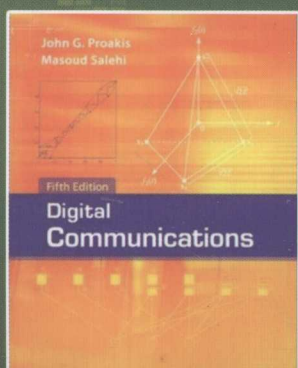


国外电子与通信教材系列

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# 数字通信

(第五版) (英文版)



Digital Communications  
Fifth Edition

[美] John G. Proakis 著



电子工业出版社  
PUBLISHING HOUSE OF ELECTRONICS INDUSTRY

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北京·BEIJING

## 内 容 简 介

本书是数字通信领域一本优秀的经典教材,在内容上既论述了数字通信的基本理论问题,又对数字通信新技术进行比较深入的分析。本书采用了信号空间和等效低通分析方法,根据最佳接收准则,先后讨论并分析了在加性高斯白噪声(AWGN)信道、带限信道(有符号间干扰和加性噪声)以及多径衰落信道等三种基本的典型信道条件下的数字信号可靠高效传输及其最佳接收问题。从信号传输角度主要介绍了通信信号、数字调制、自适应均衡、多天线系统和最佳接收内容,从信息传输角度主要介绍了信息论基础、信道容量和信道编码等内容。

本书取材新颖,讨论问题系统全面、逐步深入、概念清晰,理论分析严谨、逻辑性强,习题和参考资料丰富。本书适合信息和通信专业的高年级本科生、研究生及科技、工程技术人员阅读。

John G·Proakis: Digital Communications, Fifth Edition

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2001年7月间,电子工业出版社的领导同志邀请各高校十几位通信领域方面的老师,商量引进国外教材问题。与会同志对出版社提出的计划十分赞同,大家认为,这对我国通信事业、特别是对高等院校通信学科的教学工作会很有好处。

教材建设是高校教学建设的主要内容之一。编写、出版一本好的教材,意味着开设了一门好的课程,甚至可能预示着一个崭新学科的诞生。20世纪40年代MIT林肯实验室出版的一套28本雷达丛书,对近代电子学科、特别是对雷达技术的推动作用,就是一个很好的例子。

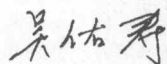
我国领导部门对教材建设一直非常重视。20世纪80年代,在原教委教材编审委员会的领导下,汇集了高等院校几百位富有教学经验的专家,编写、出版了一大批教材;很多院校还根据学校的特点和需要,陆续编写了大量的讲义和参考书。这些教材对高校的教学工作发挥了极好的作用。近年来,随着教学改革不断深入和科学技术的飞速进步,有的教材内容已比较陈旧、落后,难以适应教学的要求,特别是在电子学和通信技术发展神速、日新月异的今天,如何适应这种情况,更是一个必须认真考虑的问题。解决这个问题,除了依靠高校的老师 and 专家撰写新的符合要求的教科书外,引进和出版一些国外优秀电子与通信教材,尤其是有选择地引进一批英文原版教材,是会有好处的。

一年多来,电子工业出版社为此做了很多工作。他们成立了一个“国外电子与通信教材系列”项目组,选派了富有经验的业务骨干负责有关工作,收集了230余种通信教材和参考书的详细资料,调来了100余种原版教材样书,依靠由20余位专家组成的出版委员会,从中精选了40多种,内容丰富,覆盖了电路理论与应用、信号与系统、数字信号处理、微电子、通信系统、电磁场与微波等方面,既可作为通信专业本科生和研究生的教学用书,也可作为有关专业人员的参考材料。此外,这批教材,有的翻译为中文,还有部分教材直接影印出版,以供教师用英语直接授课。希望这些教材的引进和出版对高校通信教学和教材改革能起一定作用。

在这里,我还要感谢参加工作的各位教授、专家、老师与参加翻译、编辑和出版的同志们。各位专家认真负责、严谨细致、不辞辛劳、不怕琐碎和精益求精的态度,充分体现了中国教育工作者和出版工作者的良好美德。

