

Digital Transmission of Analog Data: PCM and Delta Modulation

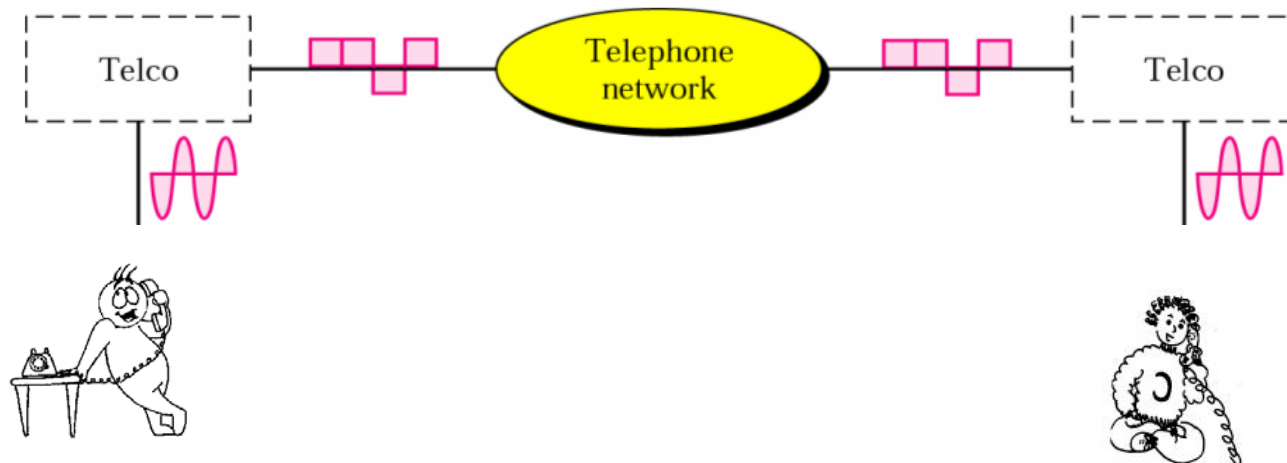
**Required reading:
Forouzan 4.2
Garcia 3.3.2 and 3.3.3**

