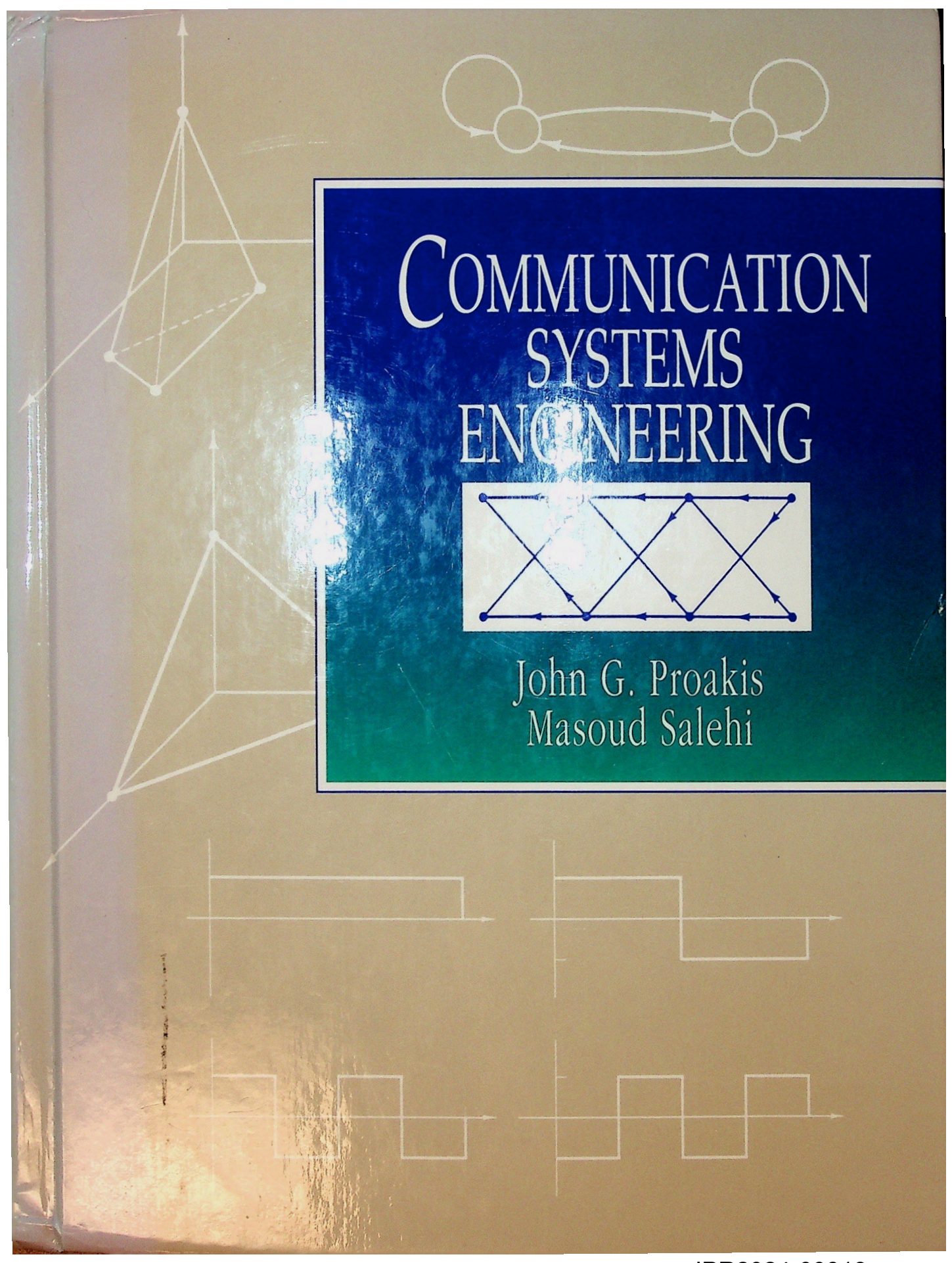
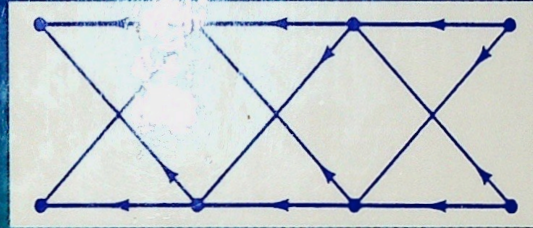


