UDC 534.86

ACOUSTICS:
IN SITU MEASUREMENTS OF PERMANENTLY INSTALLED PUBLIC ADDRESS SYSTEMS

Key words: Sound reinforcement system, in situ measurements, technical specification, test method

TABLE OF CONTENTS

1 SCOPE AND FIELD OF APPLICATION

This Nordtest method specifies a practical test method for *in situ* measurements of permanently installed public address systems. The method is restricted to selected parameters, which can be used to evaluate a system's performance and to verify if a (comparable) system's technical specification is fulfilled.

Typical parameters that may be specified for a permanently installed public address system prior to the installation are described in Appendix 9.2 “Example of Technical Specification”.

This test method is assumed to be applied by those involved in specifying, supplying, installing or verifying public address systems.

Adjustment of the public address system shall be carried out prior to the measurements.

2 REFERENCES

ANSI/EIA-426-B-98. Loudspeakers, Optimum Amplifier Power. This standard recommends the maximum power rating for an amplifier to be connected to the speaker. This standard defines acceptable performance limits in the categories of power compression, distortion, and accelerated life testing.

IEC 60268-16:1998. Sound system equipment – Part 16: Objective rating of speech intelligibility by speech transmission index.

EN 60804 + A2:1995. Integrating-averaging sound level meters.

EN 60942:1998. Electroacoustics – Sound calibrators.

EN 61094-4:1996. Measurement microphones – Part 4: Specifications for working standard microphones.

EN 61260:1996. Electroacoustics – Octave-band and fractional-octave-band filters.

IEC 60651 + A1:1995. Sound level meters.

Published by Nordtest
Tekniikantie 12
FIN–02150 Espoo
Finland

Phone: + 358 9 455 4600
Fax: + 358 9 455 4272
E-mail: nordtest@nordtest.org
Internet: www.nordtest.org

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3 DEFINITIONS AND SYMBOLS

For the purpose of this measurement method, the following definitions apply:

3.1 Area of Coverage, AOC

A given area, where the public address system meets the technical specification according to this procedure. The audience area may be divided into a number of coverage areas.

3.2 A-weighted Sound Pressure Level, L_A

The sound pressure level weighted with the A-weighting specified in IEC 60651.

3.3 C-weighted Sound Pressure Level, L_C

The sound pressure level weighted with the C-weighting specified in IEC 60651.

3.4 Equivalent Sound Pressure Level, $L_{eq,T}$

The value of the sound pressure level of a continuous steady sound that, within the measurement time interval, has the same mean square sound pressure as the sound under consideration, the level of which varies with time.

3.5 Feedback Stability Margin, FSM

The feedback stability margin is the level difference (dB) between the gain when feedback howling occurs (loop gain equals one and loop phase is a multiple of 2π radians) and the actual gain of the system.

3.6 Normal System Gain, NSG

For public address systems normal system gain is defined as the amplification of the sound system that gives a Sound Pressure Level of 73dBA in the reference measurement point. The procedure is described in chapter 7.1.1 “Normal System Gain”.

3.7 Pink Noise, PN

Pink noise is a continuous spectrum noise having constant energy per constant percentage bandwidth, with Gaussian probability distribution of instantaneous values. Wideband pink noise is in this context defined as pink noise having a bandwidth exceeding the frequency range of interest.

3.8 Reference Measurement Point, RMP

The reference measurement point shall be centrally located within the Area of Coverage (AOC), placed in the rear half, not on any lines of symmetry.

3.9 Reverberation Time, T_{60}

The time that would be required for the sound pressure level to decrease by 60dB after the sound source has stopped. The quantity is denoted T_{60} and is expressed in seconds.

3.10 Signal Source (SiS)

The signal source is defined as an electrical signal generator for generating a test or excitation signal (music, speech, noise etc.). This could be a CD-player, DAT-player (for reproducing a pre-recorded test signal) or other signal generators. The signal source could also be a part of the measurement system.

3.11 Signal to Noise Ratio, S/N

Signal to noise ratio is defined as the level difference in dB of the signal and the background noise. Note that the nominal signal level must be given. For sound pressure level measurements the nominal level shall be given in dB relative to 20µPa.

3.12 Public Address System, PA-system

A system consisting of microphones, signal processing equipment (equalisers, delays etc.), amplifiers and loudspeakers for electroacoustical amplification/reproduction of speech and music where direct acoustical transmission applies.

3.13 Sound Source (SoS)

An acoustical sound source is defined as a source for simulation of a talker. The acoustical source shall reproduce a speech spectrum according to IEC 60268-16 and have directivity similar to that of the human head or mouth.

3.14 Speech intelligibility, SI

Speech intelligibility is in this context defined as STI (Speech Transmission Index) or RaSTI (Rapid Speech Transmission Index) as defined in IEC 60268-16.

3.15 Technical Specification, TS

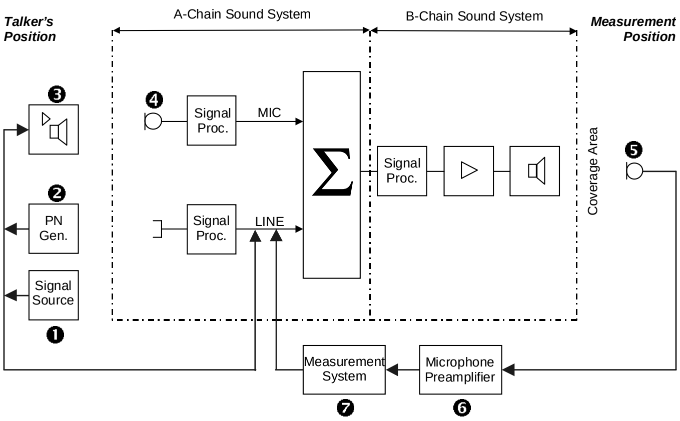
Specification that describes the required performance of the Public Address system.

