
CONTENTS

Preface xix

Preface to the First Edition xxi

Acknowledgments xxiii

Chapter 1. Trend of Mobile Wireless

1

- 1.1 History of Mobile Cellular / 1
 - 1.1.1 AMPS System (First-Generation System) / 1
 - 1.1.2 Second-Generation System / 2
 - 1.1.3 3G Systems / 3
 - 1.1.4 4G Systems / 4
 - 1.1.5 Other Cellular-Like Systems / 4
- 1.2 Wireless Data Networks / 5
 - 1.2.1 General Description / 5
 - 1.2.2 Wireless LAN Standards / 6
 - 1.2.3 Wireless WAN Evolution / 6
- 1.3 Communication Satellite Systems / 7
 - 1.3.1 History / 7
 - 1.3.2 Attributes / 9
 - 1.3.3 Satellites in Different Orbits / 9
- 1.4 Paging Systems / 11
- 1.5 Standards Bodies / 11
 - 1.5.1 International Standard Bodies / 11
 - 1.5.2 Standards Bodies in Different Areas / 13
- 1.6 Spectrum Allocation / 15
 - 1.6.1 Spectrum Allocation in the United States / 16
 - 1.6.2 ITU: Spectrum for 3G (IMT-2000) / 18
 - 1.6.3 The Other Areas of the World / 19
- 1.7 Spectrum Efficiency Considerations / 20

Chapter 2. Introduction to Cellular Systems

23

- 2.1 Basic Cellular Systems / 23
 - 2.1.1 Circuit-Switched Systems / 23
 - 2.1.2 Packet-Switched System / 25
- 2.2 Performance Criteria / 26
 - 2.2.1 Voice Quality / 26
 - 2.2.2 Data Quality / 27
 - 2.2.3 Picture/Vision Quality / 27
 - 2.2.4 Service Quality / 27
 - 2.2.5 Special Features / 28

- 2.3 Uniqueness of Mobile Radio Environment / 28
 - 2.3.1 Description of Mobile Radio Transmission Medium / 28
 - 2.3.2 Model of Transmission Medium / 30
 - 2.3.3 Mobile Fading Characteristics / 32
 - 2.3.4 Direct Wave Path, Line-of-Sight Path, and Obstructive Path / 39
 - 2.3.5 Noise Level in Cellular Frequency Band / 40
 - 2.3.6 Amplifier Noise / 41
- 2.4 Operation of Cellular Systems / 41
 - 2.4.1 Operation Procedures / 41
 - 2.4.2 Maximum Number of Calls Per Hour Per Cell / 42
 - 2.4.3 Maximum Number of Frequency Channels Per Cell / 44
- 2.5 Concept of Frequency Reuse Channels / 45
 - 2.5.1 Frequency Reuse Schemes / 45
 - 2.5.2 Frequency Reuse Distance / 46
 - 2.5.3 Number of Customers in the System / 47
- 2.6 Cochannel Interference Reduction Factor / 48
- 2.7 Desired C/I from a Normal Case in an Omnidirectional Antenna System / 49
 - 2.7.1 Analytic Solution / 49
 - 2.7.2 Solution Obtained from Simulation / 52
- 2.8 Handoff Mechanism / 52
- 2.9 Cell Splitting / 54
 - 2.9.1 Why Splitting? / 54
 - 2.9.2 How Splitting? / 54
- 2.10 Consideration of the Components of Cellular Systems / 55
 - 2.10.1 Antennas / 56
 - 2.10.2 Switching Equipment / 56
 - 2.10.3 Data Links / 57
- 2.11 Different Cellular Systems and B3G-Systems / 57

Chapter 3. Specifications of Analog Systems

59

- 3.1 Definitions of Terms and Functions / 59
- 3.2 Specification of Mobile Station (Unit) in the United States / 61
 - 3.2.1 Power / 61
 - 3.2.2 Modulation / 61
 - 3.2.3 Limitation on Emission / 63
 - 3.2.4 Security and Identification / 64
 - 3.2.5 Supervision / 64
 - 3.2.6 Call Processing / 65
 - 3.2.7 Mobile Station Controls on the Voice Channel / 67
 - 3.2.8 Signaling Format / 68
- 3.3 Specification of Land Station (United States) / 70
 - 3.3.1 Power / 70
 - 3.3.2 Limit on Emission / 70
 - 3.3.3 Call Processing / 70
 - 3.3.4 Signaling Formats / 75
 - 3.3.5 Additional Spectrum Radio (ASR) Issues / 78
- 3.4 Different Specifications of the World's Analog Cellular Systems / 79

Chapter 4. Digital Cellular Systems (2G Systems)

85

- 4.1 Introduction to Digital Systems / 85
 - 4.1.1 Advantages of Digital Systems / 85
 - 4.1.2 Digital Technologies / 86