The background of the book cover is a light beige color with several faint, white technical diagrams. In the top left, there is a 3D wireframe diagram of a cube with an arrow pointing upwards from one of its vertices. In the top right, there is a state transition diagram with two circular nodes connected by two curved arrows, one in each direction. In the bottom half, there are four rectangular waveforms arranged in a 2x2 grid, each plotted on a set of axes. The title 'COMMUNICATION SYSTEMS ENGINEERING' is printed in a large, white, serif font, centered within a dark blue rectangular area that has a subtle, mottled texture.

COMMUNICATION SYSTEMS ENGINEERING



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Communication Systems Engineering

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Contents

Preface**xv****1 Introduction****1**

- 1.1 Historical Review 2
- 1.2 Elements of an Electrical Communication System 5
 - 1.2.1 *Digital Communication System*, 8
 - 1.2.2 *Early Work in Digital Communications*, 11
- 1.3 Communication Channels and Their Characteristics 13
- 1.4 Mathematical Models for Communication Channels 21
- 1.5 Organization of the Book 23
- 1.6 Further Reading 25

vii

2 Signals and Linear Systems**26**

- 2.1 Basic Concepts 27
 - 2.1.1 Classification of Signals, 27
 - 2.1.2 Some Important Signals and Their Properties, 36
 - 2.1.3 Classification of Systems, 42
 - 2.1.4 Analysis of LTI Systems in the Time Domain, 45
- 2.2 Fourier Series 47
 - 2.2.1 Signal Space Concepts, 48
 - 2.2.2 Orthogonal Expansion of Signals, 53
 - 2.2.3 Fourier Series and Its Properties, 55
 - 2.2.4 Response of LTI Systems to Periodic Signals, 65
 - 2.2.5 Parseval's Relation, 68
- 2.3 Fourier Transforms 70
 - 2.3.1 From Fourier Series to Fourier Transforms, 70
 - 2.3.2 Basic Properties of the Fourier Transform, 78
 - 2.3.3 Fourier Transform for Periodic Signals, 91
 - 2.3.4 Transmission over LTI Systems, 94
- 2.4 Power and Energy 97
 - 2.4.1 Energy-Type Signals, 98
 - 2.4.2 Power-Type Signals, 101
- 2.5 Sampling of Signals
and Signal Reconstruction from Samples 104
 - 2.5.1 Ideal Sampling, 104
 - 2.5.2 Practical Sampling, 110
- 2.6 Bandpass Signals 112
 - 2.6.1 Properties of the Hilbert Transform, 122
- 2.7 Further Reading 125
 - Problems 125

3 Random Processes**143**

- 3.1 Probability and Random Variables 144
- 3.2 Random Processes: Basic Concepts 160
 - 3.2.1 Description of Random Processes, 162
 - 3.2.2 Statistical Averages, 164
 - 3.2.3 Stationary Processes, 167
 - 3.2.4 Random processes and linear systems, 175
- 3.3 Random Processes in the Frequency Domain 178

- 3.3.1 *Power Spectrum of Stochastic Processes*, 179
- 3.3.2 *Transmission over LTI Systems*, 185
- 3.4 Gaussian and White Processes 188
 - 3.4.1 *Gaussian Processes*, 188
 - 3.4.2 *White Processes*, 190
- 3.5 Bandlimited Processes and Sampling 193
- 3.6 Bandpass Processes 196
- 3.7 Further Reading 204
- Problems 204

