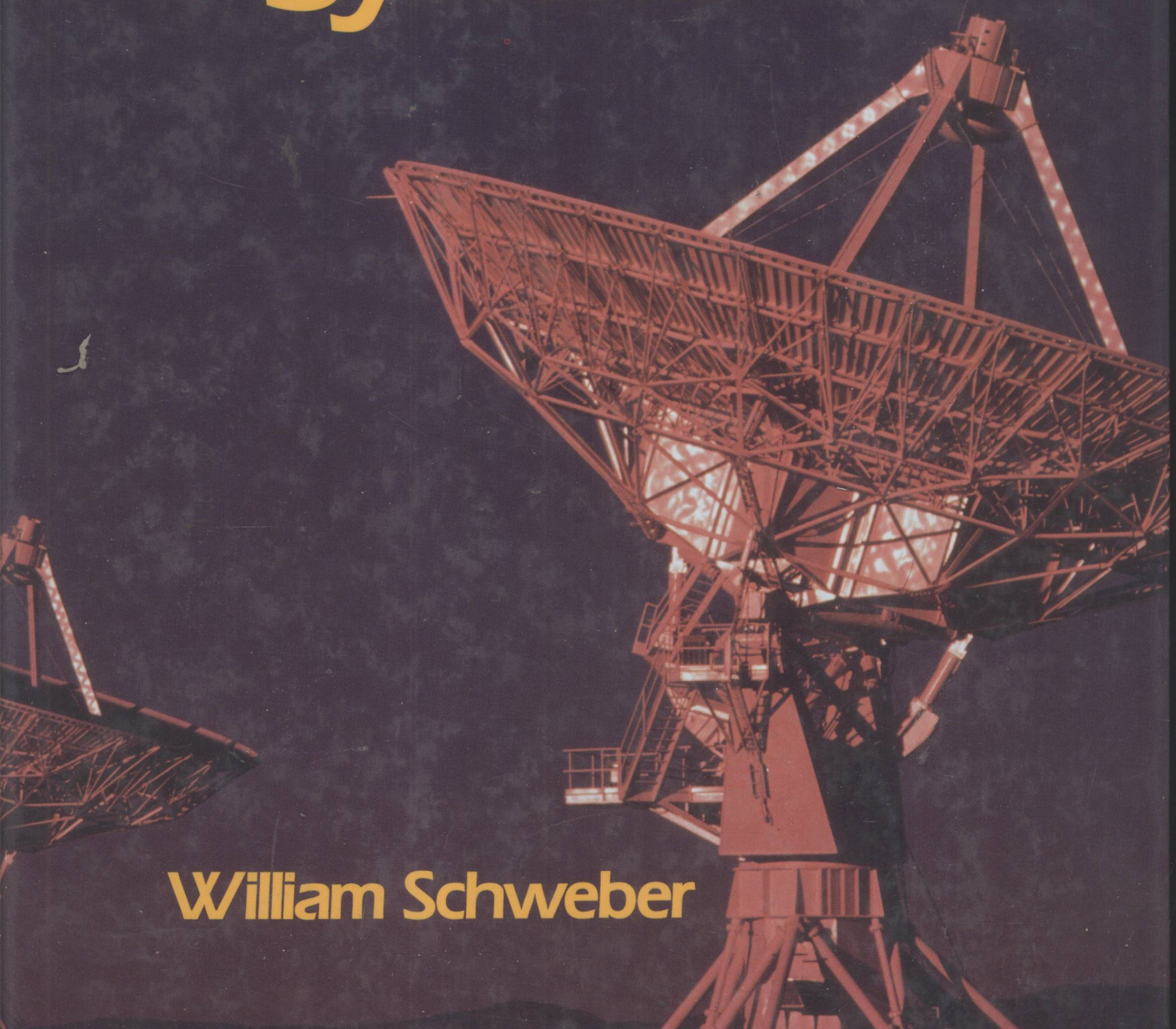
Electronic Communication Systems



William Schweber

Electronic Communications Systems

A Complete Course

WILLIAM SCHWEBER
Analog Devices, Inc.

