Sound Insulation

Measurement with the XL2 Sound Level Meter

This application note describes how to measure sound insulation. This includes airborne and impact sound insulation between two rooms and the airborne sound insulation of façades using sound pressure measurements. All measurements are performed by the XL2 Sound Level Meter and documented using the Sound Insulation Reporter software in accordance with the standard series ISO 16283.

The sound insulation is calculated by combining multiple sound pressure level and reverberation time measurements. The measured frequency range is typically from 50 Hz to 5 kHz. The measured airborne sound insulation is frequency-dependent but can be converted into a single number, the sound reduction index, to characterize the acoustic performance.

This application note applies to rooms with a volume betwee 25 m3 and 250 m3. Special methods apply to smaller rooms.

XL2-TA
Sound Level Meter

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1. Getting Ready

Instrument Configuration

The sound level meter shall meet the requirements of a class 1 instrument in accordance with the IEC 61672-1 standard. The recommended configuration consists of

- XL2 Sound Level Meter or
  XL2-TA Sound Level Meter for legally traceable measurements
  (=XL2 with Type Approval Option installed)
- Optional Extended Acoustic Pack installed in XL2
  (required for reverberation time measurement in 1/3 octave resolution
- XL2 Sound Insulation Option (permanently installed) or Sound Insulation Reporter 365 (annual subscription service)
- M2230 Measurement Microphone
- ASD Cable, 5 m
- NTi Audio Class 1 Sound Calibrator
- Lightweight Microphone Tripod
- DS3 Dodecahedron Speaker
- Tripod for DS3 Dodecahedron Speaker
- PA3 Power Amplifier
- Tapping Machine TM3
- Computer/Tablet with Sound Insulation Reporter Software

Calibration

At the beginning and at the end of each measurement day, the entire sound pressure level measurement system shall be checked with the NTi Audio Class 1 Sound Calibrator. This calibrator meets the class 1 requirements specified in the standard IEC 60942.

Notes:

- The sound pressure level measuring system shall be calibrated at intervals not exceeding two years.
- Wear hearing protection for all measurements.

2. Airborne Sound Insulation between two Rooms

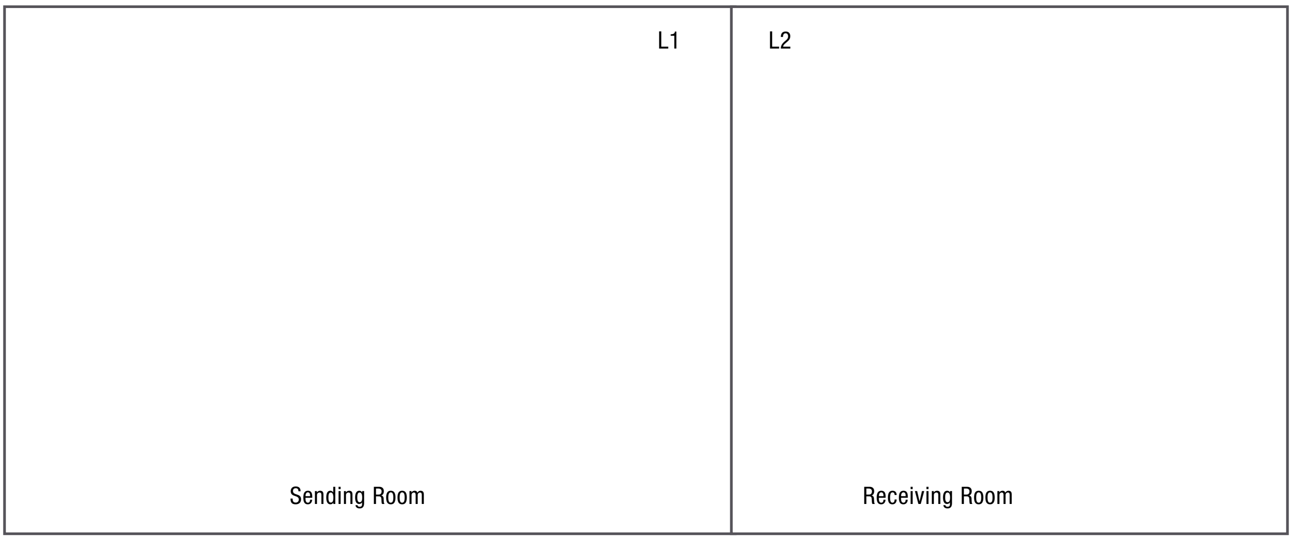
Measuring the airborne sound insulation between two room in a building requires the following measurements:

- Noise level in the sending room
- Noise level in the receiving room
- Background noise level in the receiving room
- Reverberation time in the receiving room

2.1 Getting Started

Room Selection

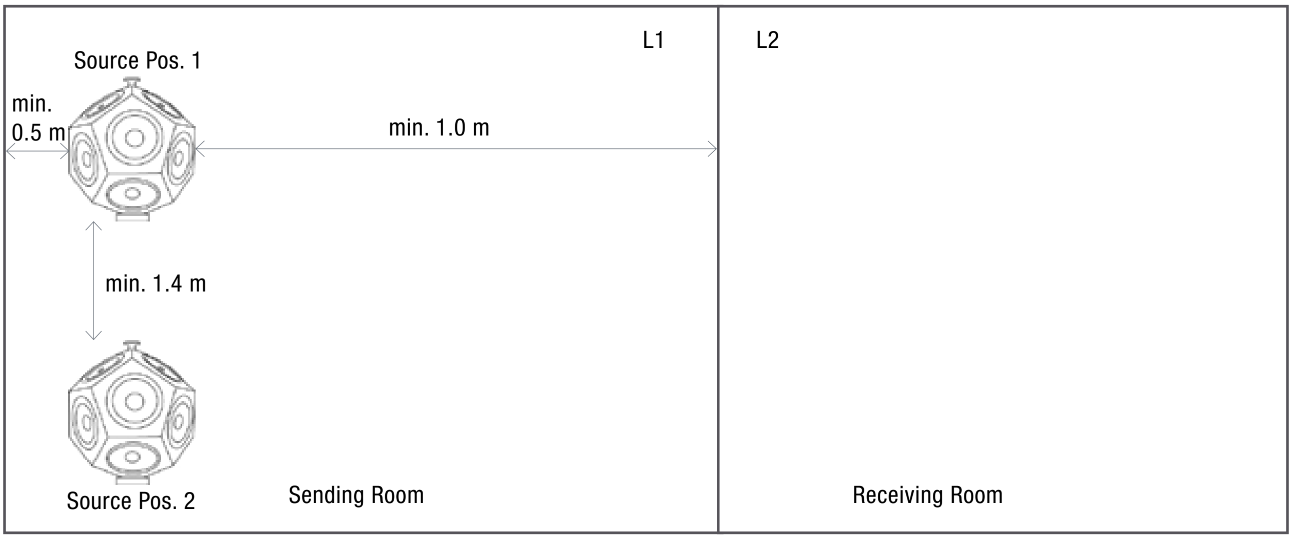
Airborne sound insulation is measured between two rooms. One room is chosen as the sending room and the other one is chosen as the receiving room. In case the volumes of the two rooms differ, then the smaller room shall be used as the receiving room. If one of the rooms is box-shaped and the other has a more complicated geometry, the box-shaped room shall be used as the receiving room.



Selecting Sending Room and Receiving Room

Speaker Position

- Position the Dodecahedron Speaker DS3 in the sending room.
- The measurements have to be carried out with at least two different speaker positions.
- Choose speaker position 1 at least 0.5 m from any room boundary and at least 1.0 m from the separating partition. Position 2 shall be similarly chosen, plus be in a different plane relative to the room boundaries, and with a minimum 1.4 m distance to position 1. In case the separation partition is a floor and the speaker is in the upper room, then the Dodecahedron Speaker DS3 has to be at least 1 m above the floor. The distances are measured from the center of the individual driver unit of the Dodecahedron Speaker DS3 closest to the boundary or other speaker position.



