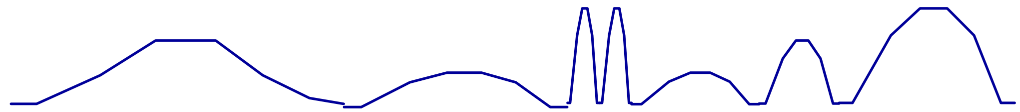
Physical layer

Overview

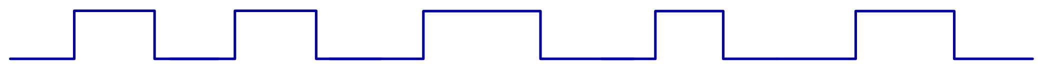
- Physical layer is responsible for transmission of a stream of bits
  - Put bits from a machine to a medium
  - Pick bits from the medium give to receiver
- Some issues
  - Medium
  - Line Encoding: representing the digital logic levels using the physical attributes associated with the media.
  - Multiplexing

From signal to packet

Analog Signal



"Digital" Signal



Bit Stream

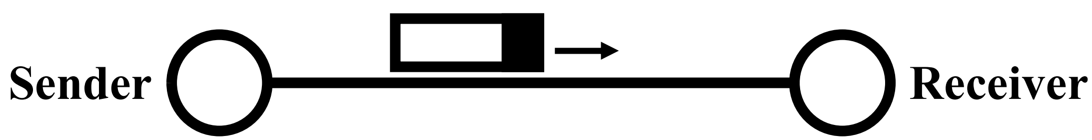
0 0 1 0 1 1 1 0 0 0 1

Packets

0100010101011100101010101011101110000001111010101110101010101101011010111001

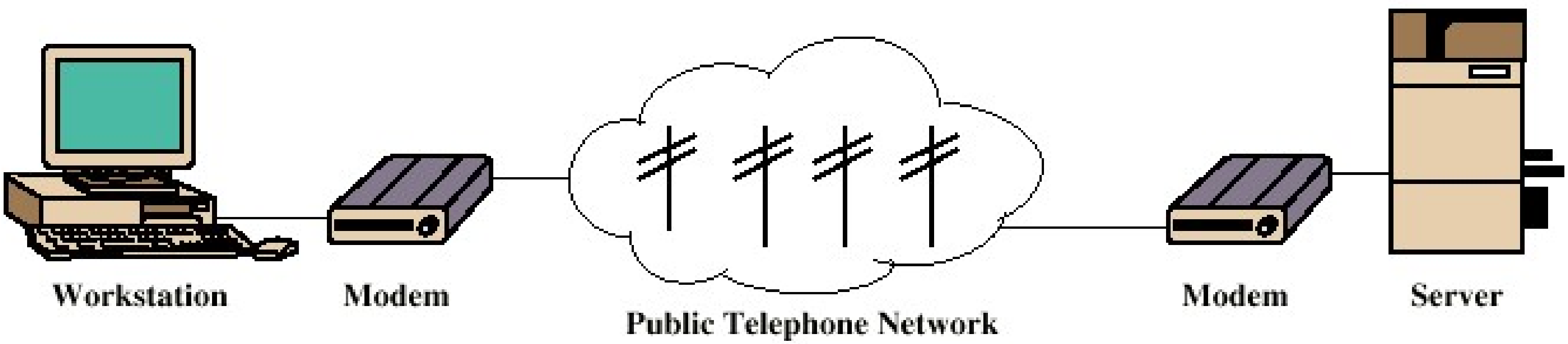
Header/Body **Header/Body** **Header/Body**

Packet Transmission



Model of data transmission system

(a) General block diagram



(b) Example

Data Communication networks

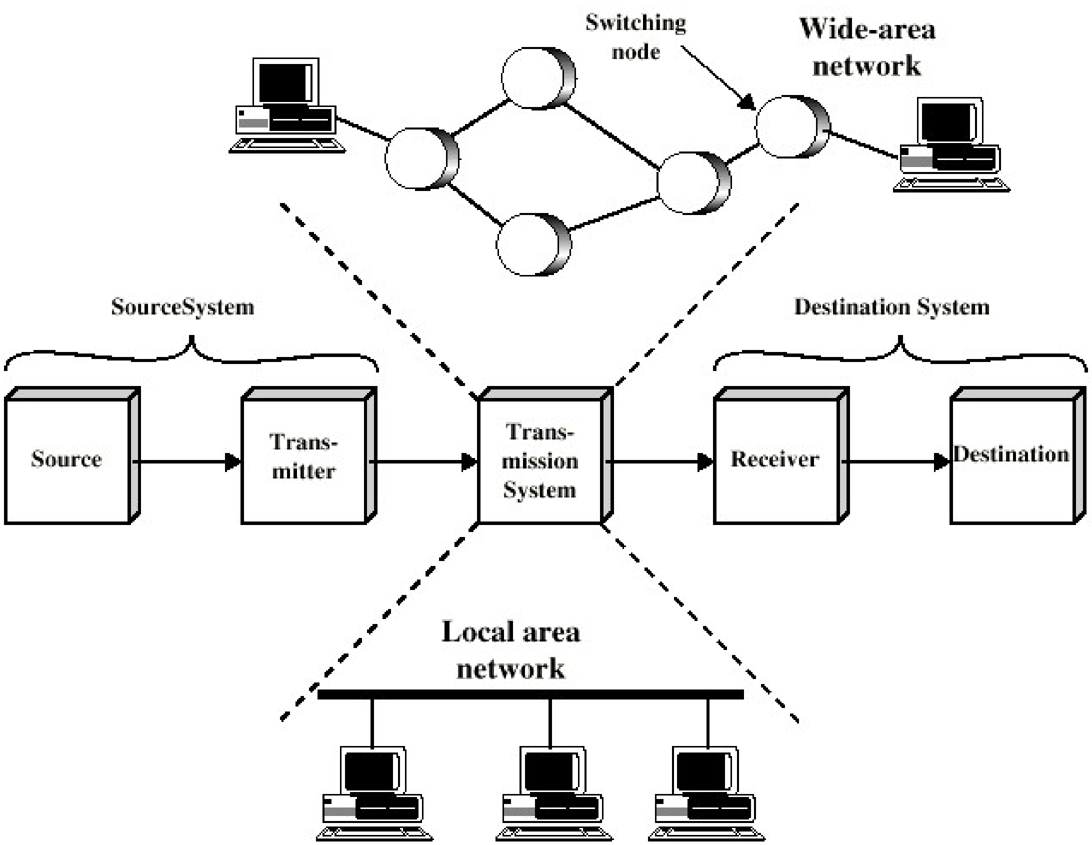
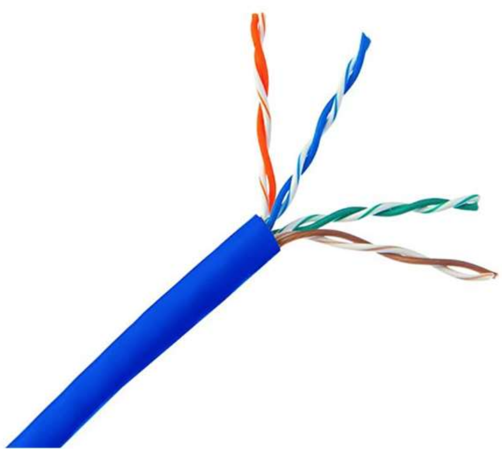