- 4.1.3 ARQ Techniques / 99
- 4.1.4 Digital Speech / 104
- 4.2 Global System for Mobile (GSM) / 110
 - 4.2.1 GSM Architecture / 111
 - 4.2.2 Layer Modeling (OSI Model) / 114
 - 4.2.3 Transmission / 115
 - 4.2.4 GSM Channels and Channel Modes / 117
 - 4.2.5 Multiple-Access Scheme / 119
 - 4.2.6 Channel Coding and Interleaving / 121
 - 4.2.7 Radio Resource (RR) Management / 124
 - 4.2.8 Mobility Management (MM) / 125
 - 4.2.9 Communication Management / 127
 - 4.2.10 Network Management (NM) / 129
 - 4.2.11 Overview of GSM / 130
- 4.3 North American TDMA / 130
 - 4.3.1 History / 130
 - 4.3.2 NA-TDMA Architecture / 131
 - 4.3.3 Transmission and Modulation / 131
 - 4.3.4 Time Alignment and Limitation of Emission / 137
 - 4.3.5 Error Corrections / 138
 - 4.3.6 Interleaving and Coding / 140
 - 4.3.7 SCM and SID / 141
 - 4.3.8 NA-TDMA Channels / 142
 - 4.3.9 Discontinuous Transmission on a Digital Traffic Channel / 143
 - 4.3.10 Authentication / 143
 - 4.3.11 Signaling Format / 143
 - 4.3.12 Word Format / 145
 - 4.3.13 Enhanced NA-TDMA (IS-136) / 145
- 4.4 CDMA / 146
 - 4.4.1 Terms of CDMA Systems / 147
 - 4.4.2 Output Power Limits and Control / 149
 - 4.4.3 Modulation Characteristics / 152
 - 4.4.4 Joint Detection (JD) / 166
 - 4.4.5 Authentication, Encryption, and Privacy / 167
 - 4.4.6 Malfunction Detection / 169
 - 4.4.7 Call Processing / 170
 - 4.4.8 Handoff Procedures / 172
- 4.5 Miscellaneous Mobile Systems / 175
 - 4.5.1 TDD Systems / 175
 - 4.5.2 Other Full-Duplexed Systems / 178
 - 4.5.3 Noncellular Systems / 181

Chapter 5. B2G Systems

187

- 5.1 GPRS (General Packet Radio Service) / 187
 - 5.1.1 GPRS Air Interface / 187
 - 5.1.2 GPRS Network Architecture / 189
 - 5.1.3 Transmission Plane and Signaling Plane / 190
 - 5.1.4 GPRS Traffic Performance / 192
- 5.2 EDGE (Enhanced Data Rates for Global Evaluation) / 193
 - 5.2.1 Introduction / 193
 - 5.2.2 Network Architecture / 194
 - 5.2.3 Network Control / 195
- 5.3 HSCSD (High Speed Circuit Switched Data) / 196
- 5.4 iDEN (Integrated Digital Enhanced Network) / 197
 - 5.4.1 History / 197

- 5.4.2 Description of iDEN's Attributes / 197
- 5.4.3 iDEN's Unique Features / 198
- 5.4.4 iDEN Communications Network / 198
- 5.4.5 Radio Link / 202
- 5.4.6 Dispatch Call Processing / 206
- 5.4.7 Packet Data Networking / 209
- 5.5 PHS (Personal Handy Phone System) / 211
 - 5.5.1 Introduction / 211
 - 5.5.2 PHS Network Structure and System Components / 211
 - 5.5.3 Value Added Service Platform / 212
 - 5.5.4 PHS Physical Layer / 213
 - 5.5.5 PHS Protocol / 215
 - 5.5.6 PHS Basic Functions and Services / 217
- 5.6 IS-95B (RTT 1X) / 219

