STTTELKOM

Modul #10

TE3113
SISTEM KOMUNIKASI 1

ADC / PCM

(ANALOG TO DIGITAL CONVERTER / PULSE CODE MODULATION)

Program Studi S1 Teknik Telekomunikasi

Departemen Teknik Elektro - Sekolah Tinggi Teknologi Telkom

Bandung – 2007

ADC (ANALOG TO DIGITAL CONVERTER) / PCM (PULSE CODE MODULATION)

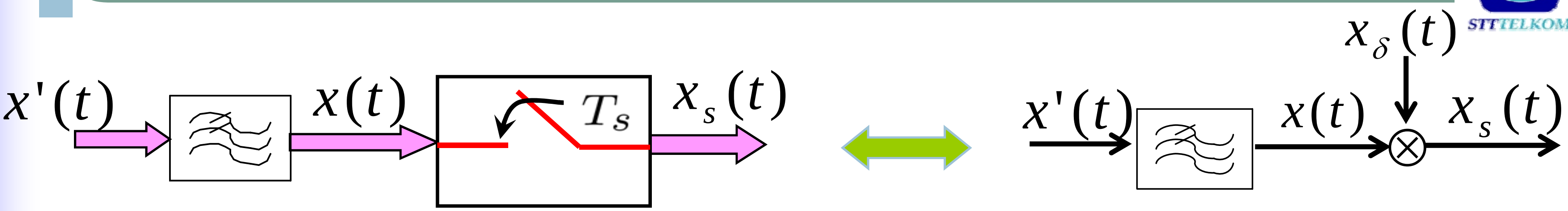
Mengubah sinyal voice analog menjadi sinyal digital

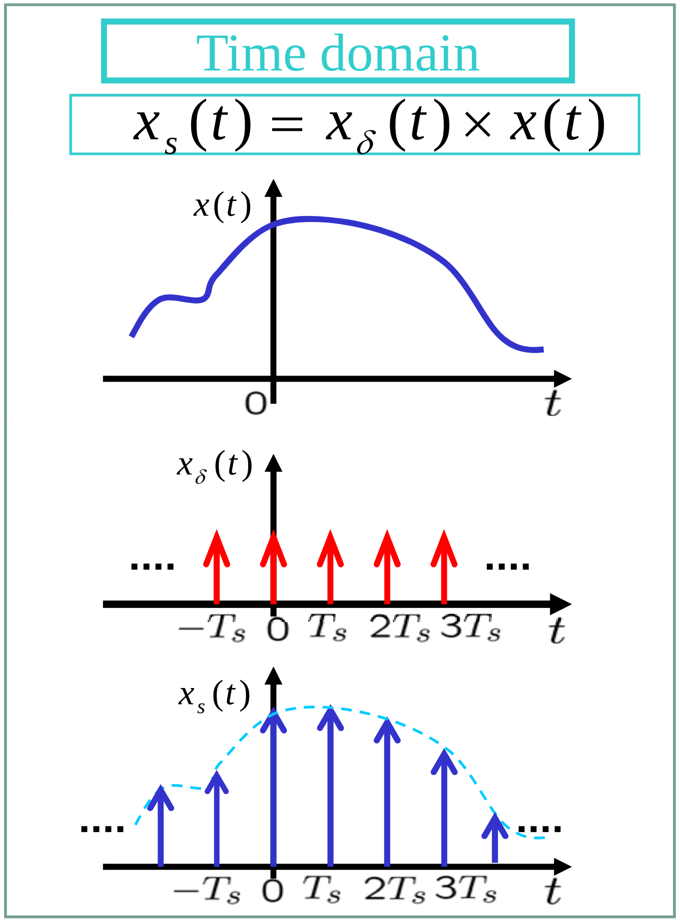
Proses yang terjadi dalam PCM :

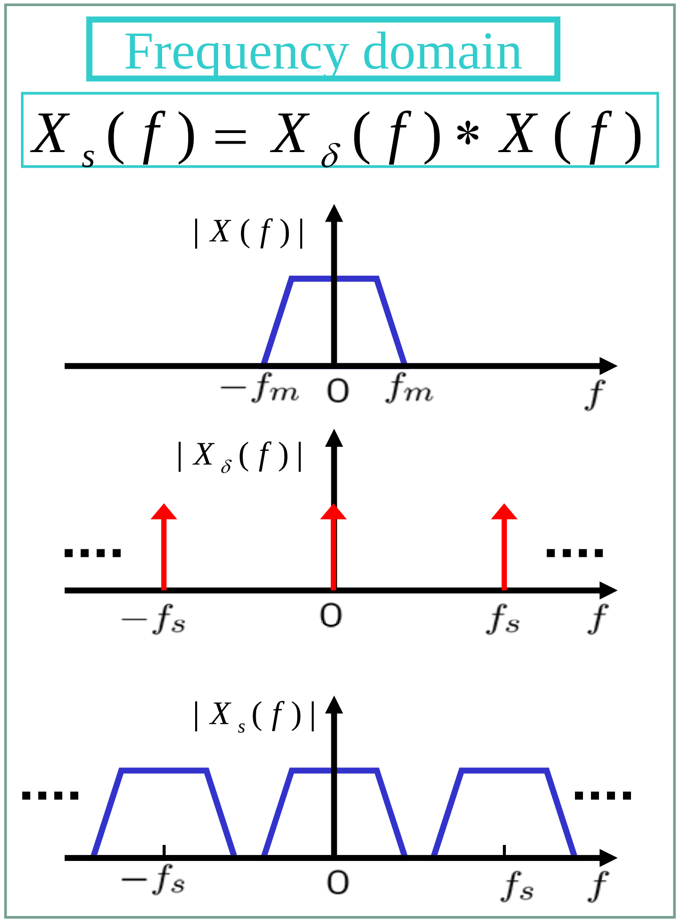
- Sampling (pencuplikan)
- Quantizing (kuantiasasi)
- Encoding (pengkodean)

$\rightarrow$ sampler $\rightarrow$ kuantiser $\rightarrow$ enkoder $\rightarrow$

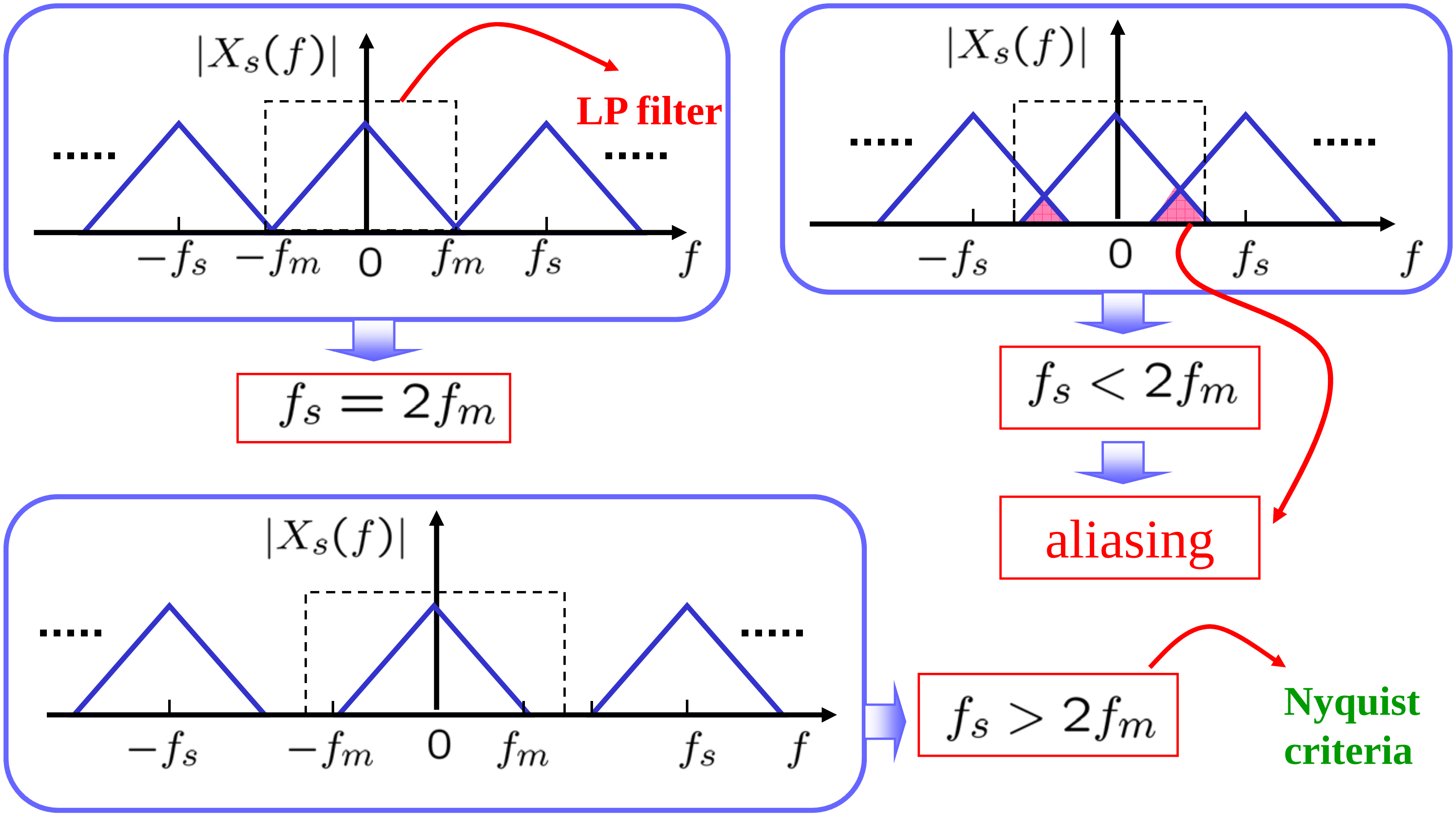
PROSES PENCUPLIKAN (SAMPLING)



