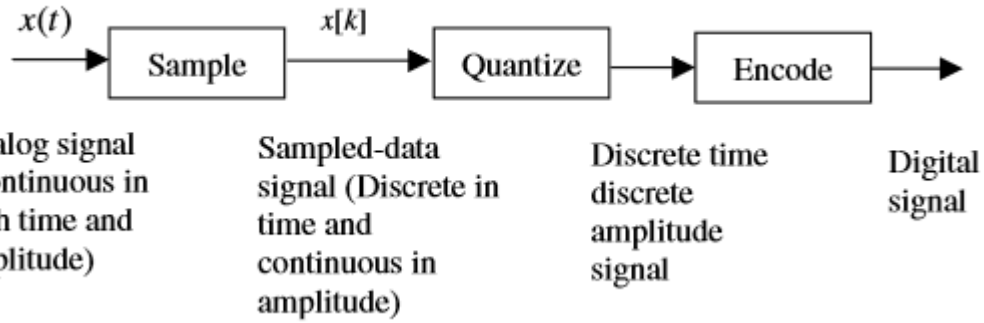
Telecommunication systems

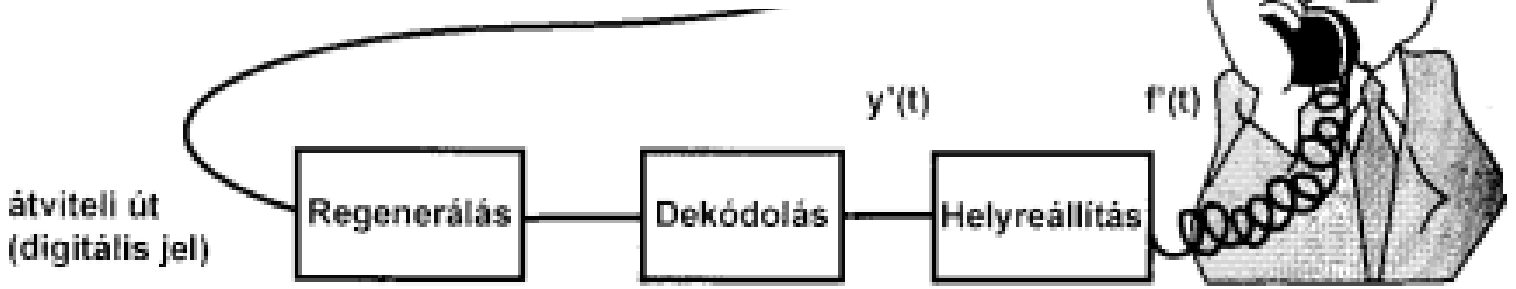
Architecture

Analog communication network

- receiver: sound wave ↔ electrical signal
- Switching system : electronic
- Transmission Path :
  - FDM (Frequency Division Multiplexing)
  - Milyen széles legyen egy beszédcsatorna?
  - Ears can hear 20 Hz -- 20 kHz-t
  - Maximum of speech signal 6-7 kHz
  - We need only 0,3 -- 3,4 kHz frequency band
  - 3,1 kHz + protection band = we use 4 kHz frequency band for speech transmission

Pulse Coded Modulation (PCM)





Sampling

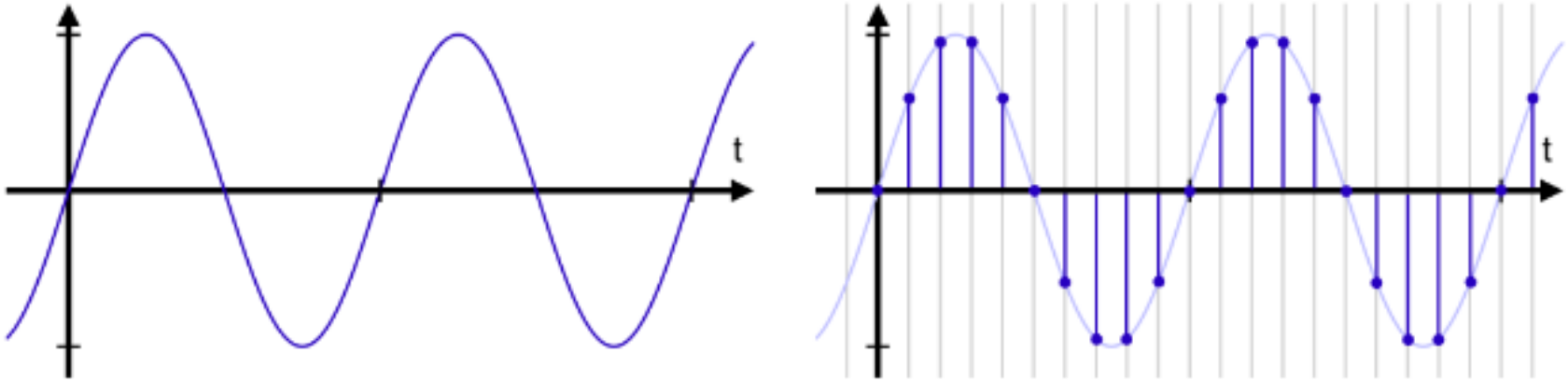


Figure 1: Sampling a sinosoid - we measure the value of the signal at regular time-intervals

