

ANSI/CTA Standard

Standard Method of Measurement for In-Home Loudspeakers

ANSI/CTA-2034-A

(Formerly ANSI/CEA-2034-A)

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(Formulated under the cognizance of the CTA **R3 Audio Systems Committee.**)

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FOREWORD

This standard describes an improved method for measuring and reporting the performance of a loudspeaker in a manner that should help consumers better understand the performance of the loudspeaker and convey a reasonably good representation of how it may sound in a room based on its off-axis response and how this response affects the consumer's experience.

Unlike previously published standards, this standard describes how to measure and report the directivity of a loudspeaker, whether it stands by itself or is mounted in or on a wall or ceiling. It also describes how to use this directivity data to estimate the in-room frequency response that more recent research has shown correlates well to subjective listening preferences of consumers.

It describes how to measure and report the maximum on-axis usable sound pressure level of a loudspeaker, and how to measure and report the impedance of a loudspeaker. It also describes how to calculate and report the size of the power amplifier needed for the consumer to get the desired SPL from the loudspeaker.

Finally, it includes a number of informational annexes to help readers gain a more thorough understanding of techniques for acquiring loudspeaker data in both anechoic and non-anechoic environments, as well as methods for using this acquired data to predict loudspeaker performance.

When used properly this standard should assist manufacturers in accurately measuring the capabilities of a full-range loudspeaker system and specifying them to consumers. Using this in conjunction with ANSI/CEA-2010-B – Standard Method of Measurement for Subwoofers, the ANSI/CEA-2034-A full-range loudspeaker ratings should make it easier for the consumer to select, purchase, and enjoy a subwoofer that will complement their main full-range loudspeaker system.

This standard was developed by the Consumer Electronics Association's Audio Systems Committee (CEA R3 Committee).

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Standard Method of Measurement for In-Home Loudspeakers

1 Scope

This standard describes how to determine the frequency response, directivity and maximum output capability of a residential loudspeaker. It is intended to determine the audio performance of a loudspeaker, not the loudspeaker's ability to survive a given input signal.

This standard applies only to loudspeaker systems, and not to raw transducers.

2 Revision History

Added Table of Figures and Tables
 Added items to Symbols & Abbreviations
 Added section for Compliance Notation
 Updated General Test Setup & Conditions
 Added section for Frequency Response and Crossover Categories
 Added section for Powered Loudspeaker Rating
 Added column for voltage to the Required Amplifier Power tables
 Added section for Matching a Subwoofer to a Full-Range Loudspeaker System
 Incorporated new additions to Consolidated Reporting Requirements section

3 References

3.1 Normative References

The following standards contain provisions that, through reference in this text, constitute normative provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed here.

3.1.1 Normative Reference List

IEC Publication 225, *Octave, Half-Octave, and Third-Octave Band Filters Intended for the Analysis of Sound and Vibration* (1966)

3.1.2 Normative Reference Acquisition

IEC Standards:

International Electrotechnical Commission, IEC Central Office, 3, rue de Varembe
 P.O. Box 131, CH - 1211 Geneva 20 – Switzerland; Phone +41 22 919 02 11;
 Fax +41 22 919 03 00; Internet <http://www.iec.ch>

3.2 Informative References

The following standards contain provisions that, through reference in this text, constitute informative provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed here.

3.2.1 Informative Reference List

AES Convention Paper 5638, *Characterizing the Amplitude Response of Loudspeaker Systems*, presented at 113th Audio Engineering Society Convention October 2002, Allan Devantier

CEA-490-A R-2008, *Test Methods of Measurement for Audio Amplifiers*

IEC 60263 ed3.0 (1982-01), *Scales and Sizes for Plotting Frequency Characteristics and Polar Diagrams*

IEC 60268-1 ed2.0 (1985-01), *Sound system equipment. Part 1: General*

IEC 60268-1-am1 ed2.0 (1988-01), *Amendment 1 - Sound system equipment. Part 1: General*