3.16 White Noise, WN

White noise is a continuous spectrum noise having a power spectral density that is independent of the operating frequency. Wideband white noise is in this context defined as white noise having a bandwidth exceeding the frequency range of interest.

4 INSTRUMENTATION AND SETUP

The sound system is in this context divided into an A- and B-Chain. Normally, the A-chain contains source dependent signal processing like pre-amplifiers, equalizers and gain controls. The B-chain normally contains the sound system's common and permanently adjusted signal processing such as delays, filters, equalisers for loudspeakers or room equalisation, compressors, limiters, loudspeaker controllers etc.



The numbered blocks in the figure are defined as follows:

❶ Signal Source for test signal

The signal source is an electrical signal generator for generating a test or excitation signal (music, speech, noise etc.). This could be a CD-player, DAT-player (for reproducing a prerecorded test signal) or other signal generators. The signal source could also be a part of the measurement system.

❷ Pink Noise Generator

The pink noise generator should reproduce wideband pink noise covering the frequency range of interest.

❸ Sound Source for simulation of a talker

The acoustic Sound Source (loudspeaker) is to be used for simulation of a talker. The source shall reproduce a speech spectrum according to IEC 60268-16 and have directivity similar to the human mouth or head. One way to do this is to design a sound source in combination with an electrical filter (speech spectrum filter). A broadband loudspeaker element with a diaphragm diameter of approximately 100mm (4") mounted in a box with approximately the same dimensions as the human head can be used. A mouth simulator can also be used but it is not required.

❹ Sound System Microphone(s)

The sound system microphone(s) shall be placed in accordance with its normal position(s).

❺ Measurement microphone

The measurement microphone shall be omni-directional and comply with the requirements for accuracy Class 2 according to IEC 60651. Microphone type shall be free field with a maximum diameter of 13mm (½").

For frequency response measurements the measurement system including the microphone shall be linear ±1dB for normal incidence (free field) within the measured bandwidth. For measurements above 10kHz the maximum diameter of the microphone shall be 7mm (¼"). The microphone axis shall be angled towards the talker's normal position. If a normal position does not exist, the microphone axis shall be angled towards the nearest loadspeaker.

❻ Microphone preamplifier

The preamplifier shall comply with the requirements for accuracy Class 2 according to IEC 60651. Using Impulse Response Analysers, the Front-End and the Microphone in use shall meet the accuracy for sound level meters of Class 2 according to IEC 60651.

❼ Measurement system

The measurement system shall comply with the requirements stated in chapter 2.1 "References". Depending on the measurements the measurement system shall be capable of measuring the following quantities using both time constants Slow and Fast:

- Sound Pressure Level, A-weighted and C-weighted
- Sound Pressure Level Spectra in 1/3 octave bands
- Equivalent Sound Pressure Level

Type of measurement system that can be used:

- Pink Noise / White Noise
- Sinusoidal Sweep
- MLS (Maximum Length Sequence)

Real Time Analysers (RTA) shall meet the accuracy for sound level meters of Class 2 according to IEC 60651.

For sound pressure level measurement the complete measurement system including the microphone shall be calibrated using a calibrator before the measurement. The calibrator shall meet the requirements of Class 2 according to EN 60942.

For transfer function measurements the measurement systems normally contains signal generators producing random noise, sinusoidal sweep, periodic pseudo random noise etc. For transfer function and frequency response measurements the input of the measurement system shall meet the following requirements:

- Dynamic range: > 70dB (unweighted 20 – 20kHz)
- Total harmonic distortion: < 0.02% (–74dB)
- Frequency response: ± 1dB within the measured bandwidth.

The frequency response of the measurement system may be corrected by measuring the impulse response (transfer function) of the system and using inverse filtering (loop compensation).

5 TEST CONDITIONS

When the measurements are performed outdoors, the maximum wind speed/air flow shall not exceed 5m/s. There shall be no rain during the measurements.

No overloading shall be allowed in any stage of the public address system. Exceptions in this respect are allowed when measuring maximum sound pressure level.

Measurements shall be made with standard mains supply voltage.

Operating conditions

All equipment shall be tested under relevant conditions as stated by the manufacturer (thermal, electrical and acoustical conditions etc.). Adjustment of the sound system has to be carried out prior to control measurements.

Climatic and environmental conditions

Unless otherwise specified, the equipment shall operate in accordance with the system specification under the following conditions:

1) Indoor equipment:
   - ambient temperature –5° C to +40° C
   - relative humidity 25% to 90%
   - air pressure 86kPa to 106kPa
2) Outdoor equipment:
   - ambient temperature –20° C to +55° C
   - relative humidity 25% to 99%
   - air pressure 86kPa to 106kPa.

6 MEASUREMENT POINTS

The number of measurement points shall be chosen so as to achieve an appropriate coverage in the room or outdoor area. In areas with more than one storey (balconies etc.) representative measurements shall be carried out for each floor.

Number of measurement points

The measurements shall be made at a sufficient number of measurement points within the Area of Coverage (AOC). If not stated in the technical specification, the number of measurement points shall be in accordance with Table 6.1.

Table 6.1. Number of measurement points.

AREA OF COVERAGE (AOC)	NUMBER OF MEASUREMENT POINTS
AOC < $30m^2$	2
$30m^2$ < AOC < $60m^2$	4
$60m^2$ < AOC < $180m^2$	6–8
AOC ≥ $180m^2$	$\frac{AOC[m^2]}{24[m^2]}$

Microphone positions

The microphone positions shall be chosen according to the following the guidelines:

1. Care should be taken that none of the microphone positions chosen are unusual.
2. One of the microphone positions shall always be placed in the Reference Measurement Point (RMP).
3. The microphone positions shall be uniformely distributed in the Area of Coverage (AOC), placed both on and off the sound source radiation axes.
4. The distance between microphone positions shall be larger than 3m.
5. The microphone shall not, if possible, be placed closer than 1.5m from the room boundaries or large reflecting obstacles.
6. Positions shall be avoided which are exactly on the lateral or transversal room centre lines.
7. The microphone shall be mounted at normal head height and not less than 0.15m above the top of any seat back. Unless otherwise stated in the technical specification, the normal head height for a person seated is 1.2m ± 0.1m and for a person standing 1.7m ± 0.2m.