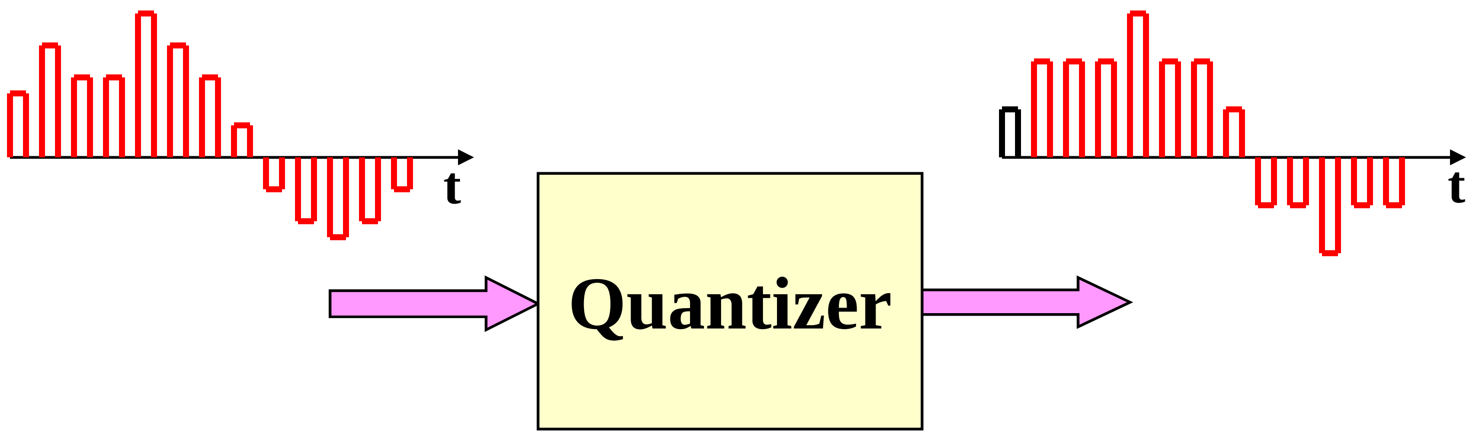




Aliasing effect



PROSES KUANTISASI (QUANTIZATION)



Kuantisasi : mengubah level amplituda menjadi diskret dengan jumlah terbatas.

Jumlah level kuantisasi $M = 2^N$ $\qquad$ N = jumlah bit pengkodean

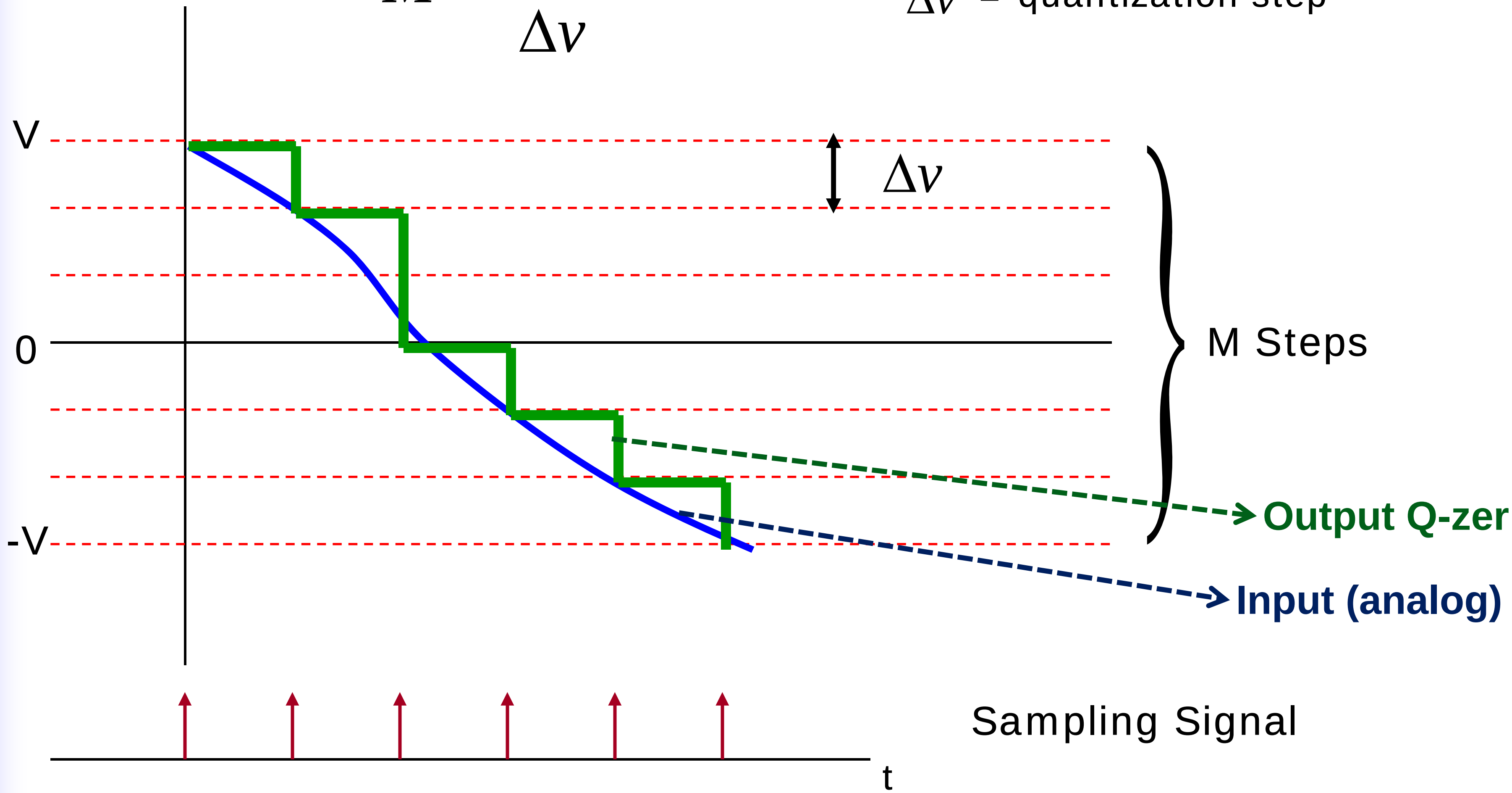
Terdapat 2 jenis kuantiser yaitu :

Kuantiser Uniform (lebar selang kuantisasi seragam)
Kuantiser Non-Uniform (lebar selang kuantisasi tidak seragam)

Quantization

$$M = \frac{2V}{\Delta v}$$

Where M = no. of steps
Δv = quantization step



QUANTISER UNIFORM

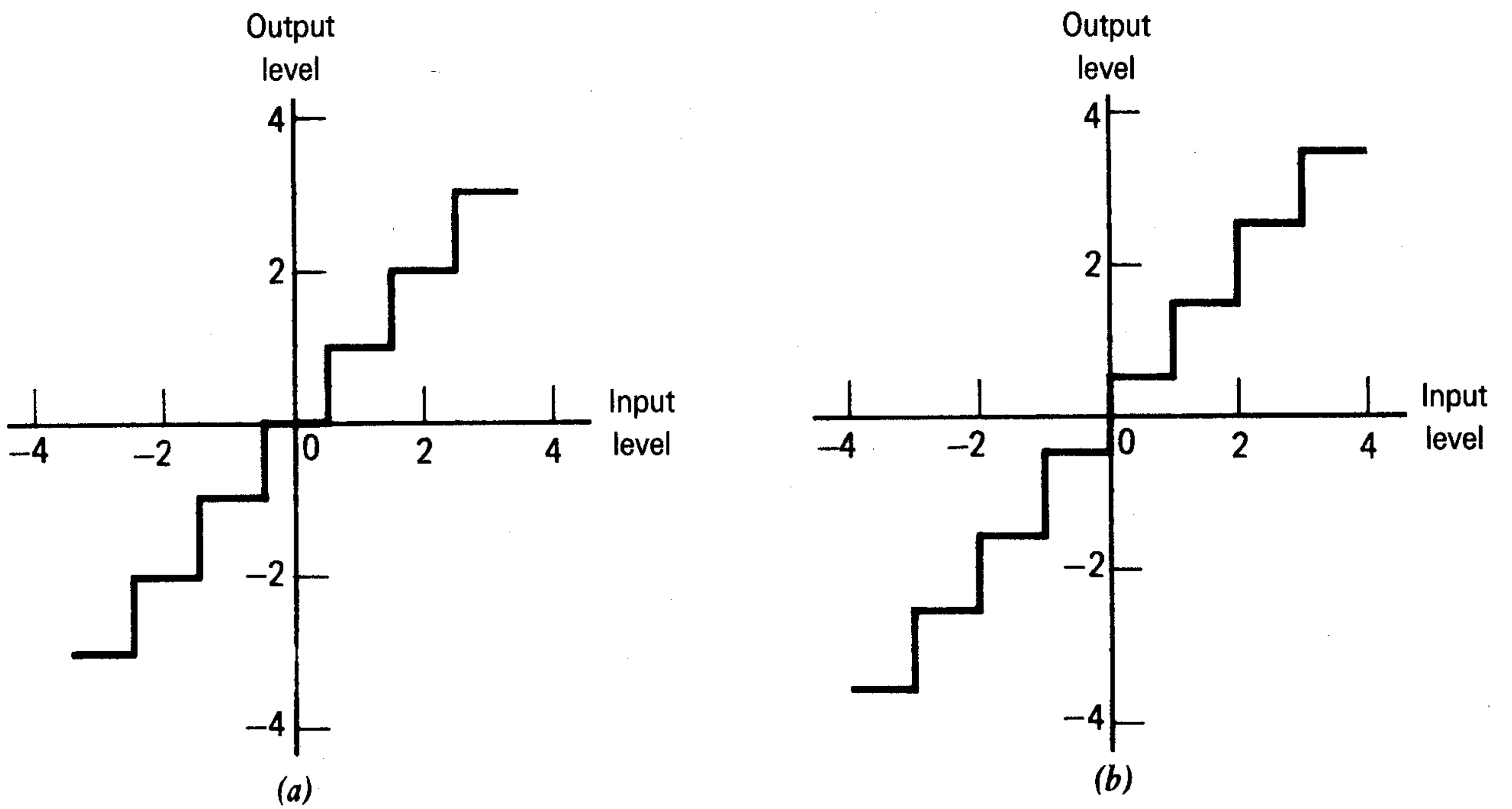
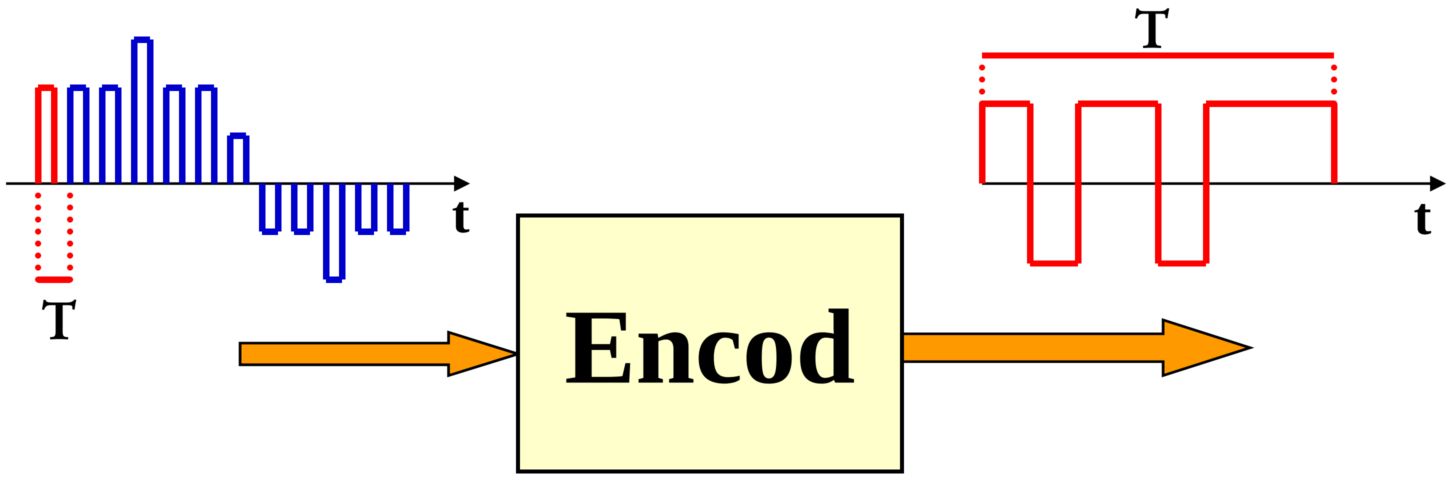