4 Information Sources and Source Coding 221

- 4.1 Modeling of Information Sources 222
 - 4.1.1 *Measure of Information*, 223
 - 4.1.2 *Joint and Conditional Entropy*, 225
- 4.2 Source-Coding Theorem 228
- 4.3 Source-Coding Algorithms 230
 - 4.3.1 *The Huffman Source-Coding Algorithm*, 230
 - 4.3.2 *The Lempel-Ziv Source Coding Algorithm*, 235
- 4.4 Rate-Distortion Theory 237
 - 4.4.1 *Mutual Information*, 238
 - 4.4.2 *Differential Entropy*, 239
 - 4.4.3 *Rate-Distortion Function*, 240
- 4.5 Quantization 246
 - 4.5.1 *Scalar Quantization*, 247
 - 4.5.2 *Vector Quantization*, 256
- 4.6 Waveform Coding 259
 - 4.6.1 *Pulse-Code Modulation*, 259
 - 4.6.2 *Differential Pulse-Code Modulation*, 264
 - 4.6.3 *Delta Modulation*, 267
- 4.7 Analysis-Synthesis Techniques 270
- 4.8 Digital Audio Transmission and Digital Audio Recording 274
 - 4.8.1 *Digital Audio in Telephone Transmission Systems*, 274
 - 4.8.2 *Digital Audio Recording*, 276
- 4.9 Further Reading 282
- Problems 282

5 Analog Signal Transmission and Reception

296

- 5.1 Introduction to Modulation 297
- 5.2 Amplitude Modulation 298
 - 5.2.1 Double-Sideband Suppressed Carrier AM, 298
 - 5.2.2 Conventional Amplitude Modulation, 306
 - 5.2.3 Single-Sideband AM, 310
 - 5.2.4 Vestigial-Sideband AM, 317
 - 5.2.5 Implementation of AM Modulators and Demodulators, 320
 - 5.2.6 Signal Multiplexing, 326
- 5.3 Angle Modulation 328
 - 5.3.1 Representation of FM and PM Signals, 329
 - 5.3.2 Spectral Characteristics of Angle Modulated Signals, 333
 - 5.3.3 Implementation of Angle Modulators and Demodulators, 343
- 5.4 Radio and Television Broadcasting 351
 - 5.4.1 AM Radio Broadcasting, 351
 - 5.4.2 FM Radio Broadcasting, 354
 - 5.4.3 Television Broadcasting, 356
- 5.5 Mobile Radio Systems 367
- 5.6 Further Reading 369
 - Problems 370

6 Effect of Noise on Analog Communication Systems

385

- 6.1 Effect of Noise on Linear Modulation Systems 386
 - 6.1.1 Effect of Noise on a Baseband System, 386
 - 6.1.2 Effect of Noise on DSB-SC AM, 386
 - 6.1.3 Effect of Noise on SSB AM, 388
 - 6.1.4 Effect of Noise on Conventional AM, 389
- 6.2 Carrier Phase Estimation with a Phase-Locked Loop 394
 - 6.2.1 Effect of Additive Noise on Phase Estimation, 398
- 6.3 Effect of Noise on Angle Modulation 404
 - 6.3.1 Threshold Effect in Angle Modulation, 414
 - 6.3.2 Pre-emphasis and De-emphasis Filtering, 418
- 6.4 Comparison of Analog-Modulation Systems 421
- 6.5 Effects of Transmission Losses and Noise in Analog Communication Systems 422
 - 6.5.1 Characterization of Thermal Noise Sources, 423

- 6.5.2 *Effective Noise Temperature and Noise Figure*, 424
- 6.5.3 *Transmission Losses*, 427
- 6.5.4 *Repeaters for Signal Transmission*, 428

- 6.6 Further Reading 431
- Problems 431

7 Digital Transmission Through an Additive White Gaussian Noise Channel 437

- 7.1 Pulse Modulation Signals
and Their Geometric Representation 438
 - 7.1.1 *Pulse Modulation Signals*, 438
 - 7.1.2 *Geometric Representation of Signal Waveforms*, 444
 - 7.1.3 *Geometric Representation of M-ary Pulse Modulation Signals*, 448
 - 7.1.4 *Modulation Codes and Modulation Signals with Memory*, 453
- 7.2 Optimum Receiver for Pulse-Modulated Signals
in Additive White Gaussian Noise 467
 - 7.2.1 *Correlation-Type Demodulator*, 469
 - 7.2.2 *Matched-Filter-Type Demodulator*, 474
 - 7.2.3 *The Optimum Detector*, 480
 - 7.2.4 *The Maximum-Likelihood Sequence Detector*, 484
- 7.3 Probability of Error for Signals
in Additive White Gaussian Noise 488
 - 7.3.1 *Probability of Error for Binary Modulation*, 488
 - 7.3.2 *Probability of Error for M-ary Modulation*, 492
 - 7.3.3 *Probability of Error for ML Sequence Detection*, 502
 - 7.3.4 *Comparison of Modulation Methods*, 504
- 7.4 Regenerative Repeaters and Link Budget Analysis 506
 - 7.4.1 *Regenerative Repeaters*, 507
 - 7.4.2 *Link Budget Analysis for Radio Channels*, 509
- 7.5 Further Reading 512
- Problems 513