7 TEST PROCEDURE

7.1 General

7.1.1 Normal System Gain

For speech reinforcement sound systems Normal System Gain (NSG) shall be adjusted as follows:

Place a sound source for simulation of a talker (❸) in front of the system microphone. The position and direction of the sound source loudspeaker in the room shall be where the talker's mouth is normally placed. The distance to the sound systems microphone is determined by the following (in descending order):

- The position normally used by the talker
- The position recommended in the manual
- 200mm from the microphone.

Apply pink noise to the sound source and adjust the A-weighted sound pressure level to 73dB at 0.5m distance on axis (67dB at 1m). Adjust the sound system gain so that the A-weighted sound pressure level at the Reference Measurement Point (RMP) is 73dB.

When testing body mounted (lavalier or headset) microphones, the microphone shall be mounted as for normal use with an acoustical source placed and aimed in front of the microphone to simulate a real talker.

7.1.2 Calculation of Results

Noise Correction

Noise correction of measured sound pressure levels with an effective Signal to Noise Ratio (S/N) less than 10dB within

1/3-octave band shall be performed in accordance with Table 7.1.2.

Table 7.1.2. Correction for background noise.

S/N RATIO	CORRECTION FACTOR
< 6dB	Reject measurement
6 – 8dB	–1dB
8 – 10dB	–0.5dB
> 10dB	No correction

Average Sound Pressure Level (SPL)

If the variation among the sound pressure levels at different measurement points is small, not exceeding 4dB, the arithmetic mean of the individual sound pressure levels in decibel can be calculated as:

$$\overline{L_{eq,T}} = \frac{1}{N}\sum_{i=1}^{N} L_{eq,T(i)}$$

N Number of measurement points
$L_{eq,T(i)}$ Measured equivalent SPL in microphone position number i.

If the variation exceeds 4dB, logarithmic average shall be calculated as:

$$\overline{L_{eq,T}} = 10 \cdot \log\left[\frac{1}{N}\sum_{i=1}^{N} 10^{0,1 \cdot L_{eq,T(i)}}\right]$$

N Number of measurement points
$L_{eq,T(i)}$ Measured equivalent SPL in microphone position number i.

Standard Deviation, σ

Standard deviation shall be calculated as:

$$\sigma = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}\left(L_{eq,T(i)} - \overline{L_{eq,T}}\right)^2}$$

N Number of measurement points
$L_{eq,T(i)}$ Measured equivalent SPL in microphone position number i
$\overline{L_{eq,T}}$ Calculated averaged SPL.

7.2 Background Noise

The background noise shall be measured at the Reference Measurement Point (RMP).

C-weighted, A-weighted and spectrum levels in 1/1- or 1/3-octave bands (31.5 – 16kHz) shall be measured.

The equivalent sound pressure level $L_{eq,T}$ shall be measured for more than 10 seconds in 3 different microphone positions around RMP. The distance between the measurement points shall preferably be 1m. The measurement results shall be averaged according to chapter 7.1.2 “Calculation of Results”.

7.2.1 Background Noise with sound system OFF

Measure the background noise with the sound system off. All active components in the measurement room and all power amplifiers shall be off.

7.2.2 Background Noise with sound system ON

The sound system gain will influence the noise from the loudspeakers.

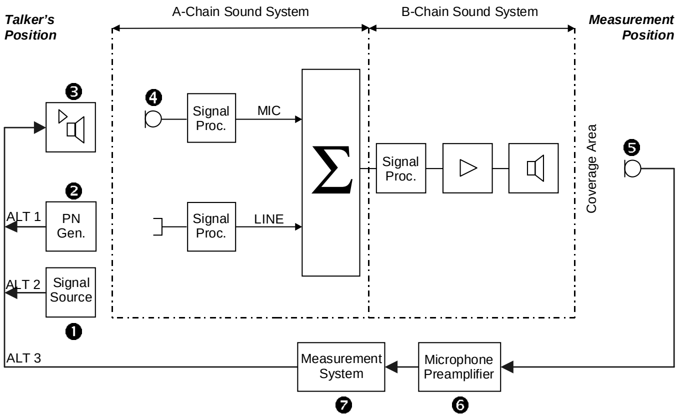
Adjust the sound system to Normal System Gain (NSG) following the procedure in chapter 7.1.1 “Normal System Gain”. If a mixer is used, set one input channel fader, group output fader and master output fader at nominal level and adjust the input gain (trim) to normal system gain. All other input channels shall be muted. All sound processing units such as equalisers, delays, compressors etc. shall be in their normal mode.

The sound system microphone shall be open during measurements.

7.3 Feedback limited Sound Pressure Level

The sound system microphone under test shall be supplied with speech spectrum or any other type of wideband noise signal from sound source ❸.

The sound system shall be in its normal mode of operation, and the microphones shall be in their normal positions. Unless otherwise stated in the technical specification, the microphone most sensitive to feedback shall be used as system microphone ❹ during measurements.