Figure 1.3 Simplified Network Models

Media

- Wired
  - Twisted Pair
  - Coaxial Cable
  - Fiber Optics
- Wireless
  - Radio
  - Infra red
  - Light
  - …

Twisted pair



(a)

(b)

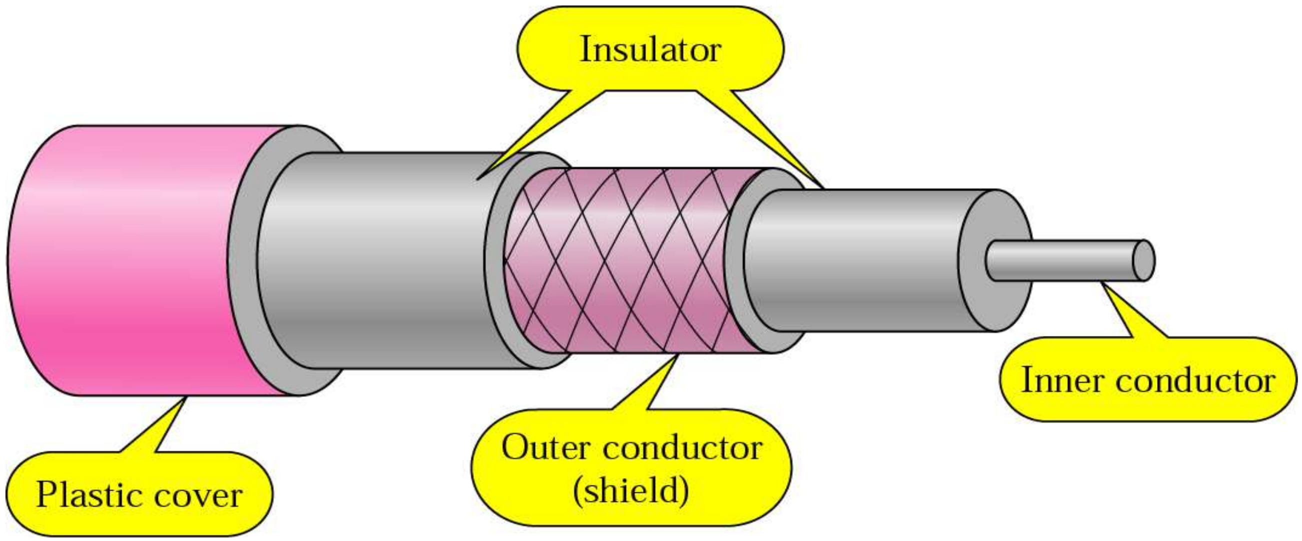
(a) Category 3 UTP.
(b) Category 5 UTP.

Evaluation

- Cheap, simple
- Widely used
- Weak resistance to noice
- Short Transmission distance

- Need amplification after each 5km in analog transmission
- In digital transmission
  - Need repeater after each 2 km
- Limited speed (100MHz)
- Noise

II. Coaxial



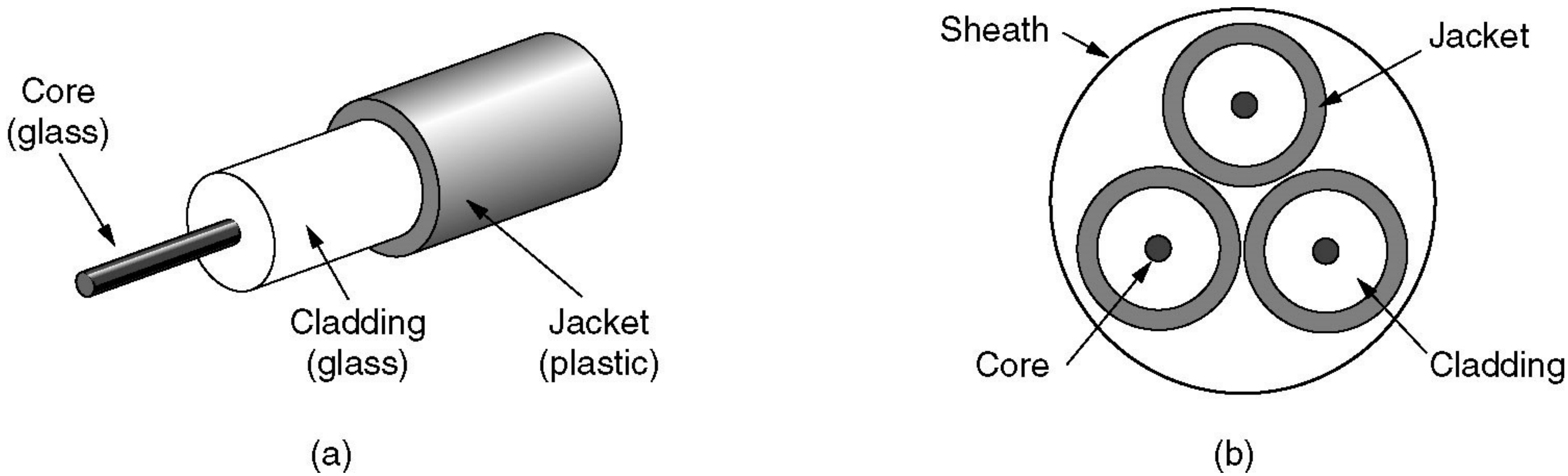
Category	Impedance	Use
RG-59	75 Ω	Cable TV
RG-58	50 Ω	Thin Ethernet
RG-11	50 Ω	Thick Ethernet

Application

- Using in TV transmission
- For transmission of telephone signal
  - 10,000 calls in the same time
  - Is being replaced by fiber optics
- Linking the computers of the short distance
- LAN 10BaseT, 100BaseT, …

- For digital transmission
  - Repeater should be used after each 1km
  - More repeater is needed for high speed transmission

