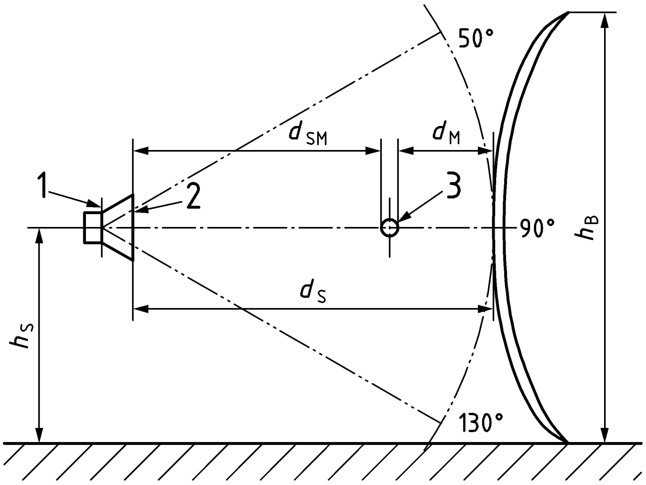
2 loudspeaker front panel

3 microphone

Figure 6 — (not to scale) Sketch of the set-up for the reflection index measurement (example for rotation in vertical direction)



(a) Reflected sound measurements, from 50° to 130° in step of 10° on the same rotation plane, in front of a concave noise reducing device



(b) Reflected sound measurements, from 50° to 130° in step of 10° on the same rotation plane, in front of a convex noise reducing device

Key

1	axis of rotation
2	loudspeaker front panel
3	microphone

Figure 7 — Sketch of the set-up for the reflection index measurement (example for rotation in vertical direction)

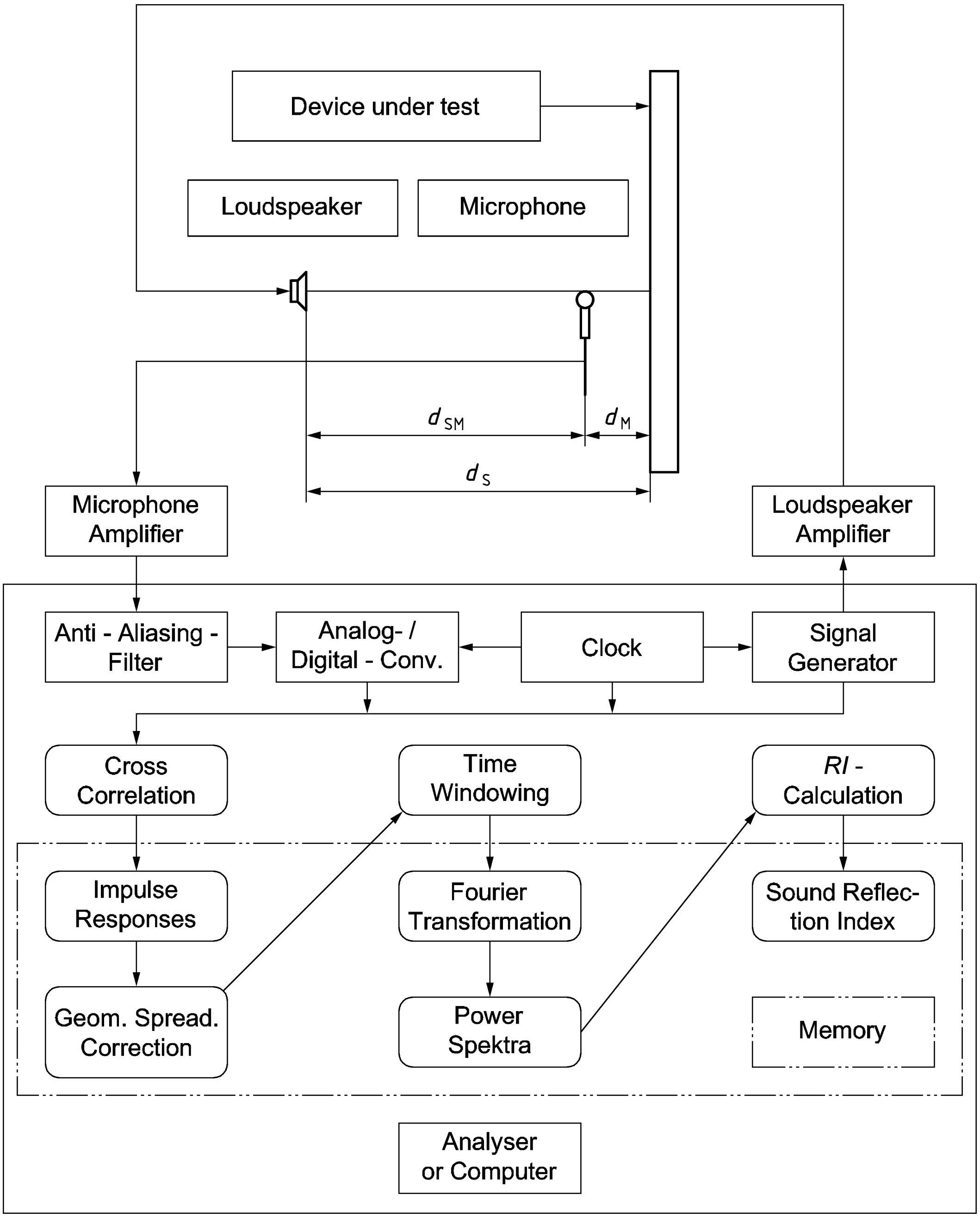


Figure 8 — Sketch representing the essential components of the measuring system

5.4 Measuring equipment

5.4.1 Components of the measuring system

The measuring equipment shall comprise: an electro-acoustic system, consisting of an electrical signal generator, a power amplifier and a loudspeaker, a microphone with its microphone amplifier and a signal analyser capable of performing transformations between the time domain and the frequency domain.

NOTE Part of these devices can be integrated into a frequency analyser or a personal computer equipped with specific add-on board(s).

The essential components of the measuring system are shown in Figure 8.

The complete measuring system shall meet the requirements of at least a type 1 instrument in accordance with EN 61672-1, except for the microphone which shall meet the requirements for type 2 and have a diameter of 1/2” maximum.

The measurement procedure here described is based on ratios of the power spectra of signals extracted from impulse responses sampled with the same equipment in the same place under the same conditions within a short time. Also, a high accuracy in measuring sound levels is not of interest here. Strict requirements on the absolute accuracy of the measurement chain are, therefore, not needed. Anyway, the requirement for a type 1 instrument is maintained for compatibility with other European Standards. The microphone should be sufficiently small and lightweight in order to be fixed in front of the loudspeaker without moving: the signal subtraction technique (see 5.5.4) requires the loudspeaker and microphone relative position be kept strictly constant. It is difficult to find on the market type1 microphones meeting this requirement. For this reason, the microphone is allowed to meet the requirements for type 2.

5.4.2 Sound source

The electro-acoustic sound source shall meet the following characteristics:

- have a single loudspeaker driver;
- be constructed without any port, e.g. to enhance low frequency response;
- be constructed without any electrically active or passive components (such as crossovers) which can affect the frequency response of the whole system;
- have a smooth magnitude of the frequency response without sharp irregularities throughout the measurement frequency range, resulting in an impulse response under free-field conditions with a length not greater than 3 ms.

NOTE As the sound reflection index is calculated from the ratio of energetic quantities extracted from impulse responses taken using the same loudspeaker-microphone assembly within a short time period, the characteristics of the loudspeaker frequency response are not critical, provided a good quality loudspeaker meeting the above prescriptions is used.

5.4.3 Test signal

The electro-acoustic source shall receive an input electrical signal which is deterministic and exactly repeatable. The input signal has to be set in order to avoid any nonlinearity of the loudspeaker.

