

Contents

Preface	xi
About the Authors	xv
Acknowledgements	xvii
1. Introduction	1
1.1 Wireless Communication Systems	1
1.1.1 Digital Broadcasting Systems	1
1.1.2 Mobile Cellular Systems	3
1.1.3 Wireless Network Systems	5
Bibliography	8
2. Digital Modulation	9
2.1 Single-Carrier Modulation	9
2.1.1 Power Spectral Densities of Modulation Signals	11
2.1.2 PSK, QAM and ASK	11
2.1.3 CPFSK and MSK	14
2.1.4 Pulse Shaping and Windowing	15
2.2 Multi-Carrier Modulation	17
2.2.1 Orthogonal Frequency-Division Multiplexing	19
2.2.2 OFDM-Related Issues	19
2.2.3 OFDM Transceiver Architecture	24
2.2.4 OFDM System Examples	26
Bibliography	28

3. Multiple Access and Error-Correcting Codes	31
3.1 Multiple Access	31
3.1.1 Frequency-Division Multiple Access (FDMA)	31
3.1.2 Time-Division Multiple Access (TDMA)	31
3.1.3 Code-Division Multiple Access (CDMA)	33
3.1.4 Carrier Sense Multiple Access (CSMA)	34
3.2 Spread Spectrum and CDMA	35
3.2.1 PN Codes	35
3.2.2 Direct-Sequence Spread Spectrum	38
3.2.3 Frequency-Hopping Spread Spectrum	40
3.3 Error-Correcting Codes	41
3.3.1 Block Codes	42
3.3.2 Reed-Solomon Codes	45
3.3.3 Convolutional Codes	48
3.3.4 Low-Density Parity-Check Codes	53
Bibliography	56
4. Signal Propagation and Channel Model	59
4.1 Introduction	59
4.2 Wireless Channel Propagation	59
4.2.1 Path Loss and Shadowing	60
4.2.2 Multipath Fading	61
4.2.3 Multipath Channel Parameters	62
4.3 Front-End Electronics Effects	68
4.3.1 Carrier Frequency Offset	68
4.3.2 Sampling Clock Offset	69
4.3.3 Phase Noise	70
4.3.4 IQ Imbalance and DC Offset	70
4.3.5 Power Amplifier Nonlinearity	73
4.4 Channel Model	74
4.4.1 Model for Front-End Impairments	75
4.4.2 Multipath Rayleigh Fader Model	77
4.4.3 Channel Models Used in Standards	78
Bibliography	84
5. Synchronization	85
5.1 Introduction	85
5.2 Synchronization Issues	86
5.2.1 Synchronization Errors	86
5.2.2 Effects of Synchronization Errors	86
5.2.3 Consideration for Estimation and Compensation	90
5.3 Detection/Estimation of Synchronization Errors	91
5.3.1 Symbol Timing Detection	91
5.3.2 Carrier Frequency Offset Estimation	100

5.3.3 Residual CFO and SCO Estimation	104
5.3.4 Carrier Phase Estimation	107
5.4 Recovery of Synchronization Errors	107
5.4.1 Carrier Frequency Offset Compensation	108
5.4.2 Sampling Clock Offset Compensation	110
Bibliography	113
6. Channel Estimation and Equalization	115
6.1 Introduction	115
6.2 Pilot Pattern	116
6.3 Pilot-Based Channel Estimation	118
6.3.1 Channel Estimation by Block-Type Pilot Symbols	122
6.3.2 Channel Estimation by Comb-Type Pilot Symbols	125
6.3.3 Channel Estimation by Grid-Type Pilot Symbols	132
6.4 Adaptive Channel Estimation	137
6.5 Equalization	138
6.5.1 One-Tap Equalizer	138
6.5.2 Multiple-Tap Equalizer	138
Bibliography	140
7. MIMO Techniques	143
7.1 Introduction	143
7.2 MIMO Basics	145
7.2.1 Capacity	145
7.2.2 Diversity	146
7.3 MIMO-OFDM	147
7.3.1 MIMO Pilot Pattern	149
7.3.2 MIMO-OFDM Synchronization	151
7.3.3 MIMO-OFDM Channel Estimation	155
7.4 MIMO Encoding and Detection	158
7.4.1 Space Block Codes	158
7.4.2 Spatial Multiplexing	161
7.4.3 Spatial De-correlation	167
Bibliography	170
8. From Algorithm to Bit-True Design	171
8.1 Design Flow Overview	171
8.2 Effect of Additive Impairment Sources	174
8.3 Analog-to-Digital Conversion	176
8.3.1 ADC Distortions	176
8.3.2 Signal Probability Distributions	178
8.3.3 Dynamic Range and Precision Setting	180
8.4 Finite Precision Effect in Digital Baseband Processing	181
8.4.1 Fixed-Point Data Format	182
8.4.2 Fixed-Point Error Model	182

8.4.3	Finite Precision Effect in FIR Filters	187
8.4.4	Finite Precision Effect in IIR Filters	188
8.5	Conversion from Floating-Point Design to Bit-True Design	189
8.5.1	Metrics for Performance Evaluation	190
8.5.2	Interpolative Design Flow	190
8.5.3	Simulation-Based Approaches	192
8.5.4	Analytical Approaches	192
	Bibliography	194
9.	Circuit Techniques	195
9.1	Introduction	195
9.2	FFT	195
9.2.1	FFT Algorithms	196
9.2.2	Architecture	201
9.2.3	Comparison	206
9.3	Delay Buffer	208
9.3.1	SRAM/Register File-Based Delay Buffer	209
9.3.2	Pointer-Based Delay Buffer	211
9.3.3	Gated Clock Strategy	212
9.3.4	Comparison	214
9.4	Circuits for Rectangular-to-Polar Conversion	216
9.4.1	Arctangent Function	216
9.4.2	Magnitude Function	221
9.4.3	Comparison	225
9.5	Circuits for Polar-to-Rectangular Conversion	225
9.5.1	Trigonometric Approximation	228
9.5.2	Polynomial Approximation	229
9.5.3	Comparison	230
	Bibliography	231
10.	System Examples	233
10.1	MC-CDMA Downlink Receiver IC	233
10.1.1	System Description	234
10.1.2	Transmitter and Receiver Design	234
10.1.3	Circuit Design	238
10.1.4	Experimental Results	241
10.2	MIMO-OFDM Cognitive Radio Receiver IC	243
10.2.1	System Overview	243
10.2.2	Architecture and Circuit Design	245
10.2.3	Experimental Results	250
	Bibliography	252
	Index	255