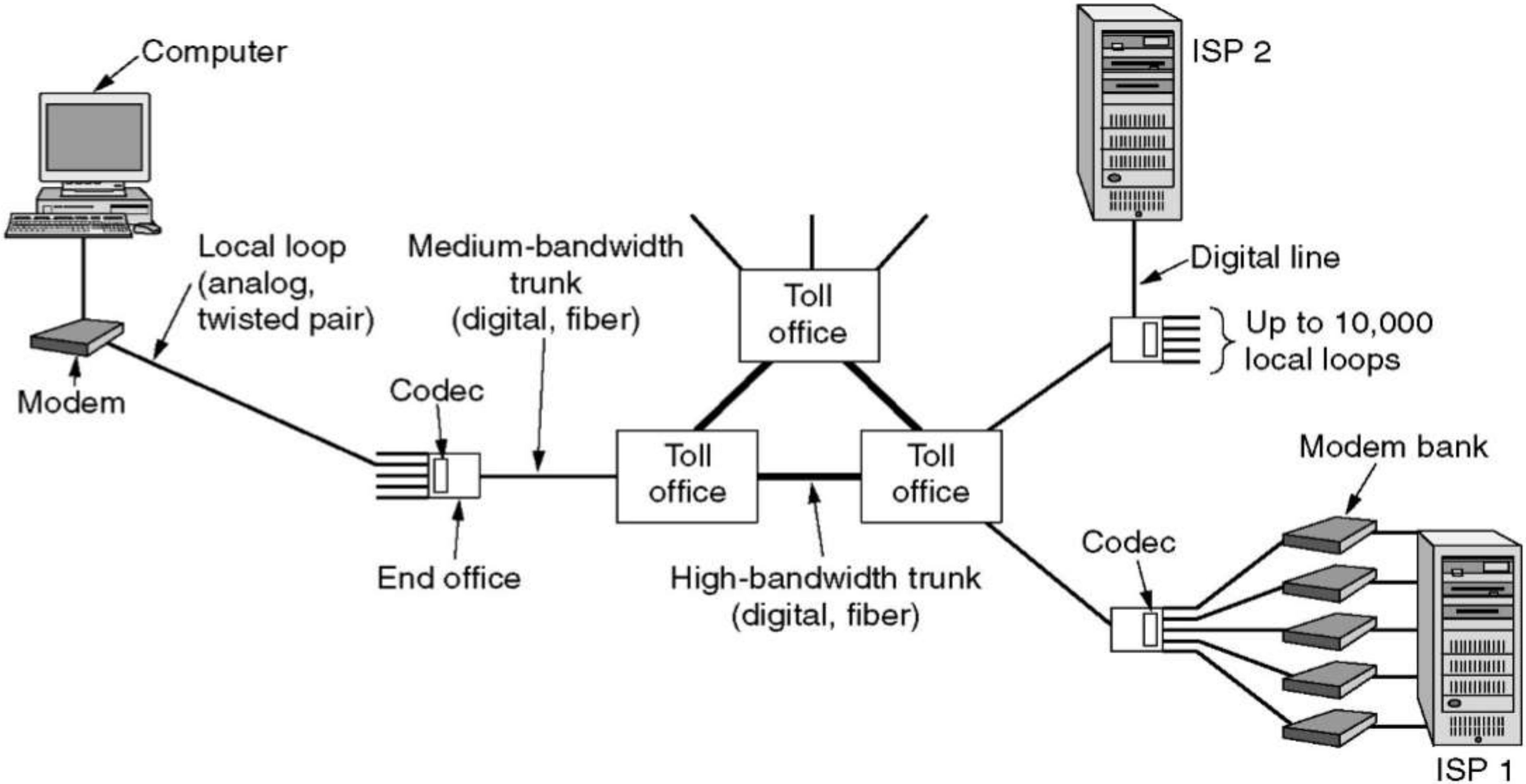
ENCODING TECHNIQUES

Analog and Digital Transmissions



- The use of both analog and digital transmissions for a computer to computer call. Conversion is done by the modemsand codecs.

Data Encoding Techniques

- Digital Data, Analog Signals [modem]
- Digital Data, Digital Signals [wired LAN]
- Analog Data, Digital Signals [codec]
  - Frequency Division Multiplexing (FDM)
  - Wave Division Multiplexing (WDM) [fiber]
  - Time Division Multiplexing (TDM)
  - Pulse Code Modulation (PCM) [T1]
  - Delta Modulation

Digital Data, Analog Signals

- **[Example –modem]**
- Basis for analog signaling is a continuous, constant

  -frequency signal known as the carrier frequency
- Digital data is encoded by modulating one of the three characteristics of the carrier

  amplitude,

  frequency, or

  phaseor some combination of these.

Encoding & Modulation

- Interpreting signals at receiver needs to know
  - Timing of bits
  - when they start and end
  - Signal levels

Factors affecting successful interpreting of incoming signals:

- Signal to noise ratio: increased SNR decreases error rate
- Data rate: increased data rate increases error rate
- Bandwidth: increased bandwidth allows increasing data rate
- Encoding schema

Data Encoding/Modulation Evaluation Factors

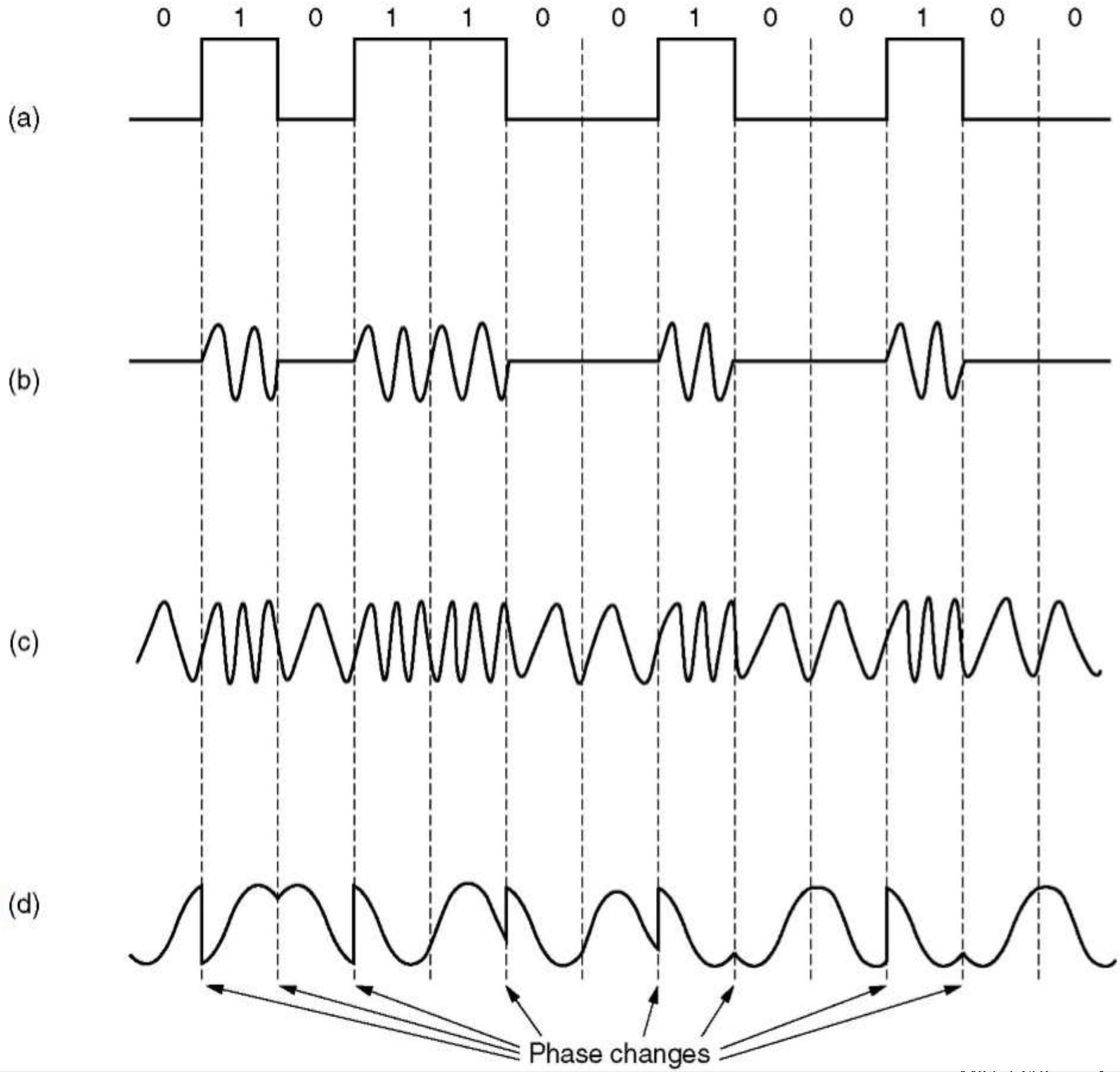
- **Signal Spectrum**
  - Lack of high frequencies reduces required bandwidth
  - Lack of dc component is desirable, i.e. it should be avoided
  - Concentrate power in the middle of the bandwidth
- **Clocking, i.e. synchronizing transmitter and receiver**
  - External clock
  - Sync mechanism based on signal
- **Error detection**
  - Can be built into signal encoding
- **Signal interference and noise immunity**
  - Some codes are better than others
- **Cost and complexity**
  - Higher signal rate (& thus data rate) lead to higher costs
  - Some codes require signal rate greater than data rate

