Book Review

Discrete Communication Systems - Review

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Number of pages in the book: 928 pages, plus index.

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Index terms: communication system, discrete communication system, digital communication system, discrete modulation, digital modulation, CDMA and OFDM systems, signal processing, deterministic signals, random signals.

1. Purpose and the Main Features of the Book

This book primarily presents the theoretical base of discrete communication systems with a reference to digital communication systems. The contents of the book solely address problems in the design of a communication system that includes a transmitter, a transmission channel, and a receiver. The signals processed in the system are presented in two domains of time, the continuous-time domain and the discrete-time domain, and in two corresponding domains of frequency, the Fourier series and transforms for continuous-time and discrete-time signals. A system operating in the continuous-time domain is named *the digital system*, while a system operating in the discrete-time domain is named *a discrete system*. The theory of discrete systems is the focus of this book because of the existing theory of digital communication systems, however, it is not sufficient to work on the design and implementation of the communication system transceiver blocks in modern DSP technology. The purpose of the book is not to explain all existing modulation techniques, but to make a firm foundation of communications systems operating in the discrete-time domain covering the basic discrete modulation methods.

The writing of this book is additionally motivated by modern trends in the design of communication systems on FPGA and DSP platforms. These trends were heavily supported by advances in the theory

of discrete-time signal processing. These trends will continue in the future supported by the everlasting increase in the processing ability of digital technology allowing the development of sophisticated communication algorithms we could not dream of in the past. For these reasons, it is necessary to know how to use the discrete-time signal processing theory and how to apply it in the design of modern communication devices. Even more important is to make available the theory of discrete-time communication systems to the researchers, practicing engineers, and designers of communications devices in the industry. Practically all modern communication devices, like wireless and cable modems, TV modems, consumer entertainment systems, satellite modems, and similar, are based on the use of digital processing technology and the principles of the discrete-time signal processing theory.

The distinguishing features of the book are:

1.   This is the first book that presents the essential theory and practice of discrete communication systems design. In contrast to already published books, the operation of the discrete communication systems is expressed in terms of the theory of discrete-time stochastic processes and related to the existing theory of digital communication systems.

2.   Based on the presented orthogonality principles, a generic structure of a communication system, based on correlation demodulation and optimum detection, is developed and presented in the form of mathematical operators.

3.   Due to the random nature of the signals processed, the theory of continuous-time and discrete-time stochastic signal processing is extensively and consequently applied to present the signals at the inputs and outputs of the transceiver blocks and develop the general system named the generic system.

4.   Based on the generic system, the traditionally defined phase shift keying (PSK), frequency shift keying (FSK), quadrature amplitude modulation (QAM), orthogonal frequency division multiplexing (OFDM), and code division multiple access (CDMA) systems are deduced as its special cases

5.   Having in mind the controversial nature of the continuous-time white Gaussian noise process having infinite power, a separate chapter is dedicated to noise discretization by introducing notions of noise entropy and the truncated Gaussian density function.

6.   The book is self-sufficient, because it uses a unified notation and terminology, both in the main ten chapters explaining communications systems theory and in nine complementary chapters dealing with the continuous and discrete-time signal processing for both the deterministic and stochastic signals. We are saying that readers do not need to go to various books on signal processing and struggle with their different notations to understand them in the context of the operation of communication systems.

7.   The unified notation and unified terminology allow clear distinction of the deterministic signals from stochastic, power signals from energy signals, the discrete-time signals and processes from the continuous-time signals and processes.

8.   For the sake of explanation and clarity, the theory of digital communication systems is presented to a certain extent and related to the main theory of discrete communication systems.

9.   The text of the book is accompanied by solutions to about 300 problems and five Projects.

2. Content of the Book

The book contains two parts, as can be seen in Fig. 1. The First Part has ten main chapters and presents an essential theory of the discrete and digital communication systems, the operation of their building blocks, and in the first place the operation of modulators and demodulators/detectors. Due to the importance of the theory of discrete and continuous-time signal processing, for both deterministic and random signals, nine chapters containing this theory are incorporated into the Second Part of the book containing nine complementary chapters.

