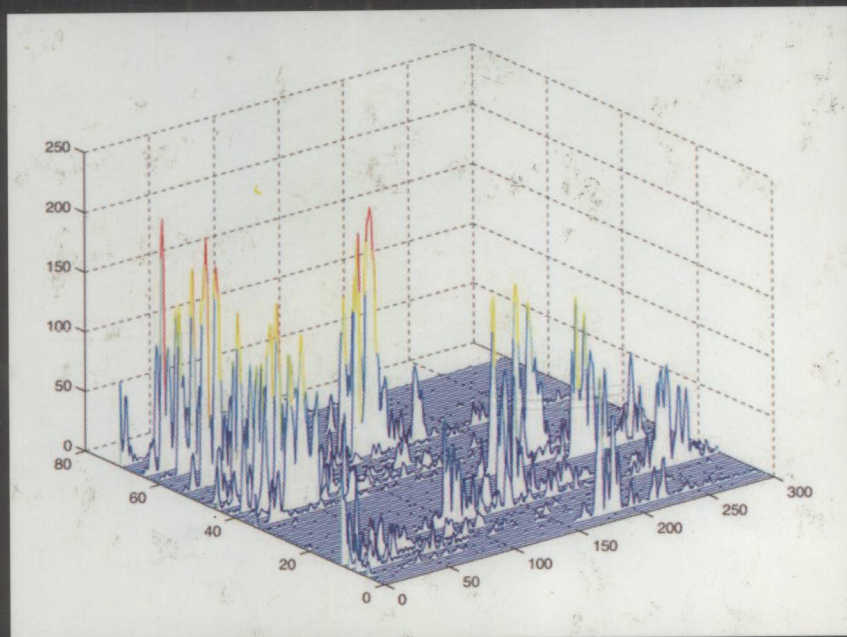


Wireless Communications Theory and Techniques



Asrar U. H. Sheikh



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WIRELESS COMMUNICATIONS

Theory and Techniques

by

Asrar U. H. Sheikh



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DEDICATION

This book is dedicated to my wife Parveen, my children Farhana, Fahim and Samia. It would have been impossible to write this book unless my family had not forgone their claim on the time they deserved.

Preface

Wireless communication systems, since their inception in the form of cellular communications, have spread rapidly throughout the western world and the trend is catching on in the developing countries as well. These systems have caused revolutionary changes in the way we live. Cellular Communications have become important both as means of communication and as a new domain of commercial enterprise. Hand held telephones are now rapidly replacing the fixed telephone and in less than twenty years, the number of subscribers has reached nearly three quarters of a billion. In a short span of twenty years, the cellular communications progressed from the first generation to the third generation systems, which started operations in Japan on October 1, 2001. The first generation wireless technology, which was thought to be obsolete is now being used for fixed wired telephony in several countries of Asia, Africa and Latin America. As some commentator said in 1983, the cellular system is the best thing that has happened in telecommunications since the introduction of computers to the masses.

This book is written to provide readers with the fundamental concepts of wireless communications. It is intended for a graduate course on wireless communications but it could be easily adopted at the senior level by skipping material involving difficult mathematical manipulations. The text does not go through the rigorous material on mathematical treatment of electromagnetic waves and propagation, rather it emphasizes more on the practical aspects of this. Besides providing some fundamental concepts, the text goes into discussions on implications of these principles on the wireless system design.