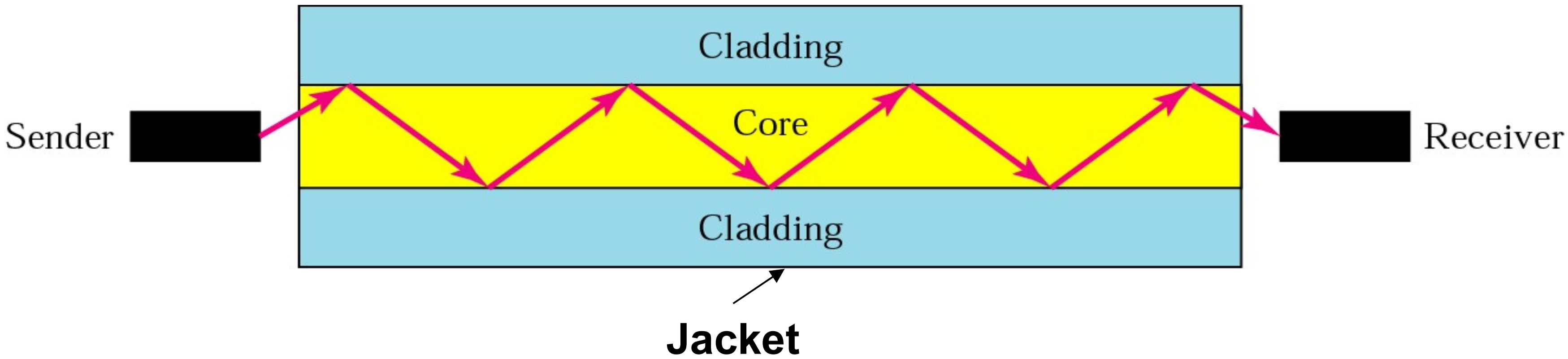
Optical fiber

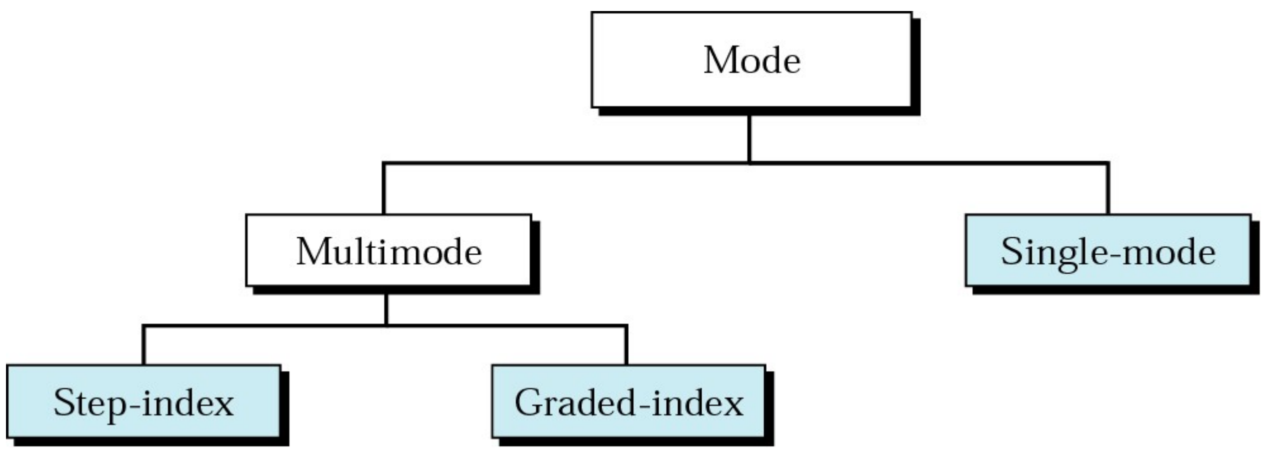


(a) Single core

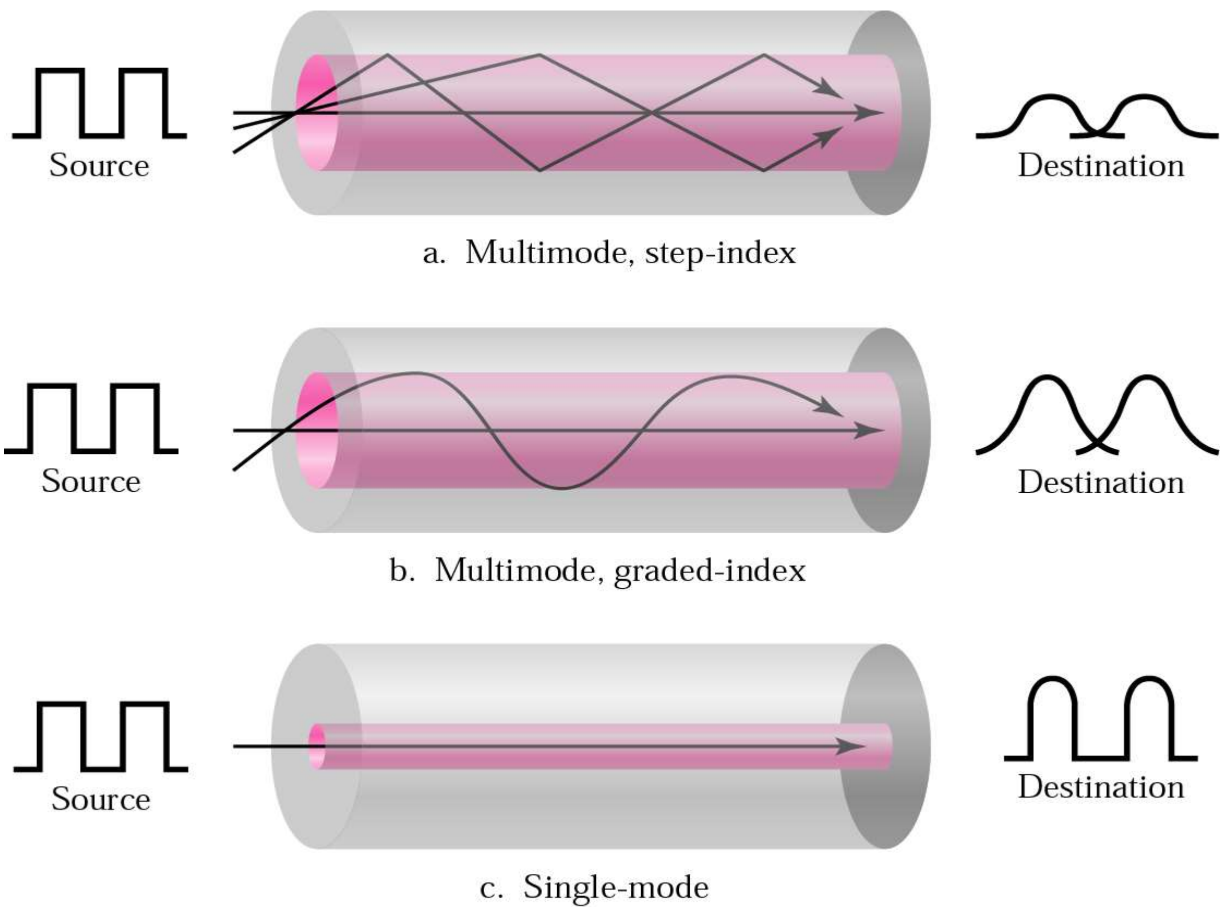
(b) Cable with 3 cores

Optical fiber transmission mode





Optical fiber



Application of optical fiber

- Used for long distance transmission
- Used for communication in metropolitan networks
- Used for connecting routers of ISP
- Used in backbone part of a LAN

- Advantage in comparison with other cables
  - Large data rate
  - Small and light cable
  - Low attenuation
  - Better isolation from electromagnetic environment
  - Large distance between repeaters (10km)