Prentice-Hall, Englewood Cliffs, N.J. 07632

Library of Congress Cataloging-in-Publication Data

Schweber, William L.
Electronic communications systems : a complete course / William L. Schweber.
p. cm.
Includes index.
ISBN 0-13-590092-1
1. Telecommunication. I. Title.
TK5101.S33 1991
621.382—dc20 90-7408
CIP

Acquisitions Editor: **Sharon Jacobus**
Editorial/production supervision: **Lillian Glennon**
Interior design: **Nancy Field**
Cover design: **Bruce Kenselaar**
Manufacturing buyer: **Mary McCartney/Ed O'Dougherty**
Technical checker: **Paul Perletti**
Photo credit: **Chuck O'Rear/West Light**

A Division on Simon & Schuster
Englewood Cliffs, New Jersey 07632

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

ISBN 0-13-590092-1

Prentice-Hall International (UK) Limited, *London*
Prentice-Hall of Australia Pty. Limited, *Sydney*
Prentice-Hall Canada Inc., *Toronto*
Prentice-Hall Hispanoamericana, S.A., *Mexico*
Prentice-Hall of India Private Limited, *New Delhi*
Prentice-Hall of Japan, Inc., *Tokyo*
Simon & Schuster Asia Pte. Ltd., *Singapore*
Editora Prentice-Hall do Brasil, Ltds., *Rio de Janeiro*

To my wife,

who is always there

Preface

Electronic Communication Systems: A Complete Course is the first book to cover the traditional aspects of communications, yet recognize and explore the three developments which have radically changed communication systems. These developments—which have changed the way that technicians and engineers must deal with these systems—are:

- the widespread use of *integrated circuits* (*ICs*) to provide system functions in a single compact, high-performance device, thus replacing circuitry which previously required many discrete components.
- the use of *microprocessors and software* to manage and improve the operation of traditional analog communication systems.
- the use of *digital techniques and signals* in the communication system itself, to supplement or virtually replace analog techniques.

These three factors have shaped major changes in the way that communication systems are designed, implemented, and maintained. *Electronic Communication Systems: A Complete Course* explores communication systems with this perspective. Due to the impact of these three factors, students must learn to approach and comprehend systems in a new manner, rather than just learn more details of the same basic circuitry. In addition, this book provides a presentation both of the way that systems are commonly implemented, along with a discussion of the tradeoffs that exist in any system design: speed, power, performance, errors, complexity. The book takes a circuitry plus systems viewpoint, discussing circuits and their resultant systems (or equipment) with equal emphasis.

Over half the book is devoted to digital communications, actual communication systems (video, facsimile, telephone, modems, RS-232, cellular phones, computer networks, satellites, radar, fiber optics) following the necessary basic topics such as bandwidth, AM, FM, antennas, transmitters, receivers, and microwaves. Whenever possible, there are sections which specifically discuss troubleshooting goals, techniques, and instrumentation.

In-Text Learning Aids

Electronic Communication Systems: A Complete Course was designed with the beginning student in mind. Each chapter opens with Chapter Objectives contained in a blue box and an Introduction. Review Questions, also shaded in blue, follow each chapter section and serve to reinforce what the student has just learned. Color is also used to highlight important elements in the illustrations. Within each chapter, clearly marked, worked-out solutions are provided for numerical examples. Every chapter concludes with a Chapter Summary (corresponding to the Chapter Objectives), Summary Questions, and numerical Practice Problems (broken out by chapter section).

To provide historical perspective, explore a subject in more depth, or go slightly off the main-line path of a chapter, the book uses sidebars to present additional material. Sidebars provide the student with interesting additional information that is not essential to the basic flow of the chapter, but which add new facets to the student's understanding of the topic.

The Supplement Package

Careful thought was put into developing a comprehensive and useful set of supplementary teaching aids for instructors and students. A brief description of each item in this package follows.

- A LAB MANUAL by Ralph Folger, et al. (Hudson Valley Community College, Troy, NY) contains 24 lab experiments keyed to the text. Its features include lists of parts readily available from any electronics store. To purchase, contact your local bookstore. ISBN: 0-13-590373-4
- The INSTRUCTOR'S RESOURCE MANUAL provides teachers with additional numerical problems and applications, worked-out solutions to these additional problems as well as to those found in the text, chapter outlines for each chapter, and black-line Transparency Masters of over 75 key illustrations from the text. Available to instructors only. ISBN 0-13-590340-8
- A TEST ITEM FILE, compiled by Paul Perletti (Mt. Hood Community College, Portland, OR), offers approximately 100 problems for each chapter to be used in preparing exams. Available to instructors only. ISBN: 0-13-590357-2

A DEDICATION

In communications, one person stands out through his far-reaching, long-lasting contributions. Major Edward H. Armstrong (1890–1954) conceived, analyzed, produced, and perfected several major innovations. Two of these—the superhetrodyne receiver and FM transmission—are still vital to communications systems in this advanced age of digital electronics, microprocessors, and ICs; his first invention—the regenerative amplifier—allowed vacuum tubes in amplifiers to have much greater effective gain for weak signals (although subsequent developments have made it obsolete).

