Quantization noise

Since q(t) is *uniformly distributed* over the interval (-Δν/2, Δν/2), i.e., the error has equal probability to lie in the range (-Δν/2, Δν/2), the probability density is then 1/Δν, hence the mean square value of q(t) is given by

$$\overline{q^2} = \int_{-\Delta v/2}^{\Delta v/2} q^2 \frac{1}{\Delta v} dq = \frac{1}{\Delta v} \int_{-\Delta v/2}^{\Delta v/2} q^2 dq = \frac{(\Delta v)^2}{12}$$

Quantization noise power

The *quantization noise power* is :

$$N_q = \overline{q^2(t)} = \frac{(\Delta v)^2}{12}$$

The output signal-to-noise ratio is

$$SNR_Q = \frac{12\overline{m^2(t)}}{(\Delta v)^2} = \frac{3L^2\overline{m^2(t)}}{m_p^2}$$

From above discussion, it is clear that quantization

results in a loss of information.

(*Information can also be lost in PAM due to noise*)

Such an information lost due to quantization may

be reduced by increasing the number of levels used, L.

e.g. 8 to 16 levels are sufficient for speech communication.

Example:1

The digital audio compact optical disc (CD) system uses **16 bit** quantization and a sampling rate of **44.1 kHz** per channel.

Assuming the audio signal has a peak to mean power ratio of **13 dB**, occupies the frequency band **0** to **20 kHz** and that the recovery filter has an *effective* bandwidth, allowing for the finite cut-off rate of a practical filter of **22 kHz**, estimate the signal to quantization noise ratio attainable.

Solution:

f_s = 44.1 kHz, n = 16, thus we have L = 2^{16} quantization levels.

$$10 \log(m_p^2 / \overline{m^2}) \;=\; 13dB, \;\; thus$$

$$m_p^2 / \overline{m^2} \;=\; 20$$

So we have:

$$SNR_Q = \frac{3L^2 \overline{m^2(t)}}{m_p^2} = \frac{3 \times 2^{32}}{20} = 6.44 \times 10^8 = 88.1dB$$

Example: 2

A 12 bit ADC having analog input voltage ranging from -2v to 2 v. Determine followings:

I. No of quantization Levels

II. Step Size

III. Quantization Level, when the analog Voltage is 1.33

IV. Quantization error (for case I)

V. Dynamic Range

Types of Quantization

There are two types of Quantization - Uniform Quantization and Non-uniform Quantization.

- **The type of quantization in which the quantization levels are uniformly spaced is termed as a Uniform Quantization.**

- **The type of quantization in which the quantization levels are unequal and mostly the relation between them is logarithmic, is termed as a Non-uniform Quantization.**

There are two types of uniform quantization. They are Mid-Rise type and Mid-Tread type. The following figures represent the two types of uniform quantization.
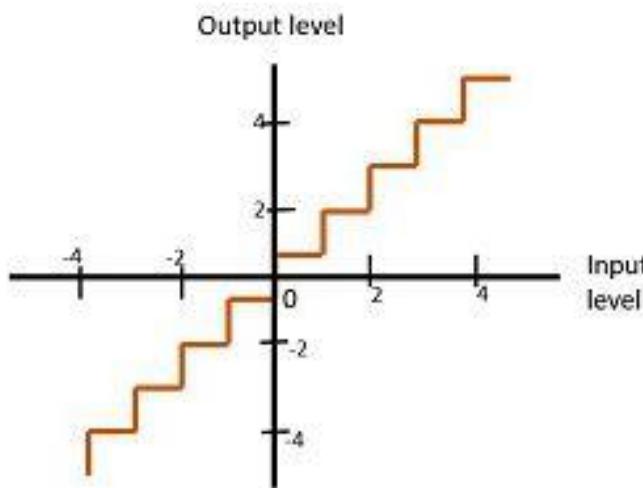
Fig 1 : Mid-Rise type Uniform Quantization
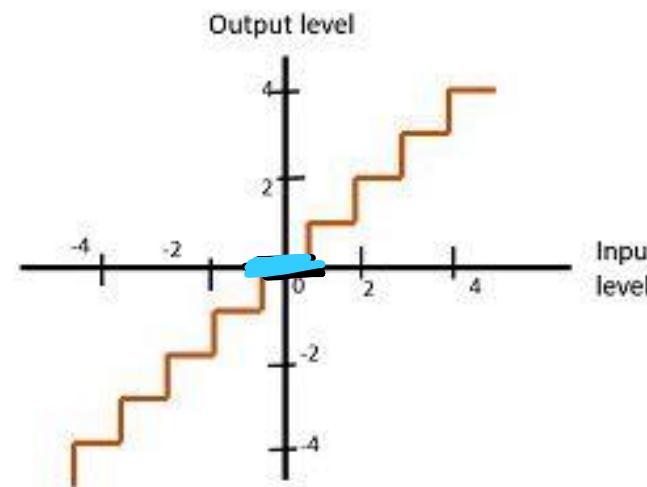
Fig 2 : Mid-Tread type Uniform Quantization

