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Akustika v stavbah - Ocenjevanje akustičnih lastnosti stavb iz lastnosti sestavnih delov - 5. del: Zvočne ravni obratovalne opreme

Building acoustics - Estimation of acoustic performance of buildings from the performance of elements - Part 5: Sounds levels due to the service equipment

Bauakustik - Berechnung der akustischen Eigenschaften von Gebäuden aus den Bauteileigenschaften - Teil 5: Installationsgeräusche

Acoustique du bâtiment - Calcul de la performance acoustique des bâtiments à partir de la performance des éléments - Partie 5 : Niveaux de bruits dus aux équipements techniques

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English Version

Building acoustics - Estimation of acoustic performance of buildings from the performance of elements - Part 5: Sounds levels due to the service equipment

Acoustique du bâtiment - Calcul des performances acoustiques des bâtiments à partir des performances des éléments - Partie 5 : Niveaux sonores dus aux équipements de bâtiment

Bauakustik - Berechnung der akustischen Eigenschaften von Gebäuden aus den Bauteileigenschaften - Teil 5: Installationsgeräusche

This European Standard was approved by CEN on 17 April 2023.

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Contents

Page

European foreword

This document (EN 12354-5:2023) has been prepared by Technical Committee CEN/TC 126 “Acoustic properties of building elements and of buildings”, the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by December 2023, and conflicting national standards shall be withdrawn at the latest by December 2023.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

This document will supersede EN 12354-5:2009 and EN 12354-5:2009/AC:2010.

EN 12354-5:2009 has been revised in order to extend its application to any type of constructions (heavy or lightweight) and to better predict low frequencies down to 50 Hz. The document has therefore been deeply restructured. The application clause, which considers all the different equipment types and their particularities has been kept and restructured.

Any feedback and questions on this document should be directed to the users’ national standards body. A complete listing of these bodies can be found on the CEN website.

According to the CEN-CENELEC Internal Regulations, the national standards organisations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Türkiye and the United Kingdom.

1 Scope

This document describes calculation models to estimate the sound pressure level in buildings due to service equipment. As for the field measurement documents (EN ISO 16032 for the engineering method and EN ISO 10052 for the survey method), it covers sanitary installations, mechanical ventilation, heating and cooling, service equipment, lifts, rubbish chutes, boilers, blowers, pumps and other auxiliary service equipment, and motor driven car park doors, but can also be applied to others equipment attached to or installed in buildings. The estimation is generally based on measured data that characterizes both the equipment (source) and the sound transmission through the building. The same equipment can be composed of different airborne and/or structure borne sources at different locations in the building; the standard gives some information on these sources and how they can be characterized; however, models of the equipment itself are out of the scope of this standard.

This document describes the principles of the calculation models, lists the relevant input and output quantities and defines its applications and restrictions. The models given are applicable to calculations in frequency bands. It is intended for acoustical experts and provides the framework for the development of application documents and tools for other users in the field of building construction, considering local circumstances.

The calculation models described use the most general approach for engineering purposes, with a link to measurable input quantities that specify the performance of building elements and equipment. However, it is important for users to be aware that other calculation models also exist, each with their own applicability and restrictions.

The models are based on experience with predictions for dwellings and offices; they could also be used for other types of buildings provided the dimensions of constructions are not too different from those in dwellings.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 15657:2017, *Acoustic properties of building elements and of buildings — Laboratory measurement of structure-borne sound from building service equipment for all installation conditions*

EN ISO 10052, *Acoustics — Field measurements of airborne and impact sound insulation and of service equipment sound — Survey method (ISO 10052)*

EN ISO 10848-1, *Acoustics — Laboratory and field measurement of flanking transmission for airborne, impact and building service equipment sound between adjoining rooms — Part 1: Frame document (ISO 10848-1)*

EN ISO 12354-1, *Building acoustics — Estimation of acoustic performance of buildings from the performance of elements — Part 1: Airborne sound insulation between rooms (ISO 12354-1)*

EN ISO 12354-2:2017, *Building acoustics — Estimation of acoustic performance of buildings from the performance of elements — Part 2: Impact sound insulation between rooms (ISO 12354-2:2017)*

EN ISO 16032, *Acoustics — Measurement of sound pressure level from service equipment in buildings — Engineering method (ISO 16032)*

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp/ui

— IEC Electropedia: available at https://www.electropedia.org/

4 Relevant quantities

4.1 General

This document describes calculation models to estimate the sound pressure level in buildings due to service equipment. The output data of the models correspond to quantities expressing the building performance (sound pressure levels in rooms generated by the equipment installed in the building), as the input data correspond to quantities expressing the product performances for both the source(s) of sound (the equipment itself) and the building elements involved in the transmission of sound.