IEC 60268-1-am2 ed2.0 (1988-01), *Amendment 2 - Sound system equipment. Part 1: General*

IEC 60268-2 ed2.0 (1987-06), *Sound system equipment. Part 2: Explanation of general terms and calculation methods*

IEC 60268-2-am1 ed2.0 (1991-05), *Amendment 1 - Sound system equipment. Part 2: Explanation of general terms and calculation methods*

IEC 60268-5 ed3.1 Consol. with am1 (2007-09), *Sound system equipment - Part 5: Loudspeakers*

NIST Special Publications 811 2008 Edition, Guide for the use of the International System of Units universally abbreviated SI (from the French *Le Systeme International d'Unites*)

3.2.2 Informative Reference Acquisition

Audio Engineering Society (AES): <http://www.aes.org/e-lib/browse.cfm?elib=11234>

CEA Standards:

Techstreet, 3916 Ranchero Drive, Ann Arbor, MI, USA 48108; Phone 800-699-9277; Fax 734-780-2046; Internet <http://www.techstreet.com>; Email techstreet.service@thomsonreuters.com

IEC Standards:

International Electrotechnical Commission, IEC Central Office, 3, rue de Varembe
P.O. Box 131, CH - 1211 Geneva 20 – Switzerland; Phone +41 22 919 02 11;
Fax +41 22 919 03 00; Internet <http://www.iec.ch>

NIST Standards:

National Institute of Standards and Technology, 100 Bureau Drive, Gaithersburg, MD 20899-8930; Phone 301 975-6478; Internet <http://www.nist.gov/publication-portal.cfm> Email inquiries@nist.gov

3.3 Definitions

Continuous	The root mean squared value of a signal over a one second interval
Normalized Transfer Function	A transfer function measurement that has been referenced to (divided by) another transfer function measurement
Peak	The instantaneous maximum value, either positive or negative, of a signal
Point of Rotation (POR)	The point on the front baffle of the loudspeaker that intersects the reference axis

3.4 Symbols and Abbreviations

CF	Crest Factor
dB	decibel
DUT	Device Under Test
ERDI	Early Reflections Directivity Index
FFT	Fast Fourier Transform
HD+N	Harmonic Distortion + Noise
Hz	hertz
kHz	kilohertz
LFCS	Low Frequency Calibration Source
m	meter
MIV	Maximum Input Voltage
Pa	pascal
PIR	Predicted In-Room Amplitude Response
POR	Point of Rotation
RCF	Room Correction Factor
rms	Root Mean Square
SPDI	Sound Power Directivity Index
SPL	Sound Pressure Level
	<i>Note:</i> Throughout this document all references to “dB SPL” refer to sound pressure level referenced to 20 μ Pa.
SPL _{MUCO}	Sound Pressure Level Maximum Usable Continuous Output
THD+N	Total Harmonic Distortion + Noise
V	volt

3.5 Compliance Notation

As used in this standard “shall” and “must” denote mandatory provisions of the standard. “Should” denotes a provision that is recommended but not mandatory. “May” denotes a feature whose presence does not preclude compliance, and implementation of which is optional. “Optional” denotes items that may or may not be present in a compliant device.

4 Test Setup and Conditions

CAUTION — WEAR EAR PROTECTION! High sound levels can cause hearing damage with prolonged exposure. The operator is advised to wear appropriate protection such as ear plugs, preferably balanced attenuation devices which will still permit the operator to listen critically for distortion or other signs of distress in the device under test.

4.1 General Test Setup and Conditions

All testing shall be conducted in an anechoic chamber or equivalent environment.

During testing the DUT shall be operated as per manufacturer’s instructions. Complete systems shall be tested intact.