The main chapters are in the middle of the diagram (1 to 10, including chapter 3 on the left). The complementary chapters, containing the theory of signal sampling and reconstruction, and the necessary theory in deterministic discrete-time signal processing, are on the left-hand side (13, 14, and 15). The chapters containing the theory of continuous-time signal processing are on the right-hand side (11, 12, and 19). Chapters 16 to 18, at the bottom of Fig. 1, contain the essential theory of digital filters and multi-rate signal processing that is relevant for nearly all chapters of the book and for Chapters 7 and 10. The chapters are interconnected by the input arrow and output diamond lines.
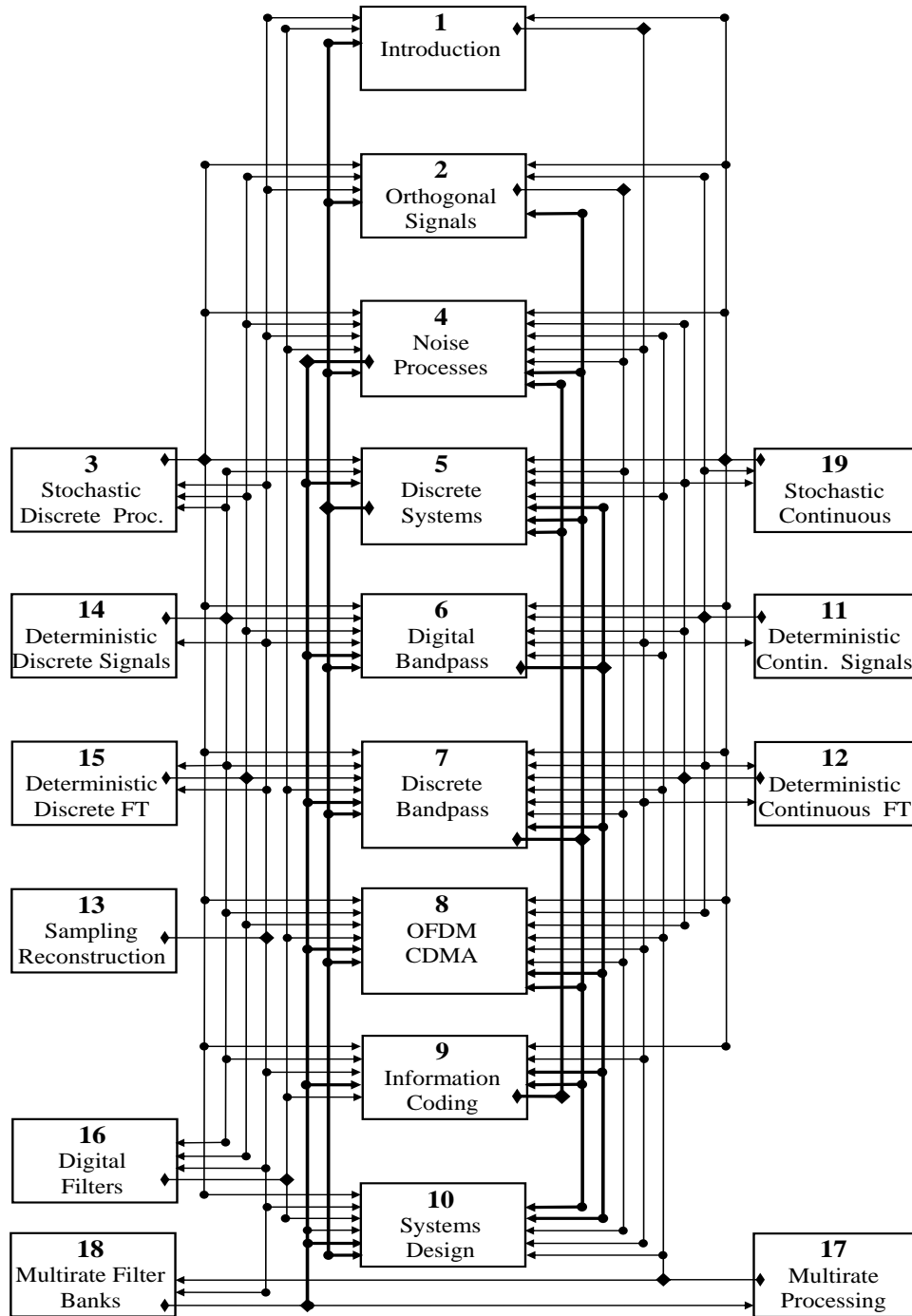
Figure 1. The Book Structure and Relationship of Chapters

3. Description of Chapters in the Main Part

Chapter 1 introduces the subject of the book, defines the main terms in communication systems, and presents the main objectives of writing this book. Chapter 2 is dedicated to the principle of discrete-time signals orthogonalization. Understanding this chapter is a prerequisite to understanding Chapters 4 to 10. Chapter 3 contains the theory of discrete-time stochastic processes, which is a prerequisite for the chapters related to the theory of discrete communication systems exposed in

