Physical Layer - Part 2

Data Encoding Techniques

Analog and Digital Transmissions

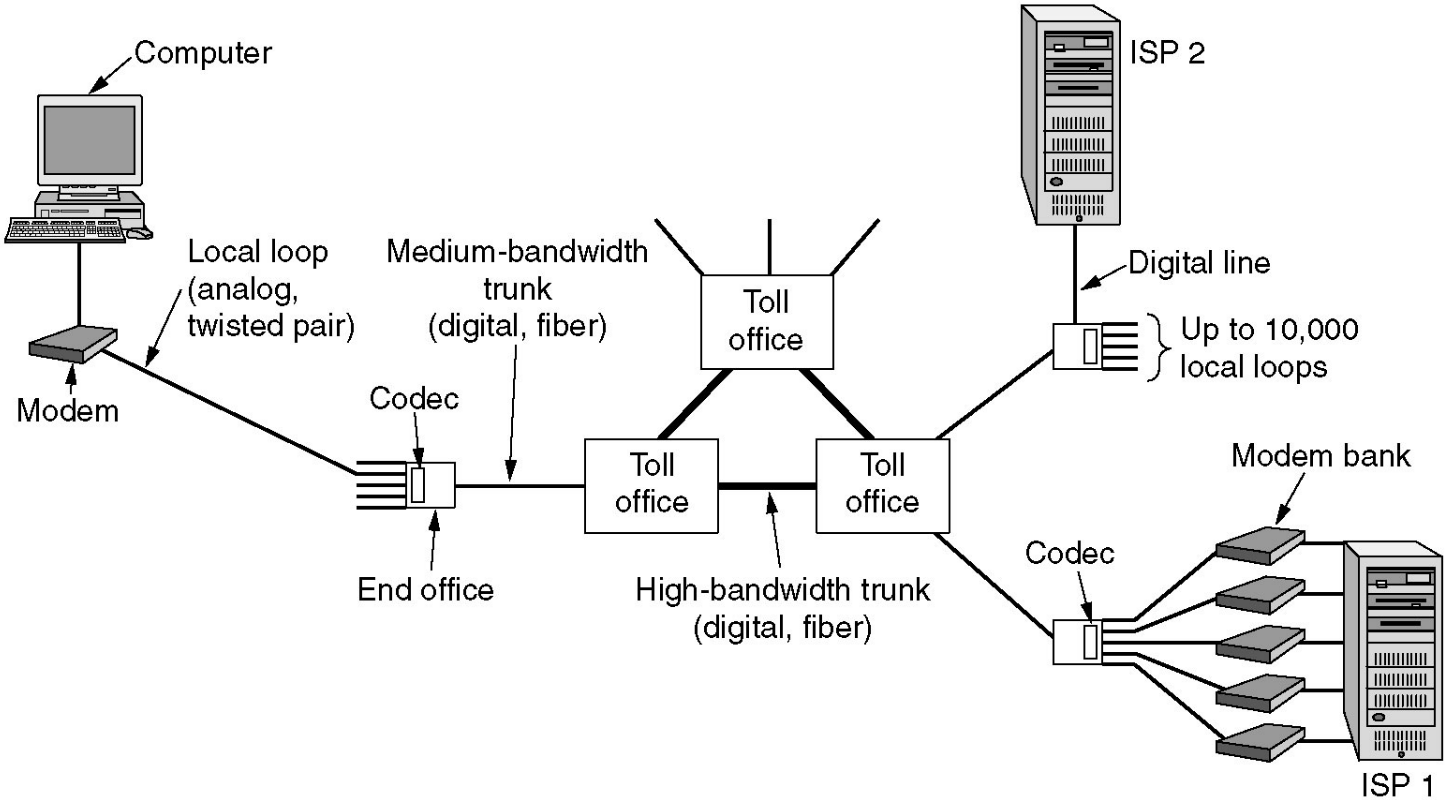

Figure 2-23.The use of both analog and digital transmissions for a computer to computer call. Conversion is done by the modems and codecs.

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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 phase or some combination of these.