Testing shall be conducted at an ambient temperature of $22\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$ ($71.6\text{ }^{\circ}\text{F} \pm 9\text{ }^{\circ}\text{F}$) and relative humidity of 30 % to 80 %. If the conditions are different, they shall be noted at the time of the test. Both of these items shall be recorded at the time of the tests. The ambient atmospheric pressure (in Pascals) shall also be recorded.

For powered loudspeakers the mains voltage used to power the DUT shall be within 1 % of the rated value specified for use by the DUT (i.e. for a DUT that requires 120 V, the mains voltage used shall be between 118.8 V and 121.2 V).

All test equipment used during the tests shall operate within its linear operating range. For example, amplifiers shall be sufficiently powerful that they never clip or distort during any of the tests.

All test equipment used during the tests shall operate within its linear operating range. For example, amplifiers shall be sufficiently powerful that they rarely clip or distort during any of the tests.

If a crossover or filter network is specified by the manufacturer, it shall be installed according to the manufacturer's instructions during all tests, including frequency response and maximum SPL tests.

If a small loudspeaker (satellite, bookshelf, etc.) without a manufacturer-specified filter network is being tested then a two pole Butterworth 80 Hz high pass filter network shall be used.

All test equipment shall be properly calibrated, and its calibration shall be documented.

The frequency response measurements shall be a transfer function type measurement employing a dual channel FFT or similar measurement apparatus.

The measurement system shall have an amplitude resolution of at least 0.1 dB.

See Appendix E for a list of all equipment needed for perform the tests in this document.

4.2 Verification of Frequency Response at DUT Input Terminals

Measure the voltage at the DUT input terminals over the range 20 Hz to 20 kHz and confirm that it is within ± 0.5 dB from the specified voltage. If it deviates more than ± 0.5 dB the appropriate corrective action shall be taken, such as the addition of equalization prior to the input terminals of the DUT.

4.3 Measurement Resolution and Calibration

The measurement resolution shall be no wider than 1/20 octave. The specific bandwidth, resolution and test stimulus used should be documented.

Calibration of the microphone and data acquisition system, and of the post processing of the resulting data, shall be such that the system yields a measured sound level identical to that of a stable pure tone stepped or swept with an rms input voltage of 2.83 V.

5 Directivity Response – Standalone Loudspeakers

The following procedure applies to conventional floor standing loudspeakers, or to small loudspeakers intended to be used on stands, both of which would normally be placed away from the walls. Loudspeakers intended to be installed in walls or ceilings or mounted on walls or ceilings are not covered by this section.

The procedure is described in two parts, one dealing with the acquisition of the raw data and one dealing with the post-processing of this data and its presentation. The description assumes that an anechoic measurement space (chamber or outdoors) is available. This is a requirement for data that are not significantly compromised in terms of frequency resolution or signal-to-noise ratio. It is recognized that such facilities are not available to all users of this document. Appendix A references some methods for acquiring data that may be useful approximations to anechoic data.

The objective of these measurements is to be able to anticipate how a loudspeaker might sound in a normally reflective room. No single curve can sufficiently describe how a loudspeaker might sound in a normally reflective room. To better predict its sound, many measurements shall be made at multiple positions surrounding the loudspeaker. These data shall then be processed to estimate the direct, early-reflected and late-reflected sound in a typical small listening room.

5.1 Data Acquisition

The specific bandwidth, resolution and test stimulus used shall be documented.

Measurement Environment

Measurements should be made in a reflection-free environment – a qualified anechoic chamber or outdoors.

Acknowledging that not everyone has access to such facilities, Appendix A references methods for acquiring data that approximates data acquired in a true anechoic space.

Measurement Apparatus

Amplitude response measurements shall be made at 10° intervals on one horizontal and one vertical orbit around the DUT. The orbits intersect at the reference axis, described below, which defines the zero degree azimuth and elevation angles (*i.e.*, the “on axis” measurement). Make 72 measurements (36 horizontal and 36 vertical). Measurements at 0° and 180° are duplicated, so the data set consists of 70 distinctive amplitude response measurements as illustrated in Figure 1.