A binary signal

Amplitude modulation

Frequency modulation

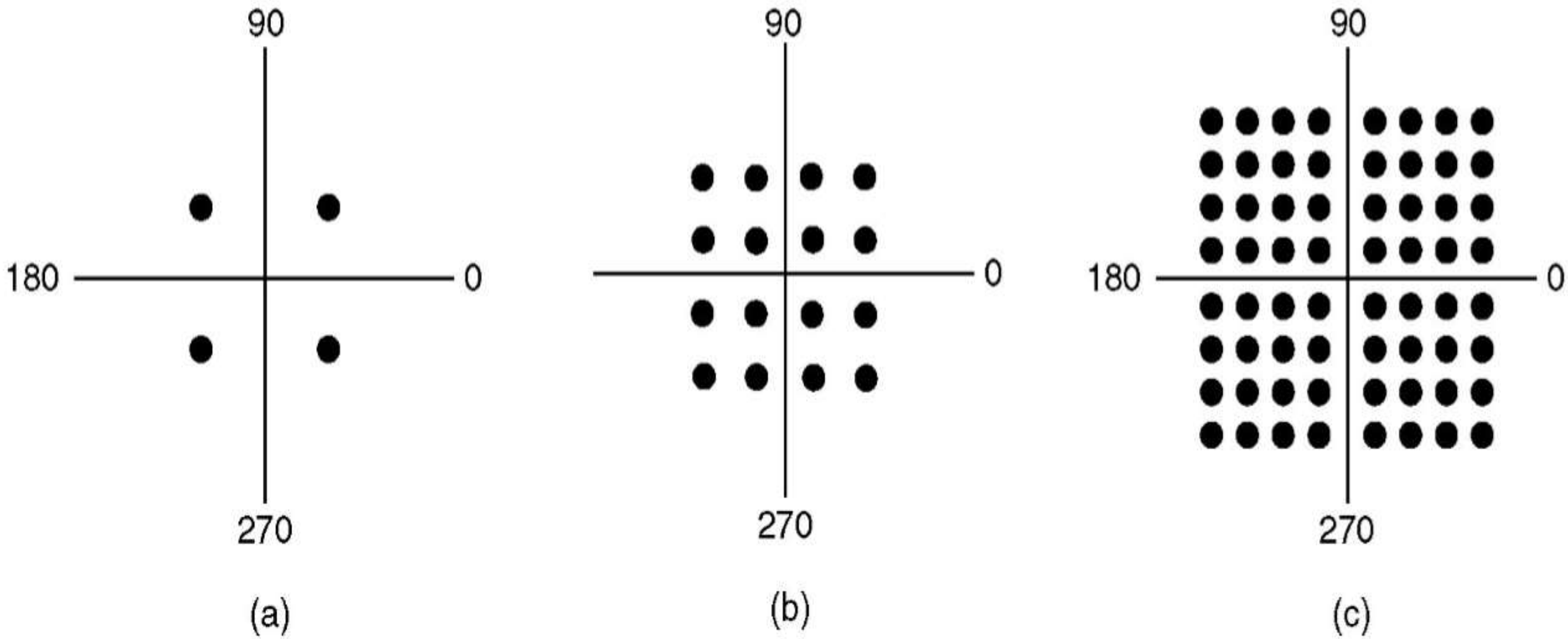
Phase modulation



Modems

- All advanced modems use a *combination of modulation techniques* to transmit multiple bits per baud.
- Multiple amplitude and multiple phase shifts are combined to transmit several bits per symbol.
- **QPSK (Quadrature Phase Shift Keying)** uses multiple phase shifts per symbol.
- **Modems** actually use **Quadrature Amplitude Modulation (QAM).**
- These concepts are explained using constellation points where a point determines a specific amplitude and phase.

Constellation Diagrams



(a) QPSK. (b) QAM-16. (c) QAM-64.

Digital Data, Digital Signals

[the technique used in a number of LANs]

- Digital signal – is a sequence of discrete, discontinuous voltage pulses.
- Bit duration :: the time it takes for the transmitter to emit the bit.
- Issues
  - Bit timing
  - Recovery from signal
  - Noise immunity

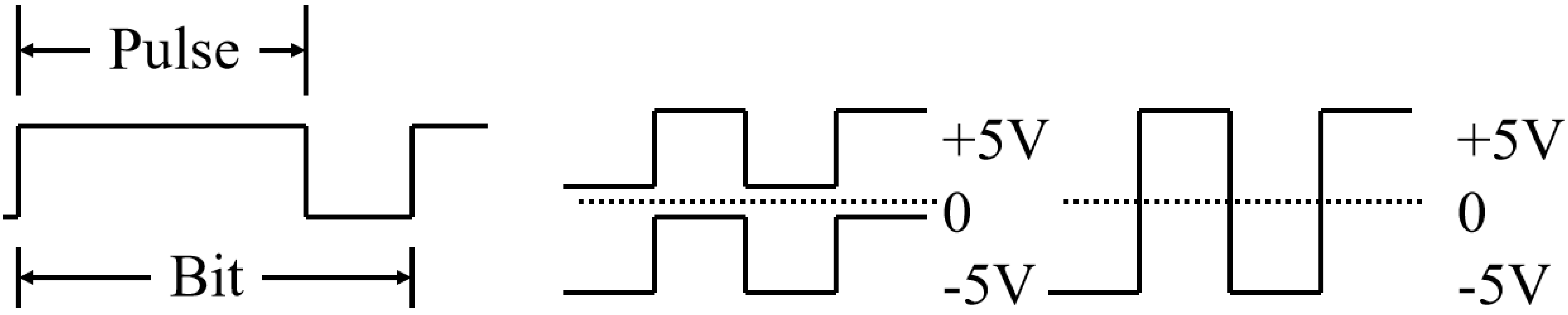
Terminology

- **unipolar** – all signal elements have the same sign
- **polar –** one logic state represented by positive voltage and the other by negative voltage
- **data rate** – rate of data (R) transmission in bits per second
- **duration or length of a bit –** time taken for transmitter to emit the bit (1/R)
- **modulation rate –** rate at which the signal level changes, measured in baud = signal elements per second.

• Encoding schemas:

- – Nonreturn to Zero-Level (NRZ-L)
- – Nonreturn to Zero Inverted (NRZI)
- – Bipolar -AMI
- – Pseudoternary
- – Manchester
- – Differential Manchester
- – B8ZS
- – HDB3
- NRZ techniques
- Multilevel binary techniques
- Biphase techniques Scrambling

Coding Terminology



- **Signal element**: Pulse (of constant amplitude, frequency, phase)
- **Unipolar**: All positive or All negative voltage
- **Bipolar**: Positive and negative voltage
- **Mark/Space**: 1 or 0
- **Modulation Rate**: 1/Duration of the smallest element =Baud rate
- **Data Rate**: Bits per second
- Data Rate = Fn(Bandwidth, signal/noise ratio, encoding)

NRZ (Non-Return-to-Zero) Codes

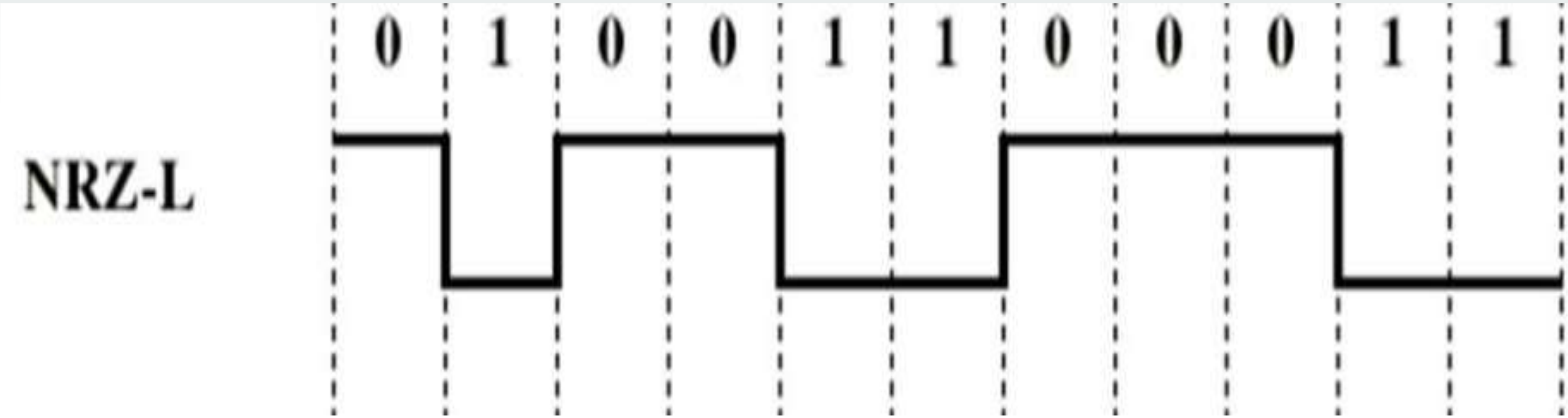
Uses two different voltage levels (one positive and one negative) as the signal elements for the two binary digits.

NRZ-L (Non-Return-to-Zero-Level)

The voltage is constant during the bit interval.

1	$\Leftrightarrow$	negative voltage
0	$\Leftrightarrow$	positive voltage

NRZ-L *is used for short distances between terminal and modem or terminal and computer.*



0 1 0 0 1 1 0 0 0 1 1
NRZ-L

NRZ (Non-Return-to-Zero) Codes

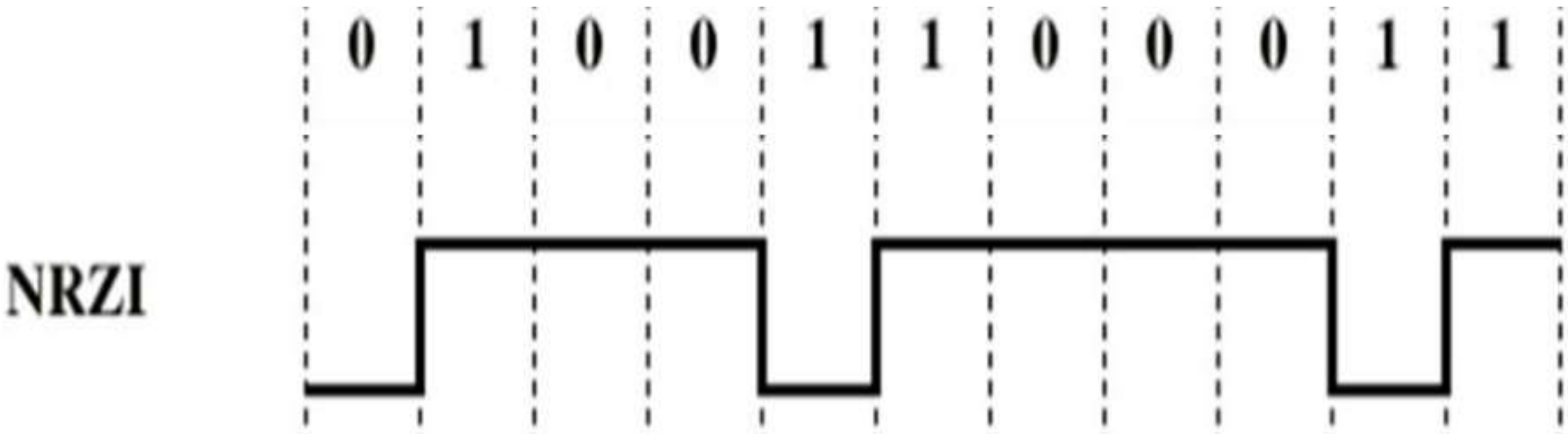
NRZ-I (Non-Return-to-Zero-Invert on ones)

