
Contents

| | |
|---|------------|
| Preface | xix |
| 1 Introduction to Wireless Communication Systems | 1 |
| 1.1 Evolution of Mobile Radio Communications | 1 |
| 1.2 Mobile Radiotelephony in the U.S. | 4 |
| 1.3 Mobile Radio Systems Around the World | 6 |
| 1.4 Examples of Wireless Communication Systems | 9 |
| 1.4.1 Paging Systems | 11 |
| 1.4.2 Cordless Telephone Systems | 12 |
| 1.4.3 Cellular Telephone Systems | 13 |
| 1.4.3.1 How a Cellular Telephone Call is Made | 15 |
| 1.4.4 Comparison of Common Wireless Communication Systems | 18 |
| 1.5 Trends in Cellular Radio and Personal Communications | 20 |
| 1.6 Problems | 22 |
| 2 Modern Wireless Communication Systems | 25 |
| 2.1 Second Generation (2G) Cellular Networks | 26 |
| 2.1.1 Evolution to 2.5G Wireless Networks | 29 |
| 2.1.2 Evolution for 2.5G TDMA Standards | 30 |
| 2.1.2.1 HSCSD for 2.5G GSM | 30 |
| 2.1.2.2 GPRS for 2.5G GSM and IS-136 | 31 |
| 2.1.2.3 EDGE for 2.5G GSM and IS-136 | 33 |
| 2.1.3 IS-95B for 2.5G CDMA | 34 |
| 2.2 Third Generation (3G) Wireless Networks | 34 |
| 2.2.1 3G W-CDMA (UMTS) | 37 |
| 2.2.2 3G cdma2000 | 38 |
| 2.2.3 3G TD-SCDMA | 39 |

| | | |
|----------|--|------------|
| 2.3 | Wireless Local Loop (WLL) and LMDS | 40 |
| 2.4 | Wireless Local Area Networks (WLANs) | 46 |
| 2.5 | Bluetooth and Personal Area Networks (PANs) | 52 |
| 2.6 | Summary | 54 |
| 2.7 | Problems | 55 |
| 3 | The Cellular Concept—System Design Fundamentals | 57 |
| 3.1 | Introduction | 57 |
| 3.2 | Frequency Reuse | 58 |
| 3.3 | Channel Assignment Strategies | 62 |
| 3.4 | Handoff Strategies | 62 |
| 3.4.1 | Prioritizing Handoffs | 65 |
| 3.4.2 | Practical Handoff Considerations | 66 |
| 3.5 | Interference and System Capacity | 67 |
| 3.5.1 | Co-channel Interference and System Capacity | 68 |
| 3.5.2 | Channel Planning for Wireless Systems | 72 |
| 3.5.3 | Adjacent Channel Interference | 74 |
| 3.5.4 | Power Control for Reducing Interference | 76 |
| 3.6 | Trunking and Grade of Service | 77 |
| 3.7 | Improving Coverage & Capacity in Cellular Systems | 86 |
| 3.7.1 | Cell Splitting | 86 |
| 3.7.2 | Sectoring | 90 |
| 3.7.3 | Repeaters for Range Extension | 93 |
| 3.7.4 | A Microcell Zone Concept | 93 |
| 3.8 | Summary | 96 |
| 3.9 | Problems | 97 |
| 4 | Mobile Radio Propagation: Large-Scale Path Loss | 105 |
| 4.1 | Introduction to Radio Wave Propagation | 105 |
| 4.2 | Free Space Propagation Model | 107 |
| 4.3 | Relating Power to Electric Field | 110 |
| 4.4 | The Three Basic Propagation Mechanisms | 113 |
| 4.5 | Reflection | 114 |
| 4.5.1 | Reflection from Dielectrics | 114 |
| 4.5.2 | Brewster Angle | 119 |
| 4.5.3 | Reflection from Perfect Conductors | 120 |
| 4.6 | Ground Reflection (Two-Ray) Model | 120 |
| 4.7 | Diffraction | 126 |
| 4.7.1 | Fresnel Zone Geometry | 126 |
| 4.7.2 | Knife-edge Diffraction Model | 129 |
| 4.7.3 | Multiple Knife-edge Diffraction | 134 |
| 4.8 | Scattering | 135 |
| 4.8.1 | Radar Cross Section Model | 136 |