8 Digital PAM Transmission Through Bandlimited AWGN Channels 530

- 8.1 Digital Transmission
Through Bandlimited Baseband Channels 531
 - 8.1.1 *Digital PAM Transmission
Through Bandlimited Baseband Channels*, 535

8.1.2	<i>The Power Spectrum of a Digital PAM Signal</i> , 537	
8.1.3	<i>The Power Spectrum of Digital Signals with Memory</i> , 542	
8.2	Signal Design for Bandlimited Channels 547	
8.2.1	<i>Design of Bandlimited Signals for Zero ISI—The Nyquist Criterion</i> , 548	
8.2.2	<i>Design of Bandlimited Signals with Controlled ISI—Partial Response Signals</i> , 555	
8.2.3	<i>Data Detection for Controlled ISI</i> , 558	
8.3	Probability of Error in Detection of Digital PAM 564	
8.3.1	<i>Probability of Error for Detection of Digital PAM with Zero ISI</i> , 565	
8.3.2	<i>Probability of Error for Detection of Partial Response Signals</i> , 566	
8.4	System Design in the Presence of Channel Distortion 570	
8.4.1	<i>Design of Optimum Transmitting and Receiving Filters</i> , 572	
8.4.2	<i>Channel Equalization</i> , 577	
8.5	Symbol Synchronization 595	
8.5.1	<i>Spectral-Line Methods</i> , 597	
8.5.2	<i>Early-Late Gate Synchronizers</i> , 600	
8.5.3	<i>Minimum Mean-Square-Error Method</i> , 603	
8.5.4	<i>Maximum-Likelihood Methods</i> , 603	
8.6	Further Reading 606	
	Problems 606	
9	Digital Transmission via Carrier Modulation	617
9.1	Carrier-Amplitude Modulation 618	
9.1.1	<i>Amplitude Demodulation and Detection</i> , 621	
9.1.2	<i>Probability of Error for PAM in an AWGN Channel</i> , 624	
9.1.3	<i>Signal Demodulation in the Presence of Channel Distortion</i> , 626	
9.2	Carrier-Phase Modulation 628	
9.2.1	<i>Phase Demodulation and Detection</i> , 633	
9.2.2	<i>Probability of Error for Phase Modulation in an AWGN Channel</i> , 636	
9.2.3	<i>Carrier Phase Estimation</i> , 640	
9.2.4	<i>Differential-Phase Modulation and Demodulation</i> , 643	
9.2.5	<i>Probability of Error for DPSK in an AWGN Channel</i> , 645	
9.3	Quadrature Amplitude Modulation 646	
9.3.1	<i>Demodulation and Detection of QAM</i> , 649	
9.3.2	<i>Probability of Error for QAM in AWGN Channel</i> , 652	

