Preface

This new third edition of *Principles of Electronic Communication Systems* is fully revised and updated to make it one of the most current textbooks available on wireless, networking, and other communications technologies. Because the field of electronic communications changes so fast, it is a never-ending challenge to keep a textbook up to date. While principles do not change, their emphasis and relevance do as technology evolves. Furthermore, students need not only a firm grounding in the fundamentals but also an essential understanding of the real world components, circuits, equipment, and systems in everyday use. This latest edition attempts to balance the principles with an overview of the latest techniques.

One of the major goals of this latest revision is to increase the emphasis on the *system level understanding* of wireless, networking, and other communications technologies. Because of the heavy integration of communications circuits today, the engineer and the technician now work more with printed circuit boards, modules, plug-in cards, and equipment rather than component level circuits. As a result, older obsolete circuits have been removed from this text and replaced with more integrated circuits and block diagram level analysis. Modern communications engineers and technicians work with specifications and standards and spend their time testing, measuring, installing, and troubleshooting. This edition moves in that direction. Detailed circuit analysis is still included in selected areas where it proves useful in understanding the concepts and issues in current equipment.

In the past, a course in communications was considered an option in many electronic programs. Today, communications is the largest sector of the electronics field with the most employees and the largest equipment sales annually. In addition, wireless, networking or other communications technologies are now contained in almost every electronic product. This makes a knowledge and understanding of communication a must rather than an option for every student. Without at least one course in communications, the student may graduate with an incomplete view of the products and systems so common today. This book can provide the background to meet the needs of such a general course.

As the Communications and Networking Editor for Electronic Design Magazine (Penton Media) and editor of the Wireless System Design Update online newsletter, I witness daily the continuous changes in the components, circuits, equipment, systems, and applications of modern communications. As I research the field, interview engineers and executives, and attend the many conferences for the articles and columns I write, I have come to see the growing importance of communications in all of our lives. I have tried to bring that perspective to this latest edition where the most recent techniques and technologies are explained. That perspective coupled with the feedback and insight from some of you who teach this subject has resulted in a text that best fits the 21st century student.

New to this Edition

Here is a chapter-by-chapter summary of revisions and additions to this new edition.

Chapter 1	Significant update of the applications section.
Chapter 2	Revised and updated section on filters.
Chapters 3–6	General editing and updating of circuits.

Chapter 7	Previously chapter 8 on Digital Communications Techniques. Extensive update of the section on data conversion to include new ADC and DAC circuits and expanded specifications section. DSP section has also been updated.
Chapter 8	Previously chapter 7 on Radio Transmitters. Expanded coverage of the I/Q architecture for digital data transmission. Addition of broadband linear power amplifiers using feedforward and adaptive predistortion techniques. Addition of ISM band IC transmitters. The section on vacuum tube power amplifiers has been removed but will be available on line if anyone needs it.
Chapter 9	Expanded coverage of receiver sensitivity and signal to noise ratio, its importance and calculation. Increased coverage of the software-defined radio (SDR) and introduction to cognitive radio. Updated section on receiver circuits and transceivers. Description of a typical wireless LAN transceiver chip.
Chapter 10	Addition of code division multiple access, the Radio Data System and SCA subsystems in FM radios. Elimination of the older no-longer-used PAM telemetry system coverage. A new section on time and frequency division duplexing.
Chapter 11	Expanded coverage of digital modulation and spectral efficiency. Addition of an explanation of how different digital modulation schemes affect the bit error rate (BER) in communications systems. Comparisons based on BER vs. carrier to noise radio (C/N) are added. Updated sections on spread spectrum and OFDM. A new section on convolutional and turbo coding.
Chapter 12	Previous chapter 12 Computer Networking has been revised into a new chapter called Introduction to Networking and LANs. The coverage has been expanded and updated to include things like mesh networking fundamentals, the latest Ethernet standards including Power over Ethernet (PoE), and improved explanation of LAN equipment.
Chapter 13	Minor revisions and updates.
Chapter 14	Improved explanation of the near and far fields. Introduction to the automatic antenna tuner.
Chapter 15	A new chapter focusing on the Internet, chapter 9 includes the Internet material from the previous chapter 12 but with extensive new material. Detailed explanation of how information travels via the Internet. Addition of descriptions of Internet core technologies like ATM, Frame Relay, and Sonet. Considerably expanded discussion of the TCP/IP protocol. Expanded explanation of routers including line cards and switch fabrics. Introduction of a new section on storage area networks (SANs) and their transmission technologies including Fibre Channel and iSCSI. A new section on Internet security including encryption and authentication.
Chapter 16	Extensively revised and updated. New material on microwave antennas including phased arrays, beam forming arrays, adaptive antennas, and the smaller ceramic and PC board antennas like the loop, meander line, and inverted-F. The concepts of diversity and multiple input multiple output (MIMO) are added.
Chapter 17	Revised and updated. New materials include a section on Very Small Aperture Terminals and expanded coverage of GPS.
Chapter 18	Elimination of the section on paging. Updated section on cordless phones. New section on voice over Internet protocol (VoIP) digital telephones.

