A comparing overview on ECAC Doc.29 3rd Edition and the new German AzB

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## Doc.29 Vol.3 vs. AzB-2008

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<th>Doc.29 3rd Edition</th>
<th>AzB-2008</th>
</tr>
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<td><strong>Model Type</strong></td>
<td>Segmentation model with specific improvements</td>
<td>Segmentation depending on receiver location</td>
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<td><strong>Emission Data</strong></td>
<td>NPD-data and spectral classes</td>
<td>Octave spectra</td>
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<td>7 subtracks (recommended)</td>
<td>15 subtracks (prescribed)</td>
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<td><strong>Receiver Height</strong></td>
<td>-</td>
<td>Solid angle correction (ISO 9613-2)</td>
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<td>Only altitude effect on propagation distance</td>
<td></td>
</tr>
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<td><strong>Reverse Thrust</strong></td>
<td></td>
<td>AzB adapted the Doc.29 model</td>
</tr>
<tr>
<td><strong>Ground Noise</strong></td>
<td>-</td>
<td>Taxiing and APU</td>
</tr>
<tr>
<td><strong>Field of Application</strong></td>
<td>Civil airports / Flexible</td>
<td>All airports / Primarily Forecast</td>
</tr>
</tbody>
</table>
Segmentation model

**AzB:** 2-step segmentation with additional segmentation step depending on aircraft-observer-geometry

**Doc.29:** Classical 2-step flight path segmentation with specific improvements
Principle of Segmentation

Original flight track

Segmented arc

Point of closest approach

Total exposition $E = \sum E_i$
Flight path segmentation: 1. Step

1. step identical for AzB an Doc.29

Path segments from 1st segmentation step

Flight track (horizontal plane) with **track segments**

Altitude profile (vertical plane) with **profile segments**
Flight path segmentation: 2. Step (Doc.29)

T/O-Roll segment:
- Segmentation in fixed time intervals (const. acceleration)
- Improved comparability to simulation

Airborne segments:
- Removal of points located close to each other
- Segmentation of long segments with great changes in aircraft speed

Transition segments adjacent to curved flight tracks
- Removal of discontinuities due to effects of bank angle

\[ s_{TO} = 1600 \text{ m} \]
Origin: \textbf{flight path segments}

\[
\Delta L_{WA}^{'i} > 1 \text{ dB} \\
\text{or} \\
\Delta L_{WA} > 1 \text{ dB}
\]

\[
L_{WA}^{'i} = L_{WA} - 10 \cdot \log \left( \frac{V}{V_{ref}} \right)_{l_0=1\text{m}}
\]

Result: \textbf{flight path subsegments} by adaption of specific emissions

\[
\Delta L_{WA}^{'i} \leq 1 \text{ dB} \\
\text{and} \\
\Delta L_{WA} \leq 1 \text{ dB}
\]
Flight path segmentation: 3. Step (AzB)

- Flight path subsegment of length $\lambda$ is subdivided in final segments of length $l_i$
- Subdivision starts at point of closest approach $Q_0$
- Final segments are represented by point sources $Q_i$

Condition:
\[ \frac{l_i}{r_i} = 0.1 \]

Segmentation depends on observer location!
Source model

AzB:  - Octave spectra
     - Spectral 2D directivity (directivity factors)

Doc.29:  - NPD data based on spectral classes
         - Semi-empirical 2D dipole model
         - Lateral directivity from installation effects
### Example of AzB-2008 approach data set

<table>
<thead>
<tr>
<th>n</th>
<th>( O_{n} ) (dB)</th>
<th>( R_{n} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>68.0</td>
<td>(0,0,0)</td>
</tr>
<tr>
<td>2</td>
<td>76.0</td>
<td>(0,0,0)</td>
</tr>
<tr>
<td>3</td>
<td>74.0</td>
<td>(0,0,0)</td>
</tr>
<tr>
<td>4</td>
<td>75.0</td>
<td>(0,0,0)</td>
</tr>
<tr>
<td>5</td>
<td>72.5</td>
<td>(0,0,0)</td>
</tr>
<tr>
<td>6</td>
<td>69.5</td>
<td>(0,0,0)</td>
</tr>
<tr>
<td>7</td>
<td>70.0</td>
<td>(0,0,0)</td>
</tr>
<tr>
<td>8</td>
<td>56.5</td>
<td>(0,0,0)</td>
</tr>
</tbody>
</table>

\( s_{0n} = 300 \text{ m} \)

