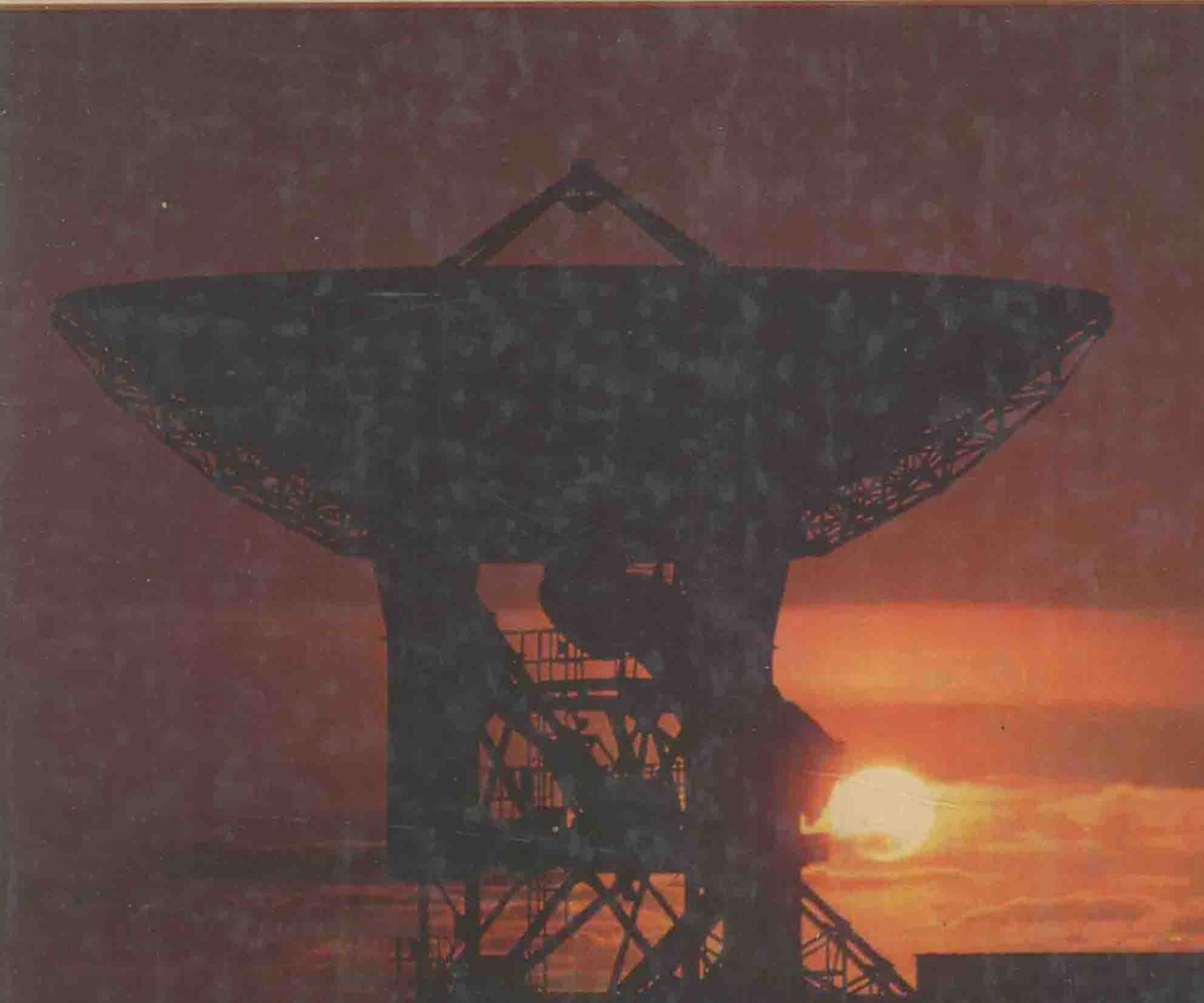
Electronic Communications Systems

FUNDAMENTALS THROUGH ADVANCED

WAYNE TOMASI



ELECTRONIC COMMUNICATIONS SYSTEMS

Fundamentals Through Advanced

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PREFACE

During the past two decades, the electronic communications industry has undergone some remarkable technological changes, primarily in the form of miniaturization. In the late 1950s and early 1960s, vacuum tubes were replaced with transistors. More recently, transistors are being replaced with multipurpose large-scale integrated circuits. The development of large-scale digital and linear integrated circuits has paved the way for many new and innovative approaches to electronic communications. Also, digital electronics principles are being implemented into electronic communications circuits and systems more and more each year. The need for these changes is attrributed to the continuing increase in the number of digital and data communications systems.

The purpose of this book is to introduce basic electronic communications fundamentals and to expand the knowledge of the reader to more modern digital and data communications systems. The book was written so that a reader with previous knowledge in basic electronic principles and an understanding of mathematics through trigonometry will have little trouble grasping the concepts presented. An understanding of calculus principles (i.e., differentiation and integration) would be helpful but is not a prerequisite. Within the text, there are numerous examples that emphasize the important concepts, and questions and problems are included at the end of each chapter. Also, answers to the odd-numbered problems are given at the end of the book.

Chapter 1 is an introduction to electronic communications. Fundamental communications terms and concepts such as modulation, demodulation, bandwidth, and information capacity are explained. Signal analysis using both frequency and time domain is discussed. Nonsinusoidal periodic waves are examined using fourier analysis, and the effects of bandlimiting on signals is discussed. Electrical noise, signal-to-noise ratio, and noise figure are explained and discussed. The basic principles of frequency and time division multiplexing are also explained in Chapter 1. Chapter 2 covers frequency generation. The basic requirements for oscillations to occur are outlined and discussed. Standard LC, crystal, and negative resistance oscillator configurations are explained. The basic concepts of frequency multiplication are discussed. Linear and nonlinear mixing with single and multiple frequency input signals are analyzed. Chapter 3 defines and explains the basic concepts of amplitude modulation transmission. A detailed analysis is presented on the voltage, power, and bandwidth considerations of amplitude modulation in both the frequency and time domain. Circuits for generating amplitude modulation are explained. High and low level transmitters are discussed. Chapter 4 introduces the basic concepts of radio receivers including a detailed analysis of tuned radio frequency and superheterodyne receivers. The primary functions of each receiver stage are explained. Amplitude modulation receivers and the detection of amplitude