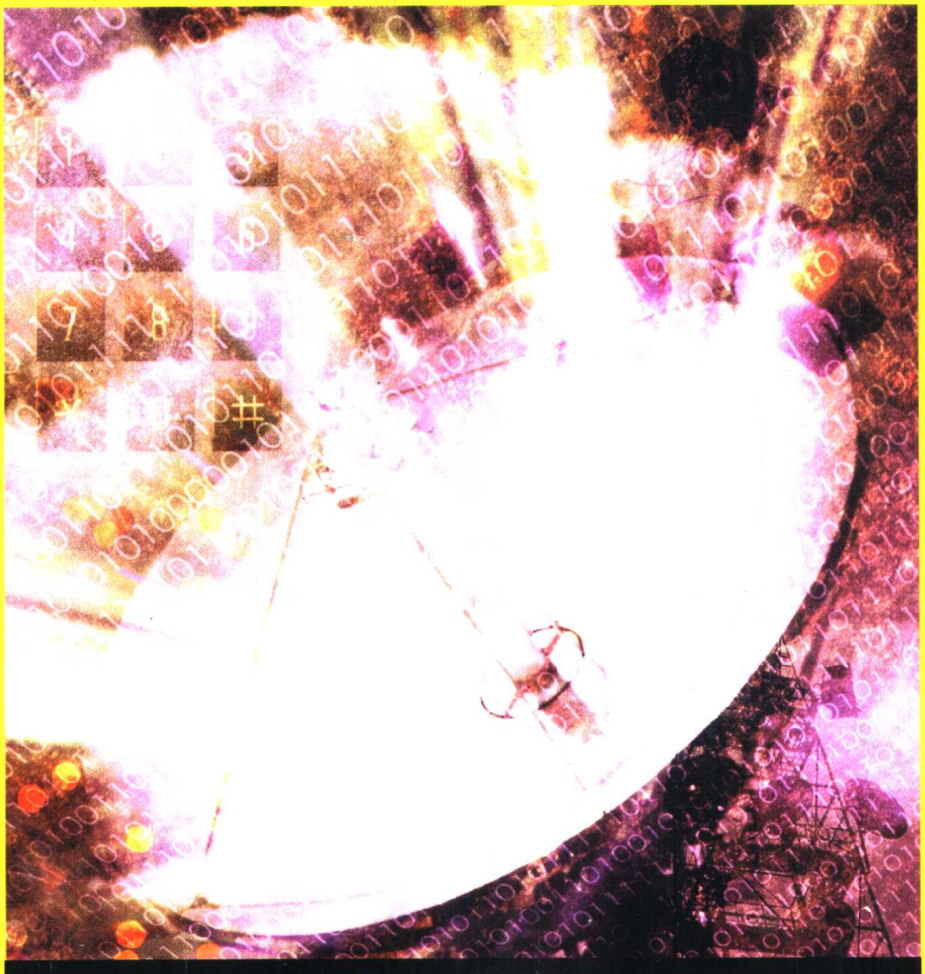
英文版

通信与信息科学教育丛书



电子通信系统（第2版）

〔加〕Roy Blake 著

Electronic Communication Systems (2nd edition)

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Publishing House of Electronics Industry

北京 · BEIJING

内容简介

本书主要介绍当今通信领域的最新技术。本书内容全面，讲解透彻，包括传统的电子通信系统和现代数字技术以及现代无线通信系统（蜂窝技术、无线电技术、寻呼系统和无线数据网络等）。第2版对数据通信、因特网技术、高分辨率电视和光纤通信等部分内容都进行了更新，以跟踪最新的技术发展趋势。全书理论与实际应用并重，采用面向系统的方式并应用 MATLAB 等软件使讲解更加详尽。