Figure 6.17 Two types of quantization: (*a*) midtread and (*b*) midrise.

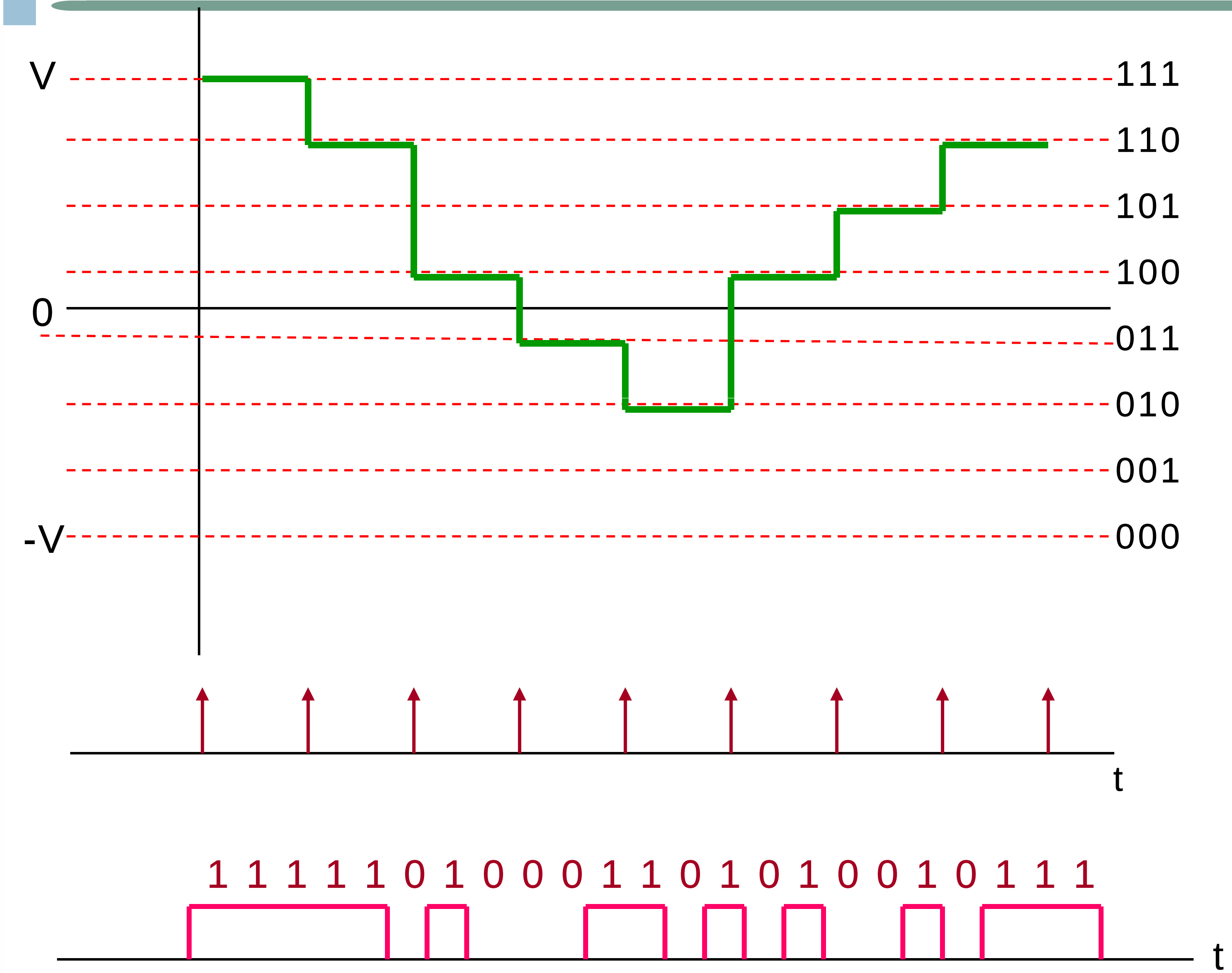
PROSES PENGKODEAN (ENCODING)



Contoh di atas menunjukkan proses encoding,
1 simbol masukan dikodekan menjadi 8 bit

Jumlah bit untuk mengkodekan tiap simbol ditentukan oleh perangkat ADC (Analog to Digital Converter)