### Acoustical data

<table>
<thead>
<tr>
<th>( \sigma' ) [m]</th>
<th>( Z ) [dB]</th>
<th>( V ) [m/s]</th>
<th>( H ) [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>-300 - ( S_{0} )</td>
<td>-10</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>-400</td>
<td>5</td>
<td>60</td>
<td>0</td>
</tr>
<tr>
<td>-300</td>
<td>0</td>
<td>65</td>
<td>0</td>
</tr>
<tr>
<td>7400</td>
<td>0</td>
<td>75</td>
<td>-</td>
</tr>
<tr>
<td>( X )</td>
<td>-1</td>
<td>108</td>
<td>( h_{0} )</td>
</tr>
<tr>
<td>( X + S_{2} )</td>
<td>-1</td>
<td>108</td>
<td>( h_{0} )</td>
</tr>
</tbody>
</table>

\( \sigma' \) [m] \( \frac{dZ/d\sigma'}{[\text{dB/m}]} \) \( \frac{dV/d\sigma'}{[\text{s}^3]} \) \( \frac{dH/d\sigma'}{} \)

\( > X + S_{2} \)

\( 0 \) \( 0 \) \( \tan \theta \)

(7) \( h_{0} = 1.4 \text{ m} \)

(8) \( Q_{0} = 3 \text{ dB} \)

(9) \( S_{0} = 900 \text{ m} \)

zugehörige APU-Klasse: APU 1 - L

\[ X = \frac{h_{0}}{\tan \theta} - 300 \]

**Deutsches Zentrum für Luft- und Raumfahrt e.V.**

in der Helmholtz-Gemeinschaft

JRC Workshop on Aircraft Noise, Brussels, 19./20. January 2010, Sheet 10
Directivity according to AzB-2008

Directivity diagram $L_{WA}(\theta)$ for departure of aircraft category S5.2
$R_n = \{1, -1, 1\}$

Representation of spectral directivity by series expansion in cosine of radiation angle $\theta$

$$D^*_i,n(\theta) = 3 \cdot [a_1 \cdot \cos(\theta) + a_2 \cdot \cos(2\theta) + a_3 \cdot \cos(3\theta)]$$
Source model of Doc.29

\[ E_{\text{seg}} = F \cdot E_{\infty} \]

- **F**: "Energy fraction"
- **\( E_{\text{seg}} \)**: Segment contribution to exposure
- **\( E_{\infty} \)**: Exposure from infinite segment

Approach: "4th-power-90°-dipole-model"

\[ p^2 \sim \sin^2\theta/d^2 \sim d^{-4} \]
The principle of the „scaled distance”

Problem:

- The energy fraction is derived from the analytical dipole-model.
- The NPD-data are derived from measurements (i.e. from real directivities).

\[ \Delta L = L_{E,\infty}(V) - L_{\text{max}} \]

⇒ The differences \( \Delta L = \Delta L_{\text{Dipole}} \neq \Delta L_{\text{NPD}} \)

Solution:

- A „scaled distance \( d_{\lambda}^* \)“ is introduced: \( \Delta L_{\text{Dipole}}(d_{\lambda}^*) = \Delta L_{\text{NPD}}(d_{\lambda}^*) \)
- The energy fraction is calculated for the scaled distance, not for the slant-distance.

The real directivity is modelled by a modified propagation distance.

⇒ The analytical model changes to a semi-empirical one!
Installation effect (lateral directivity, only Doc.29)

- Wing mounted jet
- Fuselage mounted jet

5 dB

Prop

ϕ
Both models account for
- geometrical spreading,
- atmospheric absorption and
- ground effect.

AzB: Explicit modelling of propagation effects

Doc.29: Geometrical spreading and atmospheric absorption implicit modelled by NPD
⇒ Changed atmospheric conditions require recalculation of NPD data
Excess attenuation

**AzB:**
- Ground effect correction
- Solid angle correction
⇒ Allowance for receiver height

**Doc.29:**
- Ground effect correction
- Engine installation correction
⇒ Receiver on the ground
Ground effect correction (AzB-2008)

Ground effect correction: \[ D_{Z,n} = f(\alpha) \cdot g(s) \] (spectral)

Solid angle correction: \[ D_\Omega = f(s, h_s, h_r) \]

\( \alpha \): Angle of incidence

\( h_s \): Height of receiver

\( h_r \): Height of receiver

\( s \): Distance from aircraft to receiver

Horizontal plane
Ground effect correction: \( \Lambda = f(\alpha) \cdot g(\ell) \)

\( \alpha \): Angle of incidence
Ground effect and installation correction (Doc.29)

Ground effect correction:  \[ \Lambda = f(\alpha) \cdot g(\ell) \quad \Rightarrow \text{(propagation effect)} \]

Installation correction:  \[ \Delta_{\text{Inst}} = \Delta_{\text{Inst}}(\varphi) \quad \Rightarrow \text{(source property)} \]