**CSE 3213, Fall 2015
Instructor: N. Vlajic**

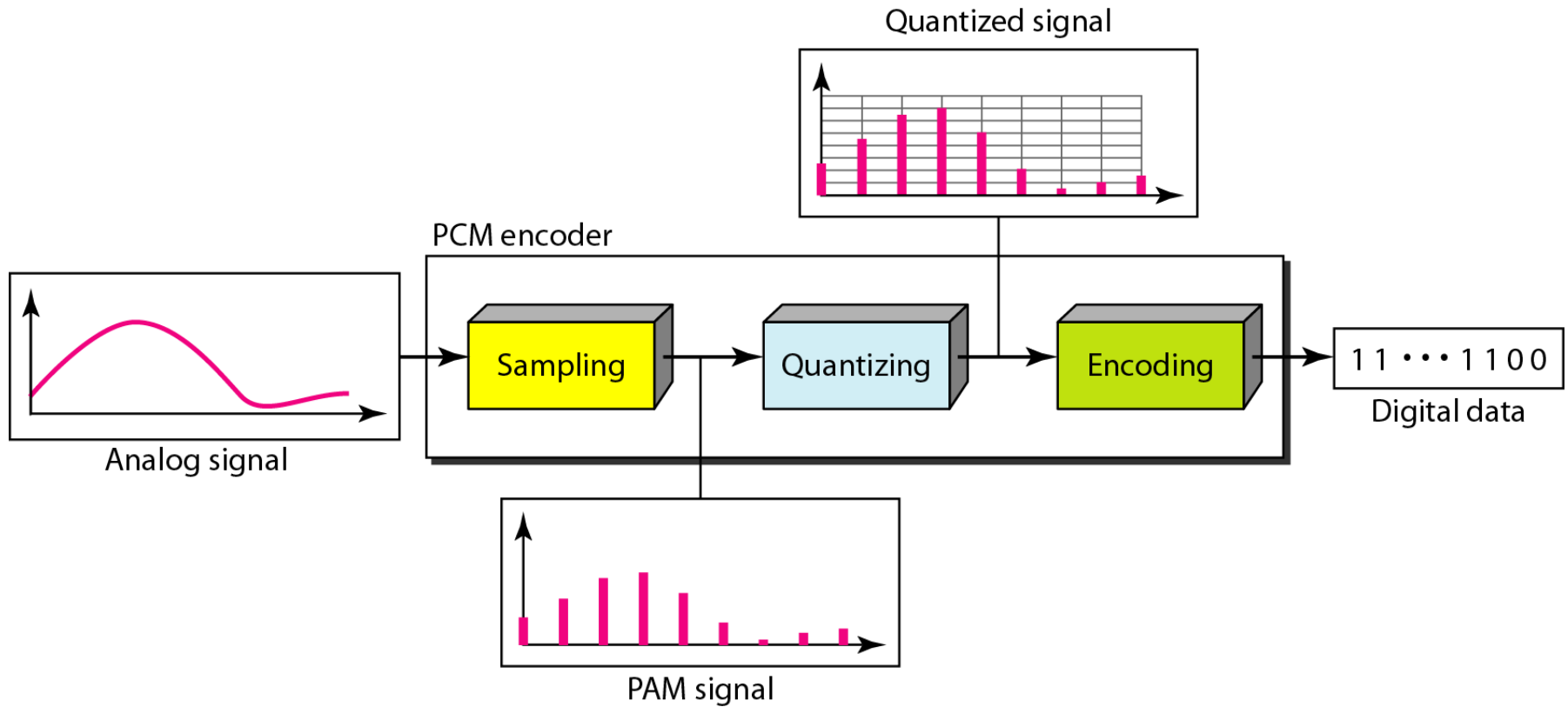
Digital Transmission of Analog Data

Digitization – process of converting analog data into digital signal

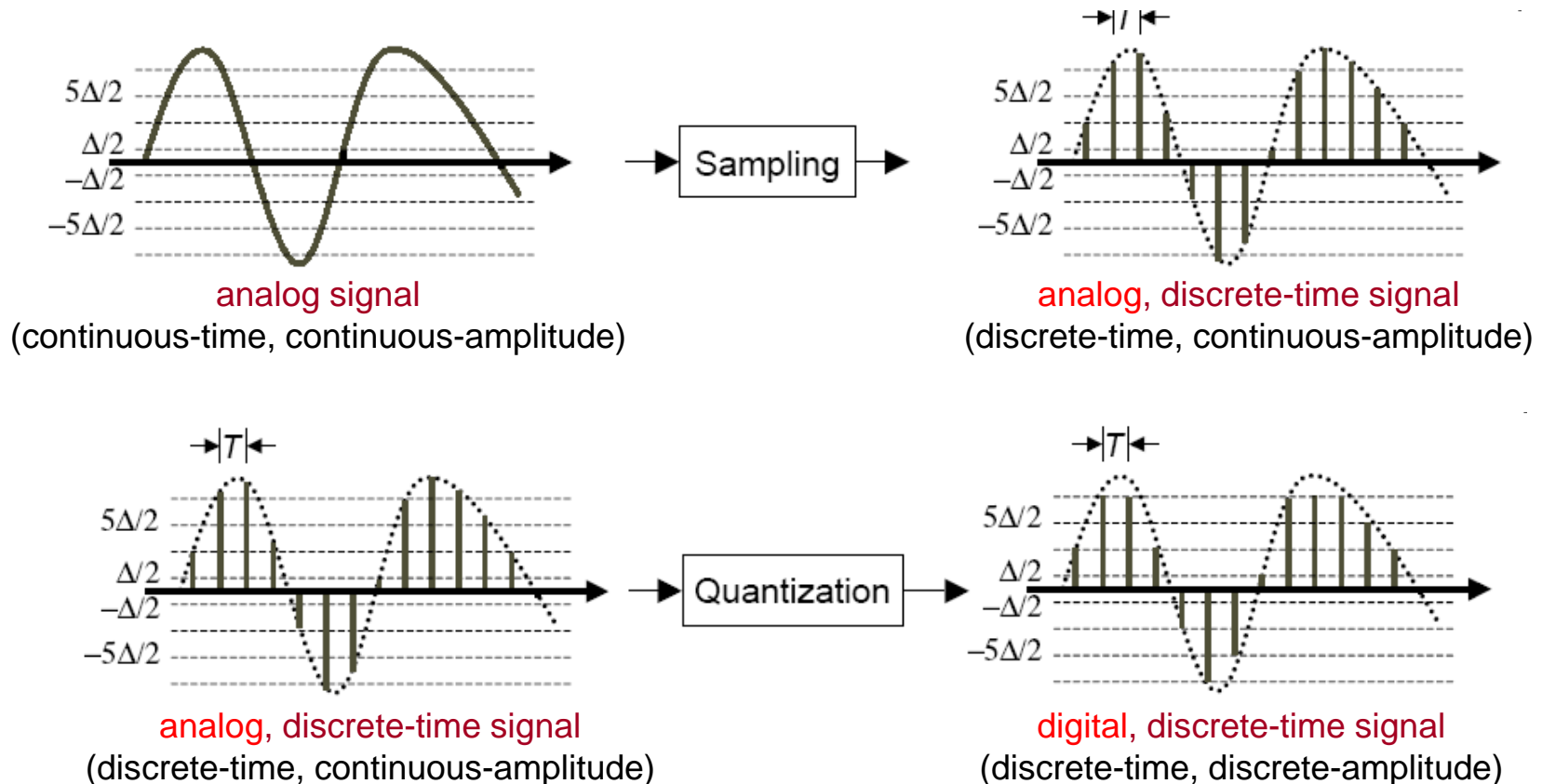
- example: telephone system
 - human voice \leftrightarrow analog data \leftrightarrow analog signal ?!
 - analog signal is sensitive to noise, especially over long distance (cannot be perfectly reconstructed)
 - solution:
 - (1) digitize the analog signal at the sender
 - (2) transmit digital signal
 - (3) convert digital signal back to analog data at the receiver