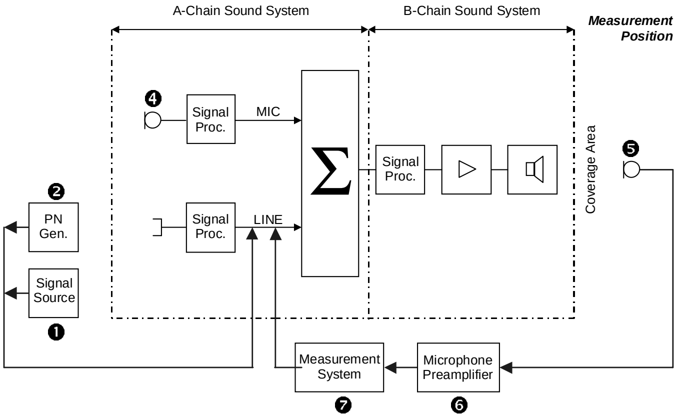
Procedure:

1. The A-weighted sound pressure level from the sound source ❸ shall be adjusted to 73dB at 0.5m (67dB at 1m). The distance from sound source to the sound system microphone shall be as described in chapter 7.1.1 “Normal System Gain”.
2. The electrical gain of the sound system is increased in steps until the limit of instability is reached (the sound system starts howling).
3. Reduce the electrical gain by 6dB (6dB feedback stability margin).

4. The feedback limited sound pressure level (FLSPL) is defined as the measured C-weighted equivalent sound pressure level in the Reference Measurement Point (RMP). Minimum measurement time is 10 seconds.
5. Items 2–4 shall be performed a minimum of three times and the mean value of the measurements shall be stated in the test report.

7.4 Sound Pressure Level Coverage

The variation in sound pressure level within the area of coverage is measured with a pink noise signal or other wideband signal. The signal is applied to the B-chain of the sound system (or to the A-chain with the signal-processing in bypass).



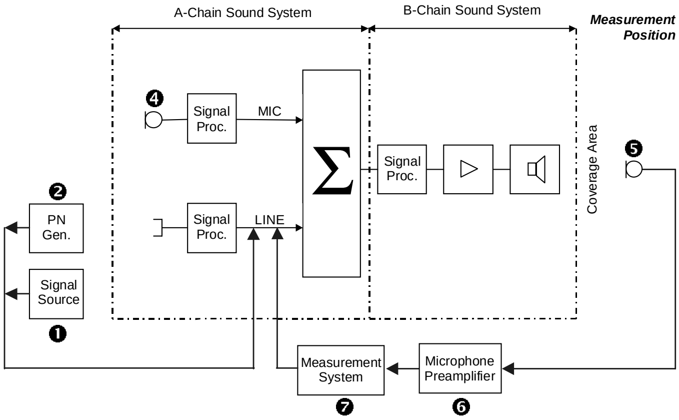
Procedure:

1. Adjust the sound system gain until the sound pressure level (10 seconds $L_{eq,T}$) is over 10dB above background noise in all 1/3-octave bands of interest or between 100–10kHz, but not above maximum SPL or FLSPL. The adjustment is performed in the Reference Measurement Point (RMP).
2. Measure the C-weighted equivalent sound pressure level over a period of 10 seconds in the Reference Measurement Point (RMP).
3. Repeat step 2 for all the measurement points.
4. For all the measurement points the sound pressure level coverage shall be presented as the mean value including the standard deviation using the formulae described in chapter 7.1.2 “Calculation of Results”.

7.5 Acoustical Frequency Response

The acoustical frequency response at a given position is the sound pressure level in a given frequency range. Unless otherwise stated the results shall be given as the sound pressure level in 1/1-octave or 1/3-octave frequency bands.

Different analysers can be used, such as Real Time Analysers (RTA), two-channel FFT type analysers, periodic pseudo-random noise analysers and Time Delay Spectrometry (TDS) analysers.



If the analyser uses constant-percentage filters (1/1- or 1/3-octave band), the acoustical frequency response shall be measured using Pink Noise. If the analyser uses constant-bandwidth filter (FFT), the acoustical frequency response shall be measured using White Noise.

Procedure:

1. Adjust the sound system gain until the sound pressure level (10 seconds $L_{eq,T}$) is over 10dB above background noise in all 1/3-octave bands of interest or between 31.5–12.5kHz, but not above maximum SPL or FLSPL. The adjustment is performed in the Reference Measurement Point (RMP).
2. The measurements shall be carried out at all measurement points. To ensure that the measured acoustical frequency response is independent of the measurement method, the measurement period given in chapter 7.5.1 “Measurement Period” shall be used.
3. The acoustical frequency response shall be presented in the test report as the mean value of all the measurement points, with a frequency range in accordance with the tolerance given in the technical specification.

7.5.1 Measurement Period

Real Time Analyser (RTA)

The equivalent sound pressure level shall be measured over a period of minimum 10 seconds after the steady state is reached.

Two-channel FFT Analyser

When using random noise or other non-deterministic sound signal and two-channel FFT analysers significant time delay bias errors must be avoided.

The impulse response shall be measured correctly up to least T60/6. This requires a minimum record length of 1.7 ∗T60.

Rectangular time window (length = $1.7 \cdot T_{60}$) and a frequency resolution of at least 5Hz (approximately four frequency lines in the lowest 1/3-octave band) shall be used.

To reduce the random error introduced by the random noise source and extraneous noise, averaging of records must be performed. The number of averages used shall be stated in the test report.

Periodic Pseudo-random noise systems

Periodic pseudo-random noise systems such as Maximum Length Sequence (MLS) systems use a record length which is matched to the noise period.

In order to avoid significant time aliasing the pseudo-random noise period and the record length shall be 0.67 times the reverberation time (40dB decay range).

The measurement shall be analysed with a rectangular time window of length at least $T_{60}/6$. The frequency resolution shall be at least 5Hz.

To ensure a signal-to-noise ratio of 10dB, averaging may be necessary in noisy environments.