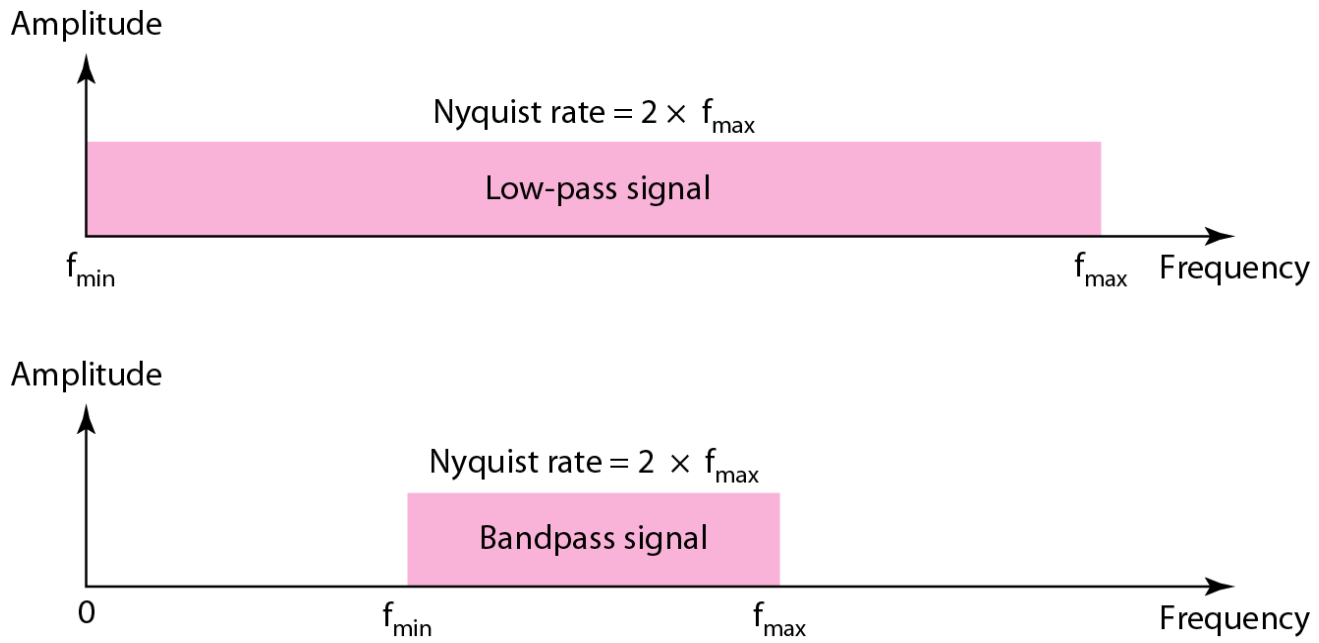
Nyquist-Shannon sampling theorem

The Nyquist-Shannon sampling theorem states that the sampling rate for exact recovery of a signal composed of a sum of sinusoids is larger than twice the maximum frequency of the signal.

$$f_m > 2f_{max},$$

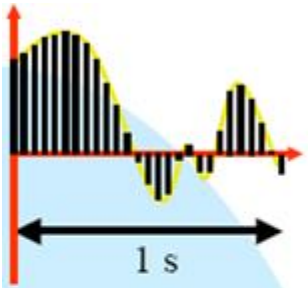
f_m - sampling rate

f_{max} – highest frequency of the signal



PCM

Példa:



L 'échantillonnage est lié au critère de Nyquist :

$f_e > 2\ f_m$

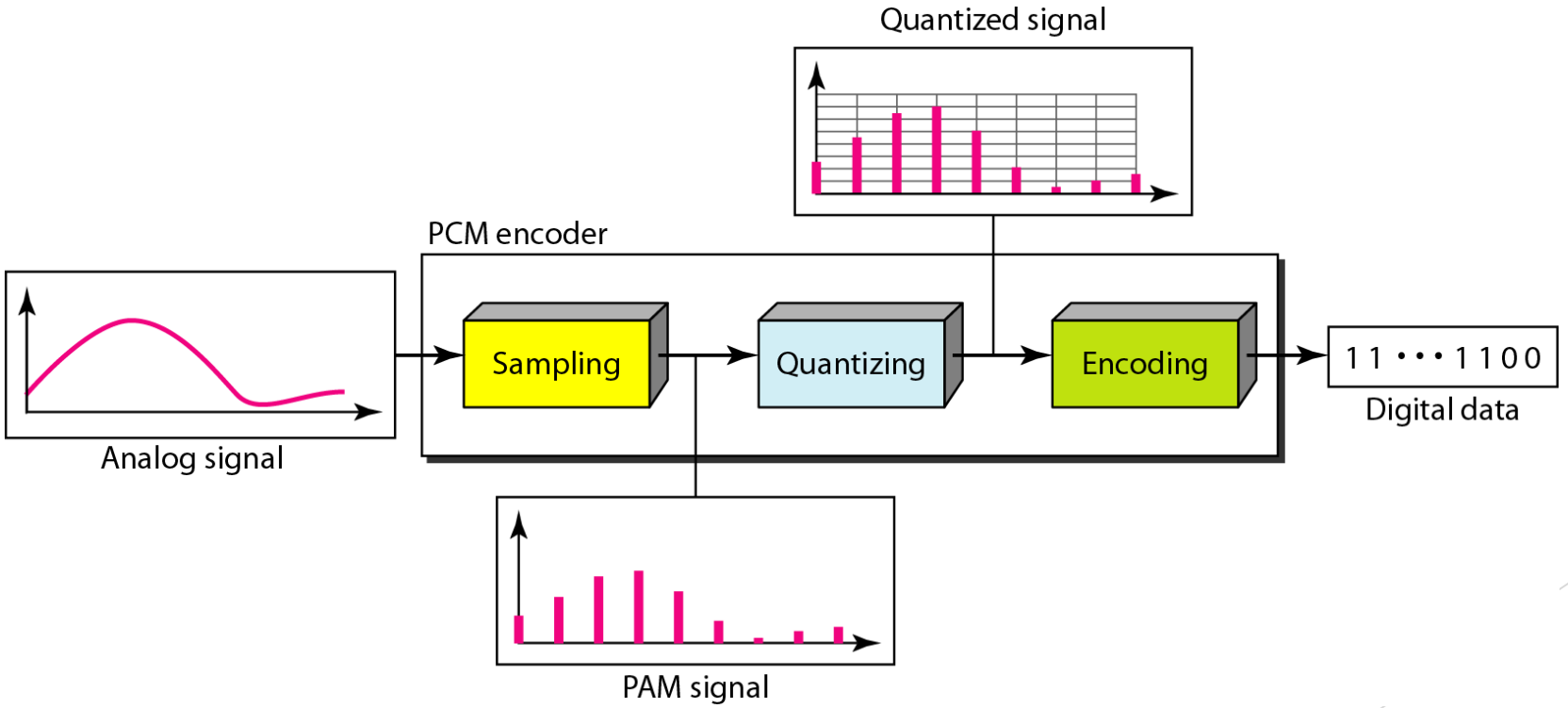
	Bande passante	f_e
Téléphone	300 - 3 400 Hz	8 000 Hz
Audioconférence	50 - 7 000 Hz	16 kHz
CD	20 - 20 000 Hz	44,1 kHz

