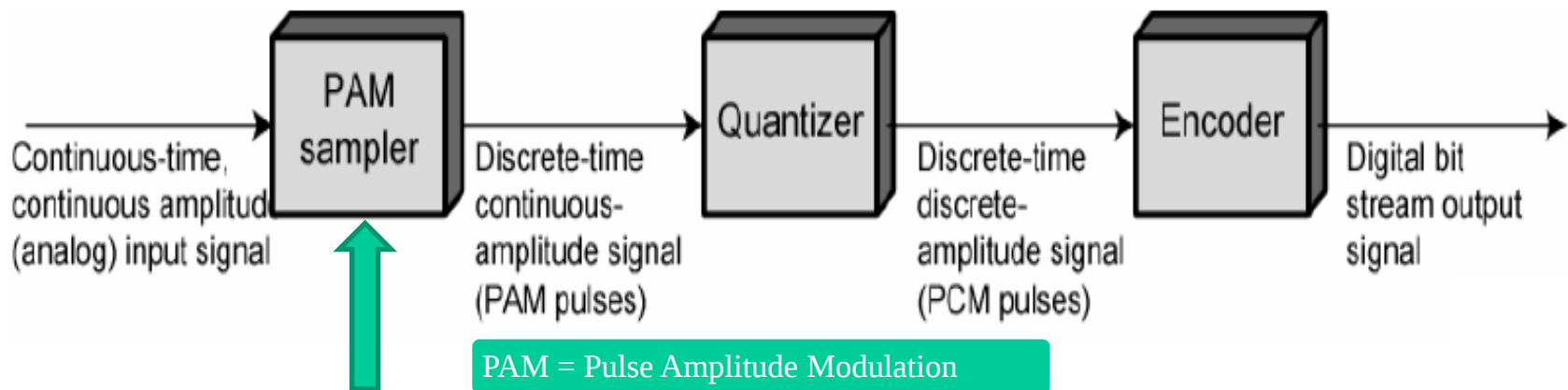


Digital Modulation Basics

Outline

- PCM
- Introduction to digital modulation
- Relevant modulation schemes
- Geometric representations
- Coherent & Non-Coherent Detection

PCM (Pulse Coded Modulation)



Nyquist rate:

Sampling rate (f_s) $\geq 2 f_{\max}$ sinyal analog

Atau

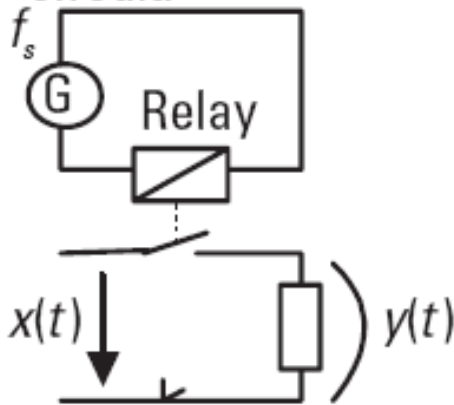
Sampling rate (f_s) ≥ 2 bandwidth sinyal analog

Untuk voice, $f_s = 8$ kHz (periode sampling = $125\mu s$)

(bandwidth kanal telepon = 4 kHz)

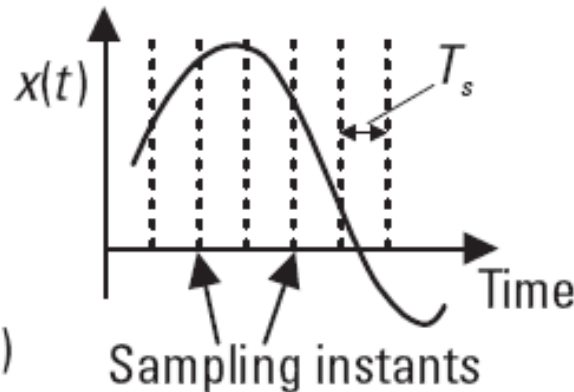
Sampling

Operation principle
of a sampling
circuit:

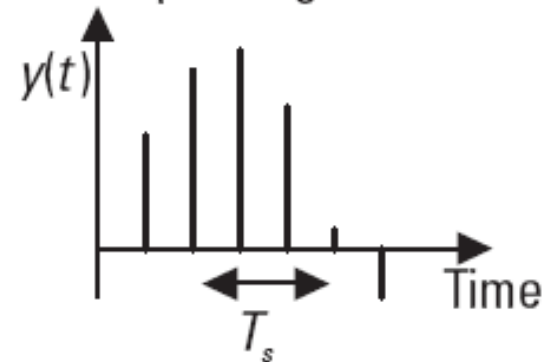


Time domain:

