UESTC4004
Digital Communications

Baseband Modulation & Demodulation

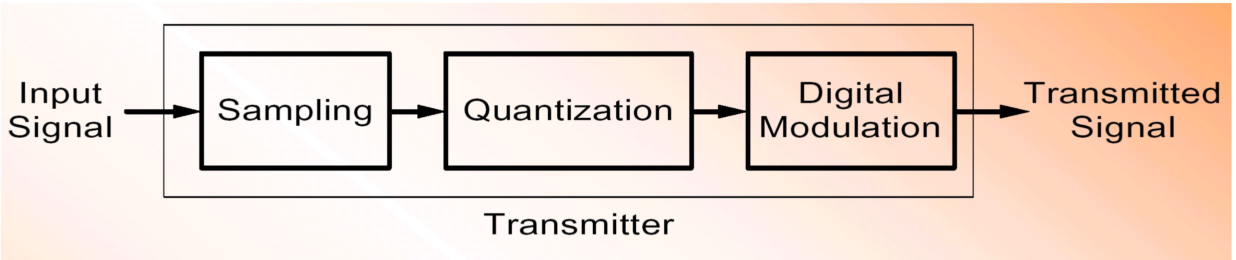
Information Representation

- The communication system converts information into electrical/ electromagnetic/optical signals appropriate for the transmission medium.

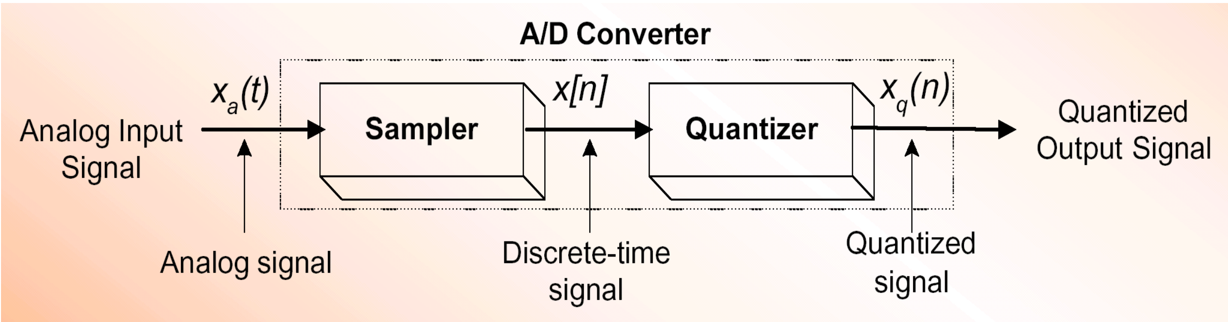
- Digital systems convert bits (digits, symbols) into signals
    - Computers naturally generate information as characters/bits
    - Analogue signals are converted to bits by sampling and quantizing (A/D conversion)