| | | |
|----------|---|------------|
| 4.9 | Practical Link Budget Design Using Path Loss Models | 138 |
| 4.9.1 | Log-distance Path Loss Model | 138 |
| 4.9.2 | Log-normal Shadowing | 139 |
| 4.9.3 | Determination of Percentage of Coverage Area | 141 |
| 4.10 | Outdoor Propagation Models | 145 |
| 4.10.1 | Longley–Rice Model | 145 |
| 4.10.2 | Durkin’s Model—A Case Study | 146 |
| 4.10.3 | Okumura Model | 150 |
| 4.10.4 | Hata Model | 153 |
| 4.10.5 | PCS Extension to Hata Model | 154 |
| 4.10.6 | Walfisch and Bertoni Model | 155 |
| 4.10.7 | Wideband PCS Microcell Model | 155 |
| 4.11 | Indoor Propagation Models | 157 |
| 4.11.1 | Partition Losses (same floor) | 157 |
| 4.11.2 | Partition Losses between Floors | 160 |
| 4.11.3 | Log-distance Path Loss Model | 161 |
| 4.11.4 | Ericsson Multiple Breakpoint Model | 161 |
| 4.11.5 | Attenuation Factor Model | 163 |
| 4.12 | Signal Penetration into Buildings | 166 |
| 4.13 | Ray Tracing and Site Specific Modeling | 167 |
| 4.14 | Problems | 168 |
| 5 | Mobile Radio Propagation: Small-Scale Fading and Multipath | 177 |
| 5.1 | Small-Scale Multipath Propagation | 177 |
| 5.1.1 | Factors Influencing Small-Scale Fading | 178 |
| 5.1.2 | Doppler Shift | 179 |
| 5.2 | Impulse Response Model of a Multipath Channel | 181 |
| 5.2.1 | Relationship Between Bandwidth and Received Power | 185 |
| 5.3 | Small-Scale Multipath Measurements | 192 |
| 5.3.1 | Direct RF Pulse System | 192 |
| 5.3.2 | Spread Spectrum Sliding Correlator Channel Sounding | 193 |
| 5.3.3 | Frequency Domain Channel Sounding | 196 |
| 5.4 | Parameters of Mobile Multipath Channels | 197 |
| 5.4.1 | Time Dispersion Parameters | 199 |
| 5.4.2 | Coherence Bandwidth | 202 |
| 5.4.3 | Doppler Spread and Coherence Time | 203 |
| 5.5 | Types of Small-Scale Fading | 205 |
| 5.5.1 | Fading Effects Due to Multipath Time Delay Spread | 205 |
| 5.5.1.1 | Flat fading | 205 |
| 5.5.1.2 | Frequency Selective Fading | 207 |
| 5.5.2 | Fading Effects Due to Doppler Spread | 208 |
| 5.5.2.1 | Fast Fading | 208 |
| 5.5.2.2 | Slow Fading | 209 |