Wireless media

- Data transmission on different frequency band of electromagnetic waves
- No physical lines
- Broadcast, half-duplex: only send or receive at a time
- Being impact by environment
  - Reflection
  - Noise/interfering
  - Scattering caused by obstacles

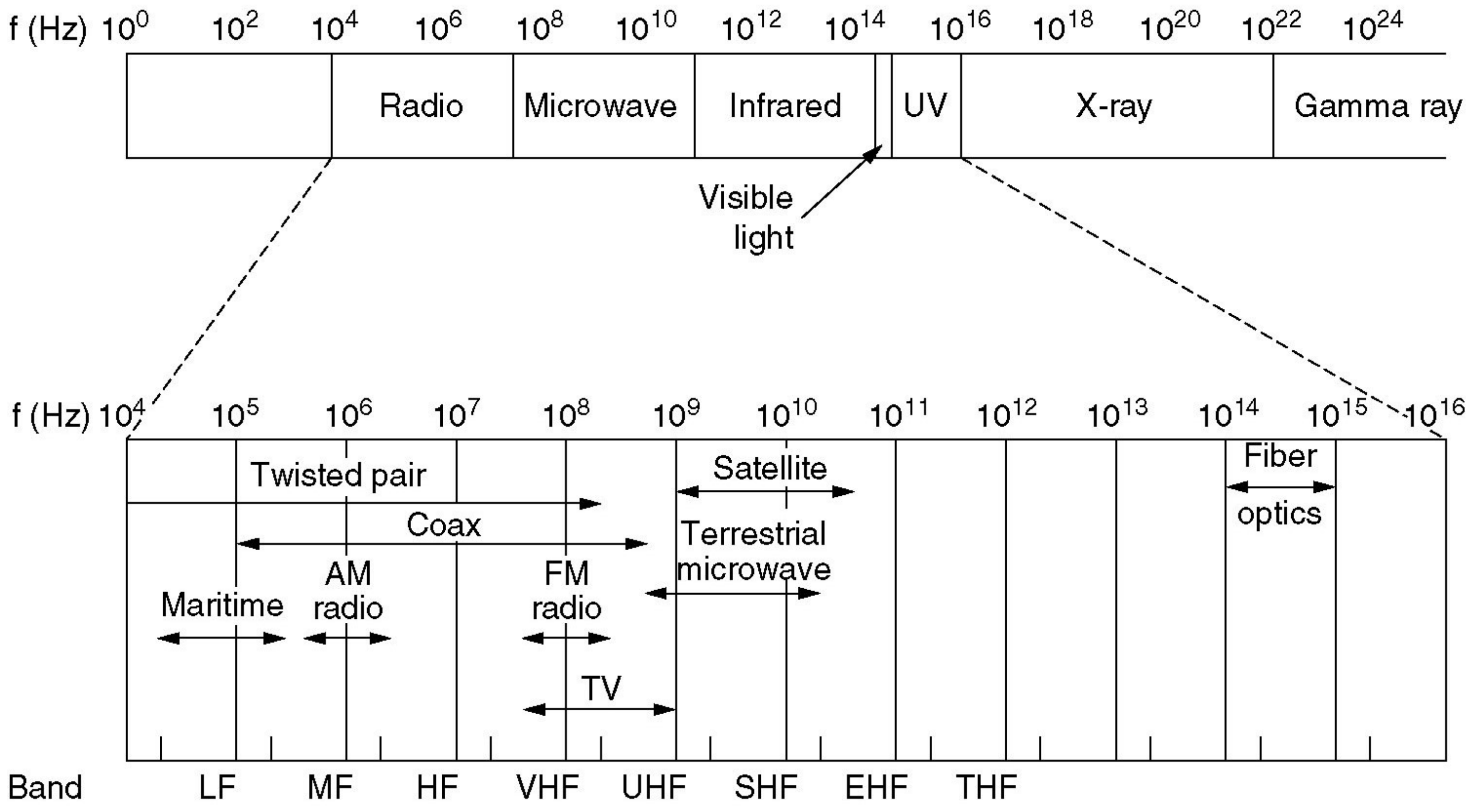
Wireless media

- Radio wave:
  - Wavelengths: 1mm – 100.000km
  - Frequencies: 3 Hz – 300 GHz
  - Ex: Bluetooth, WIFI
- Microwave:
  - Wavelengths: 1mm-1 m
  - Frequencies: 300 MHz-300 GHz
  - Terrestrial microwave : metro connection, cellular communication
  - Satelite microwave: TV, long distance telephone

Wireless media

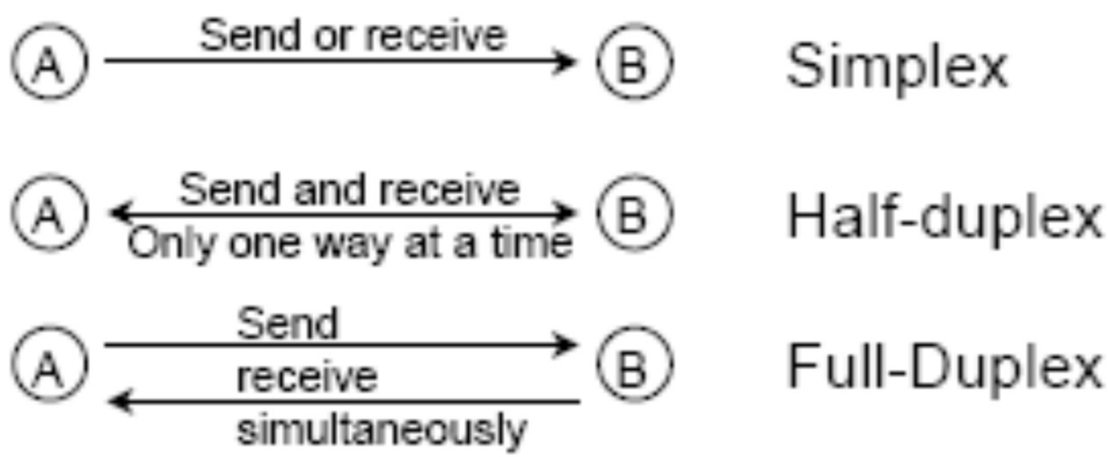
- Infra red:
  - Wavelengths: 700 nm- 1 mm
  - frequency: 300 GHz-430 THz
  - Small scope, no wall penetration
  - Ex: use in remote controls
- Free Space Optics
  - Wavelengths: 850nm, 1300nm, 1550 nm