Digital Communication Transmitter

- **Structure of Digital Communication Transmitter**

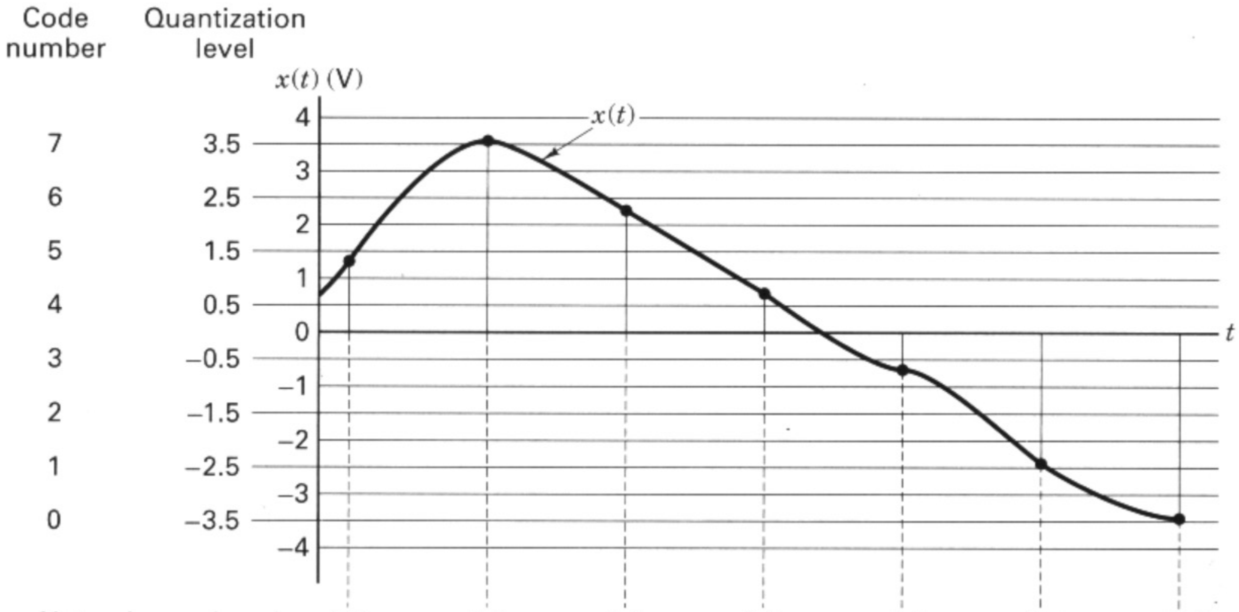


- **Analog to Digital Conversion**



Baseband Digital Modulation

- **Pulse Code Modulation**

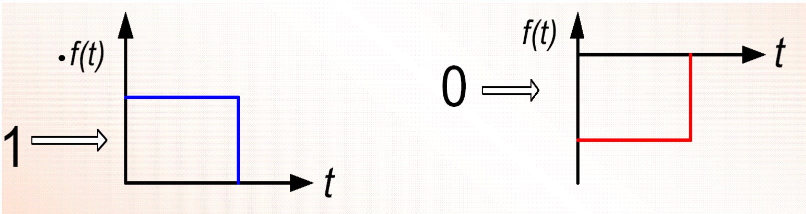


Natural sample value	1.3	3.6	2.3	0.7	−0.7	−2.4	−3.4
Quantized sample value	1.5	3.5	2.5	0.5	−0.5	−2.5	−3.5
Code number	5	7	6	4	3	1	0
PCM sequence	101	111	110	100	011	001	000

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.)

