UESTC4004
Digital Communications

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What, Why and How of the Course

- What is this course about?
- Why I need to study this course?
- How I need to learn this course?

https://www.youtube.com/watch?v=0ay2Qy3wBe8

https://www.youtube.com/watch?v=uehHMvhlBek

Course Aims

- This course aims to introduce the theory and systems engineering of modern digital communication systems and enhance understanding of communication systems protocols.

Intended Learning Outcomes

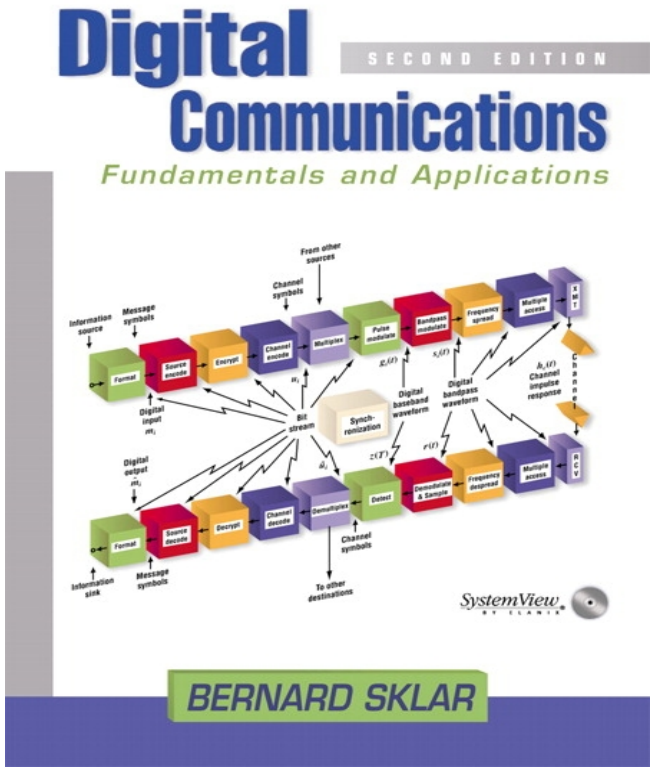
By the end of this course students will be able to:

- state the meaning of entropy in the context of communication theory and derive fundamental limits on the capacity of a communication channel;
- describe common forms of digital communication, including radio and optical transmission;
- explain standard forms of binary modulation, such as amplitude and phase-shift keying and interpret their waveforms;
- critically compare the attributes of different forms of binary modulation;
- describe the hardware needed to implement standard forms of binary modulation;
- derive the response required for an optimal decoder and describe the impact of non-optimality;
- explain how the carrier is recovered from a modulated signal and describe the hardware required;
- design an appropriate transmission method for a given type of signal;

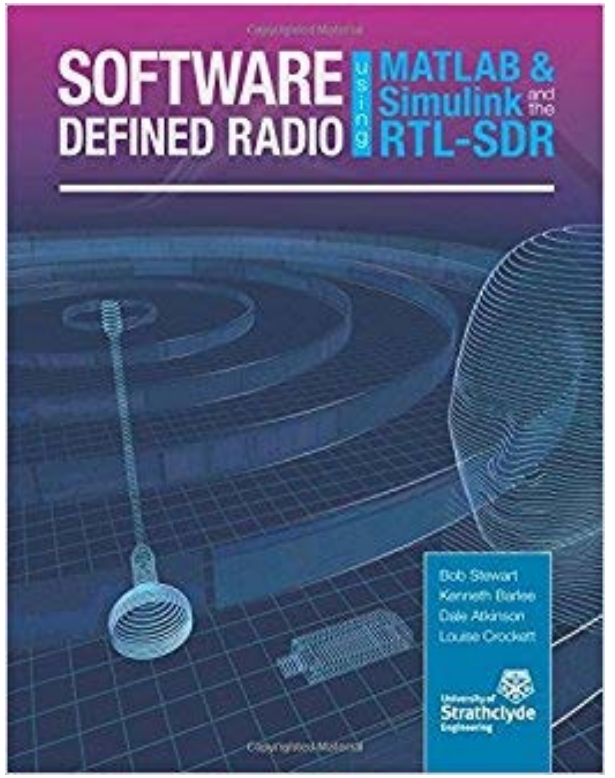
Reference Books

- You are **not required** to buy any textbook
- Recommended books for reference are:

Lectures



Labs



Prerequisites

Anticipated:

UESTC3007: Signals and Systems , UESTC4005: Digital Signal Processing

Recommended:

UESTC2012: Probability theory, Stochastic Processes

Required Software:

Matlab & Simulink

Course Material

- All course material will be available on **Moodle/Aula** (sort out your GUIDs!)
  - Syllabus
  - Lecture notes
  - Supplemental Resources
  - Lab manual
  - Videos
  - Past exam papers

Aula

- An interactive alternative to Moodle
- As part of a wider pilot study to run across different colleges at UoG to measure the effectiveness of Aula, we'll participate on behalf of GC-UESTC
- http://gla.aula.education
- Each one of you is already enrolled to Aula for Digital Communication course. You should be able to access it using your GUIDs.
- Any problem in signing in, please let me know at the earliest.

Aula

- We'll use it to share course material as well as discussions.
- Use the Feed section to ask questions, respond to the questions – contribute to the discussions.
- Very important – use only English to post and avoid inappropriate language
- I would suggest to install Aula App available for Android as well as iOS devices to stay in touch more effectively.

Course Assessment

- Closed Book Examinations - 85%
  - Midterm – 10%
    - Closed book exam during week 10 or 11 (date will be announced later)
    - Covers Week 1 & 2 lectures and labs
  - Final Exam – 75%
    - Closed book exam at the end of the semester (during week 18, 19, 20: date will be announced later)
    - Covers all lectures and labs
- Labs – 15%
  - 4 Lab Exercises
  - Marks distribution for each lab exercise given in the lab document

Requirements for Grade

- To receive a grade at the end of the course, you must:
  - attend all the labs (total 4 lab sessions)
  - attend all the exams (midterm and final)
- If you fail to fulfil any of the above requirement, you will not receive grade, you will be given “CW”.
- CW (Credit Withheld) means that you have not completed some part of the assessment (exam, laboratory report, etc) but can still do so before the next academic year. Contact the course lecturer if you are in doubt as to what you need to do.

Lab Manual

- Lab manual is available on Moodle/Aula under “Labs” tab.
- You are required to complete the tasks given in your lab manuals and get them grades by the Instructor/GTAs during each lab session.
- Save your lab manuals in the electronic format.
- Electronic submission of the manuals through Moodle/Aula will be due in the week following 4th lab session – due date Friday 20 December 2019.

Lab Sessions

- Each of you will be given one RTL-SDR device which you can keep and play with during the semester. Devices MUST be returned at the end of semester.
- When you have completed an exercise (milestone) and lab report, you can call a demonstrator to show your work, output and report for grading
- You must answer all the questions about each exercise
- Remember – most of the lab work can be done at home and therefore you should pace yourself appropriately with all lab sessions, particularly 4th lab session which has relatively more weight.

RTL-SDR rtl-sdr.com

- RTL-SDR is a cheap dongle which can be used to receive multiple type or wireless signals.
- A lot applications like sniffing GSM signals, listening to aircraft traffic control, scanning for cordless phones etc. More details on https://www.rtl-sdr.com/about-rtl-sdr/

Using RTL-SDR for lab sessions

- Installation – first we need to install Matlab hardware support package. Please watch and follow the video RTL-SDR Hardware Support Package Installation – available on Moodle/Aula. Please bear in mind to use appropriate package version according to your Matlab version.
- Testing – use sdrinfo to verify if the RTL-SDR is properly installed
- Running – perform the first lab exercise and try to discover various wireless signals available around us like GSM.
- Follow the book, 'Software Defined Radio using Matlab & Simulink and the RTL-SDR' for all the details.
- All of you are recommended to download book and resource material from the website http://www.desktopsdr.com/download-files

How to learn from the Course?

