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AES information document for acoustics - Loudspeaker modeling and measurement - Frequency and angular resolution for measuring, presenting, and predicting loudspeaker polar data

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Abstract

This document provides guidelines for measuring, presenting, and predicting polar data from a single acoustic source or from an array of acoustic sources. It describes and quantifies measurement resolution, presentation resolution, prediction techniques, and measurement environments. The information presented here is based on objective measurements and does not take subjective or psychoacoustic criteria into account.

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Foreword

[This foreword is not a part of AES-5id-1997 *AES information document for room acoustics and sound reinforcement systems — Loudspeaker modeling and measurement — Frequency and angular resolution for measuring, presenting, and predicting loudspeaker polar data.]*

This document was prepared by the AESSC SC-04-03 Working Group on Loudspeaker Modeling and Measurement of the SC-04 Subcommittee on Acoustics. The group was established in 1990 under the initial leadership of T. Telesky in response to concerns for standardization in the growing field of acoustical modeling.

At its meeting in the autumn of 1993 under the chairmanship of F. Seidel, SC-04-03 recognized that although acoustical modeling programs had become useful in roughly estimating sound coverage, they are unable, yet, to sufficiently predict nulls and lobes in the direct field of loudspeaker arrays. This is in part due to the coarse measurement resolution used to characterize loudspeakers and loudspeaker arrays. Nulls as severe as 20 dB can be measured in the polar response of simple two-horn arrays that are not predicted by commonly used methods and measurement data. In addition, measured data are often presented in such a coarse resolution that these severe nulls do not appear on polar patterns.

Acoustical modeling of sound in spaces requires knowledge concerning sources, room boundaries, and psychoacoustics. To characterize sound sources and room boundaries two AES working groups, SC-04-03 and SC-04-02, were formed. The required measurement resolution to model the total sound field for a given direct to reverberant sound ratio is not known at this time. The resolution required is likely to be a function of this ratio.

This information document evolved out of the effort of working group SC-04-03 to establish, for the direct field, the relationship between the resolution, of measurement and of data presentation, and the accuracy of presented and predicted polar patterns and frequency responses of loudspeakers, individually and in arrays.

A round robin set of measurements, designated AES-X07 experiment 1.1, was designed and executed to study, among other issues, the relationship between resolution and accuracy. AES project AES-X07 is described in detail in AESSC News in *JAES*, vol. 42, no. 9, p. 707. The results of these measurements were presented and discussed at the 97th AES Convention in San Francisco and reported in AESSC News in *JAES* vol. 43, no. 6, p. 519. This work, supplemented by subsequent analysis and further measurements by Felicity Seidel and Henrik Staffeldt, using facilities provided by Meyer Sound Laboratories, Inc., and by the Department of Acoustics Technology at the Technical University of Denmark, and reported in *JAES*, vol. 44, no. 7/8, has led to the writing of AES-5id-1997.

The application of these data in modeling the total sound field for a given direct to reverberant sound ratio has yet to be investigated and is in the scope of the working group SC-04-01.

A writing group headed by Seidel and Staffeldt prepared this document based on the instructions of the working group.

Mendel Kleiner
Chair, AESSC SC-04 Subcommittee on Acoustics
1996-04-16

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AES information document for acoustics - Loudspeaker modeling and measurement - Frequency and angular resolution for measuring, presenting, and predicting loudspeaker polar data

1 Scope

This document provides guidelines for measuring, presenting, and predicting polar data from a single acoustic source or from an array of acoustic sources. It describes and quantifies possible errors, defined as differences in numeric values, associated with measurement resolution, presentation resolution, prediction techniques and measurement environments.

> NOTE The term “error” is used in its mathematical sense and does not imply incorrect procedures, but only that the results of procedures are always associated with finite accuracies.

The information presented here is based on objective measurements and does not take subjective or psychoacoustic criteria into account. The supporting experiments were conducted in the 1-kHz to 10-kHz frequency range on small devices having commensurate ratios between the critical device or array dimensions and the measurement wavelength. Nevertheless, the results are valid from 100 Hz to 10 kHz because these ratios can also be commensurate below 1 kHz for larger devices and arrays.

Additionally, the supporting experiments were conducted on single devices and two-device arrays. Nevertheless, the results are valid for a single acoustic source and for an array of acoustic sources because the peaks and nulls appearing in the off-axis frequency responses and polar patterns of the single devices and two-device arrays used in these experiments can also be commensurate with those appearing in the frequency responses and polar patterns of arrays consisting of more than two devices. Annex D, citation 3, contains additional information.

These guidelines are not intended to be restrictive but to illuminate possible errors associated with some common practices in loudspeaker modeling and measurement. They are intended to build a common foundation from which reliable data on sound sources can be gathered and compared. The application of these data in modeling the total sound field for a given direct to reverberant sound ratio has yet to be investigated and is not in the scope of this document.

2 Normative references

The following standard contains provisions that, through reference in this text, constitute provisions of this document. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this document are encouraged to investigate the possibility of applying the most recent edition of the indicated standard.

ISO 266, *Acoustics — Preferred frequencies for measurement.* Geneva, Switzerland : International Organization for Standardization, 1975.

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3 Definitions

For the purpose of this standard, the following definitions apply.

3.1
reference point
point positioned with respect to some physical feature of the loudspeaker or loudspeaker system

NOTE The position shall be that specified by the manufacturer.