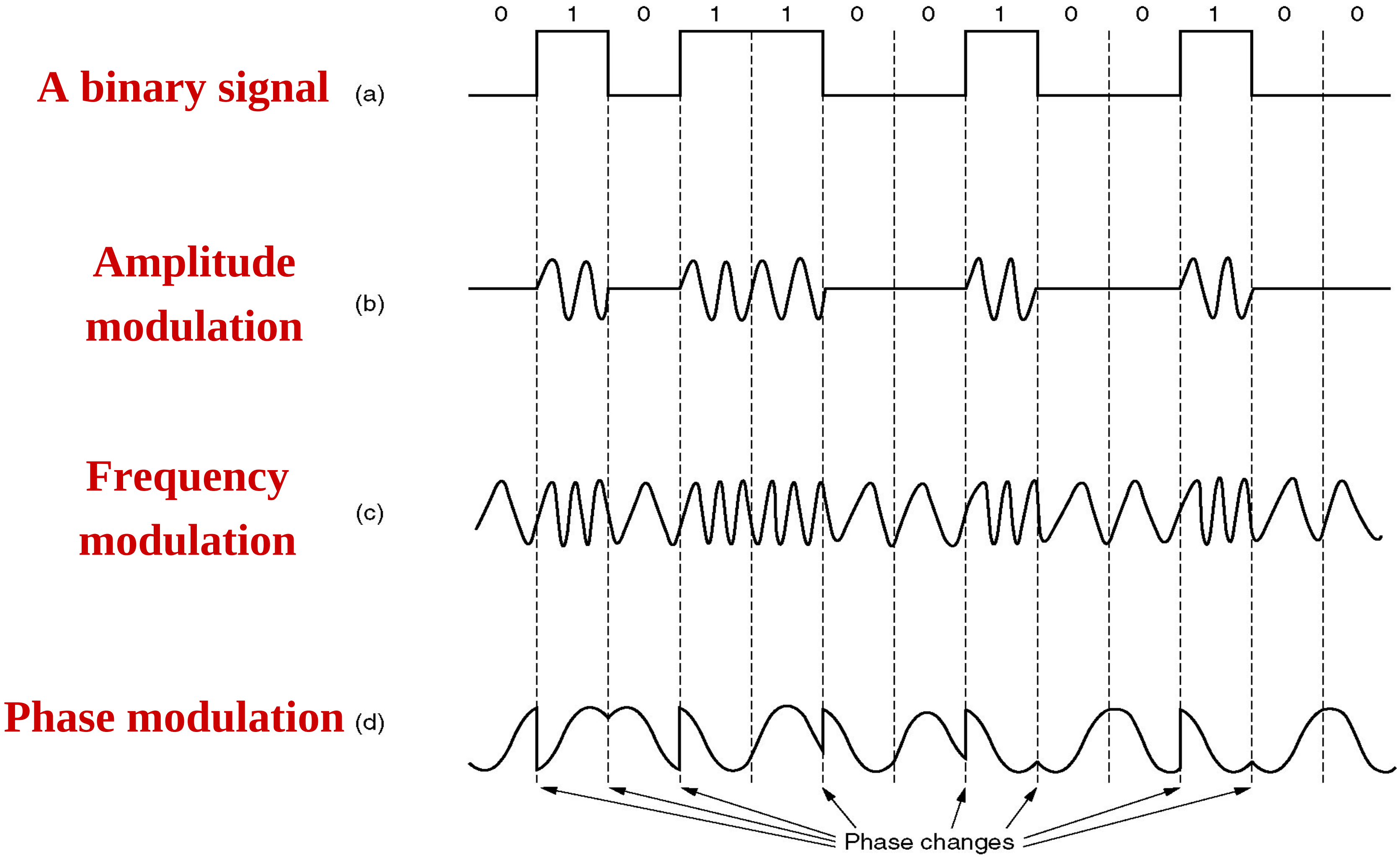

Figure 2-24.

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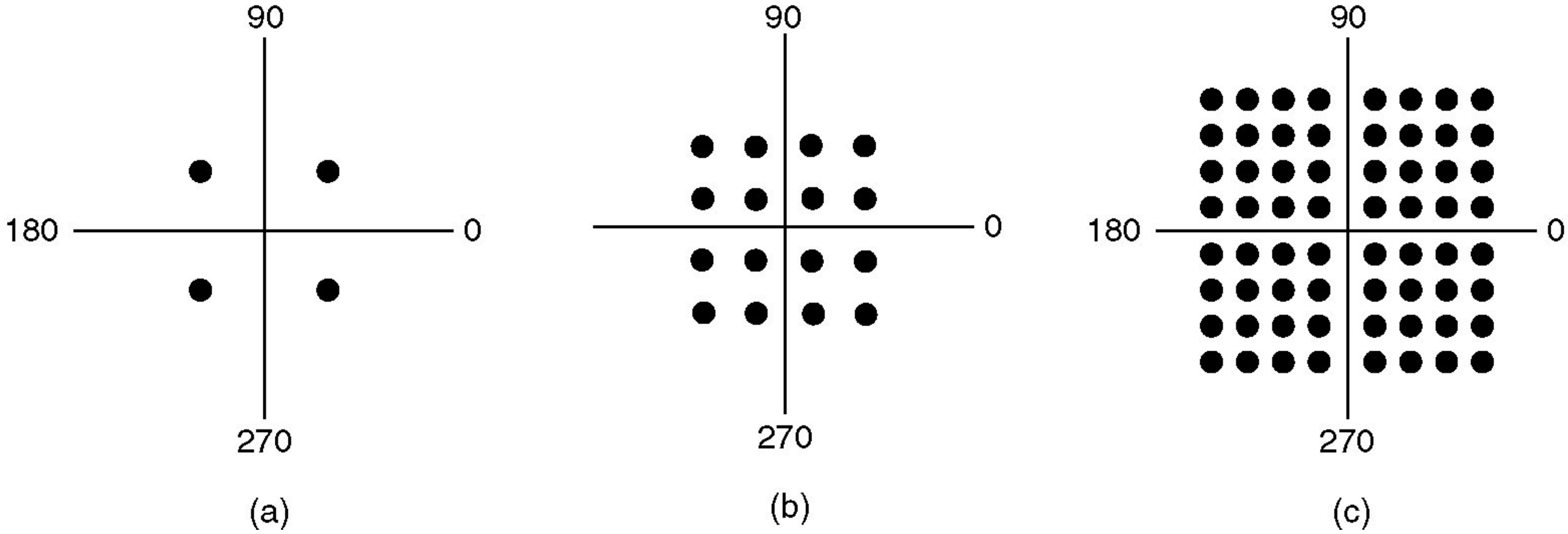
Modems

- 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.

Figure 2-25.

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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

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	⇔	negative voltage
0	⇔	positive voltage

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

"Plain" NRZ

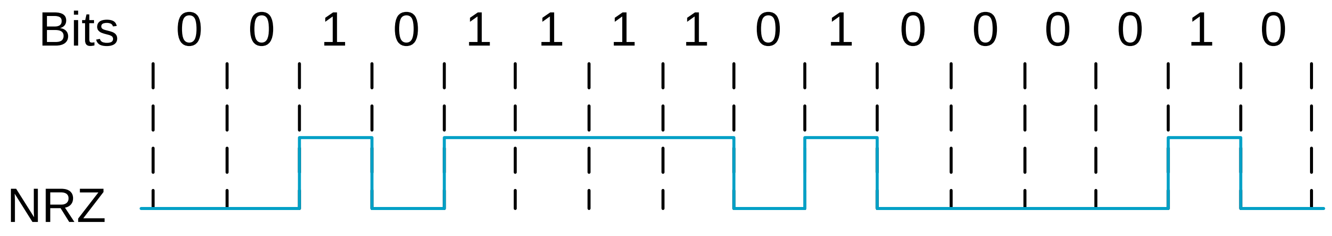

Figure 2.6

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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* (i.e., the signal is decoded by comparing the polarity of adjacent signal elements.)

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.

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.

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.

