
CONTENTS

Foreword	xiii
Acknowledgments	xvii
About the Author	xix
Contributors	xxi
1 INTRODUCTION TO GPR PROSPECTING	1
1.1 What Is a GPR?	1
1.2 GPR Systems and GPR Signals	4
1.3 GPR Application Fields	5
1.4 Measurement Configurations, Bands, and Polarizations	6
1.5 GPR Data Processing	8
2 CHARACTERIZATION OF THE HOST MEDIUM	10
2.1 The Characteristics of the Host Medium	10
2.2 The Measure of the Propagation Velocity in a Masonry	11
2.3 The Measure of the Propagation Velocity in a Homogeneous Soil	13
2.3.1 Interfacial Data in Common Offset Mode with a Null Offset: The Case of a Point-like Target	13
2.3.2 Interfacial Data in Common Offset Mode with a Null Offset: The Case of a Circular Target	17
2.3.3 Interfacial Data in Common Offset Mode with a Non-null Offset: The Case of a Point-like Target	18
2.3.4 Noninterfacial Data in Common Offset Mode with a Null Offset: The Case of a Point-like Target	22
2.3.5 Interfacial Data in Common Midpoint (CMP) Mode	25
2.4 Lossy, Magnetic, and Dispersive Media	27
Questions	31

3	GPR DATA SAMPLING: FREQUENCY AND TIME STEPS	32
3.1	Stepped Frequency GPR Systems: The Problem of the Aliasing and the Frequency Step	32
3.2	Shape and Thickness of the GPR Pulses	36
3.3	Stepped Frequency GPR Systems: The Problem of the Demodulation and the Frequency Step	40
3.4	Aliasing and Time Step for Pulsed GPR Systems	45
	Questions	47
4	THE 2D SCATTERING EQUATIONS FOR DIELECTRIC TARGETS	48
4.1	Preliminary Remarks	48
4.2	Derivation of the Scattering Equations Without Considering the Effect of the Antennas	51
4.3	Calculation of the Incident Field Radiated by a Filamentary Current	61
4.4	The Plane Wave Spectrum of an Electromagnetic Source in a Homogeneous Space	61
4.5	The Insertion of the Source Characteristics in the Scattering Equations	65
4.6	The Far Field in a Homogeneous Lossless Space in Terms of Plane Wave Spectrum	69
4.7	The Effective Length of an Electromagnetic Source in a Homogeneous Space	73
4.8	The Insertion of the Receiver Characteristics in the Scattering Equations	75
	Questions	77
5	THE 2D SCATTERING EQUATIONS FOR MAGNETIC TARGETS	79
5.1	The Scattering Equations with Only Magnetic Anomalies	79
5.2	The Contribution of the x -Component of the Fitzgerald Vector	83
5.3	The Contribution of the z -Component of the Fitzgerald Vector	88
5.4	The Joined Contribution of Both the x - and z -Components of the Fitzgerald Vector	93
5.5	The Case with Both Dielectric and Magnetic Anomalies	94
	Questions	95
6	ILL-POSEDNESS AND NONLINEARITY	96
6.1	Electromagnetic Inverse Scattering	96
6.2	Ill-Posedness	97
6.3	Nonlinearity	97

6.4	The Ill-Posedness of the Inverse Scattering Problem	100
6.5	The Nonlinearity of the Inverse Scattering Problem	103
	Questions	103
7	EXTRACTION OF THE SCATTERED FIELD DATA FROM THE GPR DATA	105
7.1	Zero Timing	105
7.2	Muting of Interface Contributions	106
7.3	The Differential Configuration	110
7.4	The Background Removal	111
	Questions	115
8	THE BORN APPROXIMATION	116
8.1	The Classical Born Approximation	116
8.2	The Born Approximation in the Presence of Magnetic Targets	119
8.3	Weak and Nonweak Scattering Objects	120
	Questions	121
9	DIFFRACTION TOMOGRAPHY	122
9.1	Introduction to Diffraction Tomography	122
9.2	Diffraction Tomography for Dielectric Targets	123
9.3	Diffraction Tomography for Dielectric Targets Seen Under a Limited View Angle	130
9.4	The Effective Maximum and Minimum View Angle	140
9.5	Horizontal Resolution	142
9.6	Vertical Resolution	145
9.7	Spatial Step	147
9.8	Frequency Step	148
9.9	Time Step	149
9.10	The Effect of a Non-null Height of the Observation Line	150
9.11	The Effect of the Radiation Characteristics of the Antennas	156
9.12	DT Relationship in the Presence of Magnetic Targets	158
9.13	DT Relationship for a Differential Configuration	160
9.14	DT Relationship in the Presence of Background Removal	163
	Questions	168