Chapter 19	New section on MSA optical transceiver modules, types and specifications. Expanded section on electronic dispersion compensation. New section on passive optical networks (PONs) used in fiber to the home (FTTH) broadband systems.
Chapter 20	This is a new chapter on Cell Phone Technologies. It covers all major analog and digital cell phone standards and systems and frequency allocations. GSM, GPRS, and EDGE TDM systems are covered as well as both cdma2000 and WCDMA systems. Typical chips are reviewed. Fourth generation systems are introduced.
Chapter 21	A new chapter on wireless technologies. Coverage includes wireless LAN (802.11a/b/g/n), Bluetooth, ZigBee, Ultra wideband (UWB), WiMAX, RFID, near field communications (NFC), ISM band short range radios, and infrared wireless. Coverage of personal area networks and mesh systems is included.
Chapter 22	Communications Tests and Measurement chapter is revised and updated. A new section on the widely used boundary scan and JTAG test system for chips and boards has been added.
Chapter 23	Television has been dropped from the book, but the chapter has been revised and updated, and placed on the Online Learning Center website for those who choose to assign it. It now includes new digital television information, new cable standards, and mobile (cell phone video) television standards.

In a large book such as this, it's difficult to give every one what he or she wants. Some want more depth others greater breadth. I tried to strike a balance between the two. As always, I am always eager to hear from those of you who use the book and welcome your suggestions for the next edition.

Learning Features

Principles of Electronic Communication Systems third edition has been completely redesigned to give it a more attractive and accessible page layout. To guide readers and provide an integrated learning approach, each chapter contains the following features:

- Chapter Objectives
- Key Terms
- Pioneers of Electronics articles
- Good to Know margin features
- Examples with solutions
- Chapter Summary
- Questions
- Problems
- Critical Thinking

Student Resources

Laboratory & Activities Manual

A major change with this third edition is the availability of a new laboratory manual. The Lab Manual developed for the second edition will be retained for those of you who use it. This new *Laboratory & Activities Manual* provides more actual hands-on hardware experiments with modern circuits and components. While many circuits are still explored, the attempt is to push toward more systems-level experiments. Building a practical, affordable but meaningful lab is one of the more difficult parts of creating a college course in communications. This new manual provides practice in the principles by

using the latest components and methods. Affordable and readily available components and equipment have been used to make it easy for professors to put together a communications lab that validates and complements the text.

Many of the exercises in the *Laboratory & Activities Manual* involve web access and search to build the student's ability to use the vast resources of the Internet and World Wide Web. The practical engineers and technicians of today have become experts at finding relevant information and answers to their questions and solutions to their problems this way. While practicing this essential skill of any communications engineer or technician knowledge, the student will be able to expand his or her knowledge of any of the subjects in this book, either to dig deeper into the theory and practice or get the latest update information on chips and other products.

Online Learning Center ("OLC") website, www.mhhe.com/frenzel3e

This text-specific site includes a number of student-oriented resources, including:

- Chapter outlines and summaries.
- MultiSim version 9 Primer, for those who want to get up and running with this popular simulation software. The section is written to provide communications examples and applications.
- MultiSim circuit files for communications electronics.
- Web Links to industrial and educational sites of interest.
- Link to the Work-Ready Electronics; these activities, created by the MATEC research center, show the practical skills needed in various areas of interest—including communications—in the context of modern industry.