Frequency range of transmission chanels



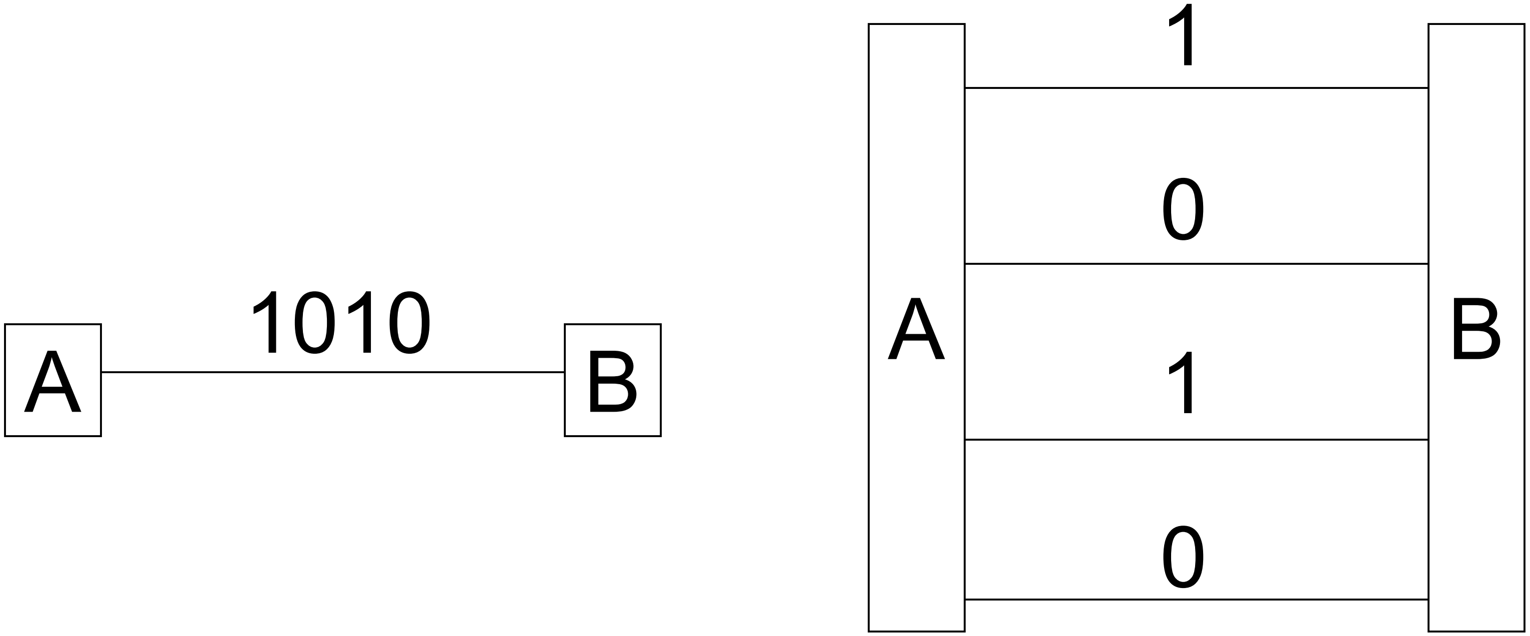
Transmission type

- Simplex: Data is trasmitted in one direction
- Full Duplex: Data can be transmitted in both directions in the same time
- Half duplex: Data can be transmitted in both directions but one direction at a time.



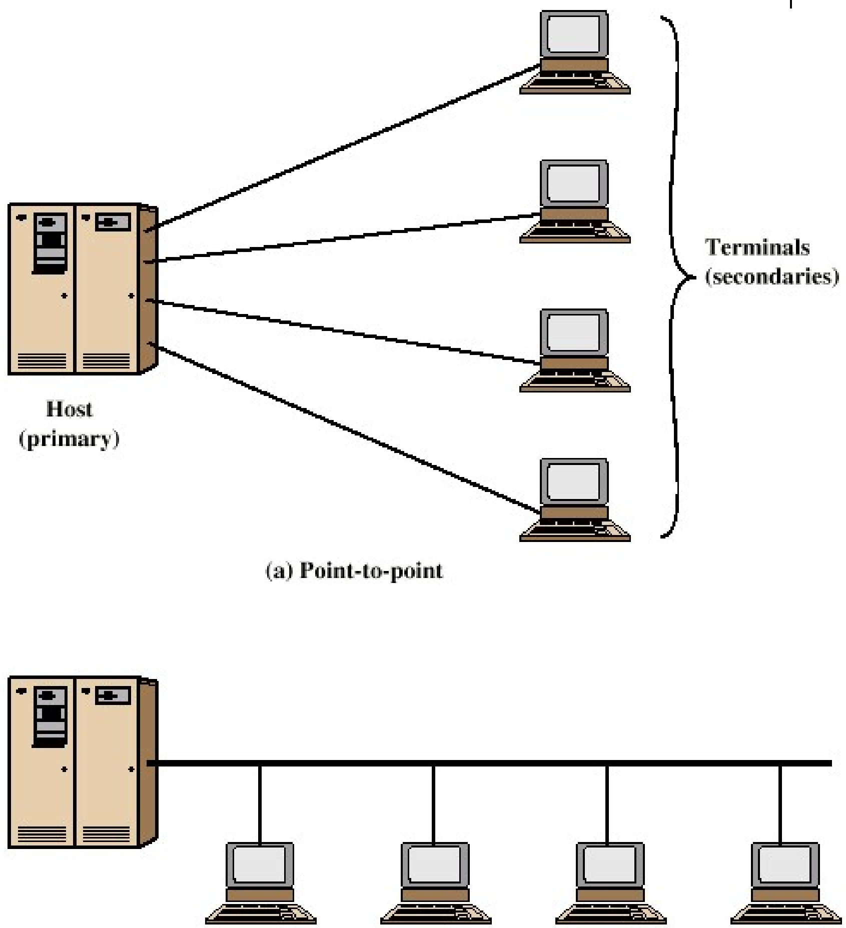
Transmission format

- Sequent transmission: Transmit 1 bit at a moment (over a signal line)
- Parallel transmission: Trasmit multiple bits in the same time (over multiple signal lines)



Topology

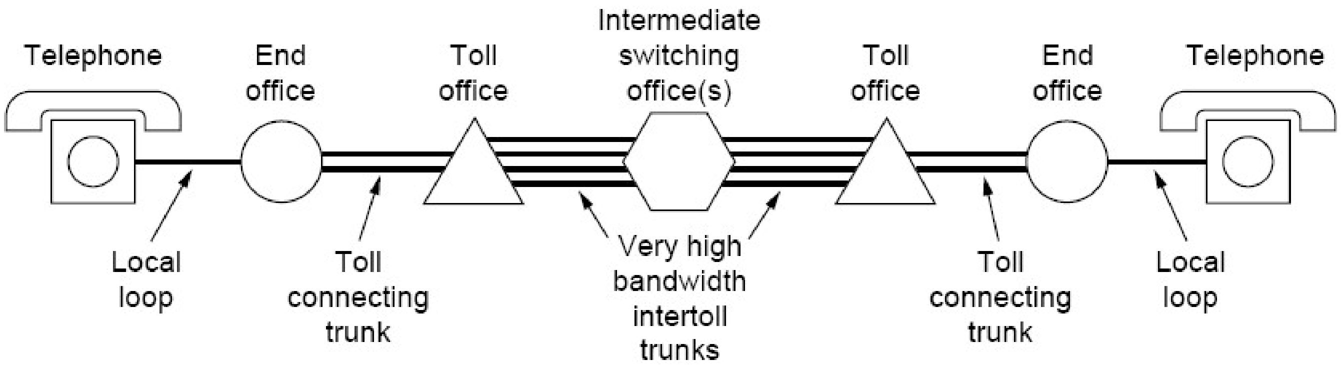
- Point-to-point
  - Star
  - Ring
  - Mesh
- Point-to-multipoint
  - Bus
  - Ring
  - Star