\(\alpha\): Angle of incidence

\(\varepsilon\): Bank angle

\(\varphi\): Depression angle

\(\ell\): Receiver
Aircraft categories and flight profiles

**AzB:**
- Limited number of aircraft groups
  (23 civil, 8 military, 5 helicopter)
- Unambiguous rules for grouping
- Fixed flight profiles
- Grouping according to „acoustic equivalence”

**Doc.29:**
- Large number of airframe/engine combinations
  (123+ civil commercial, extensible)
- Procedural flight profiles
- Substitution rules for aircraft not in database
Flight path definition

Flight track segments

Flight profile segments

- Standard profiles (AzB):
  - Fixed Profile segments
  - Performance parameters as function of distance from brake release / landing threshold
    - simple but not flexible

- Procedural profiles (Doc.29):
  - Variable profile segments
  - Performance parameters as function of procedural step of flight procedure and aircraft mass
    - flexible but complex
Example of AzB-2008 approach data set

<table>
<thead>
<tr>
<th>n</th>
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<th>$R_n$</th>
</tr>
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<tbody>
<tr>
<td>1</td>
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<td>70,0</td>
<td>(0,0,0)</td>
</tr>
<tr>
<td>8</td>
<td>56,5</td>
<td>(0,0,0)</td>
</tr>
</tbody>
</table>

$s_{on} = 300$ m

(3) $P_r$: Landeschwelle

<table>
<thead>
<tr>
<th>$\sigma'$ [m]</th>
<th>(4) $Z$ [dB]</th>
<th>(5) $V$ [m/s]</th>
<th>(6) $H$ [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>-300 - $S_z$</td>
<td>-10</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>-400</td>
<td>5</td>
<td>60</td>
<td>0</td>
</tr>
<tr>
<td>-300</td>
<td>0</td>
<td>65</td>
<td>0</td>
</tr>
<tr>
<td>7400</td>
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<td>75</td>
<td>-</td>
</tr>
<tr>
<td>$X$</td>
<td>108</td>
<td></td>
<td>$h_0$</td>
</tr>
<tr>
<td>$X + S_z$</td>
<td>-1</td>
<td>108</td>
<td>$h_0$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$\sigma'$ [m]</th>
<th>$dZ/d\sigma'$ [dB/m]</th>
<th>$dV/d\sigma'$ [s$^{-1}$]</th>
<th>$dH/d\sigma'$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$&gt; X + S_z$</td>
<td>0</td>
<td>0</td>
<td>$\tan w$</td>
</tr>
</tbody>
</table>

(7) $h_0 = 1,4$ m
(8) $Q_o = 3$ dB
(9) $S_y = 900$ m

zugehörige APU-Klasse: APU 1 - L

$X = \frac{h_0}{\tan w} - 300$
Procedural profiles: mass point model

L : Lift
W : Weight
D : Drag
F : Thrust
γ : Climb angle

Z : Centrifugal force
ε : Bank angle

Lift and drag are estimated from the coefficients $c_L$ and $c_D$. 
Example for procedural flight profiles

Departure profile B737-400, 48.5 t (calculated with INM 6.1)

Engine thrust (arbitrary units)

Stockholm: 13°C, 15 m above SL

Madrid: 27°C, 580 m above SL
Grouping criteria for AzB database

**Acoustic equivalence:**

„Two aircraft are acoustic equivalent in case that they produce similar noise footprints along the noise-relevant part of the flight path.“

⇒ They can be assigned to the same aircraft group.

**Noise significance:**

„A noise significant aircraft co-determines considerably the noise situation in the vicinity of an airport (i.e. considerable changes in number of movements induce considerable noise changes).“

⇒ A noise significant aircraft must be modelled as precise as possible.

⇒ A separate group has to be created for it in case that there are no acoustic equivalent aircraft.

⇒ Noise insignificant aircraft can be grouped disregarding acoustic equivalence.
Example of acoustic equivalence: AzB-Group S6.1

Departure profiles for ICAO-A-procedure (calculation with INM 6.2)

Calculated standard deviation of SEL under flight path in dB

Distance from brake release [km]

Altitude [m]

A310 (150 t)  A300 (170 t)  A330 (212 t)  B767 (191 t)  B777 (289 t)
## Comparison of type mix for the main AzB-groups