Chapter 6. 3G Systems

225

-
- 6.1 WCDMA-UMTS (UTRA-FDD) Physical Layer / 226
 - 6.1.1 Description of Physical Layer / 226
 - 6.1.2 Transport Channels / 228
 - 6.1.3 Physical Channels / 229
 - 6.1.4 Transmission Characteristics / 230
 - 6.1.5 User Data Transmission / 233
 - 6.1.6 Physical Layer's Functions / 234
 - 6.2 WCDMA-ARIB Physical Layer / 235
 - 6.2.1 FDD Mode / 235
 - 6.2.2 TDD Mode / 239
 - 6.2.3 Common Physical Layers for Both FDD and TDD Modes / 239
 - 6.3 WCDMA-TDD Physical Layer / 240
 - 6.3.1 WCDMA-TDD Channel Structure / 240
 - 6.3.2 Channel Mapping / 241
 - 6.3.3 Spreading (Channelization) Codes / 241
 - 6.3.4 Modulation and Spreading / 242
 - 6.3.5 Bandwidth Requirement and Capacity / 242
 - 6.4 UMTS Network Architecture / 243
 - 6.4.1 Description / 243
 - 6.4.2 MAC Layer / 245
 - 6.4.3 RLC Layer / 247
 - 6.4.4 PDCP Layer / 248
 - 6.4.5 BMC Layer / 248
 - 6.4.6 RRC Layer / 249
 - 6.4.7 Overview of 3GPP Release 99 Network / 250
 - 6.5 Evolution of UMTS-3GPP Release 4 and Beyond (Release 5, 6, 7) / 254
 - 6.5.1 Release 4 Core Network Architecture / 254
 - 6.5.2 VoIP Technology / 254
 - 6.5.3 3GPP Release 5 Core Architecture (HSDPA, IMS, PoC) / 259
 - 6.5.4 3GPP Release 6 (MBMS, EUDCH) / 261
 - 6.5.5 3GPP Release 7 / 262
 - 6.6 cdma2000 Physical Layer / 263
 - 6.6.1 Physical Channels / 263
 - 6.6.2 Radio Interface Parameters of cdma2000 FDD / 265
 - 6.6.3 Transmission Characteristics for cdma2000 TDD / 270
 - 6.7 cdma2000 Network / 271
 - 6.7.1 MAC Sublayer / 271
 - 6.7.2 RLP Layer / 273
 - 6.7.3 SRBP (Signaling Radio Burst Protocol) Layer / 275

- 6.7.4 System Access Modes / 275
- 6.7.5 LAC Sublayers / 276
- 6.7.6 Sublayer Processing / 277
- 6.7.7 Communications Among Layers and Sublayers / 278
- 6.7.8 Upper Layers / 280
- 6.7.9 Power Control / 280
- 6.7.10 Network Architecture / 283
- 6.8 cdma2000 EV-DO and EV-DV / 285
 - 6.8.1 Forward Link Physical Layer / 285
 - 6.8.2 Forward Link MAC Layer / 288
 - 6.8.3 Reverse Link Physical Layer / 289
 - 6.8.4 1xEV-DO Network / 290
 - 6.8.5 1xEV-DV / 291

Chapter 7. B3G Systems

295

- 7.1 IEEE-Based Wireless Standard Systems / 295
- 7.2 IEEE 802.11 Systems / 295
 - 7.2.1 PPM, DSSS, and FHSS Transmission Technologies / 297
 - 7.2.2 OFDM (Orthogonal Frequency Division Multiplexing) Technology / 298
 - 7.2.3 Generic Physical Layer / 305
 - 7.2.4 Physical Layer for Specific Systems (802.11 b/a/g) / 307
 - 7.2.5 Available Bandwidth for Specific Systems (802.11b/a/g) / 309
 - 7.2.6 802.11a/b/g Throughput Comparisons / 312
 - 7.2.7 802.11b and 802.11g Coexistence / 313
 - 7.2.8 MAC (Media Access Control) Layer / 315
 - 7.2.9 Wi-Fi / 328
- 7.3 Hot Spot / 329
- 7.4 802.16 and Associated Standards / 331
 - 7.4.1 802.16a (a BWA System) / 332
 - 7.4.2 802.16-2004 / 337
 - 7.4.3 802.16e / 341
 - 7.4.4 802.20 / 344
 - 7.4.5 WiMAX Forum / 345

Chapter 8. Cell Coverage and Antennas

349

- 8.1 General Introduction / 349
 - 8.1.1 Ground Incident Angle and Ground Elevation Angle / 350
 - 8.1.2 Ground Reflection Angle and Reflection Point / 350
- 8.2 Obtaining the Mobile Point-to-Point Model (Lee Model) / 351
 - 8.2.1 A Standard Condition / 352
 - 8.2.2 Obtain Area-to-Area Prediction Curves for Human-Made Structures / 352
 - 8.2.3 The Phase Difference between a Direct Path and a Ground-Reflected Path / 355
 - 8.2.4 Why There Is a Constant Standard Deviation Along a Path-Loss Curve / 358
 - 8.2.5 The Straight-Line Path-Loss Slope with Confidence / 359
 - 8.2.6 Determination of Confidence Interval / 361
 - 8.2.7 A General Formula for Mobile Radio Propagation / 362
 - 8.2.8 Comments on the Propagation Models / 363
- 8.3 Propagation Over Water or Flat Open Area / 363
 - 8.3.1 Between Fixed Stations / 364
 - 8.3.2 Land-to-Mobile Transmission Over Water / 366