This book encompasses the world of digitally-driven, microprocessor-based analog and/or digital communication while recognizing the efforts and legacy of persons like Major Armstrong.

ACKNOWLEDGEMENTS

A book is created by the author but with the guidance of others. The reviews and comments of the following individuals were essential in making sure that this book's topics and focus, as well as depth, stayed balanced on the dual path defined by traditional circuits and systems combined with the radical changes effected by digital signals, microprocessors, and ICs, for these are changes which now permeate both new and older systems.

George Borchers—ITT Technical Institute, Salt Lake City, UT
Paul Cary—Lincoln Technical Institute, Allentown, PA
Robert E. Greenwood—Ryerson Polytechnic Institute, Toronto, Ontario
Dwight Holtman—ITT Technical Institute, St. Louis, MO
David Johnson—Pennsylvania College of Technology, Williamsport, PA
George Johnson—ITT Technical Institute, St. Louis, MO
Charles M. Killman—DeVry Institute of Technology, Kansas City, MO
Eugene L. Larchar—SUNY College of Agriculture & Technology at Morrisville, NY
Russell Puckett—Texas A & M University, College Station, TX
Arlyn I. Smith—Alfred State College, Wellsville, NY
James Stewart—DeVry Institute of Technology, Woodbridge, NJ
David Tancig—Parkland College, Champaign, IL

Paul Perletti—Mt. Hood Community College, Portland, OR deserves special recognition for his meticulous attention to the technical accuracy of the text.

Bill Schweber
Sharon, Massachusetts 1990

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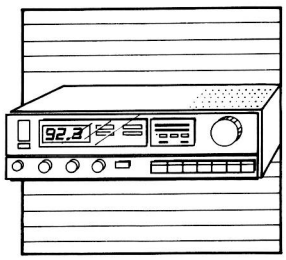

1 The Electromagnetic Spectrum

CHAPTER OBJECTIVES

When you have completed this chapter, you will understand:

- The broad issues in modern communications systems
- The relationship among frequency, wavelength, and propagation velocity
- The wide span and appearance of the overall electromagnetic spectrum
- The meaning of bandwidth and how it affects system information capacity
- The basic differences between simplex, half-duplex, and full-duplex communication systems

INTRODUCTION

The goal of a communications system is to transfer information from one place to another. This is done by sending the information as electromagnetic energy through vacuum, air, wire, or strands of glass and plastic fiber. The extremely wide range of energy frequencies and wavelengths that are used for this take up a large part of the electromagnetic spectrum. In this chapter we discuss some of the basic physical principles that define communications systems: electromagnetic frequencies, wavelengths, and velocities; energy; energy bandwidth and information that the energy can carry, and communications in one and two directions.

The electromagnetic spectrum is divided into subsections, or bands, each with some technical characteristics and peculiarities unique to that band. To avoid interference, users are assigned specific frequencies within the bands. Sending information requires a span of frequencies, and to send information at a higher

rate, a greater span is needed than for a lower rate of information transfer. Communications systems are also divided into groups that allow information transfer in one direction only, in both directions simultaneously, and in both directions but only one direction at a time.

1.1 INTRODUCTION TO MODERN COMMUNICATIONS SYSTEMS

Communications systems and modern electronics have made it possible to send messages over great distances easily and reliably. They have also made it possible to send large amounts of data quickly from one point to another. Communications capability is now so common and available that it is hard to imagine the difficulty and uncertainty that people used to accept as the best that could be achieved with the technology they had available.

Modern communications systems use a wide range and variety of electronic equipment to meet the needs of users. Hand-held radios (Figure 1.1) allow direct contact with nearby base stations. Small satellite dish antennas can communicate with orbiting satellites, while larger dishes allow contact with space vehicles and space satellites millions of miles away (Figure 1.2). Commercial radio and television stations use powerful transmitters and large antennas to reach an audience within hundreds of miles. Radar can locate ships and planes regardless of weather or darkness (Figure 1.3). Increasingly, communications systems are being used to transmit digital messages, either directly from a computer or from some other source whose signal has been converted to computer-compatible digital format. The communications distance in a system can be to another planet, around the world, or as short as the distance from one part of an electronic chassis to another.

All communications systems have at least two endpoints. At one end, there is a source of signals (a voice, someone typing at a keyboard, or computer data, for example), circuitry for converting the signal source into a signal that is compatible with the rest of the system, and a transmitter which puts the converted signal onto the communications pathway or link (wire, air, or light-carrying fiber). After the transmitted signal passes through this link, it is received by the far end, converted in signal format as needed, and finally passed to the user (Figure 1.4).