Positions of the test signal source for the sound level measurements

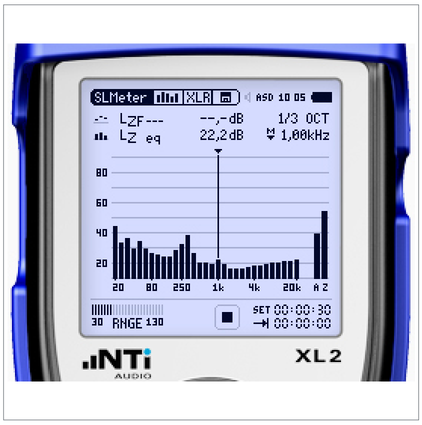
Test Signal Level

- Reduce level setting on PA3 Power Amplifier to minimum.
- Power on PA3 Power Amplifier.
- Select the signal source “EQ Pink” for a flat acoustic response in the source room. Go for “Pink” in case a higher level is required.
- Press “Signal ON” and increase the level until it is minimum of 6 dB – better 10 dB - higher in the receiving room than the background noise (in each frequency band from 50 Hz to 5000 Hz). In case this is not possible, then the Sound Insulation Reporter software will automatically apply corrections in accordance with the standard.

2.2 Background Noise Level in Receiving Room

Preparation

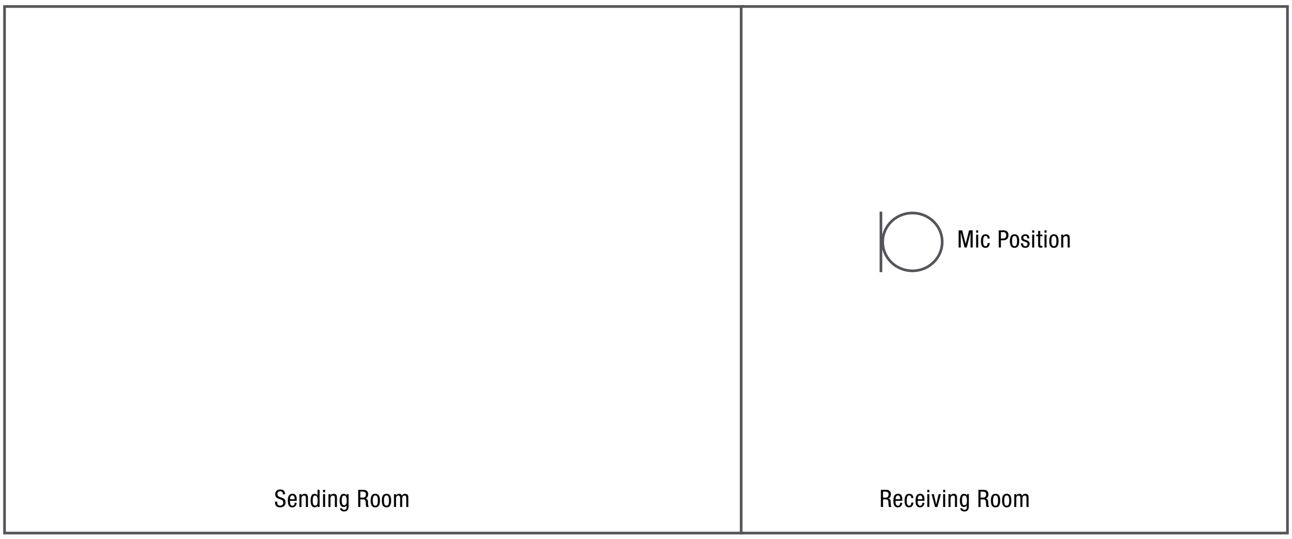
- Select the RTA page in the SLMeter function on the XL2 Sound Level Meter.
- Select 1/3 octave measurement resolution.
- It's recommended to vacate the room during the measurement so that any noise generated by the operator will not affect the measurement.



Background Noise Spectrum in the Receiving Room

Measurement

- Measure the background noise LZeq in the receiving room for 15 seconds. In case the background noise is not steady and continuous, then a longer measurement period shall be applied, e.g. 30 seconds.
- Store the reading in the XL2. This is required for post calculation of the sound insulation.
- Capture the reading as a reference for the next step. This is required to adjust the speaker output level accordingly.



Measure the Background Noise Level Lb in the Receiving Room

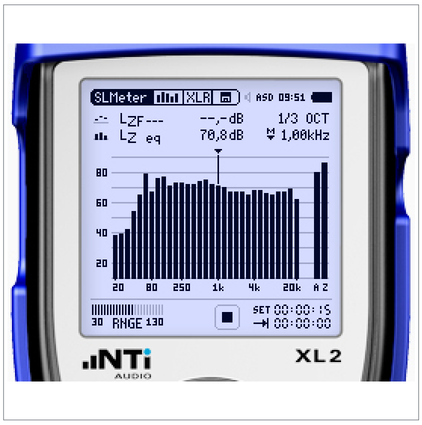
2.3 Sound Pressure Levels at speaker position 1

Preparation

Define five microphone positions in the sending and receiving room, distributed within the maximum permitted space throughout each room. The positions shall be in a different plane relative to the room boundaries and shall not form a regular grid. For example, mark the positions on the floor with a tape. The following minimum distances apply:

- 0.7 m between microphone positions
- 0.5 m from any room boundary
- 1.0 m between any microphone position and the speaker

It's recommended to vacate the room during the level measurement as the operator introduces additional absorption.

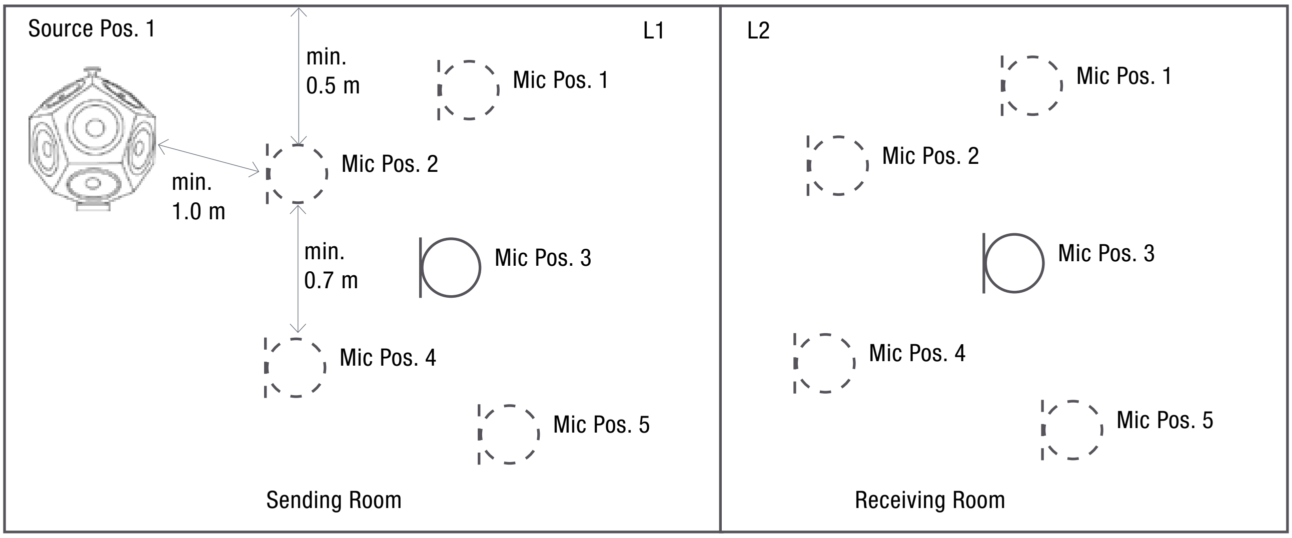


Noise Spectrum in the Sending Room

Measurements in Sending & Receiving Room

- Measure the sound level spectrum LZeq in the sending and receiving room at each position for a measurement period of 15 seconds.
- Store the individual readings in the XL2 for post calculation of the sound insulation.