| | | |
|----------|--|------------|
| 5.6 | Rayleigh and Ricean Distributions | 210 |
| 5.6.1 | Rayleigh Fading Distribution | 210 |
| 5.6.2 | Ricean Fading Distribution | 212 |
| 5.7 | Statistical Models for Multipath Fading Channels | 214 |
| 5.7.1 | Clarke's Model for Flat Fading | 214 |
| 5.7.1.1 | Spectral Shape Due to Doppler Spread in Clarke's Model | 217 |
| 5.7.2 | Simulation of Clarke and Gans Fading Model | 220 |
| 5.7.3 | Level Crossing and Fading Statistics | 223 |
| 5.7.4 | Two-ray Rayleigh Fading Model | 226 |
| 5.7.5 | Saleh and Valenzuela Indoor Statistical Model | 227 |
| 5.7.6 | SIRCIM and SMRCIM Indoor and Outdoor Statistical Models | 227 |
| 5.8 | Theory of Multipath Shape Factors for Small-Scale Fading Wireless Channels | 229 |
| 5.8.1 | Introduction to Shape Factors | 230 |
| 5.8.1.1 | Multipath Shape Factors | 232 |
| | Angular Spread, Λ | 232 |
| | Angular Constriction, γ | 233 |
| | Azimuthal Direction of Maximum Fading, θ_{\max} | 233 |
| 5.8.1.2 | Fading Rate Variance Relationships | 233 |
| | Complex Received Voltage, $V(r)$ | 233 |
| | Received Power, $P(r)$ | 234 |
| | Received Envelope, $R(r)$ | 234 |
| 5.8.1.3 | Comparison to Omnidirectional Propagation | 234 |
| 5.8.2 | Examples of Fading Behavior | 236 |
| 5.8.2.1 | Sector Channel Model | 236 |
| 5.8.2.2 | Double Sector Channel Model | 239 |
| 5.8.2.3 | Ricean Channel Model | 240 |
| 5.8.3 | Second-Order Statistics Using Shape Factors | 240 |
| 5.8.3.1 | Level-Crossing Rates and Average Fade Duration | 242 |
| 5.8.3.2 | Spatial Autocovariance | 242 |
| 5.8.3.3 | Coherence Distance | 243 |
| 5.8.4 | Applying Shape Factors to Wideband Channels | 243 |
| 5.8.5 | Revisiting Classical Channel Models with Shape Factors | 244 |
| 5.9 | Summary | 247 |
| 5.10 | Problems | 248 |
| 6 | Modulation Techniques for Mobile Radio | 255 |
| 6.1 | Frequency Modulation vs. Amplitude Modulation | 256 |
| 6.2 | Amplitude Modulation | 257 |
| 6.2.1 | Single Sideband AM | 260 |
| 6.2.2 | Pilot Tone SSB | 261 |
| 6.2.3 | Demodulation of AM signals | 262 |
| 6.3 | Angle Modulation | 264 |
| 6.3.1 | Spectra and Bandwidth of FM Signals | 266 |
| 6.3.2 | FM Modulation Methods | 267 |

| | | |
|----------|--|------------|
| 6.3.3 | FM Detection Techniques | 268 |
| 6.3.4 | Tradeoff Between SNR and Bandwidth in an FM Signal | 276 |
| 6.4 | Digital Modulation—an Overview | 277 |
| 6.4.1 | Factors That Influence the Choice of Digital Modulation | 278 |
| 6.4.2 | Bandwidth and Power Spectral Density of Digital Signals | 281 |
| 6.5 | Line Coding | 282 |
| 6.6 | Pulse Shaping Techniques | 282 |
| 6.6.1 | Nyquist Criterion for ISI Cancellation | 282 |
| 6.6.2 | Raised Cosine Rolloff Filter | 287 |
| 6.6.3 | Gaussian Pulse-Shaping Filter | 290 |
| 6.7 | Geometric Representation of Modulation Signals | 291 |
| 6.8 | Linear Modulation Techniques | 294 |
| 6.8.1 | Binary Phase Shift Keying (BPSK) | 295 |
| 6.8.2 | Differential Phase Shift Keying (DPSK) | 298 |
| 6.8.3 | Quadrature Phase Shift Keying (QPSK) | 300 |
| 6.8.4 | QPSK Transmission and Detection Techniques | 301 |
| 6.8.5 | Offset QPSK | 303 |
| 6.8.6 | $\pi/4$ QPSK | 305 |
| 6.8.7 | $\pi/4$ QPSK Transmission Techniques | 305 |
| 6.8.8 | $\pi/4$ QPSK Detection Techniques | 308 |
| 6.9 | Constant Envelope Modulation | 311 |
| 6.9.1 | Binary Frequency Shift Keying | 312 |
| 6.9.2 | Minimum Shift Keying (MSK) | 314 |
| 6.9.3 | Gaussian Minimum Shift Keying (GMSK) | 318 |
| 6.10 | Combined Linear and Constant Envelope Modulation Techniques | 322 |
| 6.10.1 | M-ary Phase Shift Keying (MPSK) | 323 |
| 6.10.2 | M-ary Quadrature Amplitude Modulation (QAM) | 325 |
| 6.10.3 | M-ary Frequency Shift Keying (MFSK) and OFDM | 328 |
| 6.11 | Spread Spectrum Modulation Techniques | 329 |
| 6.11.1 | Pseudo-Noise (PN) Sequences | 330 |
| 6.11.2 | Direct Sequence Spread Spectrum (DS-SS) | 331 |
| 6.11.3 | Frequency Hopped Spread Spectrum (FH-SS) | 334 |
| 6.11.4 | Performance of Direct Sequence Spread Spectrum | 335 |
| 6.11.5 | Performance of Frequency Hopping Spread Spectrum | 338 |
| 6.12 | Modulation Performance in Fading and Multipath Channels | 339 |
| 6.12.1 | Performance of Digital Modulation in Slow Flat-Fading Channels | 340 |
| 6.12.2 | Digital Modulation in Frequency Selective Mobile Channels | 344 |
| 6.12.3 | Performance of $\pi/4$ DQPSK in Fading and Interference | 346 |
| 6.13 | Problems | 350 |
| 7 | Equalization, Diversity, and Channel Coding | 355 |
| 7.1 | Introduction | 355 |
| 7.2 | Fundamentals of Equalization | 356 |
| 7.3 | Training A Generic Adaptive Equalizer | 359 |