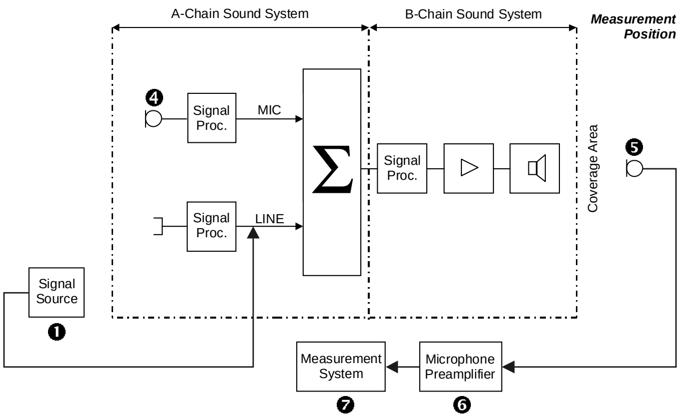
Time Delay Spectrometry, TDS

The excitation signal used in TDS is the linear sweep with constant amplitude. For frequency response measurements a tracking filter is used. The minimum sweep time is $T = F(1/B_{max})^2$.

F is the frequency range and B_{max} is the maximum bandwidth of the tracking filter that is comparable to the frequency resolution. Measuring the whole frequency range F = 15kHz with enough frequency resolution for the 31.5Hz 1/3-octave band (B_{max} = 5Hz) requires T = 10 minutes.

7.6 Maximum Sound Pressure Level

Maximum Sound Pressure Level, L_{Cmax} is defined as the level at which nonlinearity between an increased broadband noise level and the measured L_C occurs.



Signal Source (❶): Pink Noise with bandwidth as stated in the technical specification or given by the loudspeaker frequency range. Crest-factor 4 (12dB)

Reference level: –20dBC relative to expected maximum C-weighted SPL

Maximum permitted deviation: ±2dB.

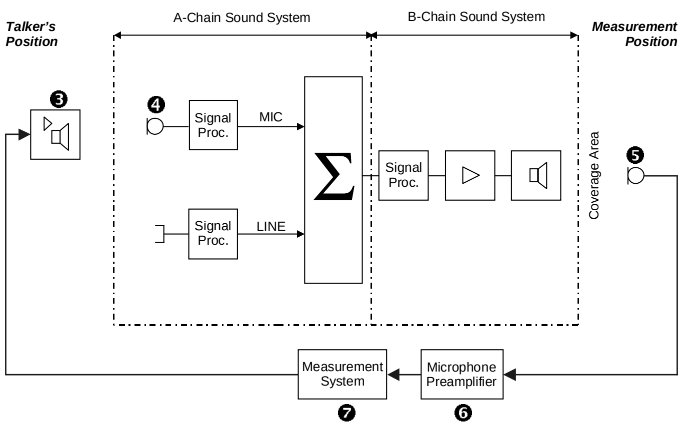
Procedure:

1. The signal source ❶ is connected to the system. It is required that the level can be adjusted in steps of 2dB.
2. The measurement microphone ❺ is placed in the Reference Measuring Point (RMP).
3. The sound system is adjusted to produce a L_C approximately 20dB below the expected maximum level.
4. L_C is measured using a linear integration time of 20 seconds.
5. The signal source ❶ is muted, and the background noise is measured. The background noise shall be more than 10 dB below the initially measured L_C.
6. The signal source ❶ is turned on, and the L_C is measured. This L_C is used as a reference for the next part of the procedure.
7. The input level is increased by 2dB, and a new measurement is performed (as in item 4).
8. Within the specified maximum permitted deviation the L_C shall hold the same relative level as the reference measurement (at a level 2dB higher).
9. The procedure (7–9) is repeated N times until L_C deviates from the reference L_C plus the number of increasing steps times 2dB ($L_{C,reference}$ + N·2dB) by more than the specified limits.
10. The level is turned down 2dB. The L_C is measured in all measurement points. The final result (L_{Cmax}) is calculated by averaging the results from all measurement points.

It shall be noted – if possible – whether the nonlinearity in the public address system is caused by compressor or limiter units in the B-Chain or by other limitations in the sound system. If the nonlinearity is caused by any of these conditions, it shall be stated in the test report.

7.7 Speech Intelligibility

A number of methods of measuring speech intelligibility (SI) exist. In this report the SI shall be measured as the Speech Transmission Index (STI or RASTI) according to IEC 60268-16:1998.



Procedure:

1. The A-weighted sound pressure level from a speech spectrum noise signal from the sound source ❸ shall be set to 73dB at 0.5m (67dB at 1m), and the distance from the sound source to the sound system microphone (❹) shall be as described in chapter 7.1.1 “Normal System Gain”.
2. Unless otherwise stated, the A-weighted sound pressure level (test signal) in the reference measuring point (RMP) shall be set to 73dB (sound system gain equal to normal system gain).
3. The STI/RASTI measurements shall be carried out in all the specified measurement points.
4. The noise level, test signal level and weighting factors shall be stated with the test results.

Notes:

- Note that neither the measurement method nor the measurement period shall reduce the (negative) influence of background noise or the reverberation time.
- IEC 60268-16 gives the weighting factors that are to be used.
- If the ambient noise level at the time of measurement differs from normal conditions (e.g. without audience noise), correction of the measurement results may be required. If no other method is available, the method given in Appendix 9.3 ”Correction of STI for the influence of background noise” shall be used.
- The conversion between different intelligibility scales is given within EN-60849:1998 Annex B.

8 PRESENTATIONS OF RESULTS IN TEST REPORT

With reference to this standard the test report shall contain the following information:

- Reference to this Nordtest Standard
- Name of the person and the organisation who has performed the measurements
- Name and address of the organisation or person(s) who has ordered the test (client)
- Date of test
- Identification of the test site and type and description of the sound system
- Type of instrumentation that has been used during the measurements
- Type of signal used (bandwidth etc.)
- Description of the test conditions (operating conditions, climatic and environmental conditions and test conditions)
- Description of the microphone positions, preferably shown on a plan or drawing.
- Subjective remarks (subjective system sound check)
- Measurement results
  - Background Sound Pressure Level with system OFF and ON
  - Feedback limited Sound Pressure Level
  - Sound Pressure Level Coverage
  - Acoustical Frequency Response
  - Maximum Sound Pressure Level
  - Speech Intelligibility.

