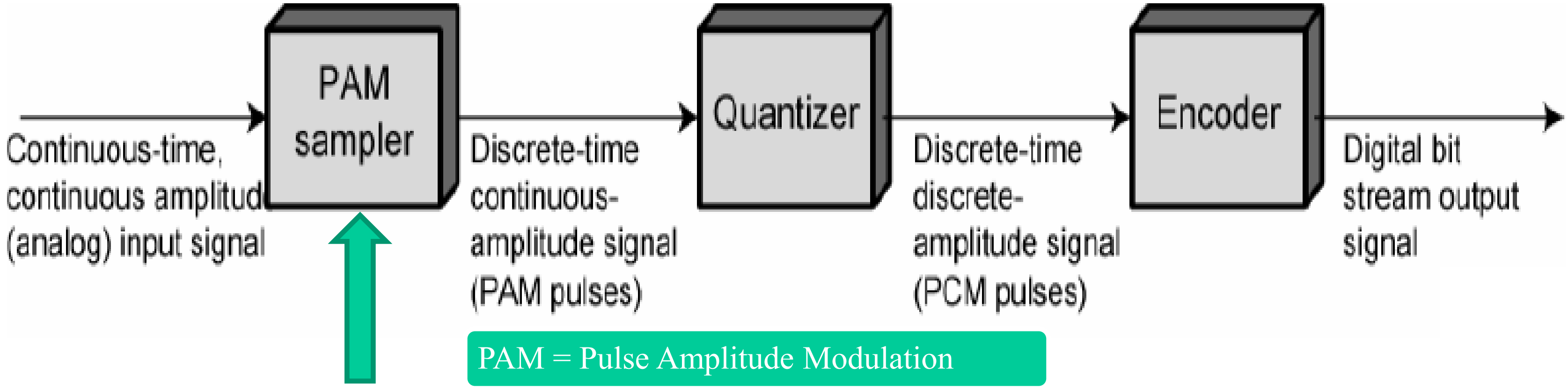
Digital Modulation Basics

Outline

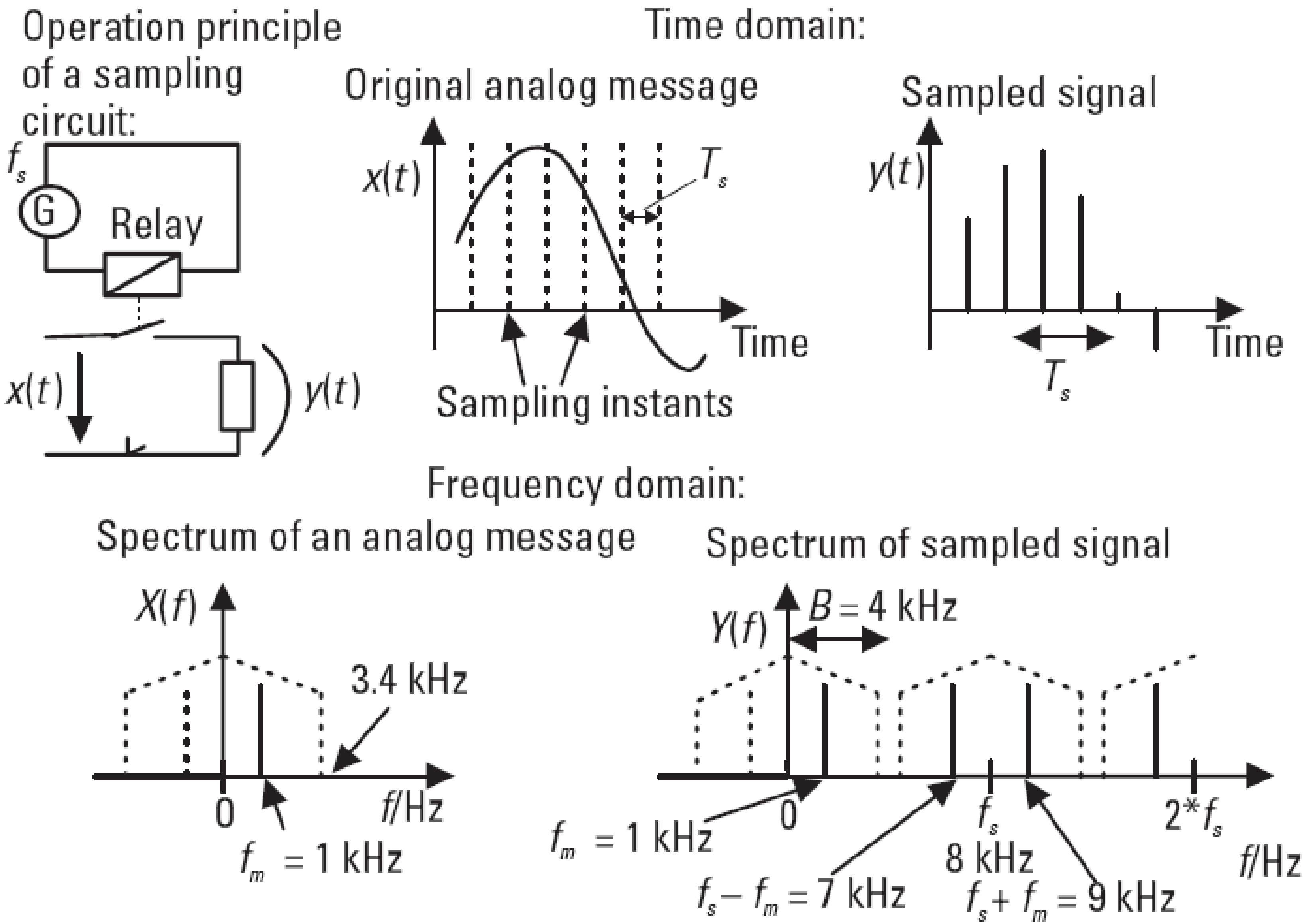
- PCM
- Introduction to digital modulation
- Relevant modulation schemes
- Geometric representations
- Coherent & Non-Coherent Detection