The book is divided into three parts. Following the introductory chapter on the overview of wireless communications, Chapters 2 and 3 examine the arduous radio signal environment in which mobile communications has to provide the subscriber with reliable telecommunication services. The second chapter reviews the basic radio wave propagation theory with a view to predict signal strength at any point within and beyond the radio coverage area of a transmitter. This is termed macro (large scale) characterization of mobile radio channels. The starting point is a theoretical model accurate only under ideal conditions, e.g., a planar perfectly conducting surface surrounding the transmitter. Modifications are then introduced to account for the effects of terrain variation on signal strength. Methods are presented for the prediction

of mean signal strength for a given transmitter-receiver geometry. Chapter 3 proceeds with a study of the micro (small scale) structure of signal variations caused primarily by scatterers in the immediate vicinity of the mobile unit. The starting point is the channel impulse response. The length and variability of the impulse response characterizes channel delay spread, fading and path strengths. In practice, vehicle movement causes rapid variations about a mean, and deep fades will be encountered, which preclude reliable communications over the channel unless sophisticated signal processing methods are used.

The second part of this book consists of five chapters that consider methods of transmission, reception, and processing of signals, which had been affected by the harsh propagation conditions. Chapter 4 examines signal transmission and reception techniques. The main emphasis in this chapter is on performance analysis under fading and frequency selective conditions. The performance of several digital modulation systems are examined under the above mentioned conditions. Interference in wireless communications has a very significant impact on the performance, quality of service and system capacity. It is a major cause of inefficiencies in spectrum utilization. Chapter 5 goes into considerable depth of interference, distortion and noise. Interference, modeling, signal outage because of channel impairments are the main topics of discussion. The impact of interference and channel fading on frequency reuse and receiver performance is analyzed.

Antennas are essential part of any wireless communications. Chapter 6 describes the various types of antennas and their characteristics. Again rigorous mathematical treatment is avoided. The chapter considers methods whereby a suitable antenna system can be employed to combat fading and substantially enhance performance. It is seen that fading can severely degrade the performance of various modulation schemes. This theme is followed up in Chapter 7 in the context of signal processing. Multiple signals distinguished, for example, by frequency, space, time or carrier polarization can be combined to minimize the effect of fading. The impact of diversity on the signal restoration is emphasized. The role of equalization, coding and interleaving in improving the performance is discussed in this chapter. Multiple access communications is introduced in Chapter 8. It discusses the methods of using spectrum resource in the multi-user environment. In this chapter, analyses on the impact of access schemes on the system capacity are presented. This chapter sets the scene for the requirements on multiuser communications introduced in the third part of the book. Conventional and multichannel trunked systems in addition to modern cellular systems are introduced.

The third part of the book consists of six chapters mostly on system aspects. This part of the book does not have solved examples or problems.

Chapter 9 introduces the principles of several wireless systems. It describes, paging, private land mobile systems and gives a brief account of wireless systems. The chapter takes a broader perspective, dealing with details on the implementation of systems operating in the mobile wireless environment. A closely related topic, treated in Chapter 10, is that of Private Mobile Data Communications Systems (PMDCS) such as packet switched radio, and voice-data integrated systems. An important application of packet switched radio is the mobile data distribution network, which has both civilian and military applications. Other applications include transportation, public safety, ambulance, and wireless local area networks (WLANS) and high speed wireless networks using ATM technology. Chapter 11 outlines the principles of designing cellular systems. It makes distinction between designing a TDMA and CDMA systems. Principles of mobile wireless systems; frequency assignment, control architecture, vehicle location and handoff are included in the discussion.

The details on several mobile communications systems in operation are explored in Chapter 12. In particular, the first two generations of cellular systems are described. These include AMPS, GSM, and CDMA. The new emerging applications in telecommunications is steering wireless communications towards multimedia wireless communications. In Chapter 13, five new standards for 3G are described. However, WCDMA (IMT-DS) is described in some detail. Chapter 14 examines a logical extension of the cellular network concept, that is systems beyond 3G. The chapter presents a window into the future by speculating on the shape of the future networks. This chapter also looks at technologies suitable for the wideband 4G systems.