- 8.4 Foliage Loss / 367
- 8.5 Propagation in Near-in Distance / 369
 - 8.5.1 Why Use a 1-mi Intercept? / 369
 - 8.5.2 Curves for Near-in Propagation / 370
 - 8.5.3 Calculation of Near-Field Propagation / 372
- 8.6 Long-Distance Propagation / 372
 - 8.6.1 Within an Area of 50-mi Radius / 372
 - 8.6.2 At a Distance of 320 km (200 mi) / 372
- 8.7 Obtain Path Loss from a Point-to-Point Prediction Model:
 - A General Approach / 373
 - 8.7.1 In Nonobstructive Condition / 373
 - 8.7.2 In Obstructive Condition / 377
 - 8.7.3 Cautions in Obtaining Defraction Loss / 381
- 8.8 Form of a Point-to-Point Model / 381
 - 8.8.1 General Formula of Lee Model / 381
 - 8.8.2 The Merit of the Point-to-Point Model / 382
- 8.9 Computer Generation of A Point-to-Point Prediction / 383
 - 8.9.1 Terrain Elevation Data / 384
 - 8.9.2 Elevation Map / 385
 - 8.9.3 Elevation Contour / 386
- 8.10 Cell-Site Antenna Heights and Signal Coverage Cells / 387
 - 8.10.1 Effects of Cell-Site Antenna Heights / 387
 - 8.10.2 Visualization of Signal Coverage Cells / 388
 - 8.10.3 Cell Breathing / 389
- 8.11 Propagation Prediction in and Through Buildings / 389
- 8.12 Mobile-to-Mobile Propagation / 391
 - 8.12.1 The Transfer Function of the Propagation Channel / 391
 - 8.12.2 Spatial Time Correlation / 393
 - 8.12.3 Power Spectrum of the Complex Envelope / 394
- 8.13 Antennas at Cell Site / 396
 - 8.13.1 For Coverage Use: Omnidirectional Antennas / 396
 - 8.13.2 For Interference Reduction Use: Directional Antennas / 397
 - 8.13.3 Location Antennas / 400
 - 8.13.4 Setup-Channel Antennas / 400
 - 8.13.5 Space-Diversity Antennas Used at Cell Site / 400
 - 8.13.6 Umbrella-Pattern Antennas / 400
 - 8.13.7 Interference Reduction Antenna / 402
- 8.14 Unique Situations of Cell-Site Antennas / 402
 - 8.14.1 Antenna Pattern in Free Space and in Mobile Environments / 402
 - 8.14.2 Minimum Separation of Cell-Site Receiving Antennas / 403
 - 8.14.3 Regular Check of the Cell-Site Antennas / 404
 - 8.14.4 Choosing an Antenna Site / 404
- 8.15 Smart Antennas / 405
 - 8.15.1 Introduction / 405
 - 8.15.2 Types of Smart Antennas / 407
 - 8.15.3 Applications / 407
 - 8.15.4 Multiple Antenna Communications / 408
- 8.16 Mobile Antennas / 411
 - 8.16.1 Roof-Mounted Antenna / 411
 - 8.16.2 Glass-Mounted Antennas / 411
 - 8.16.3 Mobile High-Gain Antennas / 413
 - 8.16.4 Horizontally Oriented Space-Diversity Antennas / 415
 - 8.16.5 Vertically Oriented Space-Diversity Antennas / 415
- 8.17 Handsets, Antennas, and Batteries / 416
 - 8.17.1 Handset Considerations / 416
 - 8.17.2 RF Antenna Characterization / 417

- 8.17.3 Different Types of Handsets and PCMCIA Antennas / 417
- 8.17.4 Battery Fundamentals / 420

Chapter 9. Cochannel and Code-Channel Interference Reductions

425

- 9.1 Cochannel Interference / 425
- 9.2 Exploring Cochannel Interference Areas in a System / 426
 - 9.2.1 Test 1: Find the Cochannel Interference Area from a Mobile Receiver / 426
 - 9.2.2 Test 2: Find the Cochannel Interference Area Which Affects a Cell Site / 427
- 9.3 Real-Time Cochannel Interference Measurement at Mobile Radio Transceivers / 428
- 9.4 Design of an Omnidirectional Antenna System in the Worst Case / 430
- 9.5 Design of a Directional Antenna System / 432
 - 9.5.1 Directional Antennas In $K = 7$ Cell Patterns / 433
 - 9.5.2 Directional Antenna in $K = 4$ Cell Pattern / 435
 - 9.5.3 Comparing $K = 7$ and $K = 4$ Systems / 436
- 9.6 Lowering the Antenna Height / 436
 - 9.6.1 On a High Hill or a High Spot / 437
 - 9.6.2 In a Valley / 438
 - 9.6.3 In a Forested Area / 438
- 9.7 Reduction of Cochannel Interference by Means of a Notch in the Tilted Antenna Pattern / 438
 - 9.7.1 Introduction / 438
 - 9.7.2 Theoretical Analysis / 439
 - 9.7.3 The Effect of Mechanically Downtilting Antenna on the Coverage Pattern / 440
 - 9.7.4 Suggested Method for Reducing Interference / 442
 - 9.7.5 Cautions in Tilting Antennas / 443
- 9.8 Umbrella-Pattern Effect / 443
 - 9.8.1 Elevation Angle of Long-Distance Propagation / 444
 - 9.8.2 Benefit of the Umbrella Pattern / 444
- 9.9 Use of Parasitic Elements / 445
- 9.10 Power Control / 447
 - 9.10.1 Who Controls the Power Level / 447
 - 9.10.2 Function of the MSO / 447
 - 9.10.3 Reduction of Code Channel Interference / 448
- 9.11 Diversity Receiver / 449
- 9.12 Designing a System to Serve a Predefined Area that Experiences Cochannel Interference / 451
 - 9.12.1 Flat Ground / 451
 - 9.12.2 Nonflat Ground / 453