In this standard, the output quantities are determined, like in EN ISO 12354-1 and EN ISO 12354-2, in one-third octave bands at least in the frequency range 100 Hz to 3 150 Hz, possibly extended down to one-third octave 50 Hz if building element data and junction data involved in the transmission of sound are available, and up to 5 kHz, particularly for airborne sound quantities. Service equipment performance data are based on measurements according to EN 15657 where measurements are performed in one-third octave bands in the frequency range 50 Hz to 3 150 Hz. However, for some service equipment, the frequency range of interest won't cover this complete range.

NOTE For measuring airborne sound power of equipment in reverberant conditions, EN 15657:2017 refers to EN ISO 3740 to EN ISO 3747, in which only limited information can be found for measurements performed in small reverberant rooms, down to 50 Hz, in one-third octave band and applied to non-stationary sources, as well as for their accuracy. Nevertheless, the measurement procedure is fully given in the standardized application documents focused on laboratory measurements for each type of service equipment (for example, in EN 14366-1 for waste water pipes).

4.2 Quantities to express building performances (output quantities)

4.2.1 General

This standard aims at predicting sound pressure levels in buildings and comparing results to values measured *in situ*. Field measurements of sound from equipment and machinery are performed according to EN ISO 16032 (engineering method) or EN ISO 10052 (survey method) with results expressed in terms of sound pressure level in various ways: maximum A-weighted and optionally C-weighted sound-pressure levels using time weighting "S" or time weighting "F" for non-stationary sources, as well as equivalent continuous sound-pressure levels determined with a specified integration time for stationary sources. A-weighted and C-weighted values are obtained from octave-band measurements in the frequency range from 63 Hz to 8 kHz. The corresponding single number values are detailed in Annex D.

NOTE 1 Time weighting "F" is likely to lead to measurement results less reproducible than time weighting "S".

NOTE 2 Octave band levels are also used to determine the so-called NC, NR or RC ratings, as described in many standards. This is especially the case for buildings such as offices, commercial buildings, schools and performance spaces.

In all cases, normalization to a reference equivalent absorption area or standardization to a reference reverberation time can be applied.

4.2.2 Relation between quantities

The above sound pressure levels depend on the applied time weighting, i.e. “S”, “F” or integration over a cycle (equivalent). The levels with these various time weightings depend on the type of sound and cannot be deduced from each other in general.

In all cases there is a direct relation between the sound pressure level (L_p), the normalized sound pressure level (L_n) and the standardized sound pressure level (L_{nT}) in frequency bands. These relations are given by:

$$L_n = L_p - 10 \lg \frac{A_0}{A} \text{ dB} \tag{1}$$

$$L_{nT} = L_p + 10 \lg \frac{T_0}{T} = L_n + 10 \lg \frac{A_0 T_0}{0{,}16 \, V} \text{ dB} \tag{2}$$

where

- A is the equivalent absorption area in the room, in square metres;
- A_0 is the reference equivalent absorption area (A_0 = 10 m²), in square metres;
- T is the reverberation time in the room, in seconds;
- T_0 is the reference reverberation time (T_0 = 0,5 s for dwellings), in seconds;
- V is the volume of the room, in cubic metres.

In this document the normalized sound pressure level L_n is chosen as the prime quantity to predict and noted L_{ne} (“e” for equipment) instead of L_n usually used for impact sound level. The other quantities can be obtained from this directly, particularly the sound pressure level L_p (to be compared to measured values) obtained using Formula (1), knowing the equivalent absorption area of the room, where the measurements have been performed.