The *S/N* ratio is improved by repeating the same test signal and synchronously averaging the microphone response. At least 16 averages shall be kept.

This Technical Specification recommends the use of a MLS signal as test signal. Alternatively, a different test signal may be used (e.g. sine sweep) as long as the results have been demonstrated to be exactly the same. This means that it shall be clearly demonstrated that:

- the generation of the test signal is deterministic and exactly repeatable;
- impulse responses are accurately sampled (without distortion) on the whole frequency range of interest (one-third octave bands between 100 Hz and 5 kHz);
- the test method maintains a good background noise immunity, i.e. the effective S/N ratio can be made higher than 10 dB on the whole frequency range of interest within a short measurement time (no more than 5 minutes per impulse response);
- the sample rate can be chosen high enough to allow an accurate correction of possible time shifts in the impulse responses between the measurement in front of the sample and the free-field measurement due to temperature changes;

— the test signal is easy-to-use, i.e. it can be conveniently generated and fed to the sound source using only equipment which is available on the market.

5.5 Data processing

5.5.1 Calibration

The measurement procedure here described is based on ratios of the power spectra of signals extracted from impulse responses sampled with the same equipment in the same place under the same conditions. An absolute calibration of the measurement chain with regard to the sound pressure level is therefore not needed. It is anyway recommended to check the correct functioning of the measurement chain from the beginning to the end of measurements.

5.5.2 Sample rate

The frequency at which the microphone response is sampled depends on the specified upper frequency limit of the measurement and on the anti-aliasing filter type and characteristics.

The sample rate f_s shall have a value greater than 43 kHz.

NOTE Although the signal is already unambiguously defined when the Nyquist criterion is met, higher sample rates facilitate a clear reproduction of the signal. This document prescribes the use of the signal subtraction technique (see 5.5.4), which implies knowledge of the exact wave form. Therefore, with the prescribed sample rates errors can be detected and corrected more easily, such as time shifts in the impulse responses between the measurement in front of the sample and the free-field measurement due to temperature changes.

The sample rate shall be equal to the clock rate of the signal generator.

The cut-off frequency of the anti-aliasing filter, f_{co}, shall have a value:

$$f_{co} \leq kf_s \tag{2}$$

where k = 1/3 for the Chebyshev filter and k = 1/4 for the Butterworth and Bessel filters.

For each measurement, the sample rate, the type and the characteristics of the anti-aliasing filter shall be clearly stated in each test report.

5.5.3 Background noise

The effective signal-to-noise ratio S/N, taking into account sample averaging, shall be greater than 10 dB over the frequency range of measurements.

NOTE Coherent detection techniques, such as the MLS cross-correlation, provide high S/N ratios.

5.5.4 Signal subtraction technique

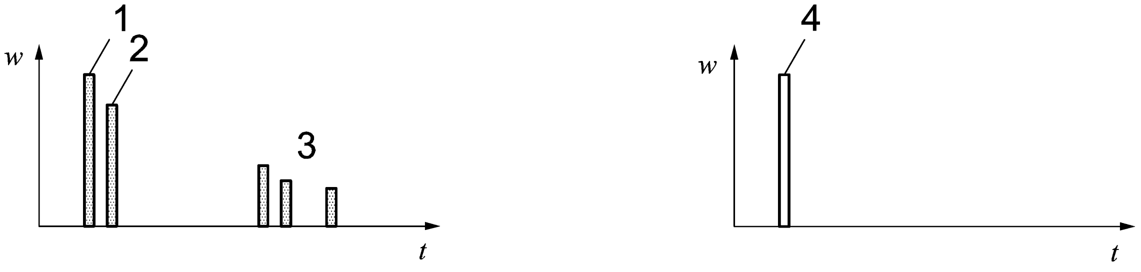
After positioning the loudspeaker-microphone assembly as described in 3.9, the overall impulse response has to be measured.

It consists of a direct component, a component reflected from the surface under test and other parasitic reflections (Figure 9 (a)). The direct component and the reflected component from the device under test shall be separated.

This European Technical Specification requires this separation be done using the signal subtraction technique: the reflected component is extracted from the overall impulse response after having removed the direct component by subtraction of an identical signal (Figures 9 (c) and 9 (d)). This means that the direct sound component shall be exactly known in shape, amplitude and time delay. This can be obtained by performing a free-field measurement using the same geometrical configuration of the loudspeaker and the microphone. In particular, their relative position shall be kept strictly constant. This requirement can be obtained by using a fixed and stable connection between the source and the microphone. The direct component is extracted from the free-field measurement (Figure 9 (b)).

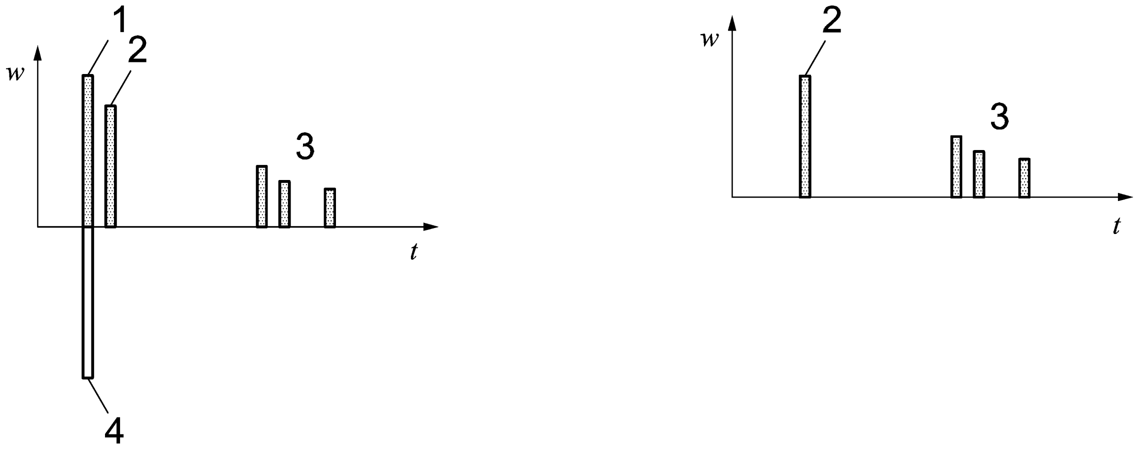
This technique allows broadening of the time window, leading to a lower frequency limit of the working frequency range, without having very long distances between loudspeaker, microphone and device under test.

The principle of the signal subtraction technique is schematically illustrated in Figure 9.



(a) Overall impulse response including: direct incident component (i) reflected component (r), unwanted parasitic components (u)

(b) Free-field direct component (i’)



(c) Direct component cancellation from the overall impulse response using the free-field direct component (i’)

(d) Result

Key

1	i
2	r
3	u
4	i'

Figure 9 — Principle of the signal subtraction technique

The measurement shall take place in a sound field free from reflections coming from objects other than the device under test. However, the use of a time window cancels out reflections arriving after a certain time delay, and thus originating from locations further away than a certain distance (see 5.6.3).

5.5.5 Adrienne temporal window

For the purpose of this Technical Specification, windowing operations in the time domain shall be performed using a temporal window, called Adrienne temporal window, with the following specifications (see Figure 10):

- a leading edge having a left-half Blackman-Harris shape and a total length of 0,5 ms (“pre-window”);

— a flat portion having a total length of 5,18 ms (“main body”);

— a trailing edge having a right-half Blackman-Harris shape and a total length of 2,22 ms.

The total length of the Adrienne temporal window is $T_{W,ADR} = 7{,}9$ ms.