Example [PCM procedure]



- Digitization Procedure** – aka Pluse Code Modulation (**PCM**), consists of two steps
- (1) **sampling** – obtain signal values at equal intervals (T)
 - (2) **quantization** – approximate samples to certain values



Sampling

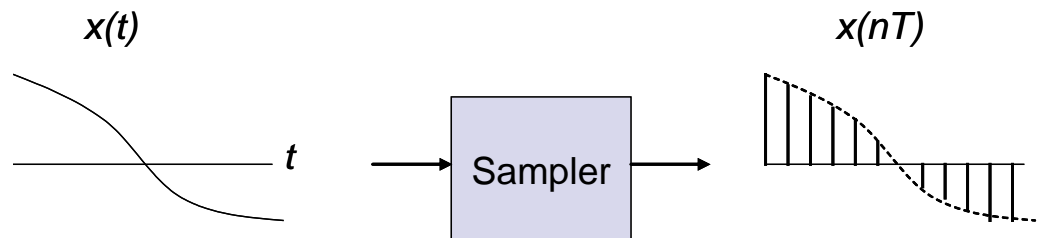
Sampling – aka Pulse Amplitude Modulation (PAM)

- “digitization in time” – sampling process results in signal that is **discrete in time but analog in amplitude!**
- choice of sampling interval T is determined by how fast a signal changes, i.e. frequency content of the signal

