ENSC327
Communications Systems
26: Intro and overview of Baseband Pulse Amplitude Modulation(PAM)

School of Engineering Science

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Outline

- Chapter 6: Introduction to Baseband Data Transmission by Pulse Amplitude Modulation (PAM)
  - No modulation, sending pulse sequences directly
  - Suitable for lowpass channels (eg, coaxial cables)
  - The model can be used for band pass modulation systems as well (Digital communication course, e.g., ENSC 428)
- In this course we will look at
  - Bit Error Rate for on-off PAM systems
  - Bit Error Rate for Bipolar PAM systems

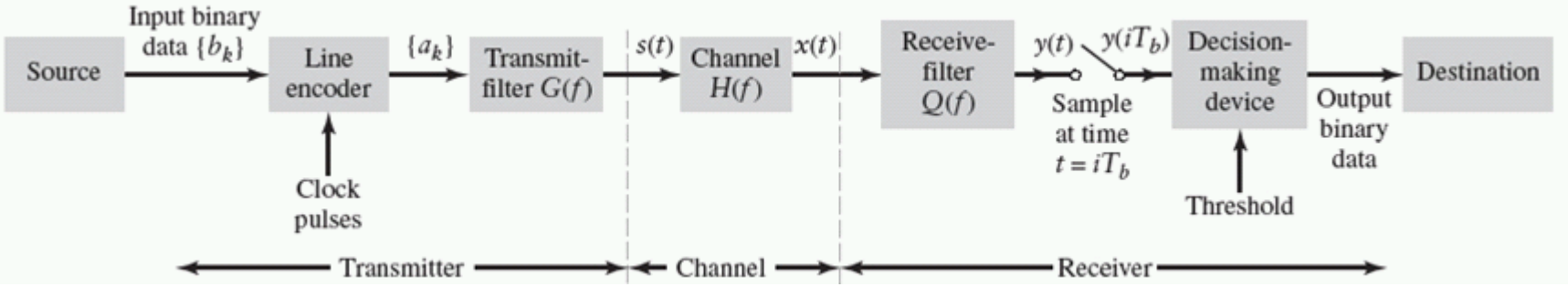
Introduction

- A digital communication system involves the following operations:
  - Usually Analog data is sampled and digitized.
  - Transmitter: maps the digital information to an analog signal.
  - Receiver: records the analog signal, and recover the digital information.

- The system can introduces two kinds of distortions:
- Channel noise: due to random and unpredictable physical phenomena.(Chaps. 9 and 10).

- Intersymbol interference (ISI): due to imperfections in the frequency response of the channel.

6.1 Baseband Transmission with PAM

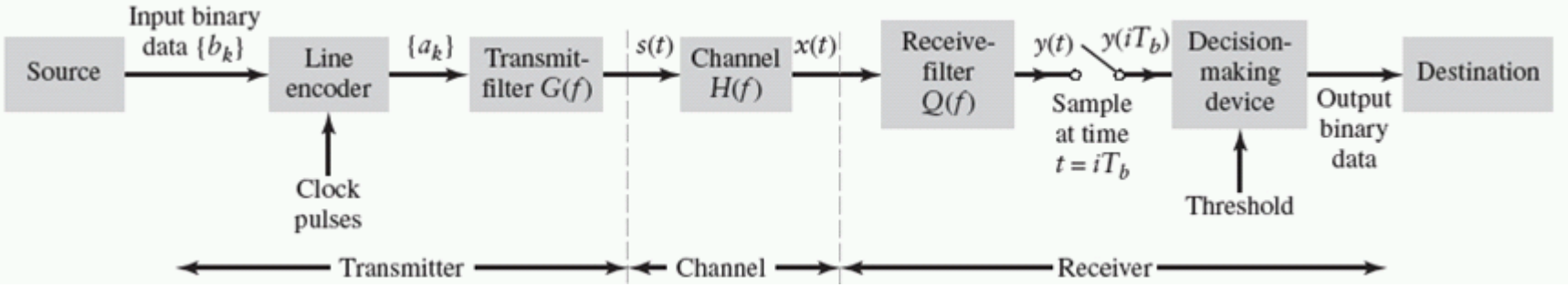


- Input: binary data, b_k = 0 or 1, with duration T_b.
  - Bit rate:

- Line encoder: Electrical representation of the binary sequences, e.g.,

$$a_k = \begin{cases} +1, & b_k = 1, \\ -1, & b_k = 0. \end{cases}$$

6.1 Baseband Transmission with PAM (Cont.)

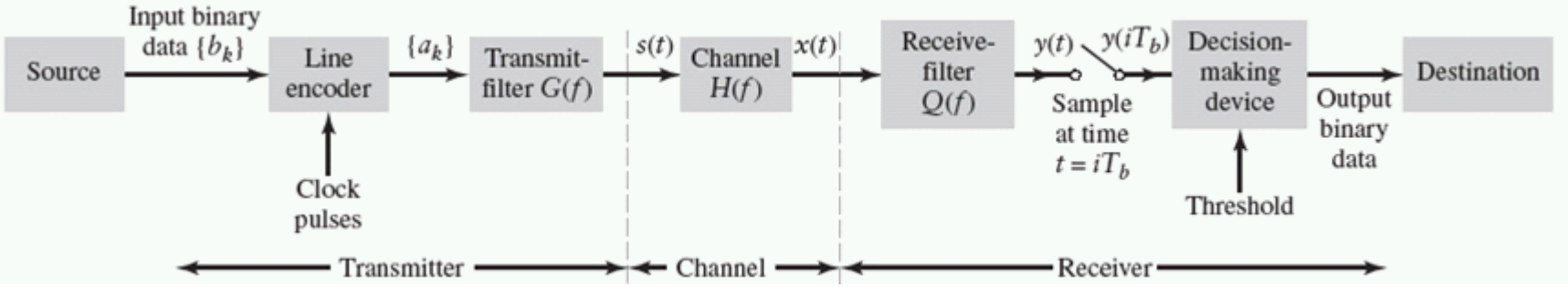


- Transmit filter: use pulses of different amplitudes to represent one or more binary bits.

- The basic shape of the pulse is represented by a filter g(t) or G(f)
- The output PAM signal from the transmitter is then:

$$s(t) = \sum_k a_k g(t - kT_b)$$

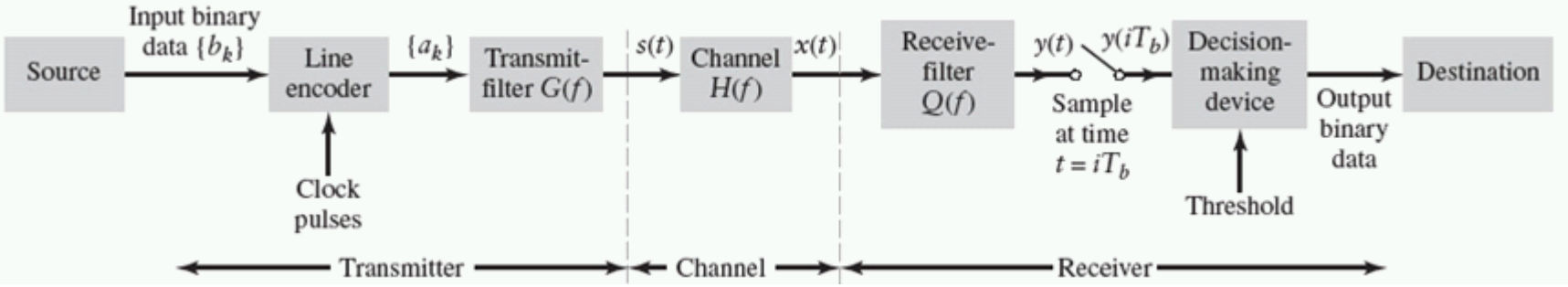
6.1 Baseband Transmission with PAM (Cont.)



- Channel:
  - If the channel is ideal (ideal all pass filter), no distortion will be introduced.
  - Not the case in reality ➔ In practice, a practical channel can be represented by a linear, time invariant (LTI) filter (H(f))
- The channel output: the convolution of the transmitted signal and the channel impulse response. This introduces inter-symbol interference (ISI)

