Fundamentals of Digital Communications – Introduction

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Objectives for this lecture

- Goal of (digital) communication systems
  - data transmission from **source** to **sink** (A → B)
  - over a **given communication channel**
  - **avoid** transmission **errors**
- Objectives: Digital communication systems
  - typical **blocks**
  - **mathematical modeling** of these blocks and of the communication **signals**
  - goal: **optimization** of blocks (system optimization)

Outline: Introduction

- What is digital communications?
- Block diagram
- Why digital?
- Introductory example

Reference: [Sklar, Section 1.1; Proakis, Ch. 1]
- for (most) figures see [Sklar]

Basic Elements of a Digital Communication System (DCS)

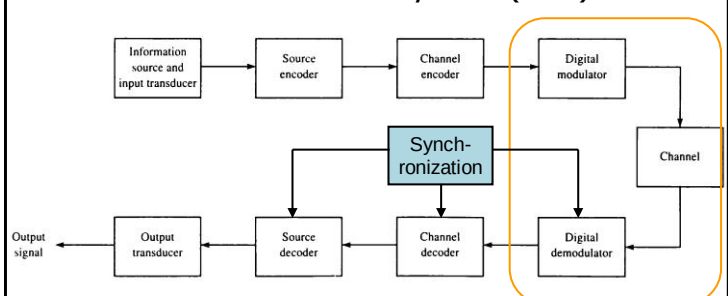
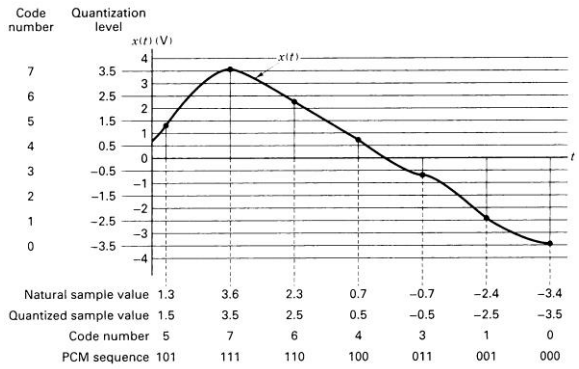


FIGURE 1-1-1 Basic elements of a digital communication system.
[Proakis]

this course!

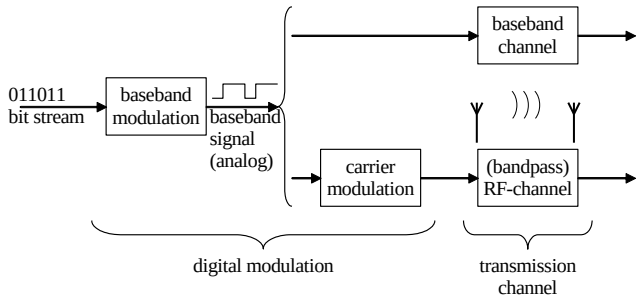
Block Diagram

Formatting – Source Coding



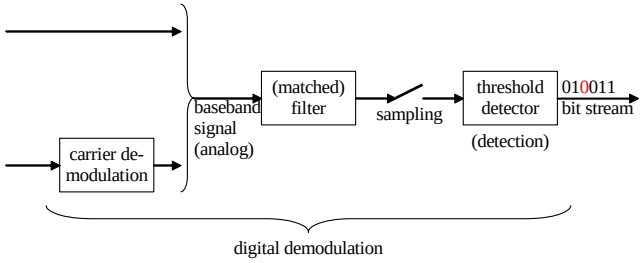
[Sklar] **Figure 2.16** Natural samples, quantized samples, and pulse code modulation. (Reprinted with permission from Taub and Schilling, *Principles of Communications Systems*, McGraw-Hill Book Company, New York, 1971, Fig. 6.5-1, p. 205.)

This lecture: Digital modulation and channel



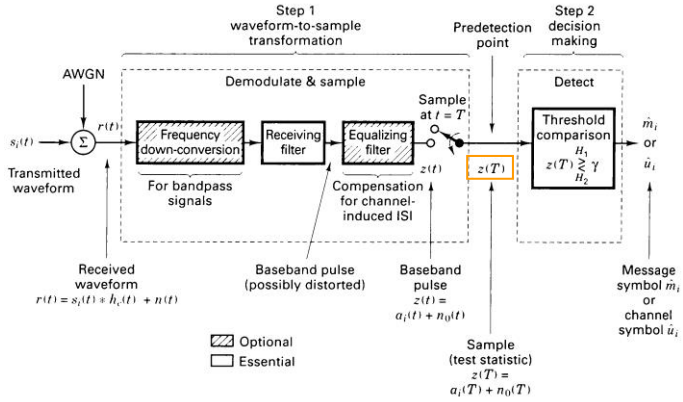
Example

This lecture: Digital Demodulator



Example

Demodulation/Detection



[Sklar] **Figure 3.1** Two basic steps in the demodulation/detection of digital signals.