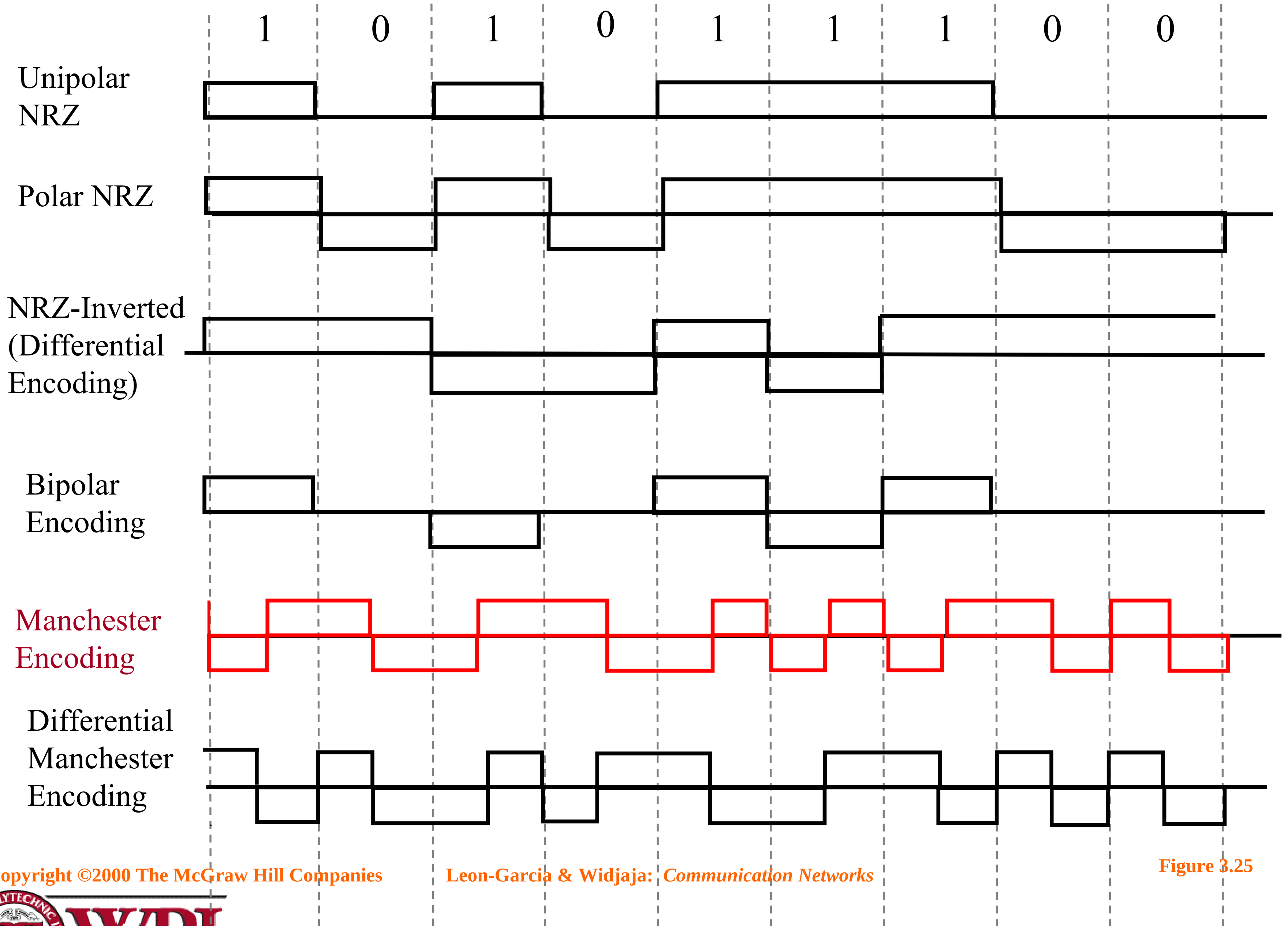
* Modulation rate for Manchester and Differential Manchester is twice the data rate ➔ inefficient encoding for long-distance applications.

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.



Leon-Garcia & Widjaja: *Communication Networks*

Figure 3.25

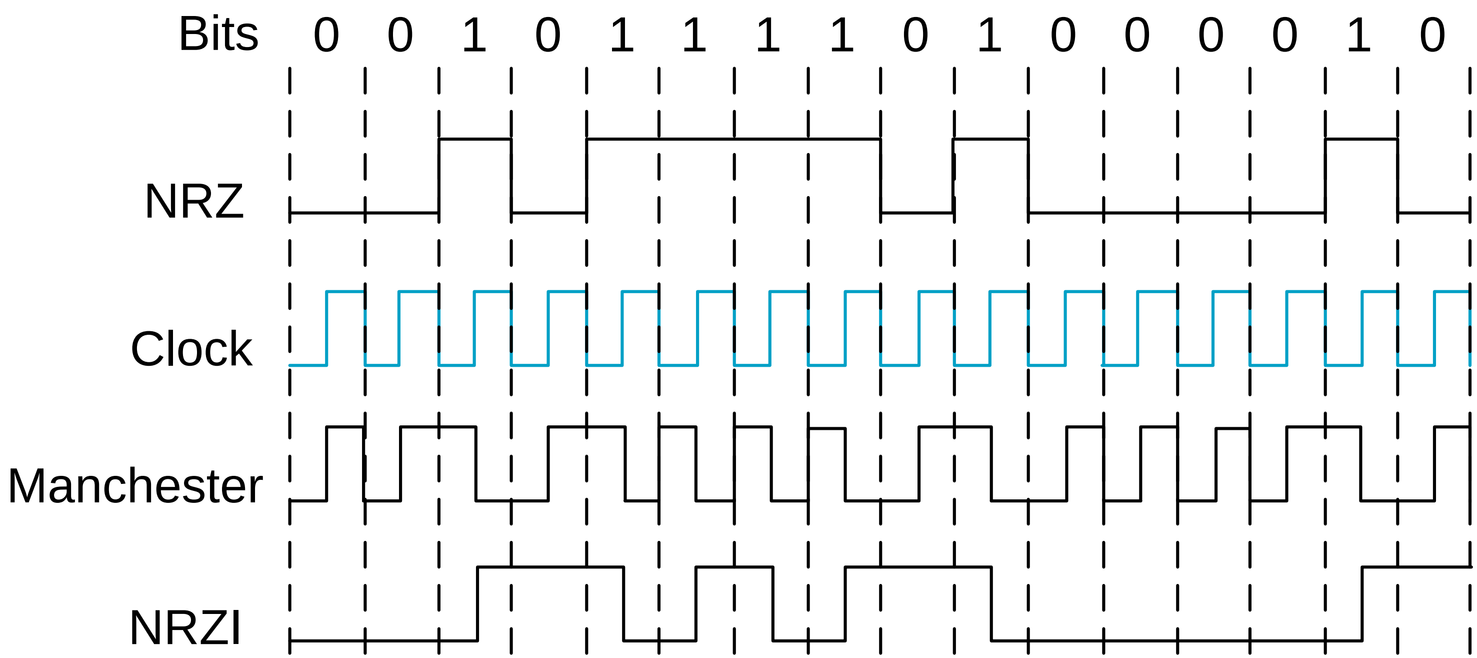


Figure 2.7

Note -Manchester is wrong!!

NRZI is also wrong!!