Chapter 10. Types of Non-Cochannel Interference

455

- 10.1 Subjective Test versus Objective Test / 455
 - 10.1.1 The Subjective Test / 455
 - 10.1.2 The Objective Test / 457
 - 10.1.3 Measurement of SINAD / 457
- 10.2 Adjacent-Channel Interference / 458
 - 10.2.1 Next-Channel Interference / 458
 - 10.2.2 Neighboring-Channel Interference / 459

- 10.2.3 Transmitting and Receiving Channels Interference / 459
- 10.2.4 Interference from Adjacent Systems / 460
- 10.3 Near-End-Far-End Interference / 460
 - 10.3.1 In One Cell / 460
 - 10.3.2 In Cells of Two Systems / 461
- 10.4 Effect on Near-End Mobile Units / 462
 - 10.4.1 Avoidance of Near-End-Far-End Interference / 462
 - 10.4.2 Nonlinear Amplification / 464
- 10.5 Cross Talk—A Unique Characteristic of Voice Channels / 465
- 10.6 Effects on Coverage and Interference by Applying Power Decrease, Antenna Height Decrease, and Beam Tilting / 467
 - 10.6.1 Choosing a Proper Cell Site / 467
 - 10.6.2 Power Decrease / 467
 - 10.6.3 Antenna Height Decrease / 468
 - 10.6.4 Antenna Patterns / 468
 - 10.6.5 Transmitting and Receiving Antennas at the Cell Site / 471
 - 10.6.6 A 39-dB μ and a 32-dB μ Boundary / 471
- 10.7 Effects of Cell-Site Components / 473
 - 10.7.1 Channel Combiner / 473
 - 10.7.2 Demultiplexer at the Receiving End / 474
 - 10.7.3 SAT Tone of AMPS System / 475
- 10.8 Interference between Systems / 477
 - 10.8.1 In One City / 477
 - 10.8.2 In Adjacent Cities / 479
- 10.9 UHF TV Interference / 479
 - 10.9.1 Interference to UHF TV Receivers from Cellular Mobile Transmitters / 479
 - 10.9.2 Interference of Cellular Mobile Receivers by UHF TV Transmitters / 482
- 10.10 Long-Distance Interference / 483
 - 10.10.1 Overwater Path / 483
 - 10.10.2 Overland Path / 483

Chapter 11. Handoffs and Dropped Calls

485

- 11.1 Value of Implementing Handoffs / 485
 - 11.1.1 Why Handoffs / 485
 - 11.1.2 Types of Handoff / 485
 - 11.1.3 Two Decision-Making Parameters of Handoff / 486
 - 11.1.4 Determining the Probability of Requirement for Hard Handoffs / 487
 - 11.1.5 Number of Hard Handoffs Per Call / 487
 - 11.1.6 Area of Soft Handoffs in a Cell / 488
- 11.2 Initiation of a Hard Handoff / 489
- 11.3 Delaying a Handoff / 490
 - 11.3.1 Two-Handoff-Level Algorithm / 490
 - 11.3.2 Advantage of Delayed Handoffs / 491
- 11.4 Forced Handoffs / 491
 - 11.4.1 Controlling a Handoff / 491
 - 11.4.2 Creating a Handoff / 491
- 11.5 Queuing of Handoffs / 492
- 11.6 Power-Difference Handoffs / 493
- 11.7 Mobile Assisted Handoff (MAHO) and Soft Handoff / 496
- 11.8 Cell-Site Handoff Only / 496
- 11.9 Intersystem Handoff / 497
- 11.10 Introduction to Dropped Call Rate / 498
 - 11.10.1 The Definition of Dropped Call Rate / 498
 - 11.10.2 Consideration of Dropped Calls / 498

- 11.10.3 Relationship Among Capacity, Voice Quality, Dropped Call Rate / 499
- 11.10.4 Coverage of 90 Percent Equal-Strength Contour / 499
- 11.11 Formula of Dropped Call Rate / 500
 - 11.11.1 General Formula of Dropped Call Rate / 500
 - 11.11.2 Commonly Used Formula of Dropped Call Rate / 501
 - 11.11.3 Handoff Distribution of Calls, α_n / 502
- 11.12 Finding the Values of δ and μ Used for Dropped Call Rate / 502
 - 11.12.1 Formula for δ and μ / 503
 - 11.12.2 Calculation of δ and μ in a Single Cell / 503
 - 11.12.3 δ_n and μ_h Are Improved due to the Natural Two-Site Diversity in the Handoff Region / 504
- 11.13 Soft Handoffs / 505

