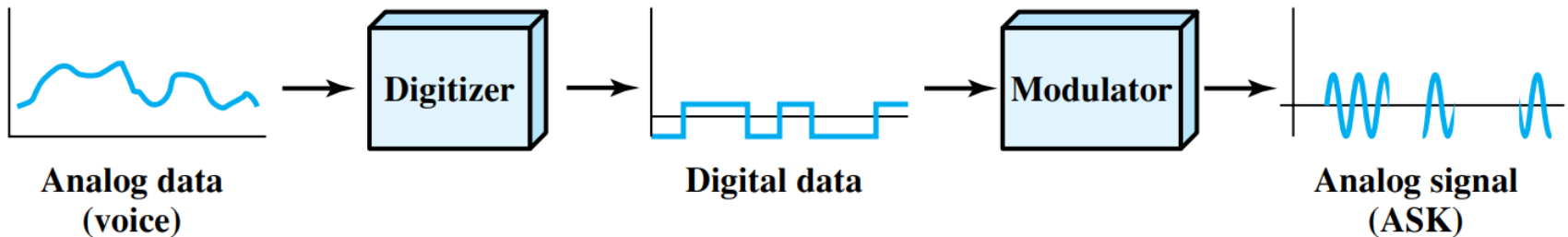# Computer Networks

Signal Encoding Techniques (Analog to Digital)

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Analog Data → Digital Signals

Digitizing Analog Data

Analog data (voice) → Digitizer → Digital data → Modulator → Analog signal (ASK)
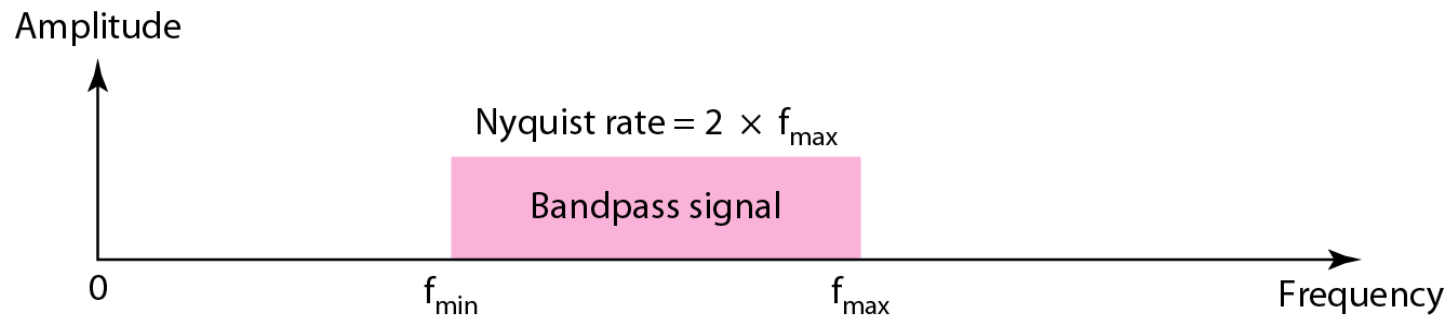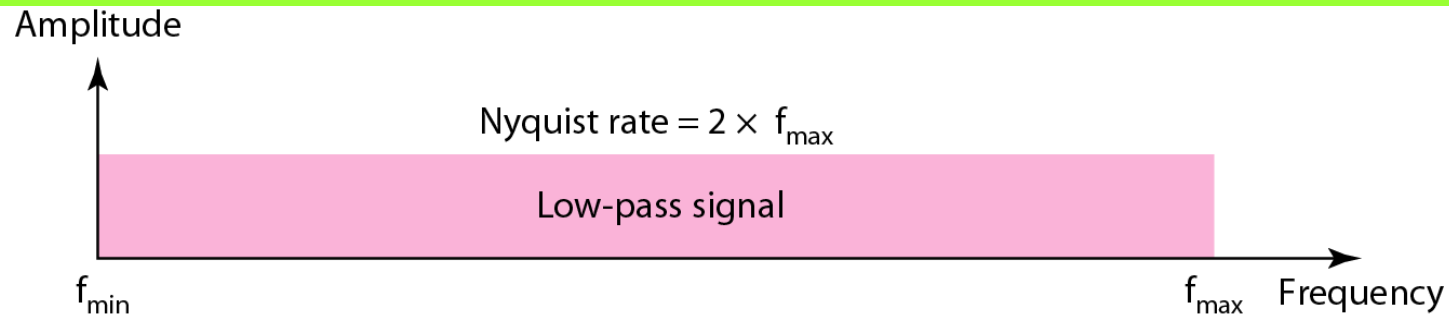