10	TWO-DIMENSIONAL MIGRATION ALGORITHMS	169
10.1	Migration in the Frequency Domain	169
10.2	Migration in the Time Domain (Raffaele Persico and Raffaele Solimene)	175
	Questions	181
11	THREE-DIMENSIONAL SCATTERING EQUATIONS	182
	<i>Lorenzo Lo Monte, Raffaele Persico, and Raffaele Solimene</i>	
11.1	Scattering in Three Dimensions: Redefinition of the Main Symbols	182
11.2	The Scattering Equations in 3D	184
11.3	Three-Dimensional Green's Functions	184
11.4	The Incident Field	185
11.5	Homogeneous 3D Green's Functions	187
11.6	The Plane Wave Spectrum of a 3D Homogeneous Green's Function	192
11.7	Half-Space Green's Functions	197
	Questions	204
12	THREE-DIMENSIONAL DIFFRACTION TOMOGRAPHY	205
12.1	Born Approximation and DT in 3D	205
12.2	Ideal and Limited-View-Angle 3D Retrievable Spectral Sets	210
12.3	Spatial Step and Transect	212
12.4	Horizontal Resolution (Raffaele Persico and Raffaele Solimene)	213
12.5	Vertical Resolution, Frequency and Time Steps	217
	Questions	218
13	THREE-DIMENSIONAL MIGRATION ALGORITHMS	219
13.1	3D Migration Formulas in the Frequency Domain	219
13.2	3D Migration Formulas in the Time Domain	222
13.3	3D Versus 2D Migration Formulas in the Time Domain	226
	Questions	228
14	THE SINGULAR VALUE DECOMPOSITION	229
14.1	The Method of Moments	229
14.2	Reminders About Eigenvalues and Eigenvectors	231
14.3	The Singular Value Decomposition	234
14.4	The Study of the Inverse Scattering Relationship by Means of the SVD	238
	Questions	241

15	NUMERICAL AND EXPERIMENTAL EXAMPLES	242
15.1	Examples with Regard to the Measure of the Propagation Velocity	242
15.1.1	Common Offset Interfacial Data with Null Offset on a Homogeneous Soil	242
15.1.2	Common Offset Interfacial Data on a Wall, Neglecting the Offset Between the Antennas	245
15.1.3	Interfacial Common Offset Data on a Homogeneous Soil: The Effect on the Offset Between the Antennas	247
15.1.4	Noninterfacial Common Offset Data with a Null Offset Between the Antennas	249
15.1.5	Common Midpoint Data	250
15.2	Exercises on Spatial Step and Horizontal Resolution	252
15.3	Exercises on Frequency Step and Vertical Resolution	264
15.4	Exercises on the Number of Trial Unknowns	271
15.5	Exercises on Spectral and Spatial Contents	274
15.6	Exercises on the Effect of the Height of the Observation Line	280
15.7	Exercises on the Effect of the Extent of the Investigation Domain	284
15.8	Exercises on the Effects of the Background Removal	295
15.9	2D and 3D Migration Examples with a Single Set and Two Crossed Sets of B-Scans (Marcello Ciminale, Giovanni Leucci, Loredana Matera, and Raffaele Persico)	304
15.10	2D and 3D Inversion Examples (Ilaria Catapano and Raffaele Persico)	311
	APPENDICES	327
	APPENDIX A (Raffaele Persico and Raffaele Solimene)	329
	APPENDIX B	334
	APPENDIX C	335
	APPENDIX D	337
	APPENDIX E	340
	APPENDIX F (Raffaele Persico and Raffaele Solimene)	346
	APPENDIX G: ANSWERS TO QUESTIONS	349
	References	358
	Index	365