Original analog message

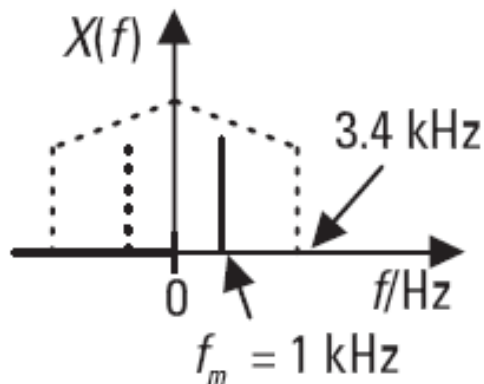


Sampled signal

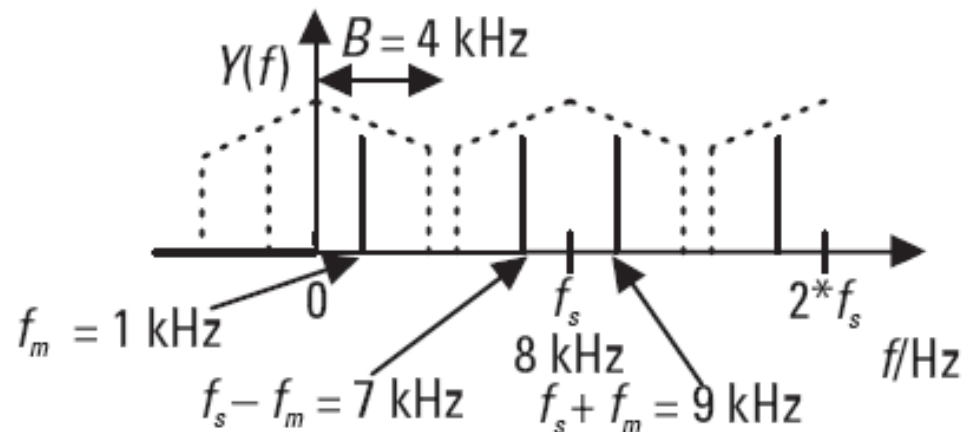


Frequency domain:

Spectrum of an analog message



Spectrum of sampled signal



Sampling

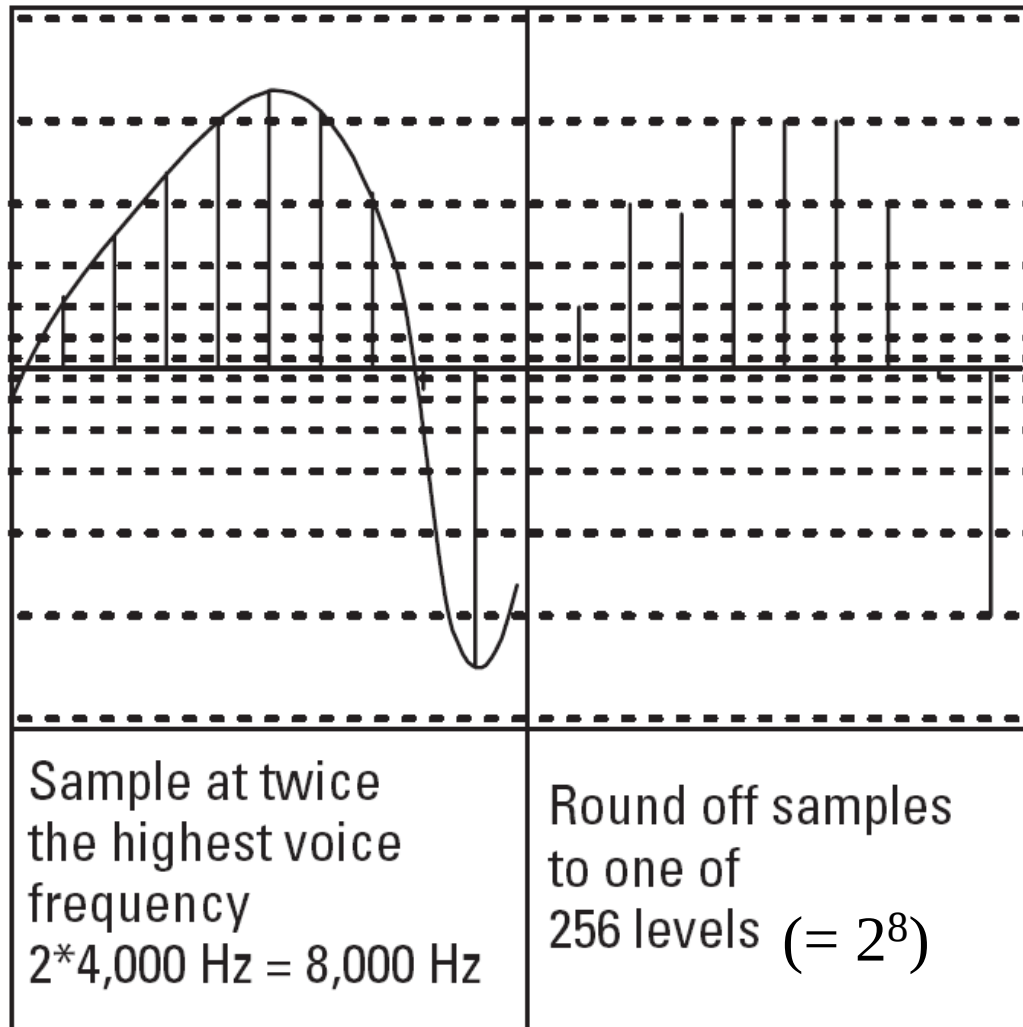
Quantizing

Encoding