- **Once digital data is converted to digital data:**
  - The digital data can be encoded into digital signals
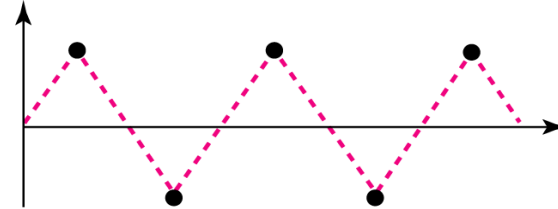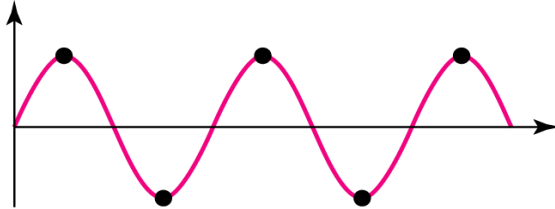 - The digital data can be into an analog signal
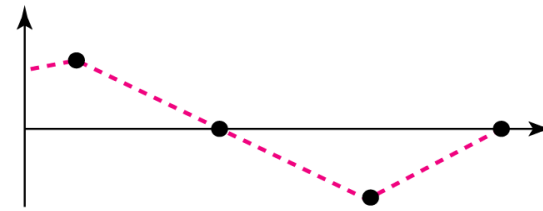
Nyquist Sampling Theorem
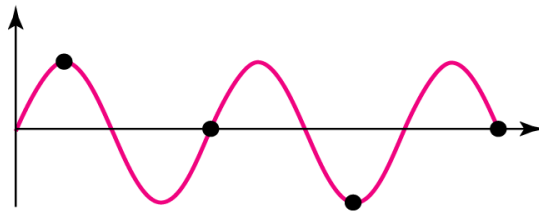
■ Sampling theorem:

According to the Nyquist theorem,
the sampling rate must be at least 2 times the highest frequency contained in the signal.

Amplitude

Nyquist rate $= 2 \times f_{max}$

Low-pass signal

f_{min} f_{max} Frequency

Amplitude

Nyquist rate $= 2 \times f_{max}$

Bandpass signal

0   f_{min} f_{max} Frequency

Nyquist Sampling Theorem

Sampling at the Nyquist rate can create a good approximation of the original sine wave

Sampling below the Nyquist rate does not produce a signal that looks like the original sine wave
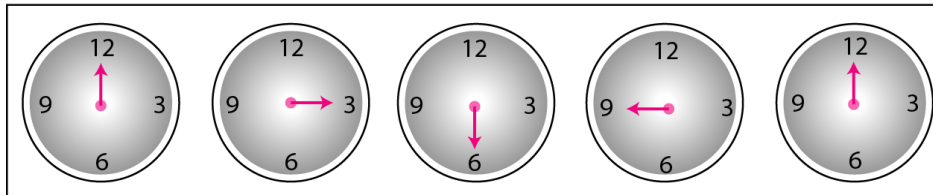
Nyquist Sampling Theorem

The second hand of a clock has a period of 60 s.
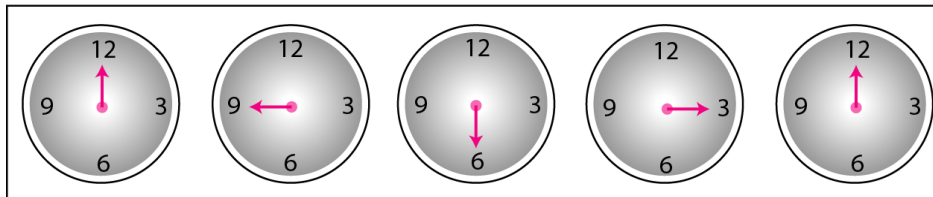According to the Nyquist theorem, we need to sample hand atleast every 30 s

a. Sampling at Nyquist rate: $T_s = T\frac{1}{2}$
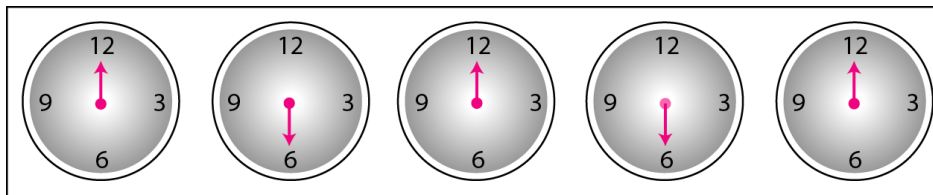
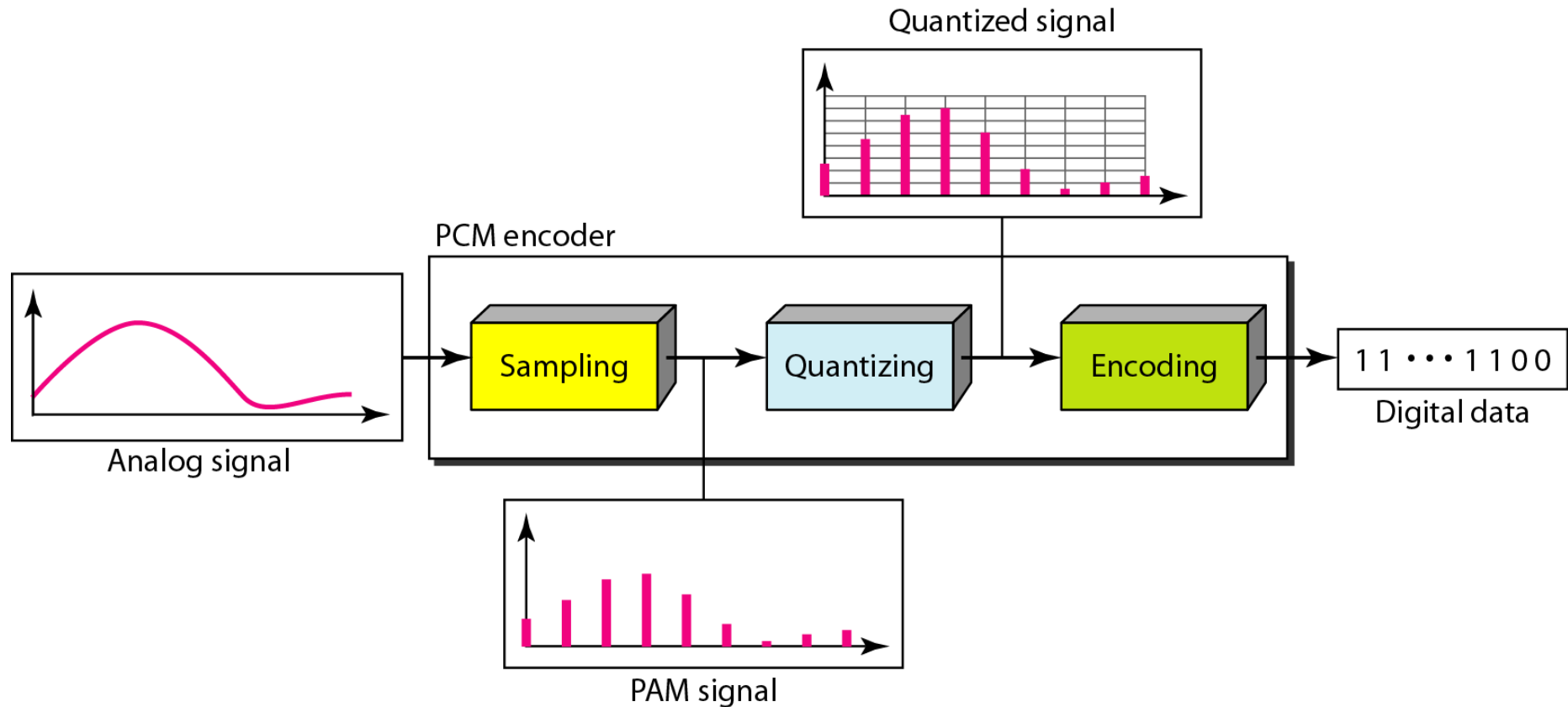Samples can mean that the clock is moving either forward or backward.
(12-6-12-6-12)