The measurements shall be made using a single, stationary microphone. The loudspeaker shall be placed on a rotating table, the front edge of which does not project beyond the front of the loudspeaker baffle. The base of the loudspeaker should be horizontal, as it would be in normal use. However, if this results in the reference axis of the DUT being tilted up or down, the turntable shall be mounted at an angle so that the reference axis of the DUT is horizontal for the purposes of making the measurements. For convenience and measurement consistency, it is useful if the rotating platform can be vertically adjusted to compensate for loudspeakers of different heights. A possible setup is illustrated in Figure 2.

Vertical Axis

Horizontal Axis

Reference Axis

Figure 1: The 70 microphone locations used to acquire the amplitude response data (from Toole, *Sound Reproduction*, Focal Press, 2008)

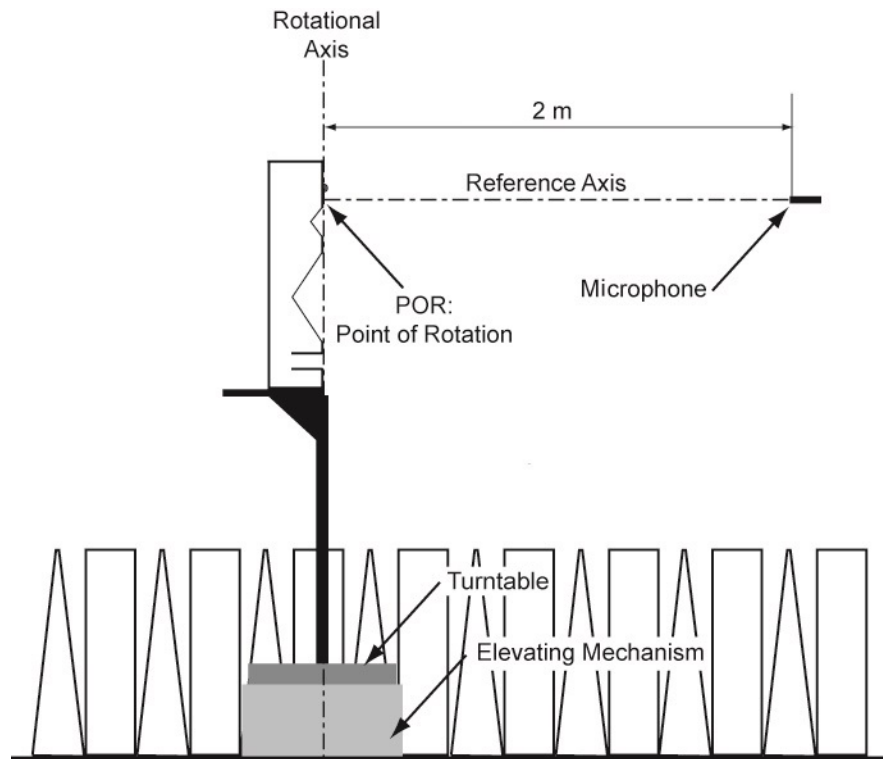


Figure 2: One of several possible physical arrangements within an anechoic chamber that allows rotation and vertical adjustment of the loudspeaker under test. The objective is to minimize acoustical clutter around the loudspeaker and the microphone

The reference axis shall be aimed at the microphone and the DUT rotated in 10° increments to complete measurements on the horizontal orbit. The DUT shall then be placed on its side, and the height of the DUT adjusted so that the reference axis is again aimed at the microphone, and the process shall be repeated. When the DUT is placed on its side to conduct the vertical directivity measurements it shall be rotated about the DUT reference axis. Care must be taken to

ensure that the height of the reference axis never deviates more than 5 cm (≈ 2 inches) between the horizontal and vertical measurements. This is illustrated in Figure 3. With large floor-standing loudspeakers placed on their sides it may be necessary to provide special outriggers to support the off-center mass.

