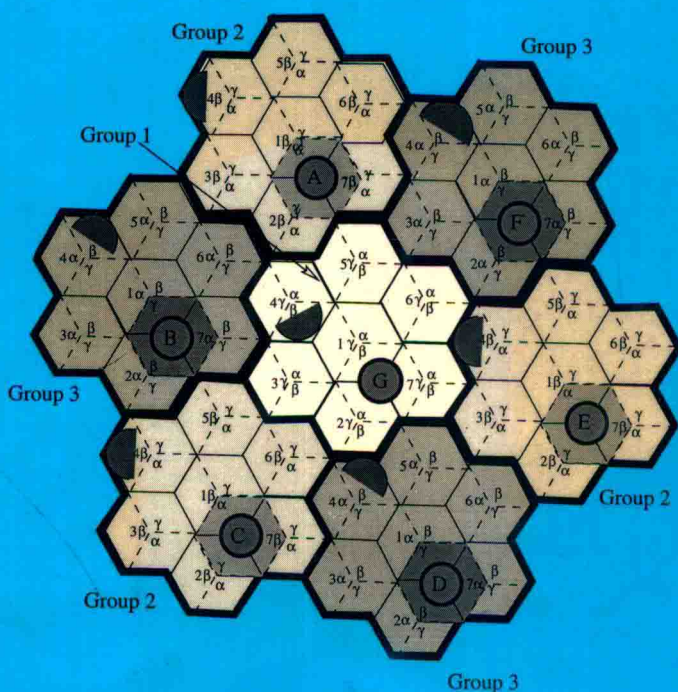


Principles of

MOBILE COMMUNICATION

Second Edition



Gordon L. Stüber

Principles of **Mobile Communication** **Second Edition**

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Atlanta, Georgia USA

Kluwer Academic Publishers
Boston/Dordrecht/London

Distributors for North, Central and South America:

Kluwer Academic Publishers
101 Philip Drive
Assinippi Park
Norwell, Massachusetts 02061 USA
Telephone (781) 871-6600
Fax (781) 871-6528
E-Mail <kluwer@wkap.com>

Distributors for all other countries:

Kluwer Academic Publishers Group
Distribution Centre
Post Office Box 322
3300 AH Dordrecht, THE NETHERLANDS
Telephone 31 78 6392 392
Fax 31 78 6546 474
E-Mail services@wkap.nl>



Electronic Services <<http://www.wkap.nl>>

Library of Congress Cataloging-in-Publication

Stüber, Gordon L., 1958-
Principles of mobile communication / Gordon L. Stüber.--2nd ed.
p. cm.
Includes bibliographical references and index.
ISBN 0-7923-7998-5
1. Mobile communication systems. I. Title.

TK6570.M6 S78 2000
621.3845--dc21

00-049332

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Printed on acid-free paper.

Printed in the United States of America

The Publisher offers discounts on this book for course use and bulk purchases. For further information, send e-mail to <agreene@wkap.com>.

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Mobile Communication
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Preface

This book follows from my first edition and is intended to provide a thorough, up to date, treatment of wireless physical communications. The book is derived from a compilation of course material that I have taught in a graduate-level course on physical wireless communications at Georgia Tech over the past decade. This textbook differs from others on the subject by stressing mathematical modeling and analysis. My approach is to include detailed derivations from first principles. The text is intended to provide enough background material for the novice student enrolled in a graduate level course, while having enough advanced material to prime the more serious graduate students that would like to pursue research in the area. The book is intended to stress the *fundamentals* of mobile communications engineering that are important to *any* mobile communication system. I have therefore kept the description of existing and proposed wireless standards and systems to a minimum. The emphasis on fundamental issues should benefit not only to students taking formal instruction, but also practicing engineers who are likely to already have a detailed familiarity with the standards and are seeking to deepen their knowledge of the fundamentals and principles of this important field.