On ne peut pas diminuer la fréquence d 'échantillonnage lorsque la bande passante est fixée

Pulse Coded Modulation (PCM)

One analog signal convert to a digital signal

- sampling
- quantizing
- encoding



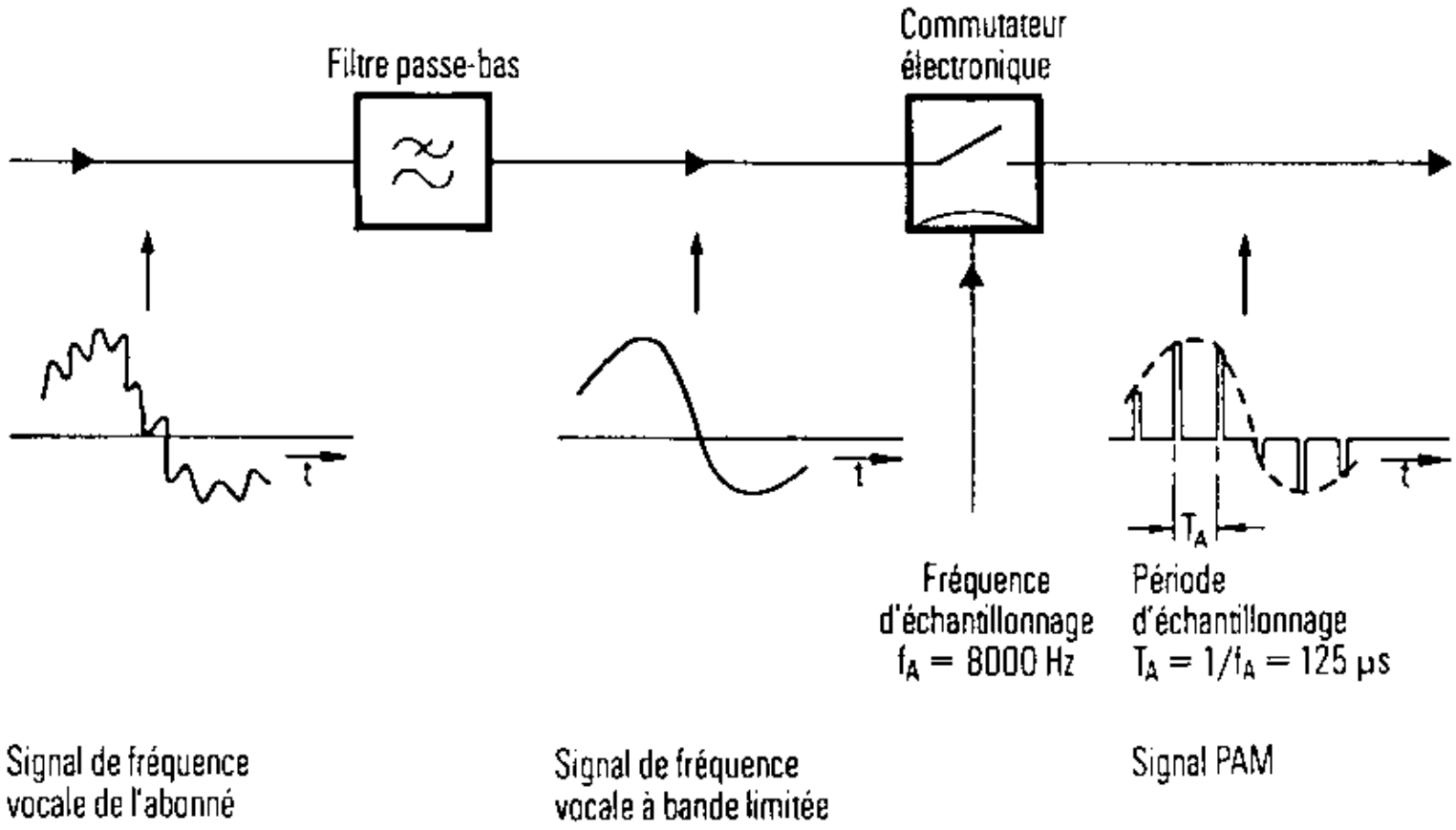
PCM

Sampling

Telephone companies digitize voice by assuming a maximum frequency of 4000 Hz. The sampling rate therefore is 8000 samples per second:

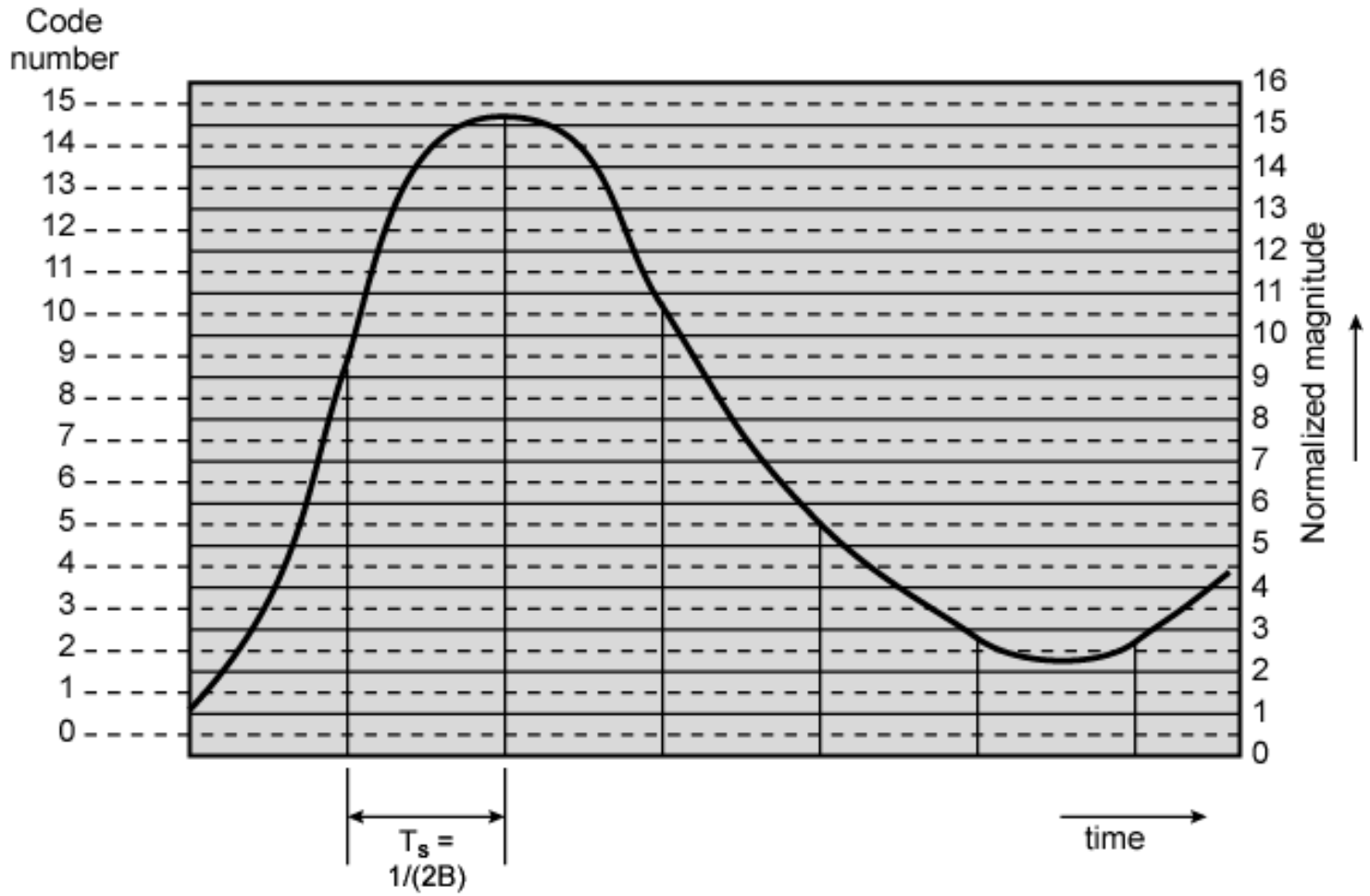
$$T_m = \frac{1}{f_m} = \frac{1}{8000\ \text{Hz}} = 125\ \text{us}$$

