

Contents

1	Introduction to Multi-user Mobile Communication Systems	1
1.1	Frequency Division Multiple Access (FDMA).....	2
1.2	Time Division Multiple Access (TDMA).....	3
1.3	Code Division Multiple Access (CDMA).....	5
1.3.1	Frequency Hopped Multiple Access (FHMA).....	5
1.3.2	Direct Sequence Code Division Multiple Access (DS-CDMA)....	6
1.4	The Hybrid Systems	9
1.4.1	The Hybrid FDMA/CDMA (FD/CDMA) System.....	10
1.4.2	The Hybrid TDMA/CDMA (TD/CDMA) System	10
1.5	The Channel.....	11
1.5.1	Additive White Gaussian Noise (AWGN)	11
1.5.2	Rayleigh Flat Fading	13
1.6	The System Performance Analysis Using the Bit Error Rate (BER).....	15
1.7	The Synchronization Problem.....	22
1.8	Conclusion and Book Organization	28
	References	28
2	Chaotic Signals and Their Use in Secure Communications	31
2.1	Chaotic Systems.....	31
2.1.1	Chaotic Flows.....	33
2.1.2	Chaotic Maps.....	35
2.2	Lyapunov Exponents	37
2.3	Application of Chaos to Communications	39
2.3.1	Chaotic Communication Systems Based on the Principles of Chaotic Synchronization.....	40
2.3.2	Chaotic Communication Systems Based on the DS-CDMA Principle	41
2.4	Noise Reduction within Chaotic Communication Systems	44
2.5	Conclusion	45
	References	46
3	Chaotic Synchronization, Conditional Lyapunov Exponents and Lyapunov's Direct Method	49
3.1	Pecora-Carroll Chaotic Synchronization Method	50
3.2	Conditional Lyapunov Exponents and the Pecora-Carroll Chaotic Synchronization	52
3.3	Lyapunov's Direct Method and the Pecora-Carroll Chaotic Synchronization	56

3.4	Synchronization of Chaotic Flows via Lyapunov's Direct Method.....	59
3.4.1	The Linear Feedback Rigid Body Motion (LFRBM) Chaotic System.....	60
3.4.2	The Rabinovich-Fabrikant Chaotic System.....	68
3.5	Conclusion	75
	References	75
4	Chaotic Synchronization of Maps	79
4.1	A Design Procedure for the Synchronization of Chaotic Maps	80
4.2	Synchronization of the \Re^1 Cubic Map Master-Slave Systems	82
4.3	Synchronization of the \Re^2 Tinkerbell Map Master-Slave Systems	87
4.4	Synchronization of the Lorenz \Re^3 Chaotic Map Master-Slave Systems	93
4.5	Conclusion	101
	References	101
5	A Novel Mathematical Analysis for Predicting Master-Slave Chaotic Synchronization	103
5.1	Synchronization and Asymptotic Stability of the Simplest Piecewise Linear Master-Slave Chaotic Flow	104
5.1.1	Master-Slave System with the Master x Signal Driving.....	104
5.1.2	Master-Slave System with the Master y Signal Driving.....	106
5.1.3	Master-Slave System with the Master z Signal Driving	107
5.1.4	Summary of the Synchronization Properties	108
5.2	The Simplest Quadratic Master-Slave Chaotic Flow.....	108
5.2.1	Master-Slave System with the Master z Signal Driving	109
5.2.2	Master-Slave System with the Master y Signal Driving.....	112
5.2.3	Master-Slave System with the Master x Signal Driving.....	116
5.2.4	Summary of the Synchronization Properties	118
5.3	The Ueda Master-Slave Chaotic System	118
5.3.1	Master-Slave System with the Master x Signal Driving.....	118
5.3.2	Master-Slave System with the Master y Signal Driving.....	130
5.3.3	Master-Slave System with the Master z Signal Driving	130
5.3.4	Summary of the Synchronization Properties	131
5.4	Conclusion	131
	References	132
6	Application of Chaotic Synchronization to Secure Communications	135
6.1	Chaotic Masking	136
6.1.1	Principles of Chaotic Masking	136
6.1.2	Chaotic Masking within the Lorenz Master-Slave System.....	137
6.2	Chaotic Modulation	139
6.2.1	Chaotic Parameter Modulation	139
6.2.1.1	Principles of Chaotic Parameter Modulation.....	139

6.2.1.2	Chaotic Parameter Modulation within the Lorenz Master-Slave System.....	140
6.2.2	General Approach to Chaotic Parameter Modulation.....	143
6.2.2.1	Principles of the General Approach to Chaotic Parameter Modulation.....	143
6.2.2.2	Chaotic Parameter Modulation within the Ueda Master-Slave System.....	144
6.2.2.3	Chaotic Parameter Modulation within the Cubic Map Master-Slave System	150
6.2.3	Other Forms of Chaotic Modulation.....	153
6.3	Initial Condition Modulation	155
6.3.1	Principles of Initial Condition Modulation.....	155
6.3.2	Initial Condition Modulation within the Ueda Master-Slave Chaotic System.....	156
6.3.3	The Communication System Implementing the Simplest Quadratic Master-Slave Chaotic Flow	160
6.3.4	The Communication System Implementing the Simplest Piecewise Linear Master-Slave Chaotic Flow.....	163
6.3.5	Discussion	165
6.4	Performance Evaluation in the Presence of Noise	166
6.5	Conclusion	167
	References	168
7	A Robust Sequence Synchronization Unit for Multi-user Chaos Based DS-CDMA Communication Systems	171
7.1	The Chaotic Communication System with the Synchronization Unit ...	175
7.2	The Code Acquisition	177
7.2.1	Theoretical Model of the System.....	177
7.2.2	Theoretical Upper Bound on the Probability of Detection	181
7.2.3	Empirical Evaluation of the Probability of False Alarm and the Probability of Detection	186
7.2.4	Theoretical and Numerical Simulation Results	189
7.3	Code Tracking with a PRBS Pilot Signal	193
7.3.1	Theoretical Model of the System.....	194
7.3.2	Performance Evaluation of the System with AWGN and Interuser Interferences	201
7.3.3	Comparison and Discussion in AWGN Channel.....	204
7.3.4	Performance Evaluation of the System in a Rayleigh Fading Channel with AWGN and Interuser Interferences.....	206
7.4	Code Tracking with a Chaotic Pilot Signal.....	208
7.4.1	Theoretical Model of the System.....	209
7.4.2	BER System Performance within AWGN and Rayleigh Fading Channels	215
7.5	Conclusion	221
	References	223