Chapter 1 begins with an overview that is intended to introduce a broad array of issues relating to wireless communications. Included is a description of various wireless systems and services, basic concepts of cellular frequency reuse, and the link budget for cellular radio systems.

Chapter 2 treats propagation modeling and was inspired by the excellent reference by Jakes. It begins with a summary of propagation models for narrow-band and wide-band multipath channels, and provides a discussion of channel simulation techniques that are useful for radio link analysis. It concludes with a discussion of shadowing and path loss models. Chapter 3 is a related chapter that provides a detailed treatment of co-channel interference, the primary impairment in high capacity cellular systems.

Chapter 4 covers the various types of modulation schemes that are used in mobile communication systems along with their spectral characteristics. Chapter 5 discusses the performance of digital signal on narrow-band flat fading channels with a variety of receiver structures, while Chapter 6 includes a treatment of antenna diversity techniques.

Chapter 7 provides an extensive treatment of digital signaling on the fading ISI channels that are typical of mid-band land mobile radio systems. The chapter begins with the characterization of ISI channels and goes on to discuss techniques for combating ISI based on symbol-by-symbol equalization and sequence estimation. The chapter concludes with a discussion of co-channel demodulation and co-channel interference cancellation.

Chapter 8 covers bandwidth efficient coding techniques. The chapter begins with a discussion of basic block and convolutional coding. It then goes on to a detailed discussion on the design and performance analysis of convolutional and trellis codes for additive white Gaussian noise channels, and interleaved flat fading channels. The chapter concludes with an introduction to Turbo coding.

Chapter 9 is devoted to spread spectrum techniques. The chapter begins with an introduction to direct sequence and frequency hop spread spectrum. This is followed by a detailed treatment of spreading sequences. Also included is a discussion of the effects of tone interference on direct sequence spread spectrum, and the RAKE receiver performance on wide-band channels. The chapter wraps up with a discussion of the error probability of direct sequence code division multiple access.

Chapter 10 considers TDMA cellular architectures. The chapter begins with a discussion of conventional TDMA systems and how they are evolved to meet traffic growth. This is followed by hierarchical overlay/underlay architectures. Finally, the chapter wraps up with macrodiversity TDMA architectures. Chapter 11 is the CDMA counterpart to Chapter 10 and considers issues that are relevant to cellular CDMA, such as capacity estimation and power control.

Chapter 10 covers the important problem of link quality evaluation and handoff initiation, and handoff performance, in cellular systems. Chapter 11 provides an overview of the various channel assignment techniques that have been proposed for FDMA and TDMA cellular systems.

The book contains far too much detail to be taught in a one-semester course. However, I believe that it can serve as a suitable text in most situations through the appropriate selection of material. My own preference for a one-semester course is to include the following in order: Chapter 1, Chapter 2, Sections 3.1 and 3.2, Chapter 4, Chapter 5, and Chapter 6. Then choose from Chapters 8 through 13 depending on my interest at the time.

I would like to acknowledge all those who have contributed to the preparation of this book. The reviewers Vijay Bhargava at the University of Victoria and Sanjiv Nanda at Lucent Technologies were very valuable in the early

stages of the first edition of this book. The subsequent review by Upamanyu Madhow at the University of Illinois and in particular the detailed review by Keith Chugg at the University of Southern California were highly useful for improving this book. I am grateful to my doctoral students, past and present, who have contributed significantly to this book. The contributions of Wern-Ho Sheen, Khalid Hamied, Mark Austin, Jeff (Lihbor) Yiin, Ming-Ju Ho, Li-Chun (Robert) Wang, Krishna Narayanan, Dukhyun Kim, Jinsoup Joung, and John (Yongchae) Kim are particularly noteworthy. Finally, I would like to thank BellSouth, GTE Labs, Motorola, Panasonic, Hitachi, Nortel, Korea Telecom, WiLAN, and the National Science Foundation, for sustaining my research efforts in wireless communications over the past 10 years. This research experience has in many cases lead to material that I brought to the classroom and have included in this book.

