# CONTENTS

PREFACE	xiii
ACKNOWLEDGMENTS	xvii
CONTENTS OF VOLUME 1	xix

#### PART III D MULTIPLE SCATTERING THEORY

#### CHAPTER 14 DIMULTIPLE SCATTERING THEORY OF WAVES IN STATIONARY AND MOVING SCATTERERS AND ITS RELATIONSHIP WITH TRANSPORT THEORY

14- <b>1</b>	Multiple Scattering Process Contained in Twersky's Theory	254
14-2	Statistical Averages for Discrete Scatterers	259
14-3	Foldy-Twersky's Integral Equation for the Coherent Field	261
14-4	Twersky's Integral Equation for the Correlation Function	263
14-5	Coherent Field	265
14-6	Plane Wave Incidence on a Slab of Scatterers-"Total Intensity"	268
14-7	Relationship between Multiple Scattering Theory and Transport Theory	274
14-8	Approximate Integral and Differential Equations for the Correlation	
	Function	276
14-9	Fundamental Equations for Moving Particles	279
14-10	Fluctuations due to the Size Distribution	285
Apper	ndix 14A Example of Twersky's Scattering Process When $N = 3$	286
Apper	ndix 14B Stationary Phase Evaluation of a Multiple Integral I	287
Appe	ndix 14C Forward Scattering Theorem	292

#### CHAPTER 15 IMULTIPLE SCATTERING THEORY OF WAVE FLUCTUATIONS AND PULSE PROPAGATION IN RANDOMLY DISTRIBUTED SCATTERERS

15-1	Fundamental Equations for Moving Scatterers	295
15-2	Correlation Function, Angular Spectrum, and Frequency Spectrum in the	
	Small Angle Approximation	296
15-3	Plane Wave Solution	298
15-4	Limitation on Image Resolution Imposed by Randomly Distributed	
	Scatterers	301
15-5	Output from Receiver in Randomly Distributed Scatterers	306
15-6	Spherical Wave in Randomly Distributed Particles	308
15-7	Backscattering from Randomly Distributed Scatterers	308
		vij

# viii 🗆 contents

15-8	Pulse Propagation in Randomly Distributed Scatterers	313
15-9	Integral and Differential Equations for Two-Frequency Mutual	
	Coherence Function in Randomly Distributed Scatterers	314
15-10	Two-Frequency Mutual Coherence Function for the Plane Wave Case	316
15-11	Weak Fluctuation Solution of a Plane Pulse Wave	318
15-12	Strong Fluctuation Solution of a Plane Pulse Wave	321

# PART IV . WAVES IN RANDOM CONTINUUM AND TURBULENCE

### CHAPTER 16 CI SCATTERING OF WAVES FROM RANDOM CONTINUUM AND TURBULENT MEDIA

16-1	Single Scattering Approximation and Received Power	370
16-2	Scattering Cross Section per Unit Volume of the Stationary Random	227
	Medium	331
16-3	Booker-Gordon Formula	334
16-4	Gaussian Model and Kolmogorov Spectrum	336
16-5	Anisotropic Random Medium	338
16-6	Temporal Fluctuation of Scattered Fields due to a Time-Varying	
	Random Medium	339
16-7	Strong Fluctuations	342
16-8	Scattering of a Pulse by a Random Medium	343
16-9	Acoustic Scattering Cross Section per Unit Volume	344
16-10	Narrow Beam Equation	345

#### CHAPTER 17 LINE-OF-SIGHT PROPAGATION OF A PLANE WAVE THROUGH A RANDOM MEDIUM—WEAK FLUCTUATION CASE

17-1	Maxwell's Equations for a Fluctuating Medium	347
17-2	Born and Rytov Methods	349
17-3	Log-Amplitude and Phase Fluctuations	351
17-4	Plane Wave Formulation	351
17-5	Direct Method and Spectral Method	352
17-6	Spectral Representation of the Amplitude and Phase Fluctuations	353
17-7	Amplitude and Phase Correlation Functions	355
17-8	Amplitude and Phase Structure Functions	358
17-9	Spectral and Spatial Filter Functions	358
17-10	Homogeneous Random Media and Spectral Filter Function	360
17-11	Geometric Optical Region $L \ll l^2/\lambda$	361
17-12	The Region in Which $L \gg l^2/\lambda$	364
17-13	General Characteristics of the Fluctuations in a Homogeneous Random	
	Medium	365
17-14	Homogeneous Random Medium with Gaussian Correlation Function	366
17-15	Homogeneous and Locally Homogeneous Turbulence	367
17-16	Inhomogeneous Random Medium with Gaussian Correlation Function	
	and the Spatial Filter Function	371
17-17	Variations of the Intensity of Turbulence along the Propagation Path	373

.