本书适合作为电子、通信等专业学生的教学参考书，也可作为电子工程师的技术参考书。

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出 版 说 明

近年来，通信与信息科技发展之快和应用之广，大大超出了人们的预料和专家的预测。从国民经济到社会生活的日益信息化，标志着通信与信息科技的空前发展。

为了满足高等院校师生教改和教学的需求以及广大技术人员学习通信与信息新技术的需要，电子工业出版社约请北京地区的清华大学、北京大学、北京航空航天大学、北京邮电大学、北方交通大学、北京理工大学，南京地区的东南大学、解放军理工大学、南京邮电学院，上海地区的上海交通大学，成都地区的西南交通大学、电子科技大学，西安地区的西安电子科技大学、西安交通大学，天津地区的南开大学，深圳地区的深圳大学，东北地区的哈尔滨工业大学等全国知名高等院校教学第一线上的教授和信息产业部有关科研院所的专家，请他们推荐和反复论证，从国外优秀的英文版图书中精选出版了这套《通信与信息科学教育丛书》（英文版）。

本套丛书可作为高等院校通信、计算机、电子信息等专业的高年级本科生、研究生的教材或教学参考书，也适合广大信息产业技术人员参考。

本套丛书所选取的均是国际上通信与信息科学领域具有代表性的经典著作，它们在全世界许多大学被用做教材或教学参考书。其主要特点是具有较强的先进性、实用性和权威性。丛书内容丰富，深入浅出，层次清楚，理论与应用并重，能够较好地引导读者将现代通信信息与信息科学的原理、技术与应用有机结合。我们希望本套丛书能够进一步推动国内高等院校教学与国际接轨，同时满足广大技术人员及时学习通信与信息科学领域中新知识的需求。

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电子工业出版社

Preface

Intended Audience

This text is intended for students in two-, three-, and four-year programs in electronics technology and electronics engineering technology. It includes both traditional analog communication—amplitude and frequency modulation and their variations—and modern developments in digital and data communications and networks. Radio and optical transmission systems are also given extensive coverage.

There is enough material in this text for a four-course sequence. For example, a basic analog communication course could include chapters 1 through 6. Chapters 7 through 13 could comprise a basic digital communication course. Chapters 14 through 17 could be the basis of a course in radio-frequency fundamentals. The chapters from 19 through 25 would be suitable for a senior-level course in the application of theory to actual systems. Of course the material can be divided in many different ways to suit the individual school.

Prerequisites

This text assumes a basic knowledge of analog and digital electronics. It is expected that students may need to be reminded of the ways in which high-frequency circuits differ from those operating at audio frequencies, so these differences are reviewed. Class C and other tuned amplifiers are also explained because students may not have covered them in previous courses. The text does not assume that students are familiar with mixing and modulation or with techniques for making measurements at radio frequencies, so these topics are covered in the text. Phase-locked loops are explained at a basic level, and no prior knowledge of these devices is assumed.

Frequency-domain analysis is essential in any book of this type, and Fourier analysis is introduced in the text. No prior knowledge is assumed.

It is assumed that the student's mathematical background includes algebra and basic trigonometry. Calculus is not required, but knowledge of logarithms and decibels is assumed in the text; these topics are reviewed in an appendix.

Organization of the Text

The text is organized according to topic, with fundamentals discussed earlier in the book and more advanced theory and applications coming later.

Chapter 1, *Introduction to Communication Systems,* is a general introduction to communication theory, especially the concepts of modulation, noise and bandwidth. Chapter 2, *Radio-Frequency Circuits,* is devoted to a review of radio-frequency circuits that will be used throughout the book. In general this

book is systems-, rather than circuits-oriented, but systems are, after all, composed of circuits, and Chapter 2 builds on the material usually found in college circuits courses, extending it into the radio-frequency field. Some of the examples in this chapter have been analyzed with MultiSIM software; the circuit files are available on the Online Companion web site.

Chapters 3 to 6 deal with analog modulation schemes and the radio transmitters and receivers associated with these techniques. Chapter 7, *Digital Communication,* introduces the digital transmission of analog signals, followed by Chapter 8, *The Telephone System,* a major application of analog and digital voice communication. Next, digital communication of data is discussed in Chapter 9, followed by a discussion of networking techniques in Chapters 10 through 13.