8 Chaos Based Multi-user TDM Communication System.....	229
8.1 Chaos Based TDM Communication System with Perfect Sequence Synchronization Assumed	231
8.1.1 Chaos Based TDM Communication System	231
8.1.2 Performance Comparison of the Chaos Based TDM to the Chaos Based DS-CDMA System in an AWGN Channel	234
8.1.3 Performance of the Chaos Based TDM System in a Rayleigh Fading Channel	236
8.1.4 Performance Comparison of the Chaos Based TDM to the Chaos Based DS-CDMA System in a Rayleigh Fading Channel	237
8.2 Chaos Based TDM Communication System without Assuming Perfect Sequence Synchronization.....	239
8.2.1 Chaos Based TDM Communication System with the Sequence Synchronization Unit	239
8.2.2 Performance Comparison of the Chaos Based TDM to the Chaos Based DS-CDMA System in an AWGN Channel without Assuming Perfect Sequence Synchronization	243
8.2.3 Performance of the Chaos Based TDM System in a Rayleigh Fading Channel without Assuming Perfect Sequence Synchronization.....	244
8.2.4 Performance Comparison of the Chaos Based TDM to the Chaos Based DS-CDMA System in a Rayleigh Fading Channel without Assuming Perfect Sequence Synchronization	246
8.3 Generalized Chaos Based TDM Communication System without Assuming Perfect Sequence Synchronization.....	247
8.3.1 Generalized Chaos Based TDM Communication System with the Sequence Synchronization Unit	248
8.3.2 Performance Comparison of the Generalized Chaos Based TDM to the Chaos Based DS-CDMA System in an AWGN Channel without Assuming Perfect Sequence Synchronization	252
8.4 Conclusion	254
References	255
9 Chaotic Synchronization Based Multi-user TDM Communication Systems	257
9.1 The CPM Based Multi-user TDM Communication System	258
9.1.1 The Principles of the CPM Based Multi-user TDM Communication System.....	259
9.1.2 The Lorenz CPM Based TDM Communication System	260
9.1.3 The Ueda CPM Based TDM Communication System	267

9.1.4	Performance Comparison of the Lorenz CPM Based to Ueda CPM Based TDM Chaotic Communication System in an AWGN Channel.....	272
9.1.5	Performance Comparison of the CPM Based TDM Systems to the Chaos Based DS-CDMA System of Chapter 7 and the Chaos Based TDM System of Chapter 8	273
9.2	The ICM Based Multi-user TDM Communication System	277
9.2.1	The Principles of the ICM Based Multi-user TDM Communication System	277
9.2.2	The Ueda ICM Based TDM Communication System	278
9.2.3	The Ueda ICM Based TDM Communication System with Only x Transmitted.....	286
9.2.4	Performance Comparison of the Ueda ICM Based TDM Chaotic Communication Systems in an AWGN Channel.....	291
9.2.5	Performance Comparison of the ICM Based TDM Systems to the CPM Based TDM Systems of Section 9.1	292
9.2.6	Performance Comparison of the ICM Based TDM Systems to the Chaos Based DS-CDMA of Chapter 7 and Chaos Based TDM System of Chapter 8.....	293
9.3	Conclusion	295
	References	296
10	Novel Bit Power Spectrum Measures for Improved Security in Chaotic Communication Systems.....	299
10.1	Communication System Based on the Synchronization of Burgers' Map Master-Slave Chaotic System.....	301
10.2	Bit Power Security Issues of Chaotic Communication Systems	306
10.2.1	Security Evaluation of the Burgers' Map CPM Based Chaotic Communication System	306
10.2.2	Security Evaluation of the Lorenz CPM Based Chaotic Communication System.....	310
10.2.3	Security Evaluation of the Ueda ICM Based Chaotic Communication System with Only x Transmitted	311
10.3	Conclusion	314
	References	315
11	Conclusions and Future Directions	317
11.1	Conclusions.....	317
11.2	Future Directions	324
Appendix		
A1	Haar Wavelet Transform.....	325
A2	Daubechies Wavelet Domain.....	326
A3	Hard-Thresholding in the Wavelet Domain	327

A4	Application to Communications	327
A4.1	Overview of the Ueda ICM Based Chaotic Communication System	327
A4.2	Low Complexity Ueda ICM Based Chaotic Communication System with Only x Transmitted	328
A4.3	Running Average FIR Filtering	331
A4.4	Filtering in the Haar Wavelet Domain	332
A4.5	Filtering in the Daubechies Wavelet Domain	333
A4.6	Results and Discussions	333
A5	Conclusion	334
	References	334
	Index	337