NOTE A four-term full Blackman-Harris window of length $T_{W,BH}$ is:

$$w(t) = a_0 - a_1 \cos\left(\frac{2\pi t}{T_{W,BH}}\right) + a_2 \cos\left(\frac{4\pi t}{T_{W,BH}}\right) - a_3 \cos\left(\frac{6\pi t}{T_{W,BH}}\right) \tag{3}$$

where

a_0 = 0,35875;

a_1 = 0,48829;

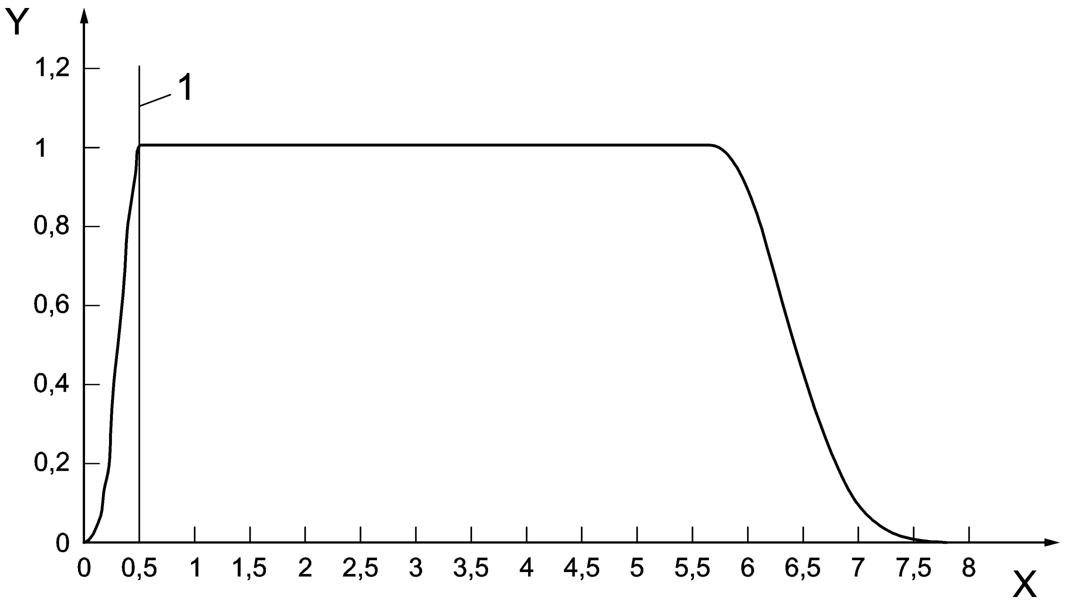
a_2 = 0,14128;

a_3 = 0,01168;

$0 \le t \le T_{W,BH}$

If the window length $T_{W,ADR}$ has to be varied (this occurs only in exceptional cases) the lengths of the flat portion and the right-half Blackman-Harris portion shall have a ratio of 7/3. As an example, when testing very large samples the window length can be enlarged in order to achieve a better low frequency limit.

The point where the flat portion of the Adrienne temporal window begins is called the marker point (MP).



Key

X time [ms]

Y Adrienne window function w(t) [relative units]

1 marker point MP

Figure 10 — The Adrienne temporal window, with the marker point MP

5.5.6 Placement of the Adrienne temporal window

For the “free-field” direct component, the Adrienne temporal window shall be placed as follows:

- the first peak of the impulse response, corresponding to the direct component, is detected;
- a time instant preceding the direct component peak of 0,2 ms is located;
- the direct component Adrienne temporal window is placed so as its marker point corresponds to this time instant.

In other words, the direct component Adrienne temporal window is placed so as its flat portion begins 0,2 ms before the direct component peak.

For the reflected component, the Adrienne temporal window shall be placed as follows:

- the time instant labelled by the direct component Adrienne temporal window marker point is located ;
- the time delay $\tau = 2d_M / c$ is added to this time instant; the resulting time instant is assumed as the position of the reflected component Adrienne temporal window marker point;
- the reflected component Adrienne temporal window is placed so as its marker point corresponds to this new time instant.

In other words, the reflected component Adrienne temporal window is placed so as its flat portion begins 0,2 ms before the first peak of the reflected component.

In computations involving the sound speed *c*, its temperature dependent value shall be assumed.

5.5.7 Low frequency limit and sample size

The method described in the present document can be used for different sample sizes.

The low frequency limit f_{min} of sound reflection index measurements depends on the shape and width of the Adrienne temporal window. The width in turn depends on the smallest dimension (height or length) of the noise reducing device under test and on the rotation angle of the loudspeaker-microphone assembly (see 5.6.2 and Figures 5, 6 and 7). In fact, the following unwanted components shall be kept out of the Adrienne temporal window for the reflected components:

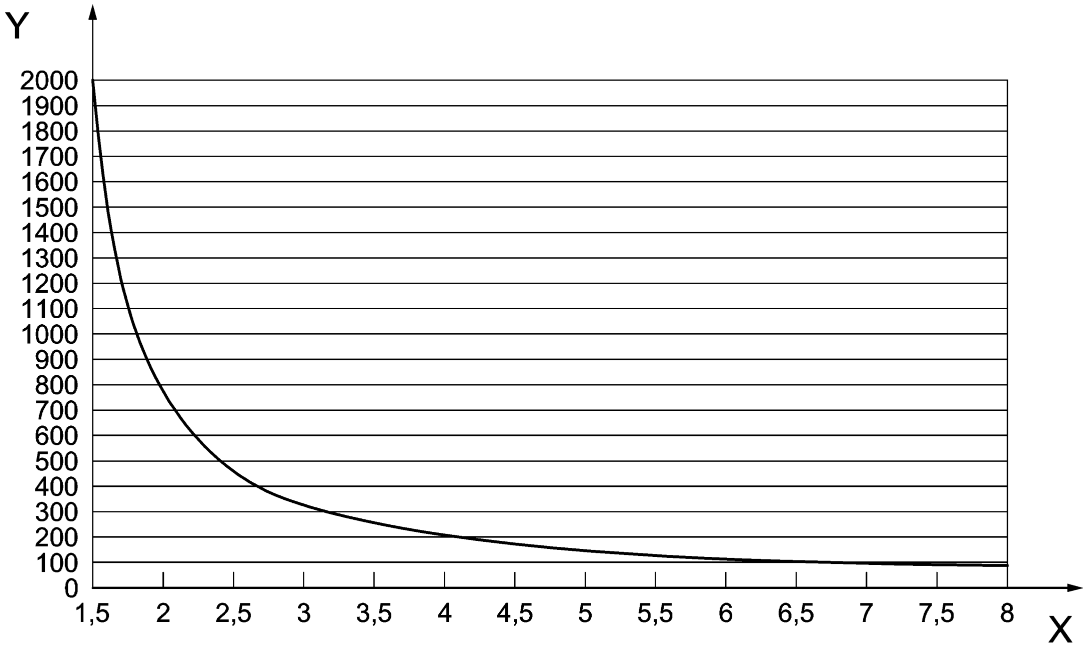
- the sound components diffracted by the edges of the noise reducing device under test;
- the sound components reflected by the ground on the sound source side of the noise reducing device under test.

For noise reducing devices having a height smaller than the length, the most critical component is that reflected by the ground and therefore the critical dimension is the height.

For noise reducing devices having a height smaller than the length, the low frequency limit f_{min} for normal incidence measurements as a function of the height of the noise reducing device under test is given in Figure 11.

For low barrier heights and/or specific shapes it may be more appropriate to carry out the rotation in the horizontal plane rather than in the vertical plane.

For qualification tests, the sample shall have minimum dimensions of 4 m in height by 4 m in length (see also Figure 4). These conditions give a low frequency limit for the sound reflection index of about 173 Hz, i.e. measurements are valid down to the 200 Hz one-third octave band. Measurement values below 173 Hz could be kept for information.