Chapters 14 through 16 are concerned with the propagation of radio-frequency waves, covering transmission lines, antennas, and wave propagation.

Chapter 17, *Microwave Devices,* prepares the student for the study of microwave systems in much the same way that Chapter 2 prepares for the study of radio frequencies. The design challenges presented by higher frequencies are discussed, along with the specialized devices used in microwave systems. Chapter 18, *Terrestrial Microwave Communication Systems,* describes applications of microwaves in terrestrial communication.

Chapters 19 through 23 explore many practical systems that use the theory discussed so far. These are television, satellite communication, cellular telephony and personal communication systems, paging, and wireless networks.

The final two chapters cover fiber-optic communication. Chapter 24, *Fiber Optics,* introduces the theory and components, and Chapter 25, *Optical Communication Systems,* describes practical systems.

Chapter Format

- Each chapter begins with a list of **Objectives** and an **Outline** of the chapter topics.
- **Interest Boxes** are included at the beginning and end of each chapter. ***Electronics . . . Rewind*** introduces each chapter and gives a glimpse into the past of communications. ***Electronics . . . Fast Forward*** concludes the chapter and highlights a current or future application.
- **Section Review Questions** are included at the end of each chapter section, and their answers are found at the end of each chapter.
- **Examples** providing step-by-step guidance in solving problems are found throughout the chapters.
- **MultiSIM and RealAudio Icons** placed throughout the text indicate the presence of additional online resources. Selected pre-created MultiSIM circuits directly tied to figures from the text can be used for troubleshooting. RealAudio sound clips present more in-depth discussions of difficult topics.
- **End-of-Chapter Materials** include:
  - **MATLAB Examples**
  - **Summary of the chapter contents**
  - **Important Equations list**
  - **Glossary**
  - **End-of-Chapter Questions and Problems**

Major Features

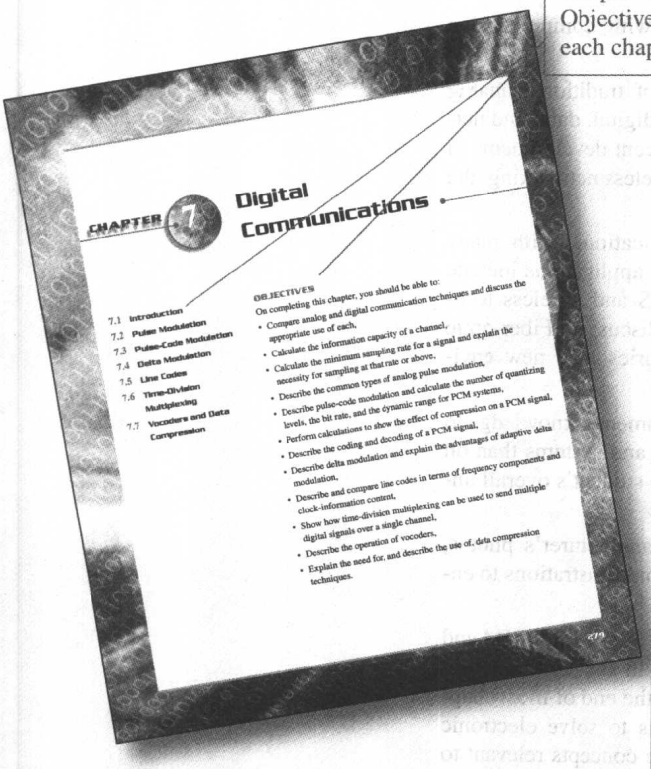
- **Thorough coverage** of fundamental communications with comprehensive treatment of data and advanced communications.
- **Advanced Communication Technologies.** Discussion of traditional analog communications is followed by modern developments in digital, data, and network communications. There is extensive treatment of recent developments in such areas as personal communication systems (PCS), wireless networking, the Internet, and fiber-optic systems.
- **Balance between theory and practice.** Practical applications, with many worked-out examples, are integrated throughout. Modern applications include digital television, LEO and MEO satellites, cellular, PCS and wireless technologies. Relevant topics, such as LANs and WANs are discussed. Fiber-optic and optical systems chapters reinforce basic wave theories in a new environment.
- **Systems-oriented approach** helps students transfer fundamental knowledge to contemporary systems. The emphasis is more on signals and systems than on circuits that quickly become obsolete and do not enhance student's overall understanding of the communication process.
- **New full-color art program** using latest full-color manufacturer's photos, along with newly rendered schematics, block diagrams, and illustrations to enhance understanding.
- **Use of modern computer tools** is introduced through the use of MultiSIM and MATLAB. MultiSIM pre-created circuits are available in the Online Companion. **Using MATLAB,** a new feature that is placed at the end of most chapters, provides information on how to use software tools to solve electronic communications-related problems, as well as to illustrate concepts relevant to each chapter. Specialized software for antenna and transmission-line analysis is also discussed.
- ***Electronics . . . Rewind*** and ***Electronics . . . Fast Forward*** interest boxes
- **Online Companion** includes RealAudio clips, MultiSIM files, and MATLAB examples. These additional resources are available for download at www.electronictech.com.