Noise Spectrum in the Receiving Room



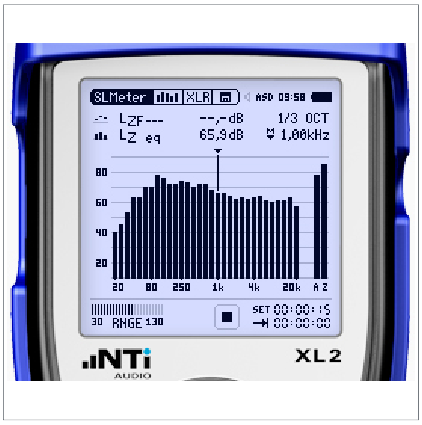
Measure the Sound Levels in the Sending and Receiving Room with the Speaker at Position 1

2.4 Sound Pressure Levels at speaker position 2

Move the Dodecahedron Speaker DS3 to source position 2.

Measurements in Sending Room

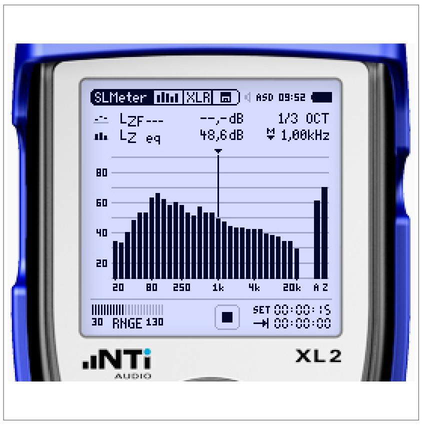
- Measure the sound level spectrum LZeq in the sending room at each position for a measurement period of 15 seconds.
- Store the individual readings in the XL2 for post calculation of the sound insulation.



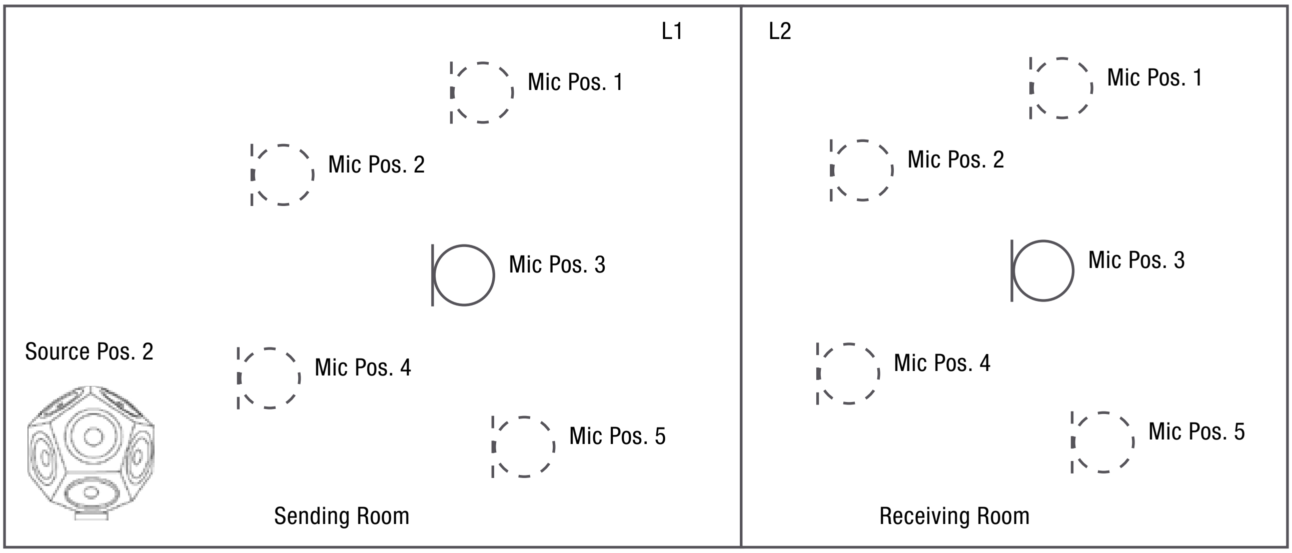
Noise Spectrum in the Sending Room

Measurements in Receiving Room

- Measure the sound level spectrum LZeq in the receiving room at each position for a measurement period of 15 seconds.
- Store the individual readings in the XL2 for post calculation of the sound insulation.



Noise Spectrum in the Receiving Room

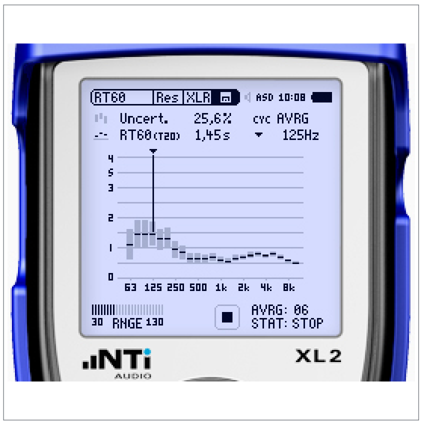


Measure the Sound Levels in the Sending and Receiving Room with the Speaker at Position 2

2.4 Reverberation Time in Receiving Room

Preparation

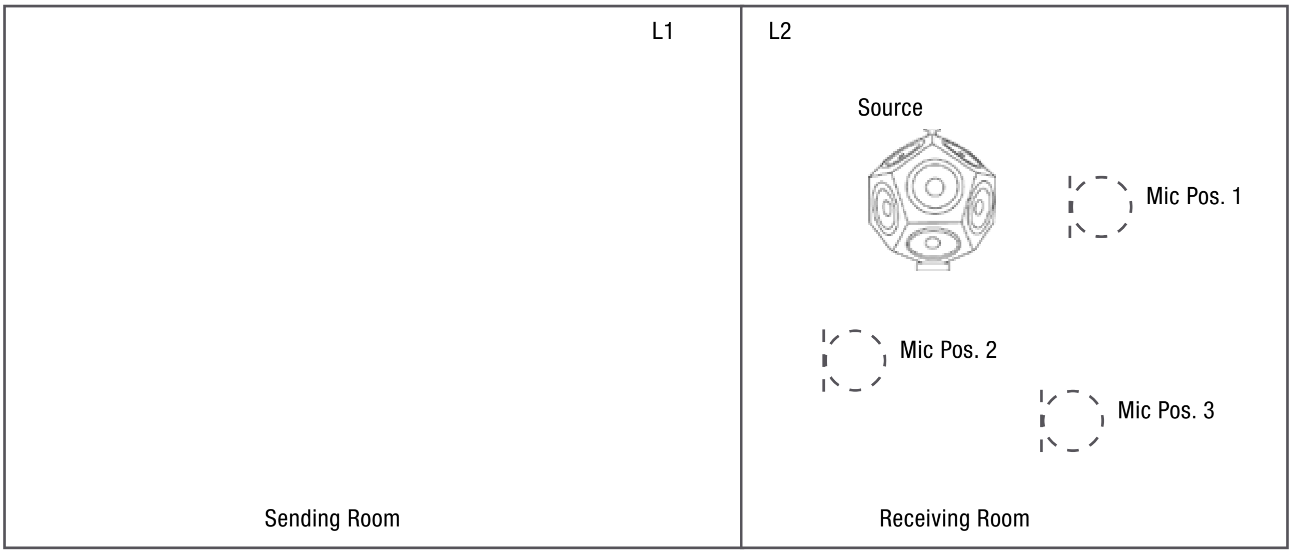
- Move the Dodecahedron Speaker DS3 to the receiving room.
- Select three microphone positions in the receiving room.
- Select the RT60 measurement function on the XL2 Sound Level Meter.
- Select the 1/3 octave resolution on the XL2.



Reverberation Time T

Measurement

- Start the measurement on the XL2.
- Start / stop the test signal.
  Guideline: Set the on/off cycle time for the signal longer than the expected reverberation time.
- Measure at least two decays per position - better three decays.
- Stop the measurement on the XL2.
- Store the individual readings on the XL2 for post calculation of the sound insulation.



Measure the Reverberation Time T in the Receiving Room

2.5 Data Analysis and Reporting

Verify and document all readings by using the Sound Insulation Reporter software. This is a PC-Software dedicated for building acoustics professionals. Load all measurement records into the software and generate the sound insulation report. The software calculates the weighted ratings based on the reference curve shifting method in accordance with the ISO 717-1 standard.