By definition the POR is the point of intersection of the rotational axis of the turntable and the DUT reference axis. The POR should be located on the front baffle of the DUT, and shall not be any farther than 5 cm (≈ 2 inches) from the front baffle.

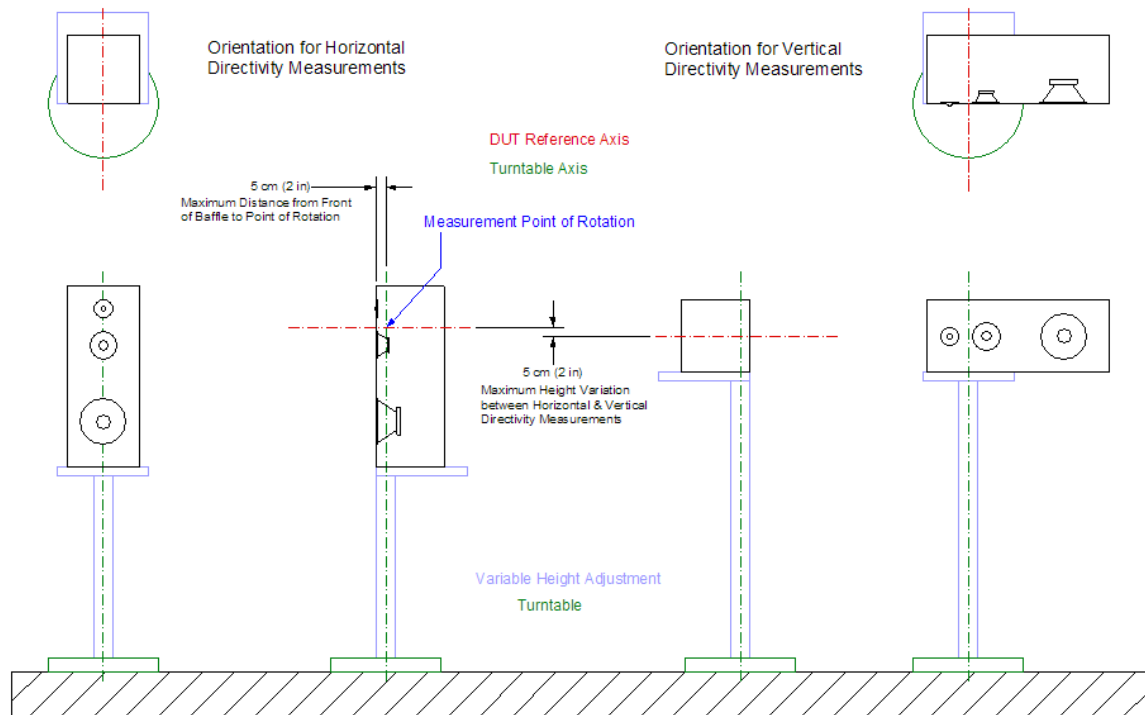


Figure 3: DUT orientation for horizontal & vertical directivity measurements showing the DUT Reference Axis and the Measurement Point of Rotation

The Reference Axis

The reference axis should be specified by the manufacturer. It approximates the direct-sound listening axis for a seated listener in the prime listening location, at a normal listening distance.

Defining the reference axis requires that assumptions be made, and perhaps for this reason manufacturers rarely specify it. Because the reference axis is needed to perform the tests described in this standard the following method shall be used to define it whenever the manufacturer has not specified it.

The starting point of the reference axis shall be either the center of the high-frequency driver (normally a tweeter) or a point midway between the high-frequency and midrange drivers. The specific point that is used shall be specified in the final report. The orientation of the reference axis depends on the design of the loudspeaker. For most conventional loudspeakers with a front baffle, the reference axis shall be perpendicular to the front baffle. If the loudspeaker design is such that there is not a conventional front baffle, the reference axis shall be in the direction of the intended forward radiation of sound from the loudspeaker.

