Sound Field Uncertainty Budget for Real-Ear Attenuation at Threshold Measurement per ANSI S12.6 Standards

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Methodology
- Meet ANSI S12.6-2008 requirements on sound field
- Measure the SPL variability with ATR
- Access sound field uncertainty

Results
- Calibration
- Delineated Results
- Results output

Conclusions
- Discussion
  - Sound field uncertainty
  - ETS guidelines
  - Testing and calibration
- Recommendation
  - TBA
  - TBA
  - TBA
- Future Research
  - Calibration
  - Sound field noise measurement

Background & Motivation
- Measurable factors in sound field
- Technical factors in sound field
- Limitations of sound field measurement
- Factors that can affect sound field measurement
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Background & Motivation

• WG11 work for uncertainty budget in ANSI S12.6
  - ANSI S12.6-2008 specifies requirements on Uniformity and Directivity (but not the resulting measurement uncertainty)
  - ANSI S12.6-201x needs uncertainty budget

• Very limited studies on sound field uncertainty

Motivation

- **WG11** work for uncertainty budget in ANSI S12.6
  - ANSI S12.6-2008 specifies requirements on Uniformity and Directivity (but not the resulting measurement uncertainty)
  - ANSI S12.6-201x needs uncertainty budget

- Very limited studies on sound field uncertainty

Table A.2 – Uncertainty budget for a Method-B determination of real-ear attenuation at threshold.

<table>
<thead>
<tr>
<th>Component</th>
<th>Standard uncertainty in dB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 250 Hz</td>
</tr>
<tr>
<td><strong>Test signal level</strong> – uncertainty of the sound pressure level associated with deviations of the test signal from the target test signal due to the uncertainty of the attenuator step size</td>
<td>0.2</td>
</tr>
<tr>
<td><strong>Sound field</strong> – Deviations from ideal uniform and random incidence sound field</td>
<td>0.5</td>
</tr>
</tbody>
</table>
• Very limited studies on sound field uncertainty

Methodology

- Meet ANSI S12.6-2006 requirements on sound field
- Measure the SPL variability with ATF
- Assess sound field uncertainty

Background & Motivation

- M331 work for uncertainty budget in ANSI S12.6
- ANSI S12.6-2006 sound field requirements on hearing conservation and employee hearing protection
- ANSI S12.6-2006 includes uncertainty budget
- Very limited studies on sound field uncertainty

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Methodology

- Meet ANSI S12.6-2008 requirements on sound field

- Measure the SPL variability with ATF

- Assess sound field uncertainty
Meet ANSI S12.6-2008

Measure the SPL, varia...
NI-PXI1033 Chassis
NI-4461, NI-4462
4 channels Hi-Fi amplifier

VIAcoustics REATplus 4.1.7

Klipsch Speaker RB81BK
requirements
3.15 semi-insert device. An earplug-like device (also called canal cap or concha-seated hearing protector) consisting of soft pods or tips that are held in place by a lightweight band. The pods are positioned in the conchae covering the entrances to the ear canals, or fitted to varying depths within the ear canals. Semi-inserts that cap the canal require the force of the band to retain their position and acoustic seal. Semi-inserts that enter the canal behave more like earplugs; they seal the ear to block noise with or without the application of band force.

3.16 white noise. Noise for which the spectrum density is independent of frequency.

4 Physical requirements of the test facility

4.1 Test signals

Test signals shall consist of pink or white noise, filtered into one-third octave-bands. Center frequencies shall include at least 125, 250, 500, 1000, 2000, 4000, and 8000 Hz.

4.2 Test site

4.2.1 Diffuse sound field requirements

4.2.1.1 Uniformity

The sound pressure level measured using an omnidirectional microphone at six positions relative to the reference point, with the subject and the subject's chair absent, 15 cm in front-back, up-down, and left-right axes, shall remain within a range of ±3 dB for each test signal. The difference between the left-right positions shall not exceed 3 dB. The orientation of the microphone shall be kept the same at each position.

4.2.1.2 Directionality

The directionality of the sound field shall be evaluated at the reference point for test bands with center frequencies greater than or equal to 500 Hz, with the subject and the subject's chair absent. The measurements shall be conducted with a directional microphone that exhibits in its free-field polar response at the one-third octave test bands, at least 10 dB front-to-side rejection for a cosine microphone, or at least 10 dB front-to-back rejection for a cardioid microphone.

The sound field shall be considered to approximate a random incidence field if, when the microphone is rotated at the reference point through 360 degrees in each of the three perpendicular planes defined by the front-back, up-down, and left-right axes coincident with the reference point, the observed sound pressure level in each test band remains within the variation allowed in Table 1 when the measurements are evaluated separately for each plane. The sound pressure levels may also be obtained by measuring at fixed 15-degree increments as the microphone is rotated 360 degrees in each plane.