PCM signal



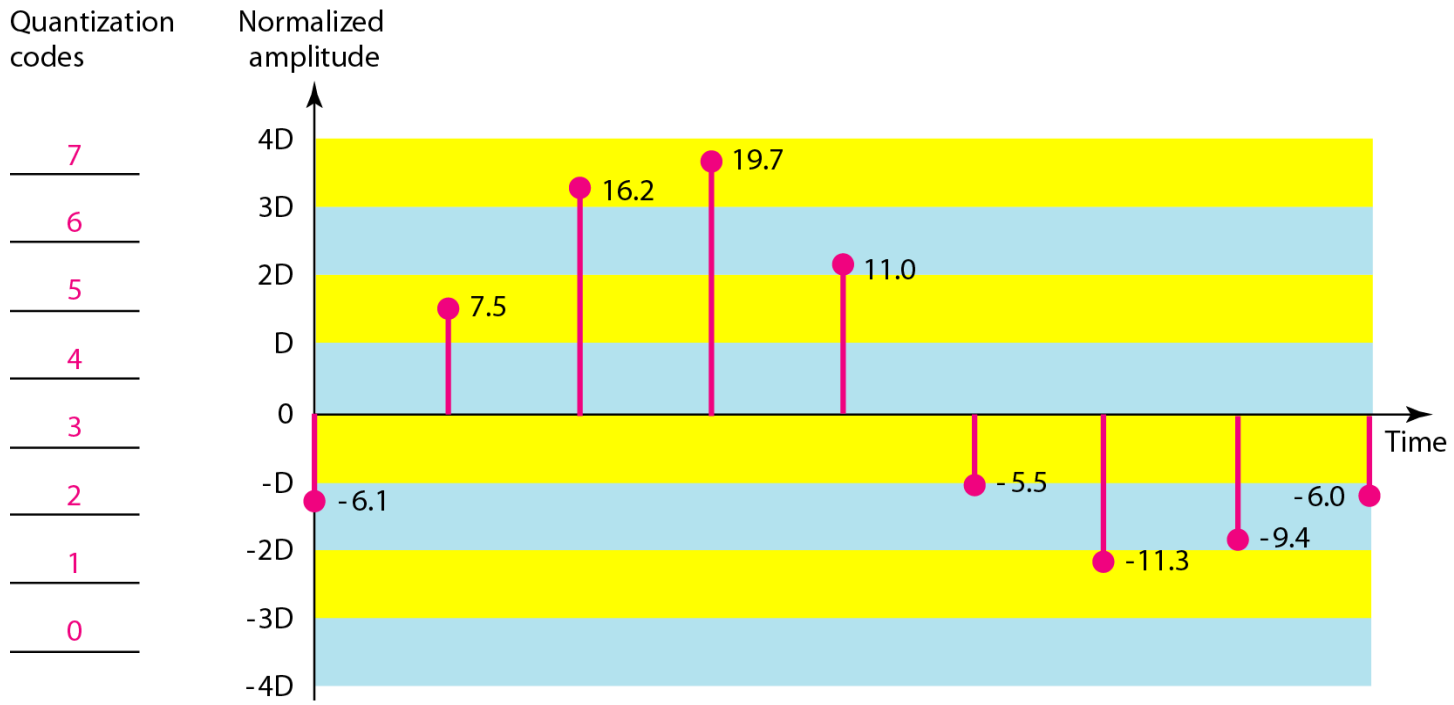
Geting PAM signal

PCM Example



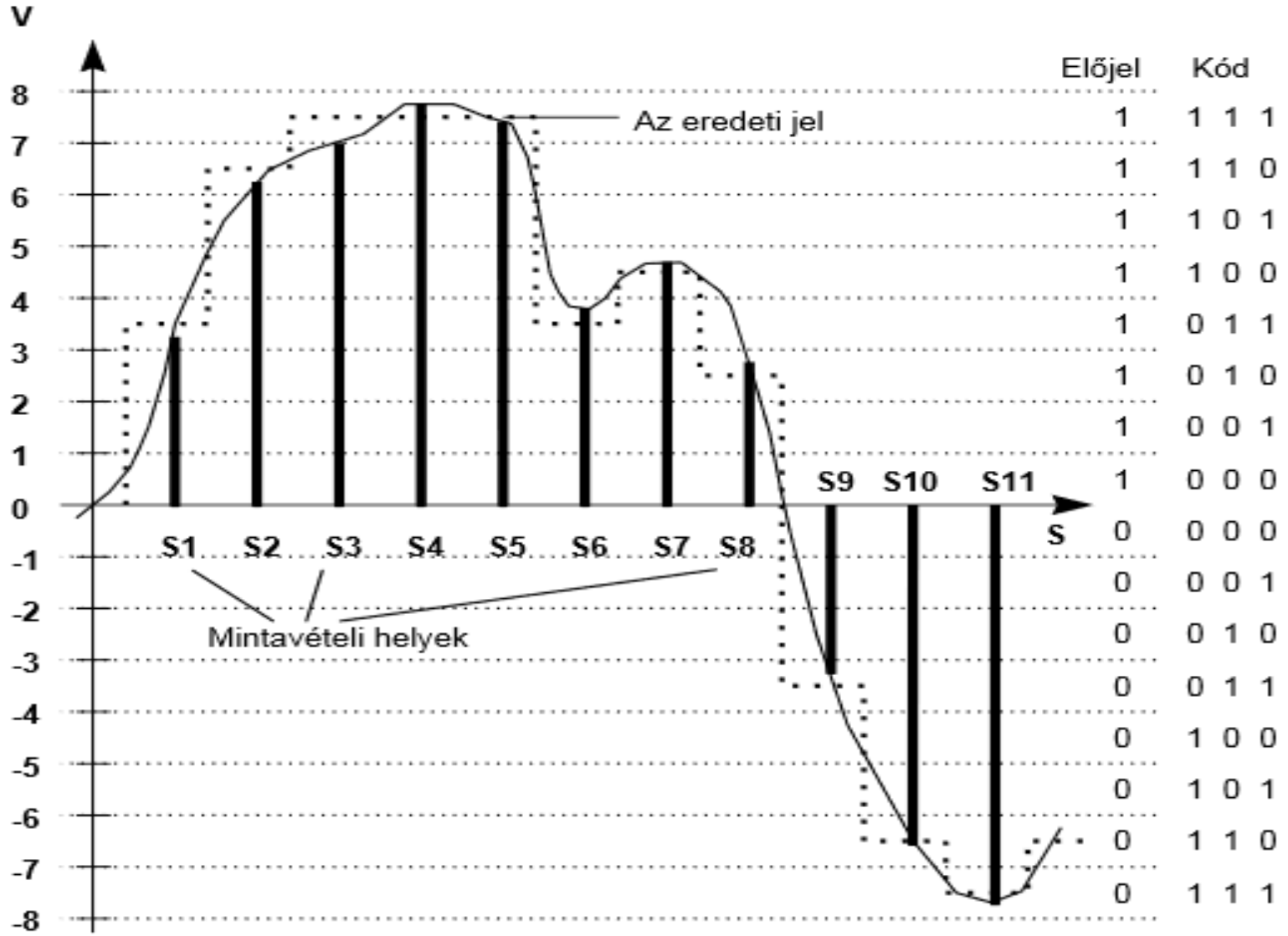
PAM value	1.1	9.2	15.2	10.8	5.6	2.8	2.7
quantized code number	1	9	15	10	5	2	2
PCM code	0001	1001	1111	1010	0101	0010	0010