Measurement Distance

Ideally measurements should be made in the far field of the DUT and, for reasons of standardization the sensitivity should be referenced to a distance of 1 m. The far field for large diaphragm loudspeakers can be several meters away and listeners may sit in the near field of these loudspeakers.

For typical loudspeakers the far field begins about 2 m from the DUT, and the typical listening distance is closer to 3 m from the DUT. By taking many measurements and displaying the results as spatial averages useful data can be gathered within the near field. Therefore measurements shall be made at 2 m from the DUT and the data shall be reported as the equivalent sound pressure level (SPL) at 1 m, which is a convenient 6 dB higher than the SPL at 2 m.

Input Signal

When conducting measurements on passive loudspeakers using the procedure described in this standard an rms input voltage of 2.83 V shall be used.

Self-powered loudspeakers or those with a line level active electronic input to the DUT shall be tested with an input voltage that produces 79 dB SPL averaged over the frequency range 500 Hz to 2 kHz at 2 m from the DUT in an anechoic environment.

The spectrum of the input signal shall span a bandwidth of at least 20 Hz to 20 kHz.

The level of the input signal that is fed into the loudspeaker under test shall be documented and shall be within the linear operating range of the loudspeaker. During the frequency response test the signal-to-noise ratio shall be measured and shall always be at least 40 dB.

5.2 Post Processing of Data

The following composite response curves shall be calculated. In each instance a power average of the specified magnitude responses shall be calculated.

Listening Window

The listening window curve is a spatial average of the nine magnitude responses in the $\pm 10^\circ$ vertical and $\pm 30^\circ$ horizontal angular range.

- 0°
- $\pm 10^\circ$ vertical
- $\pm 10^\circ, \pm 20^\circ, \pm 30^\circ$ horizontal

Early Reflections

The early reflections curve is an estimate of all single-bounce, first-reflections, in a typical listening room.

- Floor Bounce: $20^\circ, 30^\circ, 40^\circ$ down
- Ceiling Bounce: $40^\circ, 50^\circ, 60^\circ$ up
- Front Wall Bounce: $0^\circ, \pm 10^\circ, \pm 20^\circ, \pm 30^\circ$ horizontal
- Side Wall Bounces: $\pm 40^\circ, \pm 50^\circ, \pm 60^\circ, \pm 70^\circ, \pm 80^\circ$ horizontal
- Rear Wall Bounces: $180^\circ, \pm 90^\circ$ horizontal

Vertical Reflections

The "floor reflection" is defined as the spatial average of three measurements at 30 degrees below the main-axis $\pm 10^\circ$. The "ceiling reflection" is defined as the spatial average of three measurements at 50° above the main-axis $\pm 10^\circ$.

- Floor Reflection: $-20^\circ, -30^\circ, -40^\circ$ vertical

- Ceiling Reflection: + 40°, + 50°, + 60° vertical

Horizontal Reflections

- Front: 0°, ± 10°, ± 20°, ± 30° horizontal
- Side: ± 40°, ± 50°, ± 60°, ± 70°, ± 80° horizontal
- Rear: ± 90°, ± 100°, ± 110°, ± 120°, ± 130°, ± 140°, ± 150°, ± 160°, ± 170°, 180° horizontal, (i.e.: the horizontal part of the rear hemisphere).

Sound Power

The sound power is the weighted rms average of all 70 measurements, with individual measurements weighted according to the portion of the spherical surface that they represent. Calculation of the sound power curve begins with a conversion from SPL to pressure, a scalar magnitude. The individual measures of sound pressure are then weighted according to the values shown in Appendix C and an energy average (rms) is calculated using the weighted values. The final average is converted to SPL.

Sound Power Directivity Index (SPDI)

For the purposes of this standard the Sound Power Directivity Index is defined as the difference between the listening window curve and the sound power curve. An SPDI of 0 dB indicates omnidirectional radiation. The larger the SPDI, the more directional the loudspeaker is in the direction of the reference axis.