GORDON L. STÜBER

To my parents
Beatrice and Lothar Stüber

Contents

Preface	xiii
1. INTRODUCTION	1
1.1 Wireless Systems and Standards	3
1.1.1 First Generation Cellular Systems	3
1.1.2 Second Generation Cellular Systems	3
1.1.2.1 GSM/DCS1800/PCS1900	3
1.1.2.2 IS-54/136 and IS-95	5
1.1.2.3 PDC	7
1.1.3 Cordless Telephone Systems	7
1.1.4 Third Generation Cellular Systems	8
1.1.5 Wireless LANs and and PANs	14
1.2 Frequency Reuse and the Cellular Concept	16
1.3 Mobile Radio Propagation Environment	19
1.4 Co-channel Interference and Noise	21
1.5 Receiver Sensitivity and Link Budget	23
1.6 Coverage	28
1.7 Spectral Efficiency and Capacity	30
2. PROPAGATION MODELING	39
2.1 Frequency-Non-Selective (Flat) Multipath-Fading	41
2.1.1 Received Signal Correlation and Spectrum	44
2.1.2 Received Envelope and Phase Distribution	50
2.1.2.1 Rayleigh Fading	50
2.1.2.2 Ricean Fading	51
2.1.2.3 Nakagami Fading	53
2.1.2.4 Envelope Phase	55
2.1.3 Envelope Correlation and Spectra	56
2.1.3.1 Squared-Envelope Correlation and Spectra	60
2.1.4 Level Crossing Rates and Fade Durations	61
2.1.4.1 Envelope Level Crossing Rate	61
2.1.4.2 Zero Crossing Rate	66
2.1.4.3 Average Envelope Fade Duration	66
2.1.5 Spatial Correlations	67

2.1.5.1	Received Signal at the Base Station	68
2.2	Frequency-Selective Multipath-Fading	70
2.2.1	Statistical Channel Correlation Functions	74
2.2.2	Classification of Channels	75
2.2.3	Channel Output Autocorrelation	79
2.3	Laboratory Simulation of Multipath-Fading Channels	80
2.3.1	Filtered Gaussian Noise	80
2.3.2	Sum of Sinusoids Method	81
2.3.3	Multiple Faded Envelopes	85
2.3.4	Simulation of Wide-band Multipath-Fading Channels	90
2.4	Shadowing	98
2.4.1	Laboratory Simulation of Shadowing	99
2.4.2	Composite Shadowing-Fading Distributions	100
2.4.2.1	Composite Gamma-log-normal Distribution	102
2.5	Path Loss Models	103
2.5.1	Path Loss in Macrocells	103
2.5.1.1	Okumura-Hata and CCIR Models	104
2.5.1.2	Lee's Area-to-Area Model	105
2.5.2	Path Loss in Outdoor Microcells	108
2.5.2.1	COST231-Hata Model	108
2.5.2.2	COST231-Walfish-Ikegami Model	109
2.5.2.3	Street Microcells	111
2.5.3	Path Loss in Indoor Microcells	114
3.	CO-CHANNEL INTERFERENCE	127
3.1	Multiple Log-normal Interferers	129
3.1.1	Fenton-Wilkinson Method	130
3.1.2	Schwartz-and Yeh-Method	132
3.1.3	Farley's Method	134
3.1.4	Numerical Comparisons	135
3.2	Probability of Outage	135
3.3	Multiple Ricean/Rayleigh Interferers	139
3.4	Multiple Log-normal Nakagami Interferers	140
3.4.1	Statistically Identical Interferers	142
3.5	Multiple Log-normal Ricean/Rayleigh Interferers	146
3.5.1	Single Interferer	148
3.5.2	Multiple Interferers	148
4.	MODULATED SIGNALS AND THEIR POWER SPECTRA	153
4.1	Representation of Band-pass Modulated Signals	154
4.1.1	Vector Space Representations	155
4.1.2	Gram-Schmidt Procedure	156
4.1.3	Signal Energy and Correlations	159
4.2	Nyquist Pulse Shaping	161
4.3	Quadrature Amplitude Modulation (QAM)	165
4.4	Phase Shift Keying (PSK)	168
4.4.1	Offset QPSK (OQSPK)	169