Figure 1 shows the mid-rise type and figure 2 shows the mid-tread type of uniform quantization.

- **The Mid-Rise type is so called because the origin lies in the middle of a raising part of the stair-case like graph. The quantization levels in this type are even in number.**

- **The Mid-tread type is so called because the origin lies in the middle of a tread of the stair-case like graph. The quantization levels in this type are odd in number.**
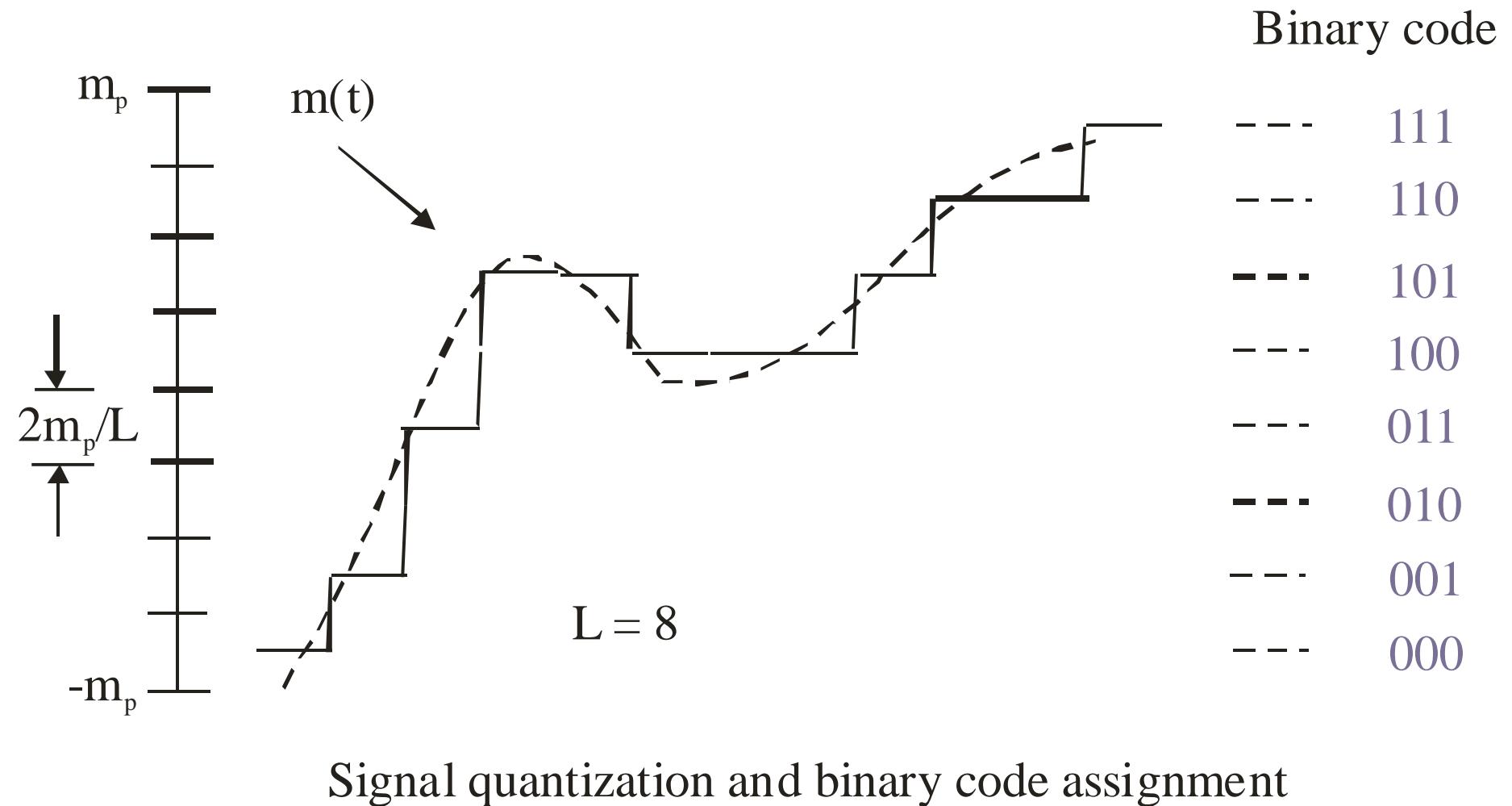
Both the mid-rise and mid-tread type of uniform quantizers are symmetric about the origin.
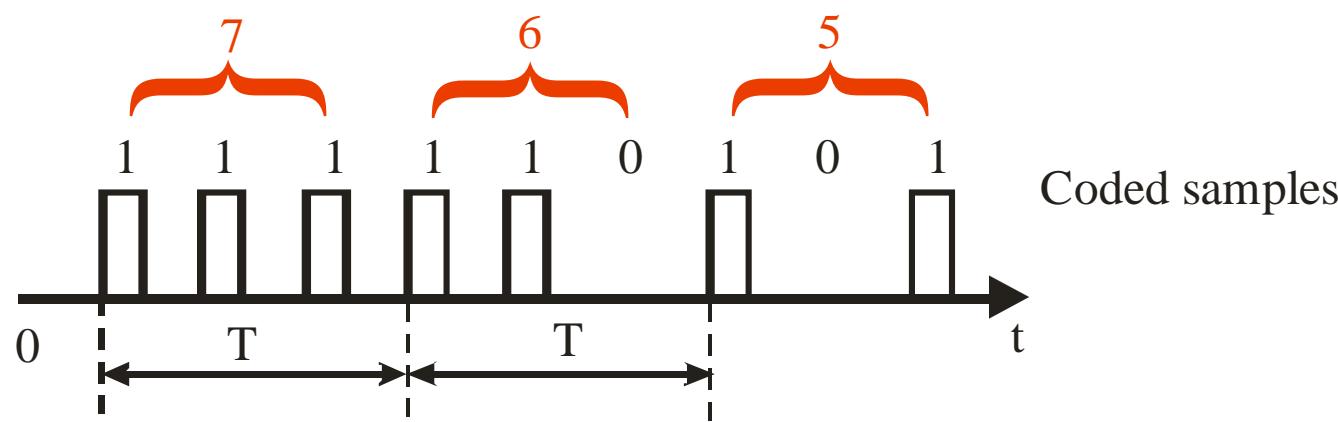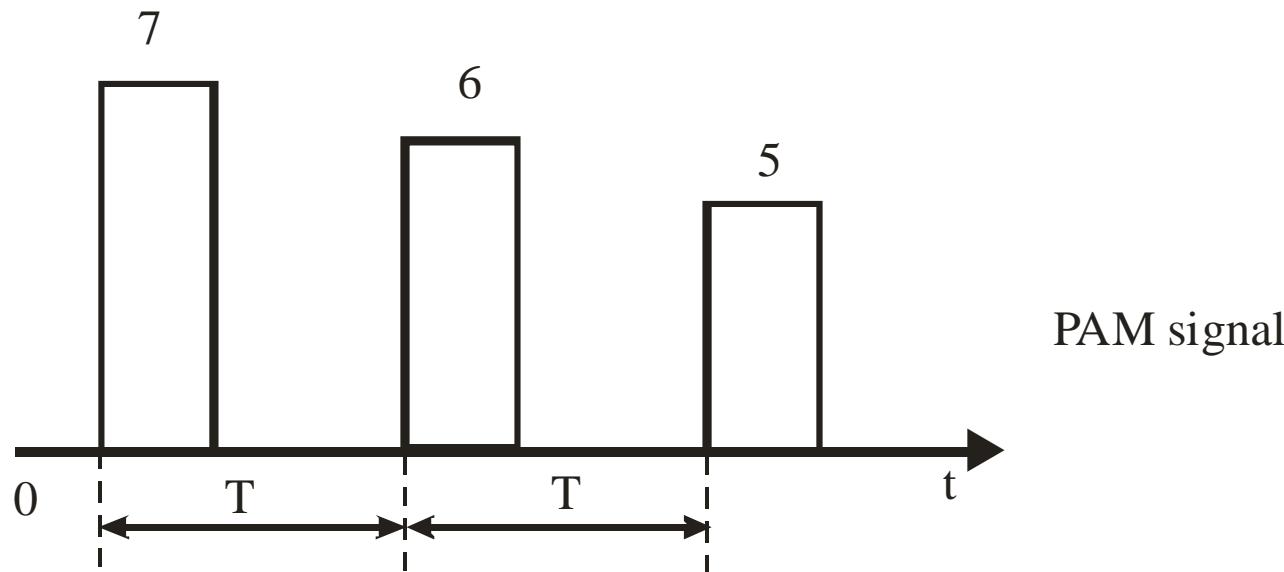
Encoding