随着我国经济建设的发展和科学技术的不断进步,对高校教学工作会不断提出新的要求和希望。我想,无论如何,要做好引进国外教材的工作,一定要联系我国的实际。教材和学术专著不同,既要注意科学性、学术性,也要重视可读性,要深入浅出,便于读者自学;引进的教材要适应高校教学改革的需要,针对目前一些教材内容较为陈旧的问题,有目的地引进一些先进的和正在发展中的交叉学科的参考书;要与国内出版的教材相配套,安排好出版英文原版教材和翻译教材的比例。我们努力使这套教材能尽量满足上述要求,希望它们能放在学生们的课桌上,发挥一定的作用。

最后,预祝“国外电子与通信教材系列”项目取得成功,为我国电子与通信教学和通信产业的发展培土施肥。也恳切希望读者能对这些书籍的不足之处、特别是翻译中存在的问题,提出意见和建议,以便再版时更正。



中国工程院院士、清华大学教授  
“国外电子与通信教材系列”出版委员会主任

# 出版说明

进入 21 世纪以来,我国信息产业在生产和科研方面都大大加快了发展速度,并已成为国民经济发展的支柱产业之一。但是,与世界上其他信息产业发达的国家相比,我国在技术开发、教育培训等方面都还存在着较大的差距。特别是在加入 WTO 后的今天,我国信息产业面临着国外竞争对手的严峻挑战。

作为我国信息产业的专业科技出版社,我们始终关注着全球电子信息技术的发展方向,始终把引进国外优秀电子与通信信息技术教材和专业书籍放在我们工作的重要位置上。在 2000 年至 2001 年间,我社先后从世界著名出版公司引进出版了 40 余种教材,形成了一套“国外计算机科学教材系列”,在全国高校以及科研部门中受到了欢迎和好评,得到了计算机领域的广大教师与科研工作者的充分肯定。

引进和出版一些国外优秀电子与通信教材,尤其是有选择地引进一批英文原版教材,将有助于我国信息产业培养具有国际竞争能力的技术人才,也将有助于我国国内在电子与通信教学工作中掌握和跟踪国际发展水平。根据国内信息产业的现状、教育部《关于“十五”期间普通高等教育教材建设与改革的意见》的指示精神以及高等院校老师们反映的各种意见,我们决定引进“国外电子与通信教材系列”,并随后开展了大量准备工作。此次引进的国外电子与通信教材均来自国际著名出版商,其中影印教材约占一半。教材内容涉及的学科方向包括电路理论与应用、信号与系统、数字信号处理、微电子、通信系统、电磁场与微波等,其中既有本科专业课程教材,也有研究生课程教材,以适应不同院系、不同专业、不同层次的师生对教材的需求,广大师生可自由选择和自由组合使用。我们还将与国外出版商一起,陆续推出一些教材的教学支持资料,为授课教师提供帮助。

此外,“国外电子与通信教材系列”的引进和出版工作得到了教育部高等教育司的大力支持和帮助,其中的部分引进教材已通过“教育部高等学校电子信息科学与工程类专业教学指导委员会”的审核,并得到教育部高等教育司的批准,纳入了“教育部高等教育司推荐——国外优秀信息科学与技术系列教学用书”。

为做好该系列教材的翻译工作,我们聘请了清华大学、北京大学、北京邮电大学、南京邮电大学、东南大学、西安交通大学、天津大学、西安电子科技大学、电子科技大学等著名高校的教授和骨干教师参与教材的翻译和审校工作。许多教授在国内电子与通信专业领域享有较高的声望,具有丰富的教学经验,他们的渊博学识从根本上保证了教材的翻译质量和专业学术方面的严格与准确。我们在此对他们的辛勤工作与贡献表示衷心的感谢。此外,对于编辑的选择,我们达到了专业对口;对于从英文原书中发现的错误,我们通过与作者联络、从网上下载勘误表等方式,逐一进行了修订;同时,我们对审校、排版、印制质量进行了严格把关。