Quantization and encoding of a sampled signal



Normalized PAM values	-1.22	1.50	3.24	3.94	2.20	-1.10	-2.26	-1.88	-1.20
Normalized quantized values	-1.50	1.50	3.50	3.50	2.50	-1.50	-2.50	-1.50	-1.50
Normalized error	-0.38	0	+0.26	-0.44	+0.30	-0.40	-0.24	+0.38	-0.30
Quantization code	2	5	7	7	6	2	1	2	2
Encoded words	010	101	111	111	110	010	001	010	010

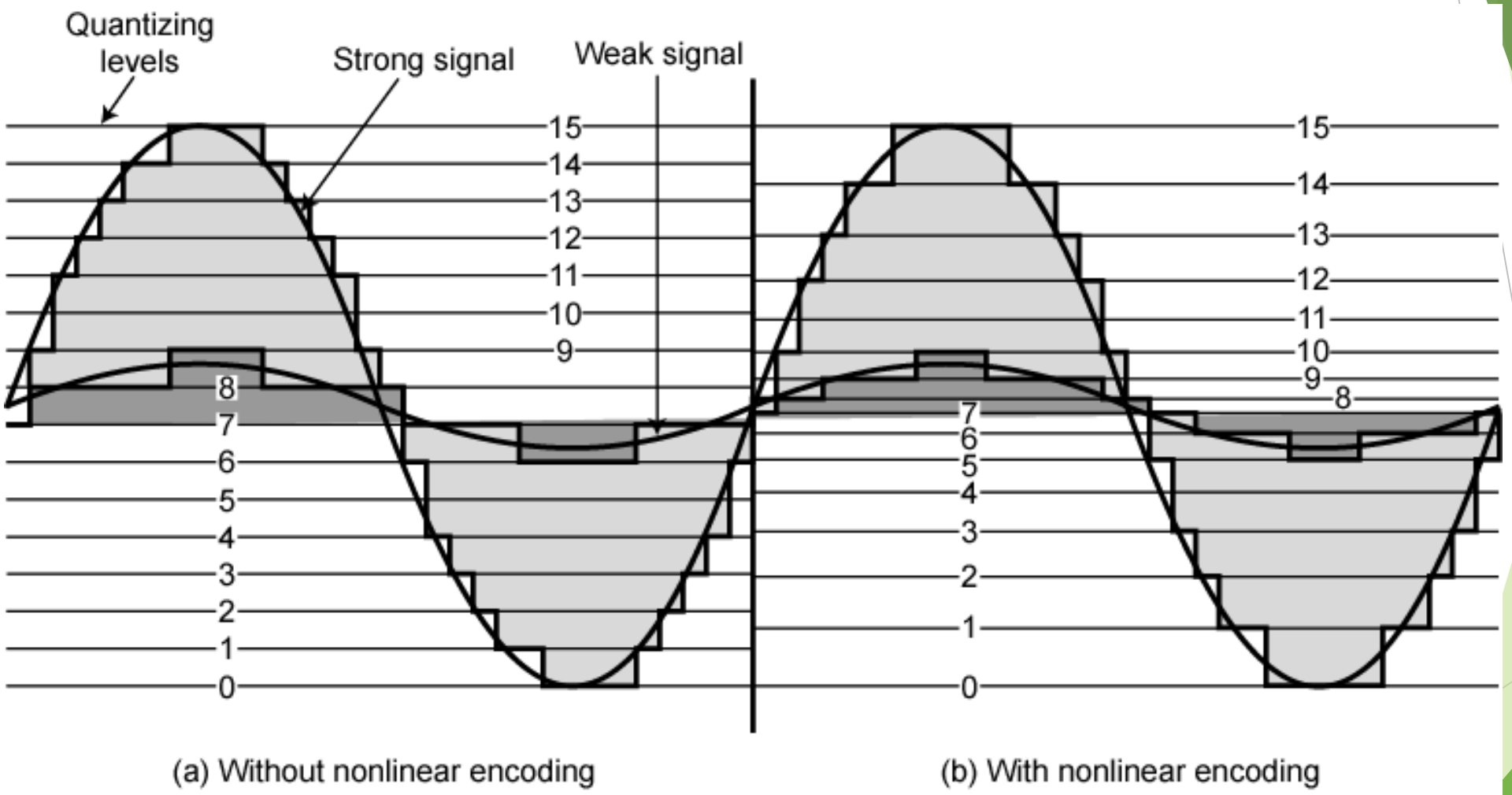
Linear Quantization