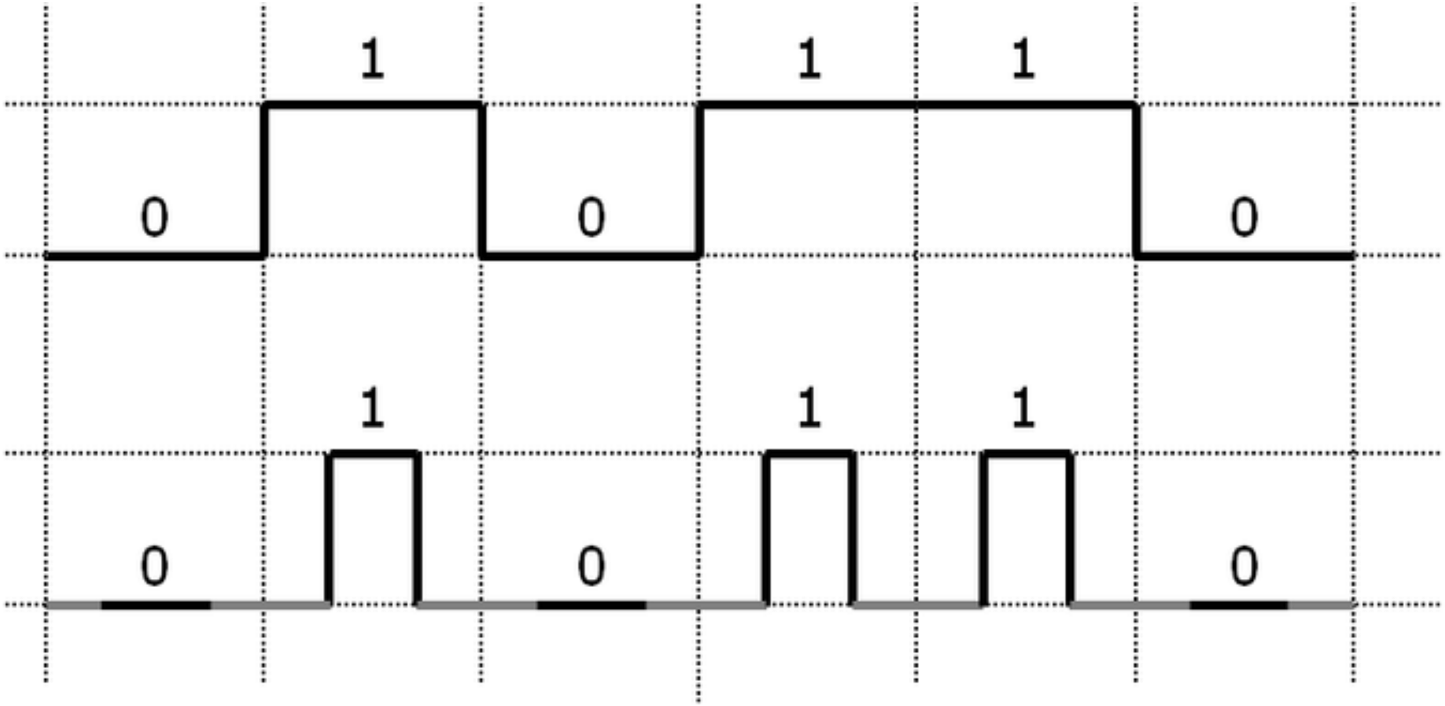
Coding bits to Waveforms

- The output of the A/D converter is a set of binary bits
- We use pulses to convey a bit of information, e.g.,



- ***A line coder or baseband binary transmitter*** transforms a stream of bits into a physical waveform suitable for transmission over a channel
- In baseband systems, binary data can be transmitted using many kinds of pulses

Discussion - What if a different waveform is used?



Compare the two waveforms in terms of Bandwidth and Energy?

Why digital Communications? ... A simple case

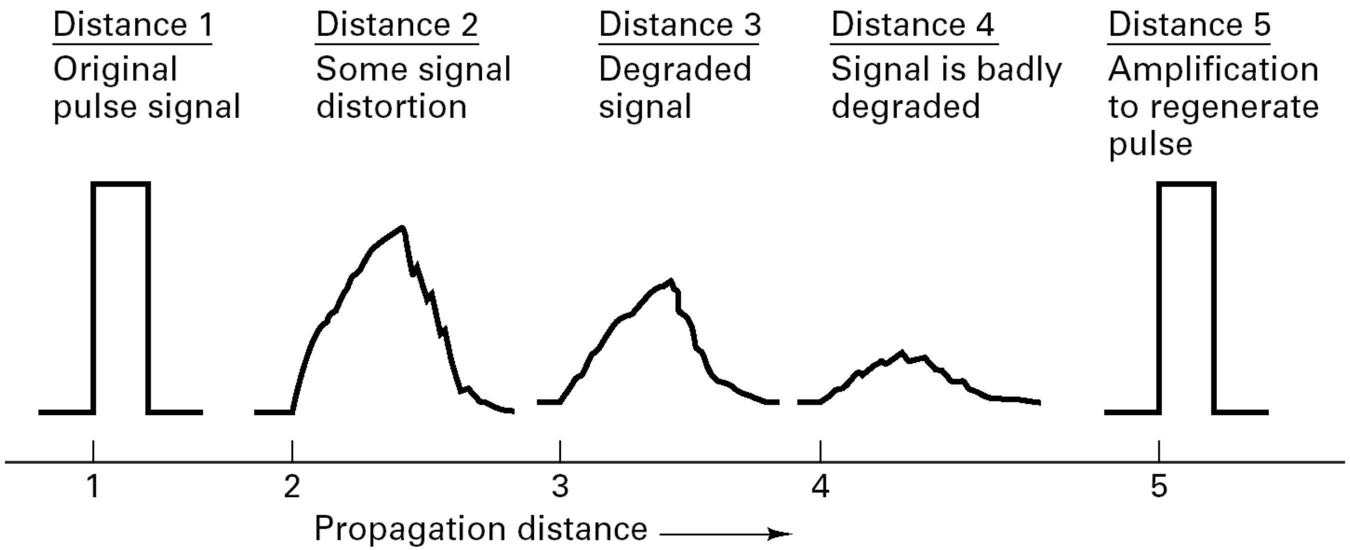


Figure 1.1 Pulse degradation and regeneration.

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
- ***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, VLSI
- ***Easier and more efficient to multiplex several digital signals***
  - Digital multiplexing techniques are easier to implement than analog techniques
- ***Encryption and privacy techniques are easier to implement***

- ***However, there are some disadvantages associated with digital communications which***
  - Requires reliable "synchronization"
  - Requires A/D conversions at a high rate

Activity

- What feature of Digital Communications do you admire the most and why?