In any communications system, both the user at the sending end and the user at the receiving send must agree on many factors for successful and meaningful communications to occur. These factors include what signals are used, the way the message is coded (such as what alphabet), the meaning of symbols within the message (the language: English, French, Spanish, etc.), and the type of modulation used. Unless this is done, the message may be received but meaningless, like getting a perfect copy of message in a language you do not understand, with strange symbols. You would not even know if the specks on the paper were mere dirt spots or part of the message. In communications systems, both parties must know the rules of the conversation or the overall communications effort will be wasted. Each of the key factors is discussed in a subsequent chapter.

Electronic communications began with *copper wire* as the only type of link between the sender and the receiver. Later, *broadcasting* was developed, which allowed signals to be transmitted through the air, without any wires at all. In recent years, *fiber optics* has become a common link between users. The principle

Figure 1.1 Hand-held radio provides direct two-way communication to a nearby station (courtesy of Tandy Corp.).

behind this type of link is to use electromagnetic energy in the form of light to convey the information. Regular electrical signals in the system are converted to lightwaves, send through hair-thin optical fibers made of glass or plastic, and then received as light. The receiver reconverts the light into conventional electrical signals for further use.

What This Book Covers

We look at the concepts, implementations, and applications of communications systems in the five parts of this book. In Chapter 1 we discuss some of the basic factors that define the potential of a communications system, including how electromagnetic energy in the form of radio transmissions, signals in wire, or light are

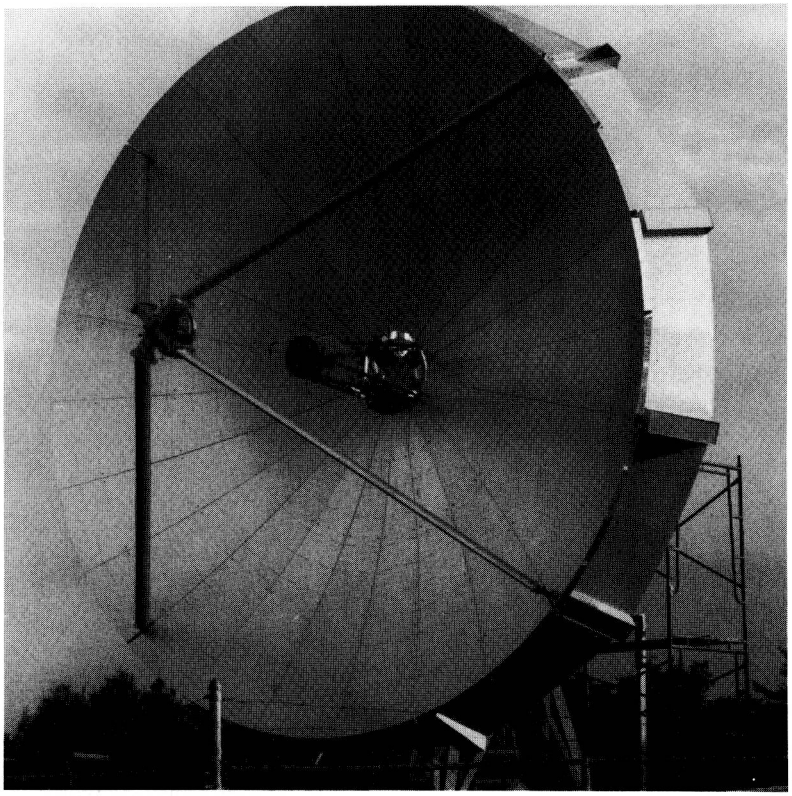

Figure 1.2 Dish antennas are needed for communications at larger distances [courtesy of Electronic Space Systems Corp. (ESSCO)].

actually used to convey the message; the wide range of frequencies that make up the electromagnetic spectrum; the need for a span of frequencies, called *bandwidth*, to pass the desired amount of information in the time available; and the basic modes of single-direction and two-direction communications.

The remainder of Part A deals with two ways of looking at and measuring signals. There is the traditional *signal versus time* and the equally important and valid *signal versus frequency components* of spectrum analysis, along with signal and noise magnitudes, and powers and decibel units of measurements. In the second half of this section we examine how an *information* signal with the desired message is used to affect another signal, called a *carrier,* which has more power or a more desired frequency. This *modulation* is a key part of a complete communications system. Modulation can change the amplitude, frequency, or even the phase of the carrier signal, and each type of modulation has advantages in performance, simplicity, and use of the available frequencies. Of course, modulation at the transmitter requires corresponding demodulation at the receiver, and all aspects are studied.

The active components of the transmitter and receiver—the tubes, transistors, and integrated circuits—play a significant role in the overall system performance. But the passive components described in Part B, such as wire and cable,