PCM (Pulse Coded Modulation)

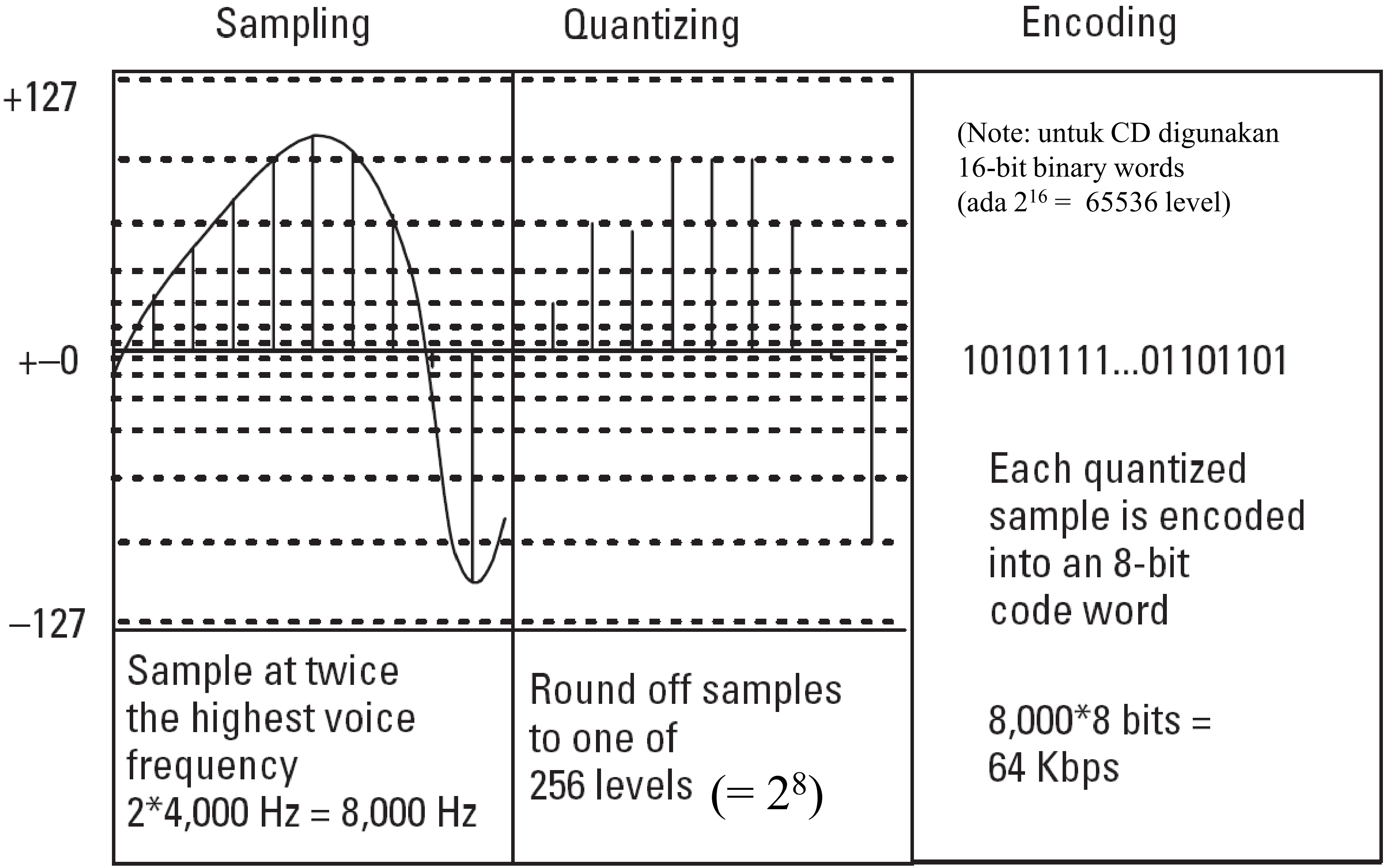


Nyquist rate:
Sampling rate (f_s) ≥ 2 f_{max} sinyal analog
Atau
Sampling rate (f_s) ≥ 2 bandwidth sinyal analog
Untuk voice, f_s = 8 kHz (perioda sampling = 125µs)
(bandwidht kanal telepon = 4 kHz)