- Attend all the lectures and lab sessions
- Lots of self-study
- Spend time in the lab, write code, test it, change it, play with RTL-SDR
- Solve problems from the book
- Solve past exam papers

Oh --- I’m already in final year

DIFFERENCE BETWEEN A TEACHER AND A PROFESSOR

A Professor of Philosophy at the University of Houston has explained the difference between high school teachers and university professors.

He said, “I am your professor, not your teacher.” He stressed that, “Teachers are evaluated on the basis of learning outcomes, generally as measured by standardized tests. If you don’t learn, then your teacher is blamed.”

He added, “It is not part of my job to make you learn. At university, learning is your job—and yours alone. My job is to lead you to the fountain of knowledge. Whether you drink deeply or only gargle is entirely up to you.”

Communications?

- What comes to your mind when you see the word Communications?
- What is the purpose of Communications?
- What could be the components of a Communication System?
- What factors could impact on Communications?
- How would you judge the Communications quality?

Communication

- Main purpose of communication is to transfer information from a source to a recipient via a channel or medium.

- Basic block diagram of a communication system:

Brief Description

- **Source:** analog or digital
- **Transmitter:** transducer, amplifier, modulator, oscillator, power amp., antenna
- **Channel:** e.g. cable, optical fibre, free space
- **Receiver:** antenna, amplifier, demodulator, oscillator, power amplifier, transducer
- **Recipient:** e.g. person, (loud) speaker, computer

- **Types of information**
  Voice, data, video, music, email etc.

- **Types of communication systems**
  Public Switched Telephone Network (voice,fax,modem)
  Satellite systems
  Radio,TV broadcasting
  Cellular phones
  Computer networks (LANs, WLANs)

Information Representation

- Communication system converts information into electrical electromagnetic/optical signals appropriate for the transmission medium.
- Analog systems convert analog message into signals that can propagate through the channel.
- Digital systems convert bits (digits, symbols) into signals
  - Computers naturally generate information as characters/bits
  - Most information can be converted into bits
  - Analog signals converted to bits by sampling and quantizing (A/D conversion)

Performance Metrics

- Analog Communication Systems
  - Metric is fidelity: want $\hat{m}(t) \approx m(t)$
  - Signal to noise ratio (SNR) typically used as performance metric
- Digital Communication Systems
  - Metrics are data rate (R bps) and probability of bit error ($P_b = p(\hat{b} \neq b)$)
  - Without noise/distortion/sync. problem, we will never make bit errors

What features should a good communication system have?

1.
2.
3.
4.
5.

