Acoustical simulation of open-plan offices according to ISO 3382-3

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Outline

• Introduction
• ISO 3382’s – ISO 3382 part 3
• Factors affecting acoustical performance
• Measurements
• Acoustical parameters
• Open-plan office example
  – Absorption
  – Screens
  – Background noise
• Conclusion
The ISO 3382 family

Acoustics -- Measurement of room acoustic parameters

- Part 1: Performance spaces
- Part 2: Reverberation time in ordinary rooms
- Part 3: Open plan offices

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Introduction


• New parameters, including:
  – Spatial sound distribution of the A-weighted sound pressure level of speech
    • Spatial decay rate of speech
  – Spatial sound distribution of the speech transmission index
    • Distraction distance
    • Privacy distance
  – Background noise level

• Computer simulations instead of measurements
Factors affecting acoustical performance according to 3382-3

- Layout of work stations
- Absorption
- Height of screens and storage units
- Background noise
- Degree of work station enclosure
- Distance between work stations
- Room dimensions
1. The office must be furnished, but unoccupied
2. Sound source should be omni directional
3. Sources and microphones are placed on work stations, height 1.2 m above floor
4. A measurement line is made from one source position and a number of receiver positions in different distances
5. Min. 4 receivers, recommended 6-10
6. At least two measurement lines should be used, and the results are averaged
Calculations

Source power – normal effort unisex speech
At every measurement point:
• SPL(A) in octave bands, 125 – 8000 Hz
• Background noise in octave bands
• STI
  – The impulse response method is preferred (as Odeon)
  – Average of background noise is used for STI (as Odeon)
Spatial decay curves

SPL(A) at 4 m

Spatial decay rate

$D_{2,S} = 6\,\text{dB}$

Distraction distance

Privacy distance

$r_D = 14\,\text{m}$

$r_P = 31\,\text{m}$

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## Target values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Poor</th>
<th>Good</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial decay rate, D$_{2,S}$</td>
<td>&lt;5 dB</td>
<td>&gt;= 7 dB</td>
</tr>
<tr>
<td>SPL(A) at 4 metres, L$_{p, A, S, 4 m}$</td>
<td>&gt; 50 dB</td>
<td>&lt;= 48 dB</td>
</tr>
<tr>
<td>Distraction distance, r$_D$</td>
<td>&gt; 10 m</td>
<td>&lt;= 5 m</td>
</tr>
</tbody>
</table>

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Simulating ISO 3382-3 in Odeon 12β

• Model of room geometry fully furnished
• Full impulse response calculated (hybrid method)
• Diffraction over screens and storage units etc. included
• Constant background noise easily included \( (L_{p,B}) \)
• SPL(A) and STI parameters can be predicted
• ISO 3382-3 quantities are automatically calculated from a selected number of receivers
• Average results from at least 2 measurement lines

• Easy to include many workstations/receivers – use > 10?
Example office
View into the ODEON model
1-point diffraction

Diffraction
- Geometric path automatically detected
- Contribution calculated according to Allan D. Pierce

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2-point diffraction

- Geometric path automatically detected
- Contribution calculated according to Allan D. Pierce

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Measurement lines

- Lines 1 and 2 with 7 mic. positions
- Lines 3 and 4 with 10 mic. Positions
Selecting receivers in Odeon 12β

Define/select a group of receivers for immediate display of

- $D_{2,S}$, $L_{p,A,S}$, 4 m (and $SPL_{(A)}$ versus distance)
- $r_D$ and $r_P$ (and STI versus distance)
<table>
<thead>
<tr>
<th></th>
<th>Line 1</th>
<th>Line 2</th>
<th>Line 3</th>
<th>Line 4</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>STI in nearest workstation</strong></td>
<td>0,64</td>
<td>0,67</td>
<td>0,75</td>
<td>0,64</td>
<td>0,68</td>
</tr>
<tr>
<td><strong>Distraction distance, ( r_D ), in m</strong></td>
<td>8,20</td>
<td>10,14</td>
<td>10,53</td>
<td>7,09</td>
<td>9,0</td>
</tr>
<tr>
<td><strong>Privacy distance, ( r_P ), in m</strong></td>
<td>22,38</td>
<td>24,08</td>
<td>21,70</td>
<td>19,13</td>
<td>21,8</td>
</tr>
<tr>
<td><strong>Spatial decay rate of A-weighted SPL of speech, ( D_{2,S} ), in dB</strong></td>
<td>6,05</td>
<td>6,11</td>
<td>6,74</td>
<td>5,12</td>
<td>6,0</td>
</tr>
<tr>
<td><strong>A-weighted SPL of speech at 4 metres, ( L_{p,A,S,4,m} ), in dB</strong></td>
<td>48,5</td>
<td>50,2</td>
<td>50,9</td>
<td>46,0</td>
<td>48,9</td>
</tr>
<tr>
<td><strong>Average A-weighted background noise, ( L_{p,A,B} ), in dB</strong></td>
<td>38</td>
<td>38</td>
<td>38</td>
<td>38</td>
<td>38</td>
</tr>
</tbody>
</table>
# Three office versions