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

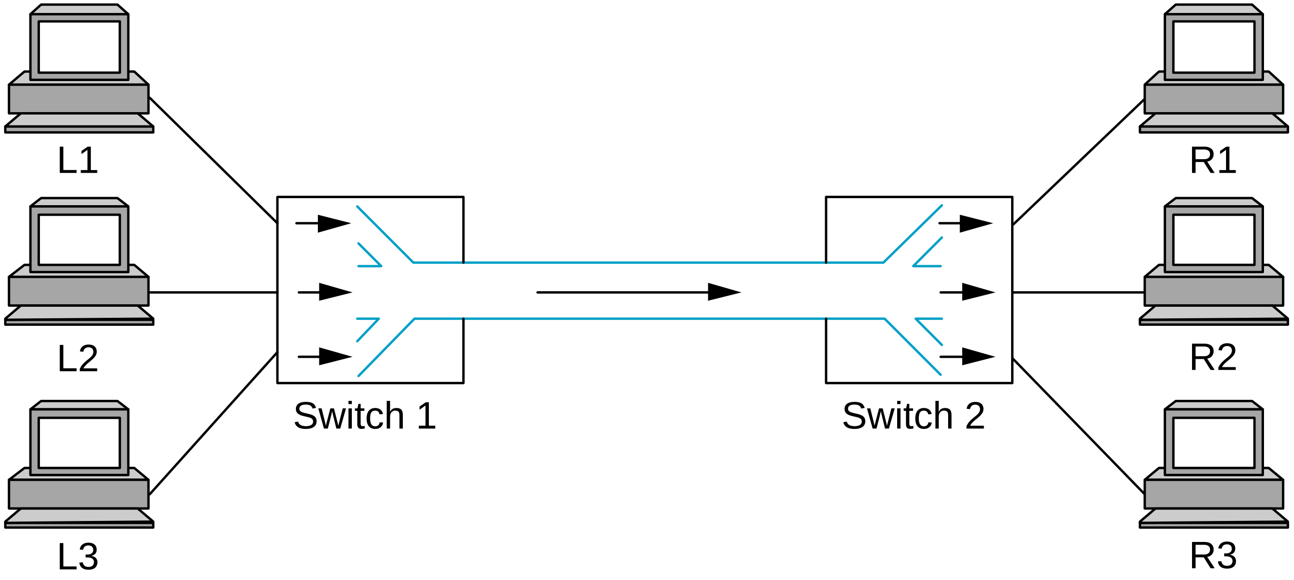
The most common technique for using digital signals to encode analog data is PCM.

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

- Time-Division Multiplexing (TDM)
- Frequency-Division Multiplexing (FDM)



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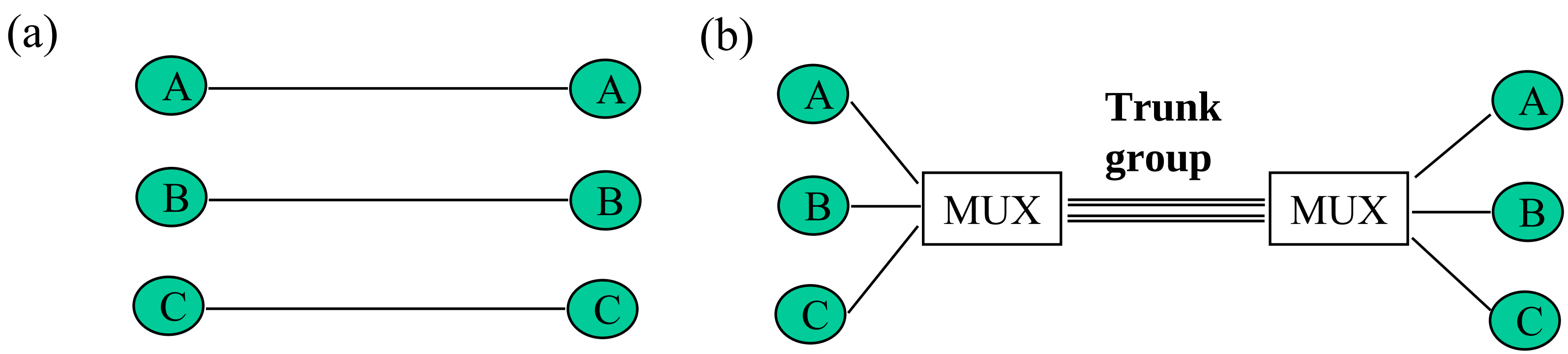
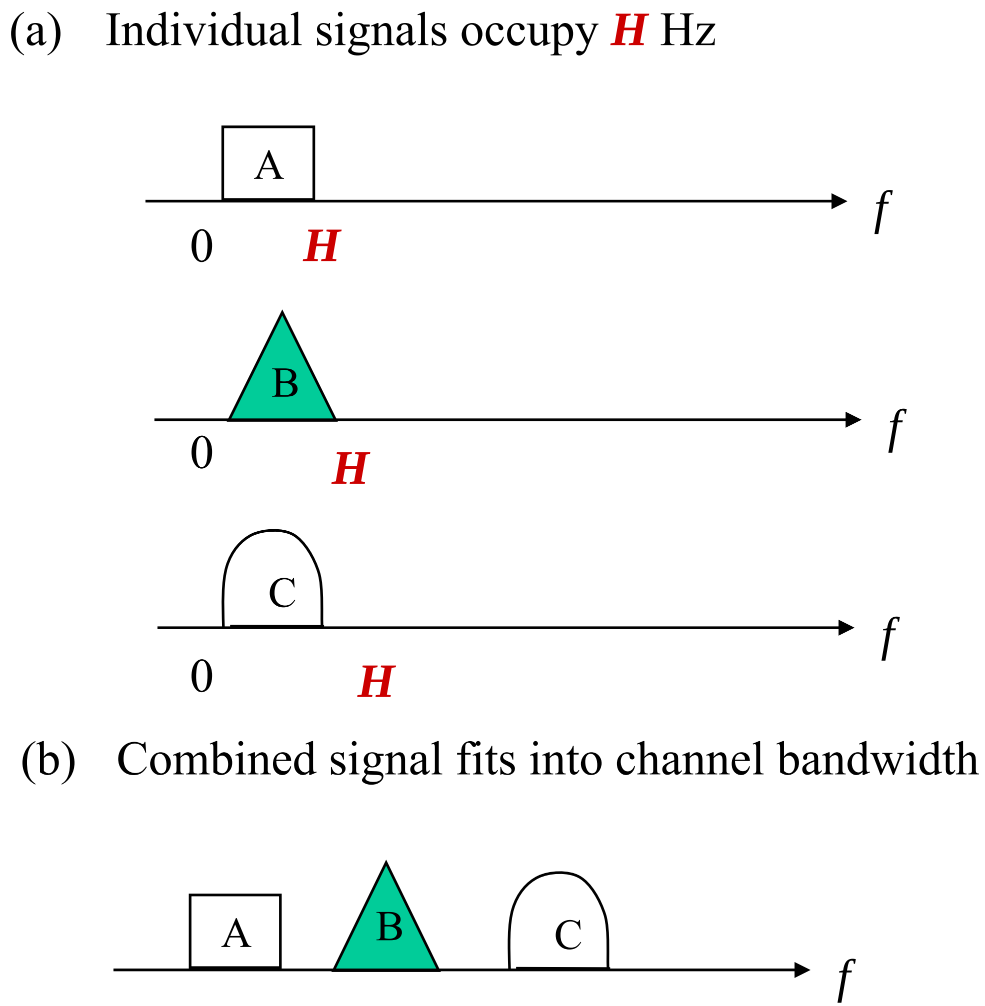
Multiplexing