Post your answers on Moodle Forum

https://moodle.gla.ac.uk/mod/forum/discuss.php?d=858857

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

Discussion with examples

- A binary signal is transmitted at 24 Mbits/sec. The same signal is transmitted using 4-level signaling. Calculate the baud rate for 4-level signaling.

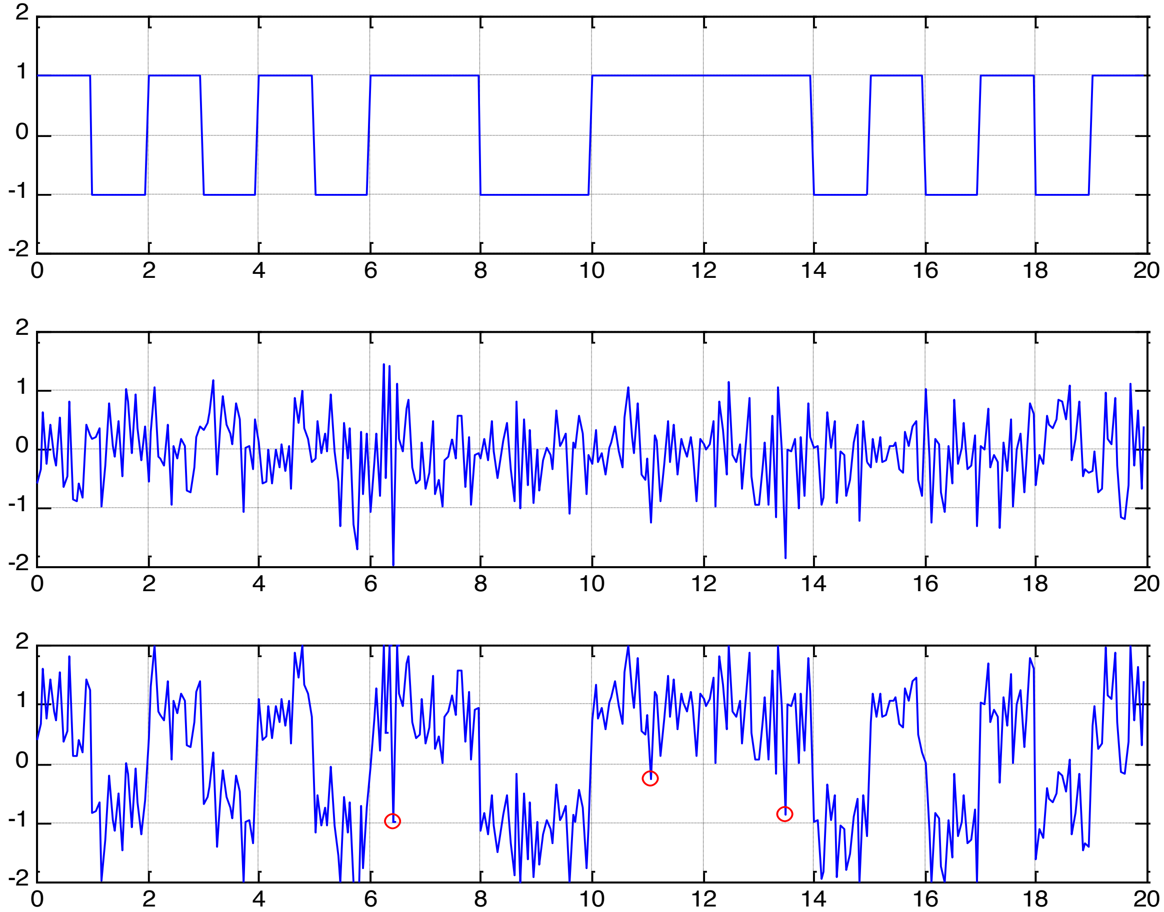
- Imagine 10 bits out of 10^6 received symbols are erroneous. What is the bit error rate if each symbol is made of 6 bits?