+127

+0

-127



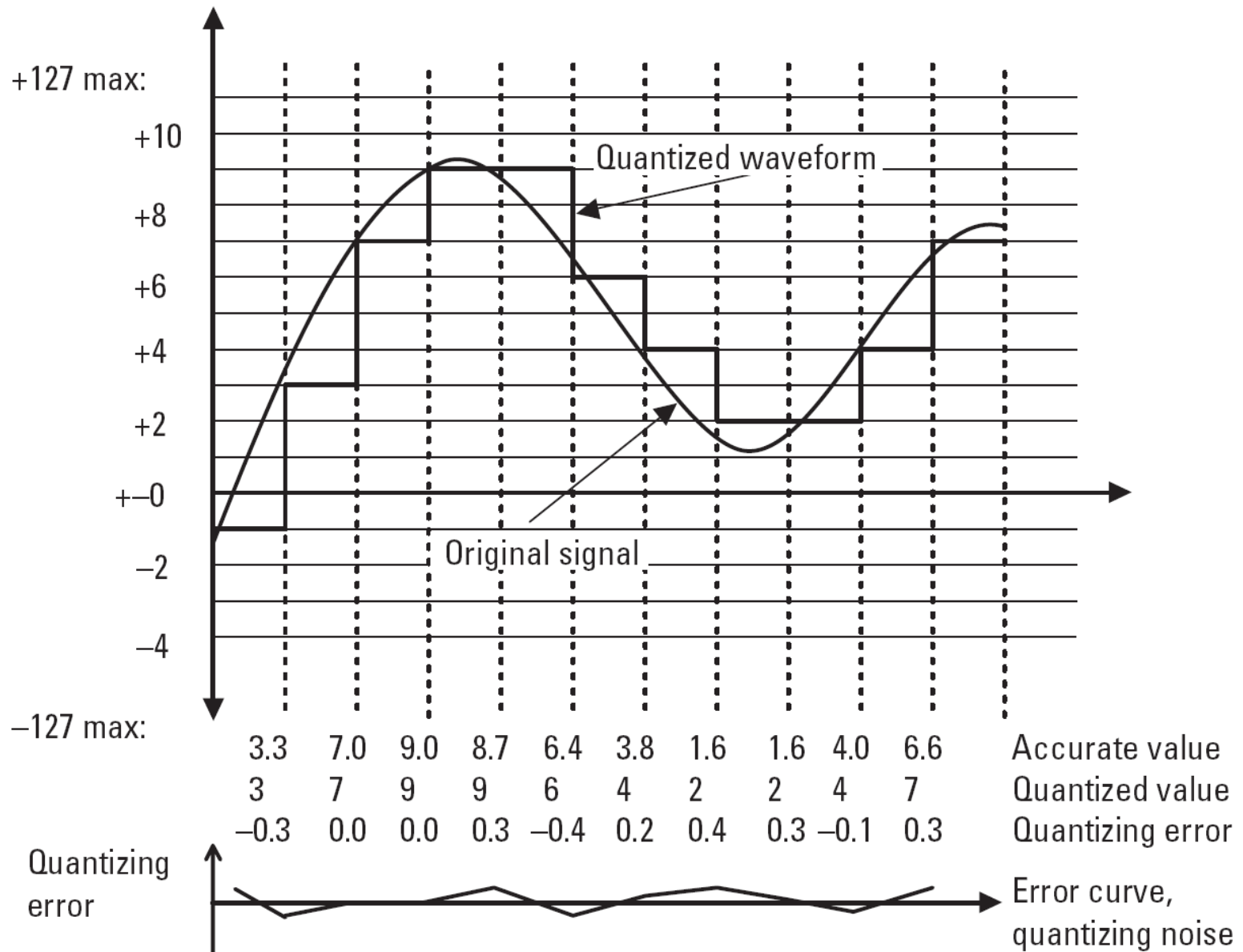
(Note: untuk CD digunakan 16-bit binary words
 (ada $2^{16} = 65536$ level))