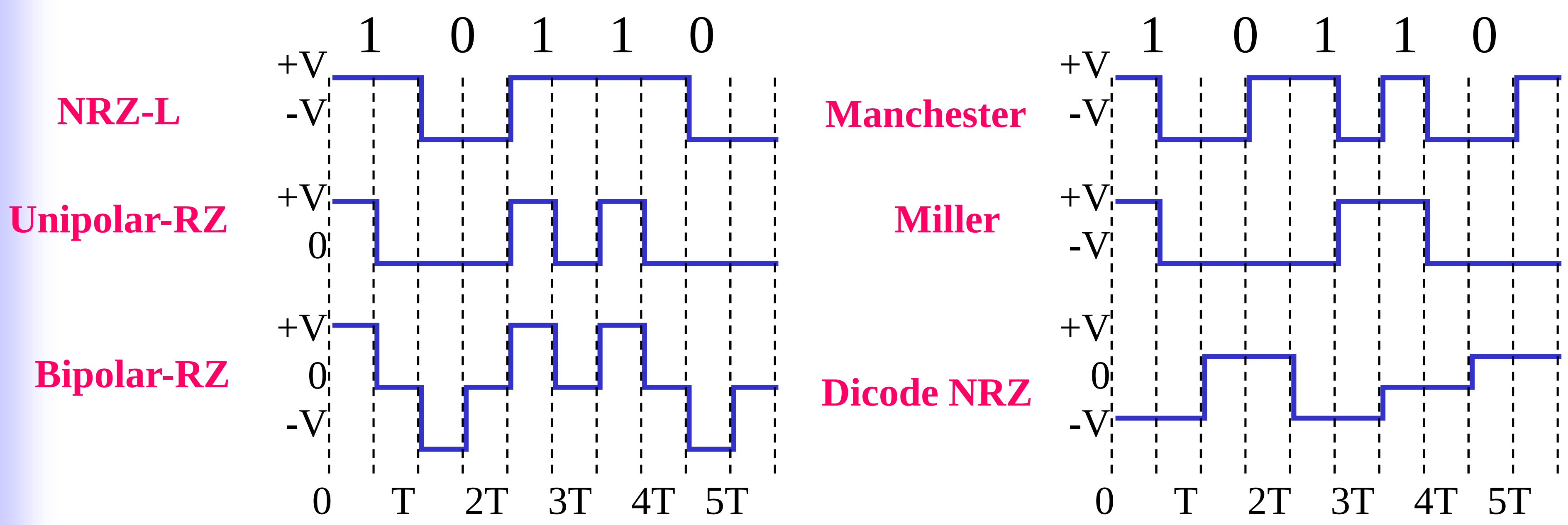
Encoding



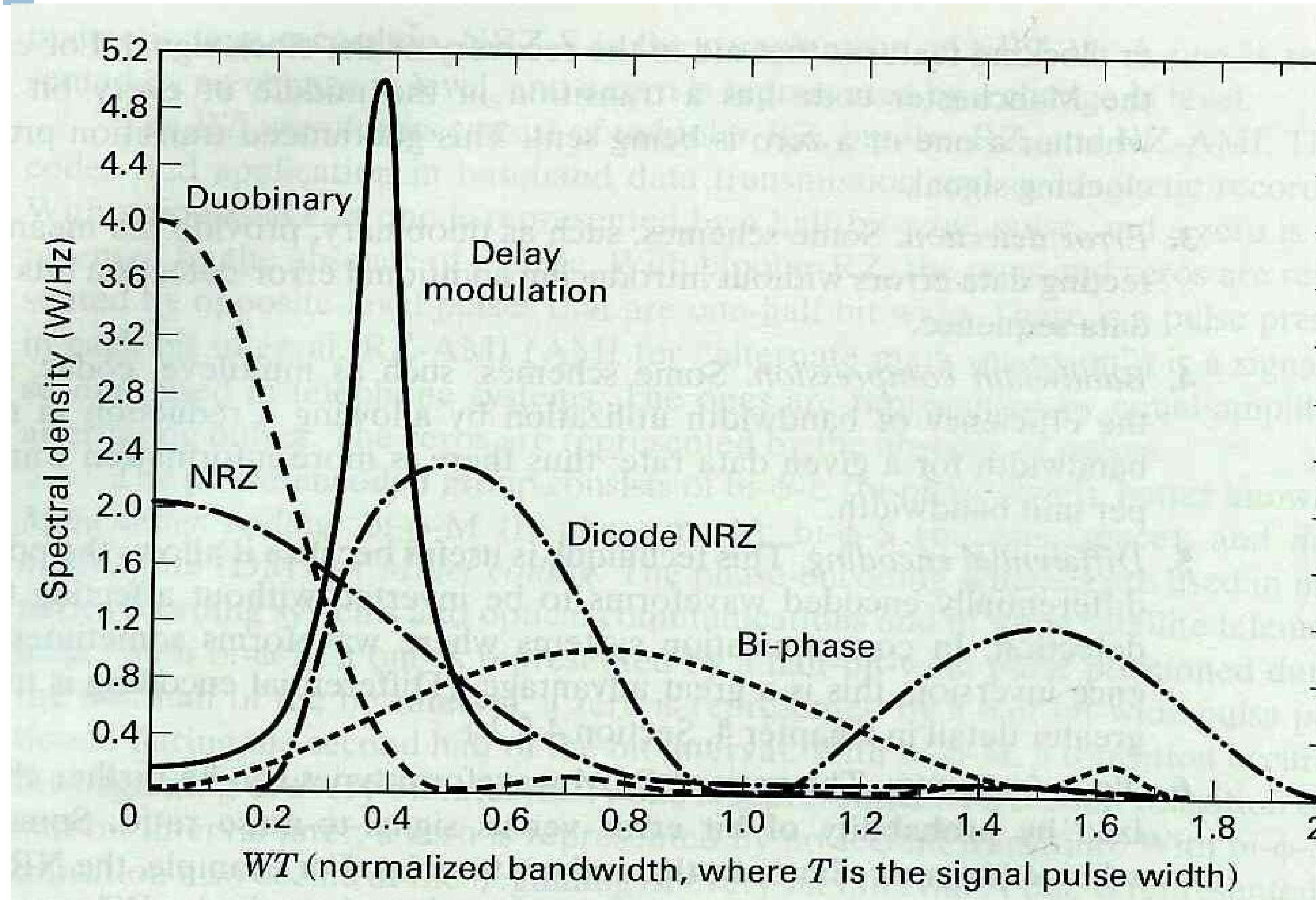
$$M = 2^N$$

Bentuk gelombang/sinyal PCM

- NonReturn-to-Zero (NRZ)
- Return-to-Zero (RZ)
- Phase encoded
- Multilevel binary



Spectrum sinyal PCM



BIT RATE KANAL VOICE

Frekuensi sampling (f_S) > 2 . BW
> 2 . frekuensi informasi maksimum
(berdasarkan kriteria Nyquist)

BW kanal suara ~ 4 kHz (300 – 3400 Hz)
Kecepatan sampling untuk tiap kanal suara = 2 x 4000 = 8000 sample/s
1 sample dikodekan menjadi 8 bit

Bit rate 1 kanal voice :

BR = 8000 sample/detik x 8 bit/sample
= 64 kbps

Quantization Error

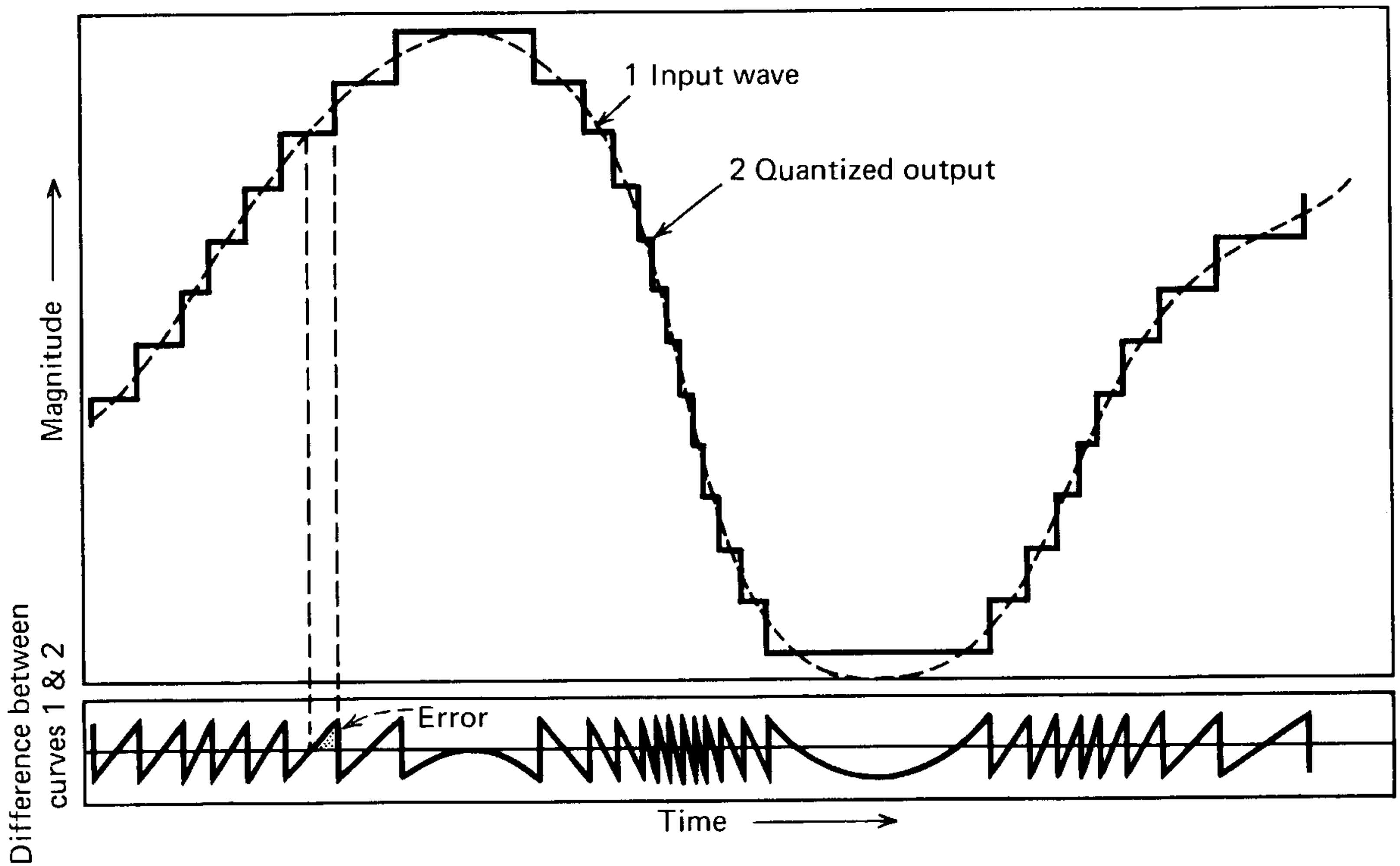
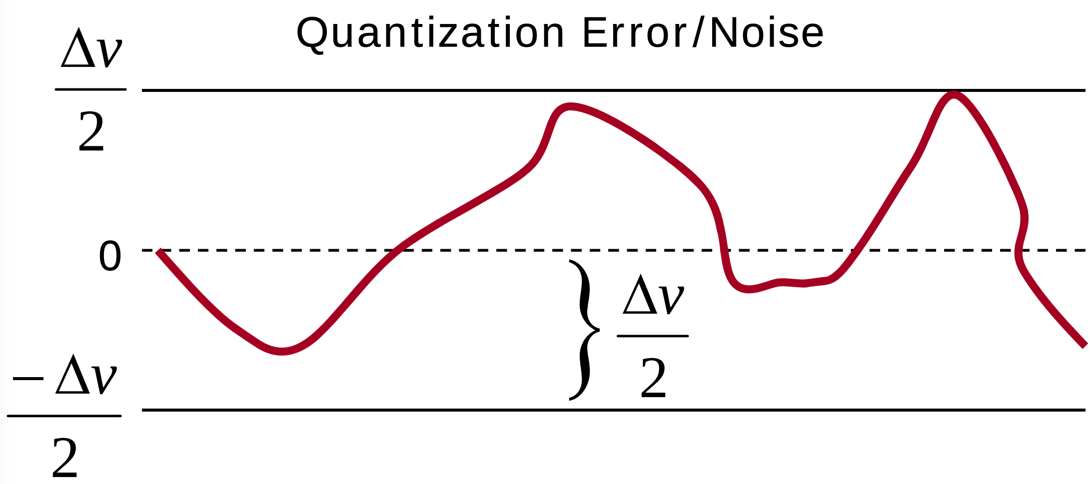
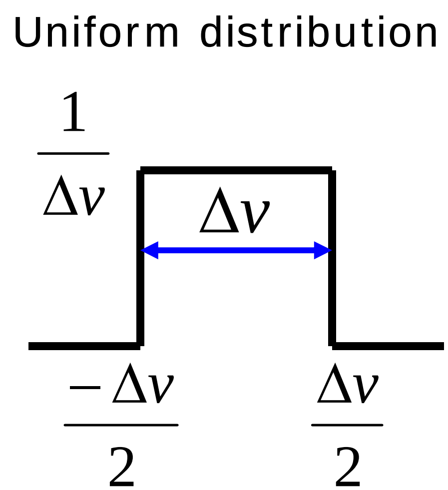


Figure 6.18 Illustration of the quantization process. (Adapted from Bennett, 1948, with permission of AT&T.)