I would like to acknowledge the contributions made by several of my present and former colleagues who encouraged me into writing the book. In particular, I would like to thank Professor J.S. Riordon who agreed to co-author this book. Unfortunately, he could not continue because of his heavy commitments to the administration and later due to my departure from Carleton University, Ottawa, Canada. However, his contributions at the start of this project are much appreciated. My thanks also go to Mohammad Abdullah Bugshan who persuaded Lucent Technologies in creating the Chair in Telecommunications that I currently hold. I would like to acknowledge the support of King Fahd University of Petroleum and Minerals in providing research facilities and reducing my teaching load to facilitate completion of this project. I should not forget to thank my students who kept me on toes by asking interesting questions and insisting on seeing the book in print.

Asrar U. H. Sheikh
Dhahran, Saudi Arabia
June 30, 2003

Contents

Chapter 1	1
OVERVIEW OF WIRELESS COMMUNICATIONS	
1.1 <i>Historical Perspective</i>	4
1.2 <i>Services</i>	5
1.3 <i>Spectrum and Management Issues</i>	8
1.4 <i>Technologies</i>	11
1.5 <i>Prognosis and Challenges</i>	12
1.6 <i>Summary</i>	14
<i>Problems</i>	14
<i>References</i>	15
Chapter 2	17
MACRO-CHARACTERIZATION OF WIRELESS CHANNELS	
2.1 <i>Signal Transmission Over Mobile Radio Channels</i>	17
2.2 <i>Free Space Field</i>	22
2.3 <i>Plane Earth Propagation</i>	23
2.4 <i>Egli's Model for Path Loss Estimation</i>	27
2.5 <i>Propagation Beyond the Line of Sight</i>	28
2.6 <i>Terrain Definitions</i>	32
2.6.1 <i>Okumura's Terrain Classification</i>	33
2.6.2 <i>Effective Antenna Height</i>	33
2.7 <i>Propagation Over Quasi-smooth Terrain</i>	35
2.8 <i>Propagation Loss Over Irregular Terrain</i>	39
2.8.1 <i>Rolling Hilly Terrain and Parameter Δh</i>	40
2.8.1.1 <i>Rolling Hilly Terrain Correction Factors</i>	40
2.8.2 <i>General Sloping Angle Parameter</i>	41
2.8.2.1 <i>General Sloping Terrain Correction Factors</i>	42
2.8.3 <i>Distance Parameter for Mixed Land-Sea Path</i>	42
2.8.3.1 <i>Mixed Land-Sea Path Correction Factor</i>	43
2.8.4 <i>Correction Factors for Mountain Ridges</i>	47
2.8.5 <i>Loss Due to Multiple Mountain Ridges</i>	49
2.8.6 <i>Street Orientation and Environmental Clutter</i>	52

2.8.6.1 <i>Environmental Clutter:</i>	52
2.9 <i>Propagation Considerations Towards Total Integration</i>	54
2.9.1 <i>Street Level Signal Strength Variations</i>	54
2.9.2 <i>Propagation Within Buildings: External Signal Source</i>	55
2.9.3 <i>Loss Sensitivity to Transmitter Location and Building Materials</i>	55
2.9.4 <i>Propagation Within Buildings: Internal Signal Source</i>	57
2.9.5 <i>Propagation in Tunnels</i>	59
2.10 <i>Shadowing in Wireless Communications</i>	60
2.11 <i>Statistical Estimation of Area Coverage</i>	61
2.11.1 <i>Signal coverage in small area</i>	61
2.11.2 <i>Wide Area Coverage Estimation</i>	62
2.12 <i>Land Mobile Satellite Path Loss</i>	67
2.13 <i>Summary</i>	70
<i>Problems</i>	70
<i>References</i>	76

