
Contents

Acronyms	V
Notation	VI
List of Symbols	VII
1 Introduction	1
2 Fundamentals	5
2.1 Physical and Acoustical Quantities – Conventions	5
2.2 Basics in Signal Processing	8
2.2.1 Description of Systems and the Time-Frequency Relation	8
2.2.2 Sampling in Time Domain	9
2.2.3 Sampling in Frequency Domain	10
2.2.4 Discrepancy between Time and Frequency Domain Models	11
2.2.5 Quantization in Time Domain	13
2.3 Parametric Transfer Function Models	14
2.3.1 Poles, Zeros and Resonators	14
2.3.2 Common Acoustic Poles and Zeros Approach	16
2.3.3 Rational Fit and Vector Fit	17
2.4 Uncertainty Modeling Techniques	18
2.4.1 Guide to the Expression of Uncertainty in Measurement .	18
2.4.2 Distribution and Probability Density Functions	19
2.4.3 Monte-Carlo Simulations	20
3 Measurement of Acoustic Systems	21
3.1 Characterization of LTI Systems	21
3.1.1 Excitation Signals and Deconvolution	22
3.1.2 Noise Influences	29
3.2 The Acoustic Measurement Chain	31
3.3 Nonlinear Systems	33
3.3.1 Basic Nonlinear Model	34
3.3.2 Wiener-Hammerstein Model	37
3.3.3 Harmonic Impulse Responses using Exponential Sweeps	40
3.3.4 Inter-modulation Artifacts	45
3.3.5 Relationship between Harmonics and Polynomial Coefficients	47
3.3.6 Generalization of the Relation	48
3.4 Implementation and Emulation of the Measurement Chain	53

3.5	Dealing with Nonlinear Systems	55
3.5.1	Separation of Harmonics	55
3.5.2	Suppressing certain Harmonics	56
3.5.3	Measuring at the Quantization Limit	59
3.6	Post-processing of Measurement Data	61
3.7	Application—Uncertainties in Room Acoustic Parameters	63
3.7.1	Simulation Setup	63
3.7.2	Derivation of Room Acoustic Parameters	67
3.7.3	Comparison with Measurement Results	71
3.8	Summary and Scientific Contribution	73
4	Uncertainties in Airborne Transfer Paths	75
4.1	Modeling Sound Sources and Receiver	75
4.1.1	Point Source in Free-Field	76
4.1.2	Directivity Patterns—Spherical Harmonics	76
4.1.3	Loudspeaker Cap Model	77
4.2	Application I—Reflection Index of Sound Barriers	79
4.2.1	Measurement Method for Reflection Index	79
4.2.2	Modeling of the Measurement Setup	82
4.3	Room Modes and Modal Superposition	94
4.3.1	Analytic Model for Rectangular Rooms	95
4.3.2	Remark on the Derivation of Room Acoustic Parameters .	101
4.3.3	Parametric Model and Rational Fitting	102
4.4	Application II—Microphone Position and Source Orientation .	105
4.4.1	Microphone Position and Room Acoustic Parameter . .	105
4.4.2	Comparison with Room Acoustic Measurements	107
4.4.3	Uncertainty Modeling—Position of Receiver	111
4.4.4	Uncertainty Modeling—Orientation of Source	114
4.5	Measurement of Transfer Functions for Variable Source Directivities	120
4.5.1	Developed Measurement Method	120
4.5.2	Limitation of the Method	121
4.5.3	Measurement in a Medium-sized Room	123
4.6	Application III—Directivity and Room Acoustic Parameters .	124
4.7	Summary and Scientific Contribution	128
5	Uncertainties in Structure-borne Transfer Paths	131
5.1	Remark on Structure-borne Uncertainty Analysis	131
5.2	Source, Receiver and their Interaction	133
5.2.1	Impedance and Mobility	134
5.2.2	Characterization of Structure-borne Sound Sources . .	136
5.2.3	Modeling the Coupling of Source and Receiver	137
5.3	TPA Methods in Matrix Notation	138
5.3.1	Load-Response Methods	139
5.3.2	Response-Response Methods	142

5.3.3	Relation of the Methods and Path Contributions	143
5.4	Characterization of Vibration Isolators	144
5.4.1	Two-Port Theory and Modeling	145
5.4.2	Matrix Notation for TPA Methods	148
5.5	Application I—Uncertainty in Sensor Position	150
5.6	Application II—Modeling of Typical Simplifications	154
5.7	Summary and Scientific Contribution	159
6	Conclusion and Outlook	161
A	Appendix	167
A.1	The ITA-Toolbox for MATLAB	167
A.1.1	Short History	167
A.1.2	Functionality and Concept	168
A.1.3	Professional Sound Boards—Hardware Communication .	169
A.1.4	Measurement Classes	170
A.2	Rotation of Physical Multipoles	171
A.3	Room Acoustic Parameters and Modal Superposition	172
A.3.1	The Schroeder Curve and Room Modes	173
A.3.2	Low-frequency Oscillation of the Schroeder Curve . . .	175
A.4	Changes in Temperature and Room Transfer Function	177
A.5	Influence of the Size of the Scan Grid	178
A.6	Influence of the Number of Modes	180
A.7	Implementation of OTPA Simulator	183
Bibliography		185
CV		203