RealAudio. multiSIM

- **Answers to Odd-Numbered Problems** are included at the back of the book.

Chapter Outline and Objectives introduce each chapter

ELECTRONICS . . . REWIND and ELECTRONICS . . . FAST FORWARD interest boxes



CHAPTER 7 Digital Communications

7.1 Introduction
7.2 Pulse Modulation
7.3 Pulse-Code Modulation
7.4 Delta Modulation
7.5 Line Codes
7.6 Time-Division Multiplexing
7.7 Vocoders and Data Compression

OBJECTIVES

On completing this chapter, you should be able to:

- Compare analog and digital communication techniques and discuss the appropriate use of each,
- Calculate the information capacity of a channel,
- Calculate the minimum sampling rate for a signal and explain the necessity for sampling at that rate or above,
- Describe the common types of analog pulse modulation,
- Describe pulse-code modulation and calculate the number of quantizing levels, the bit rate, and the dynamic range for PCM systems,
- Perform calculations to show the effect of compression on a PCM signal,
- Describe the coding and decoding of a PCM signal,
- Describe delta modulation and explain the advantages of adaptive delta modulation,
- Describe and compare line codes in terms of frequency components and clock-information content,
- Show how time-division multiplexing can be used to send multiple digital signals over a single channel,
- Describe the operation of vocoders,
- Explain the need for, and describe the use of, data compression techniques.

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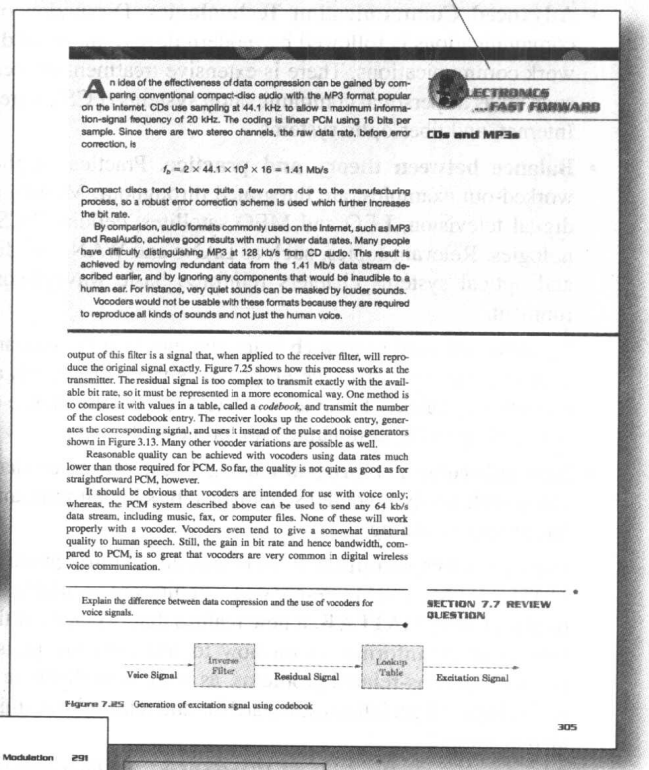