Leon-Garcia & Widjaja: *Communication Networks*

Figure 4.1

Frequency Division Multiplexing



 Leon-Garcia & Widjaja: *Communication Networks* Figure 4.2

Frequency Division Multiplexing

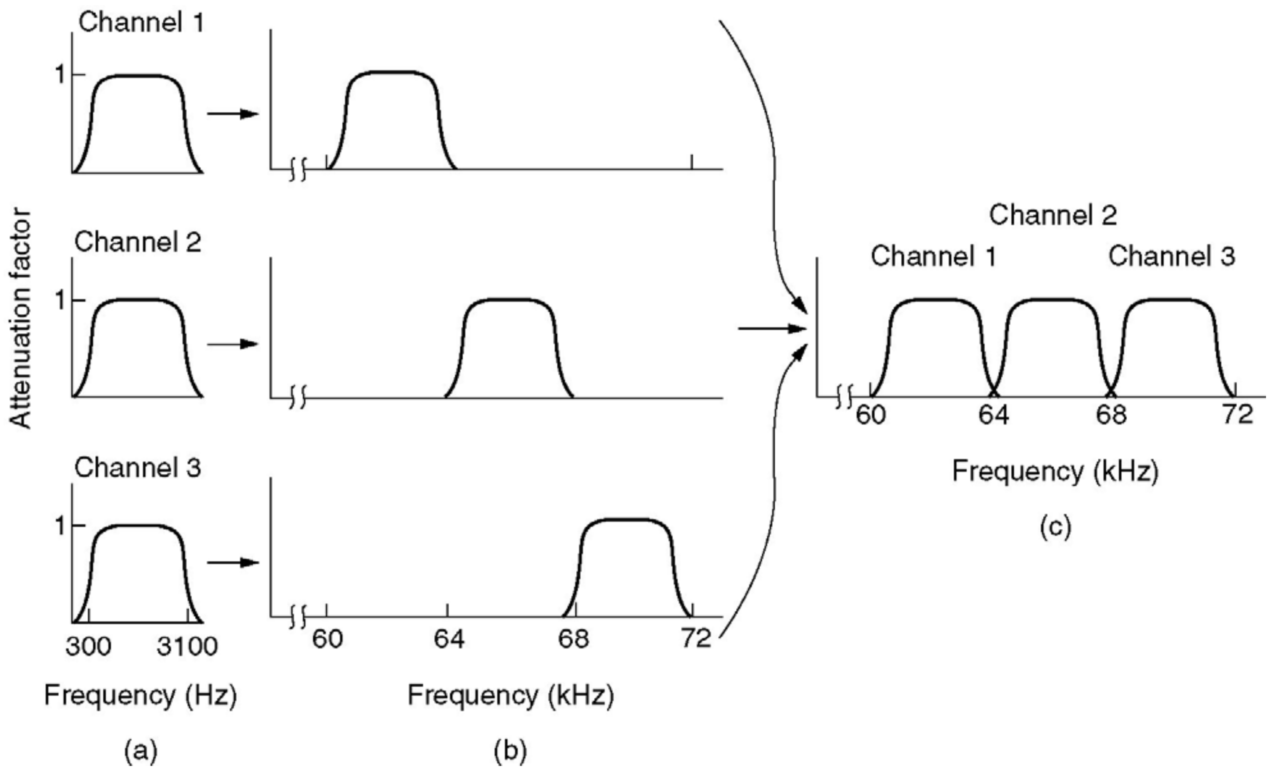


Figure 2-31. (a) The original bandwidths. (b) The bandwidths raised in frequency. (c) The multiplexed channel.

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Wavelength Division Multiplexing