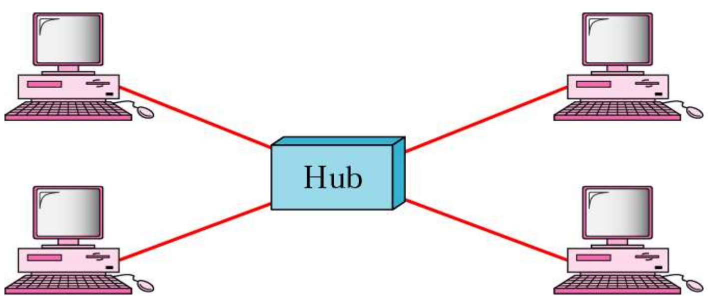


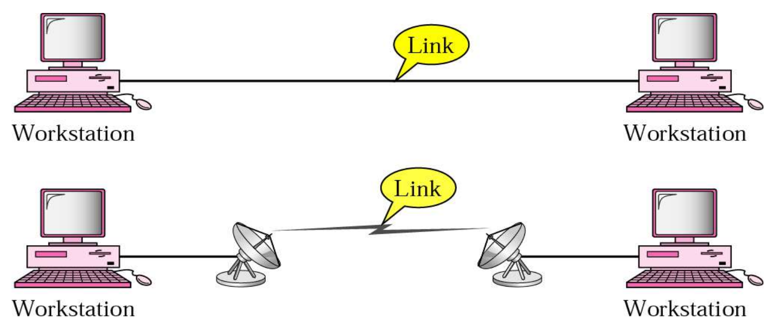
(a) Point-to-point

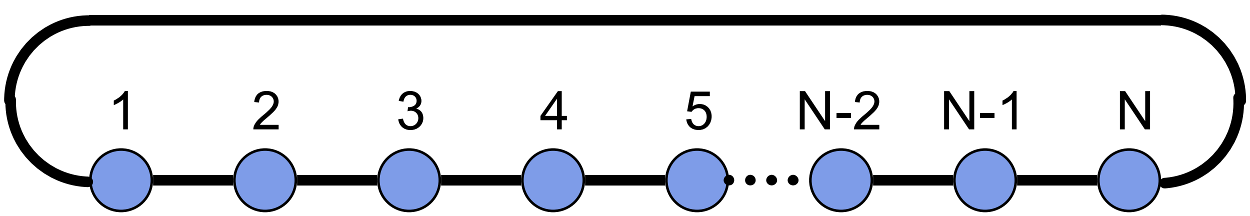
(b) Multipoint

Point -to-Point

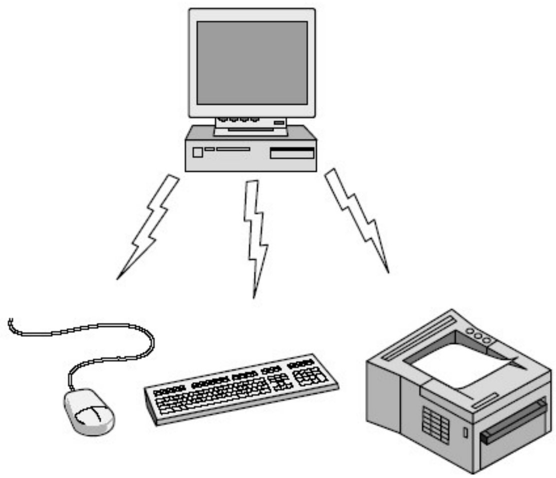


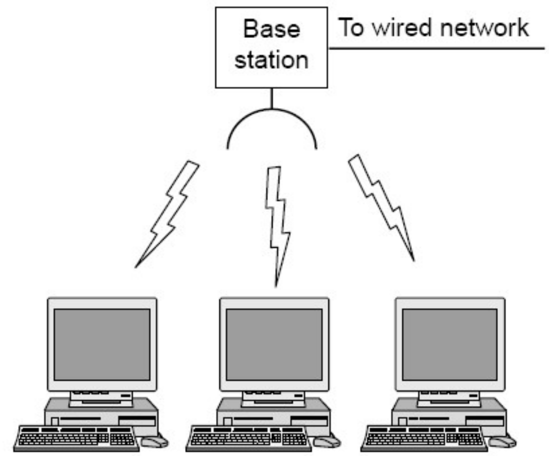


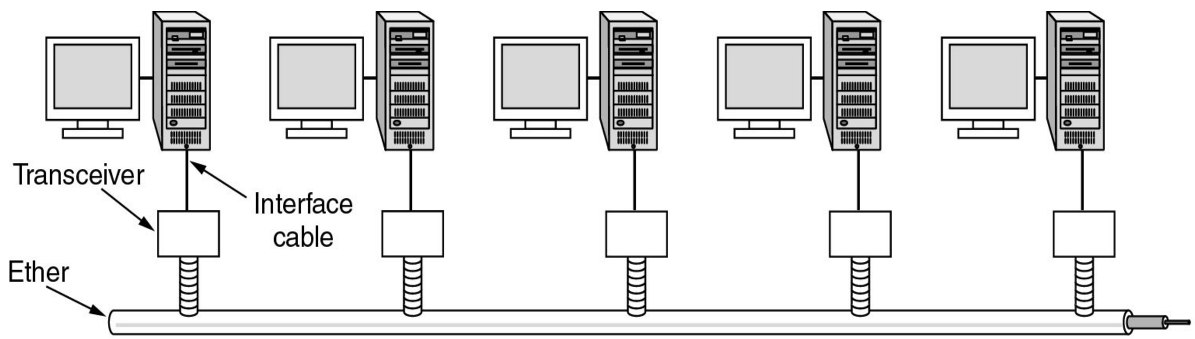




Point-to-multipoint



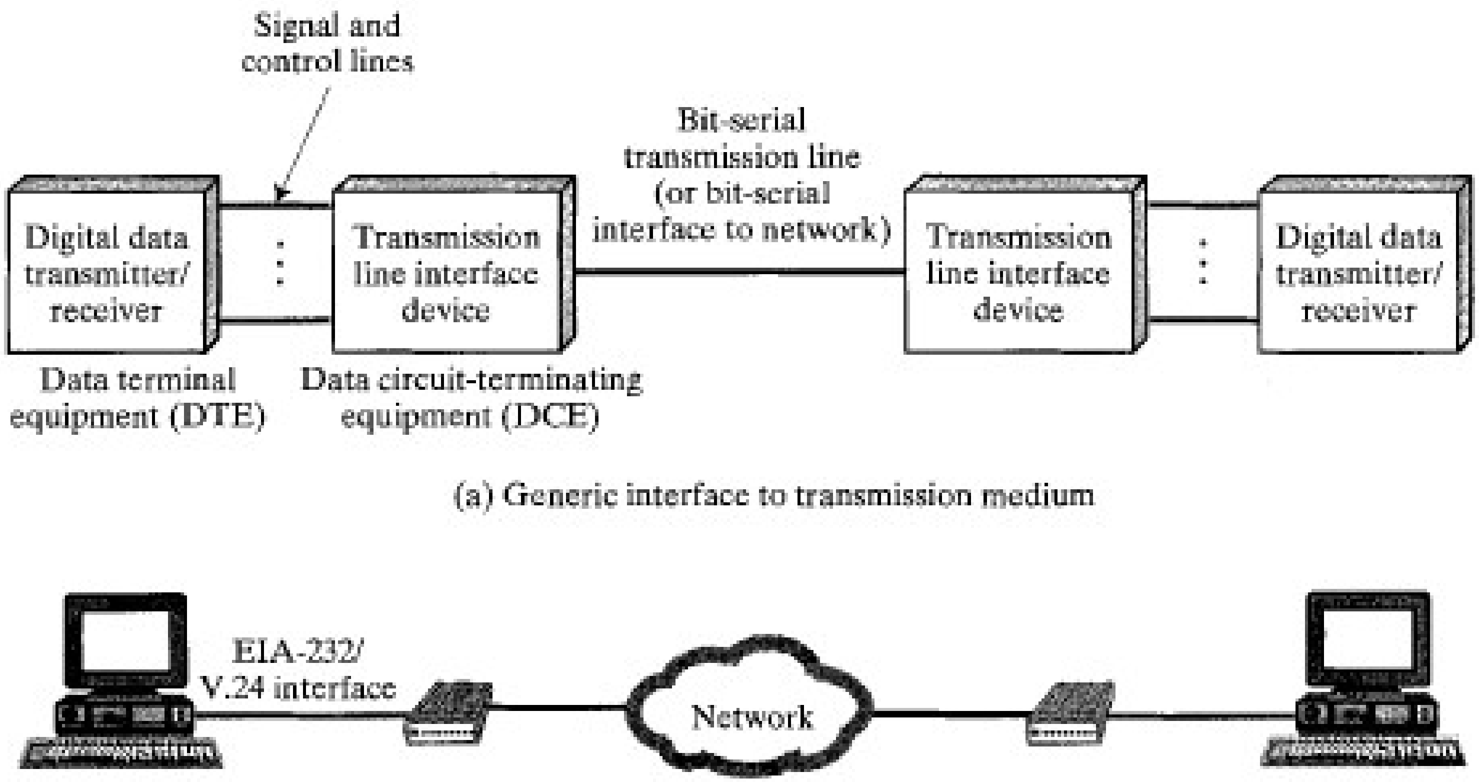




Medium interface

- Data terminal equipment (DTE)
  - Have data to transmit but has no feature for transmission
  - Need an additional device for accessing the media
- Data circuit terminating equipment (DCE)
  - Transmit bits on the media
  - Transmit data and control information with DCE through connection the media
- Need a clear interface standard between DTE, DCE

DTE-DCE



(a) Generic interface to transmission medium

(b) Typical configuration

Media interface

- Mechanism
  - Define the form of the interface, number of pins for assuring the interfaces match together
- Electrics
  - Define the level of voltage to be used
  - Define the length of pulse (frequency)
  - Define enconding method
- Functionalities
  - Functionality of each pins
  - There are 4 groups of pins: data, control, synchronization, ground
- Procedure
  - Lists of events to perform for transmitting data