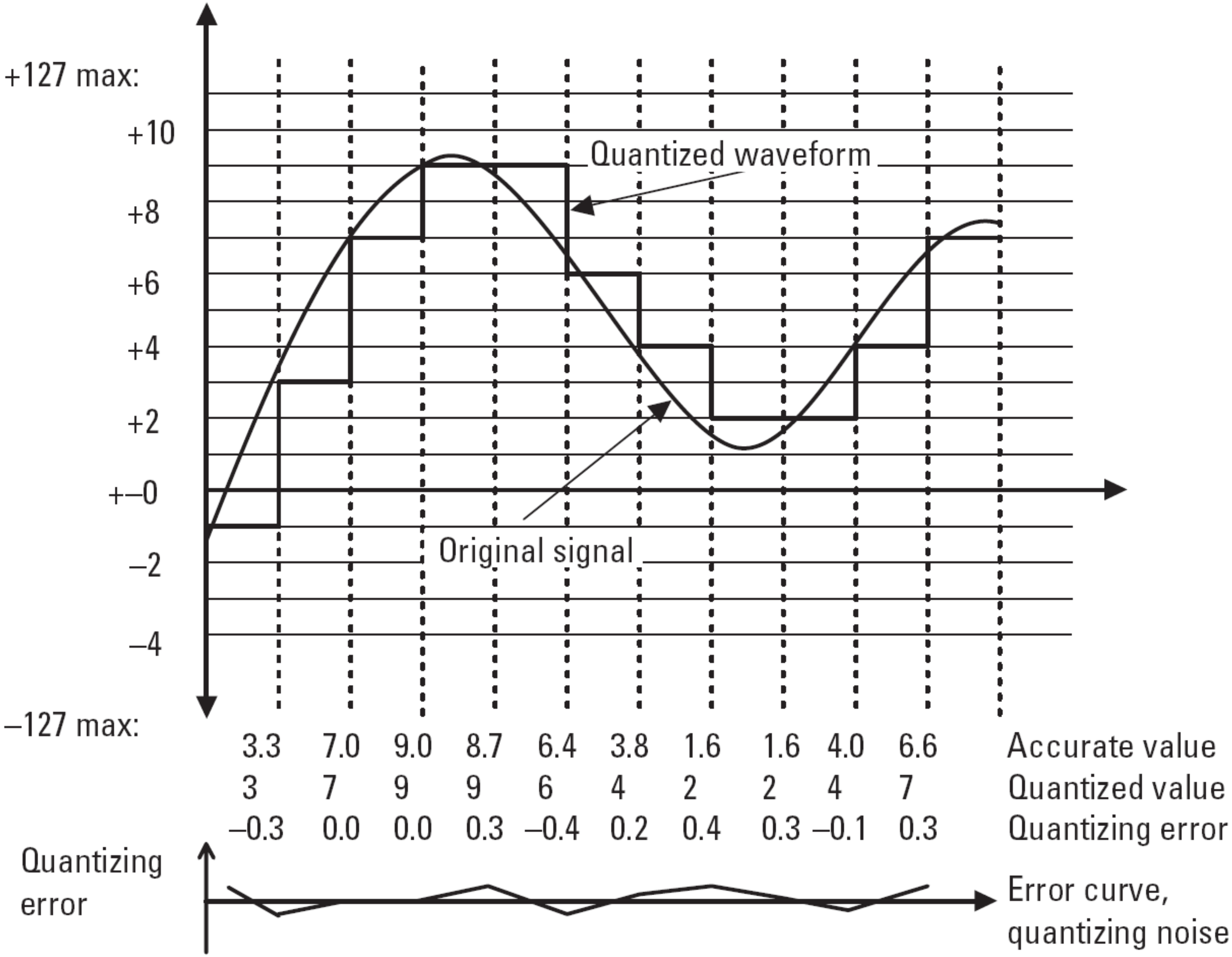
Sampling

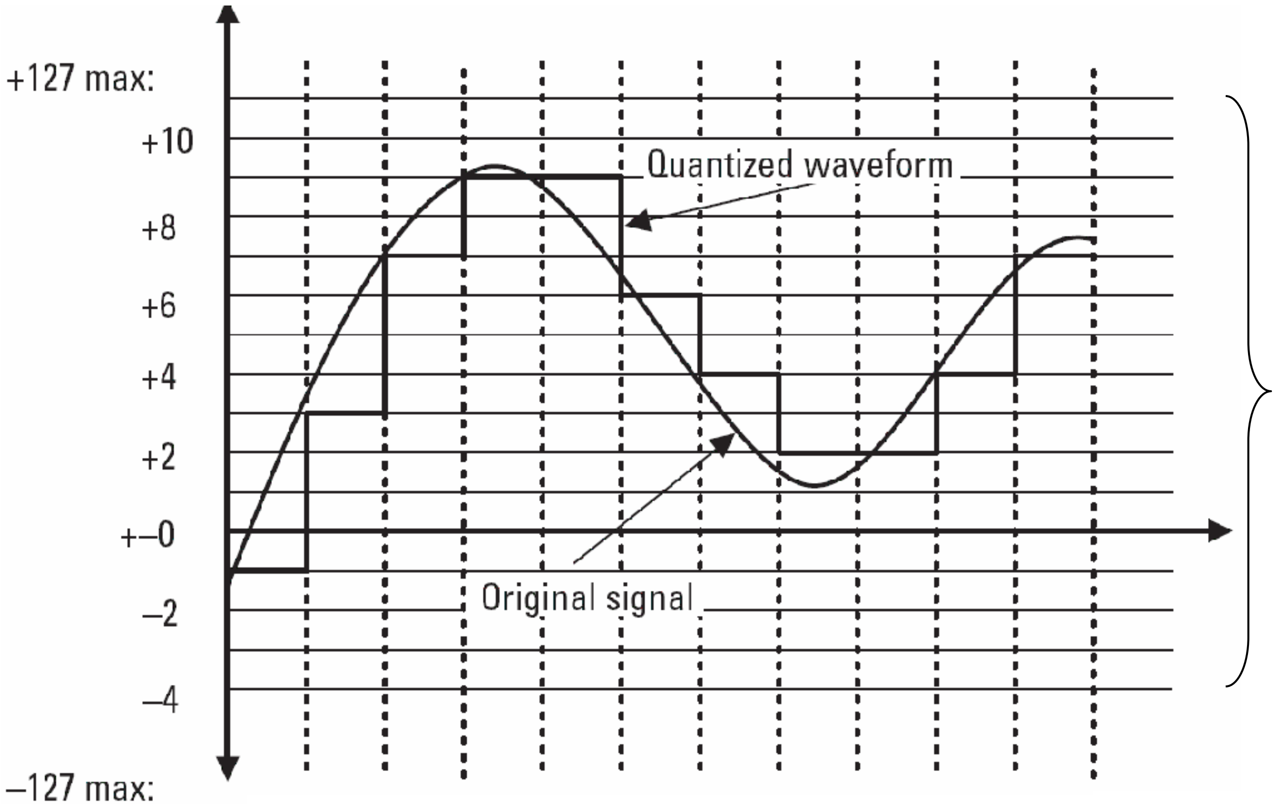


Operation principle of a sampling circuit:
f_s
G
Relay
x(t)
y(t)
Time domain:
Original analog message
x(t)
T_s
Time
Sampling instants
Sampled signal
y(t)
Time
T_s
Frequency domain:
Spectrum of an analog message
X(f)
3.4 kHz
0
f/Hz
f_m = 1 kHz
Spectrum of sampled signal
Y(f)
B = 4 kHz
0
f_s
8 kHz
2*f_s
f/Hz
f_m = 1 kHz
f_s – f_m = 7 kHz
f_s + f_m = 9 kHz


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
Sample at twice the highest voice frequency 2*4,000 Hz = 8,000 Hz
Round off samples to one of 256 levels $(= 2^8)$
8,000*8 bits = 64 Kbps