4.3 Quantities to express product performances (input quantities)

4.3.1 General

The quantities to express the performance of products relate on the one hand to the sources of sound and on the other hand to the transmission of sound. In general, this concerns both airborne and structure-borne sound.

4.3.2 Sources of sound

In the case of airborne sound sources, the basic quantity to express the source strength is the airborne sound power level, measured according to the standards specified in 4.1.

In the case of structure-borne sound sources, the basic quantity to express the source strength is the installed power level (and sometimes the blocked force level); these quantities are defined and their measurement is specified in EN 15657, which so far, is restricted to steady-state vibrating sources. Quasi-stationary sources, i.e. stationary within the time window chosen for its duration, and more generally non-stationary sources must be predicted with care, following the information given in Annex D.

If different operating stages are identified in the time response of a given equipment, each stage shall be studied separately, each considered as an independent source.

The relevant sound sources differ for the various equipment and installations considered. Therefore, the relevant quantities to express the performance of sound sources will be dealt within the appropriate sections. However, the quantities for the source shall in all cases relate to the same time weighting as the quantity to be estimated for the building performances.

4.3.3 Transmission of sound

The basic quantities to express the transmission of airborne, impact and service equipment sound are defined in EN ISO 12354-1 and EN ISO 12354-2, as well as in EN ISO 10848-1, which also specifies the measurement methods for flanking transmission. These quantities as well as the prediction methods themselves used in this standard, are defined from and based on the SEA approach, which theoretically only allows predicting sound in stationary or quasi-stationary situations; for the other cases, follow Annex D.

5 Calculation models

5.1 General principles

In general, a mixture of airborne and structure-borne sound transmission causes the sound level in a room due to service equipment. Which of those is dominant, depends on the type of equipment and installation as well as on the type of building construction. Furthermore, service equipment and installations often consist of several sound sources and several connection points between the installation and the building structure. This makes a general prediction method rather complicated.

It is assumed that a complete installation can be divided in several airborne and/or structure-borne sound elementary sources that can be considered independent from each other. The model approach is to consider one such an elementary source at the time and one operating stage at the time if several stages are identified (see 4.3.2). The resulting sound pressure level in a room follows from the sum of the contribution of each of such elementary sources.

In general, two principally different transmission situations are considered:

— airborne sound transmission through a building construction;

— structure-borne sound transmission through a building construction.

For each of these situations a general approach will be described in the next subclauses. The most appropriate applications of these general models are specified for several types of service equipment and installations in Clause 6.

The resulting normalized sound pressure level in a room in frequency bands, L'_{ne}, for the considered installation can therefore be written:

$$L'_{\mathrm{ne}} = 10\,\lg\left(\sum_{k=1}^{N_{\mathrm{a}}} 10^{L'_{\mathrm{ne,a,k}}/10} + \sum_{m=1}^{N_{\mathrm{s}}} 10^{L'_{\mathrm{ne,s},m}/10}\right) \tag{3}$$

where

L'_{ne} is the total apparent normalized sound pressure level in a room due to the considered installation, in decibels;

$L'_{\mathrm{ne,a,k}}$ is the apparent normalized sound pressure level due to elementary airborne sound source k of the installation, in decibels;

$L'_{\mathrm{ne,s},m}$ is the apparent normalized sound pressure level due to elementary structure-borne sound source m of the installation, in decibels;

N_a is the number of elementary airborne sound sources composing the considered installation;

N_s is the number of elementary structure-borne sound sources composing the considered installation.

NOTE The receiver, not explicitly mentioned here, is noted using subscript “element *i*” in the text.

In case the source and the building performance are to be expressed by maximum levels, the results from Formula (3) can be considered as an estimate of the upper limit (all events assumed simultaneous). An estimate of the lower limit would then be the maximum value of all the sources considered separately (all events occurring at different times).

The models can be used to calculate the building performance in frequency bands, based on acoustic data for the sound sources and building elements in frequency bands. From these frequency dependent performances, the single number rating for the building performance (A- or C-weighting) can be deduced similarly as for the measurement results in accordance with EN ISO 16032 and EN ISO 10052.