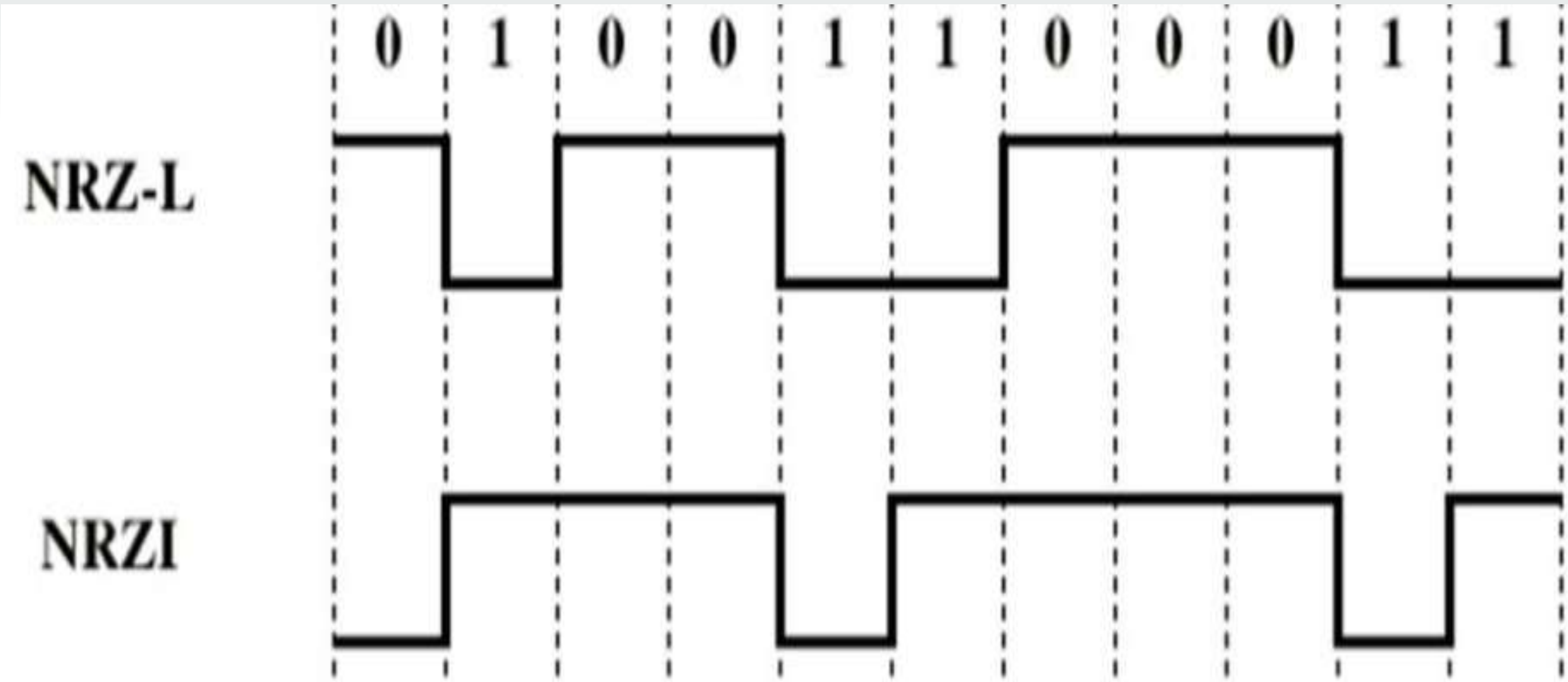
The voltage is constant during the bit interval.

1 ⇔ existence of a ***signal transition*** at the beginning of the bit time (either a low-to-high or a high-to-low transition)

0 ⇔ **no *signal transition*** at the beginning of the bit time

NRZI is a **differential encoding** *scheme* (i.e., the signal is decoded by comparing the polarity of adjacent signal elements.)


0 1 0 0 1 1 0 0 0 1 1
NRZI


0
1
0
0
1
1
0
0
0
1
1
NRZ-L
NRZI

Bi –Phase Codes

Bi- phase codes – require at least one transition per bit time and may have as many as two transitions.

➔ the maximum modulation rate is twice that of NRZ

➔ greater transmission bandwidth is required.

Advantages:

Synchronization – with a predictable transition per bit time the receiver can "synch" on the transition [self-clocking].

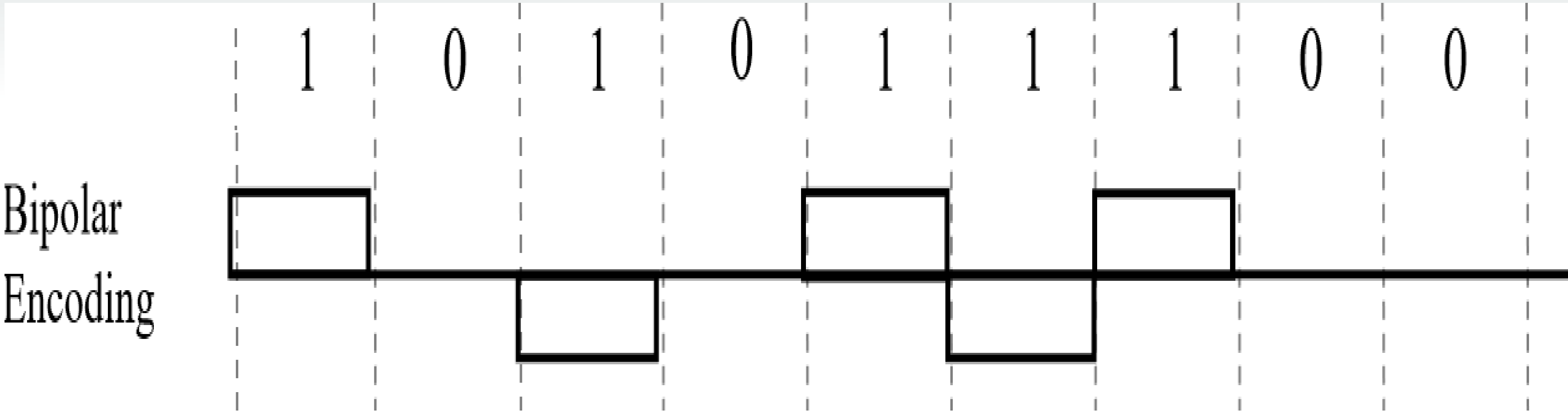
No d.c. component

Error detection – the absence of an expected transition can be used to detect errors.

Bi-Polar Encoding

1 ⇔ **alternating** +1/2 , -1/2 voltage
0 ⇔ **0** voltage

- Has the same issues as NRZI for a long string of 0's.
- A systemic problem with polar is the polarity can be backwards.


1 0 1 0 1 1 1 0 0
Bipolar
Encoding

Bi Bi-phase

- **Manchester**: Used in Ethernet

  0 = High to low transition in middle

  1 = Low to high transition in middle

- **Differential Manchester**:

  Used in Token Ring

  Always a transition in middle

  0 = transition at beginning

  1= no transition at beginning

1. No DC
2. Clock sync
3. Error detection
4. 1 bit/Hz,
5. baud rate

   $= 2 \times$ bit rate

Manchester Encoding

- There is **always** a mid-bit transition {which is used as a clocking mechanism}.
- The **direction** of the mid-bit transition represents the digital data.

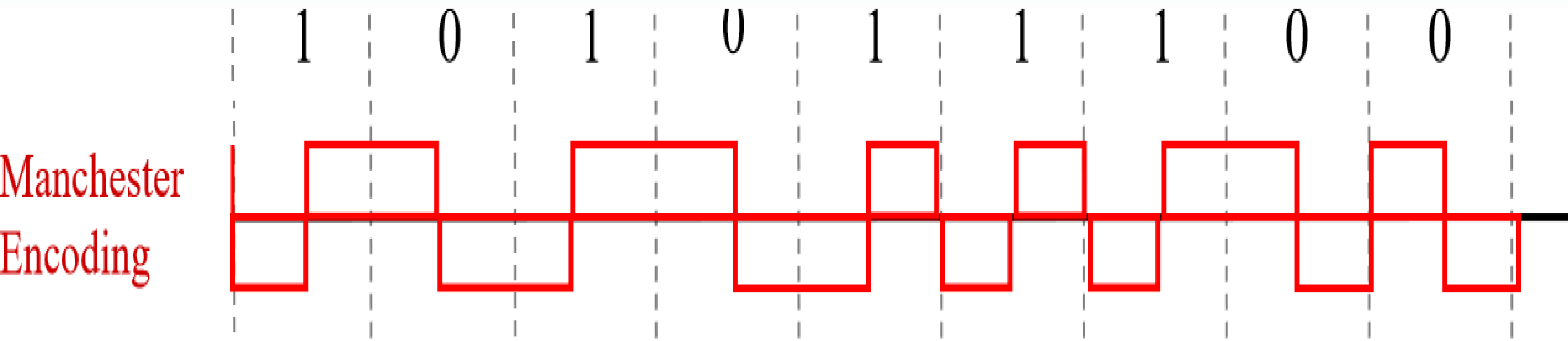
1 ⇔ **low-to-high** transition

0 ⇔ **high-to-low** transition

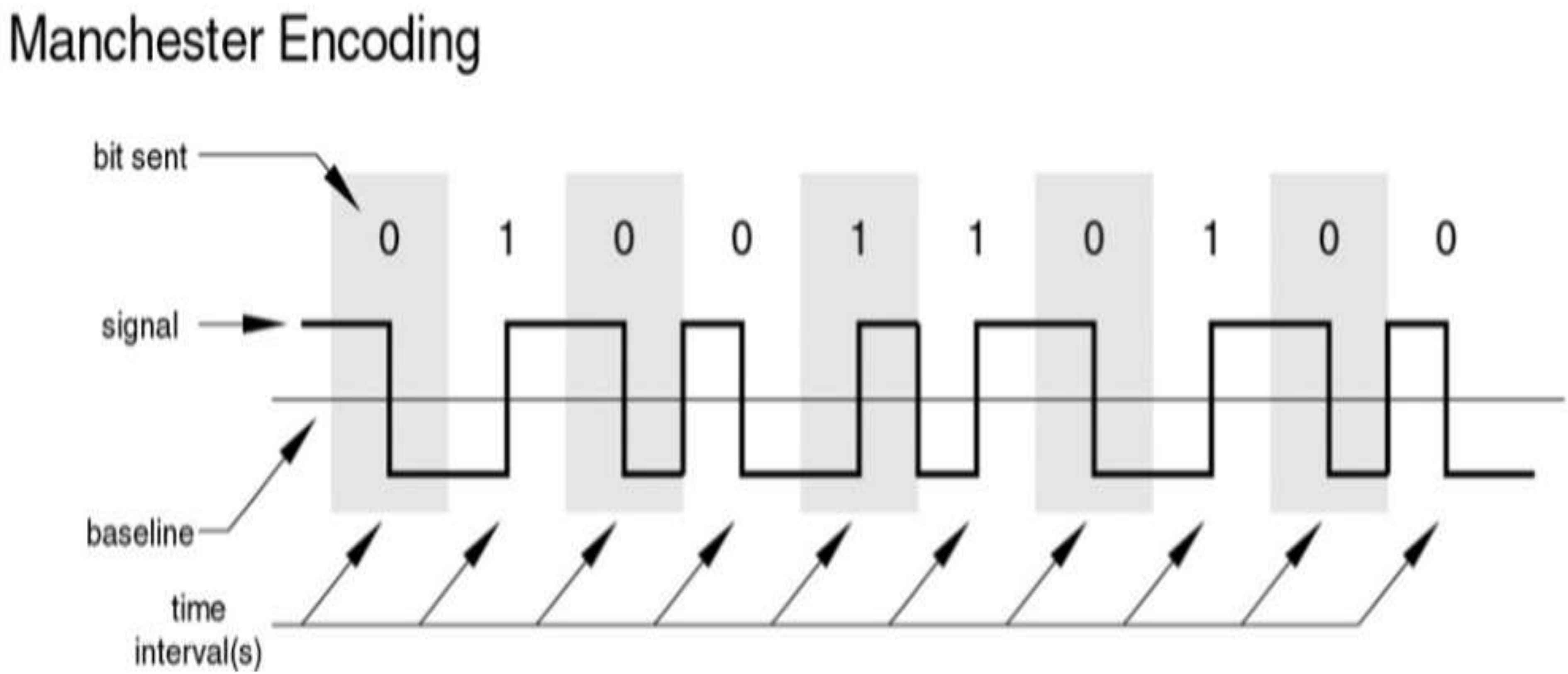
Textbooks disagree on this definition!!