Quantization Error





$$e(t) = f(t) - f_Q(t)$$

$$\frac{-\Delta v}{2} \leq e(t) \leq \frac{\Delta v}{2}$$

Signal to Noise Ratio

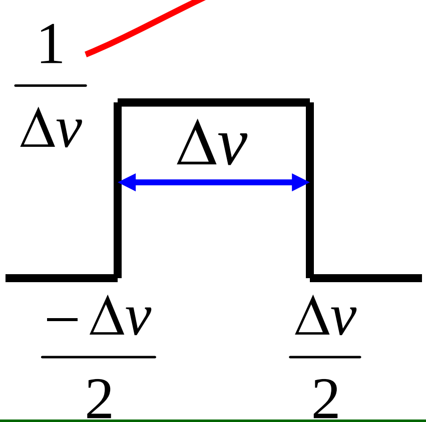
$$SNR\Big|_Q = \frac{SignalPower}{ErrorSignalPower}$$

The average power

$$\overline{P} = \lim_{T\to\infty} \frac{1}{T} \int_{-\infty}^{\infty} f^2(t)\,dt$$

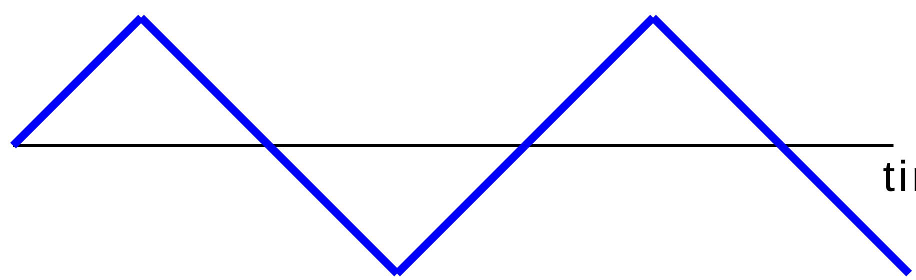
$$\overline{e^2}(t) = \frac{1}{T} \int_{-T/2}^{T/2} e^2(t)\,dt$$

Time average Noise



$$= \int_{-\infty}^{\infty} v^2 p(v)\,dv$$

Continuous Random Variable



Signal to Noise Ratio[1]

$$\overline{e^2}(t) = \int_{-\Delta v/2}^{\Delta v/2} v^2 \frac{1}{\Delta v} dv = \frac{1}{\Delta v}\left[\frac{v^3}{3}\right]_{-\Delta v/2}^{\Delta v/2}$$

$$= \frac{1}{3\Delta v}\left[\frac{\Delta v^3}{8} + \frac{\Delta v^3}{8}\right]$$

$$= \frac{\Delta v^2}{12}$$

$$SNR\big|_Q = \frac{\overline{f^2(t)}}{\overline{e^2}(t)} = \frac{12}{\Delta v^2}\overline{f^2}(t) \qquad ; \Delta v = \frac{2V}{M}$$

$$= \frac{12}{4V^2} M^2 \overline{f^2}(t)$$

$$= \frac{3M^2 \overline{f^2}(t)}{V^2} = \frac{3M^2}{\alpha}$$

where $\alpha = \frac{V^2}{\overline{f^2}(t)} = \frac{PeakPower}{AvgPower}$

Signal to Noise Ratio[2]

$$SNR\big|_Q = \frac{3M^2}{\alpha}$$

In dB $$SNR\big|_Q = 10\log_{10} 3 + 20\log_{10} M - 10\log_{10} \alpha (dB)$$
$$= 4.77 + 20\log_{10} M - 10\log_{10} \alpha (dB)$$

Encoding : each quantization level is encoded into N binary digit

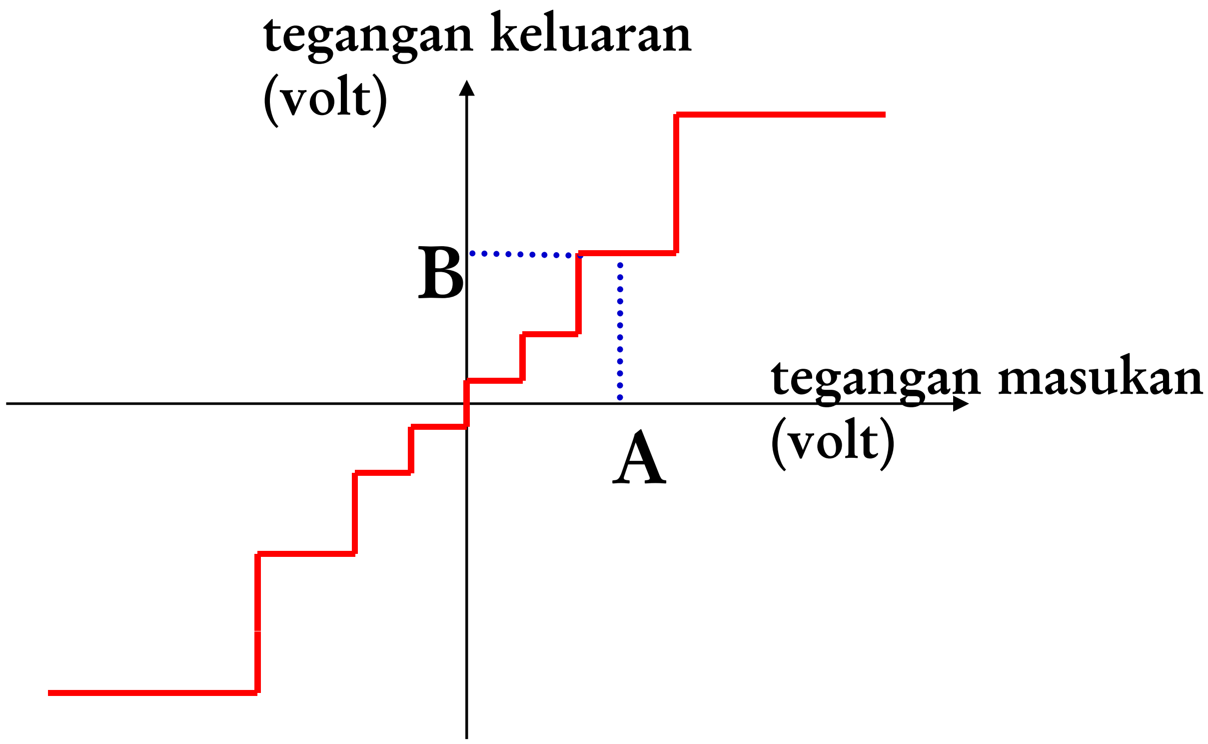
$$\therefore M = 2^N$$

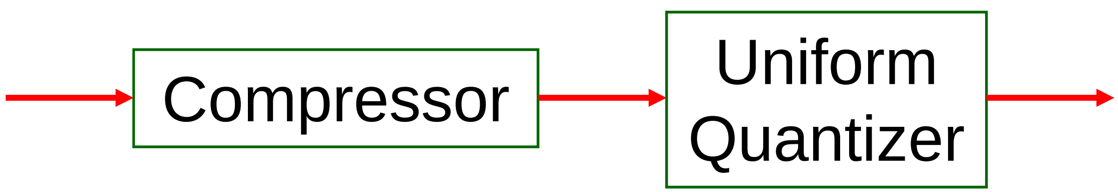
$$\boxed{\log_b a = \frac{\log_{10} a}{\log_{10} b}}$$