今后,我们将进一步加强同各高校教师的密切关系,努力引进更多的国外优秀教材和教学参考书,为我国电子与通信教材达到世界先进水平而努力。由于我们对国内外电子与通信教育的发展仍存在一些认识上的不足,在选题、翻译、出版等方面的工作中还有许多需要改进的地方,恳请广大师生和读者提出批评及建议。

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## P R E F A C E

# 前 言

It is a pleasure to welcome Professor Masoud Salehi as a coauthor to the fifth edition of *Digital Communications*. This new edition has undergone a major revision and reorganization of topics, especially in the area of channel coding and decoding. A new chapter on multiple-antenna systems has been added as well.

The book is designed to serve as a text for a first-year graduate-level course for students in electrical engineering. It is also designed to serve as a text for self-study and as a reference book for the practicing engineer involved in the design and analysis of digital communications systems. As to background, we presume that the reader has a thorough understanding of basic calculus and elementary linear systems theory and prior knowledge of probability and stochastic processes.

**Chapter 1** is an introduction to the subject, including a historical perspective and a description of channel characteristics and channel models.

**Chapter 2** contains a review of deterministic and random signal analysis, including bandpass and lowpass signal representations, bounds on the tail probabilities of random variables, limit theorems for sums of random variables, and random processes.

**Chapter 3** treats digital modulation techniques and the power spectrum of digitally modulated signals.

**Chapter 4** is focused on optimum receivers for additive white Gaussian noise (AWGN) channels and their error rate performance. Also included in this chapter is an introduction to lattices and signal constellations based on lattices, as well as link budget analyses for wireline and radio communication systems.

**Chapter 5** is devoted to carrier phase estimation and time synchronization methods based on the maximum-likelihood criterion. Both decision-directed and non-decision-directed methods are described.

**Chapter 6** provides an introduction to topics in information theory, including lossless source coding, lossy data compression, channel capacity for different channel models, and the channel reliability function.

**Chapter 7** treats linear block codes and their properties. Included is a treatment of cyclic codes, BCH codes, Reed-Solomon codes, and concatenated codes. Both soft decision and hard decision decoding methods are described, and their performance in AWGN channels is evaluated.

**Chapter 8** provides a treatment of trellis codes and graph-based codes, including convolutional codes, turbo codes, low density parity check (LDPC) codes, trellis codes for band-limited channels, and codes based on lattices. Decoding algorithms are also treated, including the Viterbi algorithm and its performance on AWGN



channels, the BCJR algorithm for iterative decoding of turbo codes, and the sum-product algorithm.

**Chapter 9** is focused on digital communication through band-limited channels. Topics treated in this chapter include the characterization and signal design for band-limited channels, the optimum receiver for channels with intersymbol interference and AWGN, and suboptimum equalization methods, namely, linear equalization, decision-feedback equalization, and turbo equalization.

**Chapter 10** treats adaptive channel equalization. The LMS and recursive least-squares algorithms are described together with their performance characteristics. This chapter also includes a treatment of blind equalization algorithms.

**Chapter 11** provides a treatment of multichannel and multicarrier modulation. Topics treated include the error rate performance of multichannel binary signal and  $M$ -ary orthogonal signals in AWGN channels; the capacity of a nonideal linear filter channel with AWGN; OFDM modulation and demodulation; bit and power allocation in an OFDM system; and methods to reduce the peak-to-average power ratio in OFDM.

**Chapter 12** is focused on spread spectrum signals and systems, with emphasis on direct sequence and frequency-hopped spread spectrum systems and their performance. The benefits of coding in the design of spread spectrum signals is emphasized throughout this chapter.

**Chapter 13** treats communication through fading channels, including the characterization of fading channels and the key important parameters of multipath spread and Doppler spread. Several channel fading statistical models are introduced, with emphasis placed on Rayleigh fading, Ricean fading, and Nakagami fading. An analysis of the performance degradation caused by Doppler spread in an OFDM system is presented, and a method for reducing this performance degradation is described.