| | | |
|----------|---|------------|
| 7.4 | Equalizers in a Communications Receiver | 363 |
| 7.5 | Survey of Equalization Techniques | 364 |
| 7.6 | Linear Equalizers | 366 |
| 7.7 | Nonlinear Equalization | 368 |
| 7.7.1 | Decision Feedback Equalization (DFE) | 369 |
| 7.7.2 | Maximum Likelihood Sequence Estimation (MLSE) Equalizer | 370 |
| 7.8 | Algorithms for Adaptive Equalization | 372 |
| 7.8.1 | Zero Forcing Algorithm | 374 |
| 7.8.2 | Least Mean Square Algorithm | 374 |
| 7.8.3 | Recursive Least Squares Algorithm | 376 |
| 7.8.4 | Summary of Algorithms | 379 |
| 7.9 | Fractionally Spaced Equalizers | 380 |
| 7.10 | Diversity Techniques | 380 |
| 7.10.1 | Derivation of Selection Diversity Improvement | 381 |
| 7.10.2 | Derivation of Maximal Ratio Combining Improvement | 384 |
| 7.10.3 | Practical Space Diversity Considerations | 385 |
| 7.10.3.1 | Selection Diversity | 386 |
| 7.10.3.2 | Feedback or Scanning Diversity | 386 |
| 7.10.3.3 | Maximal Ratio Combining | 387 |
| 7.10.3.4 | Equal Gain Combining | 387 |
| 7.10.4 | Polarization Diversity | 387 |
| 7.10.5 | Frequency Diversity | 390 |
| 7.10.6 | Time Diversity | 390 |
| 7.11 | RAKE Receiver | 391 |
| 7.12 | Interleaving | 393 |
| 7.13 | Fundamentals of Channel Coding | 394 |
| 7.14 | Block Codes and Finite Fields | 395 |
| 7.14.1 | Examples of Block Codes | 399 |
| 7.14.2 | Case Study: Reed–Solomon Codes for CDPD | 400 |
| 7.14.2.1 | Reed–Solomon Encoding | 401 |
| 7.14.2.2 | Reed–Solomon Decoding | 404 |
| 7.15 | Convolutional Codes | 407 |
| 7.15.1 | Decoding of Convolutional Codes | 409 |
| 7.15.1.1 | The Viterbi Algorithm | 409 |
| 7.15.1.2 | Other Decoding Algorithms for Convolutional Codes | 410 |
| 7.16 | Coding Gain | 411 |
| 7.17 | Trellis Coded Modulation | 412 |
| 7.18 | Turbo Codes | 412 |
| 7.19 | Problems | 412 |
| 8 | Speech Coding | 415 |
| 8.1 | Introduction | 415 |
| 8.2 | Characteristics of Speech Signals | 417 |