A Closer Look to Quantization

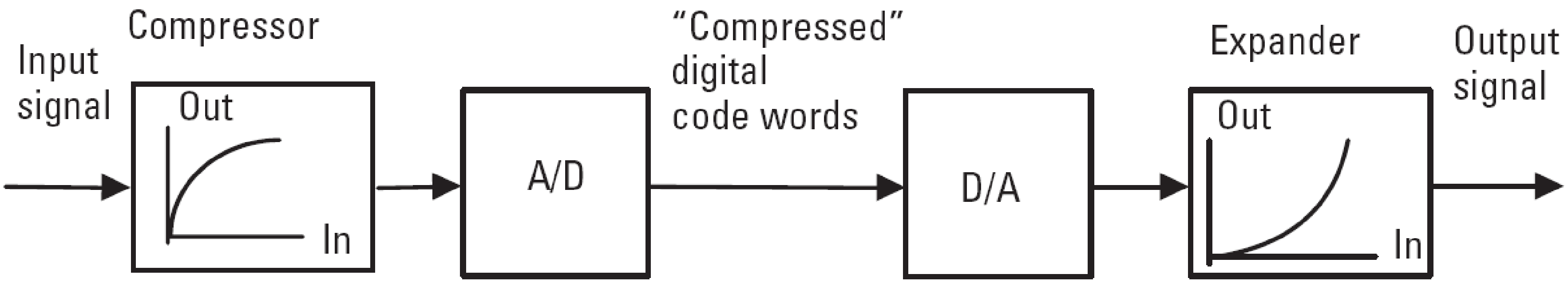


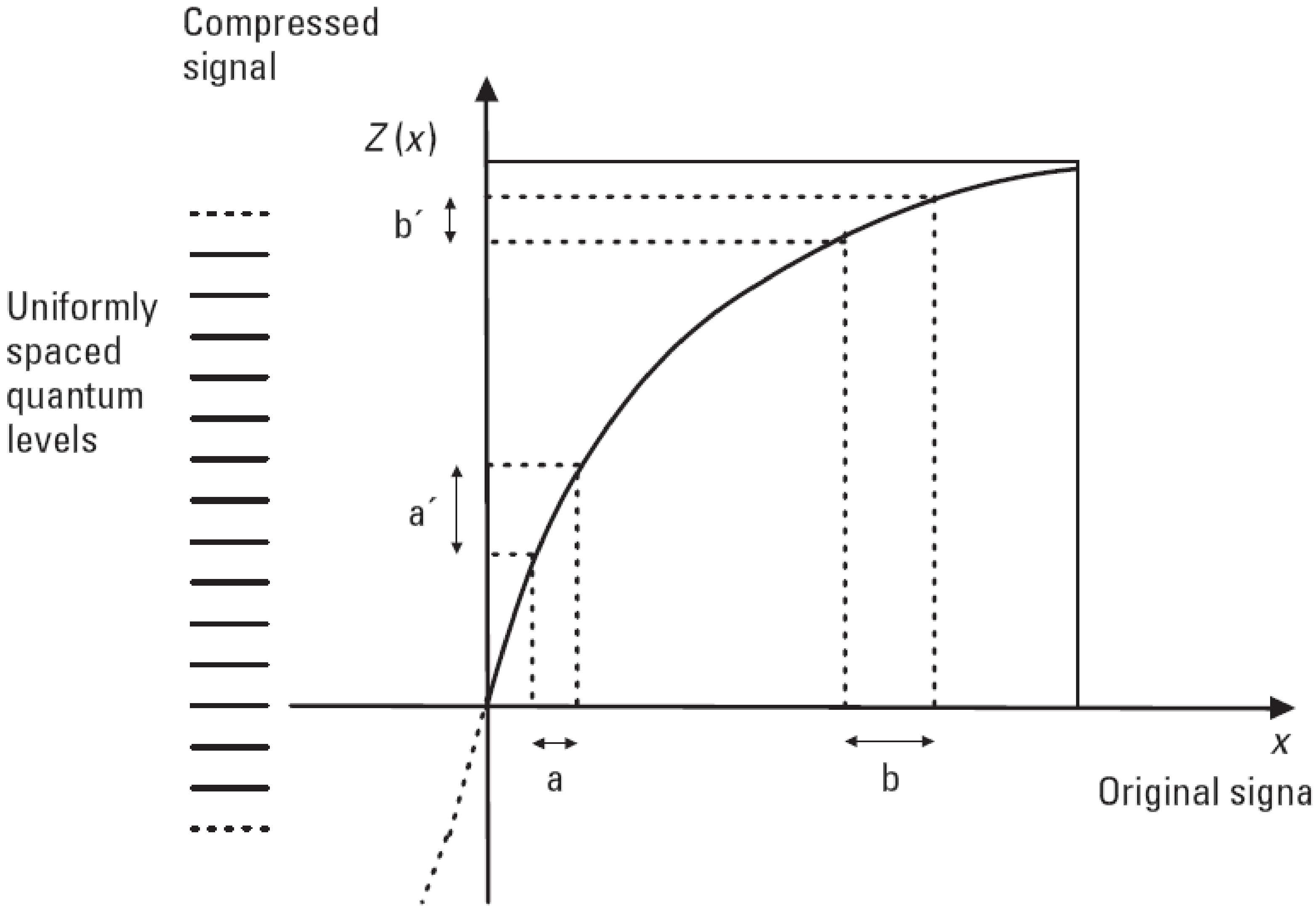


Equally spaced levels (ini disebut uniform quantizing)

- 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 mengkompress (compressing) sinyal di sumber
    - Di tujuan dilakukan proses dekompress (expanding)
    - Proses compressing dan expanding disebut companding

Companding


Compressor
Input signal
Out
In
A/D
"Compressed" digital code words
D/A
Expander
Output signal
Out
In



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)

μ-Law ⟶

$$Z(x) = \operatorname{sgn}(x) \cdot \frac{\ln(1 + \mu|x|)}{\ln(1 + \mu)}$$

x : nilai sinyal

Z(x) : sinyal ter-kompress

sgn(x) : polaritas x (+ atau –)

