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Preface

The objective of this book is to provide an introduction to the basic principles in the analysis and design of communication systems. It is primarily intended for use as a text for a first course in communications, either at a senior level or at a first-year graduate level.

BROAD TOPICAL COVERAGE

Although we have placed a very strong emphasis on digital communications, we have provided a solid introduction to analog communications. The major topics covered are:

- An introduction to analog signal transmission and reception (*Chapters 2 and 3*)
- An introduction to digital communications (*Chapters 4 – 8*)

EMPHASIS ON DIGITAL COMMUNICATIONS

Our motivation for emphasizing digital communications is due to the technological developments that have occurred during the past five decades. Today, digital communication systems are in common use and generally carry the bulk of our daily information transmission through a variety of communications media, such as wireline telephone channels, microwave radio, fiber optic channels, and satellite channels. We are currently witnessing an explo-

sive growth in the development of personal communication systems and ultrahigh speed communication networks, which are based on digital transmission of the information, whether it is voice, still images, or video. We anticipate that, in the near future, we will witness a replacement of the current analog AM and FM radio and television broadcast by digital transmission systems.

The development of sophisticated, high-speed digital communication systems has been accelerated by concurrent developments in inexpensive high speed integrated circuits (IC) and programmable digital signal processing chips. The developments in Microelectronic IC fabrication have made possible the implementation of high-speed, high precision A/D converters, of powerful error-correcting coders/decoders, and of complex digital modulation techniques. All of these technological developments point to a continuation in the trend toward increased use of digital communications as a means for transmitting information.

OVERVIEW OF THE TEXT

It is assumed that students using this book have a basic understanding of linear system theory, both continuous and discrete, including a working knowledge of Fourier series and Fourier transform techniques. It is also assumed that students have had a first course in probability. Such courses are currently required in many undergraduate electrical engineering and computer engineering programs.

Chapter 2 treats modulation and demodulation of analog signals. This treatment includes *amplitude modulation* (*AM*), *frequency modulation* (*FM*), and *phase modulation* (*PM*). Radio and television broadcasting and mobile radio cellular systems are discussed as examples of analog communication systems. Chapter 3 continues the treatment of analog communication systems by analyzing the effect of additive noise in the demodulation of AM, FM, and PM signals. The phase-locked loop, which is used for estimating the phase of a sinusoidal carrier in both analog and digital communication systems is also described in Chapter 3.

A logical beginning in the introduction of digital communication sys-

tems analysis and design is the characterization of information sources and source encoding. Chapter 4 is devoted to this topic. In this chapter we introduce the reader to the modeling of information sources, both discrete and continuous (analog), and the basic mathematical concepts of entropy and mutual information. Our discussion of source encoding for discrete sources includes the Huffman coding algorithm. For the case of analog sources, we treat both scalar and vector quantization and describe the common waveform-coding techniques, namely, PCM, DPCM, and DM. As practical examples of the source-coding methods described in this chapter we cite the digital speech transmission systems in the telephone plant, the digital audio recording systems as embodied in the compact disc (CD) player.

Digital modulation and demodulation techniques are described in Chapter 5. Binary and nonbinary modulation methods are described based on a geometric representation of signals, and their error-rate performance is evaluated and compared. This chapter also describes symbol synchronization methods for digital communication systems.

Chapter 6 treats digital transmission through bandlimited AWGN channels. In this chapter we derive the power-spectral density of linearly modulated baseband signals and consider the problem of signal design for a bandlimited channel. We show that the effect of channel distortion is to introduce intersymbol interference (ISI), which can be eliminated or minimized by proper signal design. The use of linear and nonlinear adaptive equalizers for reducing the effect of ISI is also described.

Chapter 7 treats the topic of channel coding and decoding. The capacity of a communication channel is first defined, and the capacity of the Gaussian channel is determined. Linear block codes and convolutional codes are introduced and appropriate decoding algorithms are described. The benefits of coding for bandwidth constrained channels are also described. The final section of this chapter presents three practical applications of coding.

The last chapter of this book treats topics in wireless communications. First, we consider the characterization of fading multipath channels and describe the effects of such channels on wireless digital communication sys-

tems. The design of signals that are effective in mitigating this type of channel distortion is also considered. Second, we describe the class of continuous-phase modulated signals, which are especially suitable for digital communication in wireless channels. Finally, we treat the class of spreadspectrum signals, which are suitable for multi-user wireless communication systems.

EXAMPLES AND HOMEWORK PROBLEMS

We have included a large number of carefully chosen examples and homework problems. The text contains over 130 worked-out examples and over 330 problems. Examples and problems range from simple exercises to more challenging and thought provoking problems. A Solutions Manual is available free to all adopting faculty, which is provided in both typeset form and as a diskette formatted in LATEX. Solutions are not available for sale to students. This will enable instructors to print out solutions in any configuration easily.

COURSE OPTIONS

This book can serve as a text in either a one-or two-semester course in communication systems. An important consideration in the design of the course is that some sections are marked with star (*) as optional ones. These sections can be skipped partly or fully when a shorter course is served. Another important consideration is whether or not analog modulation and demodulation techniques are to be covered. Here, we outline four scenarios. Others are certainly possible.

1. A one-term course in analog and digital communication: All of chapters 2, 3, 5, and 6, and selections from chapters 4, 7, and 8.
2. A one-term course in digital communication: Chapters 4 – 8.
3. A one-term shorter course in digital communication: Chapters 4 – 6, and selections from Chapter 7.
4. A two-term course sequence on analog and digital communications:
   (a) Chapters 2 – 5 for the first course.

(**b**) Chapters 6 – 8 for the second course.

We wish to thank Gloria Doukakis for her assistance in the preparation of the manuscript.

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Contents

1

Introduction

Every day, in our work and in our leisure time, we come in contact with and use a variety of modern communication systems and communication media, the most common being the telephone, radio, television, and the Internet. Through these media we are able to communicate (nearly) instantaneously with people on different continents, transact our daily business, and receive information about various developments and events of note that occur all around the world. Electronic mail and facsimile transmission have made it possible to rapidly communicate written messages across great distances.

Can you imagine a world without telephones, radio, and TV? Yet, when you think about it, most of these modern-day communication systems were invented and developed during the past century. Here, we present a brief historical review of major developments within the last two hundred years that have had a major role in the development of modern communication systems.

1.1 HISTORICAL REVIEW

Telegraphy and Telephony. One of the earliest inventions of major significance to communications was the invention of the electric battery by Alessandro Volta in 1799. This invention made it possible for Samuel Morse to develop the electric telegraph, which he demonstrated in 1837. The