Chapter 12. Operational Techniques and Technologies

509

- 12.1 Adjusting the Parameters of a System / 509
 - 12.1.1 Increasing the Coverage for a Noise-Limited System / 509
 - 12.1.2 Reducing the Interference / 511
 - 12.1.3 Increasing the Traffic Capacity / 512
- 12.2 Fixed Channel Assignment Schemes / 513
 - 12.2.1 Adjacent-Channel Assignment / 513
 - 12.2.2 Channel Sharing and Borrowing / 513
 - 12.2.3 Sectorization / 514
 - 12.2.4 Underlay-Overlay Arrangement / 515
- 12.3 Nonfixed Channel Assignment Algorithms / 517
 - 12.3.1 Description of Different Algorithms / 517
 - 12.3.2 Simulation Process and Results / 518
- 12.4 Coverage-Hole Filler / 521
 - 12.4.1 Enhancers (Repeaters) / 521
 - 12.4.2 Passive Reflector / 522
 - 12.4.3 Diversity / 528
 - 12.4.4 Cophase Technique / 529
- 12.5 Leaky Feeder / 529
 - 12.5.1 Leaky Waveguides / 529
 - 12.5.2 Leaky-Feeder Radio Communication / 531
- 12.6 Cell Splitting / 533
 - 12.6.1 Transmitted Power After Splitting / 534
 - 12.6.2 Cell-Splitting Technique / 535
 - 12.6.3 Splitting Size Limitations and Traffic Handling / 536
 - 12.6.4 Effect on Splitting / 536
- 12.7 Small Cells (Microcells) / 536
 - 12.7.1 Installation of a Mastless Antenna / 536
 - 12.7.2 Tailoring a Uniform-Coverage Cell / 537
 - 12.7.3 Vehicle-Locating Methods / 538
 - 12.7.4 Portable Cell Sites / 540
 - 12.7.5 Different Antenna Mountings on the Mobile Unit / 540
- 12.8 Narrowbeam Concept / 541
 - 12.8.1 Comparison of Narrowbeam Sectors with Underlay-Overlay Arrangement / 542
- 12.9 Separation between Highway Cell Sites / 543
 - 12.9.1 Omnidirectional Antenna / 544
 - 12.9.2 Two-Directional Antennas / 545
- 12.10 Low-Density Small-Market Design / 545

Chapter 13. Switching and Traffic

549

- 13.1 General Description / 549
 - 13.1.1 General Introduction / 549
 - 13.1.2 Basic Switching / 550
 - 13.1.3 System Congestion / 553
 - 13.1.4 Ultimate System Capacity / 553
 - 13.1.5 Call Drops / 555
- 13.2 Cellular Analog Switching Equipment / 555
 - 13.2.1 Description of Analog Switching Equipment / 555
 - 13.2.2 Modification of Analog Switching Equipment / 556
 - 13.2.3 Cell-Site Controllers and Hardware / 556
- 13.3 Cellular Digital Switching Equipment / 558
 - 13.3.1 General Concept / 558
 - 13.3.2 Elements of Switching / 558
 - 13.3.3 SESS (No. 5 Electronic Switching System) / 560
 - 13.3.4 Comparison Between Centralized and Decentralized Systems / 561
- 13.4 Packet Switching / 561
 - 13.4.1 General Description / 561
 - 13.4.2 Packet Switches in Mobile Tandem Switching / 561
 - 13.4.3 Packet Switching Protocols and Hardware / 563
- 13.5 Packet Related Networks / 564
 - 13.5.1 ATM Networks / 564
 - 13.5.2 Soft Switching: Next-Generation Voice Infrastructure / 565
- 13.6 Special Features for Handling Traffic / 566
 - 13.6.1 Underlay-Overlay Arrangement / 566
 - 13.6.2 Direct Call Retry / 566
 - 13.6.3 Hybrid Systems Using High Sites and Low Sites / 566
 - 13.6.4 Intersystem Handoffs / 567
 - 13.6.5 Queuing Feature / 568
 - 13.6.6 Roamers / 569
- 13.7 MSO Interconnection / 569
 - 13.7.1 Connection to Wire-Line Network / 569
 - 13.7.2 Connection to a Cell Site / 569
- 13.8 Small Switching Systems / 571
- 13.9 System Enhancement / 571