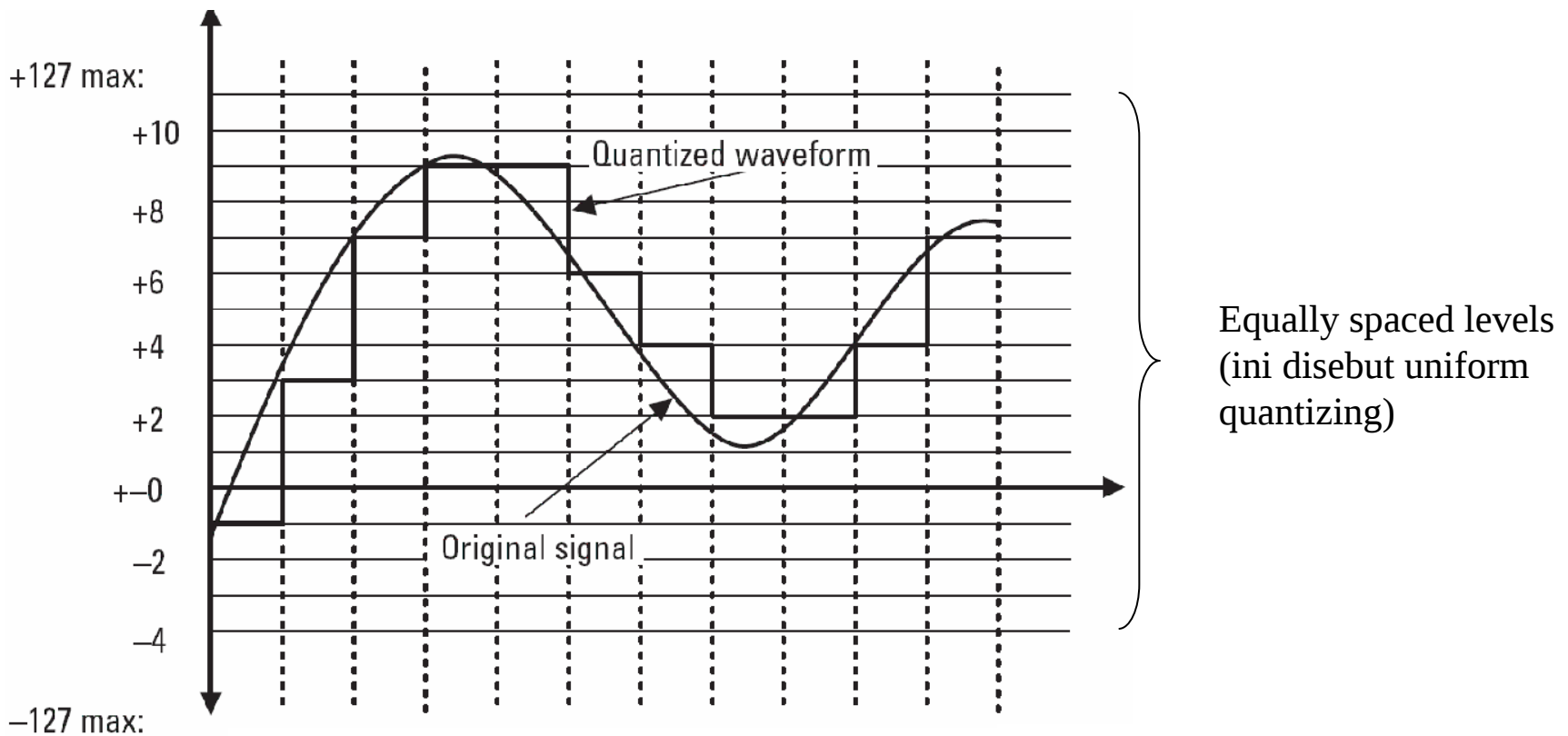
10101111...01101101

Each quantized sample is encoded into an 8-bit code word

$8,000 \times 8 \text{ bits} = 64 \text{ Kbps}$

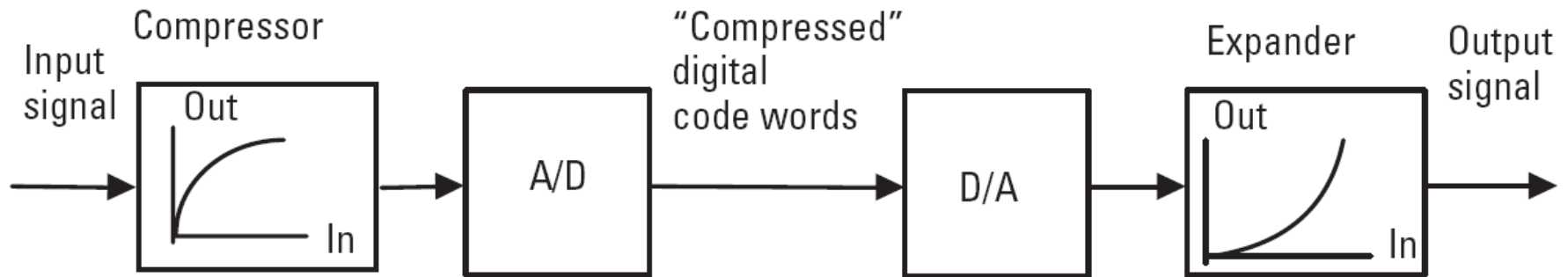
A Closer Look to Quantization

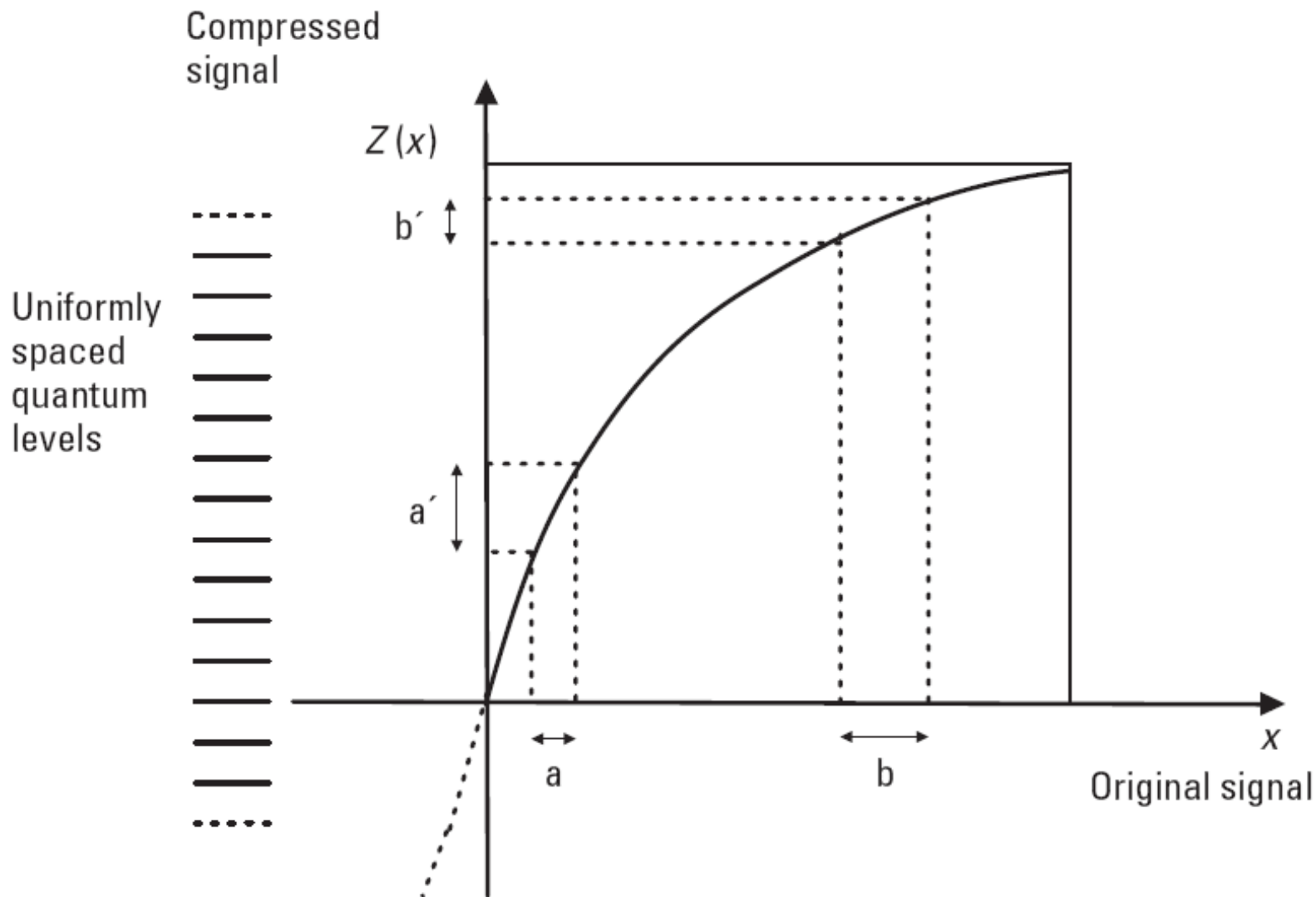




- Bila menggunakan *uniform quantizing*, noise kuantisasi akan sangat terasa pada sinyal-sinyal berlevel rendah
- Solusi untuk menanggulangi noise kuantisasi adalah dengan menambah jumlah level, tetapi akibatnya bit rate hasil pengkodean akan menjadi lebih tinggi
- Solusi elegan yang ditempuh adalah dengan tidak menambah jumlah level, melainkan dengan membedakan kerapatan level
- Level kuantisasi pada sinyal-sinyal rendah lebih rapat daripada untuk sinyal berlevel tinggi
 - Hal ini dilakukan dengan mengompres (compressing) sinyal di sumber
 - Di tujuan dilakukan proses dekompress (expanding)
 - Proses compressing dan expanding disebut companding

Companing





Dua kurva *companding* standard:

- A-law, digunakan di negara2 Eropa (Rec. ITU-T G.732)
- μ -law, digunakan di Amerika Utara dan Jepang (Rec. ITU-T G.733)

$$\mu\text{-Law} \longrightarrow Z(x) = \text{sgn}(x) \cdot \frac{\ln(1 + \mu|x|)}{\ln(1 + \mu)}$$

x : nilai sinyal

$Z(x)$: sinyal ter-kompres

$\text{sgn}(x)$: polaritas x (+ atau -)