modulated signals are explained. The basic concepts of automatic gain control and squelch are discussed and double conversion receivers are introduced. Chapter 5 is dedicated to the analysis of phase-locked loops and frequency synthesizers. Basic phase-locked loop concepts are introduced and a detailed explanation of the operation of a phase-locked loop is given. Both direct and indirect frequency synthesizers with single and multiple crystals are discussed. Chapter 6 extends the coverage of amplitude modulation given in Chapters 3 and 4 to single sideband transmission. The various types of sideband transmission are explained and contrasted. Circuits for generating single sideband waveforms are explained. Several types of single sideband receivers are discussed in Chapter 6. Chapter 7 introduces the basic concepts of angle modulation. Frequency and phase modulation are explained and contrasted. The amplitude, power, and frequency characteristic of an angle modulated wave are explained in detail. Both direct and indirect frequency and phase modulation transmitters are shown and discussed in detail. Chapter 8 extends the coverage of angle modulation to receivers. Several types of angle modulation demodulators are introduced and discussed. Frequency modulation stereo transmission, two-way frequency modulation communications, and mobile telephone communications including cellular radio are discussed. Chapter 9 explains the characteristics of an electromagnetic wave and wave propagation on a metallic transmission line. Several basic transmission line configurations are discussed and contrasted. Incident and reflected energy and the concept of standing waves are discussed in Chapter 9. Transmission line characteristic impedance and input impedance are also introduced. The concept of a matched line is explained and the consequences of a mismatched line are discussed. Chapter 10 extends the coverage of wave propagation to free space. Electromagnetic radiation concepts are explained. Spherical wavefronts are analyzed and the inverse square law is derived. Wave attenuation and absorption are covered. Chapter 10 gives a complete explanation of the optical properties of electromagnetic waves: refraction, reflection, diffraction, and interference. Ground, space, and sky wave propagation are discussed, and the fundamental limits for free space wave propagation are defined and explained. Chapter 11 introduces the antenna and describes basic antenna operation. Fundamental antenna terms are defined and explained. Radiation patterns are explained. The most basic antenna, the elementary doublet, is explained. The basic half- and quarter-wave antenna are explained along with the effects of the ground on the wave, and several antenna-loading techniques are described. Some of the more common antenna arrays and special-purpose configurations are explained including the following: folded dipole, log-periodic and loop antennas. Chapter 12 introduces the basic concepts of television broadcasting. Both monochrome and color television transmission and reception are explained. Generation of the composite video signal is explained. Basic transmitter and receiver circuits are explained. The basic concepts of scanning, blanking, and synchronization are discussed.