PDF of Signal at Detector Input

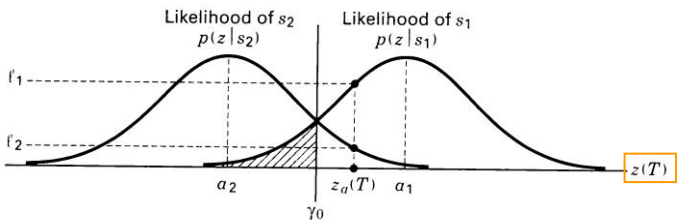


Figure 3.2 Conditional probability density functions: $p(z|s_1)$ and $p(z|s_2)$.
[Sklar]

Signal Regeneration

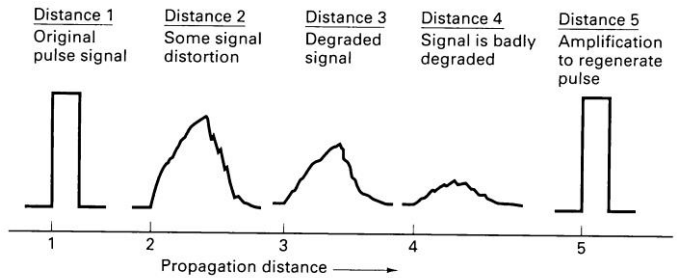


Figure 1.1 Pulse degradation and regeneration.
[Sklar]

Goals (refined)

- Derive:
  - Optimum signaling waveforms
  - Optimum receiving filter
  - Optimum detection methods

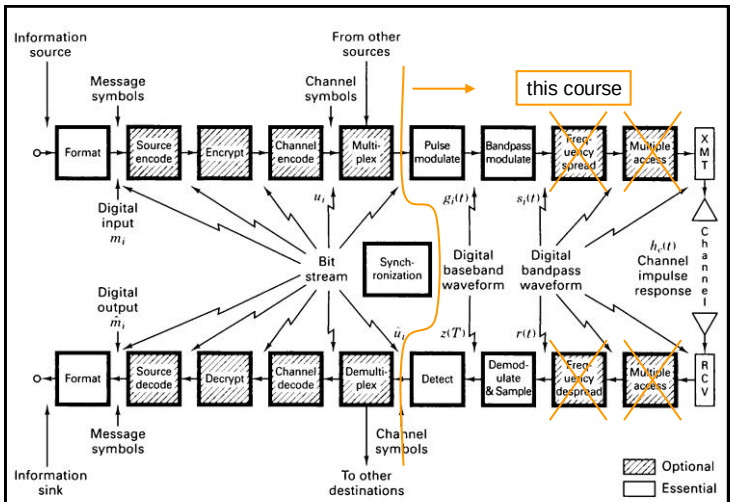
  For a variety of signaling (modulation) schemes and different channel conditions
- This implies/requires:
  - Derivation of **mathematical models** of digital communication systems
  - Analysis of performance metrics; e.g. the **error rate performance**

Outlook

- Mathematical background
  - Signal representations (time/frequency domain; signal space)
  - Linear systems
  - Stochastic processes and noise
- Modulation
  - Baseband and bandpass (passband; carrier modulated)
- Additive white Gaussian noise (AWGN) channel
  - and linear filter channel
- Optimum detection
  - Matched filter and sampling
  - Fundamentals of detection theory
  - Performance analysis (and limits): bit error rate (BER)
  - Equalization (linear filter channels), OFDM, and MIMO channels

Books – Digital Communications

- **J. G. Proakis und M. Salehi, *Communication Systems Engineering*, 2nd ed., Prentice Hall, 2002.** (German ed.: J. G. Proakis und M. Salehi, *Grundlagen der Kommunikationstechnik*, 2. Auflage, Pearson, 2003) (**Ch. 7** and 1,2,4,8)
- B. Sklar, *Digital Communications: Fundamentals and Applications*, 2nd edition, Prentice-Hall, 2001 (Ch. 1-4, App. B)
- J. R. Barry, E. A. Lee and D. G. Messerschmitt, *Digital Communication*, 3rd edition, Kluwer Academic Publishers, 2004 (Ch. 1-3, 5, 6) (more advanced text; good for further study)
- J. G. Proakis, *Digital Communications*, 3rd edition, McGraw-Hill, 1995 (Ch. 1, 2, 4, 5) (classical text)
- M. Werner, *Nachrichtentechnik*. 4. Auflage, Vieweg Verlag, 2003 (Kapitel 1-4) (very basic text; doesn't cover all aspects of the course)



[Sklar] **Figure 1.2** Block diagram of a typical digital communication system.

Block Diagram of a Typical DCS (extended)

- Block diagram of a typical digital communication system (for RF channels) [Sklar: Figure 1.2]
  - Signal processing steps (signal transformations)
- Essential blocks:
  - Formatting (source coding)
  - Modulation (generate waveforms compatible with channel)
  - Demodulation/detection
  - Synchronization
- Essential in practice:
  - Channel coding (for ARQ or FEC)

Other processing steps

- Encryption: provide privacy
- Multiplexing: combine several data streams
- Multiple access: allow several users on medium
- Frequency spreading:
  - Enhance robustness against interference (natural and man-made)
  - Code division multiple access
  - Reduction of fading