**Chapter 14** is focused on capacity and code design for fading channels. After introducing ergodic and outage capacities, coding for fading channels is studied. Bandwidth-efficient coding and bit-interleaved coded modulation are treated, and the performance of coded systems in Rayleigh and Ricean fading is derived.

**Chapter 15** provides a treatment of multiple-antenna systems, generally called multiple-input, multiple-output (MIMO) systems, which are designed to yield spatial signal diversity and spatial multiplexing. Topics treated in this chapter include detection algorithms for MIMO channels, the capacity of MIMO channels with AWGN without and with signal fading, and space-time coding.

**Chapter 16** treats multiuser communications, including the topics of the capacity of multiple-access methods, multiuser detection methods for the uplink in CDMA systems, interference mitigation in multiuser broadcast channels, and random access methods such as ALOHA and carrier-sense multiple access (CSMA).

With 16 chapters and a variety of topics, the instructor has the flexibility to design either a one- or two-semester course. Chapters 3, 4, and 5 provide a basic treatment of digital modulation/demodulation and detection methods. Channel coding and decoding treated in Chapters 7, 8, and 9 can be included along with modulation/demodulation in a one-semester course. Alternatively, Chapters 9 through 12 can be covered in place of channel coding and decoding. A second semester course can cover the topics of

communication through fading channels, multiple-antenna systems, and multiuser communications.

The authors and McGraw-Hill would like to thank the following reviewers for their suggestions on selected chapters of the fifth edition manuscript:

Paul Salama, *Indiana University/Purdue University, Indianapolis*; Dimitrios Hatzinakos, *University of Toronto*, and Ender Ayanoglu, *University of California, Irvine*.

Finally, the first author wishes to thank Gloria Doukakis for her assistance in typing parts of the manuscript. We also thank Patrick Amihood for preparing several graphs in Chapters 15 and 16 and Apostolos Rizos and Kostas Stamatiou for preparing parts of the Solutions Manual.

B R I E F C O N T E N T S

概 要 目 录

<b>Preface</b>		xvi
<b>Chapter 1</b>	Introduction	1
<b>Chapter 2</b>	Deterministic and Random Signal Analysis	17
<b>Chapter 3</b>	Digital Modulation Schemes	95
<b>Chapter 4</b>	Optimum Receivers for AWGN Channels	160
<b>Chapter 5</b>	Carrier and Symbol Synchronization	290
<b>Chapter 6</b>	An Introduction to Information Theory	330
<b>Chapter 7</b>	Linear Block Codes	400
<b>Chapter 8</b>	Trellis and Graph Based Codes	491
<b>Chapter 9</b>	Digital Communication Through Band-Limited Channels	597
<b>Chapter 10</b>	Adaptive Equalization	689
<b>Chapter 11</b>	Multichannel and Multicarrier Systems	737
<b>Chapter 12</b>	Spread Spectrum Signals for Digital Communications	762
<b>Chapter 13</b>	Fading Channels I: Characterization and Signaling	830
<b>Chapter 14</b>	Fading Channels II: Capacity and Coding	899
<b>Chapter 15</b>	Multiple-Antenna Systems	966
<b>Chapter 16</b>	Multiuser Communications	1028
<b>Appendices</b>		
<b>Appendix A</b>	Matrices	1085
<b>Appendix B</b>	Error Probability for Multichannel Binary Signals	1090
<b>Appendix C</b>	Error Probabilities for Adaptive Reception of $M$ -Phase Signals	1096
<b>Appendix D</b>	Square Root Factorization	1107
<b>References and Bibliography</b>		1109
<b>Index</b>		1142