An idea of the effectiveness of data compression can be gained by comparing conventional compact-disc audio with the MP3 format popular on the internet. CDs use sampling at 44.1 kHz to allow a maximum information-signal frequency of 20 kHz. The coding is linear PCM using 16 bits per sample. Since there are two stereo channels, the raw data rate, before error correction, is

$$f_b = 2 \times 44.1 \times 10^3 \times 16 = 1.41 \text{ Mb/s}$$

Compact discs tend to have quite a few errors due to the manufacturing process, so a robust error correction scheme is used which further increases the bit rate.

By comparison, audio formats commonly used on the Internet, such as MP3 and RealAudio, achieve good results with much lower data rates. Many people have difficulty distinguishing MP3 at 128 kb/s from CD audio. This result is achieved by removing redundant data from the 1.41 Mb/s data stream described earlier, and by ignoring any components that would be inaudible to a human ear. For instance, very quiet sounds can be masked by louder sounds.

Vocoders would not be usable with these formats because they are required to reproduce all kinds of sounds and not just the human voice.

ELECTRONICS . . . FAST FORWARD

CDs and MP3s

output of this filter is a signal that, when applied to the receiver filter, will reproduce the original signal exactly. Figure 7.25 shows how this process works at the transmitter. The residual signal is too complex to transmit exactly with the available bit rate, so it must be represented in a more economical way. One method is to compare it with values in a table, called a *codebook*, and transmit the number of the closest codebook entry. The receiver looks up the codebook entry, generates the corresponding signal, and uses it instead of the pulse and noise generators shown in Figure 3.13. Many other vocoder variations are possible as well.

Reasonable quality can be achieved with vocoders using data rates much lower than those required for PCM. So far, the quality is not quite as good as for straightforward PCM, however.

It should be obvious that vocoders are intended for use with voice only; whereas, the PCM system described above can be used to send any 64 kb/s data stream, including music, fax, or computer files. None of these will work properly with a vocoder. Vocoders even tend to give a somewhat unnatural quality to human speech. Still, the gain in bit rate and hence bandwidth, compared to PCM, is so great that vocoders are very common in digital wireless voice communication.

Explain the difference between data compression and the use of vocoders for voice signals.

SECTION 7.7 REVIEW QUESTION

Figure 7.25 Generation of excitation signal using codebook

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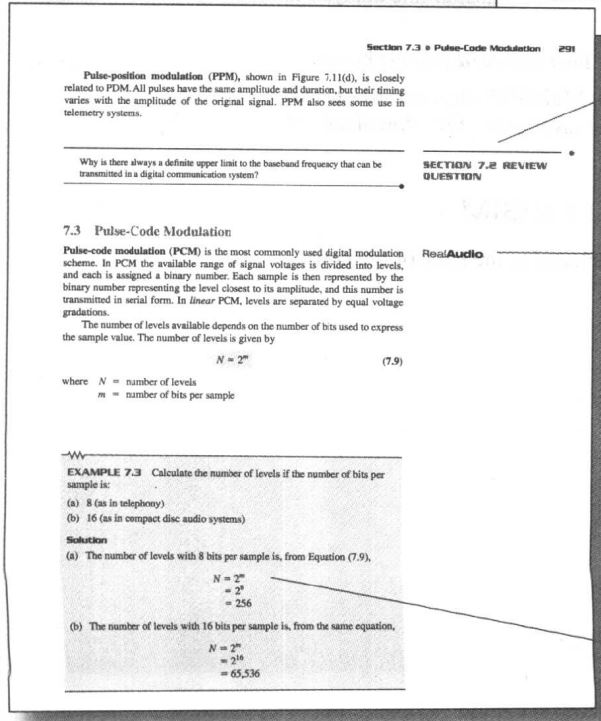

Pulse-position modulation (PPM), shown in Figure 7.11(d), is closely related to PDM. All pulses have the same amplitude and duration, but their timing varies with the amplitude of the original signal. PPM also sees some use in telemetry systems.