Key

Y t_{min} [Hz]

X h_{B} [m]

Figure 11 — Low frequency limit of sound reflection index measurements as a function of the height of the noise reducing device under test for normal incidence measurements

5.6 Positioning of the measuring equipment

5.6.1 Maximum sampled area

The size of the maximum sampled area is defined by the shortest distances of the loudspeaker front panel and the microphone to the reference circle for sound reflection index measurements of the device under test together with the width of the Adrienne temporal window.

For normal incidence measurements, the maximum sampled area is bounded by a circle with its centre at the point of incidence. Referring to the same Adrienne temporal window length used to calculate the low frequency limit (see 5.5.5 and 5.5.7 and Figures 5, 6 and 7), the radius *r* in metres of the above mentioned circle is:

$$r = \frac{1}{d_s + d_M + cT_w} \sqrt{\left(d_s + d_M + \frac{cT_w}{2}\right)\left(d_s + \frac{cT_w}{2}\right)(2d_M + cT_w)cT_w} \tag{4}$$

where

d_s distance from the loudspeaker front panel to the reference circle (m);

d_M distance from the microphone to the reference circle (m);

c speed of sound in air (m/s);

T_w width of the Adrienne temporal window for the reflected component (s).

NOTE 1 As an example, with the values of d_s, d_M, T_w specified in this Technical Specification, sample dimensions of 4 m x 4 m (height x length) and c = 340 m/s the maximum sampled area radius is 1,96 m.

NOTE 2 The radius of the surface area which contributes to the measured values of the sound reflection index is a decreasing function of frequency, but is not necessarily equal to the radius of the maximum sampled area previously defined.

NOTE 3 For oblique incidence, the maximum sampled area is the geometrical figure defined by the intersection between a vertical plane, placed between the microphone and the noise reducing device under test, tangential to the reference circle when the loudspeaker-microphone assembly is horizontal and the ellipsoid of revolution whose foci are the sound source position and the microphone position and whose major axis is given by:

$$a = cT_W + \sqrt{(d_S + d'_M)^2 + d_p^2} \tag{5}$$

with the same symbols used before and:

d'_M	distance from the microphone to the reference circle for the sound reflection index measurements, depending on the rotation angle (m);
d_p	distance from the loudspeaker front panel to the microphone projected on a vertical plane, placed between the microphone and the noise reducing device under test, tangential to the reference circle when the loudspeaker-microphone assembly is horizontal (m).

5.6.2 Selection of the measurement positions

5.6.2.1 General

The measuring equipment shall be placed in front of the noise reducing device to be tested in positions selected according to the following rules.

In all cases, distances shall be measured with an uncertainty not greater than 1 % of their nominal values.

5.6.2.2 Flat homogeneous samples

The loudspeaker-microphone assembly is located so that the microphone is in a *reference position* (see 3.12).

The microphone shall have a distance from the edge of a post equal to:

- 1 m, when the height of the device is greater or equal to 4 m;
- equal to the height of the device divided by 4, when the height of the device is less than 4 m.

The distance of the microphone from the loudspeaker shall be kept strictly constant, for the reflected component measurement in front of the sample, as well as for the direct component measurement in the free field. This can be done using a proper loudspeaker-microphone assembly (see also 5.6.4).

Around the reference position, a set of nine measurement positions, including the reference position, are defined; they are reached by rotation of the loudspeaker-microphone assembly, around the axis of rotation, on the same plane in steps of 10° (Figures 2, 5, 6 and 7). If the plane containing the above mentioned microphone positions is vertical, the nine angles are computed with reference to the vertical. If the plane containing the above mentioned microphone positions is horizontal, the nine angles are computed with reference to a line parallel to the baseline of the sample. For flat homogeneous samples having a distance between posts smaller than 4 m, the vertical rotation is recommended; otherwise, the horizontal rotation is recommended. The nine angles are labelled as follows:

50°, 60°, 70°, 80°, 90°(reference), 100°, 110°, 120°, 130°

This set of nine measurement positions is called a *rotation* (of the loudspeaker-microphone assembly).

Impulse response measurements are taken in each of the nine positions. A free-field measurement is taken displacing and/or rotating the loudspeaker-microphone assembly in order to avoid facing any nearby object, including the ground (Figure 3).

The measurements taken in front of the sample plus the corresponding free-field measurement shall be processed and averaged according to the sound reflection index Formula (1).

For each one-third octave band, the measurements to be taken into account in the averaging process are selected according to Table 2.

5.6.2.3 Non flat or non-homogeneous samples in one direction

For the purpose of this Technical Specification, a noise reducing device is considered non-flat if the depth *b* of its surface structure is at least 85 mm, see Figure 12 (a).

NOTE 1 A surface structure depth of 85 mm corresponds to one-quarter of the free-field wavelength for the nominal frequency of the predominating one-third octave band of the normalized railway noise spectrum according to prEN 16272–3-2:2012.

If the sample is non flat due to a periodic corrugation in the vertical direction, the minimum height of the sample for the measurement to be valid in the full frequency range (200 Hz to 5 kHz) shall be increased from 4 m to 4 m plus a full period of corrugation.

If the sample is non-flat due to a periodic corrugation in the horizontal direction, the minimum length of the sample for the measurement to be valid in the full frequency range (200 Hz to 5 kHz) shall be increased from 6 m to 6 m plus a full period of corrugation.

If the sample is non-flat due to a periodic corrugation in an non-vertical and non-horizontal direction, the minimum height (length) of the sample for the measurement to be valid in the full frequency range (200 Hz to 5 kHz) shall be increased from 4 m (6 m) to 4 m (6 m) plus the projection of the full period of corrugation in the vertical (horizontal) plane.

For the purpose of this Technical Specification, a noise reducing device is considered non-homogeneous when its surface to be exposed to railway noise when the device is in place is constituted by different materials (having different acoustic properties).

The loudspeaker-microphone assembly is located so that the microphone is in *reference position* “A” (see 3.12 and Figure 12 (a)) in front of the most protruding part of the surface of the noise reducing device under test and as close as possible to the middle of the sample.

One or more further reference position(s) “B”, “C”, as close as possible to the first reference position “A”, are located, according to the examples shown in Figure 12. When passing from the first reference position to the others, the loudspeaker-microphone assembly shall be shifted so as its axis of rotation lies on the same vertical plane.

Around each reference position a rotation, i.e. a set of nine measurement positions, is defined.

The plane of rotation shall intersect the surface of the device under test along a line oriented in the direction of the changes (changes in the surface orientation or in the material) on the sample.

Impulse response measurements are taken in each of the nine positions of each rotation. For each rotation a free-field measurement is taken.

NOTE 2 Usually the nine measurements of a rotation and the corresponding free-field measurement are performed within a short time (typically less than 20 min). This helps to avoid temperature differences, which may cause time shift, between the measurements in front of the sample under test and the free-field measurement.

For each rotation, the measurements taken in front of the sample plus the corresponding free-field measurement shall be processed and averaged according to the sound reflection index Formula (1).

For each one-third octave band, the number of measurements n_j to be taken into account in the averaging process is selected according to Table 2.

For samples giving a different response when sound impinges from above rather than from below, or from the left rather than from the right, in the same rotation, it is possible to compute partial and global averages at each rotation (according to the frequency dependent selection given in Table 2):

- RI^a, averaging the 50°, 60°, 70°, 80°, 90° measurements;
- RI^b, averaging the 90°, 100°, 110°, 120°, 130° measurements;

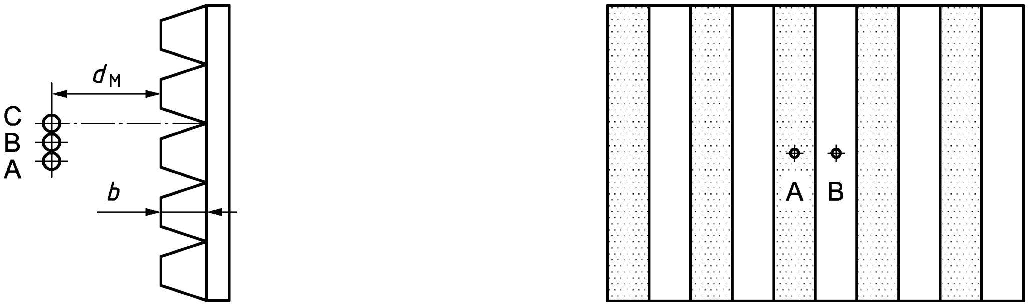
— RI^c, averaging all the 50° - 130° measurements of a rotation.