Chapter 13 introduces the concepts of digital transmission and digital modulation. In this chapter the most common modulation schemes used in modern digital radio systems—FSK, PSK, and QAM—are described. The concepts of information capacity and bandwidth efficiency are explained. Chapter 14 introduces the field of data communications. Detailed explanations are given for numerous data communications concepts, including transmission methods, circuit configurations, topologies, character codes, error control mechanisms, data formats, and data modems. Chapter 15 describes data communications protocols. Synchronous and asynchronous data protocols are first defined, then explicit examples are given for each. The most popular character- and bit-oriented protocols are described. In Chapter 15 the basic concepts of a public data network and a local area network are outlined, and the international user-to-network packet switching protocol, X.25, is explained. Chapter 16 introduces digital transmission techniques. This includes a detailed explanation of pulse code modulation. The concepts of sampling, encoding, and companding (both analog and digital) are explained. Chapter 16 also includes descriptions of two lesser-known digital transmission techniques: adaptive delta modulation PCM and differential PCM. Chapter 17 explains the multiplexing of digital signals. Time-division multiplexing is discussed in detail and the operation of a modern LSI combo chip is explained. The North American Digital Hierarchy for digital transmission is outlined, including explanations of line encoding schemes, error detection/correction methods, and synchronization techniques. In Chapter 18 analog multiplexing is explained and AT&T's North American frequency-division-multiplexing hierarchy is described. Several methods are explained in which digital information can be transmitted with analog signals over the same communications medium. Chapter 19 introduces microwave radio communications and the concept of system gain. A block diagram approach to the operation of a microwave radio system is presented and numerous examples are included. In Chapter 20 satellite communications is introduced and the basic concepts of orbital patterns, radiation patterns, geosynchronous, and nonsynchronous systems are covered. System parameters and link equations are discussed and a detailed explanation of a satellite link budget is given. Chapter 21 extends the coverage of satellite systems to methods of multiple accessing. The three predominant methods for multiple accessing—frequency-division, time-division, and code-division multiple accessing—are explained. Chapter 22 covers the basic concepts of a fiber optic communications system. A detailed explanation is given for light-wave propagation through a guided fiber. Also, several light sources and light detectors are discussed, contrasting their advantages and disadvantages. Appendix A describes the Smith chart and how it is used for transmission line calculations. Examples are given for calculating input impedance, quarter-wave transformer matching, and shorted stub matching.

WAYNE TOMASI

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Chapter 1

INTRODUCTION TO ELECTRONIC COMMUNICATIONS

INTRODUCTION

In essence, *electronic communications* is the transmission, reception, and processing of information with the use of electronic circuits. The basic concepts involved in electronic communications have not changed much since their inception, although the methods by which these concepts are implemented have undergone dramatic changes.