Preface		xvi
<b>Chapter 1 Introduction</b>		<b>1</b>
1.1 Elements of a Digital Communication System		1
1.2 Communication Channels and Their Characteristics		3
1.3 Mathematical Models for Communication Channels		10
1.4 A Historical Perspective in the Development of Digital Communications		12
1.5 Overview of the Book		15
1.6 Bibliographical Notes and References		15
<b>Chapter 2 Deterministic and Random Signal Analysis</b>		<b>17</b>
2.1 Bandpass and Lowpass Signal Representation		18
2.1-1 Bandpass and Lowpass Signals / 2.1-2 Lowpass Equivalent of Bandpass Signals / 2.1-3 Energy Considerations / 2.1-4 Lowpass Equivalent of a Bandpass System		
2.2 Signal Space Representation of Waveforms		28
2.2-1 Vector Space Concepts / 2.2-2 Signal Space Concepts / 2.2-3 Orthogonal Expansions of Signals / 2.2-4 Gram-Schmidt Procedure		
2.3 Some Useful Random Variables		40
2.4 Bounds on Tail Probabilities		56
2.5 Limit Theorems for Sums of Random Variables		63
2.6 Complex Random Variables		63
2.6-1 Complex Random Vectors		
2.7 Random Processes		66
2.7-1 Wide-Sense Stationary Random Processes / 2.7-2 Cyclostationary Random Processes / 2.7-3 Proper and Circular Random Processes / 2.7-4 Markov Chains		
2.8 Series Expansion of Random Processes		74
2.8-1 Sampling Theorem for Band-Limited Random Processes / 2.8-2 The Karhunen-Loève Expansion		
2.9 Bandpass and Lowpass Random Processes		78



2.10	Bibliographical Notes and References Problems	82 82
<b>Chapter 3</b>	<b>Digital Modulation Schemes</b>	<b>95</b>
3.1	Representation of Digitally Modulated Signals	95
3.2	Memoryless Modulation Methods 3.2-1 <i>Pulse Amplitude Modulation (PAM)</i> / 3.2-2 <i>Phase Modulation</i> / 3.2-3 <i>Quadrature Amplitude Modulation</i> / 3.2-4 <i>Multidimensional Signaling</i>	97
3.3	Signaling Schemes with Memory 3.3-1 <i>Continuous-Phase Frequency-Shift Keying (CPFSK)</i> / 3.3-2 <i>Continuous-Phase Modulation (CPM)</i>	114
3.4	Power Spectrum of Digitally Modulated Signals 3.4-1 <i>Power Spectral Density of a Digitally Modulated Signal with Memory</i> / 3.4-2 <i>Power Spectral Density of Linearly Modulated Signals</i> / 3.4-3 <i>Power Spectral Density of Digitally Modulated Signals with Finite Memory</i> / 3.4-4 <i>Power Spectral Density of Modulation Schemes with a Markov Structure</i> / 3.4-5 <i>Power Spectral Densities of CPFSK and CPM Signals</i>	131
3.5	Bibliographical Notes and References Problems	148 148
<b>Chapter 4</b>	<b>Optimum Receivers for AWGN Channels</b>	<b>160</b>
4.1	Waveform and Vector Channel Models 4.1-1 <i>Optimal Detection for a General Vector Channel</i>	160
4.2	Waveform and Vector AWGN Channels 4.2-1 <i>Optimal Detection for the Vector AWGN Channel</i> / 4.2-2 <i>Implementation of the Optimal Receiver for AWGN Channels</i> / 4.2-3 <i>A Union Bound on the Probability of Error of Maximum Likelihood Detection</i>	167
4.3	Optimal Detection and Error Probability for Band-Limited Signaling 4.3-1 <i>Optimal Detection and Error Probability for ASK or PAM Signaling</i> / 4.3-2 <i>Optimal Detection and Error Probability for PSK Signaling</i> / 4.3-3 <i>Optimal Detection and Error Probability for QAM Signaling</i> / 4.3-4 <i>Demodulation and Detection</i>	188
4.4	Optimal Detection and Error Probability for Power-Limited Signaling 4.4-1 <i>Optimal Detection and Error Probability for Orthogonal Signaling</i> / 4.4-2 <i>Optimal Detection and Error Probability for Biorthogonal Signaling</i> / 4.4-3 <i>Optimal Detection and Error Probability for Simplex Signaling</i>	203

