

# Contents

<b>1 Introduction.....</b>	<b>1</b>
1.1 Prologue.....	1
1.2 Ultrasonic System Modeling – An Overview.....	2
1.3 Some Remarks on Notation.....	19
1.4 Organization of the Book.....	19
1.5 Reference.....	20
1.6 Suggested Reading .....	20
<b>2 The Pulser.....</b>	<b>21</b>
2.1 Characteristics of a Pulser .....	21
2.2 Measurement of the Circuit Parameters of a Pulser .....	24
2.3 Pulser Models .....	31
2.4 References .....	34
2.5 Exercises.....	34
<b>3 The Cabling .....</b>	<b>35</b>
3.1 Cable Modeling .....	35
3.2 Measurement of the Cabling Transfer Matrix .....	41
3.3 References .....	44
3.4 Exercises.....	44
<b>4 Transmitting Transducer and the Sound Generation Process .....</b>	<b>47</b>
4.1 Transducer Modeling.....	47
4.2 Transducer Acoustic Radiation Impedance .....	54
4.3 Transducer Impedance and Sensitivity.....	58
4.4 The Sound Generation Process.....	60
4.5 References .....	63
4.6 Exercises.....	63
<b>5 The Acoustic/Elastic Transfer Function and the Sound Reception Process .....</b>	<b>67</b>
5.1 Wave Processes and Sound Reception .....	67
5.2 The Blocked Force.....	69

5.3 The Acoustic/Elastic Transfer Function .....	71
5.4 The Acoustic Sources and Transducer on Reception .....	77
5.5 The Cable and the Receiver in the Reception Process.....	83
5.6 A Complete Reception Process Model .....	88
5.7 References .....	93
5.8 Exercises .....	93
<b>6 Transducer Characterization .....</b>	<b>95</b>
6.1 Transducer Electrical Impedance .....	95
6.2 Transducer Sensitivity .....	98
6.3 Transducer Effective Radius and Focal Length.....	108
6.4 References .....	113
6.5 Exercises .....	114
<b>7 The System Function and Measurement System Models.....</b>	<b>115</b>
7.1 Direct Measurement of the System Function .....	115
7.2 System Efficiency Factor.....	118
7.3 Complete Measurement System Modeling.....	120
7.4 References .....	125
7.5 Exercises .....	125
<b>8 Transducer Sound Radiation.....</b>	<b>127</b>
8.1 An Immersion Transducer as a Baffled Source .....	127
8.2 An Angular Plane Wave Spectrum Model .....	130
8.3 A Rayleigh-Sommerfeld Integral Transducer Model .....	134
8.4 On-Axis Behavior of a Planar Circular Piston Transducer.....	137
8.5 The Paraxial Approximation.....	139
8.6 Far field On-Axis and Off-Axis Behavior .....	143
8.7 A Spherically Focused Piston Transducer .....	146
8.8 Wave Field in the Plane at the Geometrical Focus .....	152
8.9 Radiation of a Focused Transducer through an Interface .....	153
8.10 Sound Beam in a Solid Generated by a Contact Transducer .....	154
8.11 Angle Beam Shear Wave Transducer Model .....	159
8.12 Transducer Beam Radiation through Interfaces .....	159
8.13 Acoustic/Elastic Transfer Function – Focused Transducer .....	164
8.14 Acoustic/Elastic Transfer Function – Rectangular Transducer ..	171
8.15 References .....	174
8.16 Exercises .....	174
<b>9 Gaussian Beam Theory and Transducer Modeling.....</b>	<b>179</b>
9.1 The Paraxial Wave Equation and Gaussian Beams in a Fluid.....	180
9.2 The Paraxial Wave Equation and Gaussian Beams in a Solid.....	194