The following calculations are used:

- D = L1 – L2
- D_n = D - 10 lg (A / 10)
- D_{nT} = D + 10 lg (T / 0.5)
- R' = D + 10 lg (S / A)
- A = 0.16 * V / T

A	Equivalent absorption area of the receiving room [m^2]
D	Level difference between the sending and receiving room [dB]
D_n	Normalized level difference [dB] (the level difference D is standardized to the equivalent absorption area of 10 m^2 in the receiving room)
D_{nT}	Standardized level difference [dB] (the level difference D is standardized to the 0.5 seconds reference value of the reverberation time in the receiving room)
$D_{nT,w}$	Weighted standardized level difference (is the value of the reference curve at 500 Hz after shifting the reference curve) [dB]
L1	Sound pressure level in the sending room [dB]
L2	Sound pressure level in the receiving room [dB]
R'	Apparent sound reduction index of field measurement [dB]
R'_w	Weighted apparent sound reduction index [dB] (is the value of the reference curve at 500 Hz after shifting the reference curve)
S	Partition area between the sending and receiving room [m^2]
T	Reverberation time in the receiving room [s]
V	Volume of the receiving room in [m^3]

3. Impact Sound Insulation

Two different source types can be used for the measurement of the impact sound insulation

- Tapping Machine
  used to assess a variety of light, hard impacts such as footsteps from walkers wearing hard-heeled footwear or dropped objects
- Rubber Ball
  used to assess heavy, soft impacts such as from walkers in bare feet or children jumping, as well as quantifying absolute values that can be related to human disturbance

Here the measurement with the Tapping Machine is described.

Measuring the impact sound insulation requires the following measurements:

— Background noise level in the receiving room

— Sound pressure level in the receiving room

— Reverberation time in the receiving room

3.1 Getting Started

Room Selection

The typical configuration is to measure the impact sound insulation between two room above each other. The Tapping Machine TM3 is positioned in the upper room, the source room. The measurements are performed in the lower room, the receiving room.

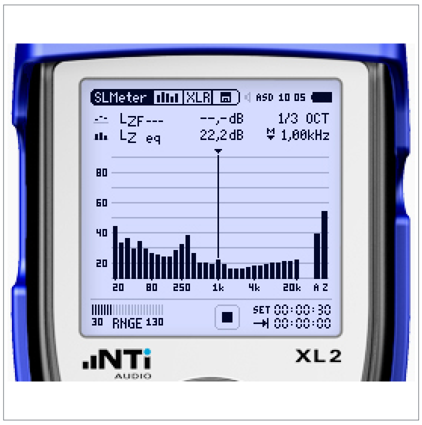
Source Position

- Position the Tapping Machine TM3 in the sending room.
- The measurements have to be carried out with at least four different source positions. The minimum distance to any wall shall be 0.5 m. In case of floor constructions with beams the tapping machine should be placed in an angel of 45° to the direction of the beams.

3.2 Background Noise Level in Receiving Room

Preparation

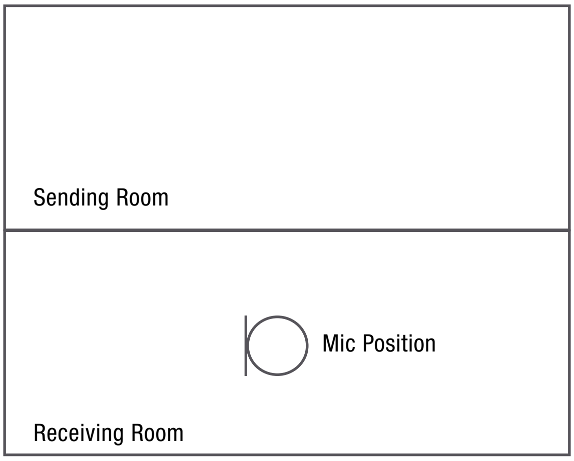
- Select the RTA page in the SLMeter function on the XL2 Sound Level Meter.
- Select 1/3 octave measurement resolution.
- It's recommended to vacate the room during the measurement so that any noise generated by the operator will not affect the measurement.



Background Noise Spectrum in the Receiving Room

Measurement

- Measure the background noise LZeq in the receiving room for 15 seconds. In case the background noise is not steady and continuous, then a longer measurement period shall be applied, e.g. 30 seconds.
- Store the reading in the XL2. This is required for post calculation of the sound insulation.



Measure the Background Noise Level Lb in the Receiving Room - Side View

3.3 Sound Pressure Level in Receiving Room

Preparation

The Tapping Machine TM3 shall be placed in at least four different positions randomly distributed on the floor under test. The hammer connecting line should be at 45° to the direction of any applicable beams or ribs in the floor. Each source position shall have a minimum distance of 0.5 m the any room boundary.

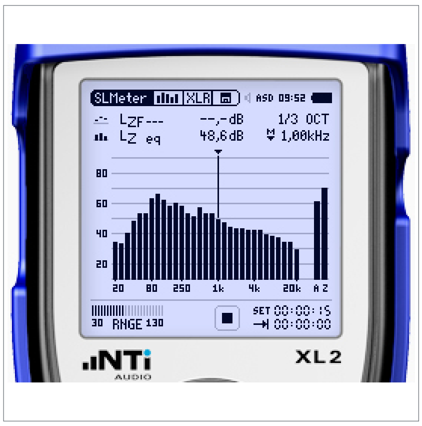
Define four microphone positions, distributed within the maximum permitted space throughout the receiving room. Use at least two microphone positions for each source position. The microphone positions shall be in a different plane relative to the room boundaries and shall not form a regular grid. For example, mark the positions on the floor with a tape. The following minimum distances apply:

- 0.7 m between microphone positions
- 0.5 m from any room boundary
- 1.0 m from the partition being excited by the impact source.

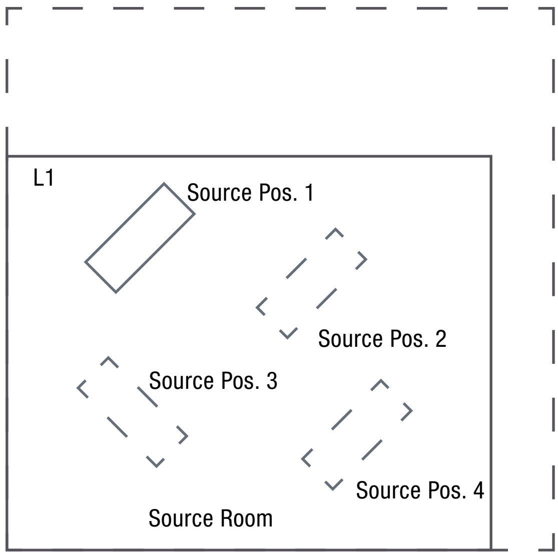
It’s recommended to vacate the room during the level measurement as the operator introduces additional absorption.

Measurements

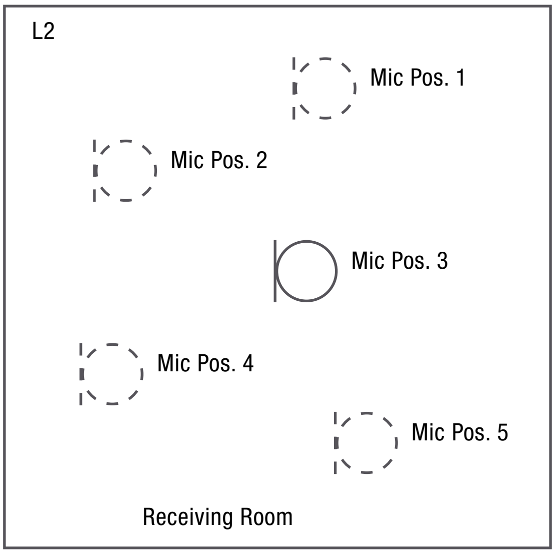
- Measure the receiving sound level spectrum LZeq at each microphone position for a measurement period of 15 seconds.
- Store the individual readings in the XL2 for post calculation of the sound insulation.