4.2.2 Reverberation time

The reverberation time at the reference point, with the subject and the subject's chair absent, shall not exceed 1.6 s for each test signal.
4.2 Test site

4.2.1 Diffuse sound field requirements

4.2.1.1 Uniformity

The sound pressure level measured using an omnidirectional microphone at six positions relative to the reference point, with the subject and the subject’s chair absent, ±15 cm in front-back, up-down, and left-right axes, shall remain within a range of 5 dB for each test signal. The difference between the left-right positions shall not exceed 3 dB. The orientation of the microphone shall be kept the same at each position.

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The directionality of the sound field shall be evaluated at the reference point for test bands with center frequencies greater than or equal to 500 Hz, with the subject and the subject’s chair absent. The measurements shall be conducted with a directional microphone that exhibits in its free-field polar response at the one-third octave test bands, at least 10 dB front-to-side rejection for a cosine microphone, or at least 10 dB front-to-back rejection for a cardioid microphone.

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4 Physical requirements of the test facility

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Test signals shall consist of pink or white noise, filtered into one-third octave-bands. Center frequencies shall include at least 125, 250, 500, 1000, 2000, 4000, and 8000 Hz.

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4.2.1 Diffuse sound field requirements

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The sound pressure level measured using an omnidirectional microphone at six positions relative to the reference point, with the subject and the subject’s chair absent, ±15 cm in front-back, up-down, and left-right axes shall remain within a range of ±3 dB for each test signal. The difference between the left-right positions shall not exceed 3 dB. The orientation of the microphone shall be kept the same at each position.

4.2.1.2 Directionality

The directivity of the sound field shall be evaluated at the reference point for test bands with center frequencies greater than or equal to 500 Hz, with the subject and the subject’s chair absent. The measurements shall be conducted with a directional microphone that exhibits its free-field polar response at the one-third octave test bands, at least 10 dB front-to-side rejection for a cosine microphone, or at least 10 dB front-to-back rejection for a cardioid microphone.

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**Uniformity**

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### 4.2.2 Reverberation time

The reverberation time at the reference point, with the subject and the subject's chair absent, shall not exceed 1.5 s for each test signal.
xy plan

directivity
xz plan
• Measure the SPL variability with ATF
  
  2 configurations
  3 translations
  1 rotation

• Assess sound field uncertainty
2 configurations
3 translations
1 rotation
Methodology

• Meet ANSI S12.6-2008 requirements on sound field

• Measure the SPL variability with ATF

• Assess sound field uncertainty
Background & Motivation

- WG11 work for uncertainty budget in ANSI S12.6
- ANSI S12.6:2008 specifies requirements on
  uncertainty and performance standards
- ANSI S12.6:2008 results a suitability budget
- Very limited studies on sound field uncertainty

Methodology

- Meet ANSI S12.6-2008 requirements on sound field
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Results

Collected Data
Statistical Analysis

Discussion

- Sound field uncertainty
- Directivity of the ear
- Directivity of the ear

Recommendations

- Certification of ANSI S12.6-2008
- Real-time data

Future Research

- Electronics development
- Alternative test methods

Deal with the remainder
Results

Collected Data

Statistical Analysis

Step 1. Normal probability density function is applied to distances found

\[ y = f(x | \mu, \sigma) = \frac{1}{\sigma \sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}} \]

Step 2. Calculation of 95% confidence intervals for the parameter estimates on the mean and standard deviation

Results - with chair

Results - no chair
Collected Data
Results - with chair
Results - no chair
**Results**

**Collected Data**

**Statistical Analysis**

Step 1. Normal probability density function is applied to distances found

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**Results - with chair**

**Results - no chair**
Statistical Analysis

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Step 2. Calculation of 95% confidence intervals for the parameter estimates on the mean and standard deviation
Results

**Collected Data**

**Statistical Analysis**

Results - with chair

Results - no chair

Conclusions

**Discussion**

- Sound field uncertainty currently <0.5 dB
- Directivity of tweeter clearly visible in both directivity and elevation

**Recommendation**

- Clarification of sound field uniformity requirements in ANSI S12.6-201x: +/- 2.5 dB
- Revise plumb bob design to block azimuthal rotation

**Future Research**
Conclusions

Discussion

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Recommendation

- Clarification of sound field uniformity required
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- Clarification of sound field uniformity requirements in ANSI S12.6-201x: +/-2.5 dB
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Future Research

- Statistical validation
- Alternative head position measurement
• Sound field uncertainty currently <0.5 dB
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• Statistical validation
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Future Research

- Statistical validation
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Deal with the real thing! at 11:05!
Future Research

- Statistical validation
- Alternative head position measurement

Deal with the real thing!

at 11:05!
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Conclusions

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Deal with the real thing!