4.4.2	$\pi/4$ -DQPSK	171
4.5	Orthogonal Modulation and Variants	172
4.6	Orthogonal Frequency Division Multiplexing (OFDM)	175
4.6.1	Multiresolution Modulation	177
4.6.2	FFT-Based OFDM System	177
4.7	Continuous Phase Modulation (CPM)	182
4.7.1	Full Response CPM	183
4.7.1.1	Minimum Shift Keying (MSK)	184
4.8	Partial Response CPM	186
4.8.1	Gaussian Minimum Shift Keying (GMSK)	189
4.8.2	Linearized GMSK (LGMSK)	192
4.8.3	Tamed Frequency Modulation (TFM)	195
4.9	Power Spectral Densities of Digitally Modulated Signals	198
4.9.1	Psd of a Complex Envelope	199
4.9.2	Psd of QAM	205
4.9.3	Psd of PSK	206
4.9.4	Psd of OQPSK	206
4.9.5	Psd of $\pi/4$ -DQPSK	207
4.9.6	Psd of OFDM	208
4.9.7	Psd of Full Response CPM	211
4.9.7.1	Psd of CPFSK	215
4.9.7.2	Psd of MSK	217
4.9.8	Psd of GMSK and TFM	218
5.	DIGITAL SIGNALING	
	ON FLAT FADING CHANNELS	227
5.1	Vector Space Representation of Received Signals	228
5.2	Detection of Known Signals in Additive White Gaussian Noise	230
5.3	Probability of Error	234
5.3.1	Pairwise Error Probability	236
5.3.2	Upper Bounds on Error Probability	237
5.3.3	Lower Bound on Error Probability	239
5.3.4	Bit Versus Symbol Error Probabilities	239
5.4	Error Probability of PSK	240
5.5	Error Probability of M-QAM	246
5.6	Error Probability of Orthogonal Signals	249
5.7	Error Probability of OFDM	252
5.8	Error Probability of MSK	256
5.9	Differential Detection	258
5.9.1	Differential Detection of $\pi/4$ -DQPSK	261
5.10	Non-coherent Detection	262
5.11	Detection of CPM Signals	267
5.11.1	Coherent CPM Demodulator	268
5.11.2	Non-coherent CPM Demodulator	268
6.	ANTENNA DIVERSITY	275
6.1	Diversity Combining	276

6.2	Selective Combining	277
6.3	Maximal Ratio Combining	280
6.4	Equal Gain Combining	284
6.5	Switched Combining	286
6.6	Differential Detection with Equal Gain Combining	290
6.7	Transmitter Diversity	291
6.7.1	Space-Time Transmit Diversity	293
7.	EQUALIZATION	
	AND INTERFERENCE CANCELLATION	301
7.1	Overview	302
7.1.1	Symbol-by-symbol Equalizers	302
7.1.2	Sequence Estimation	304
7.1.3	Co-Channel Interference Cancellation	306
7.2	Modeling of ISI Channels	307
7.2.1	Vector Representation of Received Signals	309
7.3	Optimum Receiver for ISI Channels with AWGN	310
7.3.1	Discrete-Time White Noise Channel Model	311
7.3.1.1	Time Varying Channels with Diversity	314
7.3.1.2	$T/2$ -Spaced Receiver	315
7.4	Symbol-by-Symbol Equalizers	317
7.4.1	Linear Equalizer	319
7.4.1.1	Zero-Forcing (ZF)	319
7.4.1.2	Minimum Mean-Square-Error (MMSE)	322
7.4.2	Decision Feedback Equalizer (DFE)	326
7.4.3	Comparison of Symbol-by-Symbol Equalizers	329
7.5	Sequence Estimation	329
7.5.1	MLSE and the Viterbi Algorithm	329
7.5.1.1	Adaptive MLSE Receiver	335
7.5.1.2	$T/2$ -spaced MLSE Receiver	337
7.5.2	Delayed Decision-Feedback Sequence Estimation	337
7.5.3	Reduced-State Sequence Estimation	340
7.6	Error Probability for MLSE on ISI Channels	341
7.6.1	Static ISI Channels	344
7.6.2	Fading ISI Channels	346
7.6.3	Computing the Union Bound	349
7.6.3.1	Error-State Diagram	350
7.6.3.2	The Stack Algorithm	351
7.6.4	Examples	352
7.7	Error Probability for $T/2$ -spaced MLSE Receiver	355
7.7.1	T -spaced MLSE Receiver	355
7.7.2	$T/2$ -spaced MLSE Receiver	357
7.7.3	Practical $T/2$ -spaced MLSE Receiver	359
7.7.4	Timing Phase Sensitivity	361
7.8	MIMO MLSE Receivers	362
7.8.1	System and Channel Model	363
7.8.2	Joint Maximum Likelihood Sequence Estimation	364