Chapter 14. Data Links and Microwaves

573

- 14.1 Data Links / 573
- 14.2 Available Frequencies for Microwave Links / 574
- 14.3 Microwave Link Design and Diversity Requirement / 575
- 14.4 Ray-Bending Phenomenon / 579
- 14.5 System Reliability / 581
 - 14.5.1 Equipment Reliability / 581
 - 14.5.2 Path Reliability / 581
- 14.6 Microwave Antennas / 585
 - 14.6.1 Characteristics of Microwave Antennas / 585
 - 14.6.2 Polarization and Space Diversity in Microwave Antennas / 586
 - 14.6.3 Types of Microwave-Link Antenna / 586
 - 14.6.4 Installation of Microwave Antennas / 587
- 14.7 Optical Data Link / 587
 - 14.7.1 Introduction / 587
 - 14.7.2 Optical Communication Systems / 588

- 14.7.3 Optical Multiplexing Technique: WDM / 589
- 14.7.4 High-Speed Optical Data Link Modules / 590
- 14.8 Point-to-Multipoint (PMP) Wireless Access / 591
- 14.9 LMDS (Local Multipoint Distribution Services) / 592
- 14.10 MMDS (Multipoint Microwave Distribution System) / 593
- 14.11 Cable (Wire) Replacement Devices / 594
 - 14.11.1 Bluetooth (BT) / 594
 - 14.11.2 ZigBee / 595
 - 14.11.3 UWB (Ultrawideband) / 596
 - 14.11.4 IrDA (Infrared Data Association) / 597
 - 14.11.5 RFID (Radio Frequency Identification) / 598
 - 14.11.6 Comparison of the Cable Replacement Devices / 601

Chapter 15. System Evaluations

603

- 15.1 Performance Evaluation / 603
 - 15.1.1 Blockage / 603
 - 15.1.2 Call Drops (Dropped-Call Rate) / 605
 - 15.1.3 Voice Quality / 607
 - 15.1.4 Performance Evaluation / 607
- 15.2 Signaling Evaluation / 608
 - 15.2.1 False-Alarm Rate / 609
 - 15.2.2 Word Error Rate Consideration / 609
 - 15.2.3 Word Error Rate Calculation / 610
 - 15.2.4 Parity Check Bits / 611
- 15.3 Measurement of Average Received Level and Level Crossings / 614
 - 15.3.1 Calculating Average Signal Strength / 614
 - 15.3.2 Estimating Unbiased Average Noise Levels / 617
 - 15.3.3 Signal-Strength Conversion / 620
 - 15.3.4 Receiver Sensitivity / 620
 - 15.3.5 Level-Crossing Counter / 621
- 15.4 Spectrum Efficiency Evaluation / 622
 - 15.4.1 Spectrum Efficiency for Analog Cellular Systems / 622
 - 15.4.2 Advantages and Impact of FM / 623
 - 15.4.3 Number of Frequency-Reuse Cells K / 623
 - 15.4.4 Number of Channels per Cell m / 624
 - 15.4.5 Rayleigh Fading Environment / 624
 - 15.4.6 Determination of Cell Size / 626
 - 15.4.7 Considerations of SSB Systems in a Rayleigh Fading Mobile Radio Environment / 628
 - 15.4.8 Narrowbanding in FM / 630
- 15.5 Evaluation of Spectrum Efficiency between CDMA and OFDMA / 633
- 15.6 Handsets (Portable Units) / 634
 - 15.6.1 Technology of Handsets (Portable Units) / 635
 - 15.6.2 Loss Due to Building Penetration / 635
 - 15.6.3 Building Height Effect / 637
 - 15.6.4 Interference Caused by Portable Units / 638
 - 15.6.5 Difference between Mobile Cellular and Portable Cellular Systems / 638
- 15.7 Evaluation of Data Services / 641
 - 15.7.1 Requirement for AMPS System / 641
 - 15.7.2 Digital Data Services / 641
 - 15.7.3 Testing / 644
- 15.8 Comparing WiMAX and 3G (HSDPA) for Mobile Broadband Wireless / 644

Chapter 16. Intelligent Cell Concept and Applications

647

- 16.1 Intelligent Cell Concept and Applications / 647
 - 16.1.1 What is the Intelligent Cell? / 647
 - 16.1.2 The Philosophy of Implementing Power-Delivery Intelligent Cells / 647
 - 16.1.3 Power-Delivery Intelligent Cells / 650
 - 16.1.4 Processing-Gain Intelligent Cells ($K \rightarrow 1$ System) / 657
 - 16.1.5 Summary of Intelligent Cell Approaches / 661
- 16.2 Applications of Intelligent Microcell Systems / 664
 - 16.2.1 Description of the Intelligent Microcell Operation / 664
 - 16.2.2 Applications to Increasing Capacity / 668
 - 16.2.3 Applications of Coverage Provision / 669
- 16.3 In-Building Communication / 674
 - 16.3.1 Differences between Ground Mobile and In-Building Design / 674
 - 16.3.2 Natural In-Building Radio Environment / 674
 - 16.3.3 A New In-Building Communication System / 675
 - 16.3.4 In-Building System Configuration / 676
 - 16.3.5 A PCS Application / 677
- 16.4 CDMA Cellular Radio Network / 679
 - 16.4.1 System Design Philosophy / 679
 - 16.4.2 Key Elements in Designing a CDMA System / 680
 - 16.4.3 Uniform Cell Scenario / 681
 - 16.4.4 Nonuniform Cell Scenario / 685
- 16.5 MIMO (Multiple Input–Multiple Output) / 691
 - 16.5.1 Introduction / 691
 - 16.5.2 Description of Technology / 692
 - 16.5.3 MIMO Capacity / 693

