An artificial diffuse field for in-situ microphone measurements

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Overview

- **Purpose**
- **Directivity Index**
- **Goal of Alternative Method**
- **Test Setup**
- **Sound Field Verification**
- **Results**
- **Conclusion**

Purpose

To accurately obtain the Directivity Index of a hearing device equipped with a directional microphone - *In-Situ*.

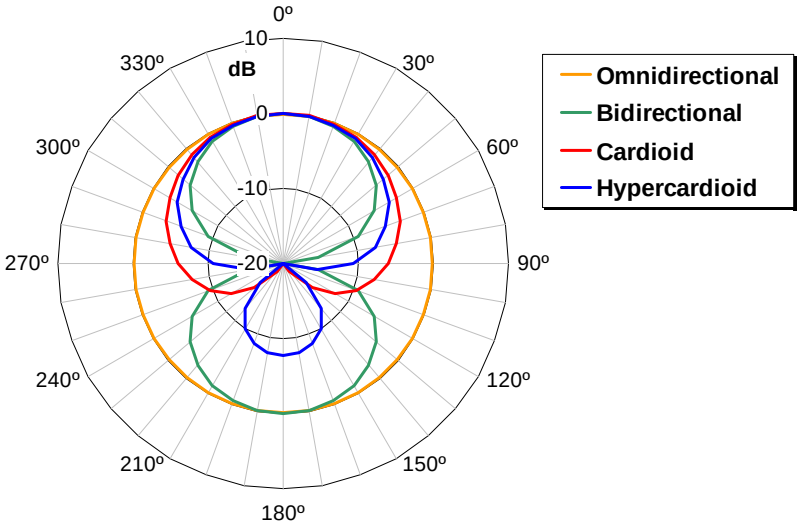
Directivity Index

- **DI is the ratio of the Free Field reference axis response to the Diffuse Field (Random Incidence) response, in dB.**
- **DI can be calculated from the free field polar response *if* the response is axially symmetric.**

Directivity Index

$$DI(f) = 10\log_{10}\left[\frac{4\pi\left|p_{ax}\right|^2}{\int_0^{2\pi}\int_0^{\pi}\left|p(\theta,\phi)\right|^2\left|\sin\theta\right|d\theta\,d\phi}\right] \quad [dB]$$

Free Field Polar Patterns



Ideal D.I.s

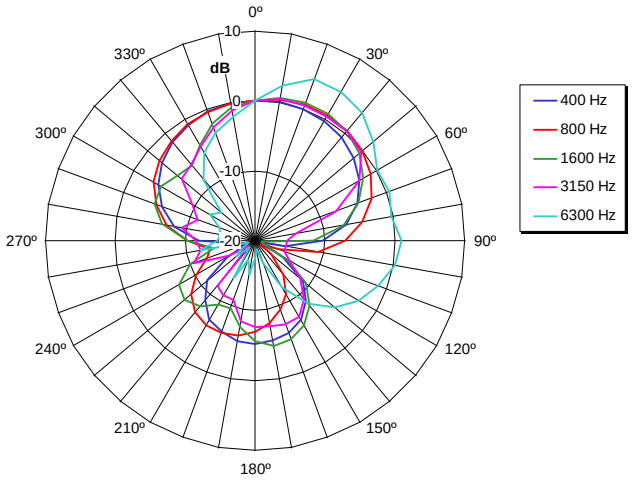
- Omnidirectional: 0 dB
- Bidirectional: 4.8 dB
- Cardioid: 4.8 dB
- Supercardioid: 5.7 dB
- Hypercardioid: 6.0 dB

(Simulated) In-Situ Response

- Simulated In-Situ = Manikin
- The presence of the head and torso profoundly alters the polar response in 3 dimensions !
- The assumption of symmetry is no longer valid

In-Situ Polar Response

Hypercardioid BTE - Horizontal Plane



DI from Diffuse Field Response

$$DI(f) = 10\log_{10}\left[\frac{10^{\frac{H_0(f)}{10}}}{10^{\frac{H_{diffuse}(f)}{10}}}\right] = H_0(f) - H_{diffuse}(f) \qquad [dB]$$