Noise Spectrum in the Receiving Room



Tapping Machine Positions in Source Room - Top View

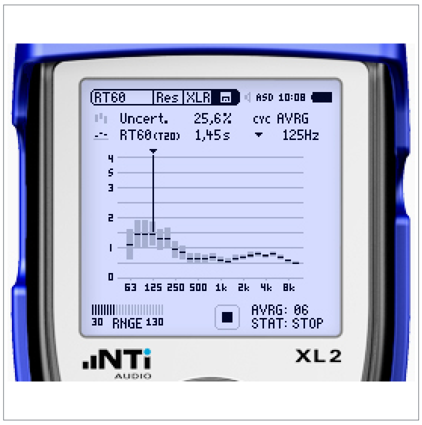


Measure the Sound Levels in the Receiving Room with Tapping Machine at Source Position 1 - Top View

3.4 Reverberation Time in Receiving Room

Preparation

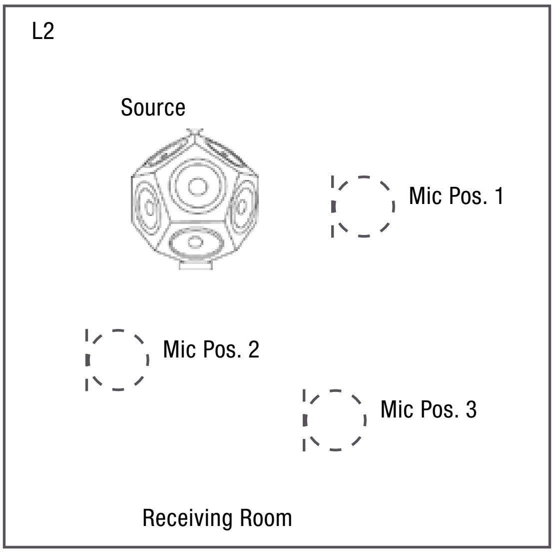
- Move the Dodecahedron Speaker DS3 to the receiving room.
- Select three microphone positions in the receiving room.
- Select the RT60 measurement function on the XL2 Sound Level Meter.
- Select the 1/3 octave resolution on the XL2.



Reverberation Time T

Measurement

- Start the measurement on the XL2.
- Start / stop the test signal.
  Guideline: Set the on/off cycle time for the signal longer than the expected reverberation time.
- Measure at least two decays per position - better three decays.
- Stop the measurement on the XL2.
- Store the individual readings on the XL2 for post calculation of the sound insulation.



Measure the Reverberation Time T in the Receiving Room

3.5 Data Analysis and Reporting

Verify and document all readings by using the Sound Insulation Reporter software. This is a PC-Software dedicated for building acoustics professionals. Load all measurement records into the software and generate the sound insulation report. The software calculates the weighted ratings based on the reference curve shifting method in accordance with the ISO 717-2 standard.

The following calculations are used:

- L'_{n} = Li + 10 log (A / 10)
- L'_{nT} = Li – 10 log (T / 0.5)
- A = 0.16 * V / T

A	Equivalent absorption area of the receiving room [m^2]
Li	Impact sound pressure level in the receiving room [dB]
L'_{n}	Normalized sound pressure level [dB]
$L_{n,w}$	Weighted normalized sound pressure level [dB] (is the value of the reference curve at 500 Hz after shifting the reference curve)
L'_{nT}	Standardized impact sound pressure level [dB]
$L'_{nT,w}$	Weighted standardized impact sound pressure level [dB] (is the value of the reference curve at 500 Hz after shifting the reference curve)
T	Reverberation time in the receiving room [s]
V	Volume of the receiving room in [m^3]

4. Airborne Sound Insulation of Facades

Two measurement methods are distinguished for the measurement of the airborne sound insulation of facades

- Element method
  - for sound insulation measurements of façade elements, e.g. windows
  - The purpose of the measurement is to obtain sound reduction index results for comparison with laboratory measurements,
- Global method
  - provides the real sound level reduction of a facade under test in a given place relative to a position 2 m in front of the façade
  - preferred method for sound insulation measurements of whole facades including all flanking paths
  - The result cannot be compared with that of laboratory measurements.

Here the global measurement method is described.

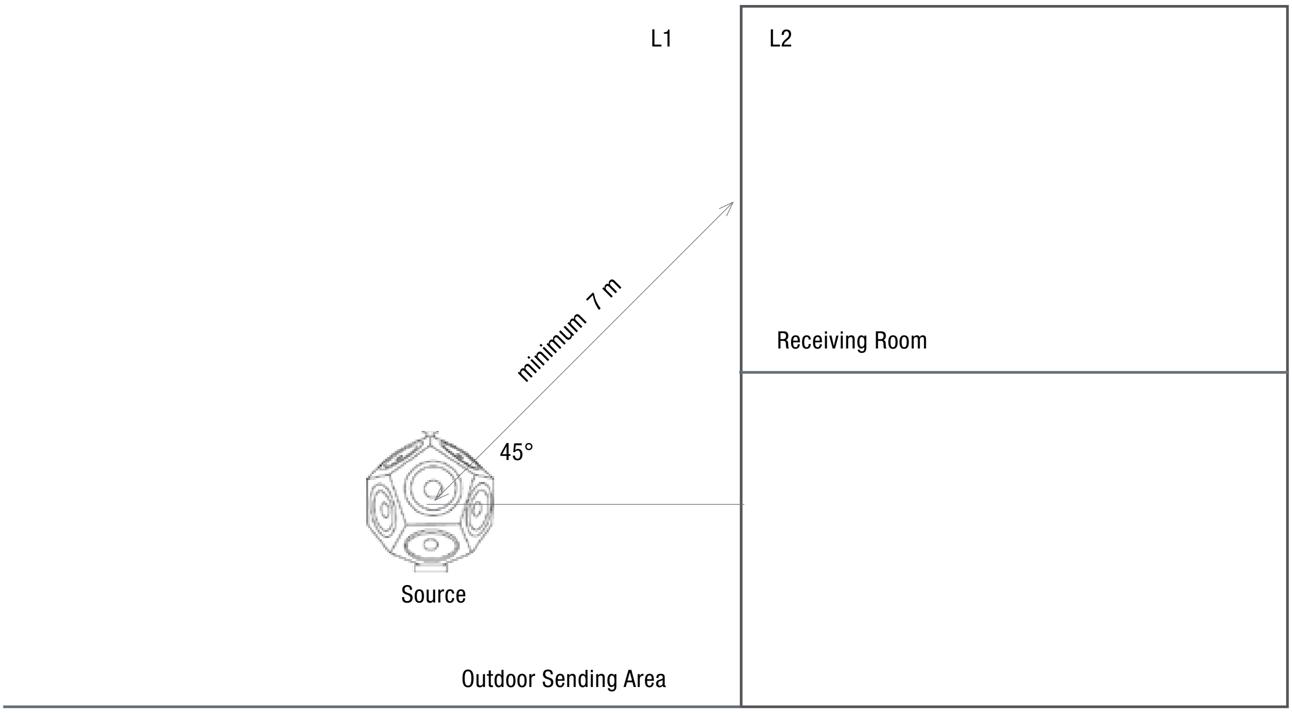
Measuring the airborne sound insulation of facades requires the following measurements:

- Background noise level in the receiving room
- Sound pressure level in front of facade
- Sound pressure level in the receiving room
- Reverberation time in the receiving room

4.1 Getting Started

Speaker Position

- Position the Dodecahedron Speaker DS3 outdoors in front of the facade. The distance D shall be at least 5 m.
- The angle of sound incidence at the facade shall be 45° +/- 5°. The distance from the loud-speaker to the center of the facade under test shall be at least 7 m.
- The sending sound pressure level is measured 2 m in front of the facade.
- The measurements may be carried out at one or multiple speaker positions. Several speaker positions are required at very large rooms or in case the room has two or more outside walls.