CONTENTS		ix
----------	--	----

CHA	PTER 18 🗆 LINE-OF-SIGHT PROPAGATION OF SPHERICAL AND BEAM WAVES THROUGH A RANDOM MEDIUM—WEAK FLUCTUATION CASE	
18-1	Rytov Solution for the Spherical Wave	376
18-2	Variance for the Kolmogorov Spectrum	378
18-3	Correlation and Structure Functions for the Kolmogorov Spectrum	380
18-4	Beam Wave	380
18-5	Variance for a Beam Wave and the Validity of the Rytov Solution	383
18-6	Remote Probing of Planetary Atmospheres	384
18-7	Some Related Problems	385
CHA	PTER 19 TEMPORAL CORRELATION AND FREQUENCY	
	SPECTRA OF WAVE FLUCTUATIONS IN A RANDOM	
	MEDIUM AND THE EFFECTS OF AN	
	INHOMOGENEOUS RANDOM MEDIUM	
19-1	Temporal Frequency Spectra of a Plane Wave	388
19-2	When the Average Wind Velocity U Is Transverse and the Wind	
	Fluctuation $V_f$ is Negligible	389
19-3	Temporal Spectra due to Average and Fluctuating Wind Velocities	393
19-4	Temporal Frequency Spectra of a Spherical Wave	394
19-5	Two-Frequency Correlation Function	396
19-6	Crossed Beams	399
19-7	Wave Fluctuations in an Inhomogeneous Random Medium	401
19-8	Wave Fluctuations in a Localized Smoothly Varying Random Medium	403
CHAI	PTER 20  STRONG FLUCTUATION THEORY	
20-1	Parabolic Equation	408
20-2	Assumption for the Refractive Index Fluctuations	409
20-3	Equation for the Average Field and General Solution	410
20-4	Parabolic Equation for the Mutual Coherence Function	412
20-5	Solutions for the Mutual Coherence Function	414
20-6	Examples of Mutual Coherence Functions	418
20-7	Mutual Coherence Function in a Turbulent Medium	420
20-8	Temporal Frequency Spectra	422
20-9	I wo-Frequency Correlation Function	424
20-10	Plane wave Solution for the Two-Frequency Mutual Coherence Function	425
20-11	Puise Snape	428
20-12	Fourth Order Manual Frequency Spectra	429
20-13	This Server Theory	431
20-14	Approximate Solution for the This Concern	434
20-13	This Server Theory for Schedular W	438
20-10	Find Screen Fneory for Spherical Waves	44(
20-1/	Extended Madium	44(
20.10		

#### X 🗆 CONTENTS

.

20-20	Modulation Transfer Function of a Random Medium	448
20-21	Adaptive Optics	454

# PART V I ROUGH SURFACE SCATTERING AND REMOTE SENSING

# CHAPTER 21 ROUGH SURFACE SCATTERING

<b>21-</b> 1	Received Power and Scattering Cross Section per Unit Area of Rough	
	Surface	465
21-2	First Order Perturbation Solution for Horizontally Polarized Incident	
	Wave	467
21-3	Derivation of the First Order Scattering Cross Section per Unit Area	473
21-4	Statistical Description of a Rough Surface	476
21-5	Bistatic Cross Section of a Rough Surface	477
21-6	Effect of Temporal Variation of a Rough Surface	481
21-7	Ocean Wave Spectra	482
21-8	Other Related Problems	483
21-9	Kirchhoff Approximation—Scattering of Sound Wayes from a Rough	
	Surface	484
21-10	Coherent Field in the Kirchhoff Approximation	487
21-11	Scattering Cross Section per Unit Area of Rough Surface	488
21-12	Probability Distribution of a Scattered Field	401
		771
CHAP	TER 22 🗆 REMOTE SENSING AND INVERSION TECHNIQUES	
22-1	Remote Sensing of the Troposphere	493
22-2	Remote Sensing of the Average Structure Constant C, over the Path	495
22-3	Remote Sensing of the Average Wind Velocity over the Path	496
22-4	Remote Sensing of the Profile of the Structure Constant and the Ill-Posed	470
	Problem	

Problem	500
Inverse Problem	504
Smoothing (Regularization) Method	504
Statistical Inversion Technique	505
Backus-Gilbert Inversion Technique	508
Remote Sensing of Observables in Geophysics	512
	Inverse Problem Inverse Problem Smoothing (Regularization) Method Statistical Inversion Technique Backus-Gilbert Inversion Technique Remote Sensing of Observables in Geophysics

# APPENDIX A SPECTRAL REPRESENTATIONS OF A RANDOM FUNCTION

A-1	Stationary Complex Random Function	513
A-2	Stationary Real Random Function	515
A-3	Homogeneous Complex Random Function	515
A-4	Homogeneous and Isotropic Random Function	516
A-5	Homogeneous and Real Random Function	518
A-6	Stationary and Homogeneous Random Function	518
<b>A-</b> 7	"Frozen-In" Random Function	519

# APPENDIX B I STRUCTURE FUNCTIONS

B-1	Structure Function and Random Process with Stationary Increments	520
B-2	Spectral Representation of the Structure Function	522
B-3	Locally Homogeneous and Isotropic Random Function	523
B-4	Kolmogorov Spectrum	526
APP	ENDIX C I TURBULENCE AND REFRACTIVE INDEX FLUCTUATIONS	
C-1	Laminar Flow and Turbulence	528
C-2	Developed Turbulence	529
C-3	Scalar Quantities Conserved in a Turbulence and Neutral, Stable, and	
	Unstable Atmosphere	531
C-4	Fluctuations of the Index of Refraction	534
C-5	Structure Functions of a Conservative Scalar and the Index of Refraction	
	Fluctuation	534
C-6	The Energy Dissipation Rate s and the Energy Budget of Atmospheric	
	Turbulence	536
C-7	The Rate of Dissipation of the Fluctuation N	537
C-8	Calculation of the Structure Constant	538
C-9	Boundary Layer, Free Atmosphere, Large- and Small-Scale Turbulence	539
C-10	The Structure Constant for the Index of Refraction in the Boundary	
	Layer	539
C-11	The Structure Constant $C_n$ for Free Atmosphere	541
C-12	Relation between The Structure Constant C <sub>n</sub> and the Variance of the Index	
	of Refraction Fluctuation	542
APP	ENDIX D 🗆 SOME USEFUL MATHEMATICAL FORMULAS	
<b>D-</b> 1	Kummer Function	544
D-2	Confluent Hypergeometric Function	544
D-3	Other Integrals	545
REFE	RENCES	547
INDEX		564