Instructor Resources

Instructor Productivity Center CD-ROM

This CD includes the following resources for adopters of the text:

- Answers and solutions to all text problems.
- Answers and information for the Lab & Activity Manual.
- Electronic test banks with a mix of questions for each text chapter.
- PowerPoint presentations for all chapters of the text.

Online Learning Center ("OLC") website, www.mhhe.com/frenzel3e

The OLC contains student resources, plus the following instructor resources:

- Answers and solutions to the text problems and lab activities, under password protection.
- PowerPoint presentations for each chapter online.
- Additional quiz questions for each chapter, which can be assigned or used for student self-study.
- Blackboard and WebCT cartridges for use with these popular classroom management systems.

Classroom Performance System (CPS) from eInstruction is available for adopters; its "clicker" system provides a vehicle for in-class quizzing and concept reinforcement, and classroom management.

Acknowledgements

While producing a new edition of a book does not involve the same effort as writing a new book, this latest revision was a major project. My special thanks to Managing Developmental Editor Jonathan Plant, and Publisher Thomas Casson for their continued support and encouragement to make this happen. It has been a pleasure to work with you both.

And my appreciation also goes out to those professors who reviewed the book and offered your feedback, criticism and suggestions. Thanks for taking the time to provide that valuable input. I have implemented virtually all of your recommendations. I especially appreciate the extensive input from Walt Curry of the United States Naval Academy, most of which I have included. The following reviewers looked over the manuscript in various stages, and provided a wealth of good suggestions for the new edition:

Heng Chan
Mohawk College (ON)

Captain Walter N. Currier Jr.
United States Naval Academy (MD)

William C. Donaldson
Wake Techical College (NC)

Robbie Edens
ECPI College of Technology (SC)

Terry Fleischman
Fox Valley Technical College (WI)

Richard Fornes
Johnson College (PA)

G. J. Gerard
Gateway Community College (CT)

Georges C. Livanos
Humber College (ON)

Robert J. Lovelace
East Mississippi Junior College (MS)

Robert Most
Ferris State University (MI)

Tom N. Neal Jr.
Griffin Technical College (GA)

Phillip C. Purvis
George C. Wallace Community College (AL)

Pravin M. Raghuwanshi
DeVry University (NJ)

William Salice
ECPI College of Technology (VA)

Randy Winzer
Pittsburg Sate University (KS)