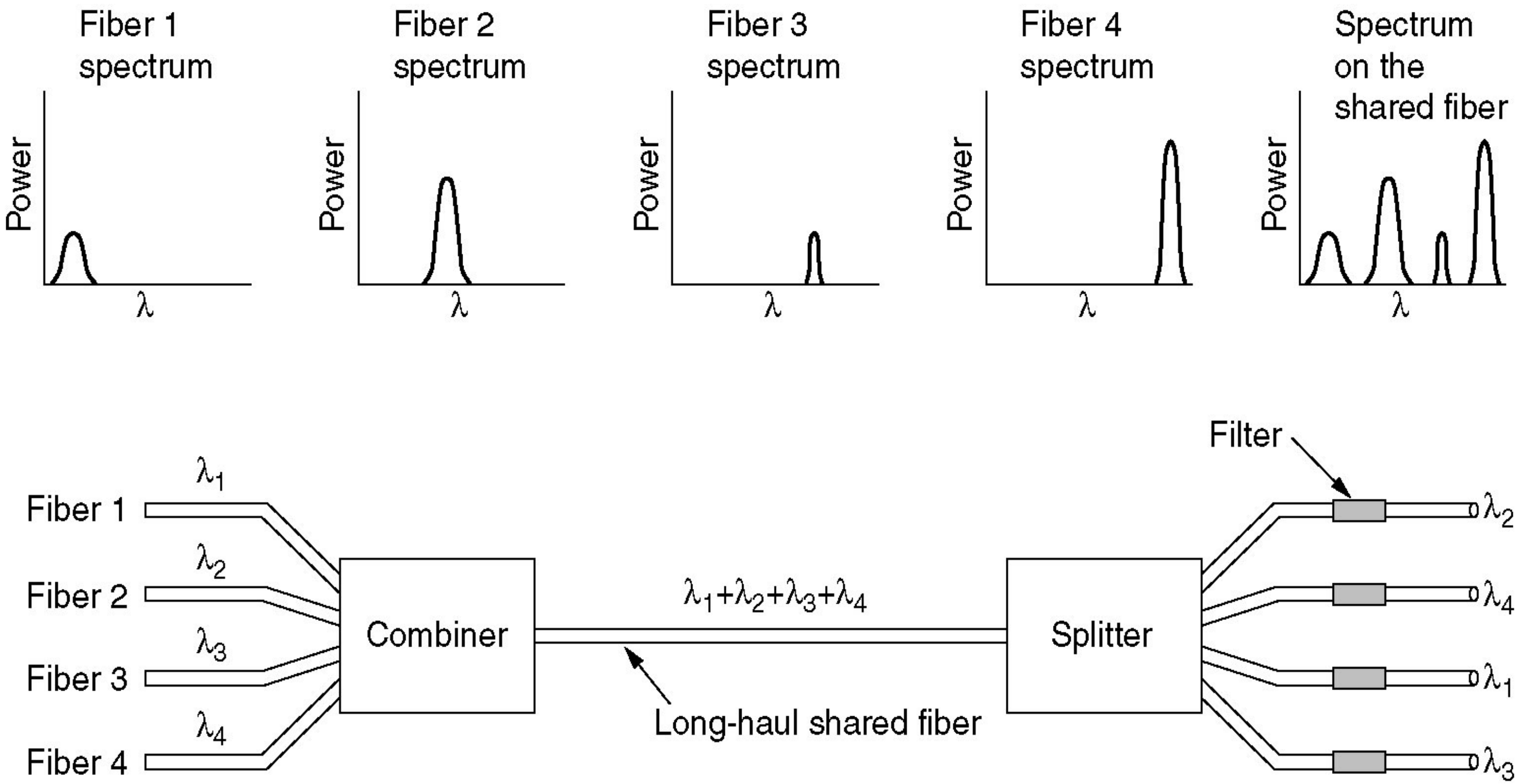

Figure 2-32.

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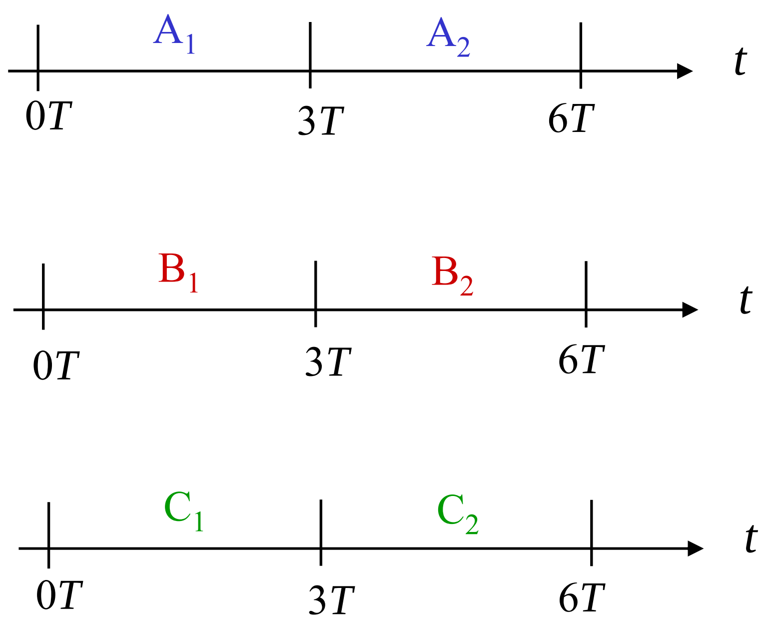
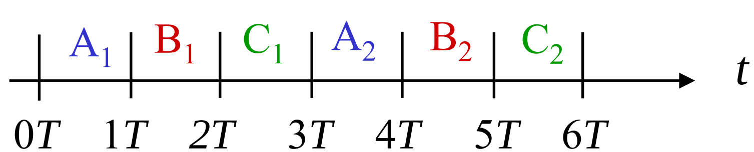
Time Division Multiplexing

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



(b) Combined signal transmits 1 unit every *T* seconds



Time Division Multiplexing

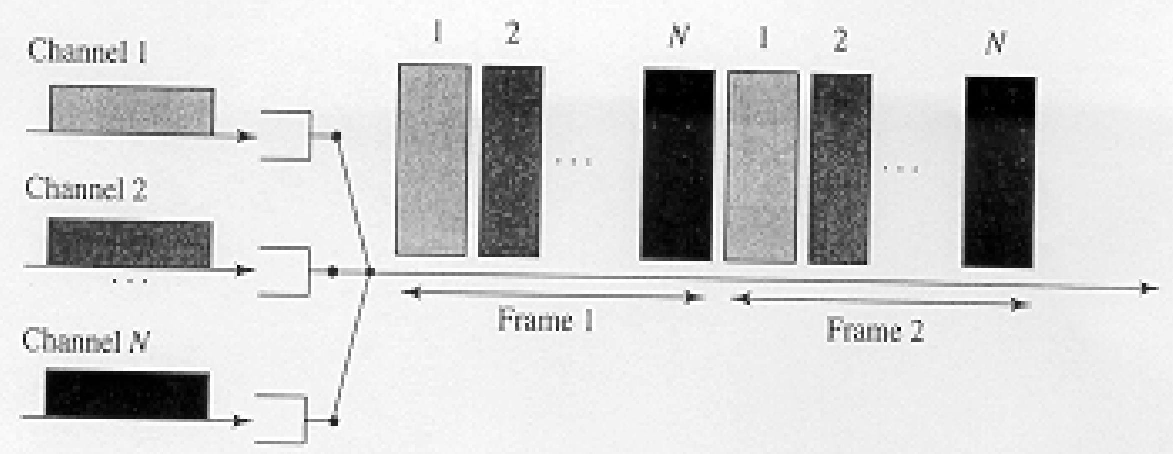


FIGURE 2.9

When a communication link is shared by time-division multiplexing, time is divided into frames. Each frame is divided into time slots that are allocated in a fixed order to the different incoming channels.