**Office 1:** As existing, absorption in ceiling  
**Office 2:** Reflective ceiling  
**Office 3:** As no. 1, plus absorbing baffles and 1.25 m screens

<table>
<thead>
<tr>
<th></th>
<th>Office 1</th>
<th>Office 2</th>
<th>Office 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_{20}$ (500 - 1000 Hz) in s</td>
<td>0,5</td>
<td>1,1</td>
<td>0,3</td>
</tr>
<tr>
<td>STI in nearest workstation</td>
<td>0,71</td>
<td>0,61</td>
<td>0,68</td>
</tr>
<tr>
<td>Distraction distance, $r_D$, in m</td>
<td>13,8</td>
<td>10,1</td>
<td>9,0</td>
</tr>
<tr>
<td>Privacy distance, $r_P$, in m</td>
<td>33,3</td>
<td>37,8</td>
<td>21,8</td>
</tr>
<tr>
<td>Spatial decay rate of A-weighted SPL of speech, $D_{2,5}$, in dB</td>
<td>4,4</td>
<td>3,8</td>
<td>6,0</td>
</tr>
<tr>
<td>A-weighted SPL of speech at 4 metres, $L_{p,A,5,4\text{ m}}$, in dB</td>
<td>51,0</td>
<td>56,5</td>
<td>48,9</td>
</tr>
<tr>
<td>Average A-weighted background noise, $L_{p,A,B}$, in dB</td>
<td>38</td>
<td>38</td>
<td>38</td>
</tr>
</tbody>
</table>

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Spatial distribution curves, $L_{p,A}$

![Graph showing spatial distribution curves for different offices.](image-url)
Spatial distribution curves, STI

Distraction distance

- Office 1
- Office 2
- Office 3
## Variation of screen height

<table>
<thead>
<tr>
<th>Office 3, Screen height</th>
<th>1,25 m</th>
<th>1,50 m</th>
<th>1,75 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>STI in nearest workstation</td>
<td>0,68</td>
<td>0,67</td>
<td>0,67</td>
</tr>
<tr>
<td>Distraction distance, $r_D$, in m</td>
<td>9,0</td>
<td>8,4</td>
<td>8,0</td>
</tr>
<tr>
<td>Privacy distance, $r_P$, in m</td>
<td>21,8</td>
<td>19,8</td>
<td>18,7</td>
</tr>
<tr>
<td>Spatial decay rate of A-weighted SPL of speech, $D_{2,S}$, in dB</td>
<td>6,0</td>
<td>6,6</td>
<td>🎉 7,1</td>
</tr>
<tr>
<td>A-weighted SPL of speech at 4 metres, $L_{p,A,S,4,m}$, in dB</td>
<td>48,9</td>
<td>48,6</td>
<td>🎉 48,4</td>
</tr>
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<td>Average A-weighted background noise, $L_{p,A,B}$, in dB</td>
<td>38</td>
<td>38</td>
<td>38</td>
</tr>
</tbody>
</table>

**Increasing the screen height means:**
- $r_D$ and $r_P$ decrease
- $D_{2,S}$ increases

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### Variation of background noise

<table>
<thead>
<tr>
<th>Average A-weighted background noise, $L_{p, A, B}$ in dB</th>
<th>40</th>
<th>45</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>STI in nearest workstation</td>
<td>0,64</td>
<td>0,54</td>
<td>0,40</td>
</tr>
<tr>
<td>Distraction distance, $r_D$, in m</td>
<td>7,1</td>
<td>😊 2,5</td>
<td>-</td>
</tr>
<tr>
<td>Privacy distance, $r_P$, in m</td>
<td>19,1</td>
<td>14,0</td>
<td>8,6</td>
</tr>
</tbody>
</table>

Increasing the background noise means:
- $r_D$ and $r_P$ decrease
- STI in nearest workstation goes down

(Actually, $r_D$ can be negative, i.e. no result)

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Conclusion

• The new parameters behaves differently to
  – Absorption
  – Screens
  – Background noise
• Computer simulations can be used to evaluate alternative solutions
• In order to meet target values for good acoustic conditions – absorbing ceiling, 1.75 m screens and approx. 43 dB background noise is needed.
• More factors can be altered in new open plan office design

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