b. Oversampling (above Nyquist rate): $T_s = T\frac{1}{4}$

Samples show clock is moving forward.
(12-3-6-9-12)

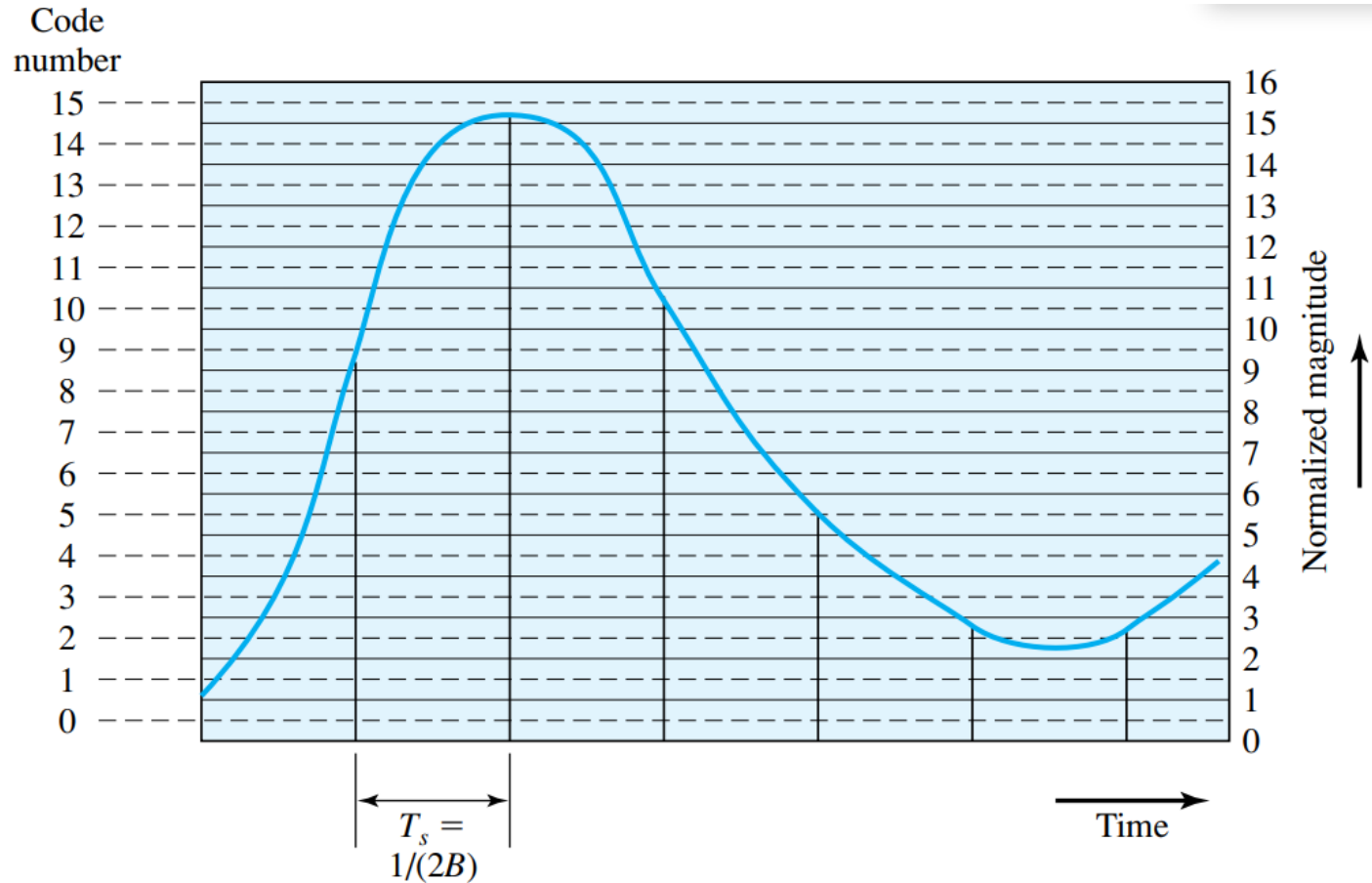c. Undersampling (below Nyquist rate): $T_s = T\frac{3}{4}$