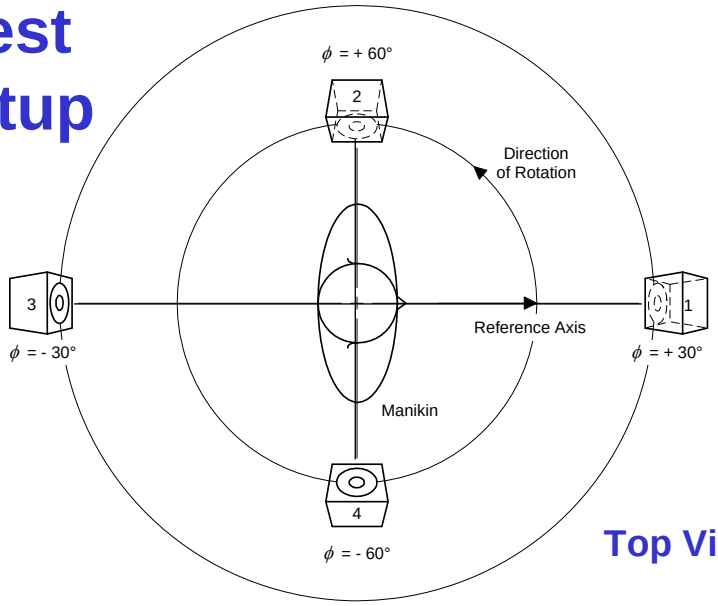
Diffuse Field (Random Incidence) Response

- **Traditional Method: Reverb Chamber**
- **Alternative Methods:**
  - **Summation (integration) of multiple free field measurements**
    - Roving source (min. 20 positions)
    - Rotating device (about 2 axes)
    - Combination
  - **Simulated Diffuse Field**

Goal

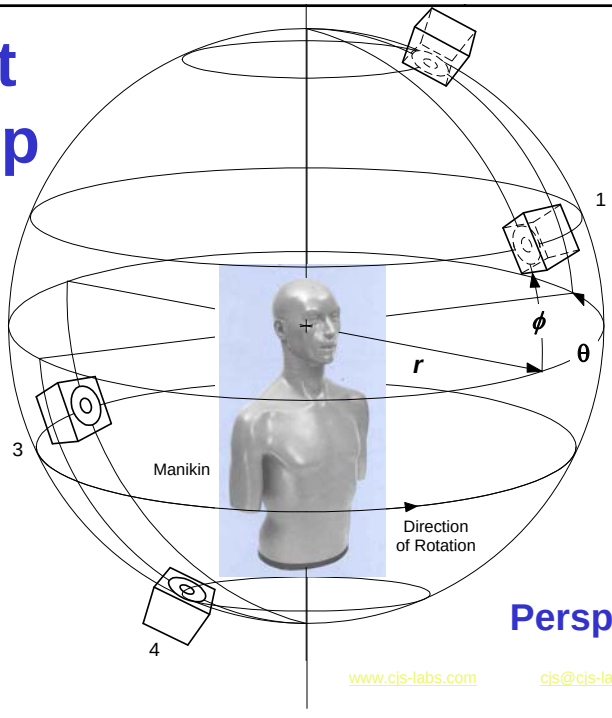
To develop a technique that enables diffuse field measurements to be performed, without a reverb chamber, in a moderately sized untreated room, over a reasonably wide bandwidth.