7.8.3	Discrete-time MIMO Channel Model	366
7.8.4	The Viterbi Algorithm	370
7.8.5	Pairwise Error Probability	370
7.8.6	$T/2$ -Spaced MIMO MLSE Receiver	371
7.8.6.1	Error Probability	373
7.8.6.2	Timing Phase Sensitivity	374
7.8.6.3	Practical Receiver	376
7.8.7	Interference Rejection Combining MLSE	378
7.8.8	Examples	381

8.	ERROR CONTROL CODING	391
8.1	Block Codes	394
8.1.1	Binary Block Codes	394
8.1.1.1	Minimum Distance	395
8.1.1.2	Syndromes	396
8.1.1.3	Error Detection	396
8.1.1.4	Weight Distribution	397
8.1.1.5	Probability of Undetected Error	397
8.1.1.6	Error Correction	398
8.1.1.7	Standard Array Decoding	398
8.1.1.8	Syndrome Decoding	399
8.2	Convolutional Codes	399
8.2.1	Encoder Description	399
8.2.2	State and Trellis Diagrams, and Weight Distribution	402
8.2.3	Recursive Systematic Convolutional (RSC) Codes	405
8.3	Trellis Coded Modulation	407
8.3.1	Encoder Description	407
8.3.2	Mapping by Set Partitioning	408
8.4	Coded Performance on AWGN Channels	412
8.4.1	Union Bound for Convolutional Codes	413
8.5	Coded Performance on Interleaved Flat Fading Channels	417
8.5.1	Design Rules for TCM on Flat Fading Channels	422
8.5.1.1	Multidimensional TCM	423
8.5.1.2	Multiple TCM (MTCM)	424
8.5.1.3	2-D Trellis Codes	426
8.6	Coded Performance on ISI Channels	427
8.6.1	TCM on Static ISI Channels	429
8.6.2	TCM on Noninterleaved Fading ISI Channels	429
8.6.3	Examples	431
8.6.3.1	Static ISI Channels	431
8.6.3.2	Multipath Fading ISI Channels	433
8.6.4	Evaluation of Union Bounds for TCM	436
8.7	Turbo Codes	443
8.7.1	PCCC Encoder	444
8.7.2	PCCC Decoder	446
8.7.3	SCCC Encoder and Decoder	448
8.7.4	Weight Distribution	448
8.7.4.1	Weight Distribution of PCCCs	450