4.5	Optimal Detection in Presence of Uncertainty: Noncoherent Detection	210
	4.5-1 <i>Noncoherent Detection of Carrier Modulated Signals</i> / 4.5-2 <i>Optimal Noncoherent Detection of FSK Modulated Signals</i> / 4.5-3 <i>Error Probability of Orthogonal Signaling with Noncoherent Detection</i> / 4.5-4 <i>Probability of Error for Envelope Detection of Correlated Binary Signals</i> / 4.5-5 <i>Differential PSK (DPSK)</i>	
4.6	A Comparison of Digital Signaling Methods	226
	4.6-1 <i>Bandwidth and Dimensionality</i>	
4.7	Lattices and Constellations Based on Lattices	230
	4.7-1 <i>An Introduction to Lattices</i> / 4.7-2 <i>Signal Constellations from Lattices</i>	
4.8	Detection of Signaling Schemes with Memory	242
	4.8-1 <i>The Maximum Likelihood Sequence Detector</i>	
4.9	Optimum Receiver for CPM Signals	246
	4.9-1 <i>Optimum Demodulation and Detection of CPM</i> / 4.9-2 <i>Performance of CPM Signals</i> / 4.9-3 <i>Suboptimum Demodulation and Detection of CPM Signals</i>	
4.10	Performance Analysis for Wireline and Radio Communication Systems	259
	4.10-1 <i>Regenerative Repeaters</i> / 4.10-2 <i>Link Budget Analysis in Radio Communication Systems</i>	
4.11	Bibliographical Notes and References	265
	Problems	266
<b>Chapter 5</b>	<b>Carrier and Symbol Synchronization</b>	<b>290</b>
5.1	Signal Parameter Estimation	290
	5.1-1 <i>The Likelihood Function</i> / 5.1-2 <i>Carrier Recovery and Symbol Synchronization in Signal Demodulation</i>	
5.2	Carrier Phase Estimation	295
	5.2-1 <i>Maximum-Likelihood Carrier Phase Estimation</i> / 5.2-2 <i>The Phase-Locked Loop</i> / 5.2-3 <i>Effect of Additive Noise on the Phase Estimate</i> / 5.2-4 <i>Decision-Directed Loops</i> / 5.2-5 <i>Non-Decision-Directed Loops</i>	
5.3	Symbol Timing Estimation	315
	5.3-1 <i>Maximum-Likelihood Timing Estimation</i> / 5.3-2 <i>Non-Decision-Directed Timing Estimation</i>	
5.4	Joint Estimation of Carrier Phase and Symbol Timing	321
5.5	Performance Characteristics of ML Estimators	323
5.6	Bibliographical Notes and References	326
	Problems	327
<b>Chapter 6</b>	<b>An Introduction to Information Theory</b>	<b>330</b>
6.1	Mathematical Models for Information Sources	331