$$x(t) = s(t) * h(t).$$

6.1 Baseband Transmission with PAM (Cont.)

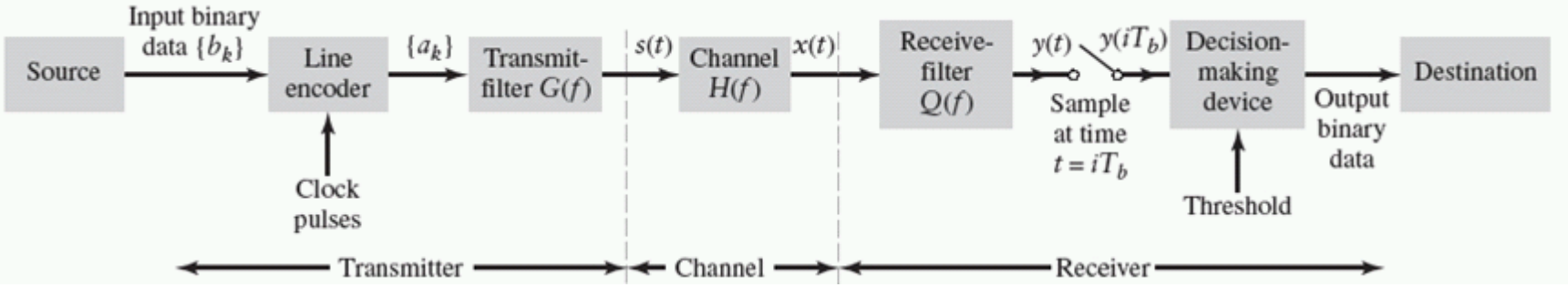


- Receiver can be represented by another filter, aiming to reduce the noise and channel distortion.
- The output of the receiver filter is:

$$y(t) = x(t) * q(t) = s(t) * h(t) * q(t).$$

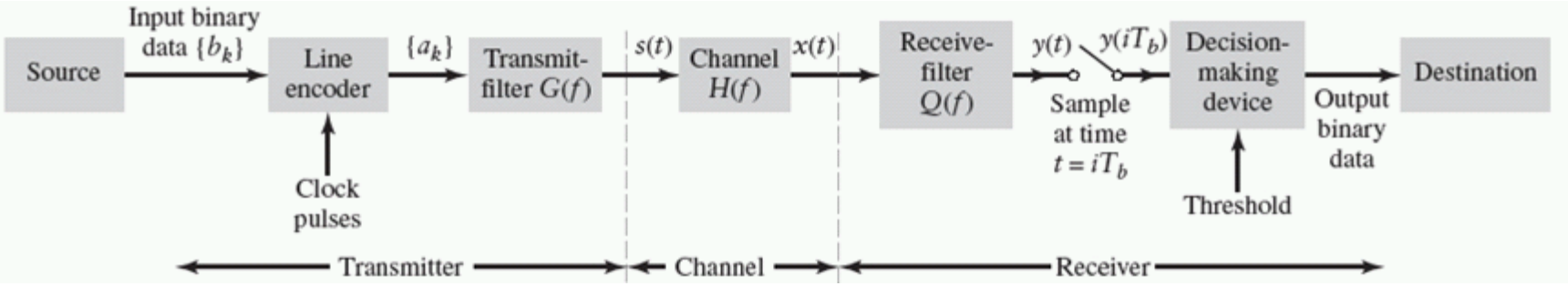
- The output is then sampled synchronously with the clock at the transmitter.
- Finally, a decision-making device is used to recover the binary bits. Different methods can be used, e.g.,
  - Threshold, equalization, maximal likelihood decoding

6.1 Baseband Transmission, non-ideal channel



- The channel's impulse response (h(t) r H(f)) is usually not under our control.
- How ever the shape of each pulse (determined by filter g(t)) and the impulse response of the receiver filter (q(t) or Q(f)) can be designed with the following objectives:
  - The transmitted signal should have a small enough bandwidth to meet the bandwidth constraint of the channel.
  - Given h(t), design g(t) and q(t) to eliminate the inter-symbol interference (ISI). (Pulse shaping – We don't cover this subject and assume that the filters are designed such that ISI is eliminated.)

6.1 Baseband Transmission, Ideal Channel



- Assuming an ideal channel, i.e., if the channel acts as an all-pass filter with constant gain (e.g. gain=1), we can have:
  - Ideal rectangular pulses at the transmitter.
  - The ideal receiver (filter + sample and hold) would be an ideal integrator that integrates the received signal over each signaling period ((k-1)T to kT).
- For the rest of this course will make the above simplifying assumptions.