Chapter 3 83

MICRO-CHARACTERIZATION OF WIRELESS CHANNELS

3.1 <i>Channel Impulse Response</i>	84
3.1.1 <i>Channel Impulse Response Measurements</i>	85
3.1.2 <i>Delay and Frequency Spread Models</i>	91
3.1.2.1 <i>Outdoor Frequency and Delay Spread Models</i>	91
3.1.2.2 <i>Delay-Frequency Models for Indoors Wireless Channels</i>	93
3.1.2.3 <i>Path-Arrival Models</i>	94
3.1.2.3.1 <i>Turin's Model</i>	94
3.1.2.3.2 <i>Saleh's Model</i>	94
3.1.2.4 <i>Indoors Measurements and Statistical Models</i>	96
3.2 <i>Doppler Spread and Coherence Time</i>	97
3.3 <i>Physically Motivated Radio Channel Models</i>	98
3.3.1 <i>Development of a Model</i>	99
3.3.1.1 <i>Channel Model for Narrowband Transmission:</i>	
<i>Single Sinusoid Transmission</i>	100
3.3.1.2 <i>Other Non-Conventional Channel Models</i>	104
3.4 <i>Spectral Theory of Signal Reception</i>	106
3.4.1 <i>Field Components Correlation Functions</i>	110
3.5 <i>Envelope and Phase Correlation Functions</i>	110
3.5.1 <i>Average Level Crossing Rate (ACR)</i>	112
3.5.2 <i>Average Fade Duration (AFD)</i>	115
3.5.3 <i>Signal Phase Characterization</i>	119
3.5.3.1 <i>Random Frequency Modulation</i>	120

3.5.3.2	<i>Power Spectrum of Random FM</i>	121
3.5.4	<i>Envelope and Phase Correlation Bandwidth</i>	124
3.6	<i>M-B and M-M Propagation Models</i>	128
3.7	<i>Wideband Channel Models</i>	130
3.8	<i>Channel Models for Simulations</i>	131
3.9	<i>Markovian Models for Digital Transmission</i>	134
3.10	<i>Summary</i>	139
	<i>Problems</i>	140
	<i>References</i>	144

Chapter 4 **149**

SIGNAL TRANSMISSION OVER MOBILE RADIO CHANNELS

4.1	<i>Frequency Modulation of Analog Signals</i>	151
4.1.1	<i>S/N in the Absence of Fading</i>	153
4.1.2	<i>Threshold Performance</i>	158
4.1.3	<i>Performance in Rayleigh Fading</i>	163
4.2	<i>DSB-AM of Analog Signals</i>	168
4.3	<i>SSB-AM</i>	169
4.3.1	<i>Diminished Pilot Carrier SSB</i>	171
4.3.2	<i>Pilot Tone-in-Band (TIB) SSB</i>	171
4.3.3	<i>Tone-Above-Band SSB</i>	175
4.3.4	<i>Amplitude Companded Single Side-Band (ACSSB)</i>	176
4.3.5	<i>Performance of SSB Systems</i>	177
4.4	<i>Digital Transmission over Mobile Channels</i>	177
4.4.1	<i>Basic Principles of Digital Communications</i>	178
4.4.2	<i>Baseband Signalling Waveforms</i>	179
4.4.2.1	<i>Power Spectrum of Signalling Waveforms</i>	180
4.4.2.1.1	<i>Polar Signalling</i>	182
4.4.2.1.2	<i>NRZ Unipolar</i>	183
4.4.2.1.3	<i>Bi-polar Pseudoternary (Alternate Mark Inversion (AMI))</i>	184
4.4.2.1.4	<i>Duobinary Signalling</i>	186
4.5	<i>Bandpass Digital Transmission Systems</i>	188
4.5.1	<i>Amplitude Shift Keying</i>	188
4.5.2	<i>Binary Phase Shift Keying</i>	189
4.5.3	<i>Differential Phase-Shift Keying</i>	191
4.5.4	<i>Binary Frequency Shift Keying (BFSK)</i>	193
4.6	<i>Performance of M-ary Signalling</i>	196
4.6.1	<i>Performance of MPSK</i>	197
4.6.2	<i>Performance of MFSK</i>	199
4.6.3	<i>Spectrally Efficient Modulation Methods</i>	201
4.6.4	<i>Minimum Frequency Shift Keying (MSK)</i>	202