6.2	A Logarithmic Measure of Information	332
6.3	Lossless Coding of Information Sources	335
	6.3-1 <i>The Lossless Source Coding Theorem</i> / 6.3-2 <i>Lossless Coding Algorithms</i>	
6.4	Lossy Data Compression	348
	6.4-1 <i>Entropy and Mutual Information for Continuous Random Variables</i> / 6.4-2 <i>The Rate Distortion Function</i>	
6.5	Channel Models and Channel Capacity	354
	6.5-1 <i>Channel Models</i> / 6.5-2 <i>Channel Capacity</i>	
6.6	Achieving Channel Capacity with Orthogonal Signals	367
6.7	The Channel Reliability Function	369
6.8	The Channel Cutoff Rate	371
	6.8-1 <i>Bhattacharyya and Chernov Bounds</i> / 6.8-2 <i>Random Coding</i>	
6.9	Bibliographical Notes and References	380
	Problems	381
<b>Chapter 7</b>	<b>Linear Block Codes</b>	<b>400</b>
7.1	Basic Definitions	401
	7.1-1 <i>The Structure of Finite Fields</i> / 7.1-2 <i>Vector Spaces</i>	
7.2	General Properties of Linear Block Codes	411
	7.2-1 <i>Generator and Parity Check Matrices</i> / 7.2-2 <i>Weight and Distance for Linear Block Codes</i> / 7.2-3 <i>The Weight Distribution Polynomial</i> / 7.2-4 <i>Error Probability of Linear Block Codes</i>	
7.3	Some Specific Linear Block Codes	420
	7.3-1 <i>Repetition Codes</i> / 7.3-2 <i>Hamming Codes</i> / 7.3-3 <i>Maximum-Length Codes</i> / 7.3-4 <i>Reed-Muller Codes</i> / 7.3-5 <i>Hadamard Codes</i> / 7.3-6 <i>Golay Codes</i>	
7.4	Optimum Soft Decision Decoding of Linear Block Codes	424
7.5	Hard Decision Decoding of Linear Block Codes	428
	7.5-1 <i>Error Detection and Error Correction Capability of Block Codes</i> / 7.5-2 <i>Block and Bit Error Probability for Hard Decision Decoding</i>	
7.6	Comparison of Performance between Hard Decision and Soft Decision Decoding	436
7.7	Bounds on Minimum Distance of Linear Block Codes	440
	7.7-1 <i>Singleton Bound</i> / 7.7-2 <i>Hamming Bound</i> / 7.7-3 <i>Plotkin Bound</i> / 7.7-4 <i>Elias Bound</i> / 7.7-5 <i>McEliece-Rodemich-Rumsey-Welch (MRRW) Bound</i> / 7.7-6 <i>Varshamov-Gilbert Bound</i>	
7.8	Modified Linear Block Codes	445
	7.8-1 <i>Shortening and Lengthening</i> / 7.8-2 <i>Puncturing and Extending</i> / 7.8-3 <i>Expurgation and Augmentation</i>	

<b>7.9</b>	<b>Cyclic Codes</b>	<b>447</b>
	<i>7.9-1 Cyclic Codes—Definition and Basic Properties /</i>	
	<i>7.9-2 Systematic Cyclic Codes / 7.9-3 Encoders for Cyclic</i>	
	<i>Codes / 7.9-4 Decoding Cyclic Codes / 7.9-5 Examples of</i>	
	<i>Cyclic Codes</i>	
<b>7.10</b>	<b>Bose-Chaudhuri-Hocquenghem (BCH) Codes</b>	<b>463</b>
	<i>7.10-1 The Structure of BCH Codes / 7.10-2 Decoding</i>	
	<i>BCH Codes</i>	
<b>7.11</b>	<b>Reed-Solomon Codes</b>	<b>471</b>
<b>7.12</b>	<b>Coding for Channels with Burst Errors</b>	<b>475</b>
<b>7.13</b>	<b>Combining Codes</b>	<b>477</b>
	<i>7.13-1 Product Codes / 7.13-2 Concatenated Codes</i>	
<b>7.14</b>	<b>Bibliographical Notes and References</b>	<b>482</b>
	<b>Problems</b>	<b>482</b>
 <b>Chapter 8 Trellis and Graph Based Codes</b>		 <b>491</b>
<b>8.1</b>	<b>The Structure of Convolutional Codes</b>	<b>491</b>
	<i>8.1-1 Tree, Trellis, and State Diagrams / 8.1-2 The Transfer</i>	
	<i>Function of a Convolutional Code / 8.1-3 Systematic,</i>	
	<i>Nonrecursive, and Recursive Convolutional Codes /</i>	
	<i>8.1-4 The Inverse of a Convolutional Encoder and</i>	
	<i>Catastrophic Codes</i>	
<b>8.2</b>	<b>Decoding of Convolutional Codes</b>	<b>510</b>
	<i>8.2-1 Maximum-Likelihood Decoding of Convolutional</i>	
	<i>Codes—The Viterbi Algorithm / 8.2-2 Probability of</i>	
	<i>Error for Maximum-Likelihood Decoding of Convolutional</i>	
	<i>Codes</i>	
<b>8.3</b>	<b>Distance Properties of Binary Convolutional Codes</b>	<b>516</b>
<b>8.4</b>	<b>Punctured Convolutional Codes</b>	<b>516</b>
	<i>8.4-1 Rate-Compatible Punctured Convolutional Codes</i>	
<b>8.5</b>	<b>Other Decoding Algorithms for Convolutional Codes</b>	<b>525</b>
<b>8.6</b>	<b>Practical Considerations in the Application of</b>	
	<b>Convolutional Codes</b>	<b>532</b>
<b>8.7</b>	<b>Nonbinary Dual-<math>k</math> Codes and Concatenated Codes</b>	<b>537</b>
<b>8.8</b>	<b>Maximum a Posteriori Decoding of Convolutional</b>	
	<b>Codes—The BCJR Algorithm</b>	<b>541</b>
<b>8.9</b>	<b>Turbo Codes and Iterative Decoding</b>	<b>548</b>
	<i>8.9-1 Performance Bounds for Turbo Codes / 8.9-2 Iterative</i>	
	<i>Decoding for Turbo Codes / 8.9-3 EXIT Chart Study of</i>	
	<i>Iterative Decoding</i>	
<b>8.10</b>	<b>Factor Graphs and the Sum-Product Algorithm</b>	<b>558</b>
	<i>8.10-1 Tanner Graphs / 8.10-2 Factor Graphs / 8.10-3 The</i>	
	<i>Sum-Product Algorithm / 8.10-4 MAP Decoding Using the</i>	
	<i>Sum-Product Algorithm</i>	