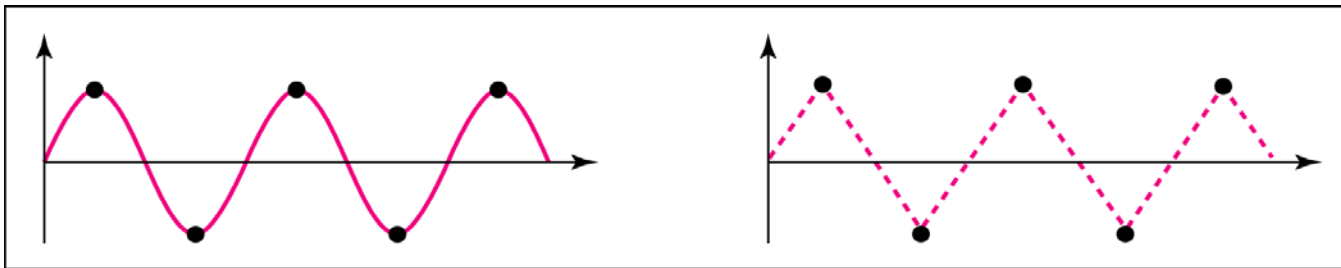
“Nyquist Sampling Rate” Theorem:

To ensure accurate reproduction of an analog signal, the sampling rate must be at least **$2 \times$ (the highest signal frequency)**.

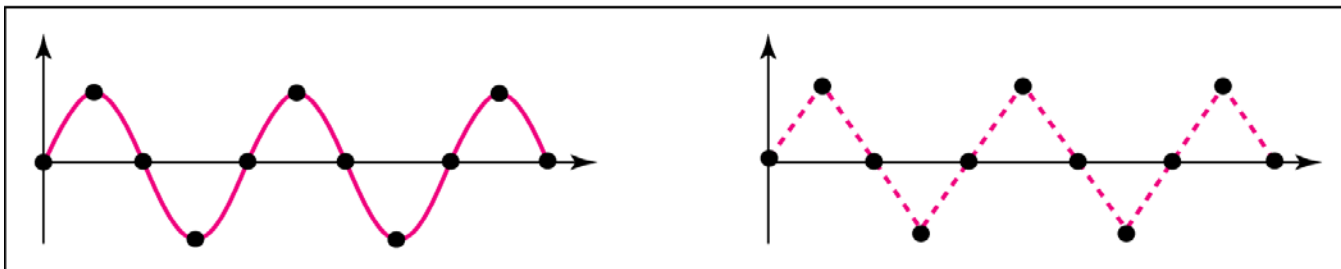
$$\text{sampling rate} = \frac{1}{T} = 2 * \text{max_signal_freq}$$



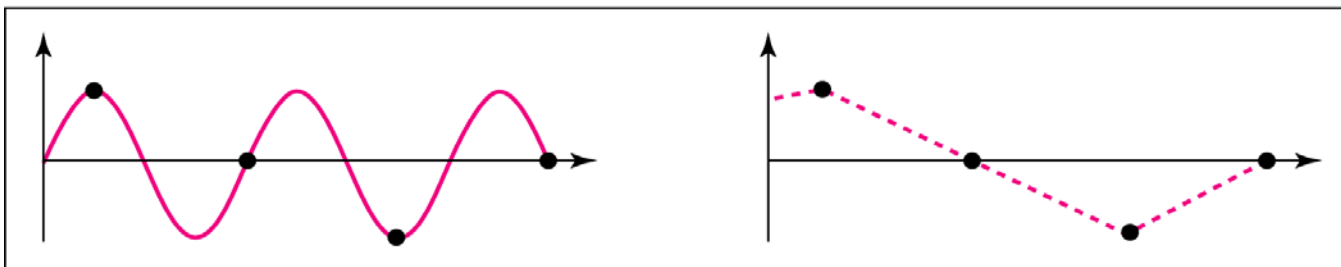
Example [Recovery of a sampled sine wave for different sampling rates]



a. Nyquist rate sampling: $f_s = 2 f$



b. Oversampling: $f_s = 4 f$



c. Undersampling: $f_s = f$