Why is there always a definite upper limit to the baseband frequency that can be transmitted in a digital communication system?

SECTION 7.2 REVIEW QUESTION

7.3 Pulse-Code Modulation

RealAudio

Pulse-code modulation (PCM) is the most commonly used digital modulation scheme. In PCM the available range of signal voltages is divided into levels, and each is assigned a binary number. Each sample is then represented by the binary number representing the level closest to its amplitude, and this number is transmitted in serial form. In *linear* PCM, levels are separated by equal voltage gradations.

The number of levels available depends on the number of bits used to express the sample value. The number of levels is given by

$$N = 2^m \tag{7.9}$$

where N = number of levels
m = number of bits per sample

EXAMPLE 7.3 Calculate the number of levels if the number of bits per sample is:

(a) 8 (as in telephony)
(b) 16 (as in compact disc audio systems)

Solution

(a) The number of levels with 8 bits per sample is, from Equation (7.9),

$$N = 2^m = 2^8 = 256$$

(b) The number of levels with 16 bits per sample is, from the same equation,

$$N = 2^m = 2^{16} = 65{,}536$$

Section Review Question tests understanding of each section

Icons indicate additional online resources

Worked-out Examples provide guidance in solving problems

Major Features

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RealAudio. multiSIM

- **Answers to Odd-Numbered Problems** are included at the back of the book.

Using MATLAB introduces computer tools to illustrate communications concepts

USING MATLAB

Purpose:
To demonstrate the operation of both a mu-law coder and decoder in SIMULINK.

Background:
In this section, SIMULINK is used to illustrate the nonlinear sampling that occurs when a mu-law coder is used, as well as the corresponding inverse process required to restore a mu-law compressed signal.

Implementation:
Start MATLAB and then type **simulink** at the command prompt to start the SIMULINK program.

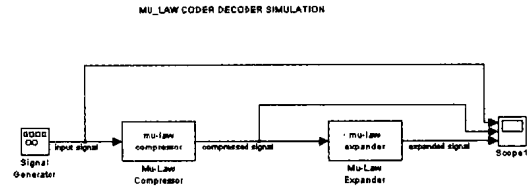
```
>> simulink
```

Select the created model by using the **File-> Open** menu option to select and open the file "codec.mdl".

Run the simulation by selecting the **Simulation-> Start** menu option in the model window.

- Double-click on the scope to view the input, compressed and expanded signals.

Experiment with other input wave types and frequencies from the function generator.



used for unvoiced sounds, and a variable-frequency pulse generator produces the voiced sounds. The pulse generator creates a tone rich in harmonics, as is the sound produced by human vocal cords. Both sources have variable amplitudes. Figure 7.24 illustrates the process at the receiver.

Residual excited linear predictive (RELP) vocoders, on the other hand, apply the inverse of the filter that will be used at the receiver to the voice signal. The

ELECTRONICS FAST FORWARD

Digital Signatures

Digital signatures are now being used to "sign" important documents that are sent electronically. First, the message to be sent is operated on by a mathematical function that produces a short bit sequence, typically 128 bits, that is called "hash." While in theory it is possible for two different messages to produce the same hash, in practice this is very unlikely. The hash is encrypted using the sender's private key, and transmitted along with the message.

The receiving station recreates the hash from the received message, and also decrypts the transmitted hash using the sender's public key. If the two hashes match, it is almost conclusive proof that the message is unchanged, and that the sender's identity is as claimed.

SUMMARY

Here are the main points to remember from this chapter.

1. Data that consists of alphanumeric characters must first be encoded using a character code such as ASCII or Baudot.
2. Asynchronous communication actually involves synchronizing the transmitter and receiver clocks at the start of each character. It is simpler but less efficient than synchronous communication, in which the transmitter and receiver clocks are continuously locked together.
3. Computer data must be converted from parallel to serial form before being transmitted and back to parallel form at the receiver.
4. Since noise is present in all communication systems, errors will occur. Errors can be detected and corrected, within limits, by adding redundant information.
5. Data can be compressed by using shorter codes for patterns that appear more often and by coding repetitive data by indicating the number of times an element repeats.
6. Encryption of data is important to ensure its privacy. It is most commonly achieved by using public-key encryption to transfer a key to be used in a symmetrical private-key system.