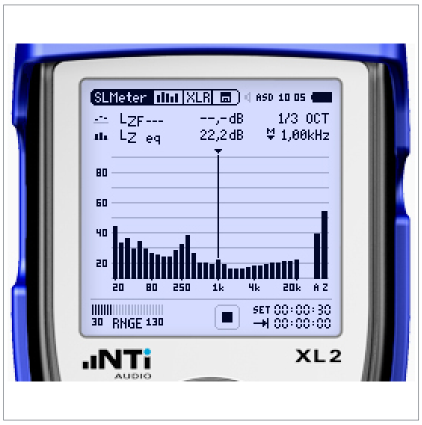
Test Signal Level

- Start the pink noise test signal at a low level.
- Increase the level until it is minimum of 6 dB – better 10 dB - higher in the receiving room than the background noise (in each frequency band from 50 Hz to 5000 Hz). In case this is not possible, then the Sound Insulation Reporter software will automatically apply corrections in accordance with the standard.

4.2 Background Noise Level in Receiving Room

Preparation

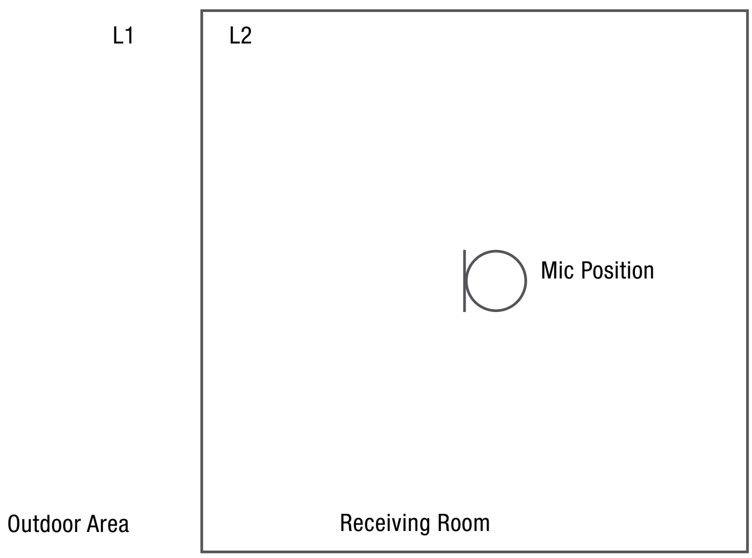
- Select the RTA page in the SLMeter function on the XL2 Sound Level Meter.
- Select 1/3 octave measurement resolution.
- It's recommended to vacate the room during the measurement so that any noise generated by the operator will not affect the measurement.



Background Noise Spectrum in the Receiving Room

Measurement

- Measure the background noise LZeq in the receiving room for 15 seconds. In case the background noise is not steady and continuous, then a longer measurement period shall be applied, e.g. 30 seconds.
- Store the reading in the XL2. This is required for post calculation of the sound insulation.
- Capture the reading as a reference for the next step. This is required to adjust the speaker output level accordingly.



Measure the Background Noise Level Lb in the Receiving Room - Top View

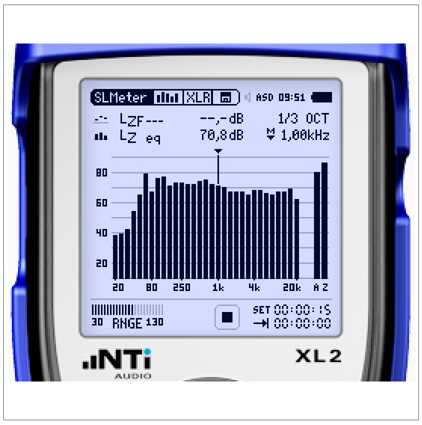
4.3 Outdoor Sound Pressure Level in front of Facade

Preparation

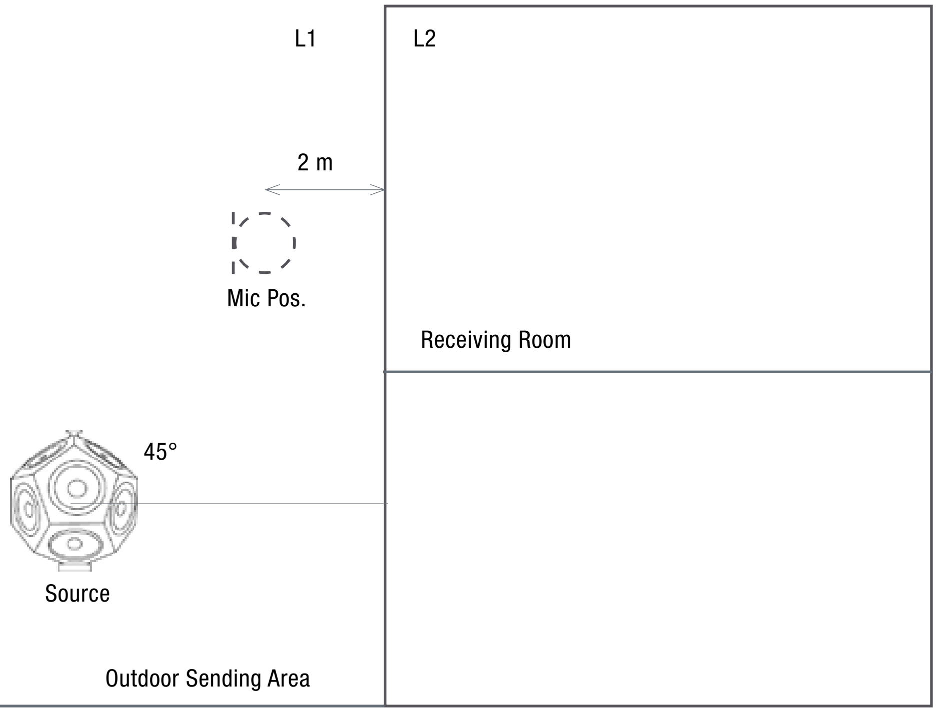
The sending sound pressure level is measured outdoor at 2 m (+/- 0.2m) in front of the facade surface center under test. The height of the microphone is 1.5 m above the receiving room floor.

Measurements

- Measure the sending and receiving sound level spectrum LZeq at each microphone position for a measurement period of 15 seconds.
- Store the individual readings in the XL2 for post calculation of the sound insulation.



Noise Spectrum in front of Facade



Measure the Sound Level in the Outdoor Sending Area - Side View

4.4 Sound Pressure Level in Receiving Room

Preparation

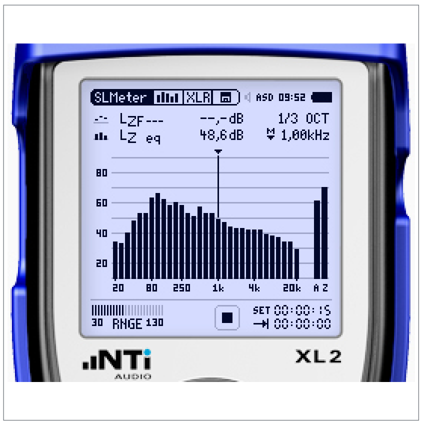
Define five microphone positions in the sending and receiving room, distributed within the maximum permitted space throughout each room. The positions shall be in a different plane relative to the room boundaries and shall not form a regular grid. For example, mark the positions on the floor with a tape. The following minimum distances apply:

- 0.7 m between microphone positions
- 0.5 m from any room boundary
- 1.0 m between any microphone position and the speaker

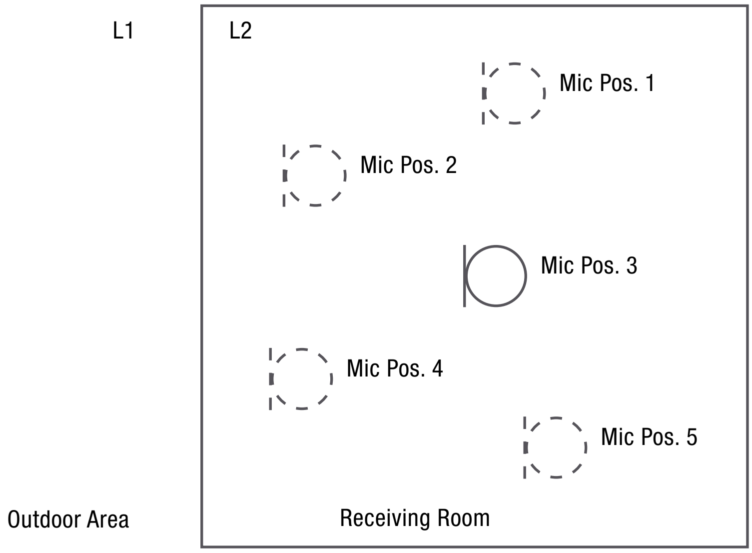
It's recommended to vacate the room during the level measurement as the operator introduces additional absorption

Measurements

- Measure the sending and receiving sound level spectrum LZeq at each microphone position for a measurement period of 15 seconds.
- Store the individual readings in the XL2 for post calculation of the sound insulation.