μ : konstanta = 255

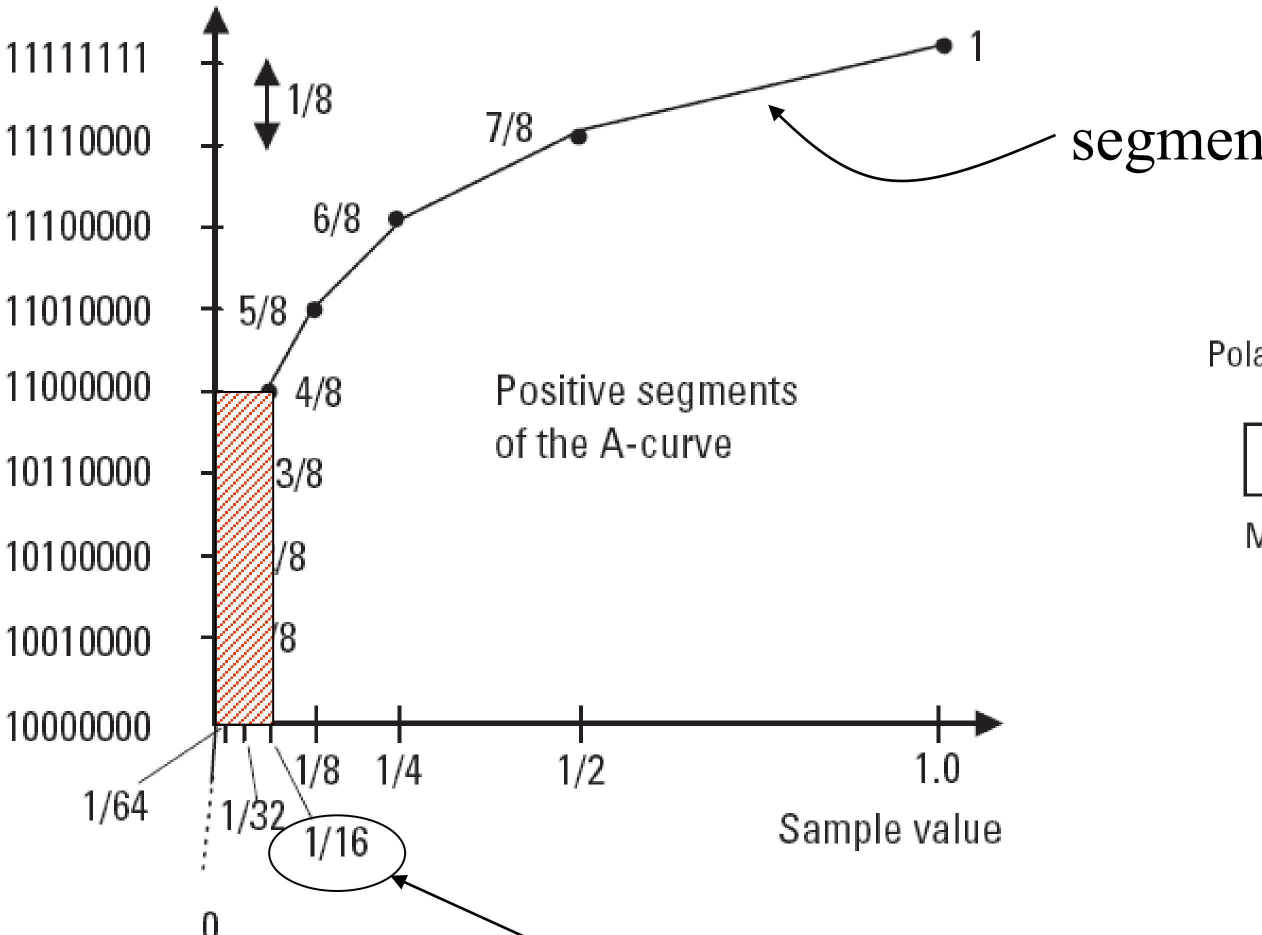
A-Law ⟶

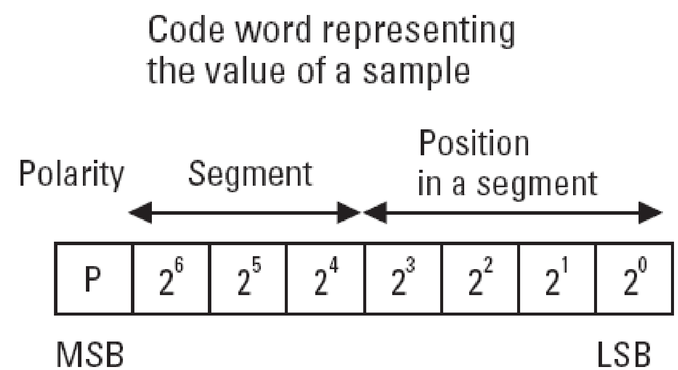
$$Z(x) = \begin{cases} \operatorname{sgn}(x) \cdot \dfrac{1 + \ln A|x|}{1 + \ln A} & \text{for } \dfrac{1}{A} < |x| < 1 \\[2ex] \dfrac{Ax}{1 + \ln A} & \text{for } \dfrac{-1}{A} < x < \dfrac{1}{A} \end{cases}$$