8.7.4.2	Weight Distribution of SCCCs	453
9.	SPREAD SPECTRUM TECHNIQUES	457
9.1	Basic Principles of Spread Spectrum	459
9.1.1	Direct Sequence (DS) Spread Spectrum	459
9.1.2	Frequency Hop (FH) Spread Spectrum	462
9.2	Spreading Sequences	464
9.2.1	Spreading Waveforms	466
9.2.2	m -sequences	467
9.2.3	Gold Sequences	469
9.2.4	Kasami Sequences	471
9.2.5	Barker Sequences	472
9.2.6	Walsh-Hadamard Sequences	473
9.2.6.1	Orthogonal and Bi-orthogonal Modulation	473
9.2.7	Variable Length Orthogonal Codes	474
9.2.8	Complementary Code Keying (CCK)	475
9.3	Power Spectral Density of DS Spread Spectrum Signals	475
9.4	Performance of DS/QPSK in Tone Interference	478
9.5	DS Spread Spectrum on Frequency-Selective Fading Channels	491
9.5.1	RAKE Receiver	495
9.6	Error Probability for DS CDMA on AWGN Channels	501
9.6.1	Standard Gaussian Approximation	505
9.6.2	Improved Gaussian Approximation	506
9.6.3	Simplified Gaussian Approximation	507
10.	TDMA CELLULAR ARCHITECTURES	515
10.1	Cell Sectoring	516
10.1.1	Cell Sectoring with Wide-beam Directional Antennas	516
10.1.2	Sectoring with Switched-beam Antennas	518
10.1.3	Trunkpool Techniques	520
10.1.4	Cellular Performance with Switched-beam Antennas	522
10.1.4.1	Reverse Channel	523
10.1.4.2	Forward Channel	524
10.1.4.3	Performance Criteria and Results	524
10.2	Conventional Cell Splitting	528
10.2.1	Reuse Partitioning	530
10.2.1.1	Cell Splitting with Reuse Partitioning	532
10.3	Cluster Planned Hierarchical Architecture	532
10.3.1	System Architecture	533
10.3.2	Underlaid Microcell Planning Algorithm	534
10.3.3	Performance Analysis of Cluster Planned Architecture	539
10.3.3.1	Macrocell Performance	540
10.3.3.2	Microcell Performance	545
10.3.3.3	Adjacent Channel Interference Analysis	553
10.4	Macrodiversity Architectures	554
10.4.1	Probability of Co-channel Interference Outage	556
10.4.2	Shadow Correlation	557
10.4.3	Numerical Examples	559

11. CDMA CELLULAR ARCHITECTURES	567
11.1 Capacity of Cellular CDMA	568
11.1.1 Reverse Link Capacity	570
11.1.2 Forward Link Capacity	577
11.1.3 Imperfect Power Control	578
11.2 Error Probability with RAKE Reception	580
11.2.1 Maximal Ratio Combining	583
12. LINK QUALITY MEASUREMENT AND HANDOFF INITIATION	589
12.1 Signal Strength Based Hard Handoff Algorithms	595
12.2 Pilot-to-Interference Ratio Based Soft Handoff Algorithms	597
12.3 Signal Strength Averaging	598
12.3.1 Choosing the Proper Window Length	599
12.3.2 Choosing the Proper Number of Samples to Average	601
12.4 Velocity Estimation in Cellular Systems	604
12.4.1 Level Crossing Rate Estimators	606
12.4.2 Covariance Approximation Methods	608
12.4.3 Velocity Estimator Sensitivity	611
12.4.3.1 Effect of the Scattering Distribution	612
12.4.3.2 Effects of Additive Gaussian Noise	615
12.5 Velocity Adaptive Handoff Algorithms	617
12.5.1 Effect of N_{λ}	618
12.5.2 Corner Effects and Sensitivity to a and W_l	619
12.5.3 Velocity Adaptive Handoff Performance	620
12.6 Hard Handoff Analysis	621
12.6.1 Simulation Results	626
12.7 Soft Handoff Analysis	627
12.7.1 Simulation Results	629
12.8 CIR-based Link Quality Measurements	631
12.8.1 Discrete-Time Model for Signal Quality Estimation	632
12.8.1.1 Estimation of $(I+N)$	633
12.8.1.2 Estimation of $C/(I+N)$	635
12.8.2 Training Sequence Based $C/(I+N)$ Estimation	636
12.9 Summary	638
13. CHANNEL ASSIGNMENT TECHNIQUES	645
13.1 Centralized DCA	650
13.1.1 Maximum Packing (MP)	650
13.1.2 MAXMIN Scheme	652
13.2 Decentralized DCA	653
13.2.1 First Available (FA) and Nearest Neighbor (NN)	653
13.2.2 Dynamic Resource Acquisition (DRA)	654
13.3 Fully Decentralized DCA	655
13.3.1 Channel Segregation (CS)	655
13.3.2 Channel Segregation with Variable Threshold	655
13.3.3 Minimum Interference (MI) Schemes	657