An example of a simple test report is presented in Appendix 9.1 “Example of a simple test report”.

9 APPENDIX

9.1 Example of a simple test report

The purpose is to suggest how the measurement results should be reported.

TEST REPORT, Control measurements of public address systems

Control measurements of the public address systems have been performed in accordance with NORDTEST Method No. ##.

Place and date		
Performed by:	*Name*	Sign:
Verified by:	*Name*	Sign:
Approved by:	*Name*	Sign:

Name of the persons and the organisation that has performed the measurements:
Name(s) of person(s) and the name of the firm they are representing

Name and address of the organisation or person(s) who has ordered the test:
Name(s) of person(s) and the name of the firm they are representing

Date of test:
Date

Identification of test site:
Type of room or area where the measurement has been performed

Description of the public address system:
Type of sound system (type of loudspeakers, basic functions etc.)

Type of instrumentation used during the measurements:
Description of the instrumentation used

Type of signal used during the measurements:
Description of the noise type, bandwidth etc.

Operating conditions, climatic conditions and environmental conditions:
Description of the overall test conditions during the measurements

Microphone positions:
Description of the heights and positions of the microphones and description of Reference Measurement Point

Subjective remarks:
A subjective description of the total sound picture of the public address system, i.e. a subjective system sound check made by the person(s) doing the measurements.

Measurement results are shown in Table 9.1.1.

Table 9.1.1. Measurement results.

DESCRIPTION OF THE MEASUREMENT POINTS			
Each measurement point with heights of the microphones is given in Annex 1. The reference measurement point (RMP) is emphasised.			
MEASUREMENT RESULTS	**Value**	**Unit**	***ANNEX***
Background SPL with the sound system OFF (in reference measurement point, RMP)	##	dBA/dBC	*2*
Background SPL with the sound system ON (in reference measurement point, RMP)	##	dBA/dBC	
Feedback limited Sound Pressure Level (defined to be 6dB below the measured instability level)	##	dBC	*3*
Sound Pressure Level Coverage (Sound Pressure Levels (SPL) for each MP, see Annex 3)	$\overline{SPL}$ = ## σ = #	dBC dB	*4*
Acoustical Frequency Response (Acoustical Frequency Response for each MP, see Annex 5)	$\overline{FR} = f_1 - f_2$ A = #	Hz dB	*5*
Maximum Sound Pressure Level (Maximum Sound Pressure Level for each MP, see Annex 6)	SPL_{Max} = ##	dBC	*6*
Speech Intelligibility (SI for each measurement point, see Annex 7)	*STI = 0.##*		*7*

9.2 Example of Technical Specification

The technical specification is restricted to selected parameters, which can be used to evaluate a sound system's performance. The requirement stated applies for the sound system after final installation and adjustments.

For a given area, defined as the Area of Coverage (AOC), the public address system shall meet the requirements given in Table 9.2.1. AOC may be divided into a number of coverage areas.

The requirements stated shall be fulfilled in a sufficient number of representative measurement points within AOC. One of the measurement points shall be defined as the Reference Measurement Point (RMP) which shall be placed in the rear half and centrally situated in AOC, but not on any lines of symmetry.

Table 9.2.1. Technical Specifications.

Parameter	Symbol	Require-ments	Unit
Speech Intelligibility	STI	≥ 0.60	–
Maximum Sound Pressure Level	$L_{C,Max}$	≥ 80	dBC
Sound Pressure Level Coverage	ΔL_{Eq}	± 5	dB
Acoustical Frequency Response • Lower cut-off frequency • Upper cut-off frequency • Tolerance	AFR f_1 f_2 A	 100 8000 3	 Hz Hz dB
Feedback limited Sound Pressure Level	FLSPL	≥ 85	dBC
Background Noise level with sound system ON		< 25	dBA/dBC
Degree of fulfilment (% of Area of Coverage)		> 85	%
Number of Measurement Points	MP	10	–

Speech Intelligibility

The speech intelligibility shall be given as the Speech Transmission Index (STI).

STI shall be measured in all defined measurement points without audience and shall be corrected for the influence of the estimated normal background sound pressure level equal to NC30 (Noise Criteria Curve 30). The test signal level in RMP shall be set to 73dBA.

Maximum Sound Pressure Level

The requirements shall be fulfilled within a frequency range between 100–12.5kHz. The minimum sound pressure level shall be measured in all defined measurement points, and the result shall be given as a logarithmically averaged value.

Sound Pressure Level Coverage

The requirements shall be fulfilled within a frequency range between 100–12.5kHz. The sound pressure level coverage shall be measured in all defined measurement points, and the result shall be given as a logarithmically averaged value together with the standard deviation.

Acoustical Frequency Response

The acoustical frequency response shall be measured in all defined measurement points with a Signal to Noise ratio of minimum 10dB.

The acoustical frequency response $f_2 - f_1$ for the PA-system shall be measured in accordance with the given tolerance, as shown in Figure 9.2.1, where the allowed area is shaded. Deviation from the allowed area can be tolerated if the deviation is within 1/3-octave.