Example: EIA-232-E/RS-232

- Define for serial communication
- Mechanism: ISO 2110
- Electrics: V. 28
- Functionality: V. 24
- Procedure: V. 24

Example: V.24 /EIA-232-E

- Mechanic:
  - 25 or 15 pins
  - Transmission distance 15m
- Electrics
  - Digital data
  - 1=-3v, 0=+3v (NRZ-L)
  - Data rate 20kbps
  - Transmission distance< 15m

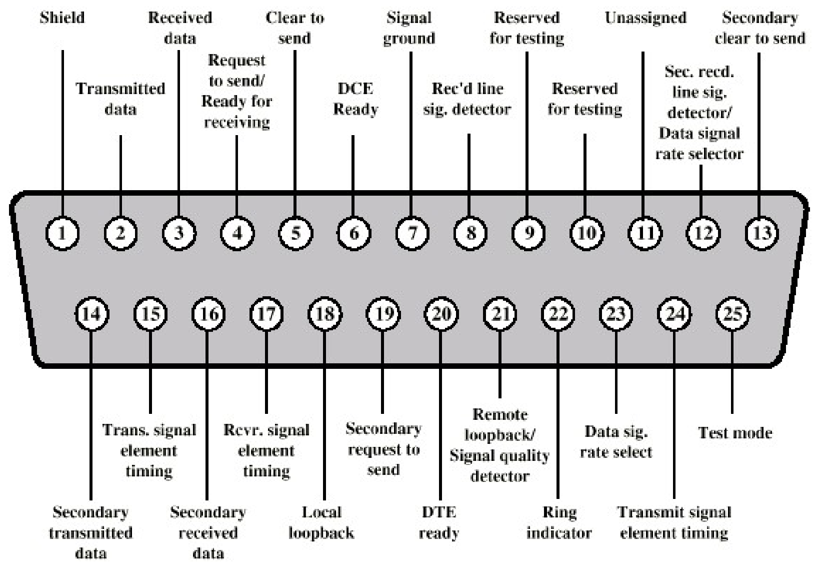


Figure 6.5 Pin Assignments for V.24/EIA-232 (DTE Connector Face)

Data Encoding

Introduction

Encoding digital data to digital signal

Encoding digital data to analogical signal

Encoding analogical data to digital signal

Encoding analogical data to digital signal

Fundamental concepts

- Objective
  - Transform the data into some signals that is suitable for transmission media

4 forms of encoding
digital data to digital signal
digital data to analogical signal
analogical data to digital signal
analogical data to digital signal

Data encoding

- Use different discrete signal, different voltage level for representing bit 0 and 1.
- Data transmission should be synchronized between sender and receiver: clock synchronization
- Encoding could be performed by bit or by a group of bit e.g., 4 or 8 bits.
- There are many way to represent 0 and 1 → See data transmission technique.

