4 Sound fields in cavities and in rooms

4.1 Cavities

4.2 Modes

4.2.1 Boundary conditions

4.3 Geometrical acoustics

4.4 Statistical reverberation theory

4.4.1 Reverberation

4.4.2 Steady-state energy density and level

5 Structure-borne sound

5.1 Waves in solid media

5.2 Waves on plates and their radiation

5.2.1 Finite-size plates

5.2.2 Internal losses and structural reverberation time

5.3 Vibrational transmission over junctions

6 Psychoacoustics

6.1 Anatomy of the peripheral hearing system

6.2 Psychoacoustic characterization

6.2.1 Loudness

6.2.2 Temporal masking

6.2.3 Time-varying loudness

6.2.4 Sharpness

6.2.5 Fluctuation strength

6.2.6 Roughness

6.2.7 Tonality, pitch, pitch strength

6.3 Binaural hearing

6.3.1 Head-related transfer functions

6.3.2 Artificial heads

6.4 Hearing in rooms

6.4.1 Reverberance

6.4.2 Strength

6.4.3 Speech intelligibility and transparence

6.4.4 Spatial impression

6.4.5 Spatial variations in a room

6.4.6 Estimation of the monaural subjective parameters

7 Signal processing for auralization

7.1 The concept of auralization

7.2 Fundamentals of signal processing

7.2.1 Signals and systems

7.2.2 Impulse response and transfer function
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.3</td>
<td>Fourier transformation</td>
<td>110</td>
<td></td>
</tr>
<tr>
<td>7.4</td>
<td>Analogue-to-digital conversion</td>
<td>112</td>
<td></td>
</tr>
<tr>
<td>7.5</td>
<td>Discrete Fourier transformation</td>
<td>115</td>
<td></td>
</tr>
<tr>
<td>7.6</td>
<td>Fast Fourier transformation</td>
<td>116</td>
<td></td>
</tr>
<tr>
<td>7.6.1</td>
<td>Sources of errors, leakage and time windows</td>
<td>117</td>
<td></td>
</tr>
<tr>
<td>7.7</td>
<td>Digital filters</td>
<td>119</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Characterization of sources</td>
<td>123</td>
<td></td>
</tr>
<tr>
<td>8.1</td>
<td>Airborne sound sources</td>
<td>123</td>
<td></td>
</tr>
<tr>
<td>8.1.1</td>
<td>Multipole synthesis</td>
<td>124</td>
<td></td>
</tr>
<tr>
<td>8.1.2</td>
<td>Musical instruments</td>
<td>126</td>
<td></td>
</tr>
<tr>
<td>8.1.3</td>
<td>Singing voice</td>
<td>128</td>
<td></td>
</tr>
<tr>
<td>8.1.4</td>
<td>Speaking voice</td>
<td>129</td>
<td></td>
</tr>
<tr>
<td>8.1.5</td>
<td>Anechoic recordings</td>
<td>129</td>
<td></td>
</tr>
<tr>
<td>8.2</td>
<td>Structure-borne sound sources</td>
<td>133</td>
<td></td>
</tr>
<tr>
<td>8.2.1</td>
<td>General approach</td>
<td>133</td>
<td></td>
</tr>
<tr>
<td>8.2.2</td>
<td>3-D force sources</td>
<td>135</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Convolution and sound synthesis</td>
<td>137</td>
<td></td>
</tr>
<tr>
<td>9.1</td>
<td>Discrete convolution</td>
<td>137</td>
<td></td>
</tr>
<tr>
<td>9.2</td>
<td>FFT convolution</td>
<td>139</td>
<td></td>
</tr>
<tr>
<td>9.2.1</td>
<td>Segmented convolution</td>
<td>139</td>
<td></td>
</tr>
<tr>
<td>9.3</td>
<td>Binaural synthesis</td>
<td>141</td>
<td></td>
</tr>
<tr>
<td>9.4</td>
<td>Binaural mixing console</td>
<td>143</td>
<td></td>
</tr>
<tr>
<td>9.5</td>
<td>Spatial resolution of HRTF</td>
<td>145</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Simulation models</td>
<td>147</td>
<td></td>
</tr>
<tr>
<td>10.1</td>
<td>Simulation methods for sound and vibrational fields</td>
<td>147</td>
<td></td>
</tr>
<tr>
<td>10.1.1</td>
<td>Reciprocity</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>10.1.2</td>
<td>Frequency domain models</td>
<td>153</td>
<td></td>
</tr>
<tr>
<td>10.1.3</td>
<td>Time domain models</td>
<td>162</td>
<td></td>
</tr>
<tr>
<td>10.2</td>
<td>Two-port models</td>
<td>166</td>
<td></td>
</tr>
<tr>
<td>10.2.1</td>
<td>Transfer path models</td>
<td>170</td>
<td></td>
</tr>
<tr>
<td>10.3</td>
<td>Other models</td>
<td>173</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Simulation of sound in rooms</td>
<td>175</td>
<td></td>
</tr>
<tr>
<td>11.1</td>
<td>General</td>
<td>175</td>
<td></td>
</tr>
<tr>
<td>11.1.1</td>
<td>CAD room model</td>
<td>176</td>
<td></td>
</tr>
<tr>
<td>11.1.2</td>
<td>Absorption coefficients</td>
<td>180</td>
<td></td>
</tr>
<tr>
<td>11.1.3</td>
<td>Scattering coefficients</td>
<td>181</td>
<td></td>
</tr>
<tr>
<td>11.2</td>
<td>Stochastic ray tracing</td>
<td>181</td>
<td></td>
</tr>
<tr>
<td>11.2.1</td>
<td>Point-in-polygon test</td>
<td>184</td>
<td></td>
</tr>
<tr>
<td>11.2.2</td>
<td>Detectors</td>
<td>185</td>
<td></td>
</tr>
</tbody>
</table>
11.2.3 Presentation of results ............................................. 186
11.2.4 Curved surfaces ..................................................... 188
11.2.5 Reproducibility in stochastic ray tracing .................... 190
11.2.6 Computation times versus uncertainties – case studies ..................................................... 197
11.3 Image source model ........................................................... 199
11.3.1 Classical model ...................................................... 199
11.3.2 Audibility test ........................................................ 202
11.3.3 Limitations ............................................................. 204
11.3.4 Diffraction ............................................................. 206
11.3.5 Reduction of computational load by preprocessing ..................................................... 207
11.4 Hybrid image source models (deterministic ray tracing) .... 210
11.5 Systematic uncertainties of geometrical acoustics .......... 213
11.6 Hybrid models in room acoustics ................................ 216
11.6.1 Hybrid deterministic-stochastic models ................ 217
11.7 Construction of binaural room impulse responses ........... 222