Samples show clock is moving backward.
(12-9-6-3-12)

Pulse Code Modulation Block Diagram

Pulse Code Modulation

PAM value	1.1	9.2	15.2	10.8	5.6	2.8	2.7
Quantized code number	1	9	15	10	5	2	2
PCM code	0001	1001	1111	1010	0101	0010	0010

Nonlinear Coding

(a) Without nonlinear encoding
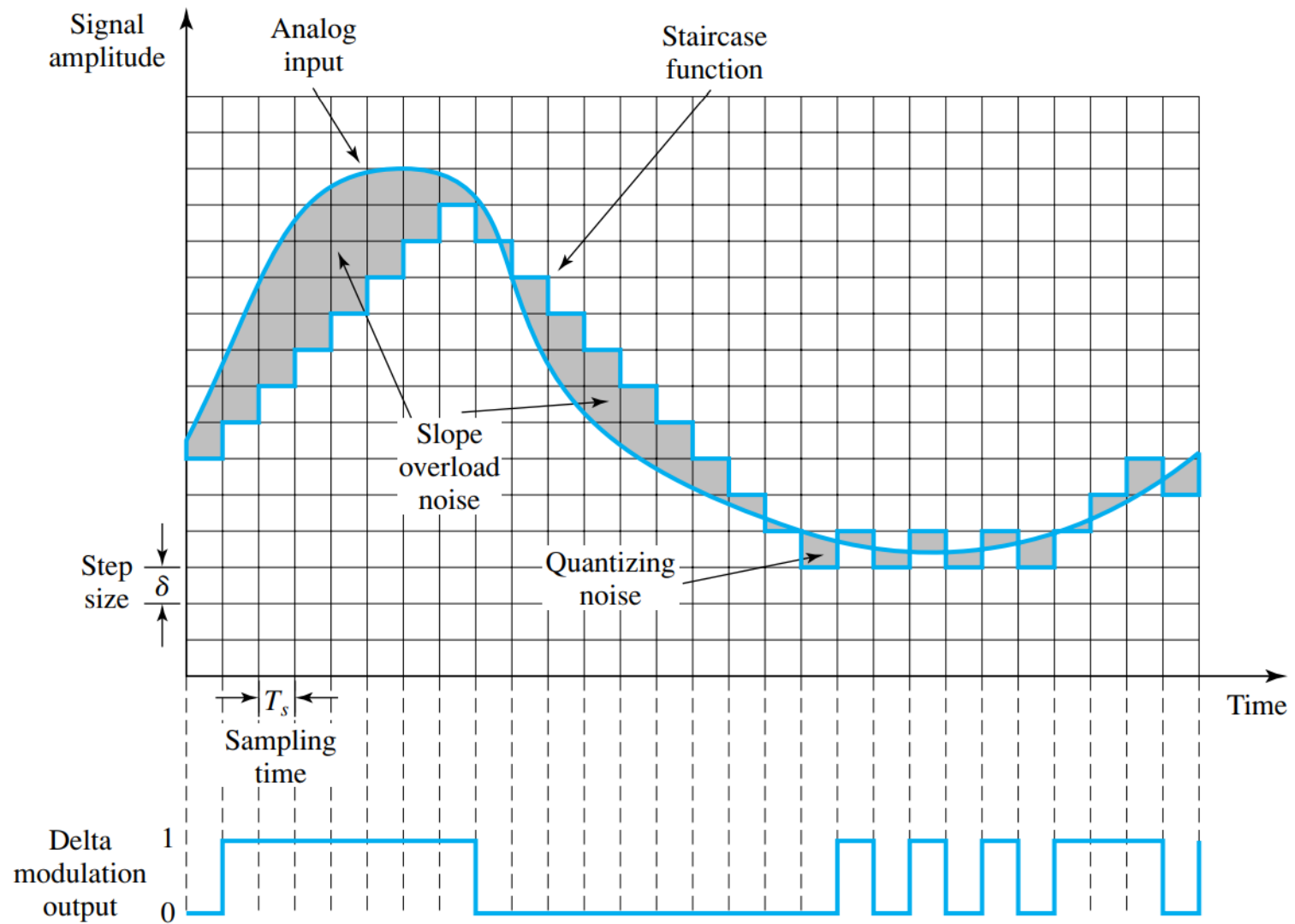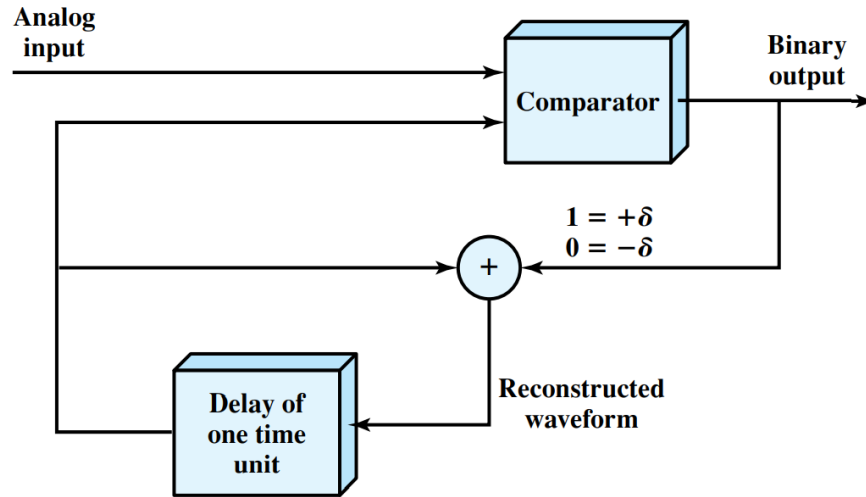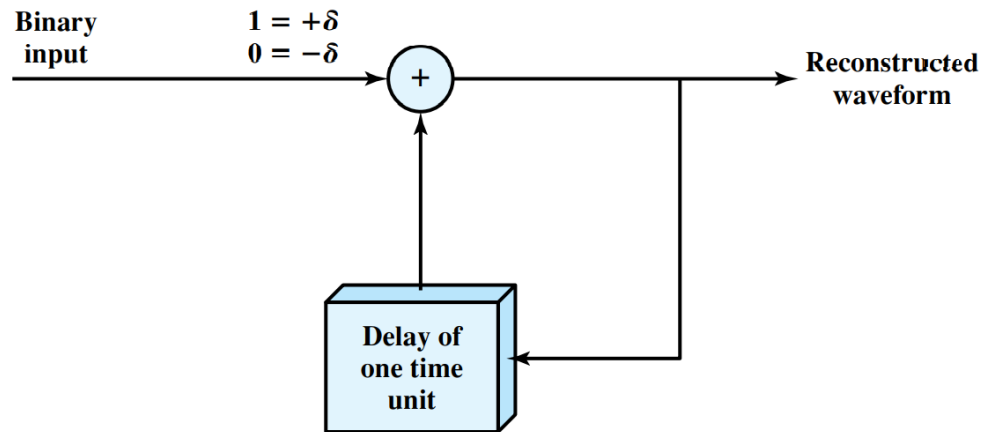
(b) With nonlinear encoding
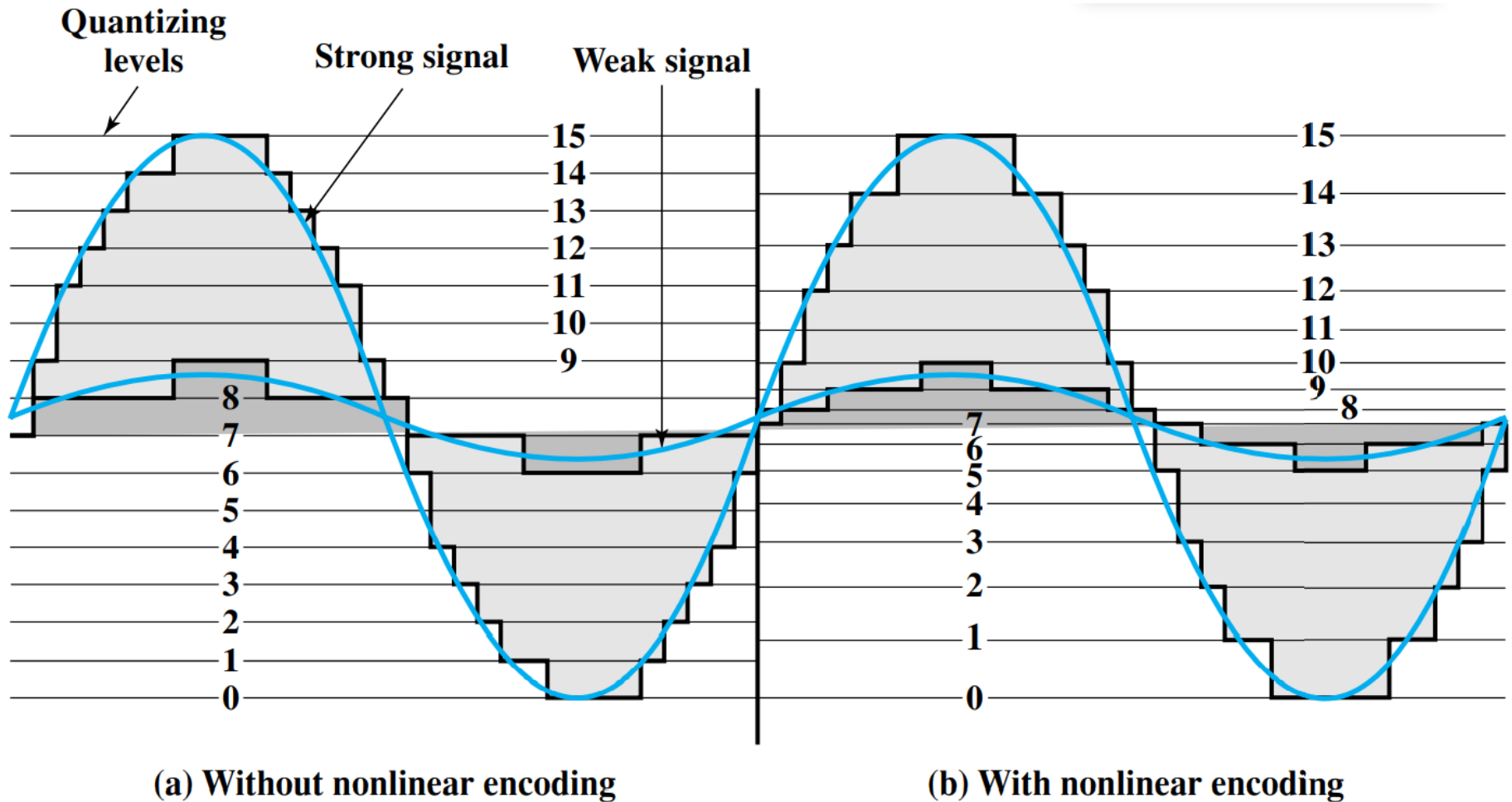