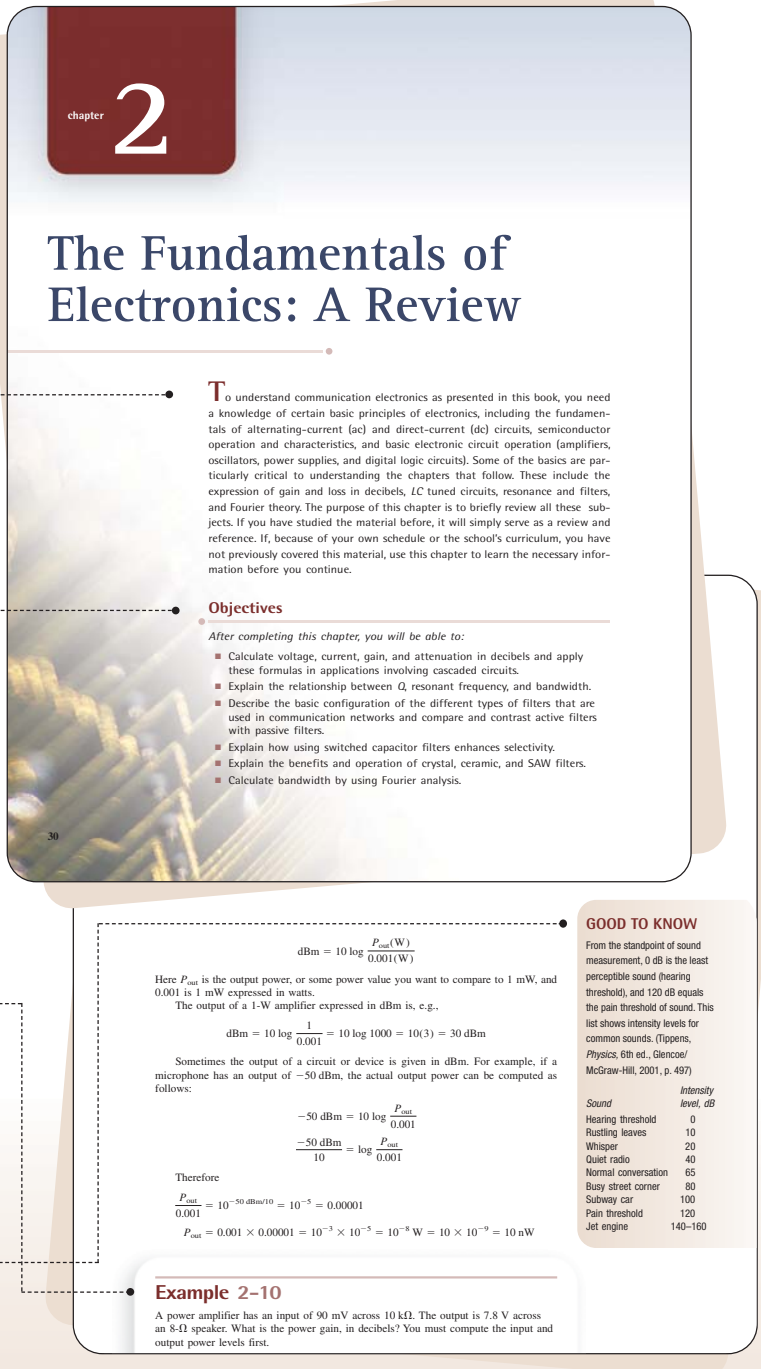
With the latest input from industry and the suggestions from those who use the book, this edition should come closer than ever to being an ideal text for teaching current day communications electronics.

Lou Frenzel
Austin, Texas
2006

Guided Tour

Learning Features

Many new learning features have been incorporated into the seventh edition of *Electronic Principles*. These learning features, found throughout the chapters, include:


chapter 2

The Fundamentals of Electronics: A Review

To understand communication electronics as presented in this book, you need a knowledge of certain basic principles of electronics, including the fundamentals of alternating-current (ac) and direct-current (dc) circuits, semiconductor operation and characteristics, and basic electronic circuit operation (amplifiers, oscillators, power supplies, and digital logic circuits). Some of the basics are particularly critical to understanding the chapters that follow. These include the expression of gain and loss in decibels, *LC* tuned circuits, resonance and filters, and Fourier theory. The purpose of this chapter is to briefly review all these subjects. If you have studied the material before, it will simply serve as a review and reference. If, because of your own schedule or the school's curriculum, you have not previously covered this material, use this chapter to learn the necessary information before you continue.

Objectives

After completing this chapter, you will be able to:

- Calculate voltage, current, gain, and attenuation in decibels and apply these formulas in applications involving cascaded circuits.
- Explain the relationship between *Q*, resonant frequency, and bandwidth.
- Describe the basic configuration of the different types of filters that are used in communication networks and compare and contrast active filters with passive filters.
- Explain how using switched capacitor filters enhances selectivity.
- Explain the benefits and operation of crystal, ceramic, and SAW filters.
- Calculate bandwidth by using Fourier analysis.

30

$$\text{dBm} = 10 \log \frac{P_{out}(\text{W})}{0.001(\text{W})}$$

Here P_{out} is the output power, or some power value you want to compare to 1 mW, and 0.001 is 1 mW expressed in watts.