Early Reflections Directivity Index (ERDI)

The Early Reflections Directivity Index is defined as the difference between the listening window curve and the early reflections curve.

5.3 Data Presentation

Data shall be referenced to an rms input voltage of 2.83 V at a distance of 1 m.

Data shall be reported in graphical form as illustrated in Figure 4. This chart follows the guidance of IEC 60263, which stipulates that the horizontal length for a 10:1 frequency ratio be equal to 50 dB on the vertical scale. For the reported data to be useful it is important that the X-Y proportions and the horizontal and vertical scaling of the graphs be standardized in this manner.

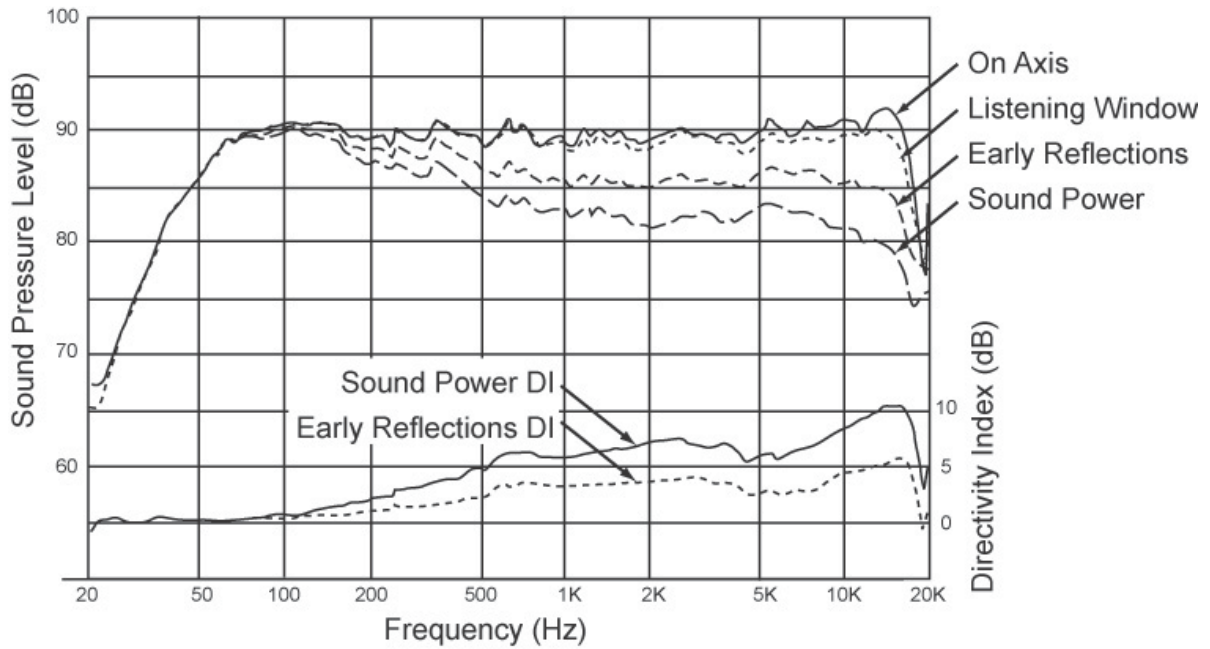


Figure 4: Standard format for reporting data, and sample data

The curves on the graph may be identified by color coding and/or by various dot-dash combinations for black and white displays. If color coding of the curves is used then the colors must be available in any printed or electronic versions made available for public consumption.