IMPORTANT EQUATIONS

$$\eta = N_D/N_T \quad (9.1)$$

$$2^n \geq m + n + 1 \quad (9.2)$$

GLOSSARY

automatic request for retransmission (ARQ) An error control system based on the repetition of data blocks that contain errors.

bit overhead Bits that do not carry the message, for example, those used for timing and error control.

bit stuffing Addition of extra bits to a data block to avoid the accidental generation of a flag pattern.

character code A set of rules that translates alphanumeric characters into binary numbers.

character set See **character code.**

Each chapter concludes with a Summary, List of Important Equations, and a Glossary

New to this Edition

- All chapters have been updated to reflect recent changes in technology
- Expanded coverage of cellular radio
- Coverage of vocoders
- Coverage of spread spectrum radio
- Coverage of radio propagation in the mobile environment
- Extensive coverage of Personal Communications Systems (PCS), including third-generation systems
- Expanded coverage of wireless LANs
- Extensive coverage of paging and wireless packet data neworks
- Updated coverage of intranets and the Internet
- Improved coverage of microwave antennas, including patch antennas
- Updated coverage of digital television and HDTV
- Coverage of microwave distribution of television signals
- Discussion of ADSL and cable modems
- Expanded coverage of satellite communications, including satellite telephony
- Updated coverage of fiber-optics communication

Supplements

The following materials are available for this text:

e.resource

This is an educational resource that creates a truly electronic classroom. It is a CD-ROM containing tools and instructional resources that enrich your classroom and make your preparation time shorter. The elements of the e.resource link directly to the text and tie together to provide a unified instructional system. ISBN #: 0-7668-2688-0

Features contained in the e.resource include:

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These slides provide the basis for a lecture outline that helps you present concepts and material. Key points and concepts can be graphically highlighted for student retention.

ExamView
This computerized testbank includes questions of varying levels of difficulty provided in multiple formats to assess student comprehension.

Image Library
200 images selected from the textbook allow you to customize power point presentations or use them as transparency masters. The Image Library comes with the ability to browse and search images with key words and allows quick and easy use.

Electronics Technology Website
Includes Netscape Communicator® so you can directly link to the Delmar Electronics Technology website at **www.electronictech.com** and to *Electronic Communication System's* Online Companion for additional resources.

Instructor's Guide

This includes answers to all end-of-chapter questions and problems.
ISBN #: 0-7668-2685-6

Lab Manual

A lab manual provides a set of experiments that cover the basic concepts of analog and digital communications systems. ISBN #: 0-7668-4957-0

WebTutor

This new web tutor course is created as a student study guide and interactive supplement. The web tutor course offers Class Notes, Flashcards, Web Links, Quizzes, and Discussion Board Topics. The course content will provide supplementary learning material to the learner including expanded coverage of technology and information not covered in the book such as 3G Wireless technology. WebTutor is available using the following platforms:
WebTutor on WebCT. ISBN #: 0-7668-0186-1
WebTutor on Blackboard. ISBN #: 0-7668-0195-0

Online Companion

To access the textbook's Online Companion, go to www.electronictech.com. The Online Companion to accompany *Electronic Communication Systems, 2e* includes pre-created MultiSIM circuits, MATLAB and Simulink files, RealAudio clips, online quizzes and additional text resources.

Acknowledgments

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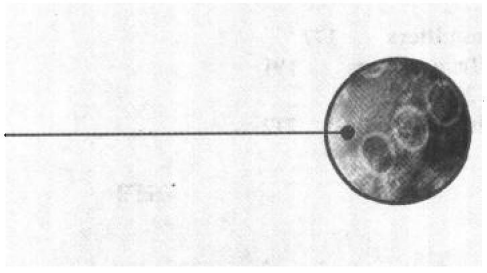

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