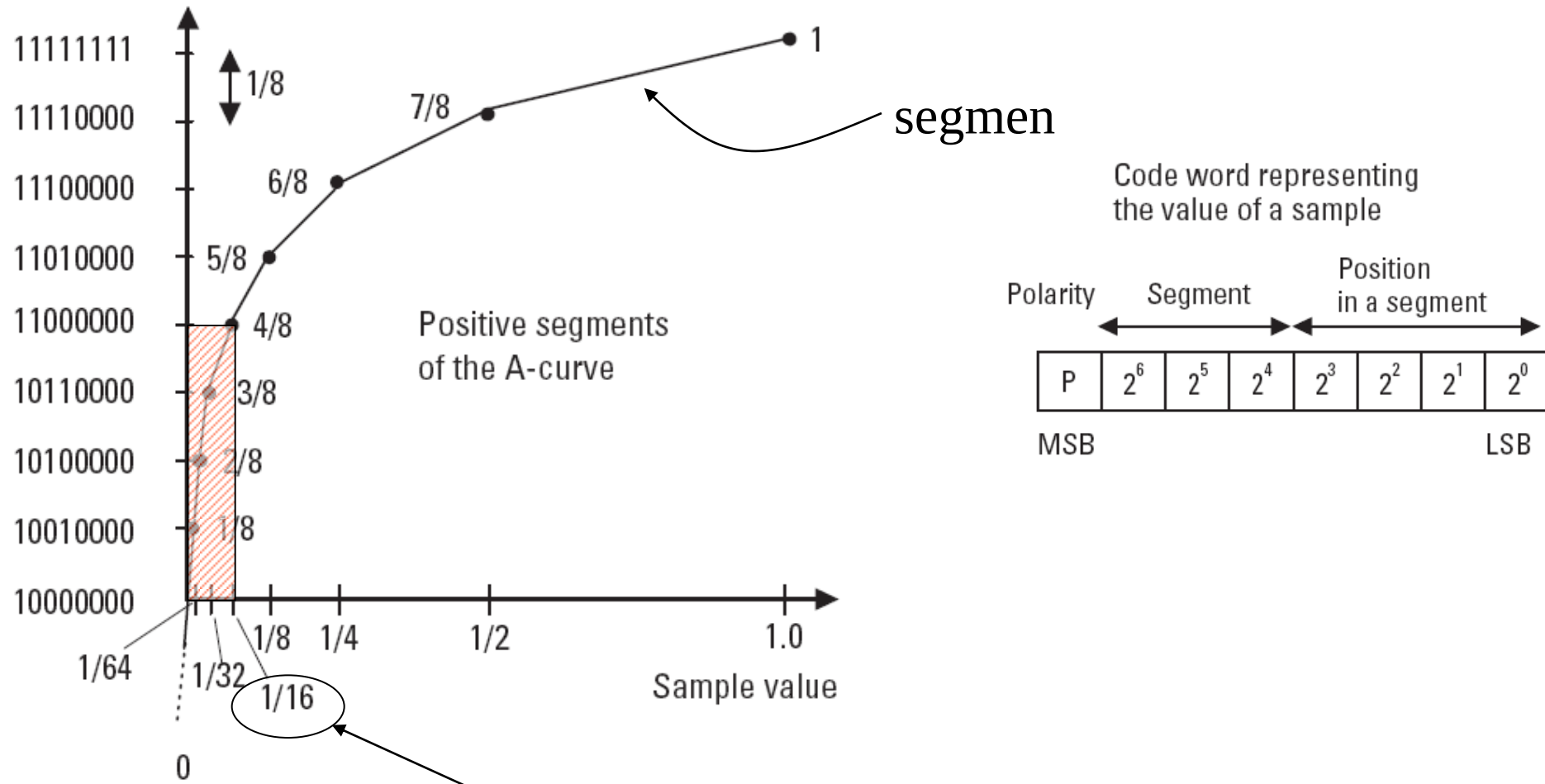
μ : konstanta = 255

$$A\text{-Law} \longrightarrow Z(x) = \begin{cases} \text{sgn}(x) \cdot \frac{1 + \ln A|x|}{1 + \ln A} & \text{for } \frac{1}{A} < |x| < 1 \\ \frac{Ax}{1 + \ln A} & \text{for } -\frac{1}{A} < x < \frac{1}{A} \end{cases}$$