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Chapters 4 to 10. Chapter 4 addressed the issues related to the theory of noise in communication systems. Adding the entropy and truncated density functions to already used autocorrelation and power spectral density functions, allowed mathematical modeling of the discrete noise generators and regenerators. This chapter is in close relation with chapters 3, 19, 13, 16, 17, and Project 3. Chapter 5 is a vital part of this book presenting the generic communication system operating in the discrete-time domain, which is based on the implementation of the orthogonal modulators, correlation demodulators, and optimum detectors, following the definition of signal synthesizers and analyzers in Chapter 2. The generic discrete system is shown in Fig. 2, to be used to deduce the practical systems as its special cases. Chapter 6 presents mathematical models of the traditional baseband and bandpass digital communication systems based on BPSK, QPSK, FSK, and QAM modulation methods. Chapter 7 presents the operation of a discrete system that processes pure discrete-time signals. The vital characteristics of the system and its blocks are expressed in terms of the amplitude spectral density, autocorrelation functions, power and energy spectral densities, and the bit error probability. This chapter presents mathematical models of the discrete baseband and bandpass communication systems based on BPSK and QPSK, FSK, and QAM modulation methods, which are deduced from the generic system structure presented in Chapter 5, which confirms the basic idea of this book that the practical communication systems are special cases of the generic system. An example of a derived BPSK system is shown in Fig. 3 operating at the intermediate frequency. Chapter 8 presents modern multiuser and multicarrier CDMA and OFDM systems, and Project 4 demonstrates the procedure of mathematical modeling, simulation, and design of a CDMA system in FPGA technology. Chapter 9 presents the fundamentals of information theory, including the theory of iterative and turbo channel coding that is demonstrated in Project 5. Chapter 10 presents practical aspects of discrete communication systems design in digital technology, primarily in DSP and FPGA
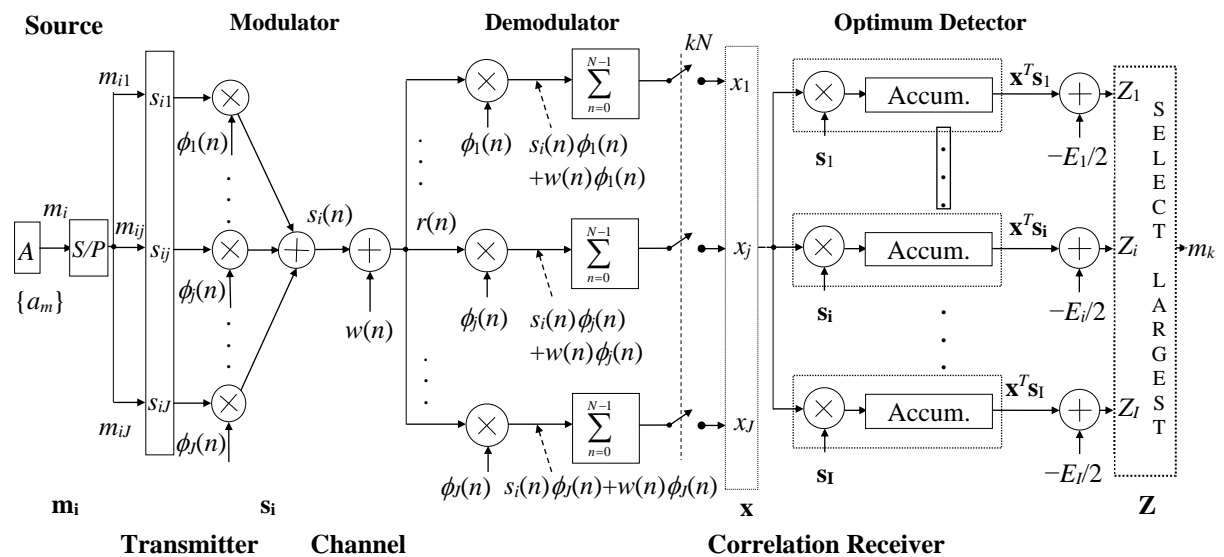