The output of a 1-W amplifier expressed in dBm is, e.g.,

$$\text{dBm} = 10 \log \frac{1}{0.001} = 10 \log 1000 = 10(3) = 30 \text{ dBm}$$

Sometimes the output of a circuit or device is given in dBm. For example, if a microphone has an output of −50 dBm, the actual output power can be computed as follows:

$$-50 \text{ dBm} = 10 \log \frac{P_{out}}{0.001}$$

$$\frac{-50 \text{ dBm}}{10} = \log \frac{P_{out}}{0.001}$$

Therefore

$$\frac{P_{out}}{0.001} = 10^{-50 \text{ dBm}/10} = 10^{-5} = 0.00001$$

$$P_{out} = 0.001 \times 0.00001 = 10^{-3} \times 10^{-5} = 10^{-8} \text{ W} = 10 \times 10^{-9} = 10 \text{ nW}$$

GOOD TO KNOW

From the standpoint of sound measurement, 0 dB is the least perceptible sound (hearing threshold), and 120 dB equals the pain threshold of sound. This list shows intensity levels for common sounds. (Tippens, *Physics*, 6th ed., Glencoe/McGraw-Hill, 2001, p. 497)

Sound	*Intensity level, dB*
Hearing threshold	0
Rustling leaves	10
Whisper	20
Quiet radio	40
Normal conversation	65
Busy street corner	80
Subway car	100
Pain threshold	120
Jet engine	140–160

Example 2–10

A power amplifier has an input of 90 mV across 10 kΩ. The output is 7.8 V across an 8-Ω speaker. What is the power gain, in decibels? You must compute the input and output power levels first.

Chapter Introduction

Each chapter begins with a brief introduction setting the stage for what the student is about to learn.

Chapter Objectives

Chapter Objectives provide a concise statement of expected learning outcomes.

Examples

Each chapter contains worked-out Examples that demonstrate important concepts or circuit operations, including circuit analysis, applications, troubleshooting, and basic design.

Good To Know

Good To Know statements, found in margins, provide interesting added insights to topics being presented

Pioneers of Electronics

Students can use summaries when reviewing for examinations, or just to make sure they haven't missed any key concepts. are listed to help solidly learning outcomes.

Chapter Review

Students can use summaries when reviewing for examinations, or just to make sure they haven't missed any key concepts. Important circuit derivations and definition are listed to help solidly learning outcomes.

Problems

Students obtain back by Problems that immediately follow most Examples. Answers to these problems are found at the end of each chapter.

Critical Thinking

A wide variety of questions and problems are found at the end of each chapter; over 30% are new or revised in this edition. Those include circuit analysis, trouble shooting, critical thinking, and job interview questions.

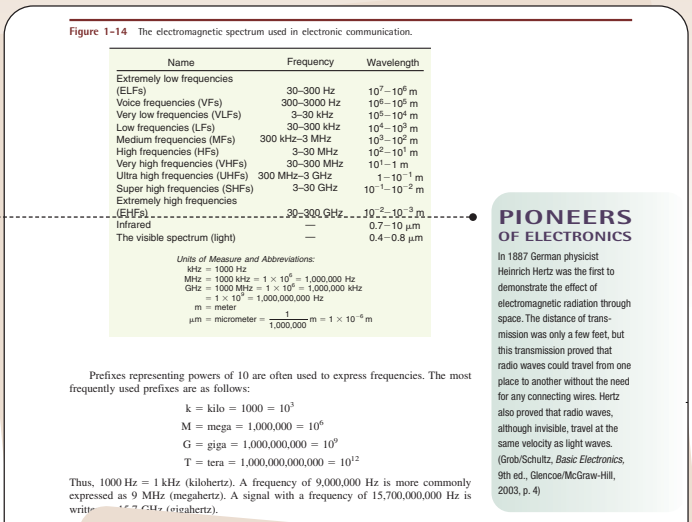


Figure 1–14 The electromagnetic spectrum used in electronic communication.

Name	Frequency	Wavelength
Extremely low frequencies (ELFs)	30–300 Hz	10^7–10^6 m
Voice frequencies (VFs)	300–3000 Hz	10^6–10^5 m
Very low frequencies (VLFs)	3–30 kHz	10^5–10^4 m
Low frequencies (LFs)	30–300 kHz	10^4–10^3 m
Medium frequencies (MFs)	300 kHz–3 MHz	10^3–10^2 m
High frequencies (HFs)	3–30 MHz	10^2–10^1 m
Very high frequencies (VHFs)	30–300 MHz	10^1–1 m
Ultra high frequencies (UHFs)	300 MHz–3 GHz	1–10^{-1} m
Super high frequencies (SHFs)	3–30 GHz	10^{-1}–10^{-2} m
Extremely high frequencies (EHFs)	30–300 GHz	10^{-2}–10^{-3} m
Infrared	—	0.7–10 μm
The visible spectrum (light)	—	0.4–0.8 μm