$$N = \log_2 M$$ ← No.of level

No.of binary digit
per code word

QUANTISER NON-UNIFORM



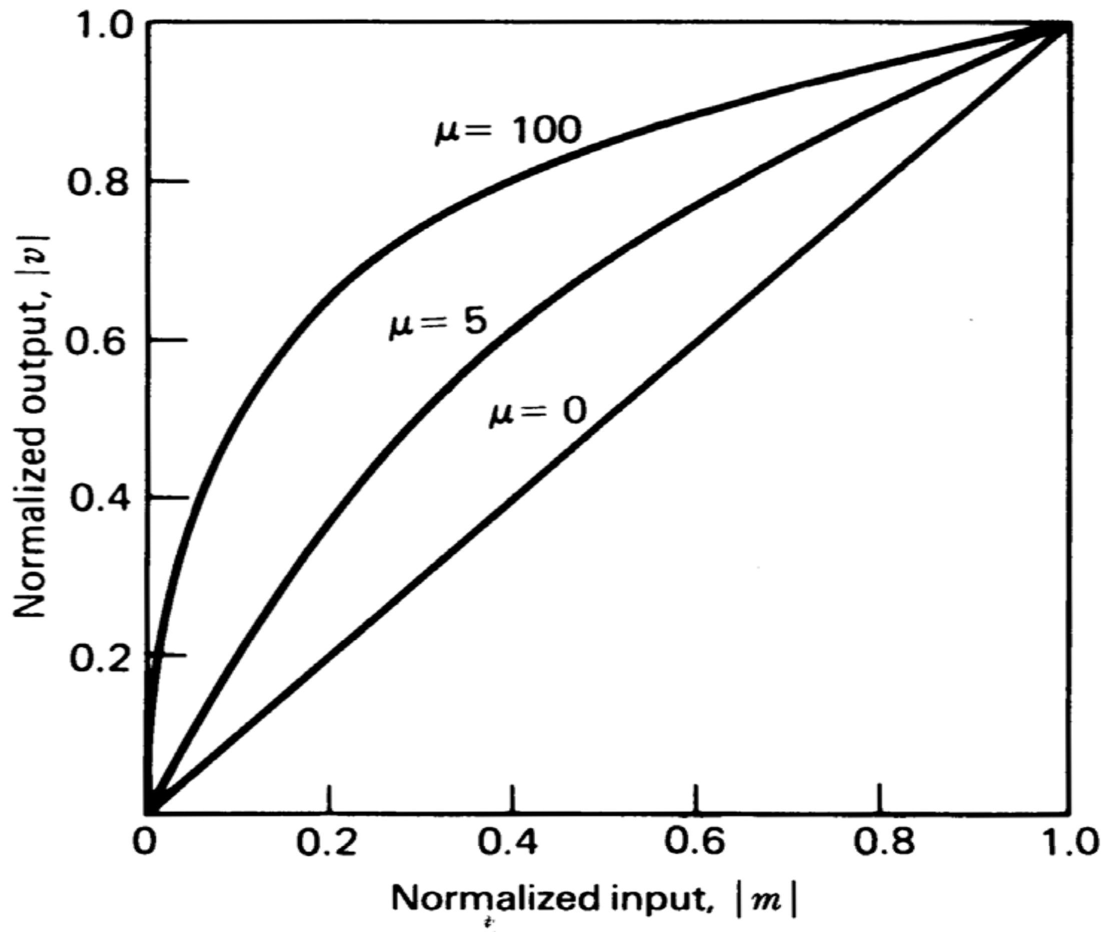


NonUniform / Nonlinear Quantizer

QUANTISER NON-UNIFORM

✶ μ - law $|v| = \dfrac{\log(1+\mu|m|)}{\log(1+\mu)}$ where $\mu > 0$

- if $\mu = 0 \rightarrow$ Uniform Quantizer



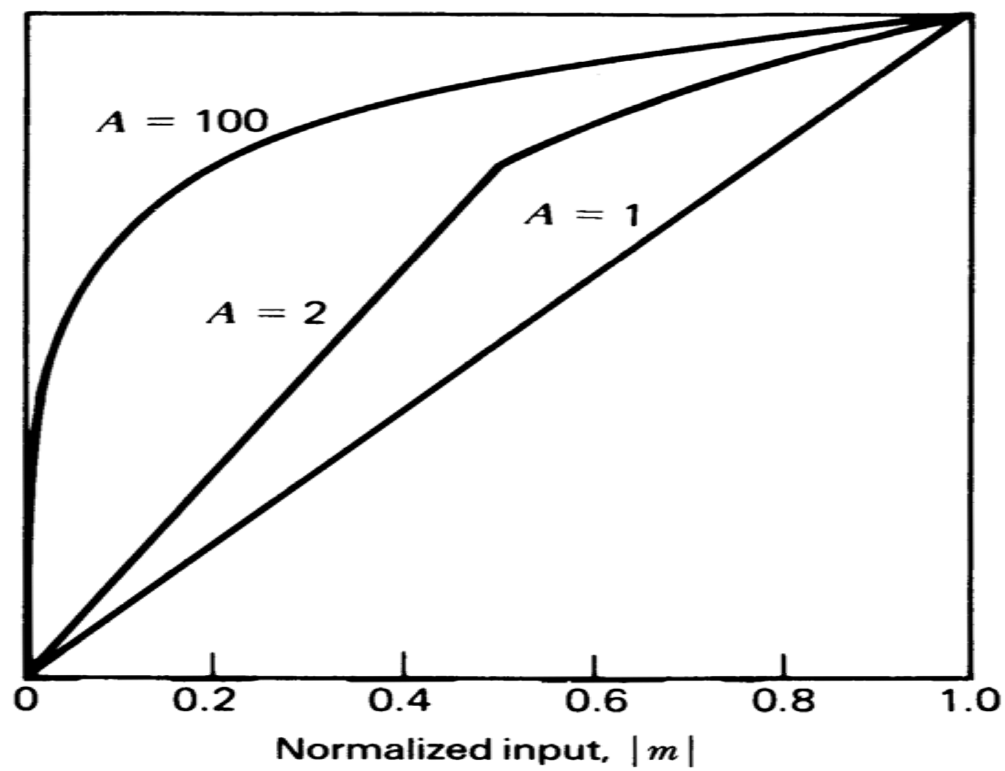
Standard Amerika Utara

QUANTISER NON-UNIFORM

- A - law

$$|v| = \begin{cases} \dfrac{A|m|}{1 + \log A}, & 0 \le |m| \le \dfrac{1}{A} \\ \dfrac{1 + \log(A|m|)}{1 + \log A}, & \dfrac{1}{A} \le |m| \le 1 \end{cases}$$

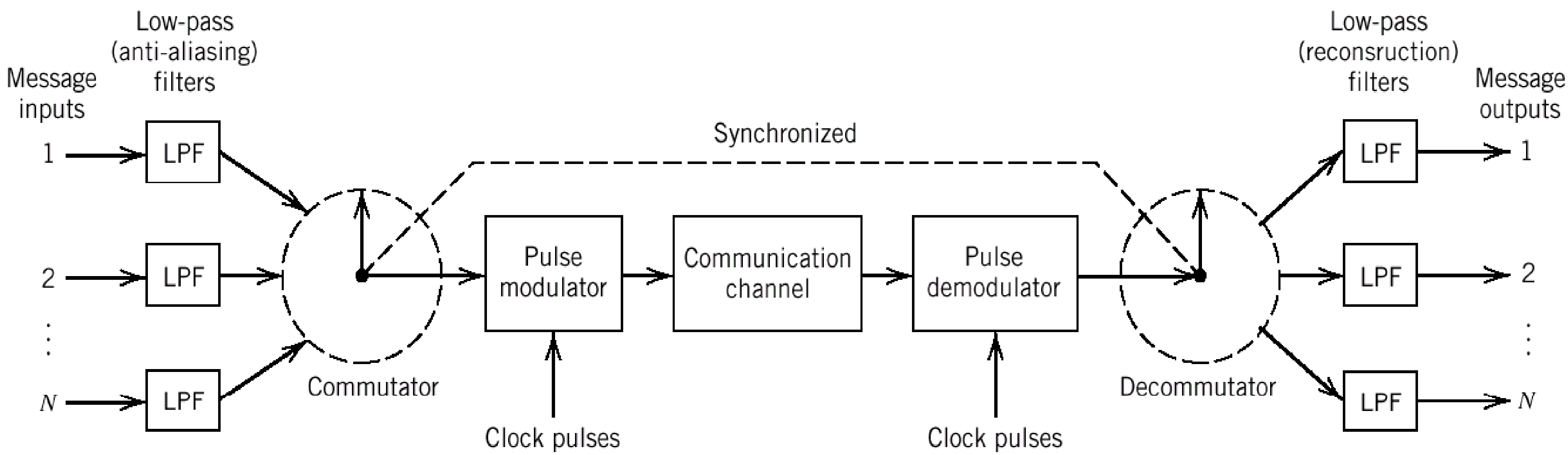
- A = 1 $\rightarrow$ Uniform Quantizer
- Practical value of A $\Rightarrow$ A $\cong$ 100
- Reciprocal slope



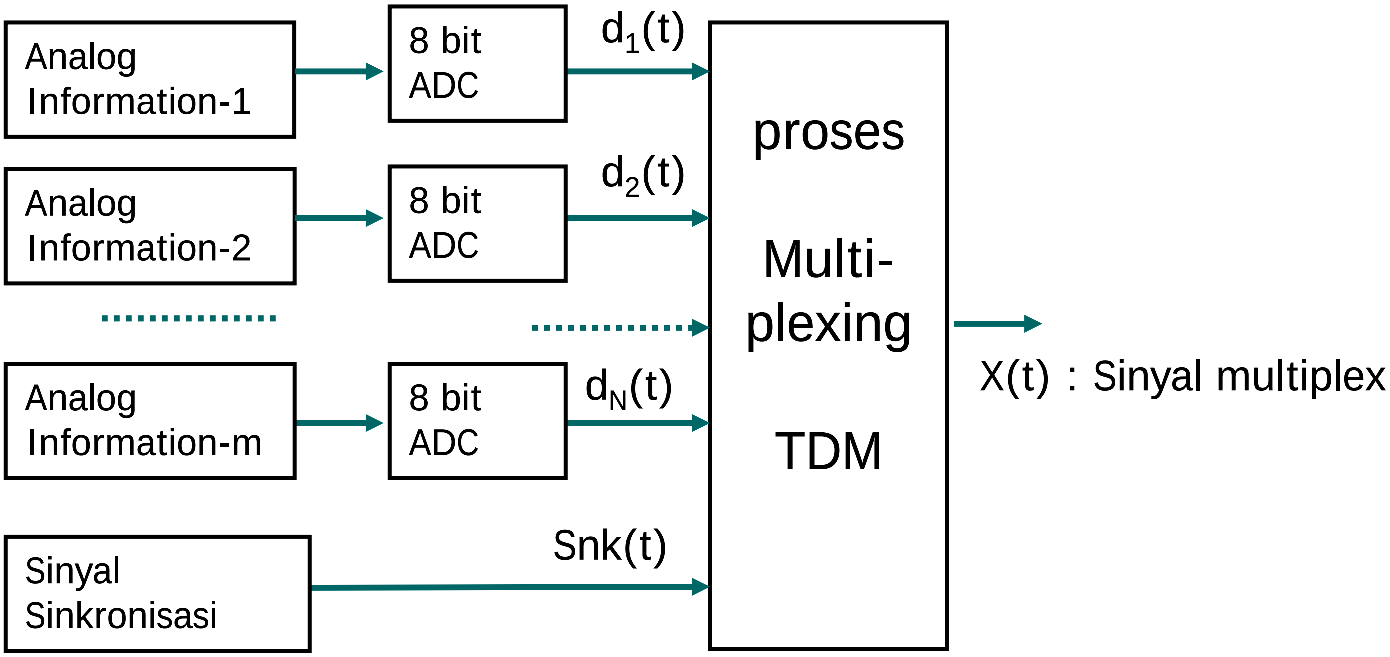
Standard Eropa
(digunakan di Indonesia)

Multiplexing TDM

- Multiplexing merupakan proses penggabungan beberapa kanal sinyal informasi kedalam satu kanal informasi dengan tujuan agar sinyal informasi dapat dikirimkan secara simultan dalam satu kanal
- Time Division Multiplexing merupakan proses multiplexing dengan cara membagi waktu menjadi slot-slot waktu yang menyatakan informasi dari tiap kanal
- TDM – PCM (Time Division Multiplexing – Pulse Code Modulation) merupakan proses multiplexing sinyal yang menggunakan teknik pengkodean PCM



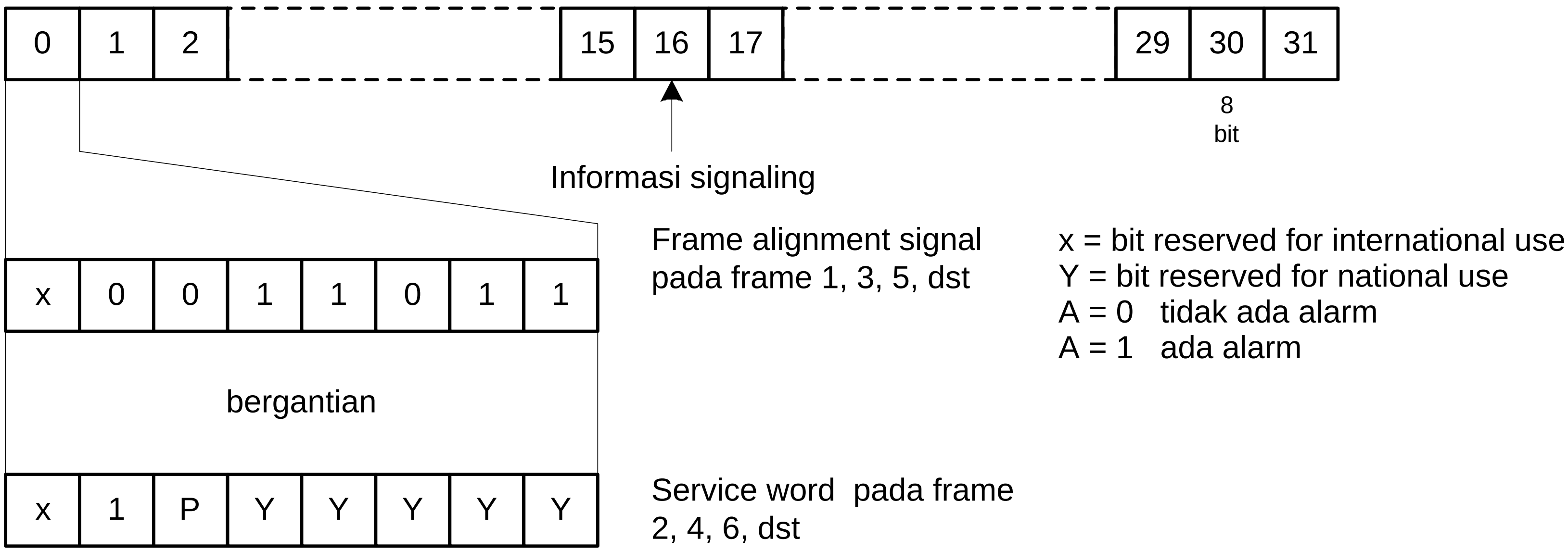
Multiplexing TDM (cont)