| | | |
|----------|---|------------|
| 8.3 | Quantization Techniques | 418 |
| 8.3.1 | Uniform Quantization | 418 |
| 8.3.2 | Nonuniform Quantization | 419 |
| 8.3.3 | Adaptive Quantization | 421 |
| 8.3.4 | Vector Quantization | 422 |
| 8.4 | Adaptive Differential Pulse Code Modulation (ADPCM) | 423 |
| 8.5 | Frequency Domain Coding of Speech | 425 |
| 8.5.1 | Sub-band Coding | 425 |
| 8.5.2 | Adaptive Transform Coding | 428 |
| 8.6 | Vocoders | 429 |
| 8.6.1 | Channel Vocoders | 429 |
| 8.6.2 | Formant Vocoders | 430 |
| 8.6.3 | Cepstrum Vocoders | 430 |
| 8.6.4 | Voice-Excited Vocoder | 431 |
| 8.7 | Linear Predictive Coders | 431 |
| 8.7.1 | LPC Vocoders | 431 |
| 8.7.2 | Multipulse Excited LPC | 434 |
| 8.7.3 | Code-Excited LPC | 434 |
| 8.7.4 | Residual Excited LPC | 436 |
| 8.8 | Choosing Speech Codecs for Mobile Communications | 436 |
| 8.9 | The GSM Codec | 440 |
| 8.10 | The USDC Codec | 442 |
| 8.11 | Performance Evaluation of Speech Coders | 442 |
| 8.12 | Problems | 445 |
| 9 | Multiple Access Techniques for Wireless Communications | 447 |
| 9.1 | Introduction | 447 |
| 9.1.1 | Introduction to Multiple Access | 448 |
| 9.2 | Frequency Division Multiple Access (FDMA) | 449 |
| 9.3 | Time Division Multiple Access (TDMA) | 453 |
| 9.4 | Spread Spectrum Multiple Access | 456 |
| 9.4.1 | Frequency Hopped Multiple Access (FHMA) | 457 |
| 9.4.2 | Code Division Multiple Access (CDMA) | 458 |
| 9.4.3 | Hybrid Spread Spectrum Techniques | 459 |
| 9.5 | Space Division Multiple Access (SDMA) | 461 |
| 9.6 | Packet Radio | 462 |
| 9.6.1 | Packet Radio Protocols | 463 |
| 9.6.1.1 | Pure ALOHA | 464 |
| 9.6.1.2 | Slotted ALOHA | 465 |
| 9.6.2 | Carrier Sense Multiple Access (CSMA) Protocols | 466 |
| 9.6.3 | Reservation Protocols | 467 |
| 9.6.3.1 | Reservation ALOHA | 467 |
| 9.6.3.2 | Packet Reservation Multiple Access (PRMA) | 468 |
| 9.6.4 | Capture Effect in Packet Radio | 468 |