4.6.5	<i>Gaussian Filtered Minimum Frequency Shift Keying (GMSK)</i>	204
4.6.6	<i>Duobinary MSK</i>	205
4.6.7	<i>TFM and GTFM</i>	206
4.7	<i>Performance Over Impaired Channels</i>	208
4.7.1	<i>Performance in Frequency Selective Channels</i>	208
4.7.2	<i>Performance Over Flat Fading Channels</i>	210
4.7.2.1	<i>Performance in Rayleigh Faded Shadowed Channels</i>	213
4.7.2.2	<i>Performance in the Presence of Frequency Selective Fading</i>	215
4.8	<i>Summary</i>	216
	<i>Problems</i>	217
	<i>References</i>	220

Chapter 5 **225**

INTERFERENCE, DISTORTION AND NOISE

5.1	<i>Interference and Frequency Reuse</i>	226
5.1.1	<i>Frequency Assignment in Fading</i>	226
5.2	<i>Co-channel Interference and Outage</i>	227
5.2.1	<i>Co-channel Interference Models</i>	228
5.2.1.1	<i>Ricean-Rayleigh Model</i>	229
5.2.1.2	<i>Ricean-Rayleigh-Lognormal Model</i>	232
5.3	<i>Signal Outage Analysis</i>	234
5.3.1	<i>Medium to Large Cell Co-channel Interference Modeling</i>	234
5.3.2	<i>Noncoherent and Coherent Interferers</i>	235
5.3.3	<i>Effect of Frequency Selective Multipath Fading</i>	236
5.3.4	<i>Effect of Shadowing</i>	236
5.4	<i>Calculation of Reuse Distance</i>	239
5.5	<i>Intermodulation Interference</i>	241
5.6	<i>Near-to-Far-End Ratio Interference</i>	244
5.7	<i>Impact of Interference on Modulated System</i>	247
5.7.1	<i>Co-channel Interference in Analog Systems</i>	247
5.7.1.1	<i>Signal and Interference Conditions Steady Channel Conditions</i>	247
5.7.2	<i>Adjacent Channel Interference</i>	255
5.7.3	<i>Effect of Fading on Co-channel Interference</i>	256
5.7.4	<i>ACI in Presence of Rayleigh Fading</i>	259
5.8	<i>Digital Transmission in Interference</i>	262
5.8.1	<i>Performance in Interference and Fading</i>	262
5.8.2	<i>GMSK Performance in Interference and Fading</i>	264
5.8.3	<i>$\pi/4$-QDPSK Performance in Interference and Fading</i>	267
5.8.4	<i>Error Bounds for $\pi/4$-QDPSK</i>	267

5.9	<i>Environmental Noise</i>	277
5.9.1	<i>Amplitude Probability Distribution</i>	278
5.9.2	<i>Average Crossing Rates</i>	278
5.9.3	<i>Pulse Width and Pulse Interval Distributions</i>	278
5.9.4	<i>Impulsive Noise Measurements</i>	279
5.10	<i>Summary</i>	281
	<i>Problems</i>	281
	<i>References</i>	283

Chapter 6 **287**

ANTENNAS FOR MOBILE RADIO SYSTEMS

6.1	<i>Base Station Antennas</i>	288
6.2	<i>Advanced Base Station Antennas</i>	289
6.3	<i>Installation of Base Station Antennas</i>	290
6.4	<i>Antenna Combiners and Multicouplers</i>	292
6.5	<i>Antennas for Mobile Terminals</i>	293
6.5.1	<i>Mounting Considerations for Mobile Antennas</i>	295
6.5.2	<i>Experimental Evaluation of Mounting Positions</i>	297
6.6	<i>Reception with Directive Antennas</i>	299
6.7	<i>Antenna Polarization and Signal Characteristics</i>	301
6.8	<i>Effect of Antenna Pattern on Handoffs</i>	302
6.9	<i>Adaptive Antennas</i>	303
	<i>Summary</i>	304
	<i>References</i>	305