Standar TDM yang digunakan Indonesia adalah PCM-30 (E1) yang mampu menggabungkan 30 kanal (masing-masing 64 kbps) menjadi sebuah sinyal multiplek TDM PCM dengan laju 2,048 Mbps

PCM-30 (E-1, Standar Eropa)

1 - 15 dan 17 - 30 adalah sinyal
telephon yang dikodekan/ data digital

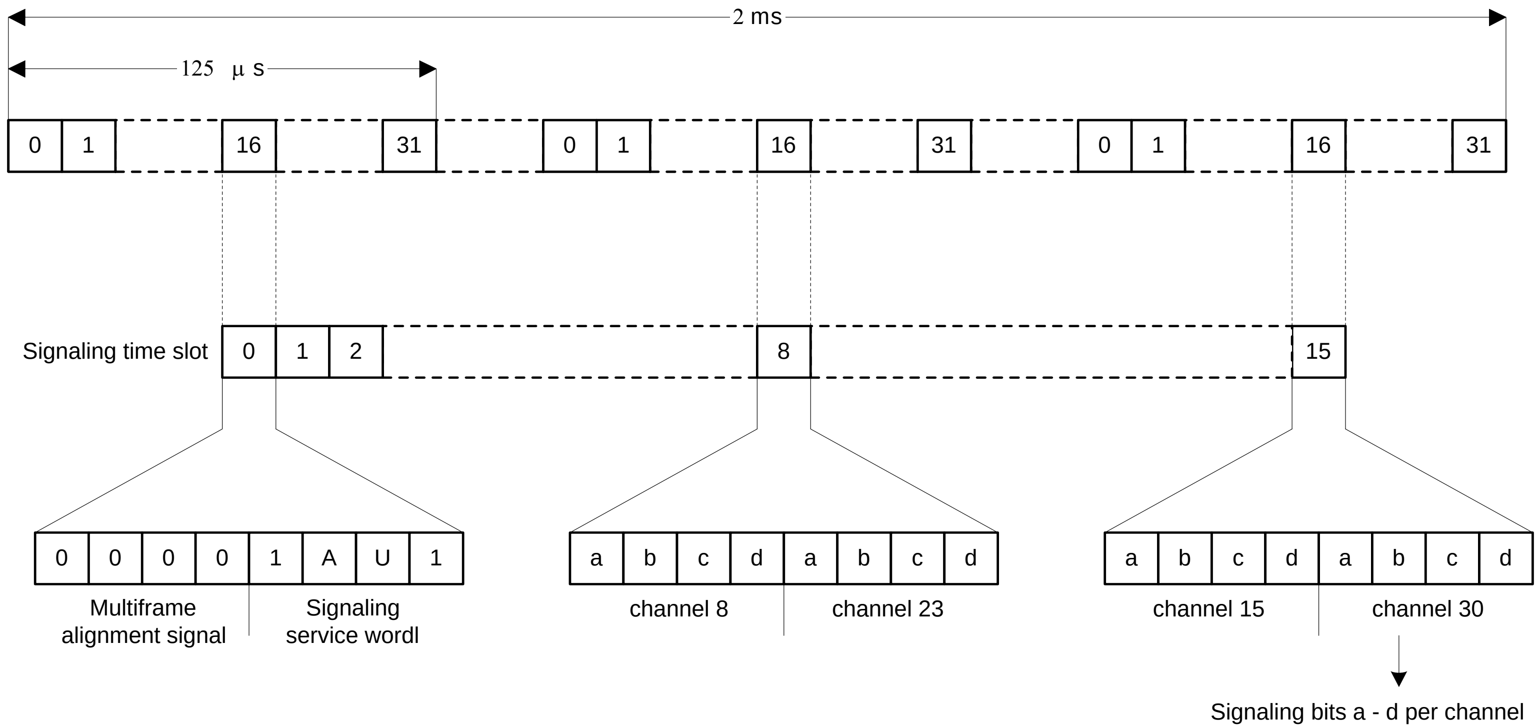


- 1 TS = 8 bit
- Terdiri dari 32 TS = 30 kanal suara + 1 sinkronisasi + 1 signaling

  Sinkronisasi : TS 0
  Signaling : TS 16
  Voice : TS 1 – 15 + TS 17 – 31
- Dalam 1 detik tdp 8000 sample, sehingga :