Why digital Communications? … A simple case

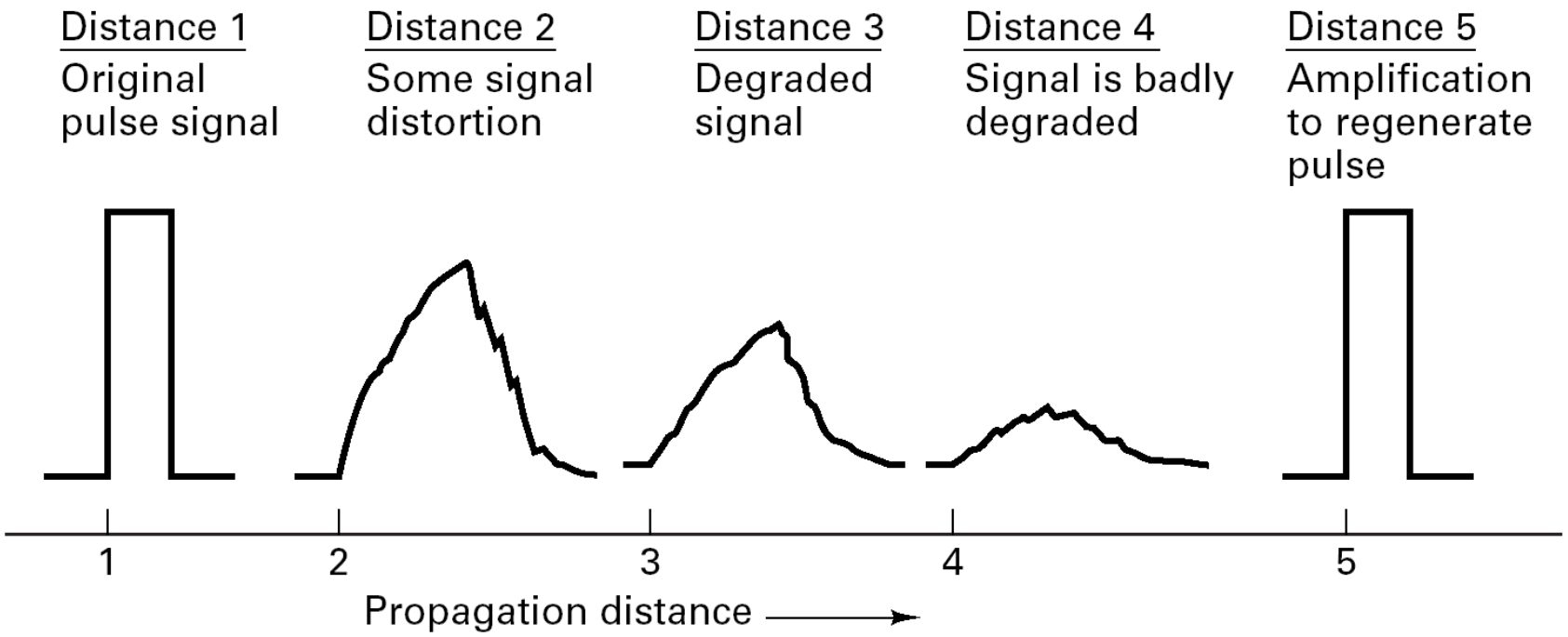


Figure 1.1 Pulse degradation and regeneration.

Why Digital Communications?

- ***Easy to regenerate the distorted signal***
  - Regenerative repeaters along the transmission path can detect a digital signal and retransmit a new, clean (noise free) signal
  - These repeaters prevent accumulation of noise along the path
  - This is not possible with analog communication systems
- ***Two-state (or M-state) signal representation***
  - The input to a digital system is in the form of a sequence of bits (binary or M_ary)
- ***Immunity to distortion and interference***
  - Digital communication is rugged in the sense that it is more immune to channel noise and distortion

Why Digital Communications?

- ***Hardware is more flexible***
  - Digital hardware implementation is flexible and permits the use of microprocessors, mini-processors, digital switching and VLSI
  - Shorter design and production cycle
- ***Low cost***
  - The use of LSI and VLSI in the design of components and systems have resulted in lower cost
- ***Easier and more efficient to multiplex several digital signals***
  - Digital multiplexing techniques – Time & Code Division Multiple Access - are easier to implement than analog techniques such as Frequency Division Multiple Access
- ***Can combine different signal types – data, voice, text, etc.***
  - Data communication in computers is digital in nature whereas voice communication between people is analog in nature

Why Digital Communications?

- The two types of communication are difficult to combine over the same medium in the analog domain.
- Using digital techniques, it is possible to combine both format for transmission through a common medium

- ***Can use packet switching***
- ***Encryption and privacy techniques are easier to implement***
- ***Better overall performance***
  - Digital communication is inherently more efficient than analog in realizing the exchange of SNR for bandwidth
  - Digital signals can be coded to yield extremely high rates, high fidelity as well as privacy