3.2
reference axis
line that passes through the reference point

NOTE The direction of the reference axis shall be specified by the manufacturer and shall be used as the zero reference axis for frequency response and polar-data measurements.

3.3
point of rotation
point about which the loudspeaker or loudspeaker system is rotated in a set of polar-data measurements

NOTE The point of rotation, which should be the same as the reference point as described in 3.1, shall be specified by the manufacturer.

3.4
acoustic center
center of curvature of the wave fronts generated by a sound-emitting transducer in its far field

NOTE The acoustic center is frequency dependent and does not include the inherent transducer and sound propagation time delays. Therefore, the acoustic center is not the same as the acoustic or time origin. The acoustic center is primarily of interest in connection with the installation and positional alignment of the individual devices in a sound system. See reference 1, annex E.

3.5
acoustic origin
time origin
point specified for a given frequency and transducer orientation, lying on the line defined by the observation point and the point of rotation of the transducer, whose distance r from the observation point is such that the total measured phase delay in the signal path, from the input terminals of the transducer to the observation point, is equal to the distance r divided by the propagation speed of sound

NOTE The time origin, which can lie outside and behind the transducer, is primarily of interest in connection with the installation and positional alignment of the individual devices in a sound system. See reference 1, annex E.

3.6
measuring axis
line joining the microphone to the point of rotation

3.7 Frequency response

3.7.1
magnitude response
generated sound pressure level as a function of frequency, measured under free-field or simulated free-field conditions, with a constant voltage source and at a stated position with respect to the reference axis and point.

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3.7.2
phase response
phase angle of the sound pressure minus the phase angle of the loudspeaker input voltage as a function of frequency, measured under free-field or simulated free-field conditions, with a constant voltage source and at a stated position with respect to the reference axis and point

3.7.3
complex data
data for which each data point is represented by a real and an imaginary part or by a magnitude and a phase value

3.7.4
transfer function
complex ratio between generated sound pressure and loudspeaker input voltage as a function of frequency, measured under free-field or simulated free-field conditions, with a constant voltage source and at a stated position with respect to the reference axis and point

3.8
plane polar data
r.m.s. sound-pressure magnitude, phase, or any quantity related to the direct-sound field from a source as a function of angle (between the measuring axis and the chosen reference axis) and the frequency or frequency band of the radiated sound, measured under free-field or simulated free-field conditions, in a specified plane

3.9
spherical polar data
r.m.s. sound pressure magnitude, phase or any quantity related to the direct-sound field from a source as a function of the spherical coordinates describing the orientation of the measuring axis with respect to the chosen reference axis and the frequency or frequency band of the radiated sound, measured under free-field or simulated free-field conditions, on a sphere centered at the reference point

3.10
complex, plane polar data
complex r.m.s. sound pressure as a function of angle (between the measuring axis and the chosen reference axis) and the frequency of the radiated sound, measured under free-field or simulated free-field conditions, in a specified plane

NOTE The complex r.m.s. sound pressure shall be represented by its magnitude and phase or its real and imaginary parts.

3.11
complex, spherical polar data
complex r.m.s. sound pressure as a function of the spherical coordinates describing the orientation of the measuring axis in relation to the chosen reference axis and the frequency of the radiated sound, measured under free-field or simulated free-field conditions on a sphere centered at the reference point

NOTE The complex r.m.s. sound pressure shall be represented by its magnitude and phase or its real and imaginary parts.

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3.12
beamwidth
angle between two measurement axes located on either side of the reference axis of a single device, in a plane containing this axis, within which the sound pressure level at the measuring distance has decreased 6 dB with respect to the sound pressure on the reference axis for a given frequency or frequency band
[See 5.3]

3.13
frequency resolution
interval equal to 1/*T*, where *T* is the length of the impulse response segment used in a fast Fourier transform (FFT) or the length of the equivalent time window used in time-delay spectrometry (TDS)

NOTE This interval is the true frequency resolution. The question of frequency resolution arises when measuring techniques based on digital signal processing such as the FFT are applied. Displayed frequency resolution is given as the sample rate divided by the FFT size. It is thus possible to have a fine display resolution but a rather coarse true resolution in which case the displayed resolution is a simple interpolation of the true resolution.

3.14
high resolution
frequency resolution finer than 96th octave

3.15
amplitude smoothing
modification of measured quantities by averaging on a mean-square basis over a band of frequencies

NOTE Amplitude smoothing can be done in successive bands by, for example, using third-octave bands per ISO 266 and their center frequencies, or in a continuous or sliding way by using the FFT bin frequencies as center frequencies. A sufficient number of frequency lines need to be present within a given band in order for smoothing to be valid. This modification is often called “frequency smoothing” or “bandwidth smoothing.”

3.16
bandwidth resolution
bandwidth in 1/*n* octaves, where *n* = 1, 2, 3, ..., as it is applied in amplitude smoothing

NOTE It should be stated as relative bandwidth in fractional octaves, for example, third octaves.

3.17
angular resolution in stepped polar-data measurements
applied measurement-angle step size in degrees

NOTE Angular resolution in displayed or stored polar data is the displayed- or stored-angle step size in degrees. The applied measurement-angle step size in degrees shall be less than or equal to the displayed- or stored-angle step size in degrees.

3.18
far field
part of the radiated sound field more distant from the radiator in which the inverse-distance law (that is, sound pressure is inversely proportional to distance) is obeyed, as opposed to the near field, where the angular field distribution is dependent on the distance from the radiator
[see 4.2]

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