9.3.3	<i>Carrier-Phase Estimation, 658</i>	
9.4	Carrier-Frequency Modulation	659
9.4.1	<i>Frequency-Shift Keying, 659</i>	
9.4.2	<i>Demodulation and Detection of FSK Signals, 661</i>	
9.4.3	<i>Probability of Error for Noncoherent Detection of FSK, 667</i>	
9.4.4	<i>Continuous-Phase FSK, 671</i>	
9.4.5	<i>Spectral Characteristics of CPFSK Signals, 678</i>	
9.5	Continuous-Phase Carrier Modulation	681
9.5.1	<i>Demodulation and Detection of CPM Signals, 686</i>	
9.5.2	<i>Performance of CPM in an AWGN Channel, 691</i>	
9.5.3	<i>Spectral Characteristics of CPM Signals, 694</i>	
9.6	Digital Transmission on Fading Multipath Channels	695
9.6.1	<i>Channel Model for Time-Variant Multipath Channels, 697</i>	
9.6.2	<i>Signal Design for Fading Multipath Channels, 703</i>	
9.6.3	<i>Performance of Binary Modulation in Rayleigh Fading Channels, 706</i>	
9.7	Further Reading	713
	Problems	714
10	Channel Capacity and Coding	726
10.1	Modeling of Communication Channels	726
10.2	Channel Capacity	729
10.2.1	<i>Gaussian Channel Capacity, 733</i>	
10.3	Bounds on Communication	736
10.3.1	<i>Transmission of Analog Sources by PCM, 740</i>	
10.4	Coding for Reliable Communication	742
10.4.1	<i>A Tight Bound on Error Probability of Orthogonal Signals, 743</i>	
10.4.2	<i>The Promise of Coding, 746</i>	
10.5	Linear Block Codes	753
10.5.1	<i>Decoding and Performance of Linear Block Codes, 757</i>	
10.5.2	<i>Burst-Error-Correcting-Codes, 767</i>	
10.6	Cyclic Codes	769
10.6.1	<i>The Structure of Cyclic Codes, 769</i>	
10.7	Convolutional Codes	777
10.7.1	<i>Basic Properties of Convolutional Codes, 779</i>	

10.7.2	<i>Optimum Decoding of Convolutional Codes—The Viterbi Algorithm</i> , 784	
10.7.3	<i>Other Decoding Algorithms for Convolutional Codes</i> , 789	
10.7.4	<i>Bounds on Error Probability of Convolutional Codes</i> , 789	
10.8	Coding for Bandwidth Constrained Channels	792
10.8.1	<i>Combined Coding and Modulation</i> , 794	
10.8.2	<i>Trellis Coded Modulation</i> , 796	
10.9	Practical Applications of Coding	803
10.9.1	<i>Coding for Deep-Space Communications</i> , 803	
10.9.2	<i>Coding for Telephone-Line Modems</i> , 804	
10.9.3	<i>Coding for Compact Disks</i> , 805	
10.10	Further Reading	809
	Problems	809
11	Spread-Spectrum Communication Systems	822
11.1	Model of a Spread-Spectrum Digital Communication Systems	823
11.2	Direct-Sequence Spread Spectrum Systems	825
11.2.1	<i>Probability of Error</i> , 829	
11.2.2	<i>Some Applications of DS Spread-Spectrum Signals</i> , 837	
11.2.3	<i>Generation of PN Sequences</i> , 844	
11.3	Frequency-Hopped Spread Spectrum	848
11.3.1	<i>Slow Frequency-Hopping Systems</i> , 851	
11.3.2	<i>Fast Frequency-Hopping Systems</i> , 853	
11.3.3	<i>Applications of FH Spread Spectrum</i> , 855	
11.4	Other Types of Spread-Spectrum Signals	856
11.5	Synchronization of Spread-Spectrum Systems	857
11.6	Further Reading	865
	Problems	865
	Appendix A: The Probability of Error for Multichannel Reception of Binary Signals	869
	References	873
	Index	881

A transducer is usually required to convert the output of a source into an electrical signal that is suitable for transmission. For example, a microphone serves as the transducer that converts an acoustic speech signal into an electrical signal, and a video camera converts an image into an electrical signal. At the destination, a similar transducer is required to convert the electrical signals that are received into a form that is suitable for the user; for example, acoustic signals, images, etc.

The heart of the communication system consists of three basic parts, namely, the transmitter, the channel, and the receiver. The functions performed by these three elements are described below.

The transmitter. The transmitter converts the electrical signal into a form that is suitable for transmission through the physical channel or transmission medium. For example, in radio and TV broadcast, the Federal Communications Commission (FCC) specifies the frequency range for each transmitting station. Hence, the transmitter must translate the information signal to be transmitted into the appropriate frequency range that matches the frequency allocation assigned to the transmitter. Thus, signals transmitted by multiple radio stations do not interfere with one another. Similar functions are performed in telephone communication systems, where the electrical speech signals from many users are transmitted over the same wire.