3. Disadvantages

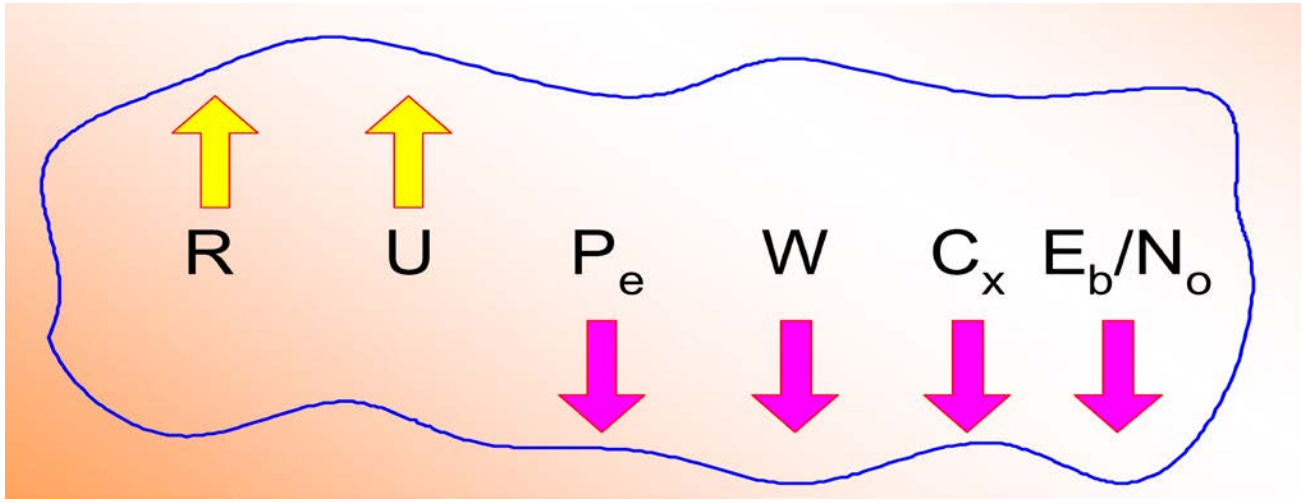
- ***Requires reliable "synchronization"***
- ***Requires A/D conversions at high rate***
- ***Requires larger bandwidth***

4. Performance Criteria

Probability of error or Bit Error Rate

Goals in Digital Communication System Design

- To maximize transmission rate, ***R***
- To maximize system utilization, ***U***
- To minimize bit error rate, P_e
- To minimize required systems bandwidth, ***W***
- To minimize system complexity, C_x
- To minimize required power, E_b/N_o