Companding
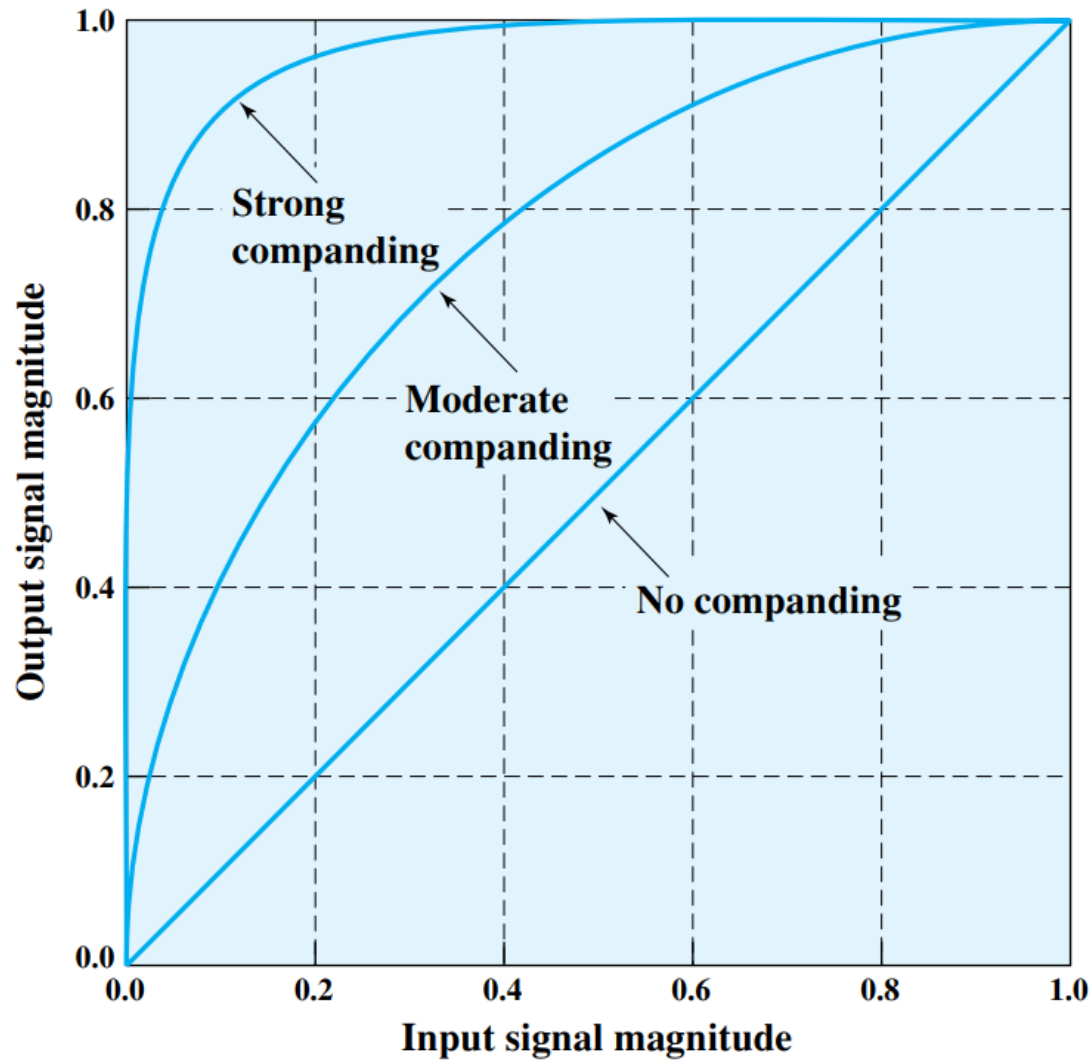
Delta Modulation

Delta Modulation Operation

(a) Transmission

(b) Reception

PCM versus Delta Modulation

- **DM has simplicity compared to PCM**
  - but has worse SNR

- **Issue of bandwidth used**
  - e.g. for good voice reproduction with PCM
  - want 128 levels (7 bit) & voice bandwidth 4khz
  - need 8000 x 7 = 56kbps

- **Data compression can improve on this**

THANK YOU

QUESTIONS???