After sampling and quantization, the analog message signal becomes *discrete in values*, but it is still *not in the form best suited for transmission*.
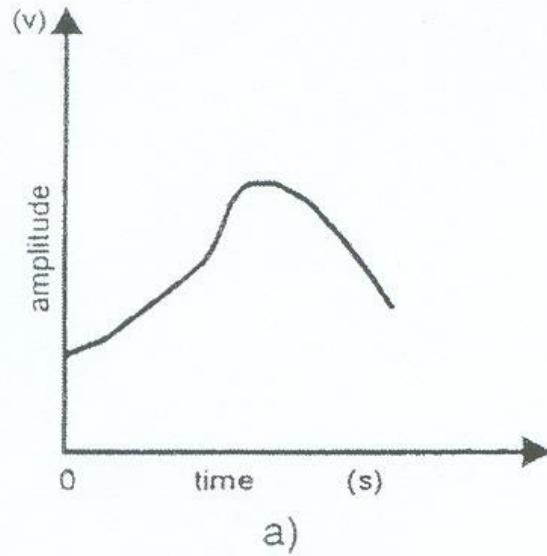
In order that the signal is best suited for transmission, i.e. *more robust to noise and interference*, an **encoding process** is required to *translate the discrete samples to a more appropriate form, such as the binary digits*.

Signal quantization and binary code assignment

PAM signal

Coded samples
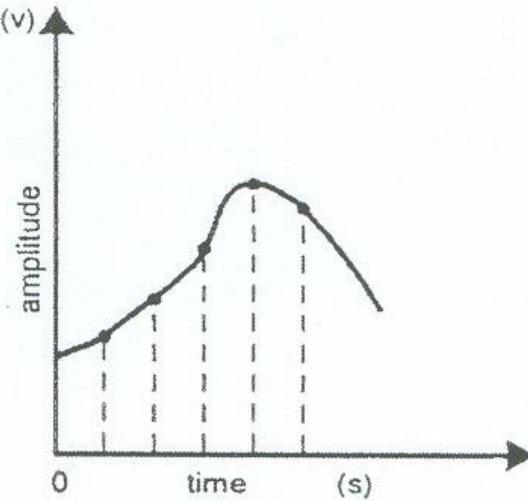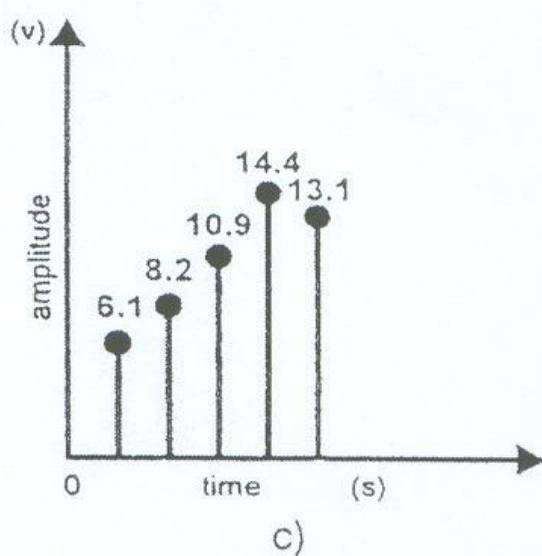
Binary coding of samples
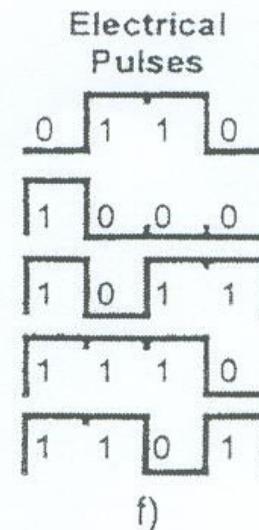
Figure 40A Pulse-code modulation (PCM) technique: (a) Original signal; (b) sampling procedure; (c) samples of the sign: (d) quantization; (e) binary coding; (f) electrical signal transmitted in digital form. (Mynbaev and Scheiner)