<table>
<thead>
<tr>
<th>AzB-Group</th>
<th>Aircraft</th>
<th>Germany 2005 (5 airports)</th>
<th>Zurich 2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>S5.1</td>
<td>Avro RJ, Bae146</td>
<td>27%</td>
<td>51%</td>
</tr>
<tr>
<td></td>
<td>Canadair RJ</td>
<td>48%</td>
<td>8%</td>
</tr>
<tr>
<td></td>
<td>Fokker 70/100</td>
<td>13%</td>
<td>14%</td>
</tr>
<tr>
<td></td>
<td>other</td>
<td>12%</td>
<td>27%</td>
</tr>
<tr>
<td>S5.2</td>
<td>A318..A321</td>
<td>48%</td>
<td>76%</td>
</tr>
<tr>
<td></td>
<td>B737</td>
<td>48%</td>
<td>21%</td>
</tr>
<tr>
<td></td>
<td>other</td>
<td>4%</td>
<td>3%</td>
</tr>
<tr>
<td>S6.1</td>
<td>A300</td>
<td>37%</td>
<td>&gt; 1%</td>
</tr>
<tr>
<td></td>
<td>A310</td>
<td>8%</td>
<td>1%</td>
</tr>
<tr>
<td></td>
<td>A330</td>
<td>24%</td>
<td>59%</td>
</tr>
<tr>
<td></td>
<td>B767</td>
<td>22%</td>
<td>33%</td>
</tr>
<tr>
<td></td>
<td>B777</td>
<td>9%</td>
<td>7%</td>
</tr>
</tbody>
</table>
Summary

- Both models use a segmentation algorithm, whereas the AzB implements an additional step depending on observer location.

- From an acoustical view the AzB uses a more detailed algorithm (spectral calculation, non-generalised directivity) that is flexible with respect to a future expansion.

- Doc.29 provides much more flexibility in generating flight paths.

- The AzB is primarily designed for forecasts (grouping). Doc.29 provides more functionality, e.g. for what-if-studies (noise mitigation studies, effects of noise abatement flight procedures).

- The AzB covers additionally military and general aviation as well as helicopters and some ground operations.

However both models are in principle easily extensible (AzB with respect to operational aspects, Doc.29 with respect to other fields of application).
The next step: DIN 45689

- AzB 2008
- DIN 45684
- Doc. 29 3rd ed.

Work starts in 2010 (1st special meeting on radar data January 26).

3 – 5 years of development expected
Problems to be discussed

... propagation modelling for aircraft noise
Problem: Conventional noise calculation procedures account only for standardised weather conditions (isotropic atmosphere, no wind).

Question: What is the error introduced by this simplifying assumption?
## Analysis of meteorological data (Hahn Airport, 2001)

### Classification used by the DLR-IPA sound propagation model

<table>
<thead>
<tr>
<th>stability class SC</th>
<th>stable</th>
<th>neutral</th>
<th>unstable</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$v_{W,10m}$ [m/s]</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>10</td>
<td>20</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\gamma_{Prandtl}$ [K/m]</td>
<td>+0.1</td>
<td>-0.01</td>
<td>-0.02</td>
</tr>
<tr>
<td>$\gamma_{Ekman}$ [K/m]</td>
<td>+0.05</td>
<td>-0.01</td>
<td>-0.01</td>
</tr>
</tbody>
</table>

### Distribution on wind direction and stability class

<table>
<thead>
<tr>
<th>wind direction</th>
<th>percentage of occurrence during daytime in stability class</th>
</tr>
</thead>
<tbody>
<tr>
<td>30° $\Rightarrow$ 120°</td>
<td>- 0.8 2.1 - 1.3 7.6 0.0 - 0.3 2.3</td>
</tr>
<tr>
<td>120° $\Rightarrow$ 210°</td>
<td>- 1.2 3.3 - 2.2 12.0 0.6 - 0.3 2.5</td>
</tr>
<tr>
<td>210° $\Rightarrow$ 300°</td>
<td>- 0.6 2.5 - 2.6 34.1 4.0 - 0.4 2.4</td>
</tr>
<tr>
<td>300° $\Rightarrow$ 30°</td>
<td>- 0.7 1.8 - 1.5 9.5 0.7 - 0.4 2.4</td>
</tr>
</tbody>
</table>
Calculation of noise contours using DLR model SIMUL

Influence of meteorology on SEL contours (runway direction 21)

- Stable, $v_w = 2 \text{ m/s} \ (SC \ 3)$
- Neutral, $v_w = 5 \text{ m/s} \ (SC \ 7)$
- Unstable, $v_w = 2 \text{ m/s} \ (SC \ 12)$
Calculation of noise contours using DLR model SIMUL

Influence of meteorology on SEL contours (runway direction 03)

- Stable, $v_w = 2$ m/s (SC 3)
- Neutral, $v_w = 5$ m/s (SC 7)
- Unstable, $v_w = 2$ m/s (SC 12)
Comparison with isotropic atmosphere

Contours SEL = 70, 80, 90 dB (weighted yearly average)

SEL_{iso} - SEL_{met}
Problems to be discussed

... measuring directivities
Example: A380-800

Jet noise generation

1.2 m microphones on 60 m radius

Angle of radiation?
Thank you!