The models assume a diffuse sound field in the source and receiving rooms. Though often a sufficiently realistic assumption, large deviations may occur at low frequencies. Since sound from some service equipment will be dominated by low frequencies, such deviations cannot be neglected. Special attention will be given to this aspect for the application of the models to specific service equipment and installations (see Clause 6). General information on this aspect is given in Annex B.

Calculation examples are given in the informative Annex G, including calculation examples of Single Number Quantities for products measured using EN 14366-1.

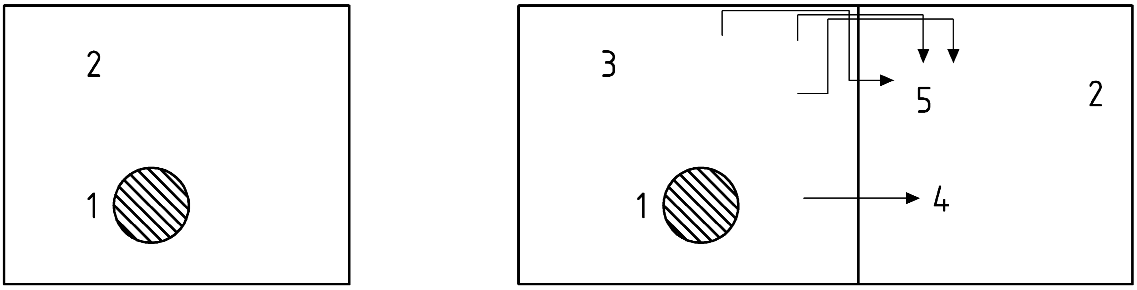
5.2 Airborne sound transmission through building constructions

5.2.1 General

The output quantity is the sound pressure level in the receiving room considered. Two different building configurations can be considered as shown in Figure 1: source within the receiving room and source in a source room adjacent to the receiving room; the term “adjacent to” means “next to”, “above” or “diagonally connected through one junction to” as specified in EN ISO 12354-1 and EN ISO 12354-2. These two configurations are considered in the next subclauses.

The sound transmitted depends on the source and the building structures involved in the transmission. The basic quantity to express the source strength is the airborne sound power level L_{Wa} in dB ref. 10^{-12} Watt, measured according to the standards specified in 4.1; the transmission term depends on the configuration considered (see 5.2.2 and 5.2.3).

NOTE The case of source outside the building is not in the scope of the standard; the prediction of this case is considered in EN ISO 12354-3:2017, Annex E.



Key

1 source
2 receiving room
3 source room
4 direct path
5 flanking paths (indicated for one junction; 4 junctions participate in the transmission)

Figure 1 — Configurations for airborne sound transmission: source in receiving room (left); source in another room, case of rooms next to each other (right)

5.2.2 Source in receiving room

The resulting normalized sound pressure level in a room, $L_{ne,a}$, for one sound source in the same room simply follows from:

$$L_{ne,a} = L_{Wa} - 4\ \text{dB} \quad (4)$$

The sound field in the receiving room is supposed to be diffuse and the sound pressure level estimated sufficiently away from the source. The transmission term reduces to a constant.

5.2.3 Source in another room

In the case of a source in another room, the transmission from source room to receiving room normally involves the transmission via various transmission paths between elements (i) of the source room and elements (j) of the receiving room as indicated in Figure 1 (right). All these paths are taken into account in the prediction method defined in EN ISO 12354-1.

The resulting transmitted normalized sound pressure level $L'_{ne,a}$ can be written as a sum of the sound power level of the source and a transmission term, expressed from either the normalized level difference D_n between source and receiving rooms or the apparent sound reduction index R':

$$L'_{ne,a} = L_{Wa} - 10\ \lg\left(\frac{A_S}{4}\right) - D_n \quad (5)$$

$$L'_{ne,a} = L_{Wa} - R' - 10\ \lg\left(\frac{A_S}{S_S}\right) - 4\ \text{dB} \quad (6)$$

where

L_{Wa} is the airborne sound power level of the source, in decibels;

A_S is the equivalent absorption area of the source room, in square metres;

D_n is the normalized level difference between the two rooms in dB, as defined in EN ISO 12354-1;

R' is the apparent sound reduction index in dB, output data in EN ISO 12354-1;

S_s is the area of the separating element, in square metres.