Test Setup

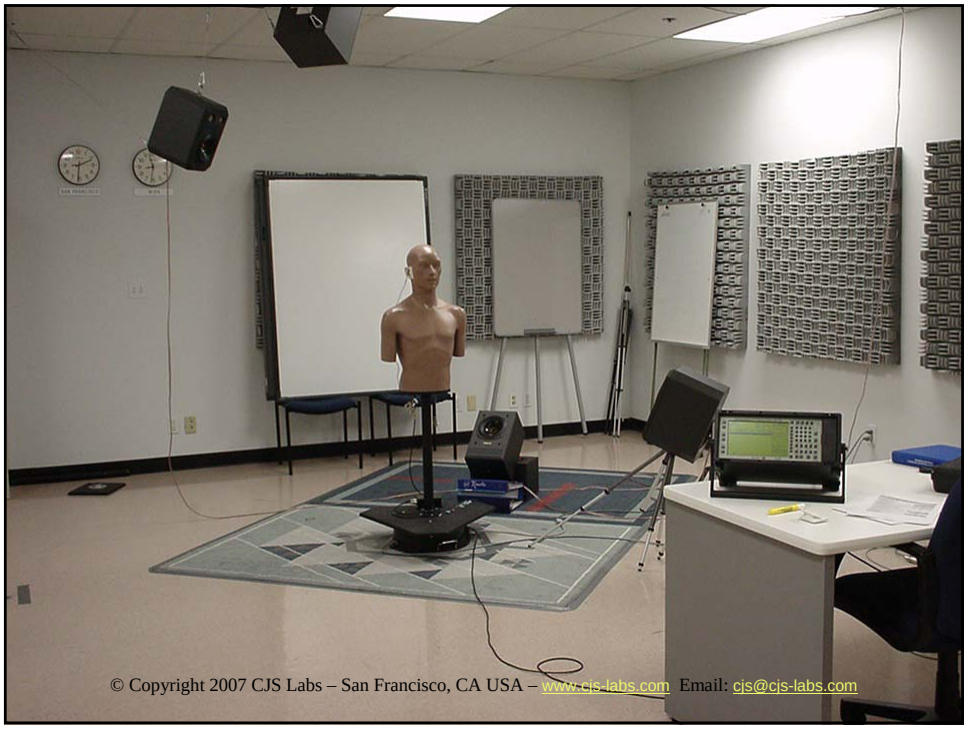


Top View

Test Setup



Perspective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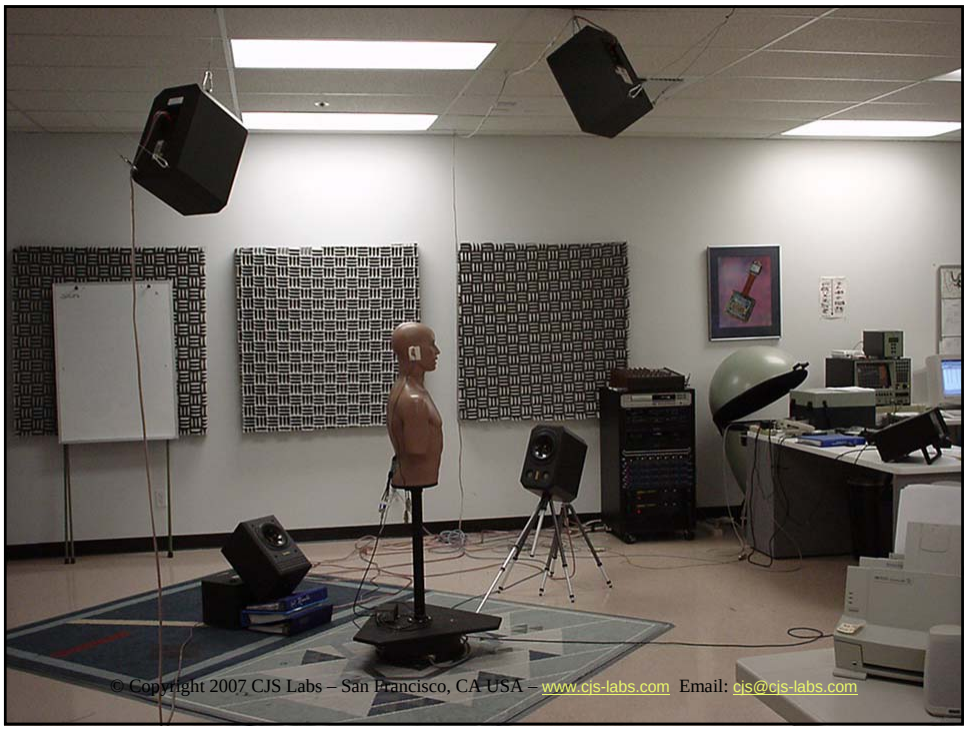
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Sound Field Verification