Chapter 7 **307**

SIGNAL PROCESSING IN WIRELESS COMMUNICATIONS

7.1	<i>Basic Diversity Classification</i>	308
7.1.1	<i>Space Diversity</i>	309
7.1.2	<i>Frequency Diversity</i>	309
7.1.3	<i>Time Diversity</i>	309
7.1.4	<i>Polarization Diversity</i>	310
7.1.5	<i>Angle Diversity</i>	310
7.2	<i>Methods of Signal Recombination</i>	310
7.2.1	<i>Scanning Diversity</i>	312
7.2.2	<i>Selection Diversity</i>	312
7.2.3	<i>Maximal Ratio Combining (MRC)</i>	318
7.2.3.1	<i>Distribution with Equal SNR in all Branches</i>	321
7.2.4	<i>Equal Gain Combining (EGC)</i>	322
7.2.5	<i>Switched Diversity Scheme (SDS)</i>	327

7.2.6	<i>Cumulative Probability Distribution</i>	328
7.3	<i>Impact of Diversity on Signal Impairments</i>	332
7.3.1	<i>Impact of Diversity on Noise</i>	333
7.3.1.1	<i>Impact of Diversity on Random FM</i>	337
7.3.2	<i>Impact of Diversity on Interference</i>	341
7.3.3	<i>Impact of Diversity on Average Fade Duration and Crossing Rate</i>	347
7.4	<i>Diversity and Digital Transmission</i>	350
7.5	<i>Optimum Diversity Combining</i>	352
7.6	<i>Diversity Reception Systems</i>	358
7.6.1	<i>Phase Perturbation Methods</i>	358
7.6.2	<i>Phase Sweeping Method</i>	359
7.6.3	<i>Special Receivers</i>	361
7.6.4	<i>Granlund Receiver</i>	362
7.7	<i>Macro-Diversity</i>	363
7.8	<i>Error Control in Mobile Communications</i>	366
7.8.1	<i>Automatic Repeat reQuest (ARQ)</i>	366
7.8.2	<i>Channel Coding</i>	368
7.8.2.1	<i>Block Codes</i>	368
7.8.2.2	<i>Convolutional Codes</i>	370
7.8.2.3	<i>Interleaving</i>	371
7.9	<i>Equalization in Mobile Communications</i>	372
7.9.1	<i>Theory of Equalization</i>	374
7.9.1.1	<i>Minimum Peak Distortion Criterion</i>	375
7.9.1.2	<i>Minimum Mean Square Criterion</i>	377
7.9.1.3	<i>Decision Feedback Equalizers</i>	379
7.9.2	<i>Adaptation Algorithms</i>	380
7.9.3	<i>Diversity and Equalization</i>	381
7.10	<i>Summary</i>	381
	<i>Problems</i>	382
	<i>References</i>	384

Chapter 8 387

MULTIPLE ACCESS COMMUNICATIONS

8.1	<i>Multiple Access Methods</i>	389
8.2	<i>Capacity of Forward Paging Channel</i>	389
8.2.1	<i>Cell Traffic and Channel Requirements</i>	391
8.3	<i>Random Channel Access</i>	395
8.3.1	<i>ALOHA Random Access Method</i>	395
8.3.2	<i>Carrier Sense Multiple Access</i>	399