  Bit rate = (8 x 8000) x 32 = 2048 kbps

Multiframe PCM-30

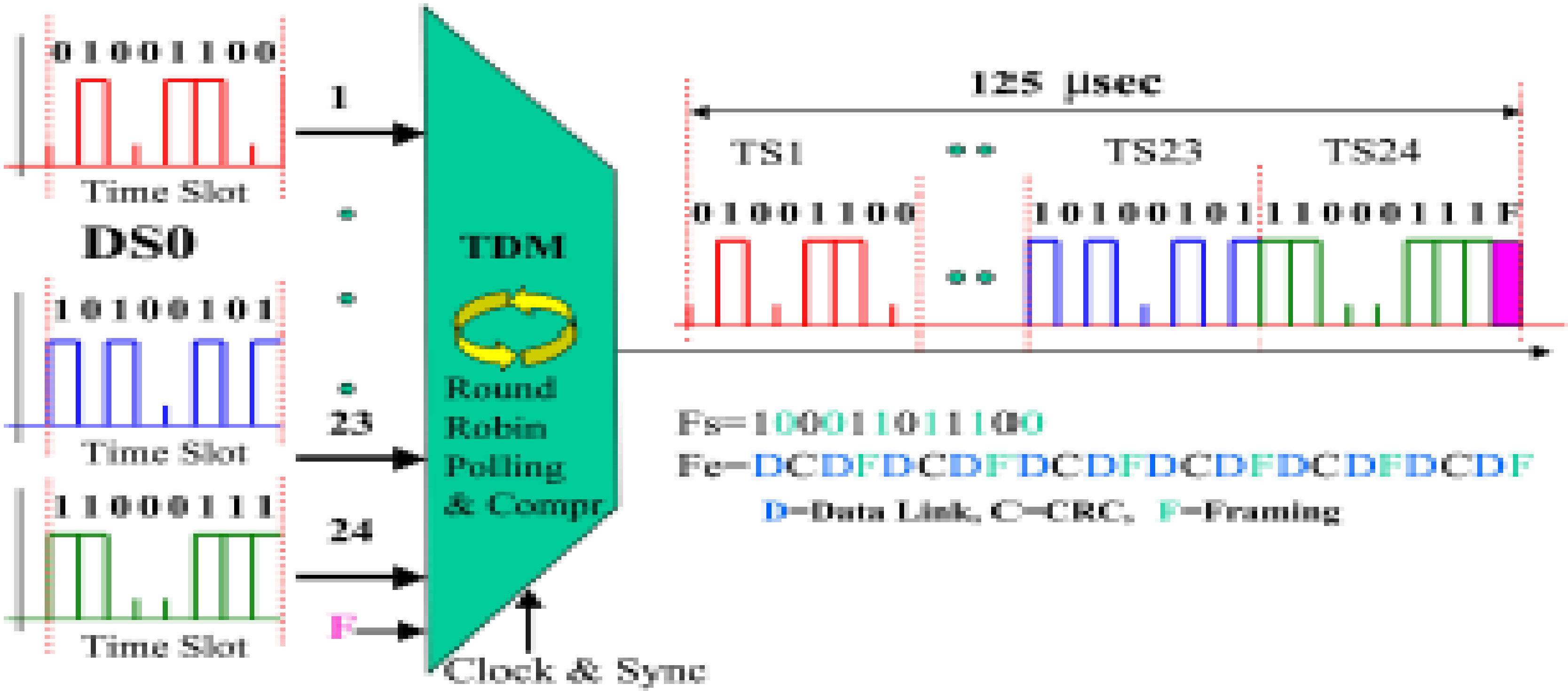


A = 0
U = 1 Tidak ada Alarm

A = 1 urgent alarm
U = 0 non urgent alarm

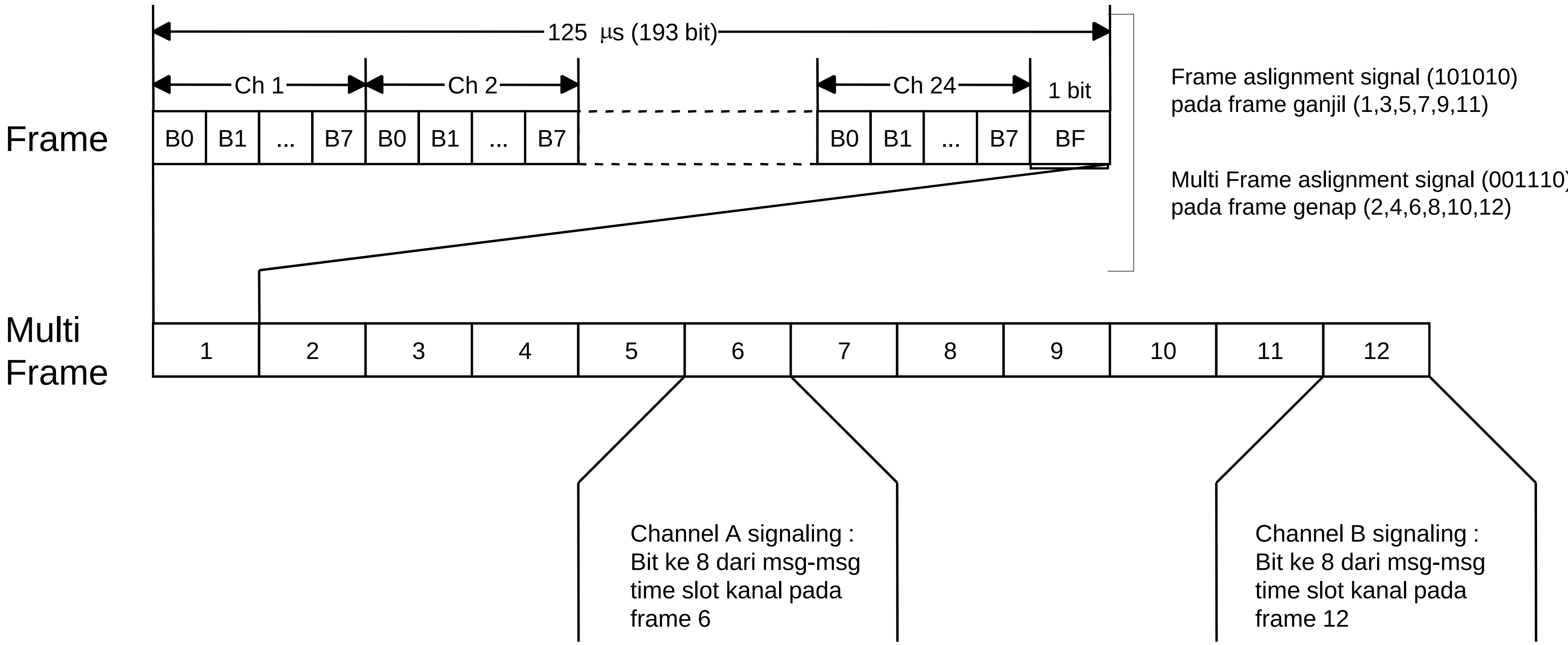
- 1 MF = 16 frame
- Signaling lengkap untuk 30 kanal voice (1 TS 16 untuk signaling 2 kanal voice)
- TS-16 untuk frame ke-0 digunakan untuk alignment / sinkronisasi multiframe

PCM-24 (T-1, Standar Amerika)



- **T1 (DS-0) System**
  - 24 voice channels are time-division multiplexed
  - Each voice signal is sampled at a rate of 8000 samples/sec. (sample duration = 125 μsec)
  - Each sample is quantized in amplitude into one of 256 levels (8 bits are used to represent each level)
  - T1 rate = (24*8 + 1)/125 μsec = 1.544 Mbps

PCM-24 (T-1, Standar Amerika)



- 1 TS = 8 bit
- Terdiri dari 24 TS = 24 kanal suara Dalam 1 detik tdp 8000 sample
- Sinkronisasi menggunakan 1 bit tambahan (=BF)
- Signaling diambil pada bit ke-8 tiap TS pada frame ke-6 dan kelipatannya
- Bit Rate = ((24 x 8) + 1) x 8000 = 193 x 8000 = 1544 kbps
- 1 MF = 12 frame

Perbandingan 3 standar (Amerika, Eropa, Jepang)

Level	Eropa	Amerika Utara	Jepang
	Bit Rate (Mbps)		
1	2.048	1.544	1544
1C	-	3.152	-
2	8.448	6.312	6.312
3	34.368	44.736	32.064
4	139.264	274.176	97.728
5	564.992		400.352

- 1.544 Mbps = T1 = PCM-24 (Amerika)
- 2.048 Mbps = E-1 = PCM-30 (Eropa)
- Standar Jepang kurang populer
- Indonesia menggunakan sistem Eropa
- Internasional menggunakan Standard **PCM-30**

Encoder (Konverter) Line coding

	Two wire BW kecil (misal kabel telepon)	Two wire BW sedang (misal kabel 2 Mbps)	Coaxial
Output Line coding	Rate kecil : bipolar , AMI , HDB-3 , B6ZS	Rate kecil / sedang : bipolar , AMI , HDB-3 , B6ZS	bilpolar , AMI , HDB-3 , B6ZS
	Rate sedang / besar : Sinyal multi level	Rate besar : sinyal multi level	

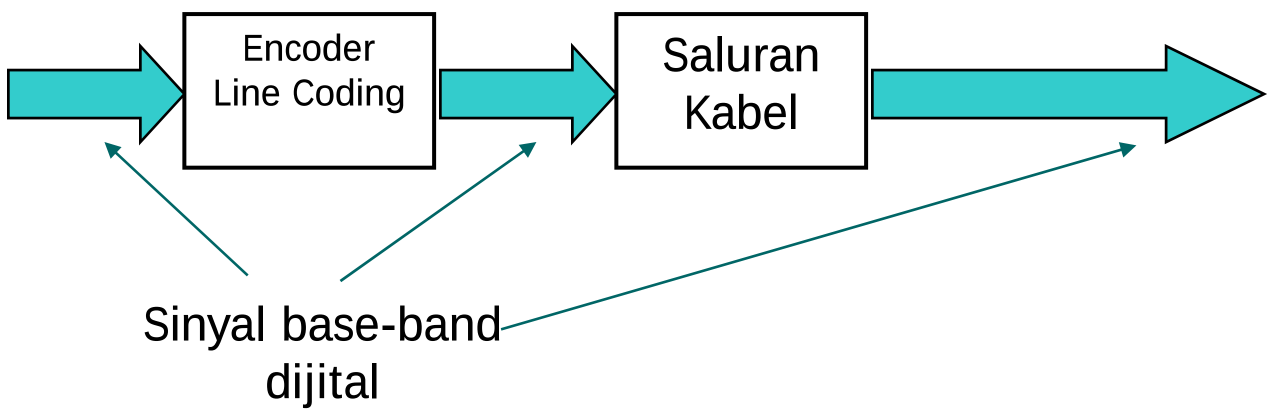
-output ADC

- sinyal TDM

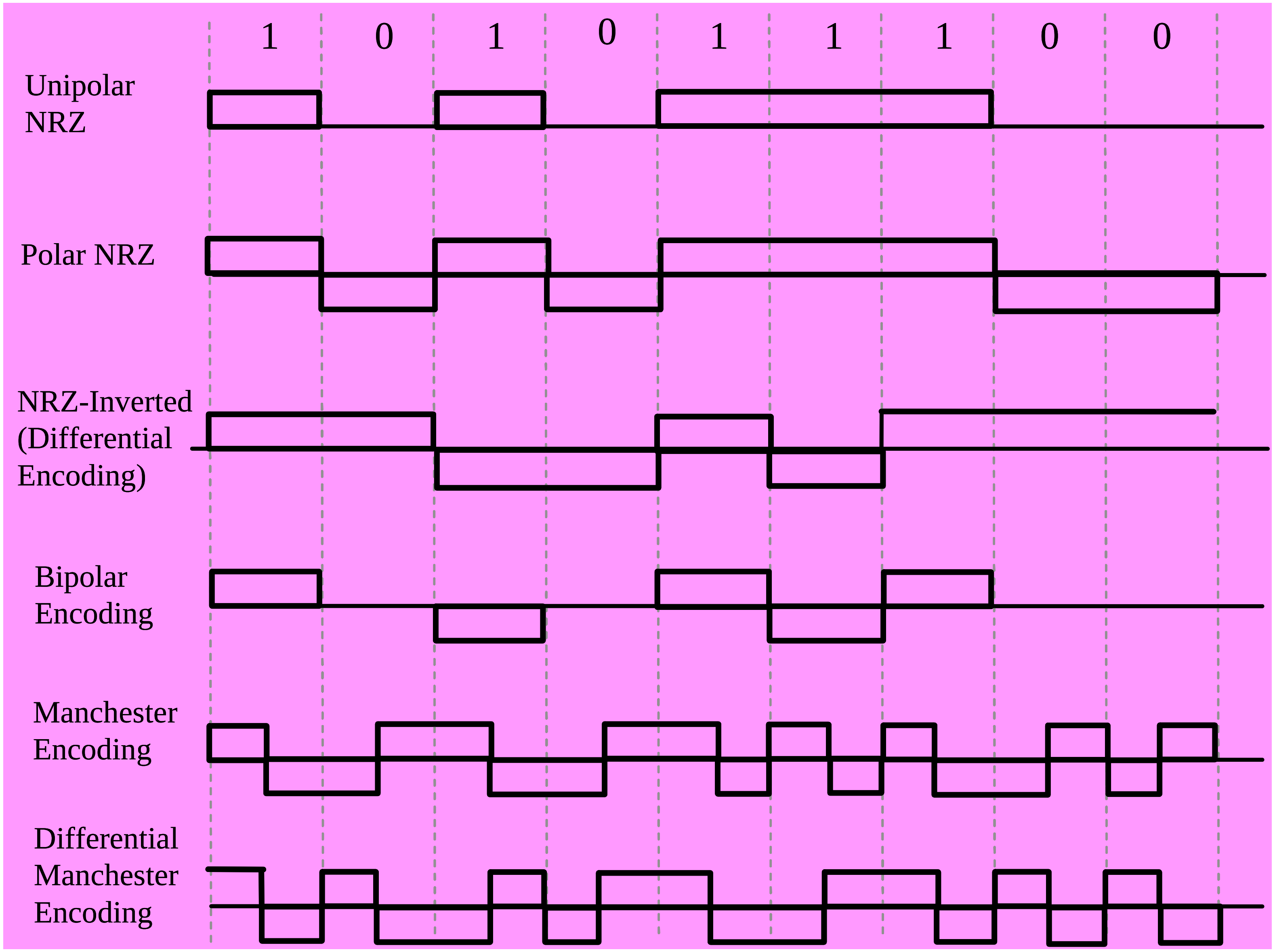
-Sinyal data text

-Output scrambler

-Output FEC



Line coding


1 0 1 0 1 1 1 0 0
Unipolar NRZ
Polar NRZ
NRZ-Inverted (Differential Encoding)
Bipolar Encoding
Manchester Encoding
Differential Manchester Encoding

Line Coding:Bipolar-AMI vs HDB3 dan B8ZS

- Deretan panjang nol dikodekan sbg ketidakadaan sinyal yg panjang. Clock receiver dpt kehilangan sync.
- Deretan nol yg panjang diganti dg pelanggaran (violation) transisi sinyal yang
  - Menghasilkan transisi sinyal yg cukup utk clock resynchronization,
  - Mengkodekan jumlah nol muncul