| | | |
|-----------|--|------------|
| 9.7 | Capacity of Cellular Systems | 469 |
| 9.7.1 | Capacity of Cellular CDMA | 474 |
| 9.7.2 | Capacity of CDMA with Multiple Cells | 477 |
| 9.7.3 | Capacity of Space Division Multiple Access | 484 |
| 9.8 | Problems | 488 |
| 10 | Wireless Networking | 491 |
| 10.1 | Introduction to Wireless Networks | 491 |
| 10.2 | Differences Between Wireless and Fixed Telephone Networks | 493 |
| 10.2.1 | The Public Switched Telephone Network (PSTN) | 493 |
| 10.2.2 | Limitations in Wireless Networking | 495 |
| 10.2.3 | Merging Wireless Networks and the PSTN | 496 |
| 10.3 | Development of Wireless Networks | 497 |
| 10.3.1 | First Generation Wireless Networks | 497 |
| 10.3.2 | Second Generation Wireless Networks | 499 |
| 10.3.3 | Third Generation Wireless Networks | 500 |
| 10.4 | Fixed Network Transmission Hierarchy | 501 |
| 10.5 | Traffic Routing in Wireless Networks | 502 |
| 10.5.1 | Circuit Switching | 503 |
| 10.5.2 | Packet Switching | 504 |
| 10.5.3 | The X.25 Protocol | 505 |
| 10.6 | Wireless Data Services | 506 |
| 10.6.1 | Cellular Digital Packet Data (CDPD) | 506 |
| 10.6.2 | Advanced Radio Data Information Systems (ARDIS) | 508 |
| 10.6.3 | RAM Mobile Data (RMD) | 508 |
| 10.7 | Common Channel Signaling (CCS) | 510 |
| 10.7.1 | The Distributed Central Switching Office for CCS | 510 |
| 10.8 | Integrated Services Digital Network (ISDN) | 512 |
| 10.8.1 | Broadband ISDN and ATM | 513 |
| 10.9 | Signaling System No. 7 (SS7) | 514 |
| 10.9.1 | Network Services Part (NSP) of SS7 | 515 |
| 10.9.1.1 | Message Transfer Part (MTP) of SS7 | 516 |
| 10.9.1.2 | Signaling Connection Control Part (SCCP) of SS7 | 517 |
| 10.9.2 | The SS7 User Part | 517 |
| 10.9.2.1 | Integrated Services Digital Network User Part (ISUP) | 517 |
| 10.9.2.2 | Transaction Capabilities Application Part (TCAP) | 518 |
| 10.9.2.3 | Operation Maintenance and Administration Part (OMAP) | 518 |
| 10.9.3 | Signaling Traffic in SS7 | 518 |
| 10.9.4 | SS7 Services | 519 |
| 10.9.5 | Performance of SS7 | 519 |
| 10.10 | An Example of SS7 — Global Cellular Network Interoperability | 520 |

| | | |
|-----------|--|------------|
| 10.11 | Personal Communication Services/Networks (PCS/PCNs) | 522 |
| 10.11.1 | Packet vs. Circuit Switching for PCN | 523 |
| 10.11.2 | Cellular Packet-Switched Architecture | 523 |
| 10.11.2.1 | Network Functionality in Cellular Packet-Switched Architecture | 527 |
| 10.12 | Protocols for Network Access | 527 |
| 10.12.1 | Packet Reservation Multiple Access (PRMA) | 528 |
| 10.13 | Network Databases | 529 |
| 10.13.1 | Distributed Database for Mobility Management | 529 |
| 10.14 | Universal Mobile Telecommunication System (UMTS) | 530 |
| 10.15 | Summary | 531 |
| 11 | Wireless Systems and Standards | 533 |
| 11.1 | AMPS and ETACS | 533 |
| 11.1.1 | AMPS and ETACS System Overview | 534 |
| 11.1.2 | Call Handling in AMPS and ETACS | 535 |
| 11.1.3 | AMPS and ETACS Air Interface | 537 |
| 11.1.4 | N-AMPS | 540 |
| 11.2 | United States Digital Cellular (IS-54 and IS-136) | 541 |
| 11.2.1 | USDC Radio Interface | 542 |
| 11.2.2 | United States Digital Cellular Derivatives (IS-94 and IS-136) | 548 |
| 11.3 | Global System for Mobile (GSM) | 549 |
| 11.3.1 | GSM Services and Features | 550 |
| 11.3.2 | GSM System Architecture | 551 |
| 11.3.3 | GSM Radio Subsystem | 553 |
| 11.3.4 | GSM Channel Types | 555 |
| 11.3.4.1 | GSM Traffic Channels (TCHs) | 555 |
| 11.3.4.2 | GSM Control Channels (CCH) | 557 |
| 11.3.5 | Example of a GSM Call | 560 |
| 11.3.6 | Frame Structure for GSM | 561 |
| 11.3.7 | Signal Processing in GSM | 563 |
| 11.4 | CDMA Digital Cellular Standard (IS-95) | 567 |
| 11.4.1 | Frequency and Channel Specifications | 567 |
| 11.4.2 | Forward CDMA Channel | 569 |
| 11.4.2.1 | Convolutional Encoder and Repetition Circuit | 569 |
| 11.4.2.2 | Block Interleaver | 571 |
| 11.4.2.3 | Long PN Sequence | 571 |
| 11.4.2.4 | Data Scrambler | 572 |
| 11.4.2.5 | Power Control Subchannel | 572 |
| 11.4.2.6 | Orthogonal Covering | 573 |
| 11.4.2.7 | Quadrature Modulation | 574 |
| 11.4.3 | Reverse CDMA Channel | 575 |
| 11.4.3.1 | Convolutional Encoder and Symbol Repetition | 576 |
| 11.4.3.2 | Block Interleaver | 576 |
| 11.4.3.3 | Orthogonal Modulation | 576 |