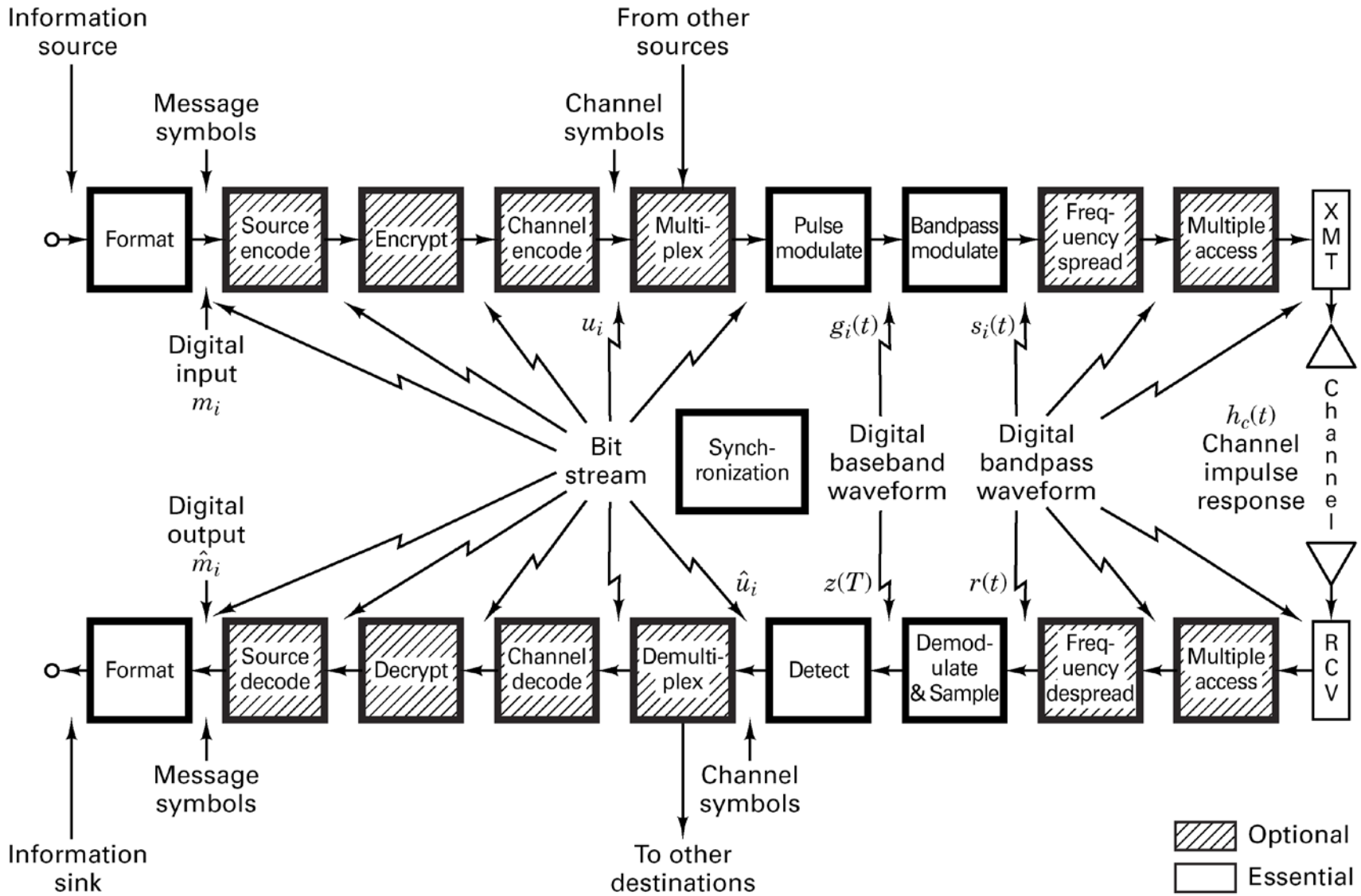
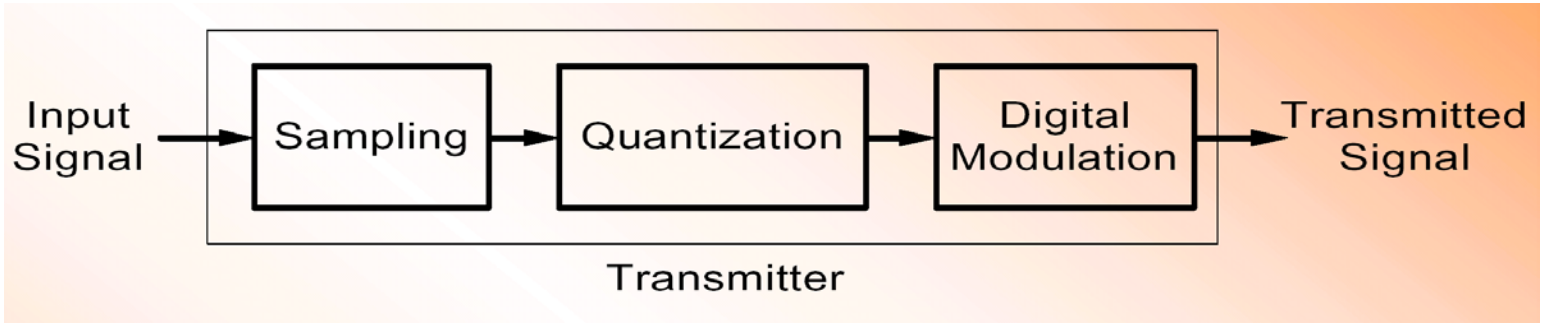