13.3.4	Aggressive and Timid DCA Strategies	657
13.4	Hybrid FCA/DCA Schemes	659
13.5	Borrowing Schemes	660
13.5.1	Borrowing with Channel Ordering (BCO)	660
13.5.2	Borrowing with Directional Locking	662
13.5.3	Borrowing without Locking	663
13.5.4	Compact Pattern Based DCA	664
13.6	Directed Retry and Directed Handoff	665
13.7	Moving Direction Strategies	665
13.8	Reduced Transceiver Coverage	666
13.8.1	Reuse Partitioning	666
13.9	Handoff Priority	667
13.10	Example DCA Schemes for TDMA Systems	668
13.10.1	The Simple DCA (SDCA) Strategy	670
13.10.2	A Queueing DCA Strategy	670
13.10.3	An Aggressive DCA Strategy	673
13.10.4	Simulation Model, Results, and Discussion	676
13.11	Concluding Remarks	682
Appendix A	Probability and Random Processes	685
A.1	Conditional Probability and Bayes' Theorem	685
A.2	Means, Moments, and Moment Generating Functions	687
A.3	Some Useful Probability Distributions	688
A.3.1	Discrete Distributions	688
A.3.2	Continuous Distributions	689
A.4	Upper Bounds on the cdfc	694
A.5	Random Processes	697
A.5.1	Moments and Correlation Functions	698
A.5.2	Crosscorrelation and Crosscovariance	703
A.5.3	Complex-Valued Random Processes	705
A.5.4	Power Spectral Density	706
A.5.5	Random Processes Filtered by Linear Systems	707
A.5.6	Discrete-time Random Processes	709
A.5.7	Cyclostationary Random Processes	711
References		713
Index		745

Chapter 1

INTRODUCTION

Wireless systems and services have undergone a remarkable development, since the first cellular and cordless telephone systems were introduced in the early 1980s. First generation cellular and cordless telephone systems were based on analog FM technology and designed to carry narrow-band circuit switched voice services. Second generation cellular and cordless telephone systems were introduced in the early 1990s that use digital modulation, and offer improved spectral efficiency, and voice quality. However, these second generation systems are still used for narrow-band voice and data services. Third generation wireless systems, currently under development that offer substantially higher bit rates ranging from 9.6 kb/s for satellite users, 144 kb/s for vehicular users, 384 kb/s for pedestrian users to 2.048 Mb/s for indoor office environments. These systems are intended to provide voice, data, the more bandwidth intensive multimedia services, while satisfying more stringent availability and quality of service (QoS) requirements in all types environments. Fourth generation systems are also on the horizon that will provide broadband wireless access with asymmetric bit rates that approach 1 Gb/s.

Radio access systems are often distinguished by their coverage areas and bit rates, as shown in Fig. 1.1. **Mobile satellite** systems provide global coverage to mobile users, but with very low bit rates. **Land mobile radio systems** use terrestrial cellular and microcellular networks to provide wide area coverage to vehicular and pedestrian users. **Fixed wireless** access systems provide radio connectivity over a campus or neighborhood area to stationary users. Finally, **wireless local area networks** provide stationary in-building users with very high speed services.