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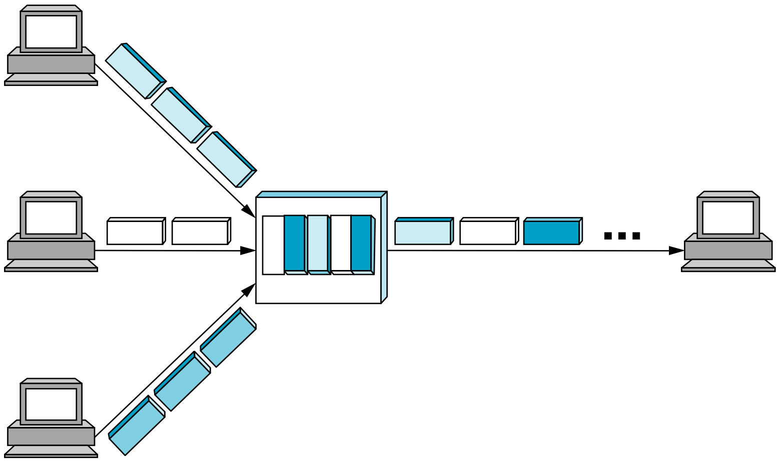
Statistical Multiplexing

- On-demand time-division
- Schedule link on a per-*packet* basis
- Packets from different sources interleaved on link
- Buffer packets that are *contending* for the link
- Buffer (queue) overflow is called *congestion*



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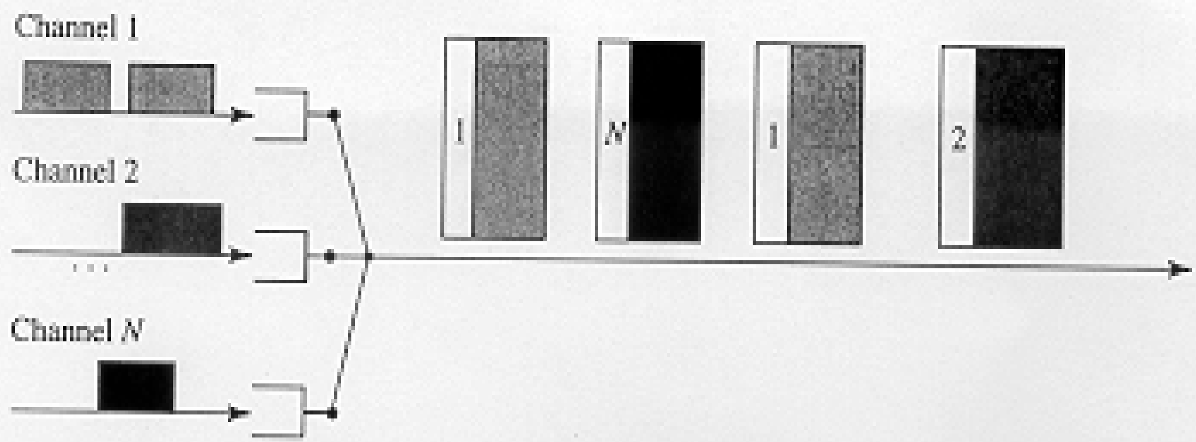
Statistical Multiplexing - Concentrator



2.10 FIGURE

In statistical multiplexing, the multiplexer visits the incoming channel buffers in some order. The multiplexer empties a buffer before moving to the next one. The buffer contents are tagged to indicate their incoming channel. An idle channel does not waste transmission time.

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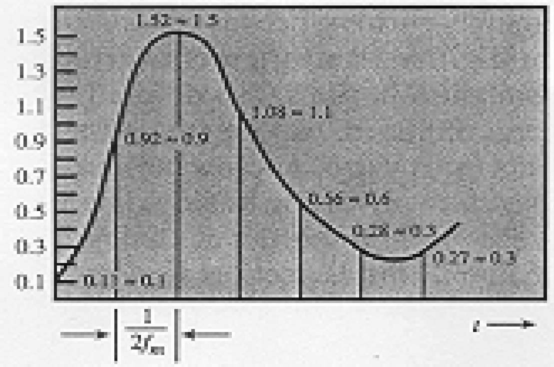
Pulse Code Modulation (PCM)

- Analog signal is sampled.
- Converted to discrete-time continuous-amplitude signal (Pulse Amplitude Modulation)
- Pulses are ***quantized*** and 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.



(a)

Digit	Binary equivalent	PCM waveform
0	0000	
1	0001	
2	0010	
3	0011	
4	0100	
5	0101	
6	0110	
7	0111	
8	1000	
9	1001	
10	1010	
11	1011	
12	1100	
13	1101	
14	1110	
15	1111	

(b)

Figure 5.10 Pulse Code Modulation

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PCM with Nonliner Quantization Levels