Consequently, there may be a second transition at the beginning of the bit interval.

Used in 802.3 baseband coaxial cable and CSMA/CD twisted pair.


1 0 1 0 1 1 1 0 0
Manchester
Encoding

Manchester Encoding



Differential Manchester Encoding

- mid-bit transition is **ONLY** for clocking.

1 ⇔ **absence** of transition at the beginning of the bit interval

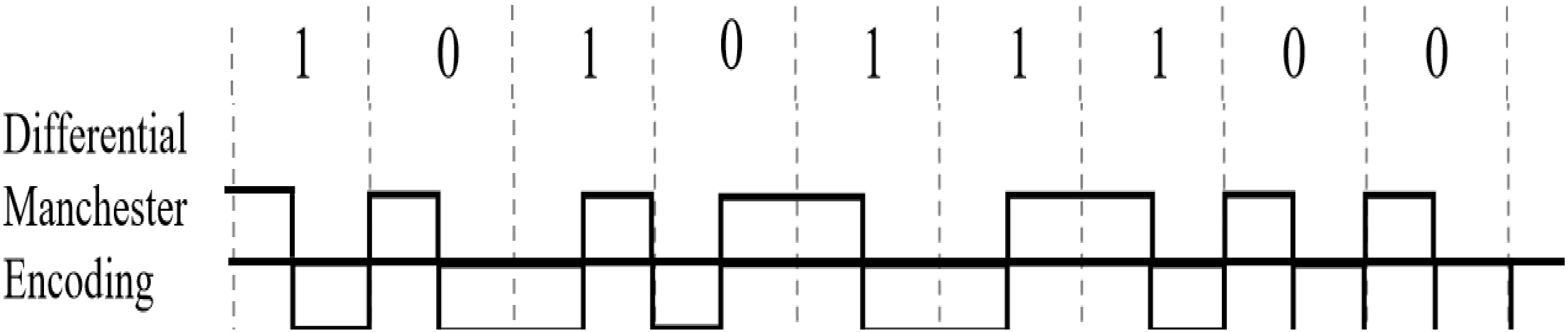
0 ⇔ **presence** of transition at the beginning of the bit interval

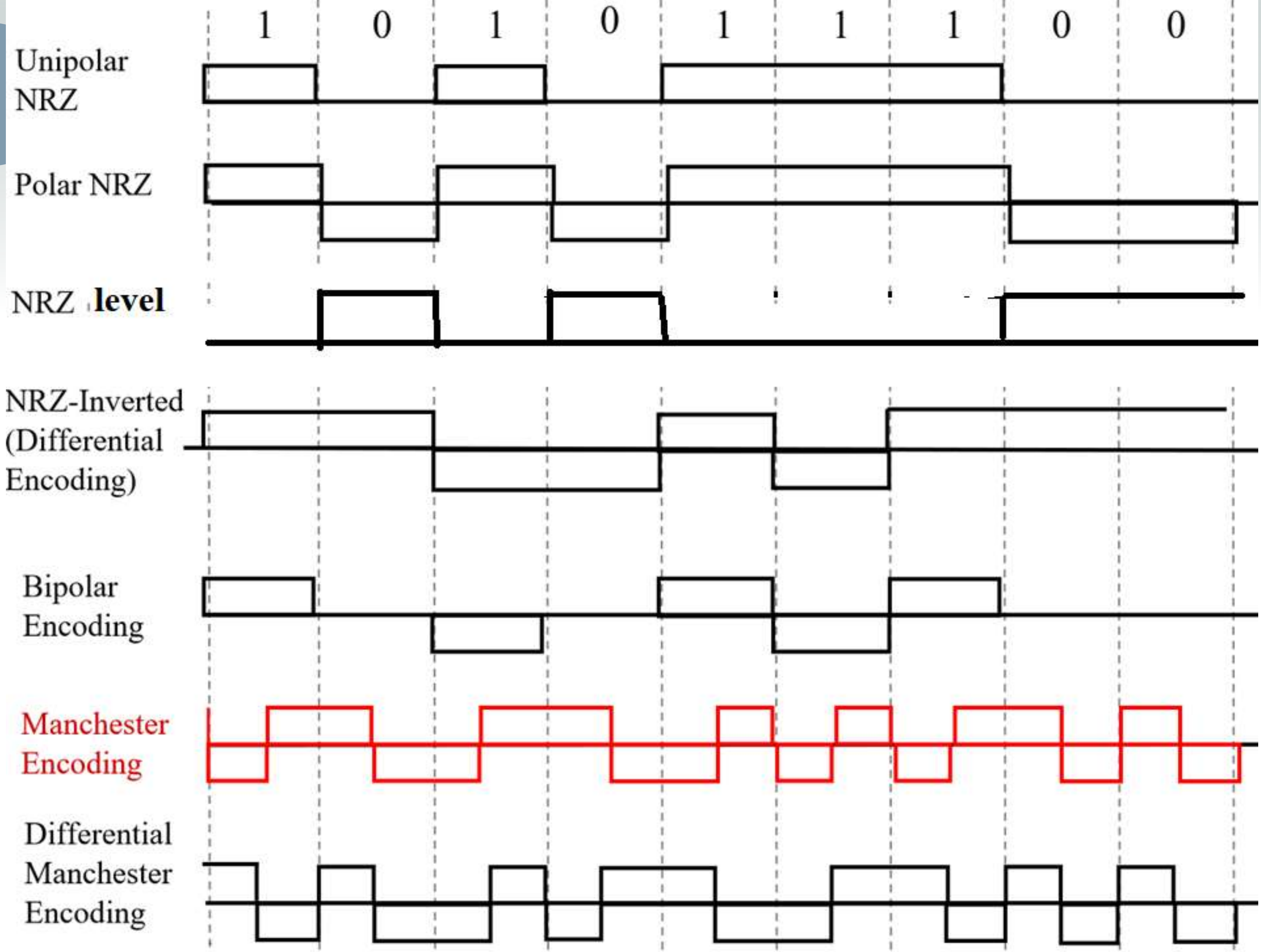
Differential Manchester is both differential and bi-phase.

Note – the coding is the opposite convention from NRZI.

Used in 802.5 (token ring) with twisted pair.

* Modulation rate for Manchester and Differential Manchester is twice the data rate ➔ inefficient encoding for long-distance applications.


1 0 1 0 1 1 1 0 0
Differential
Manchester
Encoding



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

Multilevel Binary Techniques

- **Bipolar-AMI Encoding**
– zero represented by no line signal
– one represented by positive or negative pulse
– one pulses alternate in polarity
– No loss of synchronization if a long string of ones (zeros still a problem)
- **Multilevel Binary Techniques**
- **Pseudoternary Encoding**
– One represented by absence of line signal
– Zero represented by alternating positive and negative
– No loss of sync if a long string of zeros (ones still a problem)
– No advantage or disadvantage over bipolar-AMI

Multi-level Binary Encoding

Bipolar-AMI:

0 = no line signal

1= +ve or -ve for successive 1's

Pseudo-ternary:

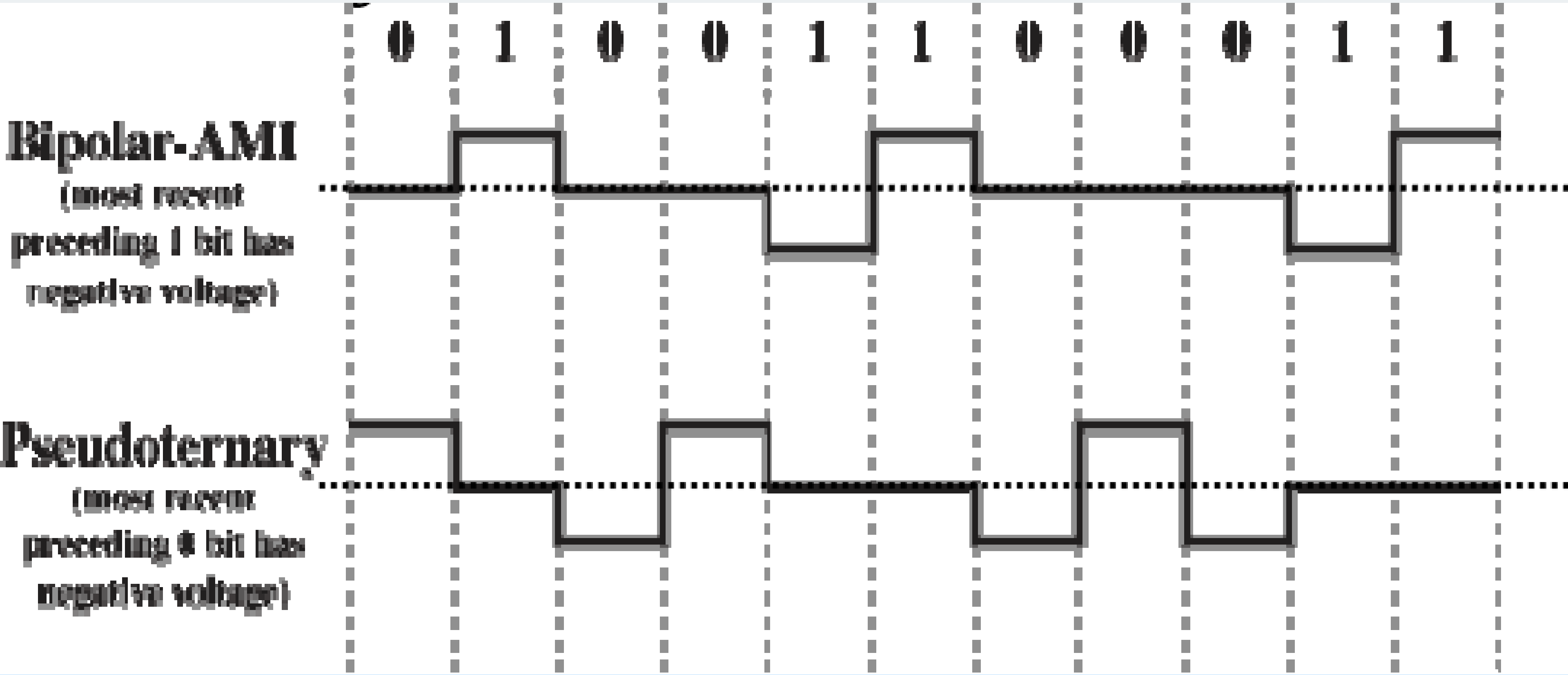
0 = +ve or -ve for successive 0's

1= no line signal

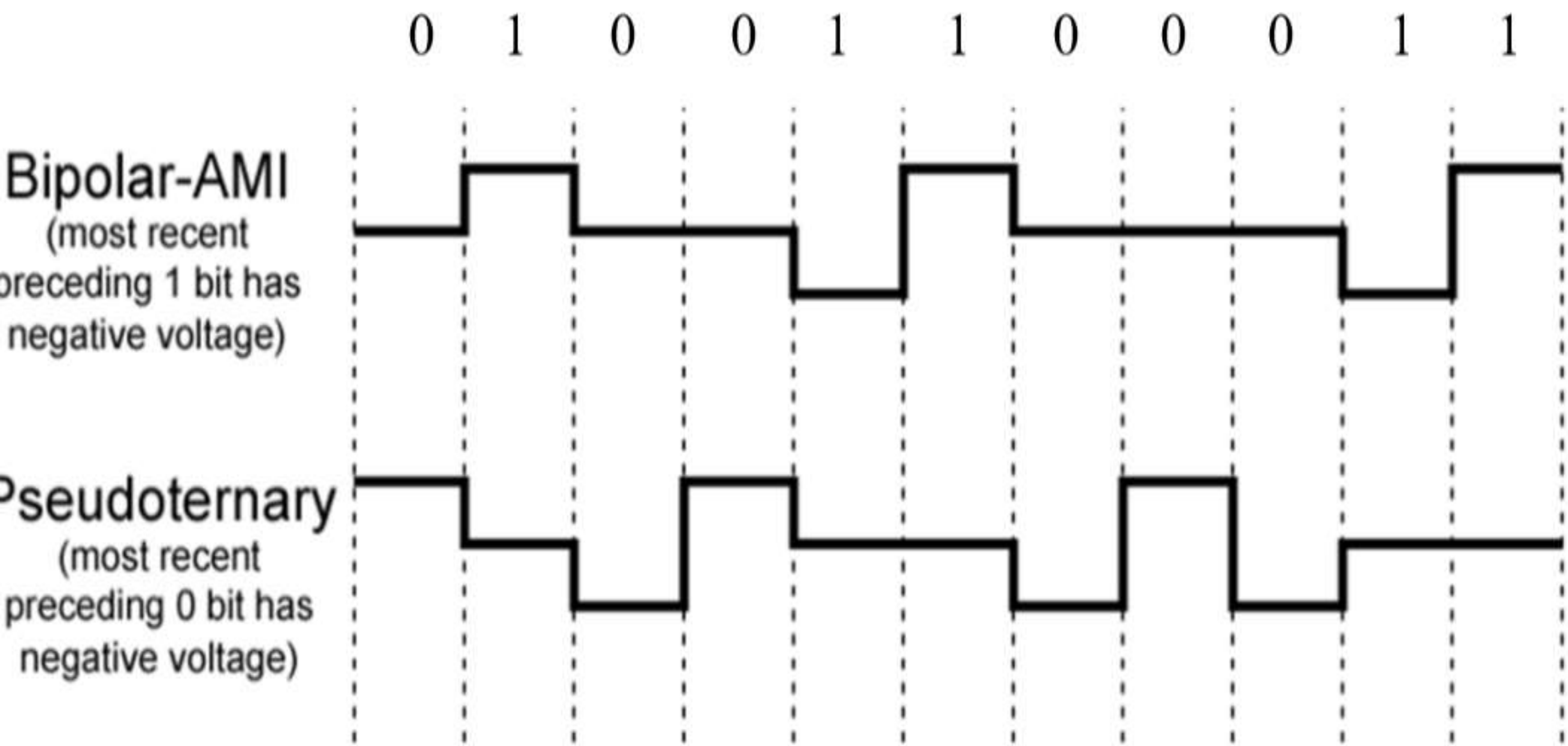
No advantage over AMI

1. No loss of sync with 1's
2. zeros are a problem
3. No net dc component
4. Error detection

   Noise ⇒ violation
5. Two bits/Hz
6. 3 dB higher S/N
7. 2b/Hz. Not 3.16 b/Hz


0 1 0 0 1 1 0 0 0 1 1
Bipolar-AMI
(most recent preceding 1 bit has negative voltage)
Pseudoternary
(most recent preceding 0 bit has negative voltage)

Multilevel Binary Techniques



Scrambling

- **Bipolar with 8-Zero Substitution (B8ZS):**

Same as AMI, except eight 0's replaced w two code violations

0000 0000 = 000V 10V1

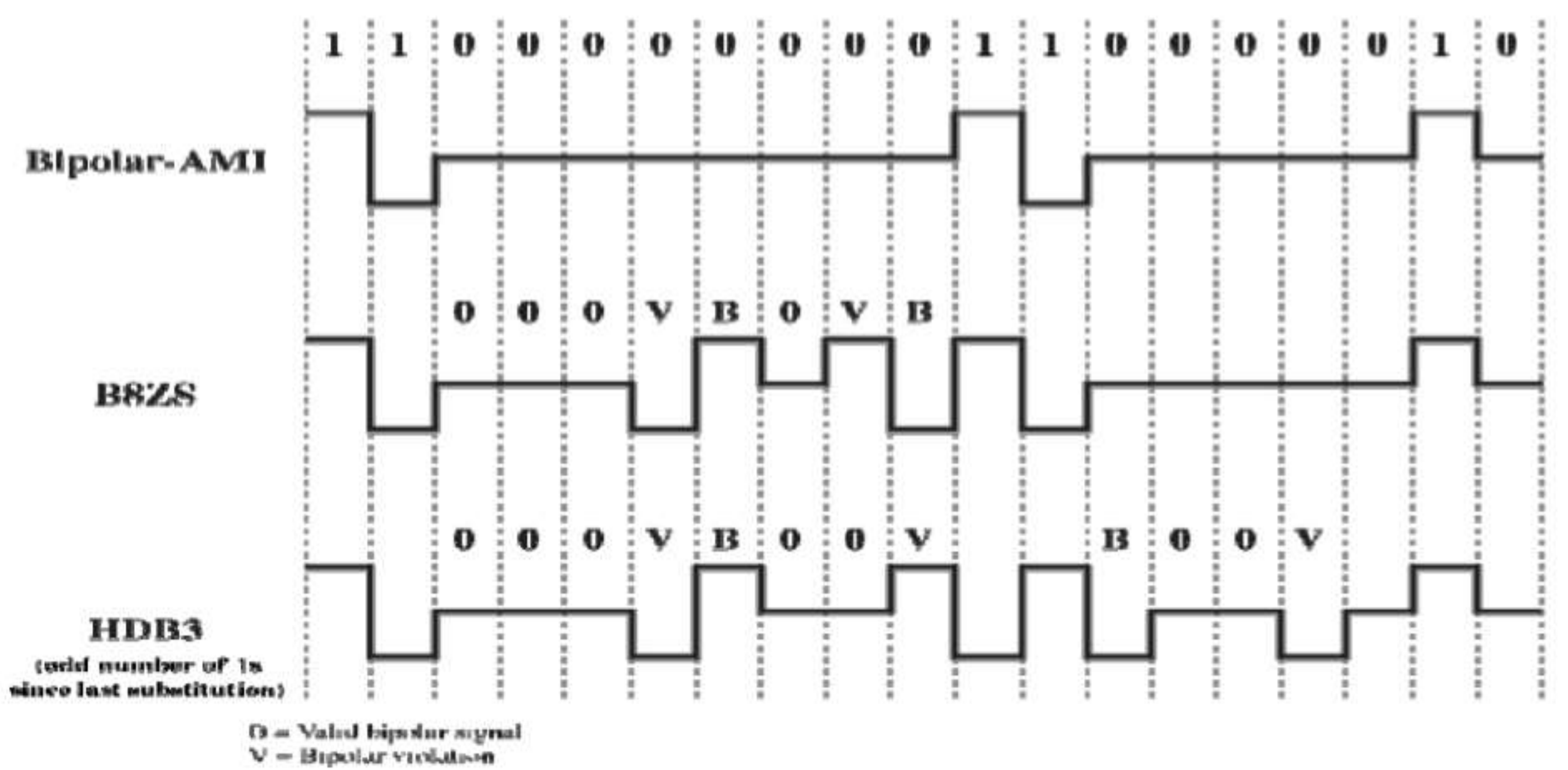
B8ZS		0	0	0	0	0	0	0	0
last pluse	+	0	0	0	+	-	0	-	+
	-	0	0	0	-	+	0	+	-

- **High Density Bi-polar w 3 Zeros (HDB3):** Same as AMI, except that four 0's replaced with one code violation

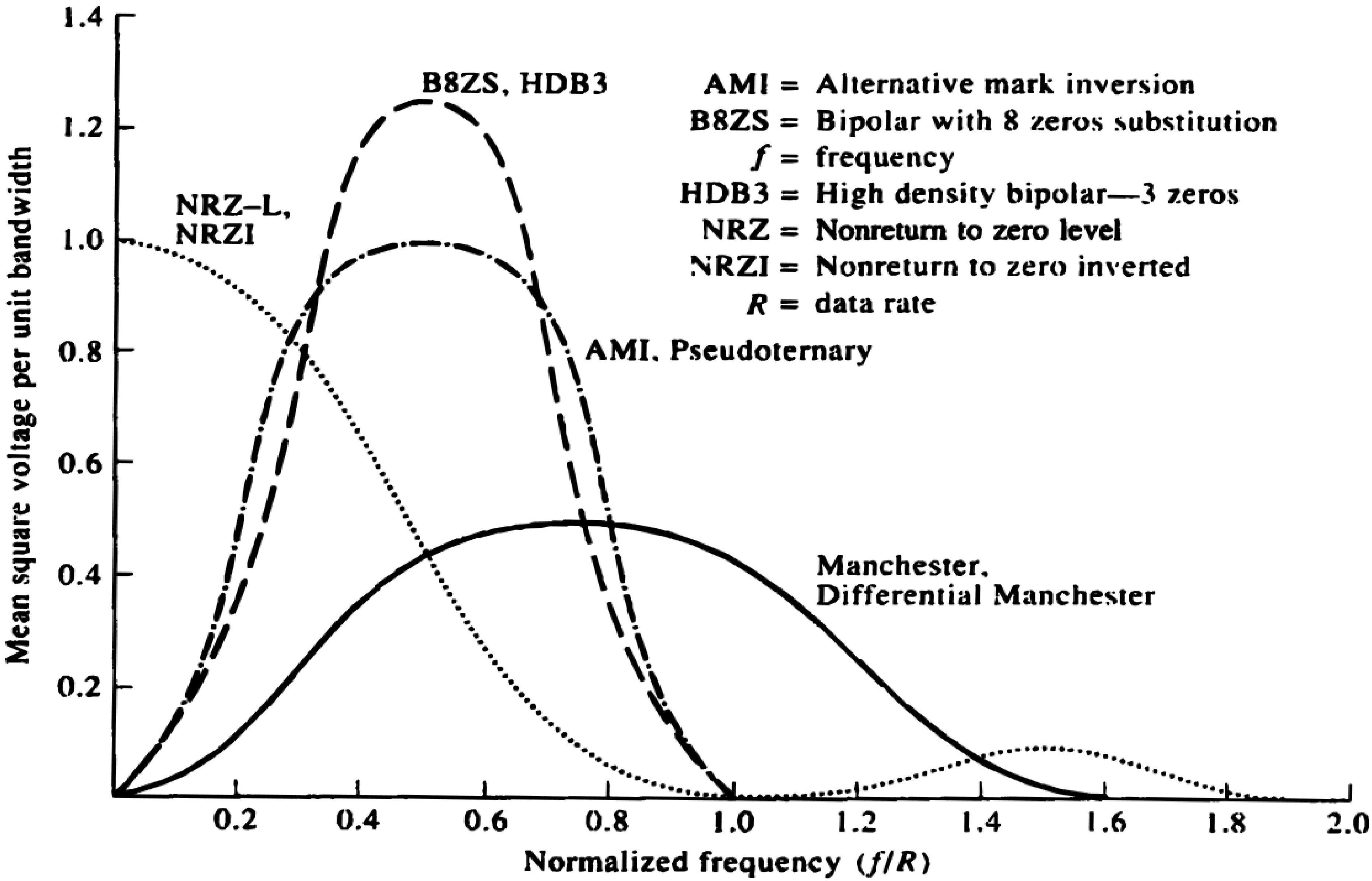
0000 = 000V if odd number of ones since last substitution