In general, the transmitter performs the matching of the message signal to the channel by a process called *modulation*. Usually, modulation involves the use of the information signal to systematically vary the amplitude, frequency, or phase of a sinusoidal carrier. For example, in AM radio broadcast, the information signal that is transmitted is contained in the amplitude variations of the sinusoidal carrier, which is the center frequency in the frequency band allocated to the radio transmitting station. This is an example of *amplitude modulation*. In FM radio broadcast, the information signal that is transmitted is contained in the frequency variations of the sinusoidal carrier. This is an example of *frequency modulation*. *Phase modulation* (PM) is yet a third method for impressing the information signal on a sinusoidal carrier.

In general, carrier modulation such as AM, FM, and PM is performed at the transmitter, as indicated above, to convert the information signal to a form that matches the characteristics of the channel. Thus, through the process of modulation, the information signal is translated in frequency to match the allocation of the channel. The choice of the type of modulation is based on several factors, such as the amount of bandwidth allocated, the types of noise and interference that the signal encounters in transmission over the channel, and the electronic devices that are available for signal amplification prior to transmission. In any case, the modulation process makes it possible to accommodate the transmission of multiple messages from many users over the same physical channel.

In addition to modulation, other functions that are usually performed at the transmitter are filtering of the information-bearing signal, amplification of the mod-

ulated signal, and in the case of wireless transmission, radiation of the signal by means of a transmitting antenna.

The channel. The communications channel is the physical medium that is used to send the signal from the transmitter to the receiver. In wireless transmission, the channel is usually the atmosphere (free space). On the other hand, telephone channels usually employ a variety of physical media, including wirelines, optical fiber cables, and wireless (microwave radio). Whatever the physical medium for signal transmission, the essential feature is that the transmitted signal is corrupted in a random manner by a variety of possible mechanisms. The most common form of signal degradation comes in the form of additive noise, which is generated at the front end of the receiver, where signal amplification is performed. This noise is often called *thermal noise*. In wireless transmission, additional additive disturbances are man-made noise and atmospheric noise picked up by a receiving antenna. Automobile ignition noise is an example of man-made noise, and electrical lightning discharges from thunderstorms is an example of atmospheric noise. Interference from other users of the channel is another form of additive noise that often arises in both wireless and wireline communication systems.

In some radio communication channels, such as the ionospheric channel that is used for long-range, short-wave radio transmission, another form of signal degradation is multipath propagation. Such signal distortion is characterized as a nonadditive signal disturbance which manifests itself as time variations in the signal amplitude, usually called *fading*. This phenomenon is described in more detail in Section 1.3.

Both additive and nonadditive signal distortions are usually characterized as random phenomena and described in statistical terms. The effect of these signal distortions must be taken into account in the design of the communication system.

In the design of a communication system, the system designer works with mathematical models that statistically characterize the signal distortion encountered on physical channels. Often, the statistical description that is used in a mathematical model is a result of actual empirical measurements obtained from experiments involving signal transmission over such channels. In such case, there is a physical justification for the mathematical model used in the design of communication systems. On the other hand, in some communication system designs, the statistical characteristics of the channel may vary significantly with time. In such cases, the system designer may design a communication system that is robust to the variety of signal distortions. This can be accomplished by having the system adapt some of its parameters to the channel distortion encountered.

The receiver. The function of the receiver is to recover the message signal contained in the received signal. If the message signal is transmitted by carrier modulation, the receiver performs *carrier demodulation* to extract the message from the sinusoidal carrier. Since the signal demodulation is performed in the presence

COMMUNICATION SYSTEMS ENGINEERING

John G. Proakis
Masoud Salehi

Communication systems have become part of our daily life through a variety of communications media such as wireline telephone channels, microwave radio, fiber-optic channels, and satellite channels. To help readers keep pace with the explosive growth of communication systems, this comprehensive volume introduces the basic principles underlying the analysis and design of both analog and digital communication systems.

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- Places a greater emphasis than existing introductory-level texts on elements of and approaches to system design.

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