In any case, the final sound reflection index as a function of frequency shall be computed as the overall average of each angle measurement selected according to Table 1 for all rotations.

For example, at 5 kHz (frequency band number *j* = 18) the number of measurements to average shall be: n_{18} = 18 measurements for 2 rotations, n_{18} = 27 measurements for 3 rotations, etc. See Formula (1) and Table 1.

Table 2 — Measurements to be taken into account for spatial averaging in different frequency bands. The “X” indicate the measurements to be taken into account in the spatial averaging process (see Formula (1)) as a function of the one-third octave band of interest

	50 °	60 °	70 °	80 °	90 °	100 °	110 °	120 °	130 °
100 Hz					X				
125 Hz					X				
160 Hz					X				
200 Hz					X				
250 Hz				X	X	X			
315 Hz		X	X	X	X	X	X	X	
400 Hz		X	X	X	X	X	X	X	
500 Hz	X	X	X	X	X	X	X	X	X
630 Hz	X	X	X	X	X	X	X	X	X
800 Hz	X	X	X	X	X	X	X	X	X
1 000 Hz	X	X	X	X	X	X	X	X	X
1 250 Hz	X	X	X	X	X	X	X	X	X
1 600 Hz	X	X	X	X	X	X	X	X	X
2 000 Hz	X	X	X	X	X	X	X	X	X
2 500 Hz	X	X	X	X	X	X	X	X	X
3 150 Hz	X	X	X	X	X	X	X	X	X
4 000 Hz	X	X	X	X	X	X	X	X	X
5 000 Hz	X	X	X	X	X	X	X	X	X



Key

b is the depth of the surface structure

a) Microphone reference positions A (first selected), B, and C for a non-flat sample (side view)

b) Microphone reference positions A and B for a flat sample combining two different materials (front view)

Figure 12 —Microphone reference positions

5.6.2.4 Non flat or non-homogeneous samples in two directions

If the sample is non-flat due to a periodic corrugation in two directions, the minimum height (length) of the sample for the measurement to be valid in the full frequency range (200 Hz to 5 kHz) shall be increased from 4 m (6 m) to 4 m (6 m) plus the projection of the full period of each of the two corrugation directions in the vertical (horizontal) plane.

The loudspeaker-microphone assembly is located so that the microphone is in *reference position* “A” (see 3.12 and Figure 13) in front of the most protruding part of the surface of the noise reducing device under test and as close as possible to the middle of the sample.

Two or more further reference positions “B”, “C”, …, as close as possible to the first reference position “A”, are located, according to the examples shown in Figure 13. When passing from the first reference position to the others, the loudspeaker-microphone assembly shall be shifted so as it axis of rotation lies on the same vertical plane.

Around each reference position a rotation, i.e. a set of nine measurement positions, is defined.

The plane of rotation shall intersect the surface of the device under test along a line oriented in the direction of the changes (changes in the surface orientation or in the material) on the sample.

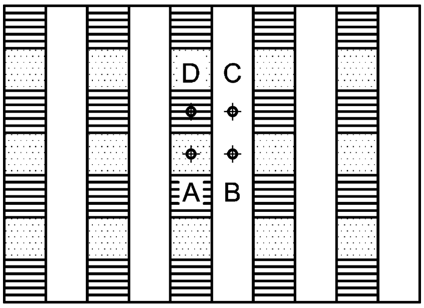


Figure 13 — Reference positions A (first selected), B, C and D for a flat sample combining three different materials in two dimensions (front view)

Impulse response measurements are taken in each of the nine positions of each rotation. For each rotation a free-field measurement is taken.

NOTE Usually the nine measurements of a rotation and the corresponding free-field measurement are performed within a short time (typically less than 20 min). This helps to avoid temperature differences, which may cause time shift, between the measurements in front of the sample under test and the free-field measurement.

For each rotation, the measurements taken in front of the sample plus the corresponding free-field measurement shall be processed and averaged according to the sound reflection index Formula (1).

For each one-third octave band, the measurements to be taken into account in the averaging process are selected according to Table 2.

For samples giving a different response when sound impinges from the top rather than from the bottom, or from the left rather than from the right, in the same rotation, it is possible to compute partial and global averages at each rotation (according to the frequency dependent selection given in Table 2):

RI^a, averaging the 50°, 60°, 70°, 80°, 90° measurements ;

RI^b, averaging the 90°, 100°, 110°, 120°, 130° measurements ;

RI^c, averaging all the 50° - 130° measurements of a rotation.

In any case, the final sound reflection index as a function of frequency shall be computed as the overall average of each angle measurement selected according to Table 2 for all rotations.

For example, at 5 kHz (frequency band number j = 18) the number of measurements to average shall be: n_{18} = 27 measurements for 3 rotations,…, n_{18} = 81 measurements for 9 rotations. See Formula (1) and Table 2.

5.6.3 Reflecting objects

Any object other than the device under test, shall be considered as a reflecting object which could cause parasitic reflections (e.g. safety rails, fences, rocks, parked cars, etc.). These objects shall remain out of the maximum sampled area and at a distance from the microphone greater than the radius of the maximum sampled area.

Care shall be taken in order that the microphone stand does not influence the measurement.

5.6.4 Safety considerations

This test method may involve hazardous operations when measurements are made on or aside railways in use. This document does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this document to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

5.7 Sample surface and meteorological conditions

5.7.1 Condition of the sample surface

Unless the measurement specifically aims at determining the influence of weather or other environmental conditions on sound propagation, measurements shall be carried out only when the sample surfaces is dry. If the sample surface can be expected to have a significant void content, then measurement shall not be made until it has been verified that the pores are dry.

The sample surface temperature shall be within 0-70 °C during the measurement.

5.7.2 Wind

Wind speed at microphone positions shall not exceed 5 m/s during the measurements.

5.7.3 Air temperature

The ambient air temperature shall be within 0-40 °C during the measurements. In calculations involving the sound speed value, its temperature dependent value shall be taken, using the actual temperature value around the test area.

5.8 Measurement uncertainty

The uncertainty of results obtained from measurements according to this European Technical Specification shall be evaluated, preferably in compliance with ISO/IEC Guide 98-3. If reported, the expanded uncertainty together with the corresponding coverage factor for a stated coverage probability of 95 % as defined in ISO/IEC Guide 98-3 shall be given. More information on measurement uncertainty is given in Annex A.

5.9 Measuring procedure

The measurement shall be carried out as follows:

a) the sample surface and meteorological conditions are checked to ensure they comply with the specifications in 5.7. If not, the measurement cannot be carried out;

b) the measuring equipment is placed on site as specified in 5.6. The safety considerations in 5.6.4 apply;

c) the radius of the maximum sampled area as specified in 5.6.1 is computed and it is checked that no reflecting objects are in this area. If not, the measurement cannot be carried out;

d) the test signal is selected;

e) the test signal is generated;

f) the total signal as received by the microphone is sampled with a sample rate selected according to 5.5.2;

g) the total signal as received by the microphone is processed in order to obtain the overall impulse response in the selected measurement position;

h) if it is suspected that the measurement may be contaminated by the background noise, the overall impulse response data are further averaged, until a given degree of accuracy is obtained in each one-third frequency band of interest. In any case, at least 16 averages shall be kept (see 5.4.3);

i) for each rotation a free-field impulse response with the measurement set-up oriented toward the free space is acquired;

j) the signal subtraction technique (5.5.4) is applied to each measurement of each rotation. The direct component from the sound source is isolated from the free-field measurement using the Adrienne temporal window (5.5.5); the components reflected by the maximum sampled area are isolated, using the Adrienne temporal window, from measurements in front of the sample under test (see 5.5.6);

k) the power spectra of the windowed signals are computed;

l) the sound reflection index is computed according to Formula (1);

m) the single-number rating is calculated according to prEN 16272-3-2:2012, if applicable;

n) the measurement uncertainty is evaluated (see Annex A);

o) the measurement report is written.