Noise Spectrum in the Receiving Room

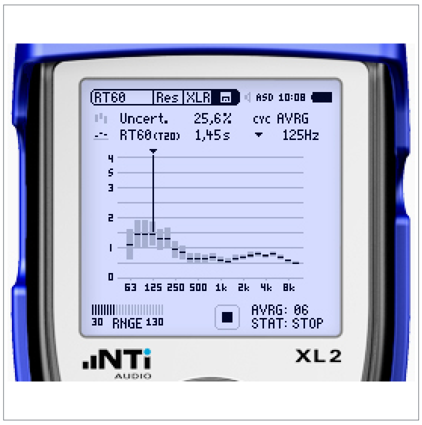


Measure the Sound Levels in the Receiving Room - Top View

4.5 Reverberation Time in Receiving Room

Preparation

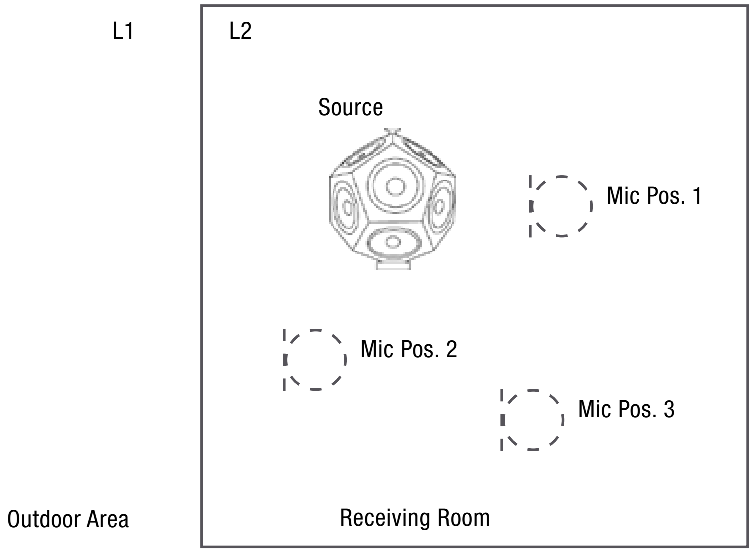
- Move the Dodecahedron Speaker DS3 to the receiving room.
- Select three microphone positions in the receiving room.
- Select the RT60 measurement function on the XL2 Sound Level Meter.
- Select the 1/3 octave resolution on the XL2.



Reverberation Time T

Measurement

- Start the measurement on the XL2.
- Start / stop the test signal.
  Guideline: Set the on/off cycle time for the signal longer than the expected reverberation time.
- Measure at least two decays per position - better three decays.
- Stop the measurement on the XL2.
- Store the individual readings on the XL2 for post calculation of the sound insulation.



Measure the Reverberation Time T - Top View

4.5 Data Analysis and Reporting

Verify and document all readings by using the Sound Insulation Reporter software. This is a PC-Software dedicated for building acoustics professionals. Load all measurement records into the software and generate the sound insulation report. The software calculates the weighted ratings based on the reference curve shifting method in accordance with the ISO 717-1 standard.

The following calculations are used:

- $D_{2m} = L_{1,2m} - L_2$
- $D_{2m,n} = D_{2m}$ - 10 lg (A / 10)
- $D_{2m,nT} = D_{2m}$ + 10 lg (T / 0.5)
- $R'_{45°}$ = D + 10 lg (S / A) - 1.5
- A = 0.16 * V / T

A	Equivalent absorption area of the receiving room [m^2]
D	Difference between facade level and receiving room level using element method [dB]
D_{2m}	Difference between level 2 m in front of facade and receiving room level [dB]
$D_{2m,n}$	Normalized level difference [dB] (the level difference D is standardized to the equivalent absorption area of 10 m^2 in the receiving room)
$D_{2m,nT}$	Standardized level difference [dB] (the level difference D is standardized to the 0.5 seconds reference value of the reverberation time in the receiving room)
$D_{nT,w}$	Weighted standardized level difference (is the value of the reference curve at 500 Hz after shifting the reference curve) [dB]
$L_{1,2m}$	Sound pressure level measured 2 m in front of facade [dB]
L_2	Sound pressure level in the receiving room [dB]
$R'_{45°}$	Apparent sound reduction index of field measurement using element method [dB]
$R'_{45°,w}$	Weighted apparent sound reduction index using element method [dB] (is the value of the reference curve at 500 Hz after shifting the reference curve)
S	Partition area between the outdoor area and receiving room [m^2]
T	Reverberation time in the receiving room [s]
V	Volume of the receiving room in [m^3]

5. Sound Insulation Reporter Software

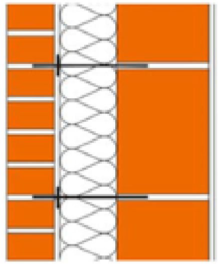
Standardized level difference in accordance with ISO 16283-1
Field measurements of airborne sound insulation between rooms

Client: Demo

Date of test: 15/11/2017

Location: Partition from Sample Room 1 to Sample Room 2

xxx



XL2 Sound Level Meter: A2A-05850-E0 (M4260: 3285), A2A-05850-E0 (M2210: 1465)

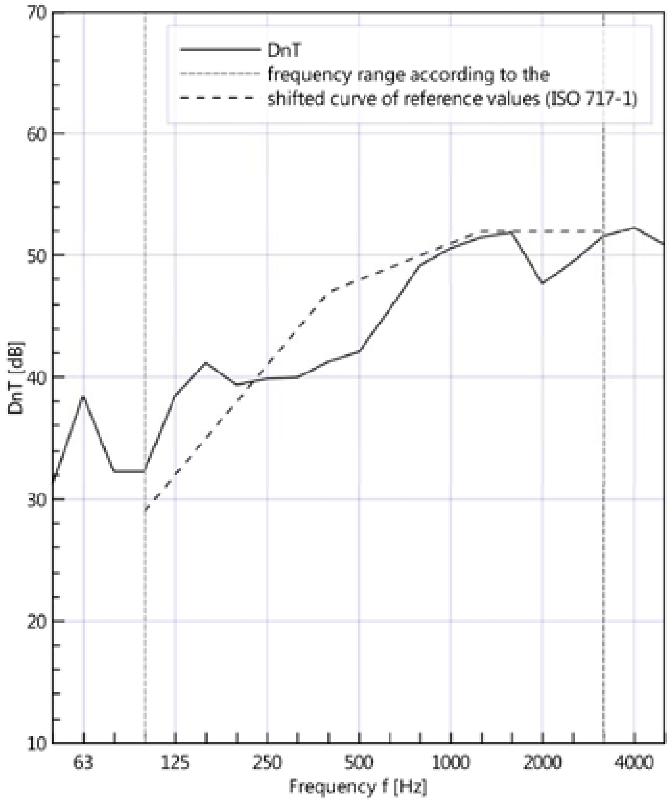
Area of common partition: 15 m²

Source room volume: 50 m³

Receiving room volume: 50 m³

Frequency f Hz	DnT 1/3 octave dB
50	31.2
63	38.5
80	32.3
100	32.3
125	38.5
160	41.2
200	39.4
250	39.9
315	40.0
400	41.3
500	42.1
630	45.6
800	49.2
1000	50.6
1250	51.5
1600	51.9
2000	47.7
2500	49.5
3150	51.6
4000	52.3 *
5000	50.9 *

* 1.3 dB correction applied, value at the limit of measurement



Rating in accordance with ISO 717-1:

DnT,w(C;Ctr) = 48 (-1; -3) dB

$C_{50-3150}$ = -1 dB; $C_{50-5000}$ = -1 dB; $C_{100-5000}$ = -1 dB

Evaluation based on field measurement using results obtained by an engineering method.