Units of Measure and Abbreviations:
kHz = 1000 Hz
MHz = 1000 kHz = 1×10^6 = 1,000,000 Hz
GHz = 1000 MHz = 1×10^6 = 1,000,000 kHz
= 1×10^9 = 1,000,000,000 Hz
m = meter
μm = micrometer = $\frac{1}{1{,}000{,}000}$ m = 1×10^{-6} m

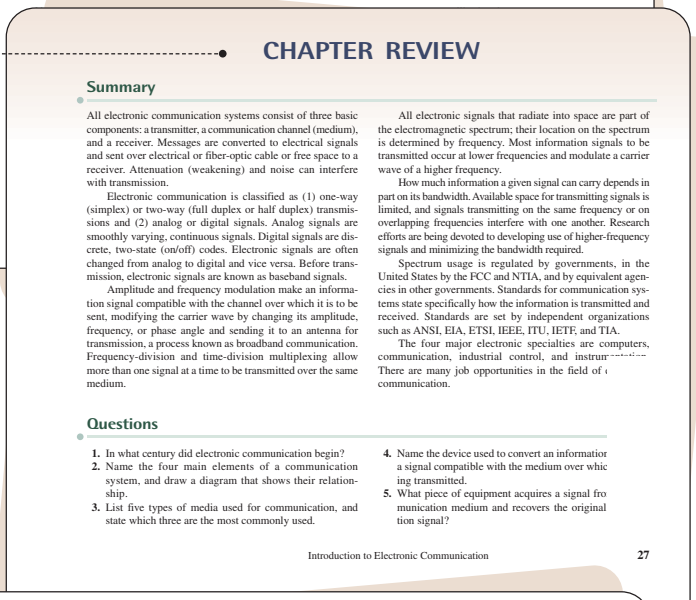
Prefixes representing powers of 10 are often used to express frequencies. The most frequently used prefixes are as follows:

k = kilo = $1000 = 10^3$
M = mega = $1{,}000{,}000 = 10^6$
G = giga = $1{,}000{,}000{,}000 = 10^9$
T = tera = $1{,}000{,}000{,}000{,}000 = 10^{12}$

Thus, 1000 Hz = 1 kHz (kilohertz). A frequency of 9,000,000 Hz is more commonly expressed as 9 MHz (megahertz). A signal with a frequency of 15,700,000,000 Hz is writte... GHz (gigahertz).

PIONEERS OF ELECTRONICS

In 1887 German physicist Heinrich Hertz was the first to demonstrate the effect of electromagnetic radiation through space. The distance of transmission was only a few feet, but this transmission proved that radio waves could travel from one place to another without the need for any connecting wires. Hertz also proved that radio waves, although invisible, travel at the same velocity as light waves. (Grob/Schultz, *Basic Electronics*, 9th ed., Glencoe/McGraw-Hill, 2003, p. 4)



CHAPTER REVIEW

Summary

All electronic communication systems consist of three basic components: a transmitter, a communication channel (medium), and a receiver. Messages are converted to electrical signals and sent over electrical or fiber-optic cable or free space to a receiver. Attenuation (weakening) and noise can interfere with transmission.

Electronic communication is classified as (1) one-way (simplex) or two-way (full duplex or half duplex) transmissions and (2) analog or digital signals. Analog signals are smoothly varying, continuous signals. Digital signals are discrete, two-state (on/off) codes. Electronic signals are often changed from analog to digital and vice versa. Before transmission, electronic signals are known as baseband signals.

Amplitude and frequency modulation make an information signal compatible with the channel over which it is to be sent, modifying the carrier wave by changing its amplitude, frequency, or phase angle and sending it to an antenna for transmission, a process known as broadband communication. Frequency-division and time-division multiplexing allow more than one signal at a time to be transmitted over the same medium.

All electronic signals that radiate into space are part of the electromagnetic spectrum; their location on the spectrum is determined by frequency. Most information signals to be transmitted occur at lower frequencies and modulate a carrier wave of a higher frequency.