A : konstanta = 87,6

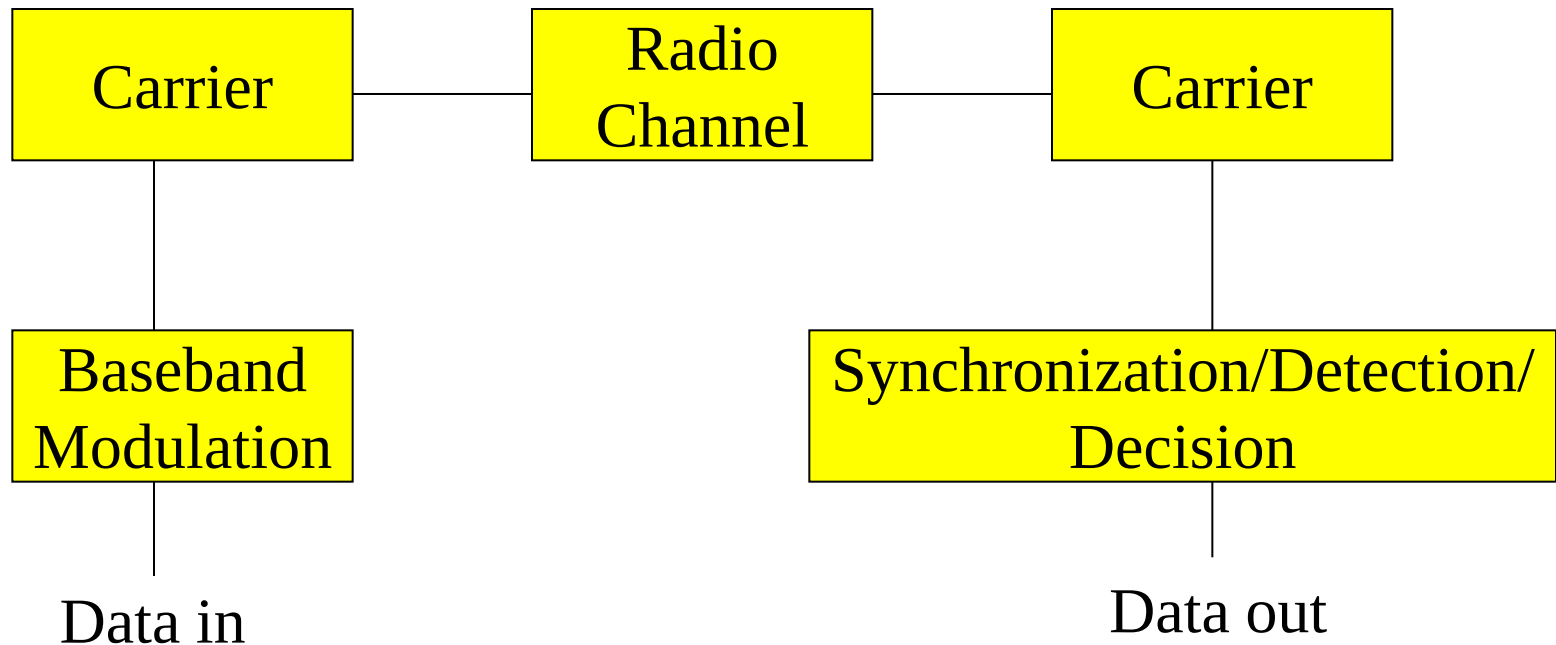
Binary Coding (Menentukan bit-bit biner yang merepresentasikan sinyal voice)

- Contoh untuk kurva A-law



Setengah dari jumlah level diperuntukkan bagi sinyal yang levelnya lebih rendah dari 6,25% level sinyal maksimum

Modulation & Demodulation



Modulation

- Modulation - process (or result of the process) of translation the baseband message signal to bandpass (modulated carrier) signal at frequencies that are very high compared to the baseband frequencies.
- Demodulation is the process of extracting the baseband message back the modulated carrier.
- An information-bearing signal is non-deterministic, i.e. it changes in an unpredictable manner.

Why Carrier?

- Effective radiation of EM waves requires antenna dimensions comparable with the wavelength:
 - Antenna for 3 kHz would be ~100 km long
 - Antenna for 3 GHz carrier is 10 cm long
- Sharing the access to the telecommunication channel resources

Modulation Process

$$f = f(a_1, a_2, a_3, \dots, a_n, t) \text{ (= carrier)}$$

$$a_1, a_2, a_3, \dots, a_n \text{ (= modulation parameters)}$$

$$t \text{ (= time)}$$

- Modulation implies varying one or more characteristics (modulation parameters $a_1, a_2, \dots, a_n$) of a carrier f in accordance with the information-bearing (modulating) baseband signal.
- Sinusoidal waves, pulse train, square wave, etc. can be used as carriers

Continuous Carrier

Carrier: $A \sin[\omega t + \varphi]$

- $A = \text{const}$
- $\omega = \text{const}$
- $\varphi = \text{const}$
- Amplitude modulation (AM)
 - $A = A(t)$ – carries information
 - $\omega = \text{const}$
 - $\varphi = \text{const}$
- Frequency modulation (FM)
 - $A = \text{const}$
 - $\omega = \omega(t)$ – carries information
 - $\varphi = \text{const}$
- Phase modulation (PM)
 - $A = \text{const}$
 - $\omega = \text{const}$
 - $\varphi = \varphi(t)$ – carries information