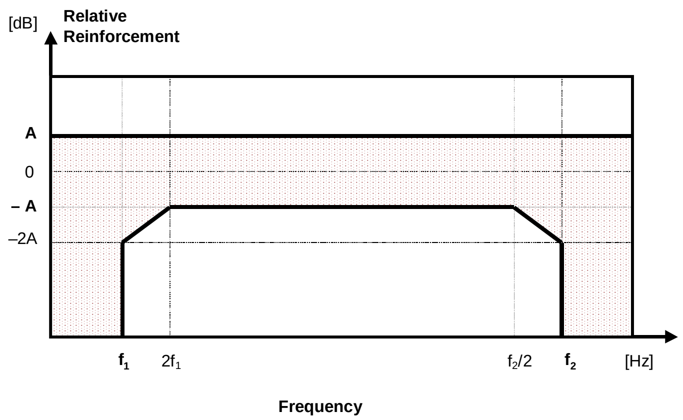


Figure 9.2.1. Specification of the acoustical frequency response measured within the Area of Coverage (AOC).

Feedback limited Sound Pressure Level

The feedback limited sound pressure level shall be measured in RMP. The system microphone most sensitive to feedback shall be used during the measurements.

Background Noise level with sound system ON

The background noise level shall be measured in RMP. The background noise level includes set noise from the loudspeakers and from all the equipment enclosed in the sound system.

Measurement Points

Total number of measurement points: 15.

Control Measurements

Control measurements of the public address system after final installation and adjustments shall be performed in accordance with NORDTEST Method NT ACOU 108.

9.3 Correction of STI for the influence of background noise

This procedure describes a method of correcting measured STI values due to the influence of expected or simulated noise level differing from the noise level contained in the original measurements.

The index STI is calculated from a matrix of Modulation Transfer Functions (MTF). A full MTF analysis provides seven octave band specific MTFs (centre frequencies from 125Hz to 8kHz), each MTF consisting of 14 *m* values (for modulation frequencies of 0.63Hz up to 12.5Hz in 1/3 octave intervals).

The correction of STI for the influence of background noise contains 9 steps, and can easily be implemented in a spreadsheet. If the octave band specific Modulation Transfer Index (MTI_k) is available from the STI measurement, it may be used in the succeeding calculations instead of the full MTF matrix. Steps 1 and 2 may then be omitted.

Input parameters

- The full 14 x 7 Modulation Transfer Function (MTF) or the 1 x 7 Modulation Transfer Index matrix (MTI).
- Octave band specific test signal level (S_k) in dBC or dB (Flat)
- Octave band specific expected (or simulated) noise level (N''_k) in dBC or dB (Flat) as for S_k. 14 modulation frequencies and 7 octave band centre frequencies as stated in Table 9.3.1.

1. **Transformation to apparent SN-ratio (SN’)**
   Each of the 98 m values in the MTF matrix from the STI measurement is converted into a corresponding apparent signal-to-noise ratio (SN’), as if the *m* values ($0 < m < 1$) resulted from interfering noise only.

   $$SN' = 10 \cdot \log\left(\frac{m}{1-m}\right)$$

2. **Limiting SN’ to a 30dB range**
   Since (theoretically) the apparent signal-to-noise ratio can take all values between $-\infty$ and $+\infty$, the SN’ is truncated when exceeding the range of ±15dB. Thus, if SN’ > 15dB, the signal-to-noise ratio is defined as SN’ = 15dB. Similarly, if SN’ < –15dB it is defined as SN’ = –15dB.

3. **Octave band specific mean SN’**
   All 14 values of SN’ derived from one octave band specific MTF, are arithmetically averaged. This results in the octave band specific apparent signal-to-noise ratio (SN'_k), the index k referring to the seven octave bands considered.

   $$SN'_k = \frac{1}{14}\sum_{f=0.63Hz}^{f=12.5Hz} SN'_{f,k}$$

   Alternative
   The octave band-specific Modulation Transmission Index (MTI_k) is calculated from the full MTI matrix. Thus, if the MTI_k for each octave band is available from the STI measurement, these can be used in calculating the SN’ instead of the full MTF matrix (omitting steps 1 and 2).

   $SN'_k = 30\ \ MTI_k - 15$

Table 9.3.1. Modulation frequencies and octave band centre frequencies.

Modulation frequencies, f [Hz]													
0.63	0.8	1.0	1.25	1.6	2.0	2.5	3.15	4.0	5.0	6.3	8.0	10	12.5
Centre frequencies, k [Hz]													
125		250		500		1000		2000		4000		8000	

4. **Octave band specific apparent noise level (N'_k)**
For each of the seven octave bands, the apparent noise level (N'_k) is found from the difference between the test signal level (S_k) and the apparent signal-to-noise ratio (SN'_k).

$N'_k = S_k - SN'_k$

5. **Octave band specific total noise level (N_k)**
For each of the seven octave bands, the total noise level (N_k) is found from the energy sum of the apparent noise level (N'_k) and the expected (or simulated) noise level (N''_k).

$$N_k = 10 \cdot \log\left(10^{\frac{N'_k}{10}} + 10^{\frac{N''_k}{10}}\right)$$

6. **Octave band-specific total SN-ratio (SN_k)**
For each of the seven octave bands, the total signal-to-noise ratio (SN_k) is found from the difference between the test signal level (S_k) and the total noise level (N_k).

$SN_k = S_k - N_k$

7. **Overall weighted total SN-ratio ($\overline{SN}$)**
The seven values of SN_k are averaged, taking into account octave band specific weighting factors w_k, where w_k = 0.13 – 0.14 – 0.11 – 0.12 – 0.19 – 0.17 – 0.14

$$\overline{SN} = \sum_{k=125Hz}^{8000Hz} w_k \cdot SN_k$$

8. **Limiting $\overline{SN}$ to a 30dB-range**
Before converting the overall weighted total SN-ratio ($\overline{SN}$) into the index STI, truncation to the ±15dB range as described under step 2 has to be carried out.