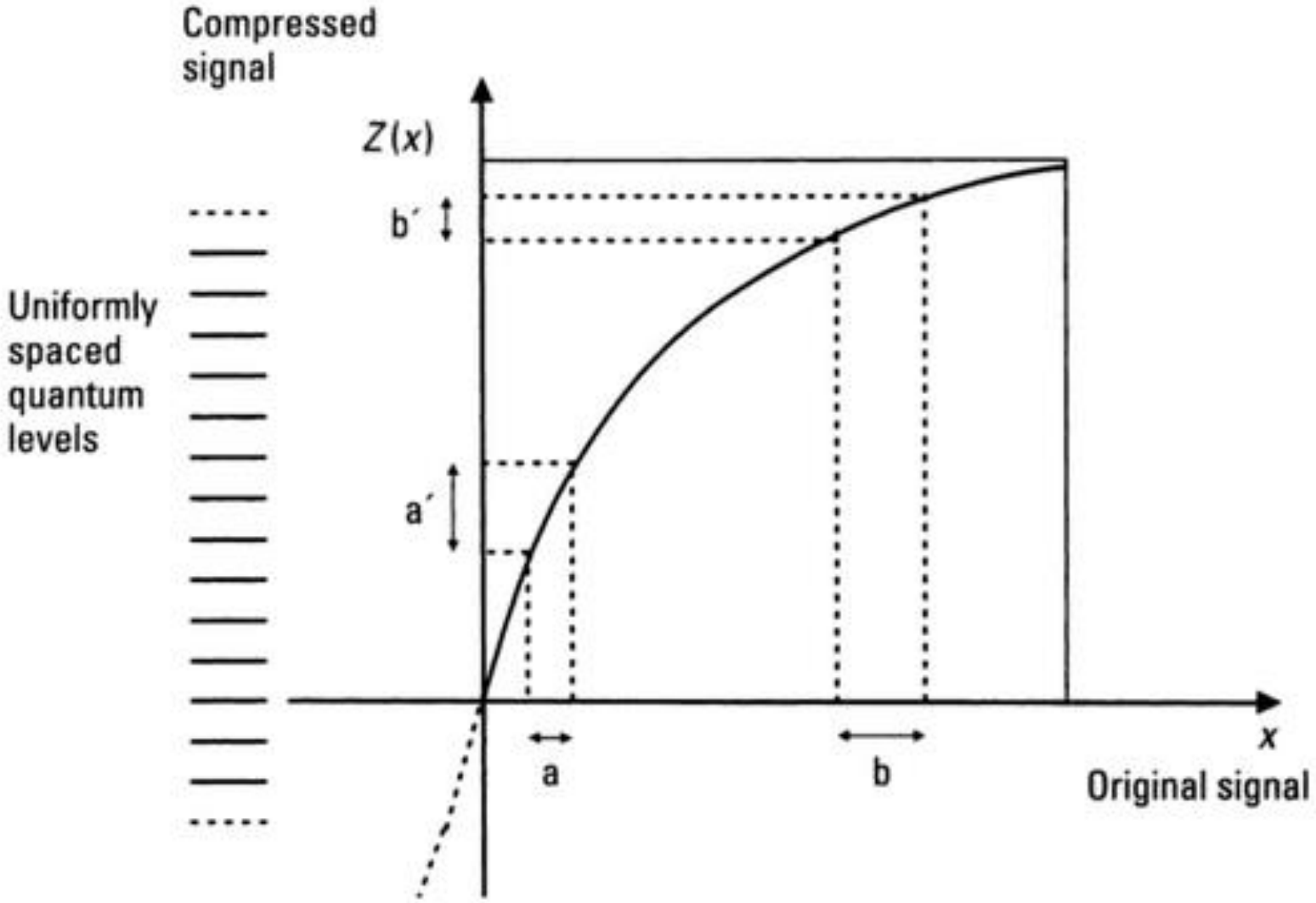
PCM

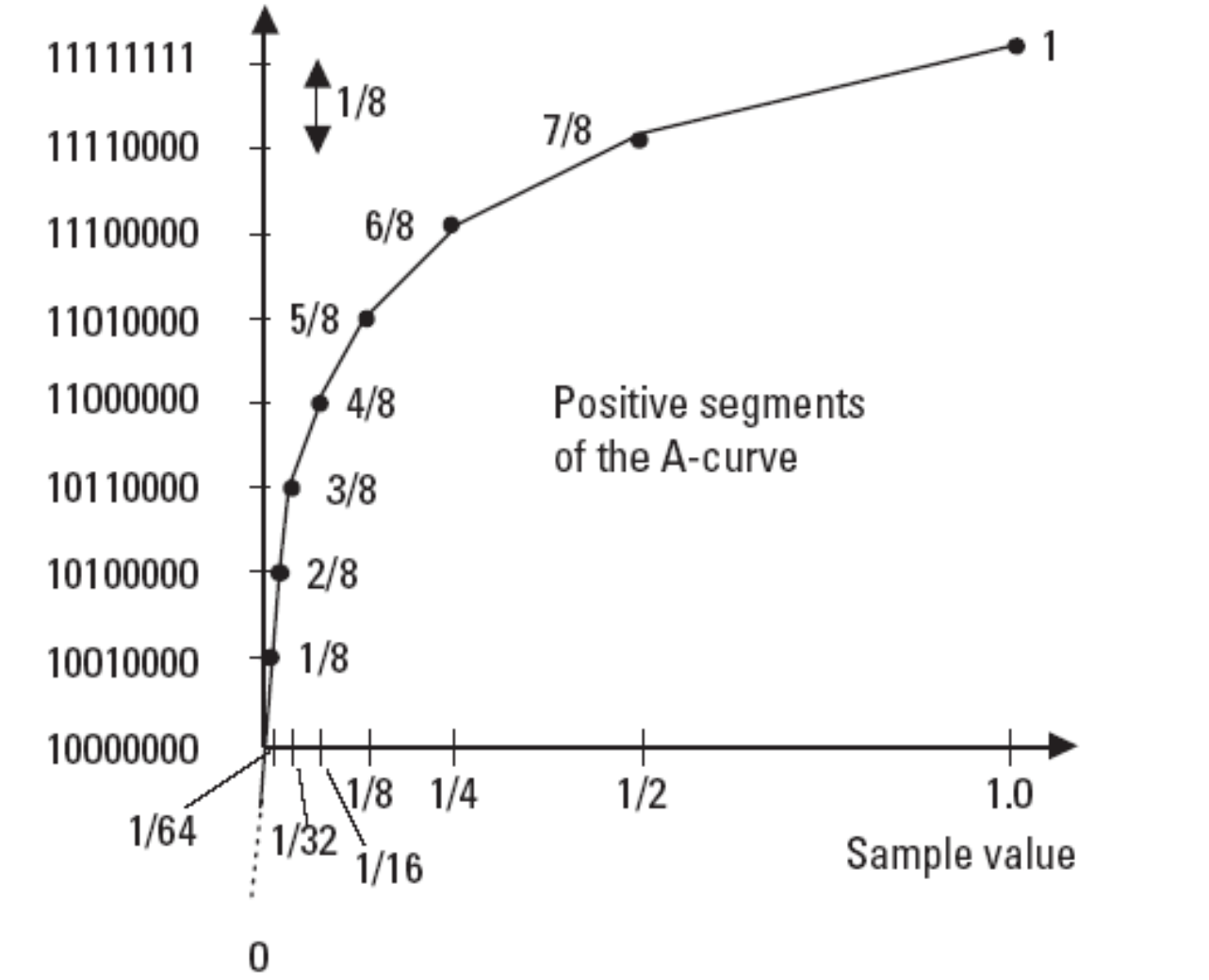
- Problems with uniform quantization
  - Only optimal for uniformly distributed signal
  - Real audio signals (speech and music) are more
  - concentrated near zeros
  - Human ear is more sensitive to quantization errors at small values
- Solution
  - Using non-uniform quantization
  - quantization interval is smaller near zero