8.3.3	<i>Polling</i>	403
8.4	<i>Performance of ALOHA and Slotted ALOHA Over Impaired Channels</i>	404
8.4.1	<i>Impact of Fading and Shadowing on ALOHA</i>	405
8.4.1.1	<i>Capture Effect</i>	407
8.5	<i>Access Protocol Analyses for Finite Population-Finite Buffer Systems</i>	408
8.6	<i>Multiuser Transmission Techniques</i>	408
8.6.1	<i>Frequency Division Multiple Access (FDMA)</i>	412
8.6.2	<i>Time Division Multiple Access (TDMA)</i>	414
8.6.3	<i>Direct Sequence Spread Spectrum</i>	416
8.6.3.1	<i>Frequency Hopped Spread Spectrum</i>	420
8.6.3.2	<i>Comparison of Spread Spectrum Techniques</i>	422
8.7	<i>Orthogonal Frequency Division Multiple Access (OFDMA)</i>	423
8.8	<i>Efficiencies and Capacities of Multiple Access Techniques</i>	424
8.8.1	<i>Spectral Efficiency Due to Modulation</i>	425
8.8.2	<i>Multiple Access Spectral Efficiency</i>	427
8.8.2.1	<i>FDMA Spectral Efficiency</i>	427
8.8.2.2	<i>TDMA Spectral Efficiency</i>	427
8.8.3	<i>Capacity and Frame Efficiency of TDMA System</i>	428
8.8.3.1	<i>Capacity</i>	428
8.8.3.2	<i>TDMA Frame Efficiency</i>	429
8.8.4	<i>Capacity of a DS-CDMA System</i>	430
8.8.4.1	<i>Spectrum Efficiency of CDMA</i>	433
8.8.4.2	<i>Impact of Fading on FDMA, TDMA and CDMA Capacities</i>	435
8.8.4.3	<i>Multicell Capacity</i>	436
8.9	<i>Summary</i>	437
	<i>Problems</i>	438
	<i>References</i>	441

Chapter 9 **443**

MOBILE WIRELESS SYSTEMS AND SERVICES

9.1	<i>Mobile Radio Systems and Services</i>	446
9.1.1	<i>Paging Systems</i>	446
9.2	<i>Conventional mobile systems</i>	447
9.3	<i>Multichannel Trunked Systems</i>	447
9.3.1	<i>MOBITEX</i>	449
9.3.2	<i>APCO-25</i>	450
9.3.3	<i>TETRA</i>	450
9.4	<i>Cellular Mobile Telephone System</i>	450

9.4.1 Cellular Systems in Operation	453
9.5 Battery Life Considerations	453
9.6 Summary	454
Problems	455
References	456

Chapter 10 457

WIRELESS DATA SYSTEMS

10.1 Packet Structure	457
10.2 Error Control	459
10.3 Paging Systems	461
10.3.1 Paging System Design Requirements	462
10.3.1.1 Calculation of Paging Capacity	464
10.4 Commercial Paging Systems	465
10.4.1 POCSAG Paging System	465
10.4.2 Golay Sequential Code (GSC) Paging System	467
10.4.3 NEC Paging System	469
10.4.4 RDS System	469
10.5 Packet Radio Systems	469
10.6 Packet Reservation Multiple Access	471
10.7 Packet Transmission Over Fading Mobile Wireless Channels	473
10.7.1 System Performance	475
10.7.2 Throughput Comparison of Access Schemes	476
10.8 Packet Transmission Systems	477
10.8.1 ARDIS	477
10.8.2 MOBITEX	479
10.8.3 APCO-25	480
10.8.4 CDPD	481
10.8.5 TETRA	483
10.8.6 ATCS	485
10.8.7 Wireless LAN's	486
10.9 Summary	487
Problems	488
References	489