How much information a given signal can carry depends in part on its bandwidth. Available space for transmitting signals is limited, and signals transmitting on the same frequency or on overlapping frequencies interfere with one another. Research efforts are being devoted to developing use of higher-frequency signals and minimizing the bandwidth required.

Spectrum usage is regulated by governments, in the United States by the FCC and NTIA, and by equivalent agencies in other governments. Standards for communication systems state specifically how the information is transmitted and received. Standards are set by independent organizations such as ANSI, EIA, ETSI, IEEE, ITU, IETF, and TIA.

The four major electronic specialties are computers, communication, industrial control, and instrum... There are many job opportunities in the field of ... communication.

Questions

1. In what century did electronic communication begin?
2. Name the four main elements of a communication system, and draw a diagram that shows their relationship.
3. List five types of media used for communication, and state which three are the most commonly used.
4. Name the device used to convert an informatio... a signal compatible with the medium over whic... ing transmitted.
5. What piece of equipment acquires a signal fro... munication medium and recovers the original ... tion signal?

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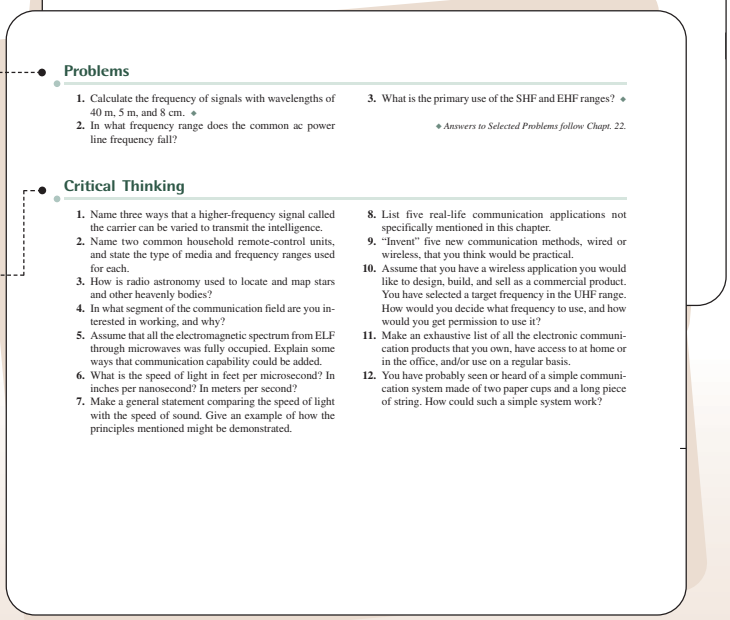

Problems

1. Calculate the frequency of signals with wavelengths of 40 m, 5 m, and 8 cm. ◆
2. In what frequency range does the common ac power line frequency fall?
3. What is the primary use of the SHF and EHF ranges? ◆

◆ *Answers to Selected Problems follow Chapt. 22.*

Critical Thinking

1. Name three ways that a higher-frequency signal called the carrier can be varied to transmit the intelligence.
2. Name two common household remote-control units, and state the type of media and frequency ranges used for each.
3. How is radio astronomy used to locate and map stars and other heavenly bodies?
4. In what segment of the communication field are you interested in working, and why?
5. Assume that all the electromagnetic spectrum from ELF through microwaves was fully occupied. Explain some ways that communication capability could be added.
6. What is the speed of light in feet per microsecond? In inches per nanosecond? In meters per second?
7. Make a general statement comparing the speed of light with the speed of sound. Give an example of how the principles mentioned might be demonstrated.
8. List five real-life communication applications not specifically mentioned in this chapter.
9. "Invent" five new communication methods, wired or wireless, that you think would be practical.
10. Assume that you have a wireless application you would like to design, build, and sell as a commercial product. You have selected a target frequency in the UHF range. How would you decide what frequency to use, and how would you get permission to use it?
11. Make an exhaustive list of all the electronic communication products that you own, have access to at home or in the office, and/or use on a regular basis.
12. You have probably seen or heard of a simple communication system made of two paper cups and a long piece of string. How could such a simple system work?