- Comparison using a known directional device
- Sound Intensity mapping:

$$\vec{I} = \overline{p(t) \cdot \vec{u}(t)} = 0$$

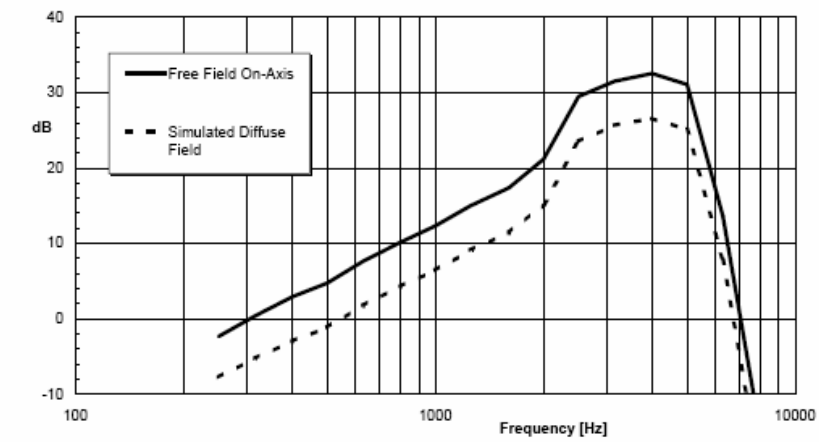
Test Conditions

- 4 uncorrelated pink noise sources
- Overall level: 75 dBSPL
- Real-time digital filter analysis in 1/3 octave bands. Avg. Time: 60s
- KEMAR manikin, re: center of head, 2 rotations/minute
- Ref. Axis: $\theta = 0°, \phi = 0°$

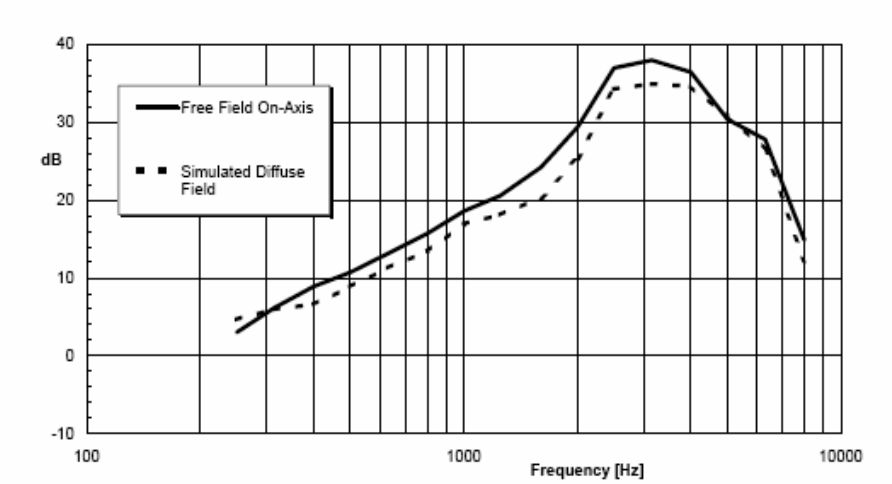
Data Handling

- Reference axis response obtained Simulated Free Field (TDS) and converted to equivalent 1/3 octave filter response
- DI calculated as the ratio of the Free Field Reference Axis Response to the Diffuse Field Response