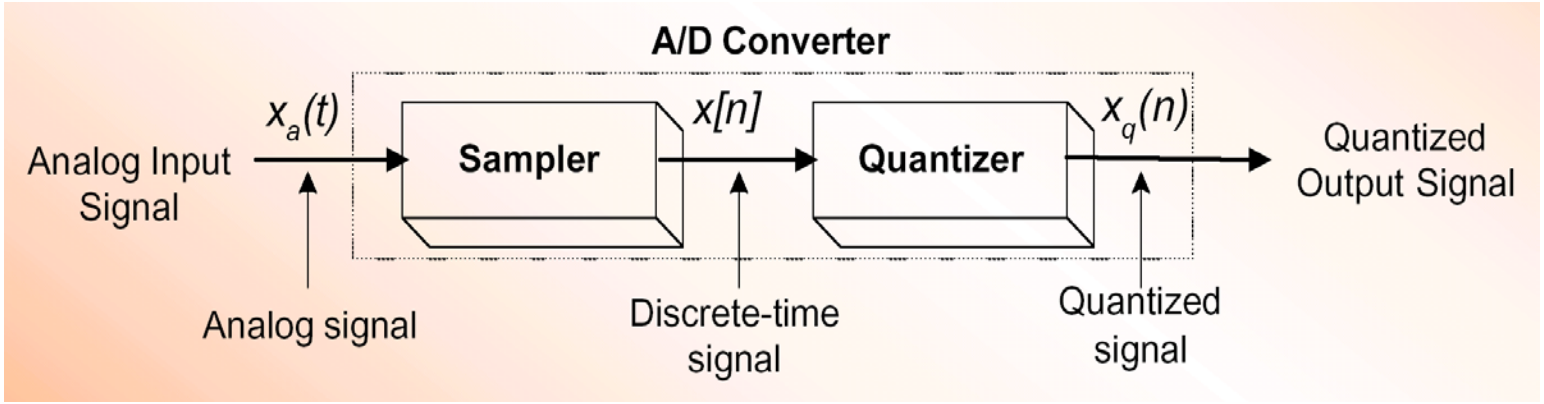
Figure 1.2 Block diagram of a typical digital communication system.

Digital Communication Transmitter

- **Structure of Digital Communication Transmitter**

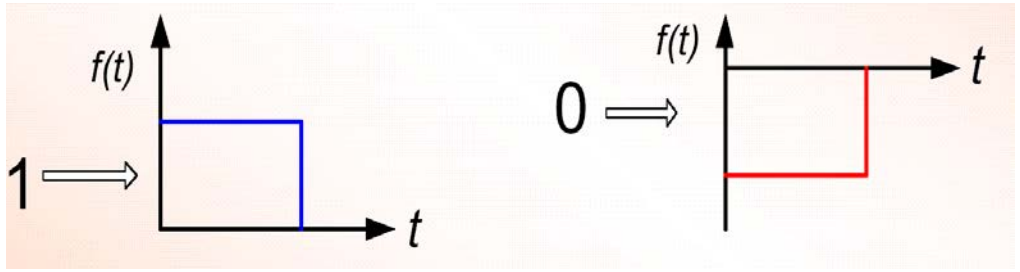


- **Analog to Digital Conversion**



Coding bits to Waveforms

- The output of the A/D converter is a set of binary bits
- But binary bits are just abstract entities that have no physical definition
- We use pulses to convey a bit of information, e.g.,



- In order to transmit the bits over a physical channel they must be transformed into a physical waveform
- ***A line coder or baseband binary transmitter*** transforms a stream of bits into a physical waveform suitable for transmission over a channel
- Line coders use the terminology ***mark*** for “1” and ***space*** to mean “0”
- In baseband systems, binary data can be transmitted using many kinds of pulses

Digital Signal Nomenclature

- **Information Source**
  - Discrete output values e.g. Keyboard
  - Analog signal source e.g. output of a microphone
- **Bits and Byte**
  - Binary Digit: Fundamental unit of information made up of 2 symbols (**0** and **1**)
  - A group of 8 bits is called byte.
- **Binary Stream**
  - A sequence of binary digits, e.g., 10011100101010
- **Symbol**
  - A digital message made up of groups of *k*-bits considered as a unit

Digital Signal Nomenclature

- **M - ary**
  - A digital message constructed with *M* symbols
- **Digital Waveform**
  - Current or voltage waveform that represents a digital symbol

- **Bit Rate**
  - Actual rate at which information is transmitted per second

- **Baud Rate**
  - Refers to the rate at which the signaling elements (symbols) are transmitted, i.e. number of signaling elements per second.

- **Bit Error Rate**
  - The probability that one of the bits is in error or simply the probability of error

Review Questions

- Give some examples of analogue communication systems.

- Why digital communication is more immune to noise than analogue communication?

- Name three features that can be possibly added in digital communication which are not possible to have in analogue communications.

- What are the benefits/disadvantages of using more than 2 waveform levels?