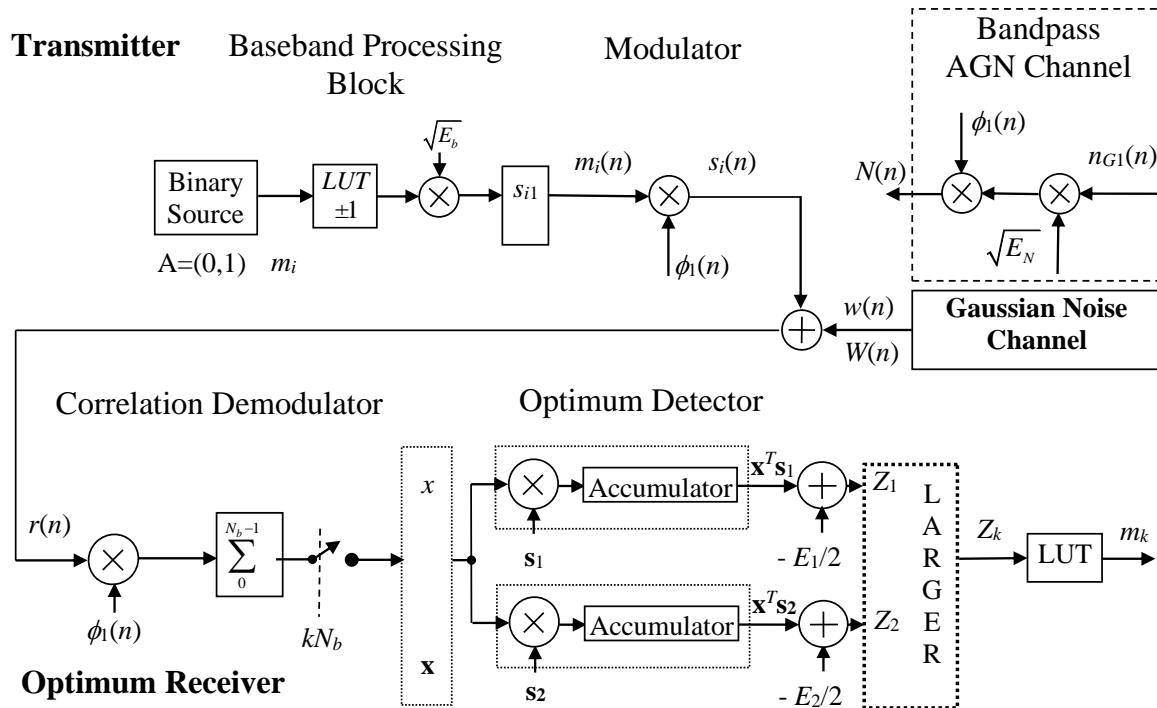**Figure 2. Generic Discrete Communication System Operating in the Discrete-time Domain.**

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Figure 3. Discrete BPSK, an Example Special Case of the Generic Discrete System

4. Description of Chapters in the Complementary Part

Complementary chapters 11 to 19 are added for three reasons. Firstly, they contain the basic theory of continuous-time and discrete-time signal processing that is essential for the understanding of mathematical models and operations of the digital and discrete transceivers, where we are using the theory of deterministic and stochastic signal processing. Secondly, the unified notation and terminology in all 19 chapters simplify the understanding of their content. Thirdly, presenting the signal processing and communication systems theory with a unified notation makes this book to be self-sufficient, allowing readers to avoid wasting time and getting confused by reading various books with different notations. Even though a reader can be very familiar with the signal processing theory contained in the complementary chapters, it is advisable to read them before starting to work on the main 10 chapters.

5. Book Dedication

The book is dedicated to undergraduate and graduate students doing courses in communication systems, and also to the practicing engineers working on the design of transceivers in discrete communication systems. A one-semester senior-level course, for students who have had prior exposure to classical communication systems covering passband and baseband signal transmission, can use the material in Chapters 1 to 6, and Chapter 9 supported with related complementary Chapters 11 to 15, Chapter 19 and Projects 1, 2 or 3. In a first-year postgraduate level course, the first six chapters provide the students with a good review of the digital and discrete communication systems theory and the main lecturing will cover Chapters 2 to 5 and Chapters 7 to 10 that present the discrete communications

systems and their design, and related Projects 1 to 5. The background theory for this course is contained in complementary Chapters 13 to 18.

For practicing engineers, who are experienced in the theory of digital communication systems, the material covered in Chapters 2 to 5, Chapters 7 to 10 supported by complementary chapters 13 to 18 is a good base for understanding the vital concepts in discrete communication systems. All Projects are relevant for them, in particular Projects 4 and 5.

6. Supplementary Material

The book contains the Supplementary Material that is composed of two parts: The Solutions of the Problems in the book, and Research Projects with offered solutions. To master the theory, key chapters contain sets of problems for students' exercises. The solutions to the problems are inside a separate book belonging to the Supplementary Material for the readers. In addition to the solved problems, the book contains several real-world case studies in the form of Projects related to the advanced modeling and designs of modern communication systems based on digital and discrete-time signal processing and the application of modern technologies like DSP and FPGA. Any of these Projects is not a laboratory exercise but a self-contained piece of research work related to a particular book chapter, and as such can be a part of a one-semester project inside the course in discrete and digital communication systems.