---

9.3 Transmission/Reflection of a Gaussian Beam at an Interface .....	196
9.4 Gaussian Beams and ABCD Matrices .....	212
9.5 Multi-Gaussian Transducer Beam Modeling .....	221
9.6 References .....	230
9.7 Exercises .....	231
<b>10 Flaw Scattering .....</b>	<b>235</b>
10.1 The Far-Field Scattering Amplitude .....	235
10.2 The Kirchhoff Approximation for Volumetric Flaws .....	241
10.3 The Leading Edge Response of Volumetric Flaws .....	247
10.4 The Kirchhoff Approximation for Cracks .....	251
10.5 Validity of the Kirchhoff Approximation .....	258
10.6 The Kirchhoff Approximation for Side-drilled Holes .....	268
10.7 The Born Approximation .....	277
10.8 Separation of Variables Solutions .....	286
10.9 Other Scattering Models and Methods .....	293
10.10 References .....	296
10.11 Exercises .....	298
<b>11 Ultrasonic Measurement Models .....</b>	<b>301</b>
11.1 Reciprocity-based Measurement Model .....	301
11.2 The Thompson-Gray Measurement Model .....	314
11.3 A Measurement Model for Cylindrical Reflectors .....	316
11.4 References .....	319
11.5 Exercises .....	320
<b>12 Ultrasonic Measurement Modeling with MATLAB .....</b>	<b>323</b>
12.1 A Summary of the Measurement Models .....	323
12.2 The Multi-Gaussian Beam Model .....	327
12.3 Measurement Model Input Parameters .....	331
12.4 A Multi-Gaussian Beam Model in MATLAB .....	337
12.5 Ultrasonic Attenuation in the Measurement Model .....	348
12.6 The System Function .....	350
12.7 Flaw Scattering Models .....	353
12.8 The Thompson-Gray Measurement Model .....	357
12.9 A Large Flaw Measurement Model .....	373
12.10 A Measurement Model for Cylindrical Reflectors .....	378
12.11 References .....	387
<b>13 Applications of Ultrasonic Modeling .....</b>	<b>389</b>
13.1 Obtaining Flaw Scattering Amplitudes Experimentally .....	389
13.2 Distance-Amplitude-Correction Transfer Curves .....	393

13.3 Angle Beam Inspection Models and Applications .....	404
13.4 Model-Assisted Flaw Identification .....	425
13.5 Model-Assisted Flaw Sizing.....	433
13.6 References .....	437
<b>A Fourier Transforms and the Delta Function .....</b>	<b>439</b>
A.1 The Fourier Transform and Its Inverse .....	439
A.2 The Discrete Fourier Transform .....	447
A.3 The Delta Function .....	452
A.4 References.....	454
A.5 Exercises .....	455
<b>B Impedance Concepts and Equivalent Circuits .....</b>	<b>459</b>
B.1 Impedance .....	459
B.2 Thévenin's Theorem .....	463
B.3 Measurement of Equivalent Sources and Impedances.....	468
B.4 References.....	470
B.5 Exercises .....	470
<b>C Linear System Fundamentals .....</b>	<b>473</b>
C.1 Two Port Systems .....	473
C.2 Linear Time-Shift Invariant (LTI) Systems .....	480
C.3 References.....	486
C.4 Exercises .....	486
<b>D Wave Propagation Fundamentals .....</b>	<b>491</b>
D.1 Waves in a Fluid .....	491
D.2 Plane Waves in a Fluid .....	493
D.3 Waves in an Isotropic Elastic Solid .....	496
D.4 Plane Waves in an Isotropic Elastic Solid .....	498
D.5 Reflection/Refraction of Plane Waves – Normal Incidence .....	504
D.6 Reflection/Refraction of Plane Waves – Oblique Incidence .....	507
D.7 Spherical Waves .....	522
D.8 Ultrasonic Attenuation.....	525
D.9 References.....	529
D.10 Exercises .....	529
<b>E Waves Used in Nondestructive Evaluation .....</b>	<b>535</b>
E.1 Shear Waves.....	535
E.2 Rayleigh Waves .....	537
E.3 Plate (Lamb) Waves.....	539
E.4 References.....	542

---

<b>F Gaussian Beam Fundamentals .....</b>	<b>543</b>
F.1 Gaussian Beams and the Paraxial Wave Equation .....	543
F.2 Quasi-Plane Wave Conditions and the Paraxial Approximation..	549
F.3 Transmission/Reflection of a Gaussian Beam.....	552
F.4 Gaussian Beams at Multiple Interfaces and ABCD Matrices .....	558
F.5 Multi-Gaussian Beam Modeling .....	568
F.6 References .....	570
F.7 Exercises.....	570
 <b>G MATLAB Functions and Scripts .....</b>	 <b>575</b>
G.1 Fourier Analysis Functions.....	575
G.2 Setup Functions .....	578
G.3 Ultrasonic Beam Modeling Functions .....	578
G.4 Flaw Scattering Functions .....	580
G.5 Ultrasonic Measurement Modeling Functions.....	581
G.6 Miscellaneous Functions.....	582
G.7 MATLAB Script Examples .....	582
G.8 Code Listings of Some Supporting Functions .....	584
 <b>Index.....</b>	 <b>599</b>

Ultrasonic Nondestructive Evaluation Systems

Models and Measurements

Schmerr Jr, L.W.; Song, J.-S.

2007, XV, 602 p., Hardcover

ISBN: 978-0-387-49061-8