Figure 1-1 shows a communications system in its simplest form, which comprises three primary sections: a *source* (transmitter), a *destination* (receiver), and a *transmission medium* (wire pair, coaxial cable, fiber link, or free space).

The *information* that is propagated through a communications system can be *analog* (proportional), such as the human voice, video picture information, or music; or it can be *digital pulses*, such as binary-coded numbers, alpha/numeric codes, graphic symbols, microprocessor op-codes, or data base information. However, very often the source information is unsuitable for transmission in its original form and therefore must be converted to a more suitable form prior to transmission. For example, with digital communications systems, analog information is converted to digital form prior to transmission, and with analog communications systems, digital data are converted to analog signals prior to transmission. This book is concerned with the basic concepts of conventional analog radio communications and the concepts of digital radio communications.

Modulation and Demodulation

For reasons that are explained in Chapter 10, it is impractical to propagate low-frequency electromagnetic energy through the earth's atmosphere. Therefore, with *radio communi-*

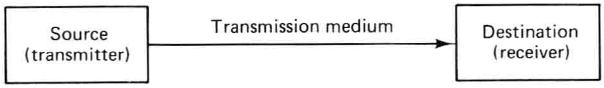

FIGURE 1-1 Block diagram of a communications system in its simplest form.

cations, it is necessary to superimpose a relatively low-frequency intelligence signal onto a relatively high-frequency signal for transmission. In electronic communications systems, the source information (intelligence signal) acts upon or modulates a single-frequency sinusoidal signal. *Modulate* simply means to vary or change. Therefore, the source information is called the *modulating signal*, the signal that is acted upon (modulated) is called the *carrier*, and the resultant signal is called the *modulated wave*. In essence, the source information is transported through the system on the carrier.

With analog communications systems, *modulation* is the process of changing some property of an analog carrier in accordance with the original source information and then transmitting the modulated carrier. Conversely, *demodulation* is the process of converting the changes in the analog carrier back to the original source information. The total or *composite information signal* that modulates the main carrier is called *baseband*. The baseband is converted from its original frequency band to a band more suitable for transmission through the communications system. Baseband signals are *up-converted* at the transmitter and *down-converted* at the receiver. *Frequency translation* is the process of converting a frequency or band of frequencies to another location in the total frequency spectrum.

Equation 1-1 is the general expression for a time varying sine wave of voltage such as an analog carrier. There are three properties of a sine wave that can be varied: the *amplitude* (V), the *frequency* (F), or the *phase* (θ). If the amplitude of the carrier is varied proportional to the source information, *amplitude modulation* (AM) results. If the frequency of the carrier is varied proportional to the source information, *frequency modulation* (FM) results. If the phase of the carrier is varied proportional to the source information, *phase modulation* (PM) results.

$$v = V \sin (2\pi F t + \theta) \tag{1-1}$$

where

v = time-varying sine wave of voltage
V = peak amplitude (V)

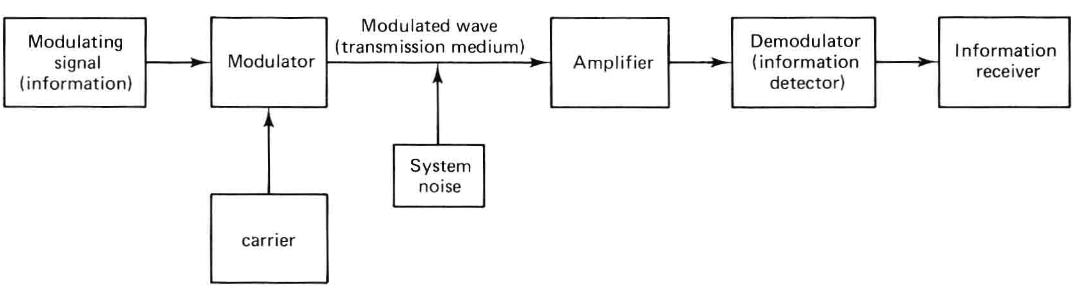

FIGURE 1-2 Communications system block diagram.