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Standard Practice for Measurement of Sound Pressure Level Differences and Decay Curves Using the Impulse Response Method with Swept Sinusoidal Signals[1]

This standard is issued under the fixed designation E3359; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

This practice describes the method of using sweep signals to measure impulse responses, and the subsequent evaluation of decay rates or sound pressure level differences. The signal generation and post-processing steps are clearly defined to ensure consistent results across different users of the method. This practice can be referenced in standard methods, in which decay rates or sound pressure level differences are measured, to replace the conventional random noise method.

1. Scope

1.1 This practice covers the impulse response measurement method using sweep signals, and its use to determine two important room-acoustical quantities: the difference in sound pressure levels between two positions, as used for example in standards determining transmission loss; and decay curves, as used in standards determining the decay rate or reverberation time.

1.2 The practice shall be used in conjunction with test methods that use one or both of the quantities described in 1.1.

1.3 *Units*—The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C634 Terminology Relating to Building and Environmental Acoustics

E2235 Test Method for Determination of Decay Rates for Use in Sound Insulation Test Methods

E3091 Specification for Systems to Measure Sound Levels

2.2 *Other Standards:*

ASA/ANSI S1.11-2014/Part 1/IEC 61260-1:2014 Electroacoustics — Octave-band and fractional-octave-band filters — Part 1: Specifications[3]

IEC 60268-5:2003+A1:2007 Sound system equipment — Part 5: Loudspeakers[4]

ISO 18233:2006 Acoustics — Application of new measurement methods in building and room acoustics[5]

3. Terminology

3.1 Terms used in this standard are defined either in Terminology C634 or within this standard. The definition of terms explicitly given within this standard take precedence over definitions given in Terminology C634. The definitions within the terminology section of Terminology C634 and this standard

[1] This practice is under the jurisdiction of ASTM Committee E33 on Building and Environmental Acoustics and is the direct responsibility of Subcommittee E33.05 on Research.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[4] Available from International Electrotechnical Commission (IEC), 3, rue de Varembé, 1st floor, P.O. Box 131, CH-1211, Geneva 20, Switzerland, https://www.iec.ch.

[5] Available from International Organization for Standardization (ISO), ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, https://www.iso.org.

take precedence over any other definitions found in any other documents, including other documents that are referenced in this standard.

3.2 *Definitions*—The following terms used in this practice have specific meaning that are defined in Terminology C634: background noise, decay rate, reverberation time, sound attenuation, sound pressure level.

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 The following terms are either not in Terminology C634 or have definitions in this document different from those stated in the terminology section of Terminology C634.

3.3.2 *backward integration, n*—method of obtaining the decay curve from an impulse response, achieved by reversing the squared impulse response in time before integration, and subsequently reversing the integrated result in time again.

3.3.3 *decay curve, n*—decay of sound pressure level over time from steady-state after a sound source has been switched off.

3.3.4 *fractional octave band, n*—band of frequencies encompassing an entire octave or fractions of an octave (for example, one-third of an octave).

3.3.5 *impulse response, h(t), n*—response of a system under test after excitation with a Dirac delta impulse.

3.3.6 *intersection time, t_i[T] (s), n*—time instance in seconds in an impulse response when the idealized straight-line sound pressure level decay intersects with the constant background noise level.

3.3.7 *level difference, LD [dimensionless] (dB), n*—difference in sound pressure level between the sensors at two different receiver locations.

3.3.8 *playback device, n*—device that uses a sweep signal stored as digital data to create a voltage signal, which is fed to the combination of power amplifier and excitation device (typically a loudspeaker).

3.3.9 *recording device, n*—device that receives a voltage signal from the combination of pre-amplifier and sensor (typically a microphone) and converts the voltage signal into digital data, which is typically stored before further processing.

3.3.10 *stop margin, [T] (s), n*—duration of zero-padding, in seconds, added to the end of a sweep signal to continue recording the response of the system under test after the excitation has stopped.

3.3.11 *sweep rate, [T^{-1}] (1/s), n*—rate of change of instantaneous frequency in a sweep signal.

3.3.12 *sweep signal, n*—sinusoidal signal with time-varying instantaneous frequency, typically from low to high frequencies.

4. Summary of Practice

4.1 A sinusoidal sweep signal covering the frequency range of interest is played through a loudspeaker and one or several microphones are used to record the response of the system under test to the sweep signal. The impulse response (IR) of the system under test is obtained by applying a compensation filter to the recorded response. From the measured IR, the sound pressure level difference (LD) between two positions or the decay curve can be determined through integration over time.

5. Significance and Use

5.1 ASTM standard test methods that involve sound attenuation and those test methods that involve absorption or decay rates use a noise signal to determine these quantities. The IR method using a sweep signal given in this standard practice can be referenced by these other standards to provide an alternative measurement technique. This alternative technique has the advantage of providing more reliable results in a shorter period of time.

5.2 The results obtained with the noise and IR method are considered identical to within the typical measurement uncertainty for the noise method under repeatability conditions. A mandatory validation procedure is given in this practice to ensure a correct implementation of the IR method when developing software or hardware according to the requirements in this standard.

5.3 To avoid ambiguity in the implementation of the IR method and to ensure consistent results across different users, this practice prescribes the values of methods and parameters to be used in the signal generation and post-processing. This is in contrast to similar standards describing this method, such as ISO 18233, which provide less guidance.

6. Superseding Requirements from Referencing Standards

6.1 Unless specified otherwise in the referencing standard, all of the measurement or instrumentation requirements in this standard shall be satisfied.

7. Sound Source Requirements

7.1 Sound sources shall be loudspeaker systems driven by power amplifiers.

7.2 The combination of sound source and power amplifier shall be designed to handle the output levels required for the specific measurement to avoid excessively exciting loudspeaker non-linearities. The total harmonic distortion (THD) of the combination of power amplifier and loudspeaker at the output power level used in the measurements shall not exceed 10% in the frequency range of interest.

NOTE 1—THD can be measured according to IEC 60268-5:2003+A1:2007.

7.3 If the sound for different frequency bands is radiated from separate loudspeakers (for example, subwoofer/satellite combination), the loudspeakers shall be as close in space to each other as possible.

8. Restrictions for Sound Sources and Receivers

8.1 Only stationary sound sources and receivers shall be used.

8.2 Only a single sound source shall be active at the same time in each frequency band.

NOTE 2—A single sound source in this context can consist of different loudspeakers for different frequency bands that comply with the requirement in 7.3.