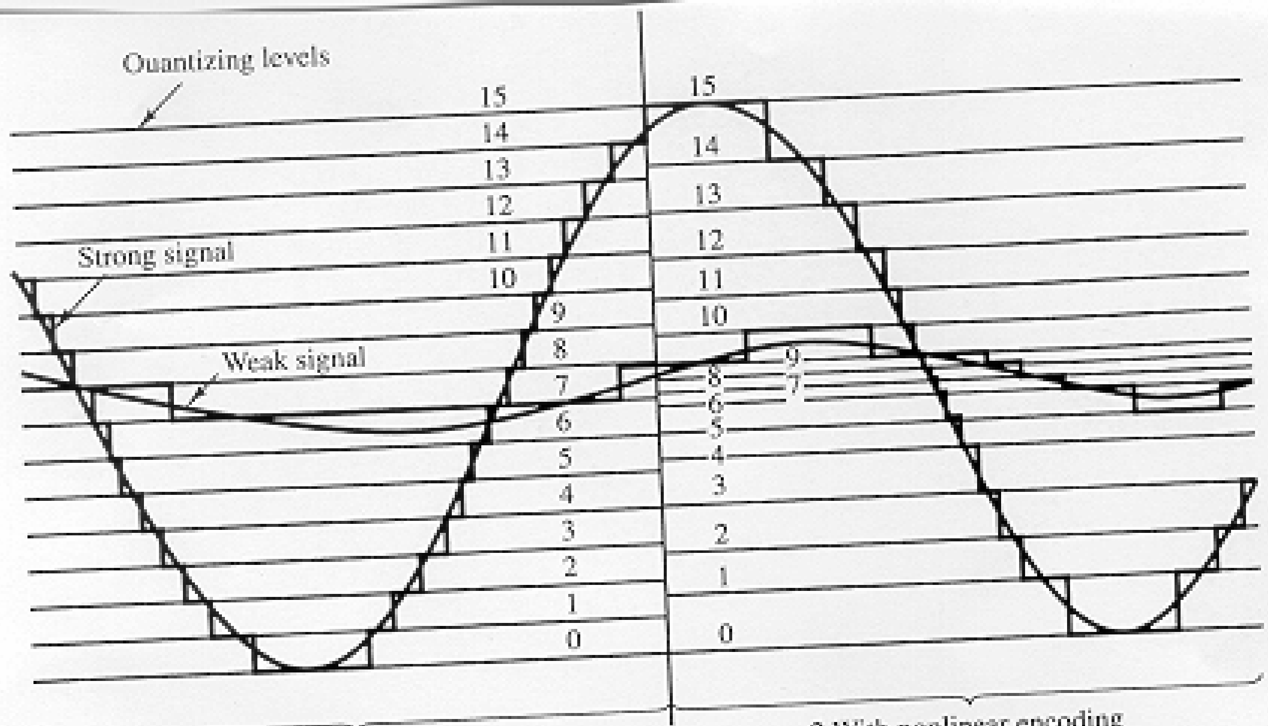

Figure 5.11 Effect of Nonlinear Coding

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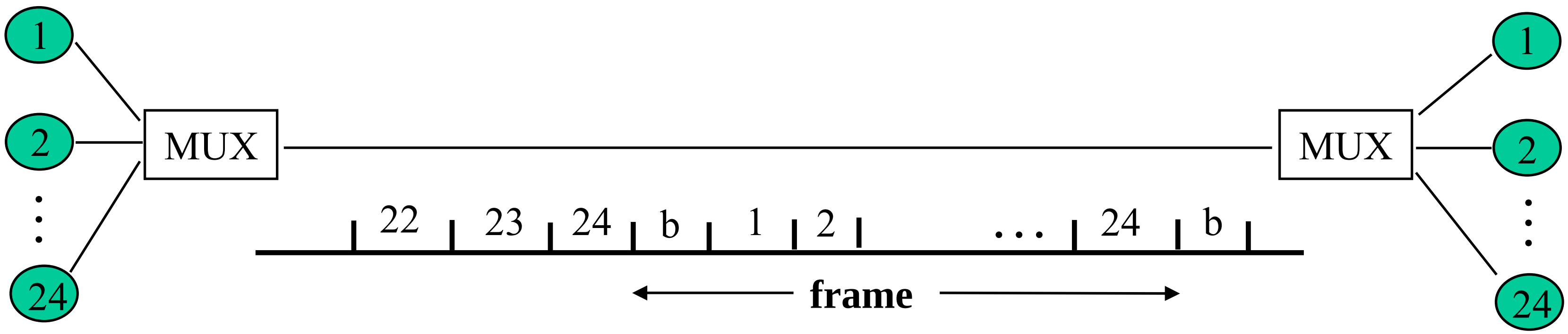
T1 System



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T1 – a TDM System

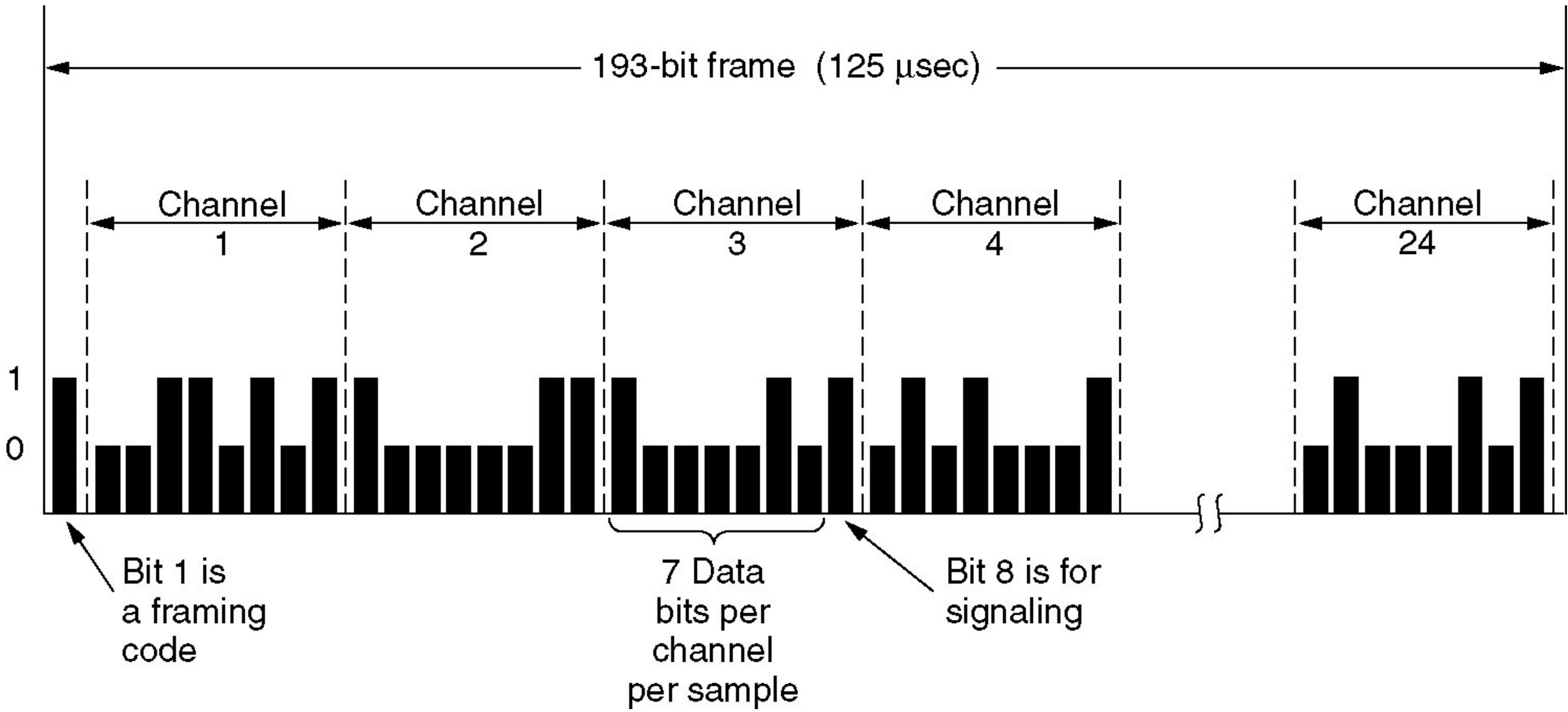

Figure 2-33.T1 Carrier (1.544Mbps)

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Delta Modulation (DM)

- The basic idea in *delta modulation* is 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. ➔ output of DM is a single bit.
- PCM preferred because of better SNR characteristics.

Delta Modulation DCC 6th Ed. W.Stallings