| | | |
|----------|--|-----|
| 11.4.3.4 | Variable Data Rate Transmission | 576 |
| 11.4.3.5 | Direct Sequence Spreading | 578 |
| 11.4.3.6 | Quadrature Modulation | 580 |
| 11.4.4 | IS-95 with 14.4 kbps Speech Coder [ANS95] | 580 |
| 11.5 | CT2 Standard for Cordless Telephones | 580 |
| 11.5.1 | CT2 Services and Features | 580 |
| 11.5.2 | The CT2 Standard | 581 |
| 11.6 | Digital European Cordless Telephone (DECT) | 582 |
| 11.6.1 | Features and Characteristics | 582 |
| 11.6.2 | DECT Architecture | 582 |
| 11.6.3 | DECT Functional Concept | 584 |
| 11.6.4 | DECT Radio Link | 584 |
| 11.7 | PACS — Personal Access Communication Systems | 587 |
| 11.7.1 | PACS System Architecture | 587 |
| 11.7.2 | PACS Radio Interface | 587 |
| 11.8 | Pacific Digital Cellular (PDC) | 590 |
| 11.9 | Personal Handyphone System (PHS) | 590 |
| 11.10 | US PCS and ISM Bands | 591 |
| 11.11 | US Wireless Cable Television | 593 |
| 11.12 | Summary of Standards Throughout the World | 594 |
| 11.13 | Problems | 597 |

APPENDICES

| | | |
|----------|--|------------|
| A | Trunking Theory | 601 |
| A.1 | Erlang B | 602 |
| A.1.1 | Derivation of Erlang B | 602 |
| A.2 | Erlang C | 607 |
| A.2.1 | Derivation of Erlang C | 607 |
| B | Noise Figure Calculations for Link Budgets | 611 |
| C | Rate Variance Relationships for Shape Factor Theory | 615 |
| C.1 | Rate Variance for Complex Voltage | 615 |
| C.2 | Rate Variance for Power | 617 |
| C.3 | Rate Variance for Envelope | 617 |
| D | Approximate Spatial Autocovariance Function for Shape Factor Theory | 619 |
| E | Gaussian Approximations for Spread Spectrum CDMA | 621 |
| E.1 | The Gaussian Approximation | 629 |
| E.2 | The Improved Gaussian Approximation (IGA) | 635 |
| E.3 | A Simplified Expression for the Improved Gaussian Approximation (SEIGA) | 637 |

| | | |
|--------------|---|------------|
| F | <i>Q</i>, <i>erf</i> & <i>erfc</i> Functions | 645 |
| F.1 | The <i>Q</i> -Function | 645 |
| F.2 | The <i>erf</i> and <i>erfc</i> Functions | 648 |
| G | Mathematical Tables, Functions, and Transforms | 651 |
| H | Abbreviations and Acronyms | 661 |
| I | References | 675 |
| INDEX | | 693 |