12 Simulation and auralization of airborne sound insulation ..... 227
12.1 Definitions of airborne sound transmission ................. 228
12.2 Sound insulation of building elements ....................... 229
12.3 Sound insulation of buildings ....................................... 233
12.3.1 Flanking transmission ............................................ 235
12.4 Sound transmission prediction models .................... 235
12.5 Auralization of airborne sound insulation ...................... 238

13 Simulation and auralization of structure-borne sound ....... 245
13.1 Definitions of impact sound transmission ...................... 245
13.2 Impact sound model .................................................... 246
13.3 Impact sound auralization ............................................ 249
13.4 Structure-borne interaction model ................................. 251

14 Binaural transfer path synthesis ........................................ 255
14.1 Source identification and characterization ...................... 257
14.1.1 Airborne sound sources ......................................... 258
14.1.2 Structure-borne sound sources ............................... 261
14.2 Transfer path characterization ........................................ 262
14.3 Auralization in BTPS .................................................. 264

15 Aspects of real-time processing ........................................... 267
15.1 Real-time binaural synthesis ........................................... 268
15.1.1 HRTF in multiple degrees of freedom ..................... 269
15.2 Room acoustical real-time auralization.............................. 270
  15.2.1 Source and receiver................................................ 271
  15.2.2 Real-time processing of image sources ................. 272
  15.2.3 Real-time modelling of reverberation.................... 275
15.3 Hybrid real-time room auralization................................. 277

16 3-D sound reproduction and virtual reality systems ............ 279
  16.1 Headphone systems............................................................ 280
    16.1.1 Headphone equalization for binaural signals......... 283
    16.1.2 Individual filters..................................................... 284
  16.2 Loudspeaker systems ......................................................... 287
    16.2.1 VBAP surround sound........................................... 288
    16.2.2 Ambisonics ............................................................ 288
    16.2.3 Wave field synthesis .............................................. 289
    16.2.4 Binaural loudspeaker technology........................... 293
  16.3 VR technology and integrated VR systems ....................... 298

Annex .......................................................................................... 303
  Material data................................................................................. 303
  Tables of random-incidence absorption coefficients, $\alpha$........ 304
  Tables of random-incidence scattering coefficients, $s$ ......... 311
  Tables of sound reduction indices, $R$................................. 316

References .......................................................................................... 319

Index ..................................................................................................... 331
Auralization
Fundamentals of Acoustics, Modelling, Simulation, Algorithms and Acoustic Virtual Reality
Vorländer, M.
2008, XV, 335 p., Hardcover
ISBN: 978-3-540-48829-3