100V otherwise

HDB3	0	0	0	0	
	0	0	0	V	; # of non zero since last substitution is odd
	B	0	0	V	; Even


1 1 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 1 0
Bipolar-AMI
0 0 0 V B 0 V B
B8ZS
0 0 0 V B 0 0 V B 0 0 V
HDB3
(odd number of 1s since last substitution)
B = Valid bipolar signal
V = Bipolar violation

Signal Spectrum



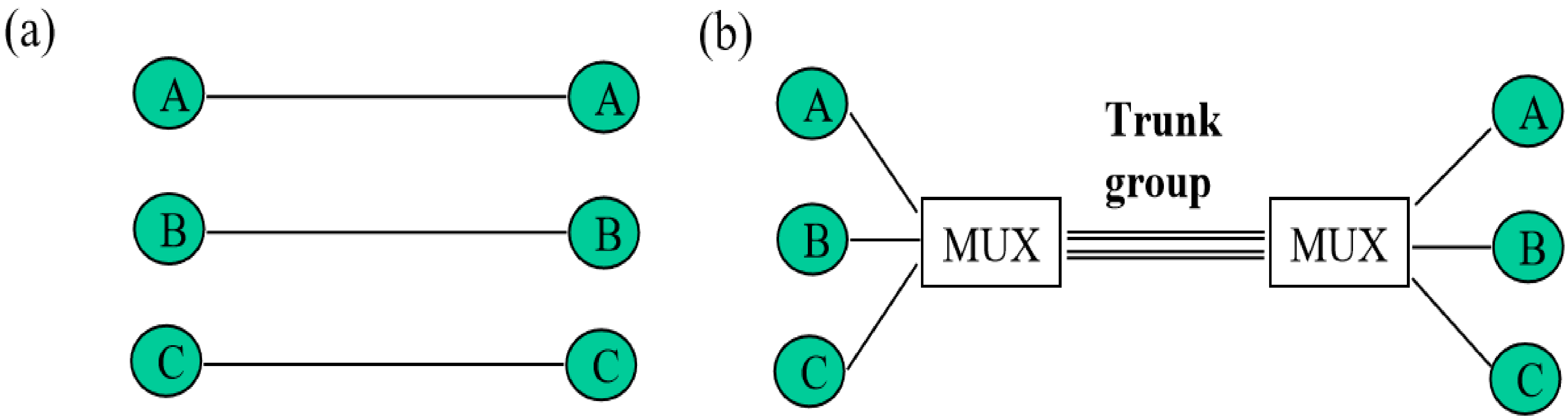
Analog Data, Digital Signals [Example –PCM (Pulse Code Modulation)]

- The most common technique for using digital signals to encode analog data is PCM.

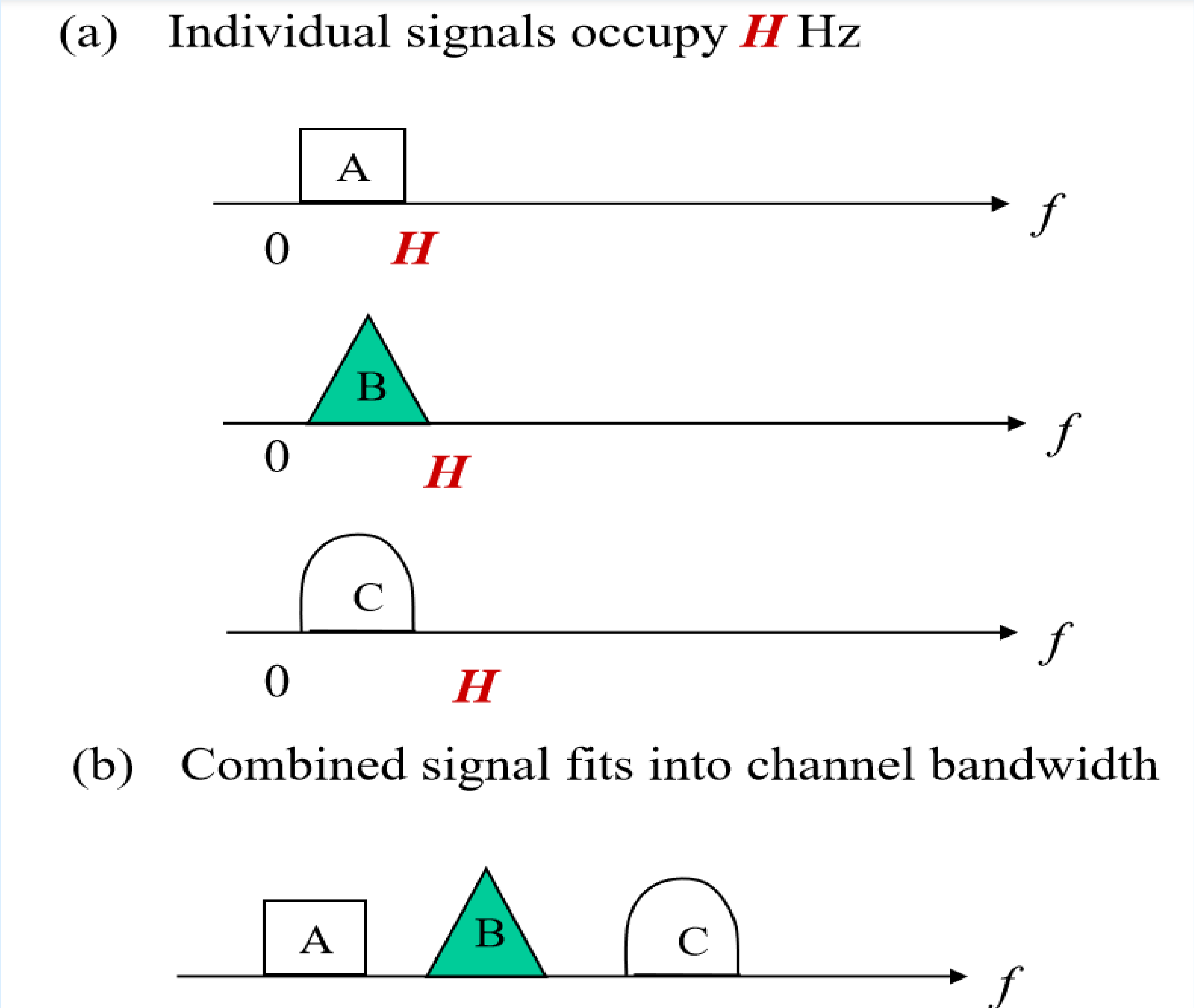
- Example:To transfer analog voice signals off a local loop to digital end office within the phone system, one uses a codec.

- Because voice data limited to frequencies below 4000 HZ, a codec makes 8000 samples/sec. (i.e., 125 microsec/sample).