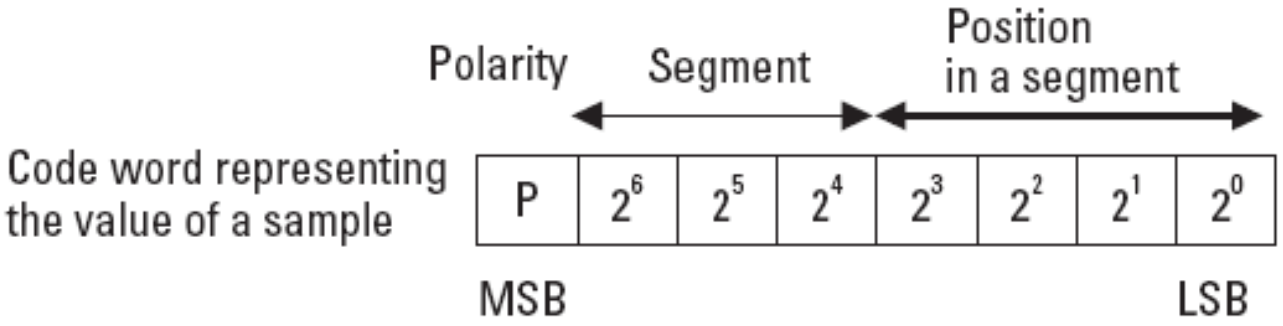
Effect of Non-Linear Coding



Quantization and encoding




11111111
11110000
11100000
11010000
11000000
10110000
10100000
10010000
10000000
1/8
7/8
6/8
5/8
4/8
3/8
2/8
1/8
1
Positive segments
of the A-curve
1/64
1/32
1/16
1/8
1/4
1/2
1.0
Sample value
0


Polarity
Segment
Position
in a segment
Code word representing
the value of a sample
P
2^6
2^5
2^4
2^3
2^2
2^1
2^0
MSB
LSB

Quantization and encoding