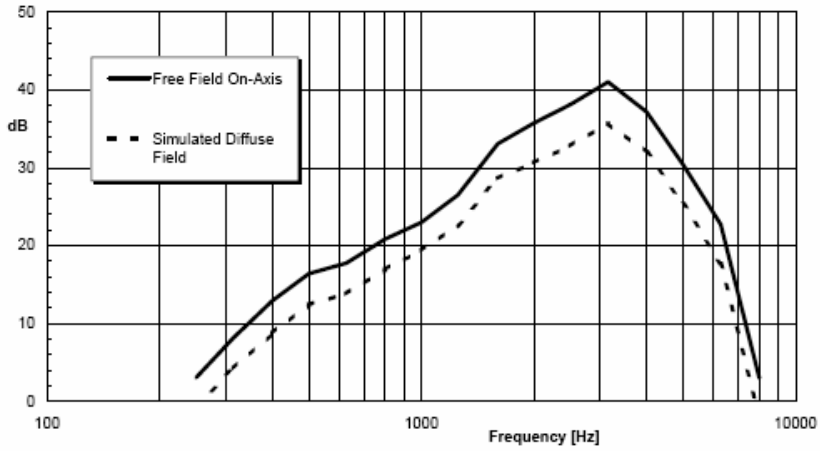
Small Hypercardioid Mic



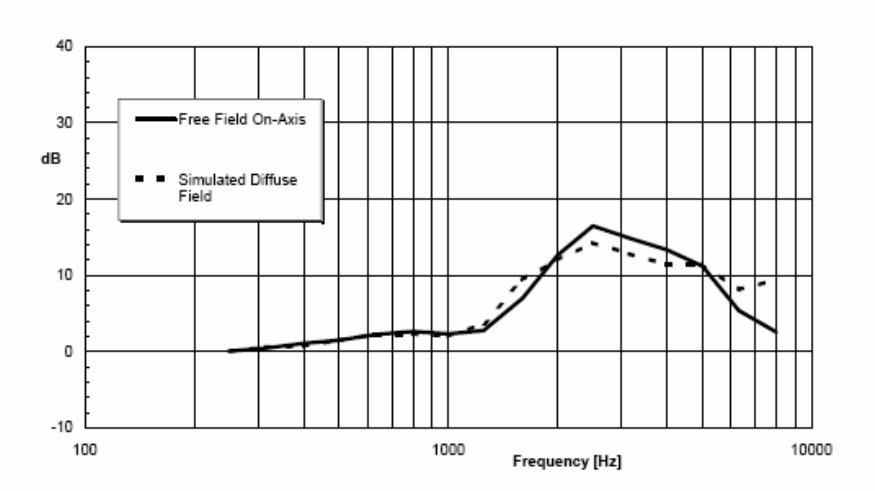
BTE In-Situ



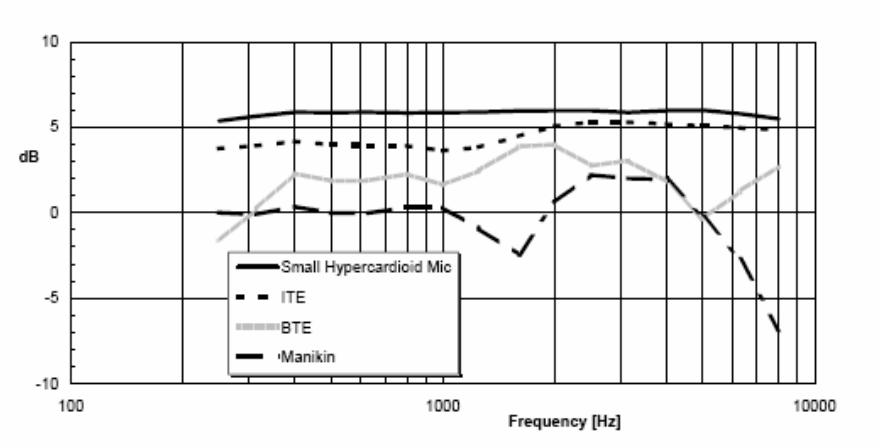
ITE In-Situ



Measurement Manikin



Directivity Index



In-Situ DI Interpretation

- DI = 0 is omnidirectional.
- DI < 0 is NOT *less* directionality.
- DI < 0 is directionality that is not in the reference direction (0°)!

Conclusion

- Determination of the In-Situ DI requires measurement of the Diffuse Field (Random Incidence) response.
- A simulated diffuse field can be created in an ordinary, untreated laboratory.
- Rotation of the device and manikin reduces the number of sources necessary to create the sound field.

Conclusion

- The time-averaged “diffusivity” of the sound field can be verified using sound intensity techniques.
- This test method is relatively fast, simple, and practical compared to a reverb chamber, or roving/multiple source techniques.

Conclusion

- The method is applicable to headsets, lavaliere microphones, and loudspeaking telephones.
- This method was proposed as an amendment to:

ANSI S3.35-2004 “Method of Measurement of Performance Characteristics of Hearing Aids Under Simulated Real-Ear Working Conditions”.