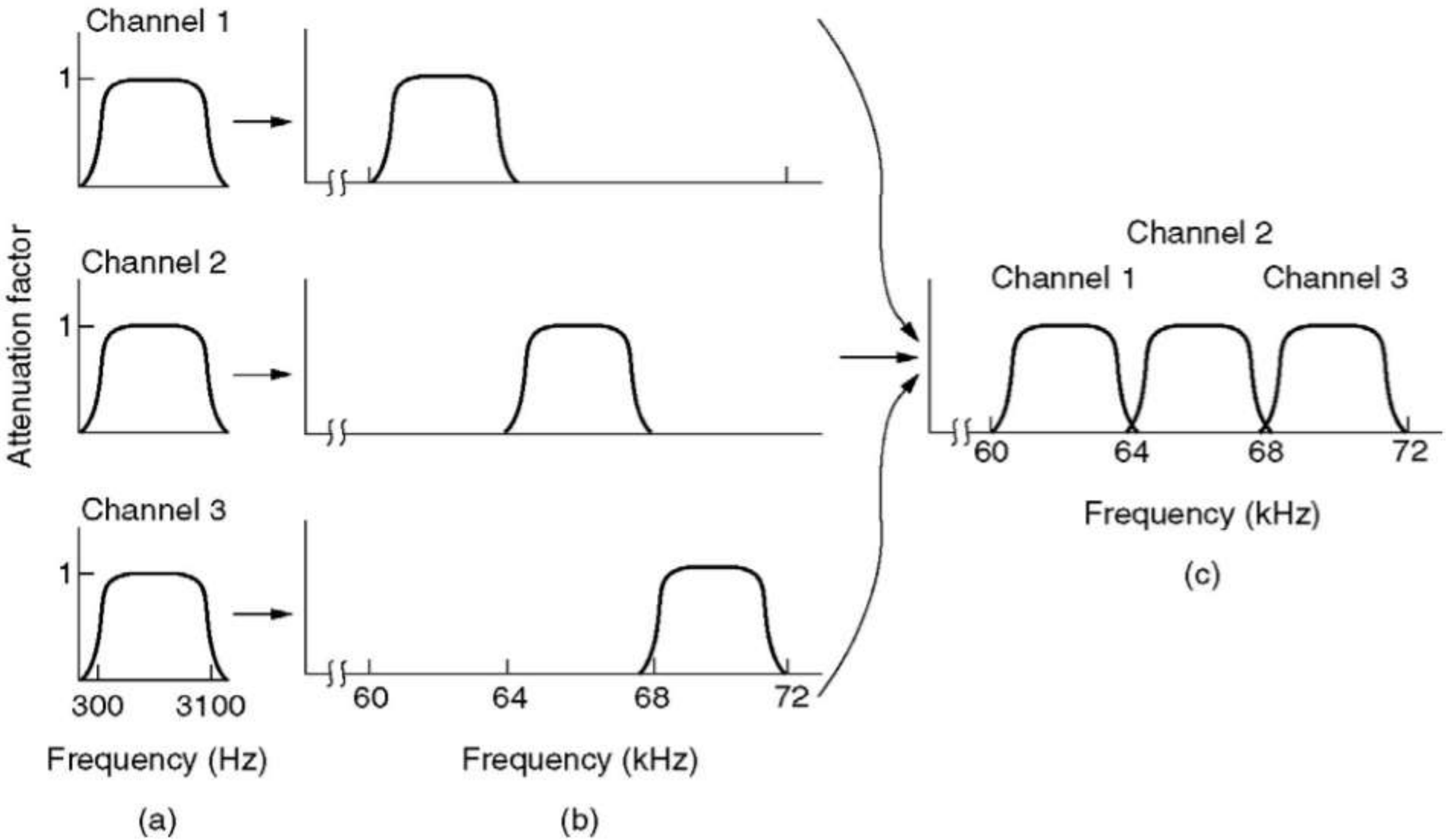
Multiplexing



Frequency-division Multiplexing



Frequency-division Multiplexing

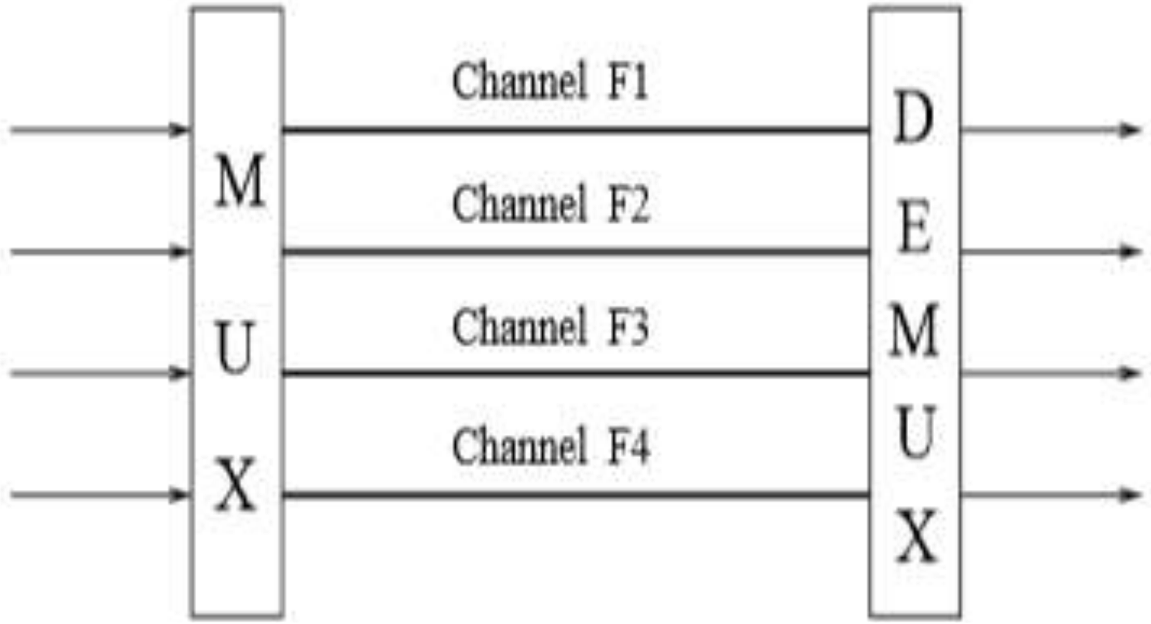


(a)The original bandwidths. (b)The bandwidths raised in frequency. (c)The multiplexed channel.

Broadband vs. baseband

Presence or absence of carrier wave: allows many channels to co-exist at the same time

⟶ frequency division multiplexing (FDM)



Ex.: AM radio (535 kHz–1705 kHz)

⟶ tuning to specific frequency: Fourier transform

⟶ coefficient of Fourier transform!

Ex.: FM radio

$\longrightarrow$ 88 MHz–108 MHz

$\longrightarrow$ 200 kHz slices

$\longrightarrow$ how might it work?

$\longrightarrow$ better or worse than AM?

Ex.: Digital radio

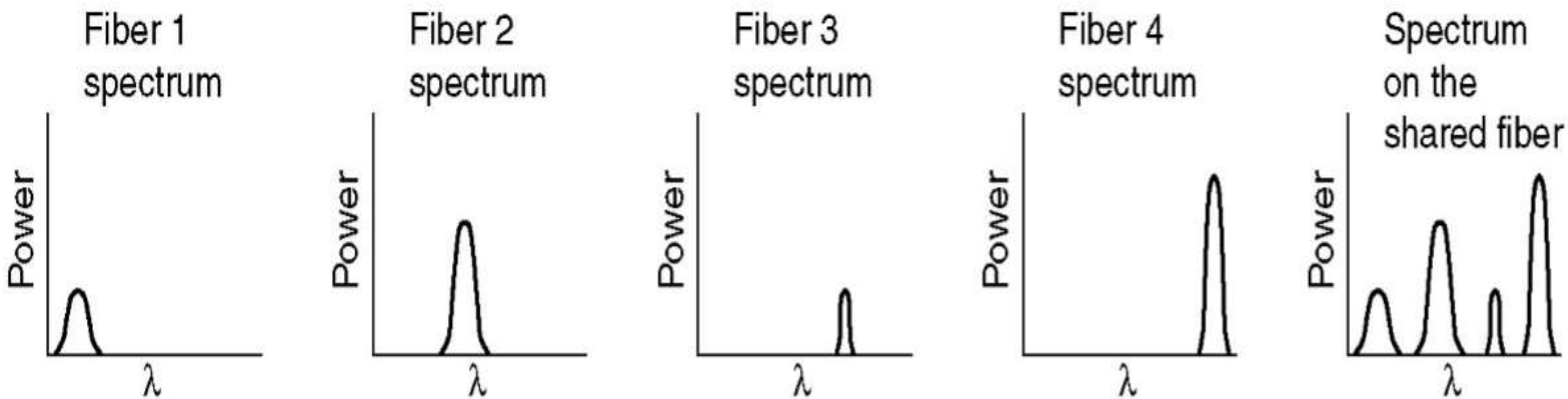
$\longrightarrow$ digital audio radio service

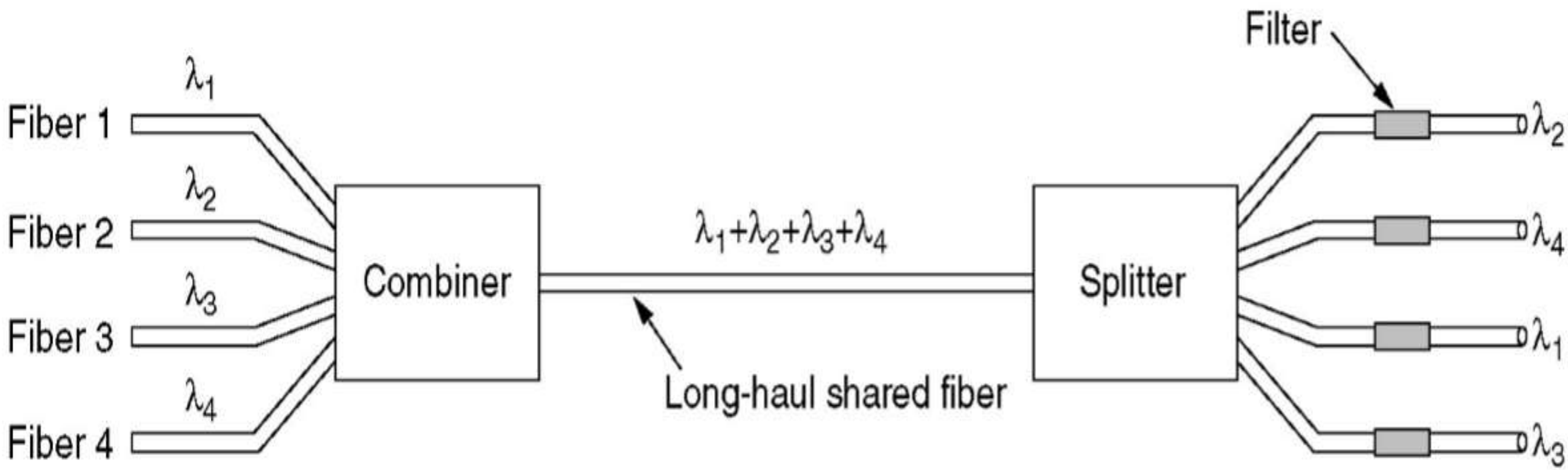
$\longrightarrow$ GEO satellites (a.k.a. satellite radio)

$\longrightarrow$ uses 2.3 GHz spectrum (a.k.a. S-band)

$\longrightarrow$ e.g., XM, Sirius

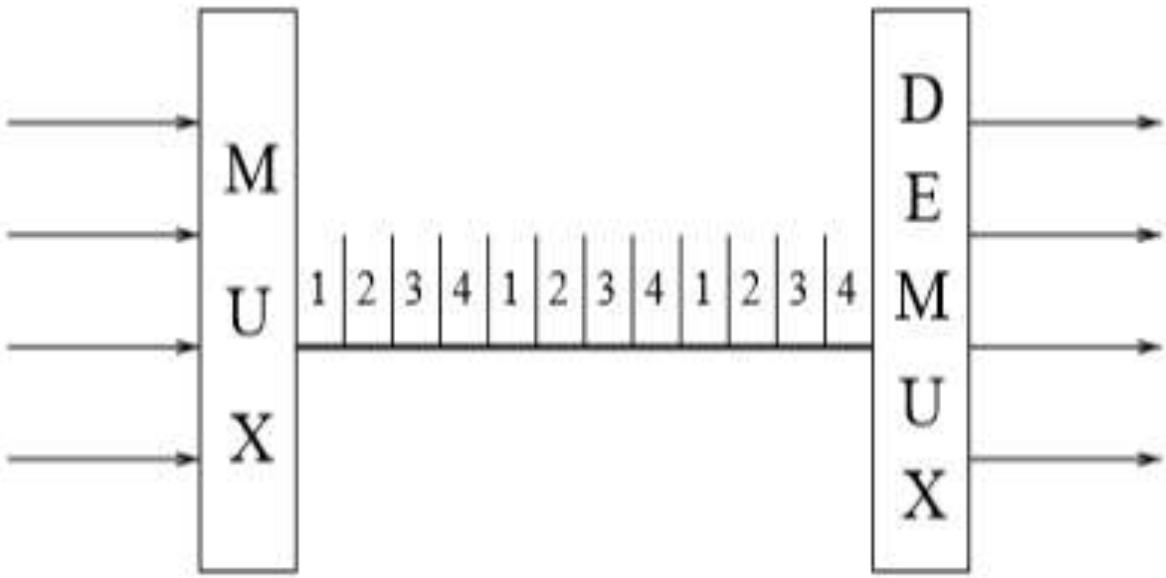
Wavelength Division Multiplexing





In the absence of carrier wave, can still use multiplexing:

$\longrightarrow$ time-division multiplexing (TDM)



- digital transmission of digital data

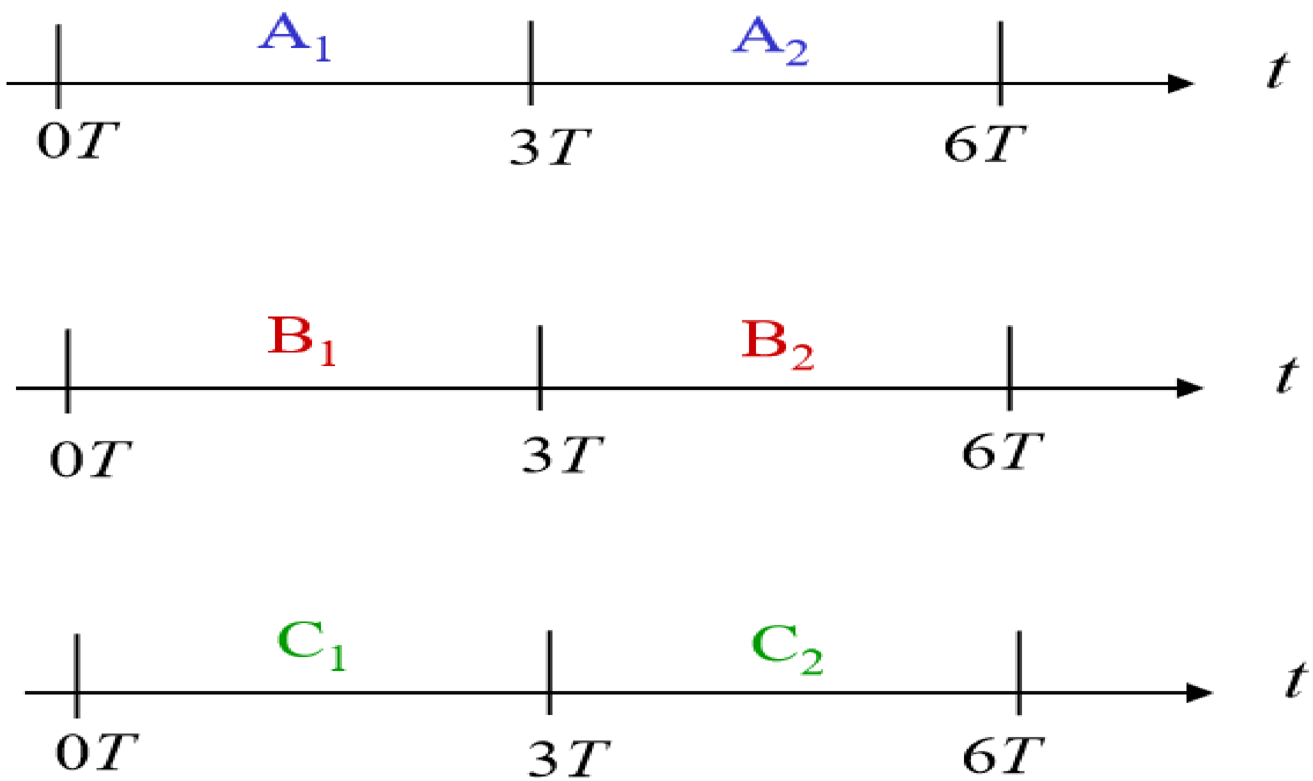
  $\rightarrow$ e.g., telephony backbone network

- digital transmission of analog data

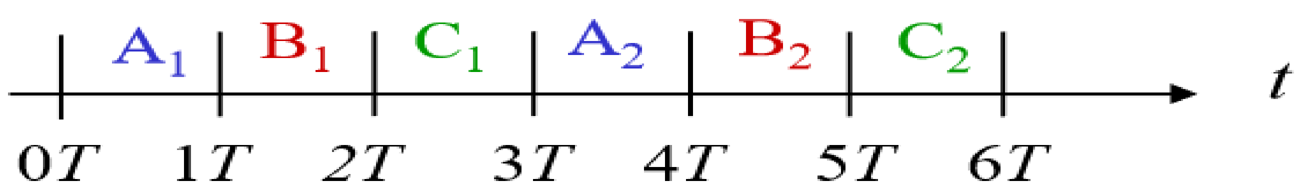
  $\rightarrow$ PCM (e.g., PC sound cards), modem

Time-division Multiplexing

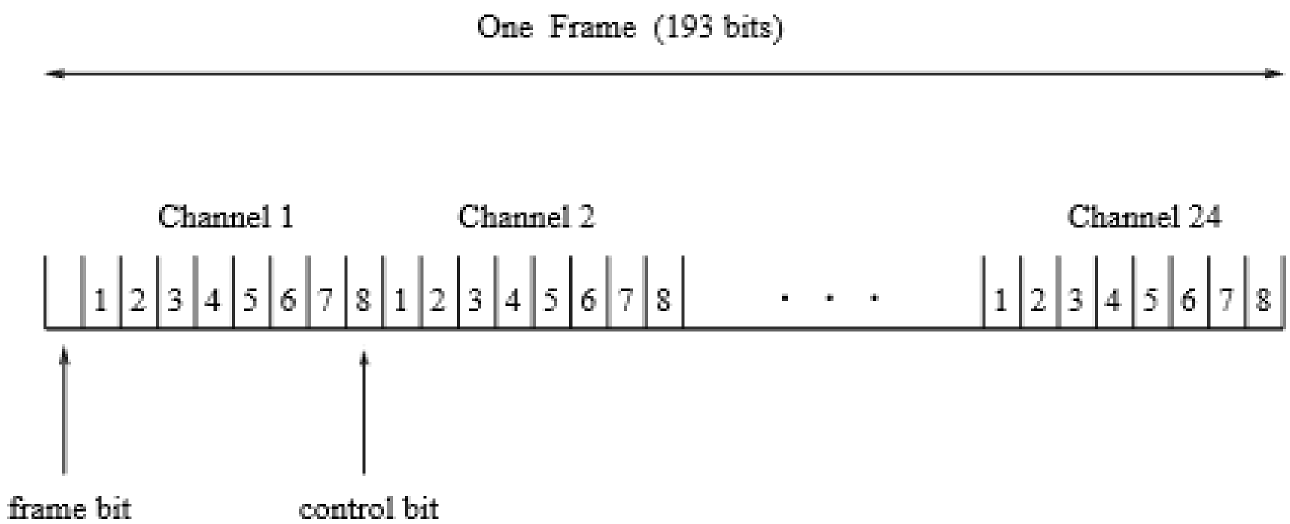
(a) Each signal transmits 1 unit every $3T$ seconds



(b) Combined signal transmits 1 unit every T seconds



Example: T1 carrier (1.544 Mbps)



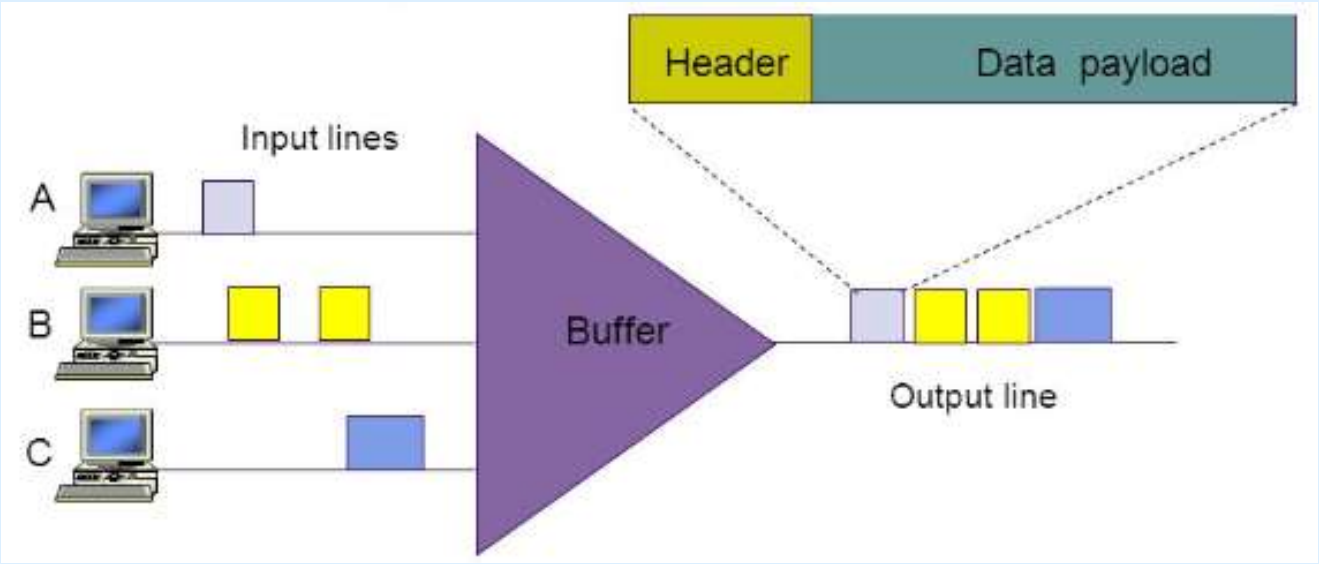
- 24 simultaneous users
- 7 bit quantization

Assuming 4 kHz telephone channel bandwidth, Sampling Theorem dictates 8000 samples per second.

$\longrightarrow$ 125 μsec inter-sample interval

Bandwidth $= 8000 \times 193 = 1.544$ Mbps

Statistical Multiplexing



- It is a technique in which information from multiple logical channels can be transmitted across a single physical channel.
- It dynamically **allocates bandwidth** only to **active input channels**, making better use of available bandwidth.
- It allowing more devices to be connected than with other multiplexing techniques.
- Also referred to as statistical time-division multiplexing or stat mux.

Pulse Code Modulation (PCM)

- Analog signal is sampled.
- Converted to discrete-time continuous amplitude signal (Pulse Amplitude Modulation)
- Pulses are quantizedand assigned a digital value.
-
    - A 7-bit sample allows 128 quantizing levels.

Pulse Code Modulation (PCM)

- PCM uses non-linear encoding,
  i.e., amplitude spacing of levels is non-linear.
  - There is a greater number of quantizing steps for low amplitude.
  - This reduces overall signal distortion.

- This introduces quantizing error (or noise).

- PCM pulses are then encoded into a digital bit stream.

- 8000 samples/sec x 7 bits/sample = 56 Kbps for a single voice channel.

Delta Modulation (DM)

- The basic idea in delta modulationis to approximate the derivative of analog signal rather than its amplitude.
- The analog data is approximated by a staircase function that moves up or down by one quantization level at each sampling time. Îoutput of DM is a singlebit.
- PCM preferred because of better SNR characteristics.

Delta Modulation

DCC 6th Ed. W.Stallings