The source room shape and sound field distribution, the source direct and near field and the radiation pattern of the source will influence the actual excitation of the building elements in the source room. However, all these aspects involve non-diffuse fields and are not considered in EN ISO 12354-1, which assumes a diffuse field in the emission room.

Formula (6) allows calculating $L'_{ne,a}$ from the airborne sound power of the source, assumed known, and the apparent sound reduction index calculated using EN ISO 12354-1.

NOTE 1 It is useful to define a unit power apparent sound pressure level $L'_{ne,a,0}$ characterizing the global airborne sound transmission to the receiving room and obtained by replacing the equipment by a unit power airborne sound source (L_{Wa} = 120 dB) in Formula (6); see examples in G.3.2.

Formula (5) allows checking before the equipment is installed, if there is a noise problem, assuming L_{Wa} known and D_n measured on site.

NOTE 2 The above formulae assume that the reference values for pressure and power are such that $\rho_0 c_0 W_0 / p_0^2 = 1$. This is the case with ISO-reference values and $\rho_0 c_0 = 400\ \text{Ns/m}^3$.

NOTE 3 The SEA-based prediction method used in EN ISO 12354-1 theoretically implies that the source should be anywhere and everywhere in the room (thus generating a diffuse field), which is not the way equipment are characterized in laboratory (see 5.3). More generally, nearfield airborne excitation from a source close to an element is included as structural excitation [15] and characterized using EN 15657.

If the source is close to any element i in the source room and mechanically linked to it, the airborne sound nearfield of the source is taken into account within the structural power (installed power) transmitted to element i, input quantity for predicting structure-borne sound defined and measured according to EN 15657 (see 5.3). More generally, nearfield airborne excitation from a source close to an element is included as structural excitation [15] and characterized using EN 15657.

If the actual source is enclosed or partly enclosed, the whole system can be considered as the source for which the sound power level follows from the sound power insertion loss D_{Wa} of the enclosure and the sound power level of the source: $L_{Wa,enclosed} = L_{Wa} - D_{Wa}$ [13]. The sound power insulation can be measured according to ISO 11546 [1].

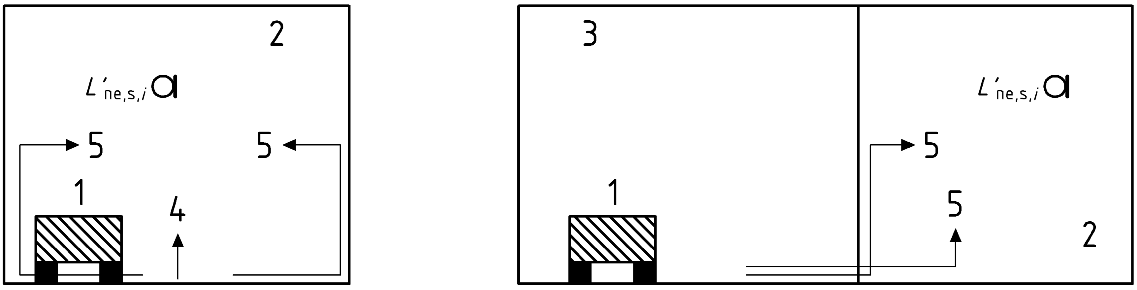
5.3 Structure-borne sound transmission through building constructions

5.3.1 General

The output quantity is the sound pressure level in the receiving room considered. Two building configurations can be considered again as shown in Figure 2: source within the receiving room and source in a source room adjacent to the receiving room; the term “adjacent to” means “next to”, “above” or “diagonally connected through one junction to” as specified in EN ISO 12354-1 and EN ISO 12354-2. However, both configurations lead to the same types of path, direct and/or flanking.

NOTE In the case where the source is mechanically fixed on an element of the receiving room, the transmission paths are the same whether the source is mounted inside or outside the room.