8.11	Low Density Parity Check Codes	568
	8.11-1 Decoding LDPC Codes	
8.12	Coding for Bandwidth-Constrained Channels—Trellis Coded Modulation	571
	8.12-1 Lattices and Trellis Coded Modulation /	
	8.12-2 Turbo-Coded Bandwidth Efficient Modulation	
8.13	Bibliographical Notes and References	589
	Problems	590
<b>Chapter 9</b>	<b>Digital Communication Through Band-Limited Channels</b>	<b>597</b>
9.1	Characterization of Band-Limited Channels	598
9.2	Signal Design for Band-Limited Channels	602
	9.2-1 Design of Band-Limited Signals for No Intersymbol Interference—The Nyquist Criterion /	
	9.2-2 Design of Band-Limited Signals with Controlled ISI—Partial-Response Signals /	
	9.2-3 Data Detection for Controlled ISI /	
	9.2-4 Signal Design for Channels with Distortion	
9.3	Optimum Receiver for Channels with ISI and AWGN	623
	9.3-1 Optimum Maximum-Likelihood Receiver /	
	9.3-2 A Discrete-Time Model for a Channel with ISI /	
	9.3-3 Maximum-Likelihood Sequence Estimation (MLSE) for the Discrete-Time White Noise Filter Model /	
	9.3-4 Performance of MLSE for Channels with ISI	
9.4	Linear Equalization	640
	9.4-1 Peak Distortion Criterion /	
	9.4-2 Mean-Square-Error (MSE) Criterion /	
	9.4-3 Performance Characteristics of the MSE Equalizer /	
	9.4-4 Fractionally Spaced Equalizers /	
	9.4-5 Baseband and Passband Linear Equalizers	
9.5	Decision-Feedback Equalization	661
	9.5-1 Coefficient Optimization /	
	9.5-2 Performance Characteristics of DFE /	
	9.5-3 Predictive Decision-Feedback Equalizer /	
	9.5-4 Equalization at the Transmitter—Tomlinson-Harashima Precoding	
9.6	Reduced Complexity ML Detectors	669
9.7	Iterative Equalization and Decoding—Turbo Equalization	671
9.8	Bibliographical Notes and References	673
	Problems	674
<b>Chapter 10</b>	<b>Adaptive Equalization</b>	<b>689</b>
10.1	Adaptive Linear Equalizer	689
	10.1-1 The Zero-Forcing Algorithm /	
	10.1-2 The LMS Algorithm /	
	10.1-3 Convergence Properties of the LMS	