6 Directivity Response – In-Wall, In-Ceiling, On-Wall and On-Ceiling Loudspeakers

The device under test shall be tested in an anechoic, or hemi-anechoic, chamber. It shall also be mounted in (for in-wall/in-ceiling DUTs) or on (for on-wall/on-ceiling DUTs), a rigid surface that represents a wall, ceiling or floor to yield a 2π measurement space, or in a baffle. It may be easier to extend the size of the rigid surface if it is laid horizontally on the floor of the test chamber. If the manufacturer specifies a particular rear box design then this rear box shall be installed during testing, otherwise the cavity behind the device under test shall be no larger than 40 liters, which approximates the cavity between the studs in a typical wall. If a baffle is used it must be at least 1.98 m high by 1.98 m wide, and the device under test shall be mounted in the center of the baffle.

The microphone used for taking measurements shall be 2 m from the device under test.

All of the requirements regarding the measurement environment, measurement apparatus, measurement distance and input signal described in Section 5.1 also apply here.

With the device under test mounted as described above, one of the following measurement methods shall be used for collecting data.

6.1 Data Acquisition – Stationary Microphone

Record complete (180°) horizontal and vertical polar measurements at 10° increments. These measurements shall be taken by rotating the turntable and DUT in a 180° rotation to acquire the horizontal data. The DUT is then rotated 90° about its reference axis. Another 180° rotation of the turntable and DUT is made to acquire the vertical data. The measurement microphone remains stationary during this test.

6.2 Data Acquisition – Rotating Microphone

Record the front hemispherical (180°) horizontal and vertical polar measurements at ten degree increments. These measurements shall be taken by moving the measurement microphone from one angular position to the next in sequence around the vertical axis as shown in Figure 1 until the front 180° have been covered. Then by moving the measurement microphone from one angular position to the next in sequence around the horizontal axis as shown in Figure 1 until the front 180° have been covered.

Instead of moving a single microphone it may be preferable to use 37 separate stationary microphones (note that the microphone directly in front of the DUT would be used twice, once for each axis). The DUT remains stationary during this test.

Also, instead of moving the microphone around the horizontal axis it may be preferable to rotate the DUT 90° about its reference axis and repeat the original rotation of the microphone about the vertical axis to obtain the required measurements.

6.3 Data Presentation

Data shall be presented using the method described in Section 5.3.

7 Frequency Response and Crossover Category

The frequency response of a loudspeaker shall be measured in order to determine how low in frequency it may be used. This should be helpful in determining if a particular loudspeaker can be recommended for use with a particular subwoofer system, or vice-versa. This assumes that a similar high frequency limit is known for the subwoofer. Four *Crossover Categories* are introduced to simplify and assist with this matching process.

7.1 Data Acquisition

The loudspeaker (DUT) shall be loaded in a manner similar to that of normal operating conditions.

If there are any adjustable high pass or low pass filters on the DUT the high pass filters shall be set to the highest frequency possible. The low pass filters shall be set to the lowest frequency possible. If the roll-off rate of these filters is adjustable it shall be set to the slowest roll-off rate possible.

A transfer function measurement with a frequency resolution of at least 1/12 octave within the pass band limits of the DUT shall be made. The measurement shall cover the entire operating bandwidth of the DUT.

7.2 Upper Frequency Limit

The level of the transfer function measurement shall be averaged over the frequency range from 100 Hz to 1 kHz. This level shall be the Average Level of the DUT.

The frequency at which the transfer function has a level of no less than the Average Level minus 3 dB shall be the Lower Frequency Limit of the DUT.

7.3 Crossover Category Qualification

The DUT shall be qualified for each of four crossover categories W, X, Y, and Z. The frequency limit for each of these categories is shown in Table 1.

Table 1: Lower frequency limit of Crossover Categories

Crossover Category			
W	X	Y	Z
80 Hz	100 Hz	120 Hz	150 Hz

If the Lower Frequency Limit of the DUT is lower than the frequency of a crossover category it qualifies for that crossover category.

As an example, a DUT with a Lower Frequency Limit of 90 Hz would qualify for crossover categories X, Y, and Z. It would not qualify for crossover category W.

7.4 Crossover Category Data Presentation

The crossover categories for a loudspeaker shall be reported in the following format:

Crossover Categories: W, X, Y, and/or Z