5.10 Test report

The test report shall include the information listed below (see Annex B):

a) reference to this document;

b) name and address of testing organization;

c) date and place of the test;

d) description of the test site: drawing or pictures showing the noise reducing device under test, measurement set-up, reflecting objects nearby the maximum sampled area (if any);

e) description of the noise reducing device under test: brand, type, dimensions, age, actual conditions, composition (number of layers, thickness(es), material specification, etc.);

f) surface conditions of the noise reducing device with regard to dryness and temperature;

g) meteorological conditions prevailing during the test (wind speed and direction, air temperature);

h) test arrangement, indicating, on a scale drawing or a sketch with dimensions marked on it, the reference positions of the source and the microphone and the number of measurements;

i) equipment used for measurement and analysis, including name, type, serial number and manufacturer;

j) type and characteristics of the anti-aliasing filter and sample rate of the sampling/analysis device;

k) shape and length of the Adrienne temporal window used for the analysis;

l) low frequency limit of the measurement and its relationship with the smallest dimension of the noise reducing device under test (see 5.5.7);

m) result of the measurements, including the partial results RI^a, RI^b and RI^c;

n) measurement uncertainty;

o) single-number rating of the result (when applicable);

p) signature of the person responsible for the measurements.

The test results shall be given in the form of a graph and a table, showing the values of the sound reflection index in one-third octave frequency bands between 100 Hz and 5 kHz. If it is not possible to get valid measurements results over the whole frequency range indicated, the results shall be given in a restricted frequency range and the reasons of the restriction(s) shall be clearly reported.

The values of the sound reflection index shall be rounded off to two decimal places.

The single-number rating shall be calculated according to 5.8 and reported after having being rounded to the nearest integer.

Annex A
(informative)

Measurement uncertainty

A.1 General

The accepted format for expression of uncertainties generally associated with methods of measurement is that given in ISO/IEC Guide 98-3. This format incorporates an uncertainty budget, in which all the various sources of uncertainty are identified and quantified, from which the combined total uncertainty can be obtained.

The intention of this annex is to provide a basis for the development of suitable information by which the ISO/IEC Guide 98-3 could be applied. However, the information in this annex has not been validated through round robin testing, and further research could reveal additional considerations. It remains the final responsibility of a laboratory performing a measurement to determine its uncertainty (which might be higher or lower than the data given) and this annex should only be regarded as a guide.

A.2 Expression for the calculation of sound reflection index

At the present stage, no information exists to develop an analytical model of the sound reflection index as a function of (many) input variables. Preliminary estimations show that the sound reflection index of a noise reducing device, RI_j, determined according to this Technical Specification, is a function of a number of parameters, indicated by the following formula:

$$RI_j = \overline{RI}_j + \delta_1 + \delta_2 + \delta_3 + \delta_4 + \delta_5 + \delta_6 \tag{A.1}$$

where

$\overline{RI}_j$ is the time and space averaged sound reflection index in the *j*-th one-third-octave frequency band;

δ_1 is an input quantity to allow for any uncertainty in the incident reference component of the free-field impulse response acquisition;

δ_2 is an input quantity to allow for any uncertainty in the reflected components of the impulse response acquisition;

δ_3 is an input quantity to allow for any uncertainty in the measuring equipment;

δ_4 is an input quantity to allow for any uncertainty due to the finite number of microphone and source positions;

δ_5 is an input quantity due to fluctuations in air temperature;

δ_6 is an input quantity due to fluctuations in air humidity.

A probability distribution (normal, rectangular, Student’s t, etc.) is associated with each of the input quantities. Its expectation (mean value) is the best estimate for the value of the input quantity and its standard deviation is a measure of the dispersion of values. The uncertainty in the estimate of the input quantity is termed the standard uncertainty. It is a function of the standard deviation, probability distribution and number of degrees of freedom.

A.3 Contributions to measurement uncertainty

The combined uncertainty associated with the value of the sound reflection index depends on each of the input quantities, their respective probability distributions and sensitivity coefficients, c_i. The sensitivity coefficients are a measure of how the values of the sound reflection index are affected by changes in the values of the respective input quantities. Mathematically, these coefficients are equal to the partial derivatives of the function RI_j (Formula (A.1)) with respect to the relevant input quantities. The contributions of the respective input quantities to the overall uncertainty are then given by the products of the standard uncertainties and their associated sensitivity coefficients. For the case of negligible correlation between the input quantities, the combined standard uncertainty of the determination of the sound reflection index, $u(RI_j)$, is given by the following formula:

$$u\left(RI_j\right)=\sqrt{\sum_{i=1}^{6}\left(c_i u_i\right)^2} \tag{A.2}$$

The standard uncertainties from the various contributions remain to be established by research. An example of the type of information needed to derive the overall uncertainty of the method is given in Table A.1.

Table A.1 — Example of the type of information needed to derive the overall uncertainty of the method

Quantity	Estimate	Standard uncertainty	Probability distribution	Sensitivity coefficient
Sound reflection index in the *j*-th one-third octave frequency band	$\overline{RI}_j$	$u\left(\overline{RI}_j\right)$	normal	
incident reference component of the free-field impulse response	$h_{i,j}(t)$	δ_1		
reflected components of the impulse response at the *k*-th angle	$h_{rk,j}(t)$	δ_2		
uncertainty in the measuring equipment	-	δ_3		
uncertainty due to the finite number of microphone and source positions	-	δ_4		
uncertainty due to fluctuations in air temperature	-	δ_5		
uncertainty due to fluctuations in air humidity	-	δ_6		
Combined standard uncertainty	$u\left(SI_j\right)=\sqrt{\sum_{i=1}^{6}\left(c_i u_i\right)^2}$		normal	-
Expanded uncertainty	$U = k \times u$			-

A.4 Expanded uncertainty of measurement

The ISO/IEC Guide 98-3 requires an expanded uncertainty, U, to be specified, such that the interval $[RI_j - U, RI_j + U]$ covers e.g. 95 % of the values of RI_j that might reasonably be attributed to SI_j. To that purpose, a coverage factor, k, is used, such that $U = k \times u$. The coverage factor depends on the probability distribution associated with the measurand.

A.5 Measurement uncertainty based upon reproducibility data

In the absence of data for uncertainty contributions, values for the standard deviation of reproducibility, when available, may be used as an estimate of the combined standard uncertainty of determinations of sound reflection index. A value may then be selected for the coverage factor, and the product of the two will yield an estimate of the expanded measurement uncertainty, with the chosen coverage probability. By convention, a coverage probability of 95 % is usually chosen. To avoid any misinterpretations, the chosen coverage probability should always be stated in test reports together with the expanded measurement uncertainty.

The information on measurement reproducibility can be helpful towards the derivation of measurement uncertainties, but it is incomplete. In particular, it does not give an analysis of the various components of measurement uncertainty and their magnitudes.