$C_{tr,50-3150}$ = -4 dB; $C_{tr,50-5000}$ = -4 dB; $C_{tr,100-5000}$ = -3 dB

No. of test report: 1234

Date: 20/11/2017

Name of test institute: Building Acoustic Inc.

Signature:

NTi Audio AG
Im alten Riet 102
LI - 9494 Schaan
www.nti-audio.com

Sound Insulation Reporter - Airborne Sample Report

6. Know How

Diffuse Sound Field

One of the assumptions commonly made in sound insulation measurements is that the sound field in a room can be considered as being diffuse (= the sound energy density is uniform throughout the space). This is not strictly correct because diffuse sound fields don't occur in real box-shaped rooms with stationary surfaces and absorbent boundaries. However, in the field situation there are some rooms in which there are close approximations to a diffuse sound field in the mid and high frequency ranges. In frequency bands lower than about 400 Hz in general and especially lower than 100 Hz, no diffuse-field conditions in the test room can be expected especially when room volumes of 50 m^3 or less are considered.

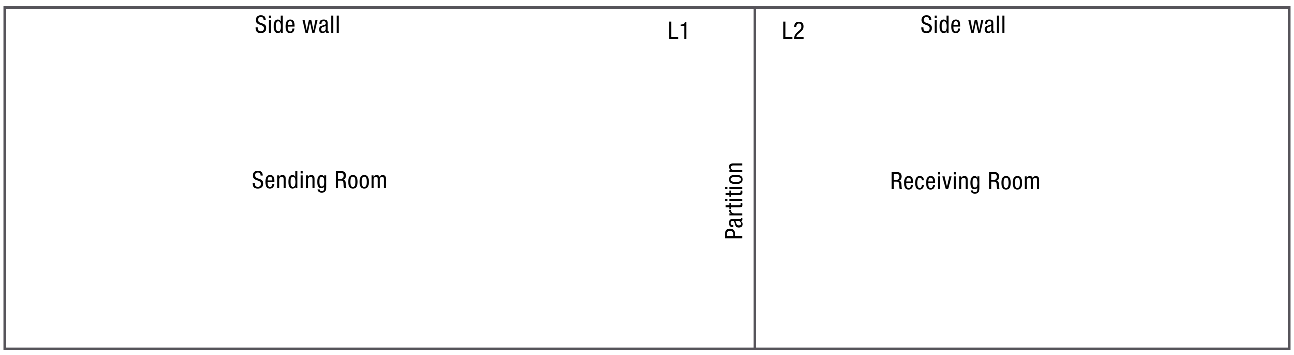
The preceding described measurement procedure allows for measurements to be taken without any knowledge as to whether the sound field can be considered as diffuse or non-diffuse.

Source Position

For airborne sound insulation measurements in non-diffuse sound fields it is necessary to excite the majority of the modes in the source room. For this reason, loudspeaker positions near the corners are used in box-shaped rooms as well as other shapes of room. Many more modes are excited by the source in a corner position than a central point. In addition, it is necessary to take average measurement from more than one source position. (Sound Insulation by Carl Hopkins, 2007, Elsevier & Revision of international standards by Carl Hopkins, 2015, Elsevier)

R ... Sound Reduction Index

The sound insulation capabilities of a particular wall, ceiling, or component can be measured in a laboratory, and a sound reduction index R assigned to it. For such laboratory measurements it's important that the sound transmitted from the sending room into the receiving room not directly through the partition under test (e.g. via the side walls) is at least 15 dB below the sound transmitted directly through the partition.



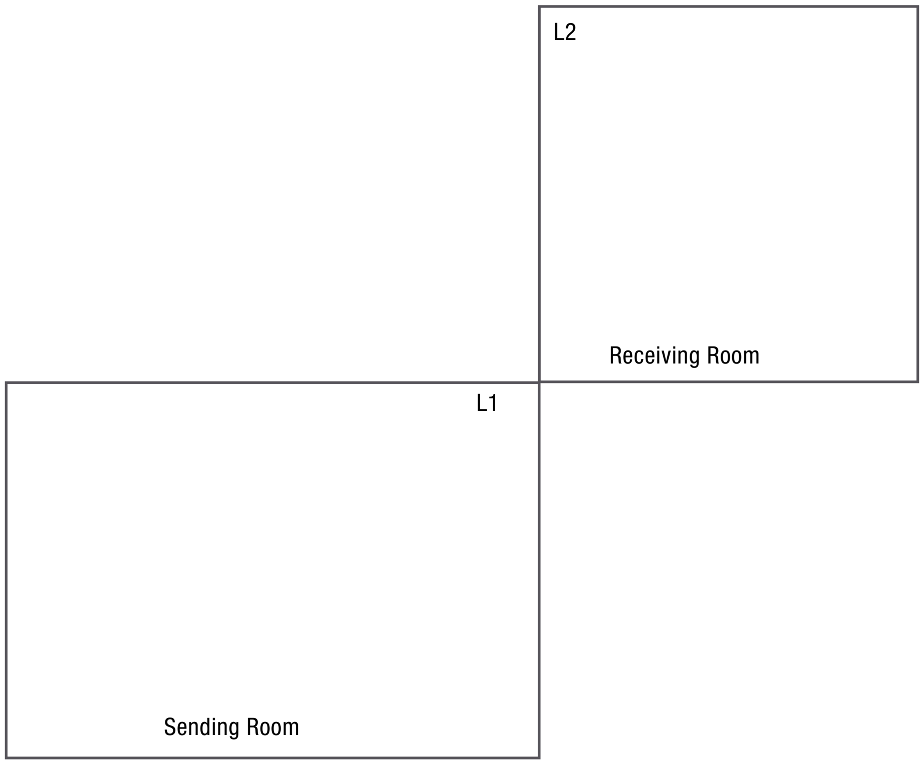
Default room layout

R' ... Apparent Sound Reduction Index

In an actual building (outside of the laboratory), sound may find a way around the main room-separating partition e.g. through a window or an electric wiring channel; the sound level in the receiving room is not just the sound transmitted through the partition itself. Therefore, the so-called Apparent Sound Reduction Index R' is measured.

Normalized level difference Dn

The normalized level difference Dn is used for situations where there is no common partition area or where the partition area is not easily determined (e.g. fan opening, ventilation, etc). The sound pressure level is measured in the sending and receiving room and the difference D calculated. As the level in the receiving room depends on the absorption within the room, the level difference is normalized with the actual absorption area in the receiving room in relation to a reference absorption area of 10 m^2. In relation to the sound insulation index R, a normalized level difference Dn of, for example, 40 dB can be seen as a wall area of 10 m^2 with R = 40 dB.



Room layout without common partition area

Standardized level difference DnT

The standardized level difference describes the sound insulation between two rooms. This term is commonly specified in local standards with minimum requirements. The sound pressure level is measured in the sending and receiving room and the difference D calculated. As the level in the receiving room depends on the reverberation time T in the room, the level difference is standardized to the measured reverberation time in the receiving room in relation to a reference reverberation time of 0.5 seconds.

Related Standards

ISO 16283-1	Acoustics — Field measurement of sound insulation in buildings and of building elements — Part 1: Airborne sound insulation
ISO 16283-2	Acoustics — Field measurement of sound insulation in buildings and of building elements — Part 2: Impact sound insulation
ISO 16283-3	Acoustics — Field measurement of sound insulation in buildings and of building elements — Part 3: Façade sound insulation
ISO 717-1	Acoustics — Rating of sound insulation in buildings and of building elements — Part 1: Airborne sound insulation
ISO 717-2	Acoustics — Rating of sound insulation in buildings and of building elements — Part 2: Impact sound insulation
IEC 61672-1	Electroacoustics – Sound level meters – Part 1: Specifications
IEC 61260-1	Electroacoustics – Octave-band and fractional-octave-band filters – Part 1: Specifications
IEC 60942	Electroacoustics - Sound calibrators
ISO 3382-2	Acoustics — Measurement of room acoustic parameters — Part 2: Reverberation time in ordinary rooms