

# Contents

<b>Preface</b> .....	iii
<b>Acknowledgements</b> .....	ix
<b>1 Chaos and Communications</b> .....	1
1.1 Historical Account .....	2
1.2 Chaos.....	5
1.3 Quantifying Chaotic Behavior .....	5
1.3.1 Lyapunov Exponents for Continuous-Time Nonlinear Systems.....	6
1.3.2 Lyapunov Exponent for Discrete-Time Systems .....	8
1.3.3 Kolmogorov Entropy.....	8
1.3.4 Attractor Dimension.....	10
1.4 Properties of Chaos .....	12
1.5 Chaos-Based Communications .....	14
1.5.1 Conventional Spread Spectrum .....	14
1.5.2 Spread Spectrum with Chaos .....	16
1.5.3 Chaotic Synchronization .....	16
1.6 Communications Using Chaos as Carriers.....	19
1.6.1 Chaotic Masking Modulation.....	19
1.6.2 Dynamical Feedback Modulation .....	20
1.6.3 Inverse System Modulation.....	21
1.6.4 Chaotic Modulation.....	22
1.6.5 Chaos Shift Keying .....	22
1.6.6 Differential Chaos Shift Keying Modulation .....	24
1.7 Remarks on Chaos-Based Communications .....	25

**Reconstruction of Chaotic Signals with Applications to Chaos-Based Communications**

- 1.7.1 Security Issues.....25
- 1.7.2 Engineering Challenges.....25
  
- 2 Reconstruction of Signals .....27**
  - 2.1 Reconstruction of System Dynamics .....28
    - 2.1.1 Topological Embeddings.....29
    - 2.1.2 Delay Coordinates .....30
  - 2.2 Differentiable Embeddings .....33
  - 2.3 Phase Space Reconstruction—Example .....34
  - 2.4 Problems and Research Approaches .....39
  
- 3 Fundamentals of Neural Networks .....41**
  - 3.1 Motivation.....41
  - 3.2 Benefits of Neural Networks.....43
  - 3.3 Radial Basis Function Neural Networks .....46
    - 3.3.1 Background Theory .....46
    - 3.3.2 Research Progress in Radial Basis Function Networks.....49
  - 3.4 Recurrent Neural Networks .....56
    - 3.4.1 Introduction .....56
    - 3.4.2 Topology of the Recurrent Networks.....57
    - 3.4.3 Learning Algorithms .....58
  
- 4 Signal Reconstruction in Noisefree and Distortionless Channels.....60**
  - 4.1 Reconstruction of Attractor for Continuous Time-Varying Systems .....60
  - 4.2 Reconstruction and Observability .....62
  - 4.3 Communications Based on Reconstruction Approach.....63
    - 4.3.1 Parameter Estimations.....64
    - 4.3.2 Information Retrievals.....66
  - 4.4 Reconstruction of Attractor for Discrete Time-Varying Systems .....69
  - 4.5 Summary.....71

<b>5</b>	<b>Signal Reconstruction from a Filtering Viewpoint: Theory</b> .....	72
5.1	The Kalman Filter and Extended Kalman Filter .....	72
5.1.1	The Kalman Filter .....	72
5.1.2	Extended Kalman Filter .....	76
5.2	The Unscented Kalman Filter .....	77
5.2.1	The Unscented Kalman Filtering Algorithm .....	78
5.2.2	Convergence Analysis for the UKF Algorithm .....	82
5.2.3	Computer Simulations .....	86
5.3	Summary .....	89
<b>6</b>	<b>Signal Reconstruction from a Filtering Viewpoint: Application</b> .....	91
6.1	Introduction .....	91
6.2	Filtering of Noisy Chaotic Signals .....	92
6.2.1	Filtering Algorithm .....	92
6.2.2	Computer Simulation .....	94
6.3	Blind Equalization for Fading Channels .....	101
6.3.1	Modeling of Wireless Communication Channels .....	101
6.3.2	Blind Equalization of Fading Channels with Fixed Channel Coefficients .....	103
6.3.3	Blind Equalization for Time-Varying Fading Channels ....	106
6.4	Summary .....	109
<b>7</b>	<b>Signal Reconstruction in Noisy Channels</b> .....	110
7.1	Review of Chaotic Modulation .....	110
7.2	Formulation of Chaotic Modulation and Demodulation .....	112
7.3	On-Line Adaptive Learning Algorithm and Demodulation .....	116
7.3.1	Description of the Network .....	116
7.3.2	Network Growth .....	118
7.3.3	Network Update with Extended Kalman Filter .....	119
7.3.4	Pruning of Hidden Units .....	121
7.3.5	Summary of the Flow of Algorithm .....	121
7.4	Computer Simulation and Evaluation .....	123
7.5	Application to Non-coherent Detection in Chaos-Based Communication .....	131

- 7.6 Summary .....139
- 8 Signal Reconstruction in Noisy Distorted Channels**.....140
  - 8.1 Preliminaries .....141
    - 8.1.1 Conventional Equalizers .....142
    - 8.1.2 Reconstruction of Chaotic Signals and Equalization .....143
    - 8.1.3 Recurrent Neural Network and Equalization .....144
  - 8.2 Training Algorithm .....148
  - 8.3 Simulation Study.....151
    - 8.3.1 Chaotic Signal Transmission.....151
    - 8.3.2 Filtering Effect of Communication Channels.....152
    - 8.3.3 Results .....156
  - 8.4 Comparisons and Discussions.....161
  - 8.5 Summary .....164
- 9 Chaotic Network Synchronization and Its Applications in Communications**.....165
  - 9.1 Chaotic Network Synchronization .....166
    - 9.1.1 Network Synchronization.....167
    - 9.1.2 Chaos Control.....168
    - 9.1.3 Implementation of the Synchronization Scheme.....172
  - 9.2 Implementation of Spread-Spectrum Communications .....175
    - 9.2.1 Encoding and Decoding .....175
    - 9.2.2 Test Results for Communications .....178
  - 9.3 Summary .....181
- 10 Conclusions**.....183
  - 10.1 Summary of Methods.....183
  - 10.2 Further Research .....185
- Bibliography** .....188
- Index**.....214