Detection of Binary Signal in Gaussian Noise

Original bit waveform

Noise

Received waveform



Detection of Binary Signal in Gaussian Noise

- For any binary channel, the transmitted signal over a symbol interval (0,T) is:

$$s_i(t) = \begin{cases} s_0(t) \quad 0 \le t \le T & \textit{for a binary } 0 \\ s_1(t) \quad 0 \le t \le T & \textit{for a binary } 1 \end{cases}$$

- The received signal r(t) degraded by noise n(t) and possibly degraded by the impulse response of the channel $h_c(t)$, is

$$r(t) = s_i(t) * h_c(t) \; + \; n(t) \qquad i = 0,1 \tag{3.1}$$

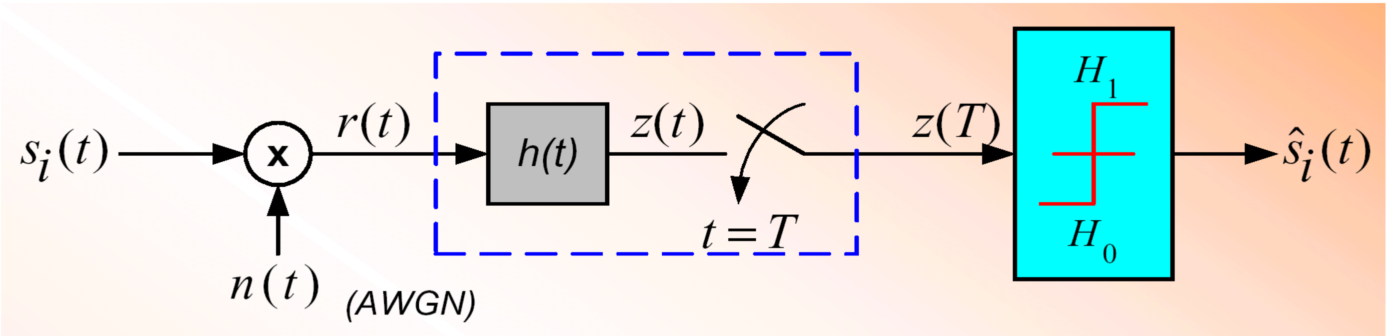
Where n(t) is assumed to be zero mean AWGN process

- For ideal distortionless channel where $h_c(t)$ is an impulse function and convolution with $h_c(t)$ produces no degradation, r(t) can be represented as:

$$r(t) = s_i(t) \; + \; n(t) \qquad i = 0,1 \qquad 0 \le t \le T \tag{3.2}$$

h(t)为δ消noise

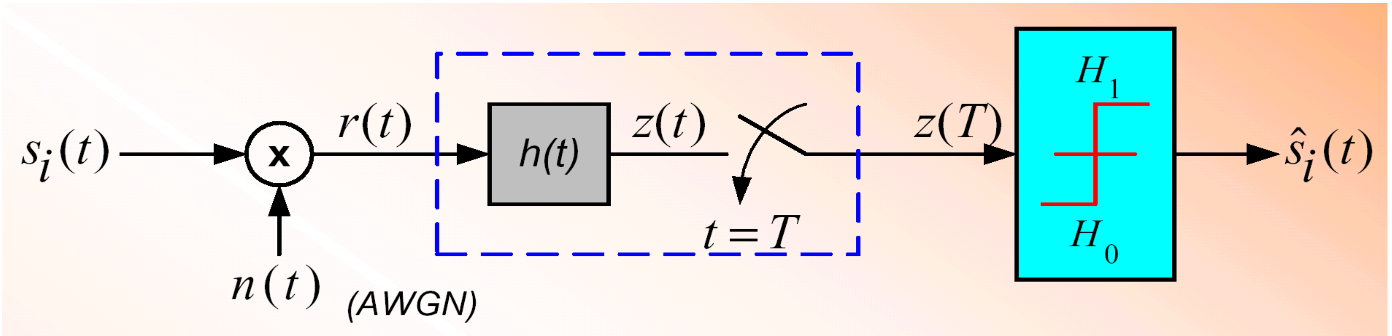
Demodulation and Detection



■The digital receiver performs two basic functions:

- Demodulation by using matched filter *h(t)*, to recover a waveform to be sampled at $t = nT$.
- Detection, decision-making process of selecting possible digital symbol

Detection of Binary Signal in Gaussian Noise



- The recovery of signal at the receiver consist of two parts
  - **Matched Filter h(t)**
    - Reduces the received signal to a single variable *z(T)*
    - *z(T)* is called the ***test statistics***
  - **Detector (or decision circuit)**
    - Compares the *z(T)* to some threshold level γ_0, i.e.,

还原数字信号

$$z(T) \underset{H_0}{\overset{H_1}{\gtrless}} \gamma_0$$

where H_1 and H_0 are the two possible binary hypothesis

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?