Chapter 11 493

WIRELESS CELLULAR SYSTEM DESIGN PRINCIPLES

11.1 Cell Structure and Frequency Planning	496
11.2 Frequency Assignments	498
11.2.1 Fixed Channel Assignment (FCA)	507

11.2.2 Dynamic Channel Assignment	508
11.2.3 Hybrid Channel Assignment	508
11.3 Cell Traffic and Channel Requirements	510
11.3.1 Access Channel Requirements	512
11.4 Control Architecture	512
11.4.1 System Control Elements	513
11.4.2 Control Functions	515
11.4.3 Paging and Access	515
11.4.4 Data Requirements and Formats	517
11.4.5 Operation of Cellular System	518
11.5 Vehicle Location Techniques	521
11.6 Handoff Considerations	527
11.6.1 Handoff Based on Measured Signal Strength	528
11.6.2 Handoff Based on Signal Strength Difference	531
11.6.3 Handoff Decisions Based on Other Criteria	532
11.6.4 Soft Handoff	533
11.7 Power Control in CDMA	535
11.7.1 Up Link Power Control Algorithm	535
11.7.1.1 Open Loop Power Control	535
11.7.1.2 Closed Loop Power Control	536
11.7.2 Down Link Power Control Algorithm	536
11.8 Base station and Subscriber's Equipment	537
11.8.1 Base station Equipment	537
11.8.2 Mobile Unit Equipment	539
11.9 Network Aspects of Cellular Systems	540
11.10 Software Considerations	542
11.11 Summary	543
Problems	544
References	545

Chapter 12 **549**

MOBILE WIRELESS CELLULAR SYSTEMS

12.1 First Generation Cellular System	549
12.2 The North American AMPS System	550
12.2.1 System Control Elements	551
12.2.2 Operation of Cellular System	551
12.2.3 Control Functions	554
12.2.4 Paging And Access Channels	554
12.2.5 Supervision	556
12.3 Call Processing	556
12.3.1 Initialization	557

12.3.1.1	<i>Paging Channel Selection</i>	557
12.3.1.2	<i>Access</i>	558
12.3.1.3	<i>Scan Access Channels</i>	558
12.3.1.4	<i>Seize Reverse Control Channel - (RECC)</i>	558
12.3.1.5	<i>Access Attempt Parameters</i>	558
12.3.1.6	<i>Updating overhead information</i>	559
12.3.1.7	<i>Alerting</i>	560
12.3.1.8	<i>Conversation</i>	561
12.3.1.9	<i>Data Requirements and Formats</i>	561
12.4	<i>Nordic Mobile Telephone System</i>	563
12.4.1	<i>Call Processing</i>	564
12.5	<i>Other Analog Cellular Systems</i>	566
12.5.1	<i>Total Access Mobile Communication System (TACS)</i>	566
12.5.2	<i>NEC Japanese System</i>	567
12.5.3	<i>The German Cellular System, C450</i>	567
12.6	<i>Digital Cellular Systems</i>	567
12.6.1	<i>Developments in North America</i>	569
12.6.2	<i>Developments in Europe</i>	570
12.7	<i>North American Second Generation Systems</i>	571
12.8	<i>System Description</i>	573
12.8.1	<i>System Architecture</i>	573
12.8.2	<i>Frequency Parameters</i>	573
12.8.3	<i>Access and Control</i>	575
12.8.3.1	<i>Initialization</i>	575
12.8.3.2	<i>Access</i>	575
12.8.3.3	<i>Supervision</i>	576
12.8.3.4	<i>Release</i>	578
12.8.4	<i>Modulation and Coding</i>	578
12.8.4.1	<i>Analog Voice</i>	578
12.8.5	<i>Voice Encoding and Digital Voice</i>	579
12.8.6	<i>Channel Coding</i>	581
12.8.7	<i>Receiver Functions</i>	582
12.8.8	<i>Message Exchange on Digital Traffic Channel</i>	583
12.8.8.1	<i>Transmission of Messages</i>	583
12.8.9	<i>Reverse Digital Traffic Channel (RDTC)</i>	585
12.8.9.1	<i>Messages</i>	586
12.9	<i>GSM (European CEPT) System</i>	587
12.9.1	<i>GSM Channel Structure</i>	590
12.9.1.1	<i>Frame and Slot Structures in GSM</i>	592
12.9.1.2	<i>GSM Services</i>	594