A : konstanta = 87,6

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

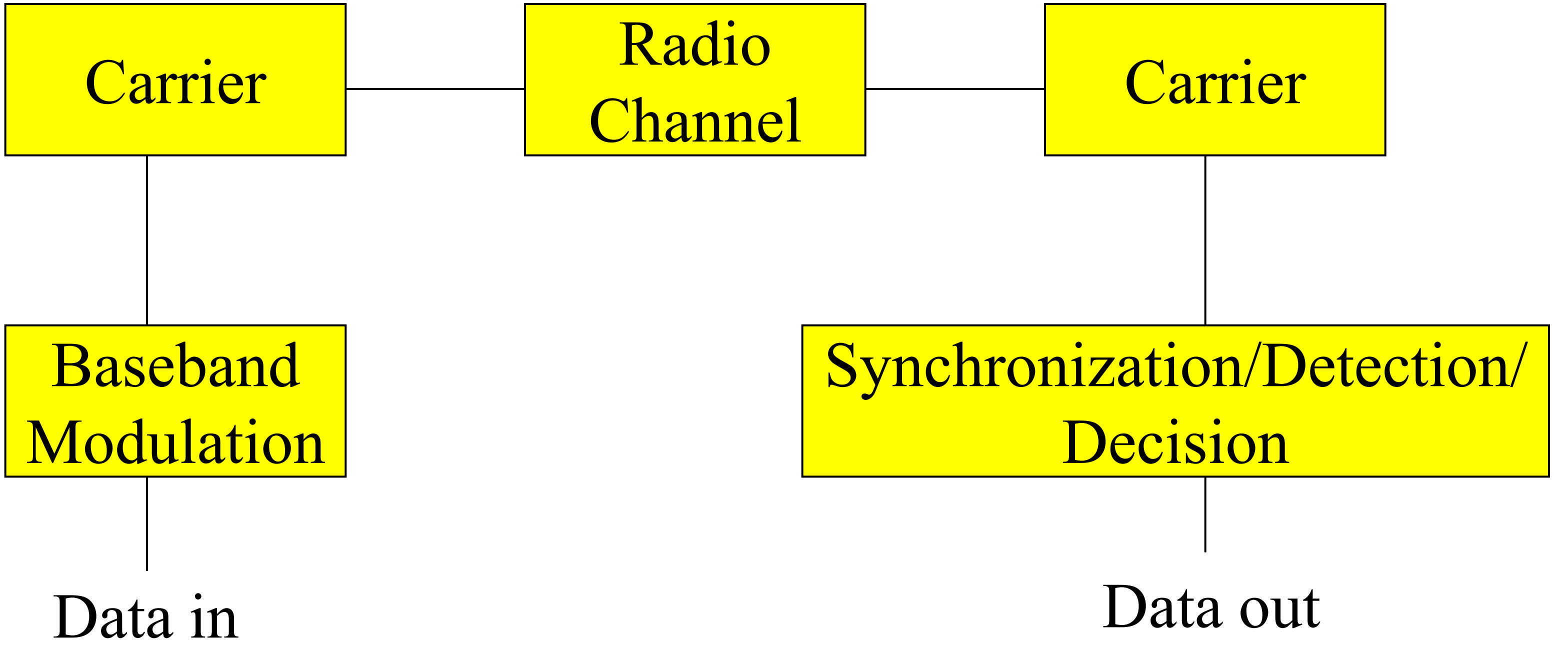
- Contoh untuk kurva A-law





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

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

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

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

- Modulation implies varying one or more characteristics (modulation parameters a_1, a_2, … 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 = const
- ω = const
- φ = const

- Amplitude modulation (AM)
  - $A = A(t)$ – carries information
  - ω = const
  - φ = const

- Frequency modulation (FM)
  - A = const
  - $\omega = \omega(t)$ – carries information
  - φ = const

- Phase modulation (PM)
  - A = const
  - ω = const
  - $\varphi = \varphi(t)$ – carries information