Annex B
(informative)

Template of test report on sound reflection of railway noise barriers

B.1 Template of test report

for product xxxx produced by the firm yyyyy

(a)	*Remark:* The present test is based on the test method according to the European Technical Specification CEN/TS 16272–5. If the single-number rating is to be calculated, this shall be done in accordance to prEN 16272–3-2:2012.
(b)	**Name and address of testing organization:**
(c)	**Date of test:** **Place of test:**
(d)	**Test situation:** see description and photographic presentation in **B.1**
(e)	**Test object** **Manufacturer:** **Type:** **ensions:** height, length, distance between support posts or ribs **Date of manufacture:** **Date of installation:** **Exposure classes according to** EN 60721–3-4: **Physical condition during test (by visual inspection):** **Composition:** see description and photographic presentation in **B.2**. Drawings and photographs shall clearly show how the product is built; include at least front view, side view, back view.
(f)	**Surface conditions of the test object** **Dryness:** **Temperature:**
(g)	**Meteorological conditions prevailing during the test** **Wind speed:** **Wind direction:** **Air temperature:**
(h)	**Test arrangement:** see description and photographic presentation in **B.2.** Note that this representation should include the exact positions of the microphone with respect to the sample e.g. showing the microphone positions opposite a ridge on a non-flat product.
(i)	**Equipment used for measurement and analysis** **Sound source:** ***Manufacturer:***

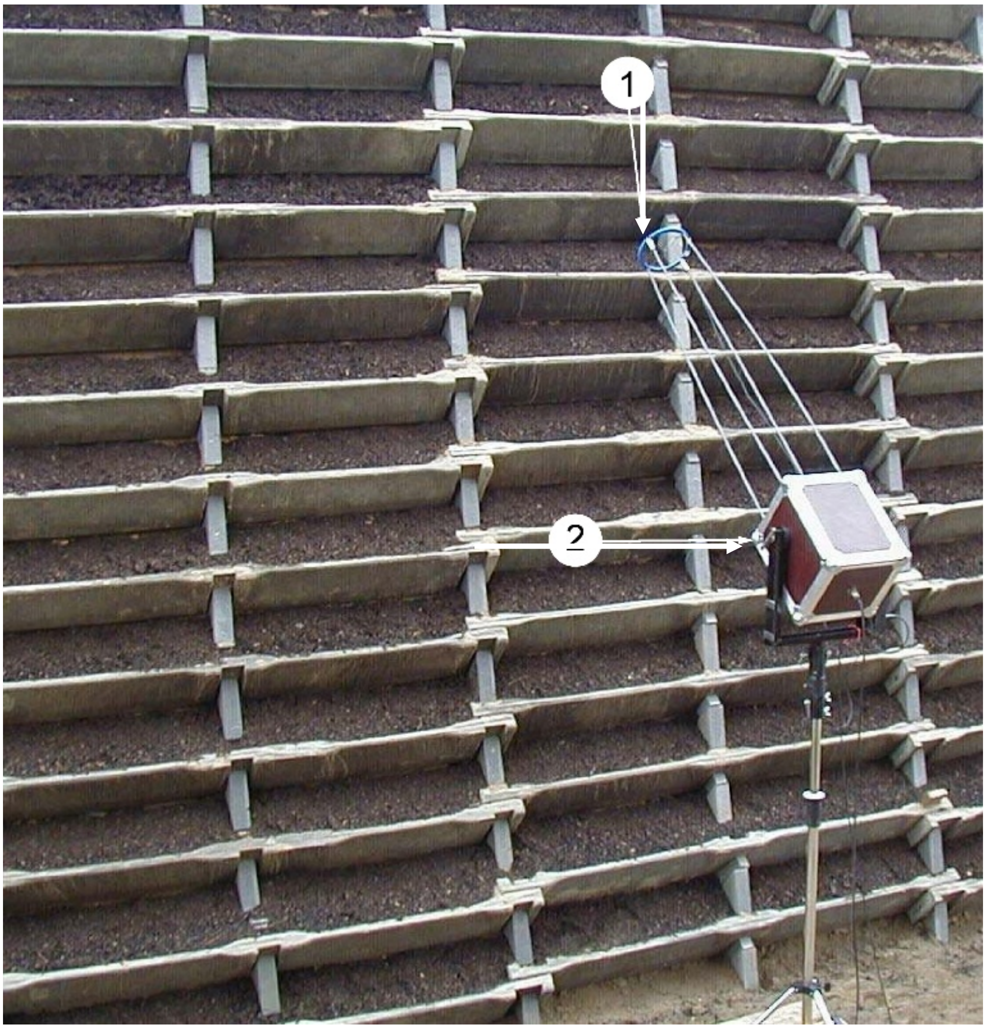
	Type: ***Serial number:*** **Microphone:** ***Manufacturer:*** ***Type:*** ***Serial number:*** **Analyser:** ***Manufacturer:*** ***Type:*** ***Serial number:***
(j)	**Filtering and sampling** **Type and characteristics of the anti-aliasing filter:** **Sample rate:**
(k)	**Adrienne temporal window** **Length:**
(l)	**Test frequency range** **Low frequency limit:** **Smallest dimension of the test object:**
(m)	**Test results:** see tables and graphs in **B.3**
(n)	**Measurement uncertainty** **Combined standard uncertainty:** **Expanded uncertainty:** **Coverage factor:** **Confidence level:**
(o)	**Single-number rating (optional)** **The single-number rating for the sound reflection index amounts to:** **DL_{RI} = ___ dB**
(p)	**Signature of the person responsible for the measurements** **Name:** **Place, date:** .... **signature**

B.2 Test setup (example)

The test object is 5,50 m high and 6,00 m long, so that each reference position (see B.2) can be tested in the centre of an area of 4,00 m height and 4,00 m length. The source is at a height of 2,0 m above the ground.

There are no sound reflecting nor sound diffracting parasitic objects acting on the sampled area.

The test situation is shown in Figure B.1.



Key

1 microphone holding device

2 sound source

Figure B.1 — General view of test barrier (from front (rail) side), showing also loudspeaker and microphone in front of the acoustic elements

B.3 Test object and test situation (example)

The test wall is made of recycled plastic material elements. They are filled with earth which has been compacted by vibration. The part of the test object which is exposed to the noise (railway side) contains plastic shells which are inclined by 45° downwards and which retain the earth filling. The earth filled parts are covered by 4 cm to 5 cm of mulch and they are inclined by 45° upwards.

Figure B.2 shows the basic composition of the single elements of the noise barrier, with relevant dimension data and markings of the measurement positions A, B, C and D.

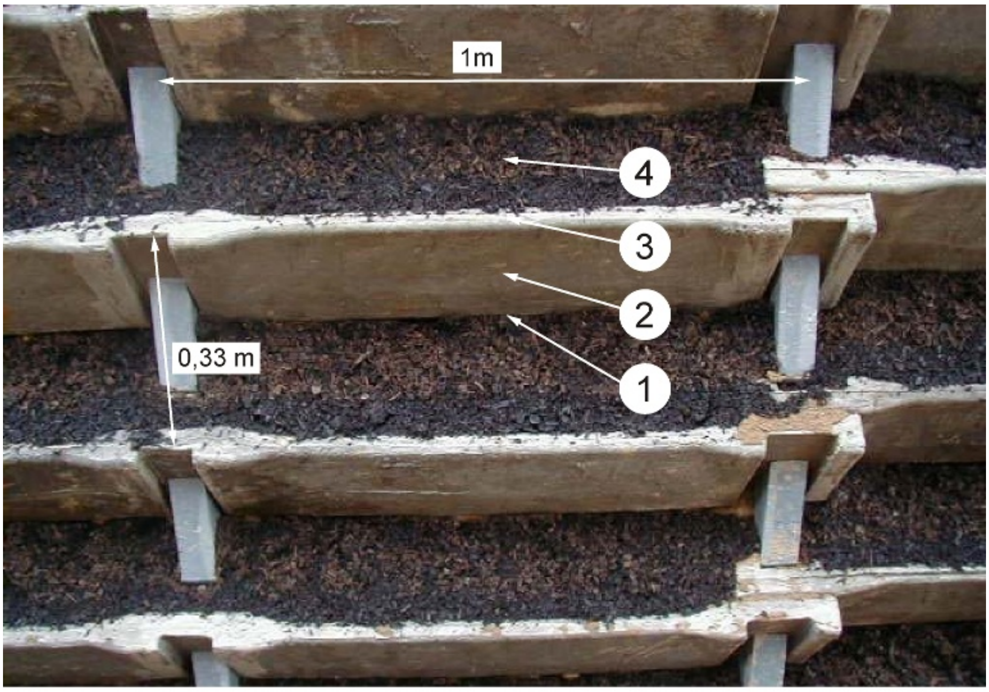
According to the specifications of CEN/TS 16272-5, section 5.6.2, the tests were carried out each time with 9 vertical rotation angles (cf. B.1) at the following 4 “reference positions“:

A centred in front of the back edge of the shell/filling

B in front of the centre of the shell

C in front of the front edge of the shell

D in front of the centre of the filling



Key

1 Position A, centred in front of the back edge of the shell/filling

2 Position B, in front of the centre of the shell

3 Position C, in front of the front edge of the shell

4 Position D, in front of the centre of the filling

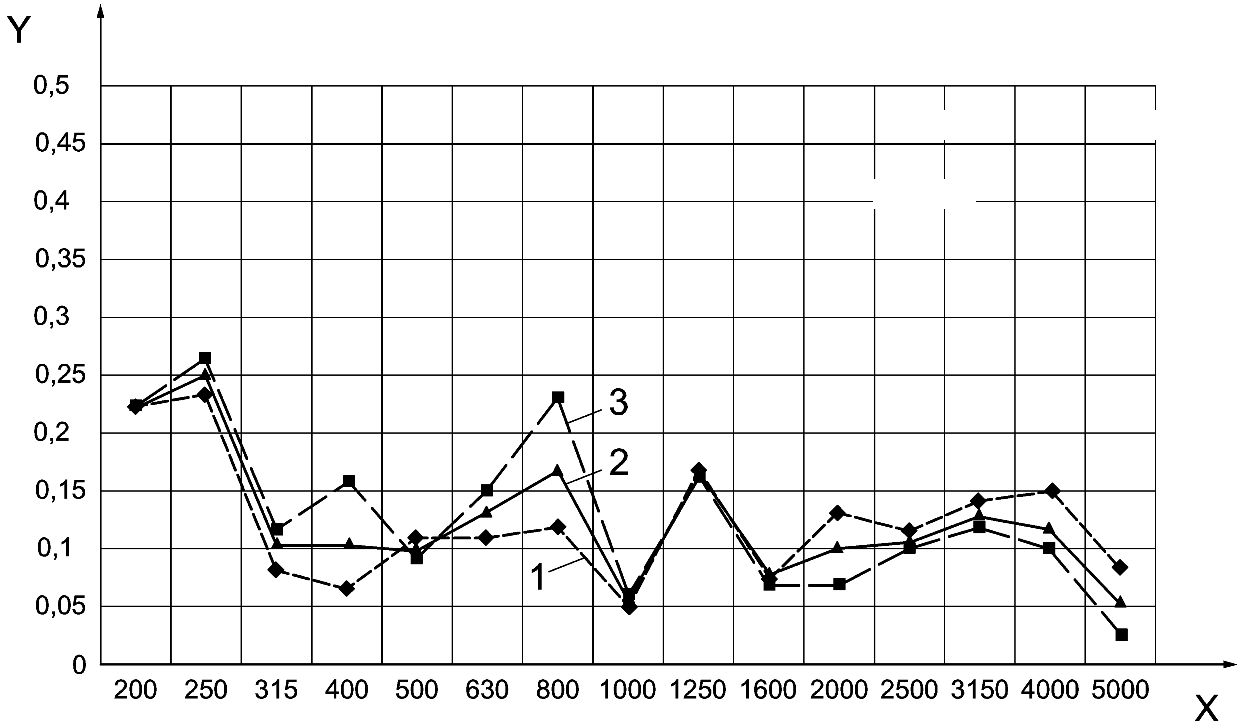
Figure B.2 — Basic composition of the single elements of the noise barrier, with relevant dimension data and markings of the measurement positions A, B, C and D

B.4 Results (example)

B.4.1 Part 1 – Results in tabular form

Third-octave band centre frequency in Hz	**Mean values of “Sound reflection index” RI for the angles 50° - 90° (partial result RI^{a}), 90° - 130° (partial result RI^{b}) and 50° - 130° (total result RI^{c}), for the different “reference positions” A, B, C and D and in mean**														
	Position A			**Position B**			**Position C**			**Position D**			**Mean**		
	RI^{a}	**RI^{b}**	**RI^{c}**	**RI^{a}**	**RI^{b}**	**RI^{c}**	**RI^{a}**	**RI^{b}**	**RI^{c}**	**RI^{a}**	**RI^{b}**	**RI^{c}**	**RI^{a}**	**RI^{b}**	**RI^{c}**
200	0,09	0,09	0,09	0,42	0,42	0,42	0,24	0,24	0,24	0,13	0,13	0,13	**0,22**	**0,22**	**0,22**
250	0,19	0,15	0,21	0,40	0,33	0,32	0,21	0,33	0,25	0,13	0,27	0,21	**0,23**	**0,27**	**0,25**
315	0,06	0,12	0,10	0,09	0,13	0,11	0,09	0,13	0,11	0,08	0,10	0,10	**0,08**	**0,12**	**0,11**
400	0,06	0,18	0,14	0,08	0,17	0,11	0,09	0,16	0,11	0,04	0,14	0,09	**0,07**	**0,16**	**0,11**
500	0,15	0,13	0,13	0,10	0,09	0,09	0,10	0,06	0,09	0,07	0,09	0,09	**0,11**	**0,09**	**0,10**
630	0,11	0,12	0,13	0,17	0,18	0,15	0,12	0,13	0,12	0,05	0,18	0,12	**0,11**	**0,15**	**0,13**
800	0,11	0,09	0,11	0,19	0,35	0,24	0,09	0,10	0,10	0,09	0,37	0,24	**0,12**	**0,23**	**0,17**
1000	0,04	0,06	0,06	0,06	0,09	0,08	0,05	0,05	0,05	0,05	0,09	0,07	**0,05**	**0,07**	**0,06**
1250	0,13	0,15	0,15	0,25	0,16	0,20	0,13	0,16	0,15	0,16	0,17	0,16	**0,17**	**0,16**	**0,17**
1600	0,08	0,08	0,09	0,10	0,06	0,08	0,07	0,09	0,08	0,07	0,03	0,05	**0,08**	**0,07**	**0,08**
2000	0,13	0,06	0,10	0,15	0,09	0,12	0,13	0,07	0,09	0,11	0,07	0,10	**0,13**	**0,07**	**0,10**
2500	0,11	0,09	0,11	0,13	0,11	0,11	0,11	0,07	0,09	0,12	0,12	0,11	**0,12**	**0,10**	**0,11**
3150	0,13	0,12	0,14	0,13	0,14	0,13	0,16	0,09	0,12	0,12	0,15	0,14	**0,14**	**0,12**	**0,13**
4000	0,15	0,09	0,13	0,16	0,08	0,11	0,15	0,12	0,14	0,13	0,10	0,12	**0,15**	**0,10**	**0,12**
5000	0,10	0,02	0,07	0,09	0,03	0,06	0,08	0,04	0,06	0,08	0,03	0,06	**0,09**	**0,03**	**0,06**

B.4.2 Part 2 – Results in graphic form



Key

X third-octave band centre frequency [Hz]

Y sound reflection index *RI*

1 RIa, 50° - 90°

2 RIc, 50° - 130°

3 RIb, 90° - 130°

Figure B.3 — Results in graphic form

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