The sound transmitted depends on the source and the building structures involved in the transmission. The basic quantity to express the source strength is generally the installed power (structural power transmitted to the receiving element), defined in EN 15657; the installed power depends on the characteristics of the source, the mounting and the supporting building element. The transmission terms depend on the configuration considered and the type of elements, heavy or lightweight (more precisely of type A or type B respectively, as defined in EN ISO 12354-1 and EN ISO 10848-1) involved in the transmission.



Key

1 source connected to element *i*

2 receiving room

3 source room

4 direct path *ii*

5 flanking path *ij*

Figure 2 — Configurations for structure-borne sound transmission: source in receiving room (left); source in another room, case of rooms next to each other (right)

The general case, corresponding to any mobility conditions between source and receiver and any type of receiving building elements is considered first in 5.3.2. Predicting equipment sound levels in the case where the receiver mobility is much lower than the source mobility is very specific [2] and considered separately in 5.3.3.

5.3.2 General case

5.3.2.1 General

The general case corresponds to any mobility conditions between source and receiver and any type of receiving building elements. The two key input parameters for prediction are the equipment installed power $L_{Ws,i}$ of the source connected to element *i*, in dB ref. 10^{-12} Watt as defined in EN 15657, and a quantity characterizing the transmission path from element *i* to the receiving room called unit power apparent sound pressure level, (symbol $L'_{ne,s,0,i}$) for transmission.

Source term

The installed power level $L_{Ws,i}$ is determined according to EN 15657:2017, Clause 5 for any installation conditions from the source characteristics and the receiver mobility:

$$L_{Ws,i} \approx 10\lg\left(\frac{\mathrm{Re}\left(Y_{R,eq,i}\right).Y_0}{\left|Y_{S,eq}\right|^2+\left|Y_{R,eq,i}\right|^2}\right)+L_{vf,eq}-60\,\mathrm{dB} \quad (7)$$

where

$Y_{S,eq}$ is the equipment single equivalent mobility as defined in EN 15657;

$Y_{R,eq,i}$ is the receiving element *i* single equivalent mobility as defined in EN 15657;

$L_{vf,eq}$ is equipment single equivalent free velocity level in dB ref. 10^{-9} m/s as defined in EN 15657;

Y_0 Y_0 = 1m/sN

The source and receiver mobilities in Formula (7) can be either measured according to EN 15657 or estimated according to Annex F.

Formula (7) can also be expressed as a function of the equipment single equivalent blocked force level $L_{Fb,eq}$:

$$L_{Ws,i} \approx 10\lg\left(\frac{\mathrm{Re}\left(Y_{R,eq,i}\right)Y_0}{1+\frac{\left|Y_{R,eq,i}\right|^2}{\left|Y_{S,eq}\right|^2}}\right)+L_{Fb,eq} \quad (8)$$

where

$L_{Fb,eq}$ is the equipment single equivalent blocked force in dB ref. 10^{-6} N as defined in EN 15657.

In order to reduce the power transmitted to the receiver, isolators can be inserted between source and receiver. The performance of the isolator, preferably defined as power-based insertion gain (thus leading to negative values for a power reduction), is explained in Annex F, and so is its dependence on the source and receiver mobilities.

Transmission term

The transmission normally involves various transmission paths from element *i* to the elements *j* radiating in another room or in the same room. The corresponding transmission terms $L'_{ne,s,0,ij}$ are defined and their measuring method given in EN ISO 10848-1 and represent the normalized sound pressure level in the receiving room produced by a structure-borne sound source injecting a unit power (1 Watt) at different positions on the element *i* considered in the source room. The same notation/definition can be used to characterize the transmission with all paths included (called apparent unit power sound level of the receiver; symbol $L'_{ne,s,0,i}$), or the direct path of the receiver only (called unit power sound level of the receiver; symbol $L_{ne,s,0,i}$), from which the normalized apparent equipment sound pressure level $L'_{ne,s,i}$ can be calculated using the following two straightforward prediction methods.

5.3.2.2 Using the apparent unit power sound pressure level of the receiver

This method is usually applied to Type B building structures.

The noise level generated by the equipment connected to element *i* in the source room and transmitted in the receiving room through all the paths is straightforward:

$$L'_{ne,s,i} = L'_{ne,s,0,i} + L_{Ws,i} - L_{W0} \quad (9)$$

where