9. **Conversion to noise-corrected STI**
The index STI corrected for the influence of expected (or simulated) noise is found by

$$STI_{Corr} = \frac{\overline{SN} + 15}{30}$$

9.4 Test CD Contents

Table 9.4.1 gives an example of contents of a test CD for use with this measurement procedure. In addition there is an Excel spreadsheet for calculation of the corrected STI due to background sound pressure level.

Table 9.4.1. Test CD contents.

TRACK NUMBER	TRACK TITLE	DESCRIPTION	REFERENCE (Source)
1	Pink Noise (–30 dB)	BW = 20 Hz – 20 kHz; Crest-factor = 4	Cool Edit Pro
2	Pink Noise (–28 dB)	BW = 20 Hz – 20 kHz; Crest-factor = 4	Cool Edit Pro
3	Pink Noise (–26 dB)	BW = 20 Hz – 20 kHz; Crest-factor = 4	Cool Edit Pro
4	Pink Noise (–24 dB)	BW = 20 Hz – 20 kHz; Crest-factor = 4	Cool Edit Pro
5	Pink Noise (–22 dB)	BW = 20 Hz – 20 kHz; Crest-factor = 4	Cool Edit Pro
6	Pink Noise (–20 dB)	BW = 20 Hz – 20 kHz; Crest-factor = 4	Cool Edit Pro
7	Pink Noise (–18 dB)	BW = 20 Hz – 20 kHz; Crest-factor = 4	Cool Edit Pro
8	Pink Noise (–16 dB)	BW = 20 Hz – 20 kHz; Crest-factor = 4	Cool Edit Pro
9	Pink Noise (–14 dB)	BW = 20 Hz – 20 kHz; Crest-factor = 4	Cool Edit Pro
10	Pink Noise (–12 dB)	BW = 20 Hz – 20 kHz; Crest-factor = 4	Cool Edit Pro
11	Pink Noise (–10 dB)	BW = 20 Hz – 20 kHz; Crest-factor = 4	Cool Edit Pro
12	Pink Noise (–8 dB)	BW = 20 Hz – 20 kHz; Crest-factor = 4	Cool Edit Pro
13	Pink Noise (–6 dB)	BW = 20 Hz – 20 kHz; Crest-factor = 4	Cool Edit Pro
14	Pink Noise (–4 dB)	BW = 20 Hz – 20 kHz; Crest-factor = 4	Cool Edit Pro
15	Pink Noise (–2 dB)	BW = 20 Hz – 20 kHz; Crest-factor = 4	Cool Edit Pro
16	Pink Noise (+0 dB)	BW = 20 Hz – 20 kHz; Crest-factor = 4	Cool Edit Pro
17	Pink Noise	BW = 20 Hz – 20 kHz; Crest-factor = 6	Cool Edit Pro
18	Pink Noise	BW = 20 Hz – 20 kHz; Crest-factor = 8	Cool Edit Pro
19	Pink Noise	BW = 20 Hz – 20 kHz; Crest-factor = 10	Cool Edit Pro
20	Shaped Pink Noise	BW = EIS RS-426A Standard Crest-factor = 2 (6dB)	Cool Edit Pro
21	Shaped Pink Noise	BW = 200 Hz – 8 kHz; Crest-factor = 10	Cool Edit Pro
22	White Noise	BW = 20 Hz – 20 kHz; Crest-factor = 4	Cool Edit Pro
23	Brown Noise	BW = 20 Hz – 20 kHz; Crest-factor = 4	Cool Edit Pro
24	Impulse	1 s between impulses; (Adjusting delays)	Cool Edit Pro
25	Sine Sweep	32 Hz octave band	
26	Sine Sweep	63 Hz octave band	
27	Sine Sweep	125 Hz octave band	
28	Sine Sweep	250 Hz octave band	
29	Sine Sweep	500 Hz octave band	
30	Sine Sweep	1k Hz octave band	
31	Sine Sweep	2k Hz octave band	
32	Sine Sweep	4k Hz octave band	
33	Sine Sweep	8k Hz octave band	
34	Sine Sweep	16k Hz octave band	
35	Sine Signal	f = 315 Hz	Cool Edit Pro
36	Sine Signal	f = 1000 Hz	Cool Edit Pro
37	RaSTI Signal	+ 0 dB	B&K
38	RaSTI Signal	+ 10 dB	B&K
39	Danish Male Speech	30 seconds	DELTA CD
40	Danish Female Speech	30 seconds	DELTA CD
41	Norwegian Male Speech	30 seconds	
42	Norwegian Female Speech	30 seconds	
43	Swedish Male Speech	30 seconds	
44	Swedish Female Speech	30 seconds	
45	Music – Rock		High Fidelity CD
46	Music – Rhythm & Blues		High Fidelity CD
47	Music – Classic		High Fidelity CD
48	Music – Techno		High Fidelity CD
49	Music – Folk		High Fidelity CD
50	Music – Country & Western		High Fidelity CD

Spreadsheet

TRACK NUMBER	TRACK TITLE	DESCRIPTION	REFERENCE (Source)
–	Excel Spreadsheet	Correction of STI for the influence of background noise	ICG

ANNEX A (OTHER REFERENCES)

References that may contain useful information (manuals, text books etc.) for persons performing the verification measurements are listed in Annex A. These references do not contain requirements that have to be fulfilled whilst using the measurement procedure presented in this Nordtets procedure.

AES2-1984 (ANSI S4.26-1984)

AES Recommended Practice Specification of Loudspeaker Components Used in Professional Audio and Public Address systems.

EN 60268-5:1998

Sound system equipment – Part 5: Loudspeakers.

EN 61329:1996

Sound system equipment – Methods of measuring and specifying the performance of sounders (electroacoustic transducers for tone production).

ISO 2969:1987

Cinematography – B-chain electroacoustic response of motion-picture control rooms and indoor theatres – Specifications and measurements.

ISO 3382:1997

Acoustics – Measurement of the reverberation time of rooms with reference to other acoustical parameters.