An Introduction to Analog and Digital Communications

Simon Haykin

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PREFACE

In this book I present an introductory treatment of communication theory as applied to the transmission of information-bearing signals, with attention given to both analog and digital communications. Numerous examples, worked out in detail, have been included to help students develop an intuitive grasp of the theory under discussion. Each chapter begins with introductory remarks and (except for Chapter 1) ends with a set of problems. Also, except for Chapter 1, each chapter includes exercises that are intended to help students improve their understanding of the material covered in the chapter. Answers to the exercises are given at the end of the book.

Chapter 1 is an introduction to communication theory and a review of some basic concepts.

In Chapter 2, I review two classic methods for frequency analysis, namely, the Fourier series and the Fourier transform. In Chapter 3, I discuss the time-domain and frequency-domain descriptions of signal transmission through linear filters and channels. In Chapter 4, I present a unified treatment of the spectral density and correlation functions of energy signals and power signals. Thus, Chapters 2 through 4 constitute the first major part of the book, pertaining to the *characterization of signals and systems.*

In Chapter 5, I describe pulse-code modulation (PCM) and related techniques for the conversion of information-bearing analog signals into digital form. In Chapter 6, I cover issues that arise in baseband data transmission. In Chapter 7, I describe various modulation techniques, with attention given to both analog and digital signals as the modulating wave. Thus, Chapters 5 through 7 constitute the second major part of the book, concerned with the *transmission of message (information-bearing) signals over communication channels.*

The third major part of the book, made up of Chapters 8 through 10, deals with *noise in analog and digital communications.* In Chapter 8, I present a review of probability theory and random processes. This is followed by a discussion of the effects of channel (receiver) noise on the performance of analog modulation schemes in Chapter 9. Finally, in Chapter 10, I discuss the design of optimum receivers for data transmission over a noisy communication channel.

The book also includes four appendixes. In Appendix A, I review power ratios and the decibel. In Appendix B, I review Bessel functions of the first kind and their properties. In Appendix C, I describe various sources of noise and present a treatment of noise calculations in communication systems. Appendix D includes various mathematical tables. To assist the student, I have also included a glossary of notations and abbreviations.

Footnotes are included in the text to add historical notes, to cite reference material, and to highlight points of interest. A list of references and bibliography is appended at the end of the book.

The book is essentially self-contained and suited for a one-semester course in communication systems taken by electrical engineering juniors or seniors. For juniors, the course may be organized as follows:

1. Chapter 1 for an overview of the issues involved in communications.
2. Chapter 2 on Fourier analysis, emphasizing properties of the Fourier transform and the interplay between time-domain and frequency-domain descriptions of signals.
3. Chapter 3 on filtering and signal distortion, with particular attention given to the transmission of signals through band-pass filters and channels.
4. Chapter 4 on spectral densities and correlation functions, emphasizing the application of these concepts to both energy and power signals.
5. Material taken from Chapter 7 on standard amplitude modulation, double-sideband suppressed-carrier modulation, and frequency modulation.

For seniors, the course may be organized as follows:

1. An overview of communications, and a review of Fourier analysis of signals and systems, emphasizing the important roles of Fourier transformation and linear filtering in communications; material from Chapters 1 through 4 may be used for this review.
2. Chapter 5 on pulse-code modulation and related techniques for analog-to-digital conversion.
3. Chapter 6, to provide an appreciation for intersymbol interference in data transmission and practical cures for it.
4. Chapter 7 on modulation techniques for both analog and digital signals.
5. Sections 8.1 through 8.4 for a review of probability theory, the extent of which depends on the background of students taking the course. This review is followed by a study of random processes (Section 8.5 through 8.14), with emphasis on the characterization of wide-sense stationary processes and narrow-band Gaussian processes.
6. Chapter 9 on noise in (continuous-wave) amplitude and frequency modulation.
7. Chapter 10 on optimum receivers for data transmission, to develop an understanding of the matched filter and the role it plays in digital communications.

The book offers enough flexibility for organizing the course material to suit the interests of course teachers and students in other ways.

Attention is given to both analog and digital communications at an *introductory* level. Readers who wish to avail themselves of a more advanced treatment of digital communications, may refer to a companion book written by the author on this subject: S. Haykin, *Digital Communications*, Wiley 1988.

As aids to teachers of the course, the following material is available from the publishers of the book:

A complete manual, containing detailed solutions of all the problems in the book, master transparencies of all the figures and tables in the book and six computer-oriented experiments, with detailed results for all the experiments.

I am grateful to the following reviewers for their helpful suggestions: F. Carden, New Mexico State University; S. Kesler, Drexel University; M. Siegel, Michigan State University; and Dr. M. C. Wernicki, an independent consultant. I thank S. Rappaport, State University of New York at Stony Brook, for some helpful inputs.

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