Chapter 17. Intelligent Network for Wireless Communications

697

- 17.1 Advanced Intelligent Network (AIN) / 697
 - 17.1.1 Intelligent Network Evolution / 697
 - 17.1.2 AIN Elements / 698
 - 17.1.3 AIN Interfaces / 699
- 17.2 SS7 Network and ISDN For AIN / 700
 - 17.2.1 History of SS7 / 700
 - 17.2.2 SS7 Protocol Model / 700
 - 17.2.3 SS7 Network Link Deployment for AIN / 701
 - 17.2.4 ISDN / 701
 - 17.2.5 SONET and ATM / 702
- 17.3 Ain for Mobile Communication / 703
- 17.4 Asynchronous Transfer Mode (ATM) Technology / 705
 - 17.4.1 LAN Applications / 706
 - 17.4.2 Connectionless Service / 706
 - 17.4.3 Star Configuration / 706
 - 17.4.4 ATM Packet-Switching Techniques / 706
 - 17.4.5 ATM Applications / 706
 - 17.4.6 Connection-Oriented Service / 707
- 17.5 IP Network / 709
 - 17.5.1 History of the Internet / 709
 - 17.5.2 Internet Architecture / 709
 - 17.5.3 TCP/IP / 710
 - 17.5.4 IP Packet Format and IP Addressing / 711
 - 17.5.5 Addressing in the Internet / 714
 - 17.5.6 Security on the Internet / 715

- 17.6 Future of IP Networks / 716
 - 17.6.1 IP Network Standards / 716
 - 17.6.2 The Problems of the Internet / 717
 - 17.6.3 IP Switch / 717
 - 17.6.4 Tag Switching / 718
 - 17.6.5 Summary / 719
- 17.7 An Intelligent System: Future Public Land Mobile Telecommunication System (FPLMTS) / 719
 - 17.7.1 Future Enhancement / 719
- 17.8 Mesh Network/Ad Hoc Network / 720
 - 17.8.1 Radio Structure of Ad Hoc Mesh / 720
 - 17.8.2 MAC Layer of Ad Hoc Network / 720
 - 17.8.3 Protocols for Mesh and Ad Hoc Networks / 722
 - 17.8.4 ODMA (Opportunity Driven Multiple Access) / 722
 - 17.8.5 Mesh Network Attributes / 723
 - 17.8.6 Wireless Sensor Network (WSN) Attributes / 724
- 17.9 Wireless Information Superhighway / 725
 - 17.9.1 An Example for Applying the Last 50 Meters / 728

Chapter 18. Perspective Systems of 4G and Related Topics

731

- 18.1 Perspective Systems of 4G / 731
 - 18.1.1 Introduction / 731
 - 18.1.2 Different Proposed 4G Systems / 731
- 18.2 A CDD System: CS-OFDMA / 734
 - 18.2.1 Realization of a CDD System / 734
 - 18.2.2 Code Attributes / 735
 - 18.2.3 CS-OFDMA System / 736
- 18.3 Complementary Code Keying (CCK) Codes and Modulation / 739
- 18.4 Turbo Codes and LDPC / 743
 - 18.4.1 Turbo Code / 743
 - 18.4.2 LDPC (Low Density Parity Check) Code / 744
- 18.5 Study of A 60-GHz Cellular System / 747
 - 18.5.1 Propagation in the Scattered Environment / 747
 - 18.5.2 Fixed Terminals / 748
 - 18.5.3 Moving Terminal / 748
 - 18.5.4 System Consideration / 750
- 18.6 Diversity Media System With Millimeter-WAVE Link and Optical-Wave Link / 750
 - 18.6.1 Introduction / 750
 - 18.6.2 Comparison of Two Signal Attenuations from Their PDC Curves / 751
- 18.7 MVNO and MVNE / 753
 - 18.7.1 MVNO (Mobile Virtual Network Operator) / 753
 - 18.7.2 MVNE (Mobile Virtual Network Enabler) / 754

Appendix A 757**Appendix B 765****Appendix C 769****Appendix D 775****Appendix E 779****Abbreviations and Acronyms 781****Index 797**