1. Digital data- Digital signal

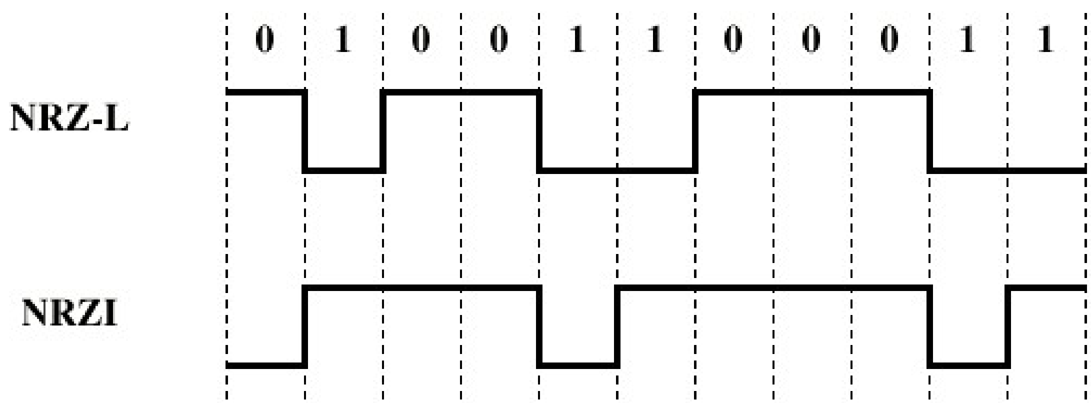
- Data unit: 1 bit
- Digital data is a digital signal
  - Each pulse is considered as a signal unit.
  - A signal unit can be considered as 1 bit
- Data encoding: mapping data to signal
- Set of mapping is called Encoding scheme
- Mark:1, Space:0

Line encoding method

- NRZ
  - NRZ-L,NRZI
- Bipolar
  - Bipolar alternate mark inversion
  - Pseudoternary
- Phase encoding
  - Manchester
  - Differential Manchester (Manchester vi sai)

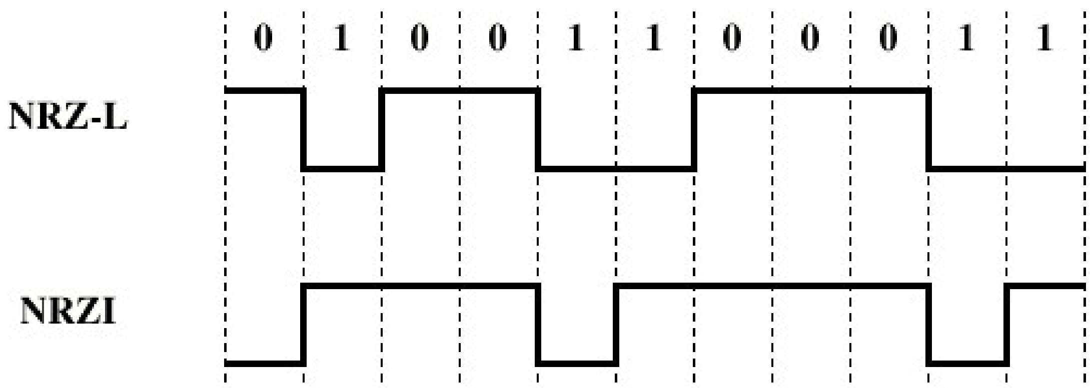
NRZ-L Non Return to Zero Level

- During bit time, signal does not go back to 0 level
- Signal level is not changed during bit time.
- NRZ-L Non return to zero level
  - Bit 1 signal is in low/high level
  - Bit 0 signal is in high/low level



NRZ-I Non return to zero invert

- Bit 0: signal level is not changed at the begining of bit time
- Bit 1: signal level is changed at the begining of bit time
- A differential encoding method :
  - 0 and 1 represent by the signal level change, not by the level itself.
  - Reliable/ simple.



Line encoding consideration

- Two aspects should be consider in any encoding methods:
  - **Clock recovery on receiver side**: If the clock recovery is not ideal, then the signal to be decoded will not be sampled at the optimal times. This will increase the probability of error in the received data.
  - **DC-component**: Directed Current vontage component.
    - DC-component makes recepter mistakenly detect level of signal
    - Encoding should avoid DC-component by having signal mean altitude to be around 0.

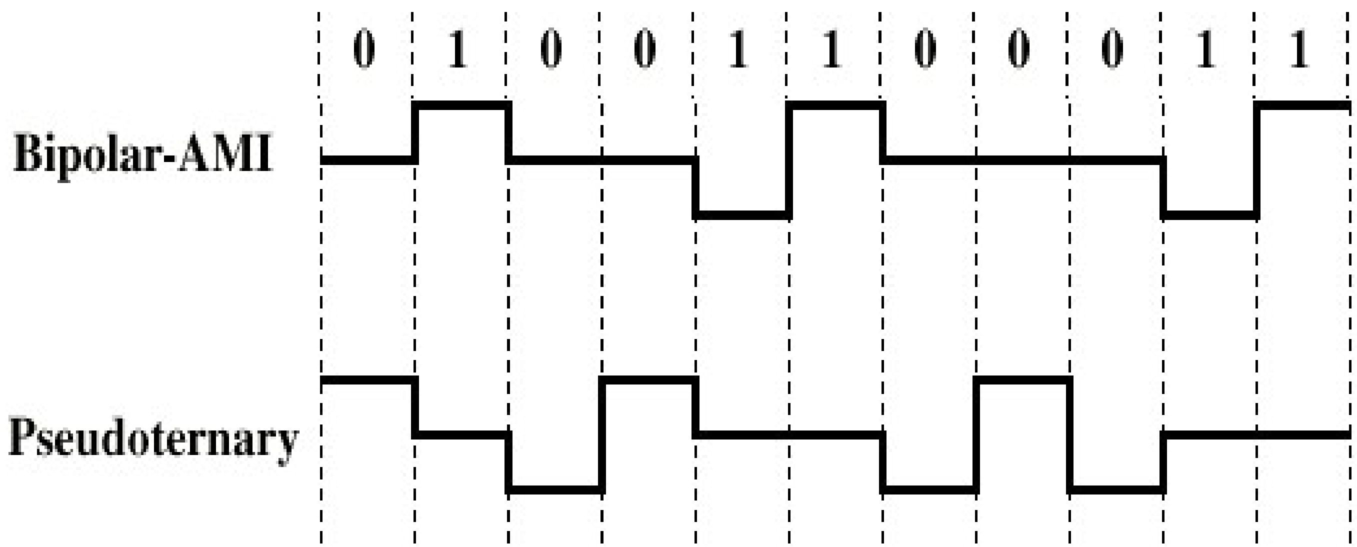
NRZ

- NRZ Advantage
  - Simple, utilise the maximum capacity of the line
  - Frequency range from 0 - ½ data speed
    - Example: 9600bps -> 4800khz
- NRZ Weakness
  - NRZ does not contain element supporting clock synchorization
    - Example: when sending a suit of 1 or 0 with many consecutive signals of the same level → lost synchronization.
    - Set of 0 for NRZI and set of 1 for NRZ-L
  - Contain DC-component when sending a suit of 1.
- Application
  - Encoding data on magnetic storage
  - Not popular in data transmission

Bipolar AMI

- Use more than 2 signal level for 1 bit
- Bipolar alternate mark inversion
  - 0 : No signal
  - 1: Presence of signal. Two consequent 1 have two different signal levels
- pseudoternary
  - 1 : No signal
  - 0 : Presence of signal. Two consequent 0 have two different signal levels

Bipolar-AMI



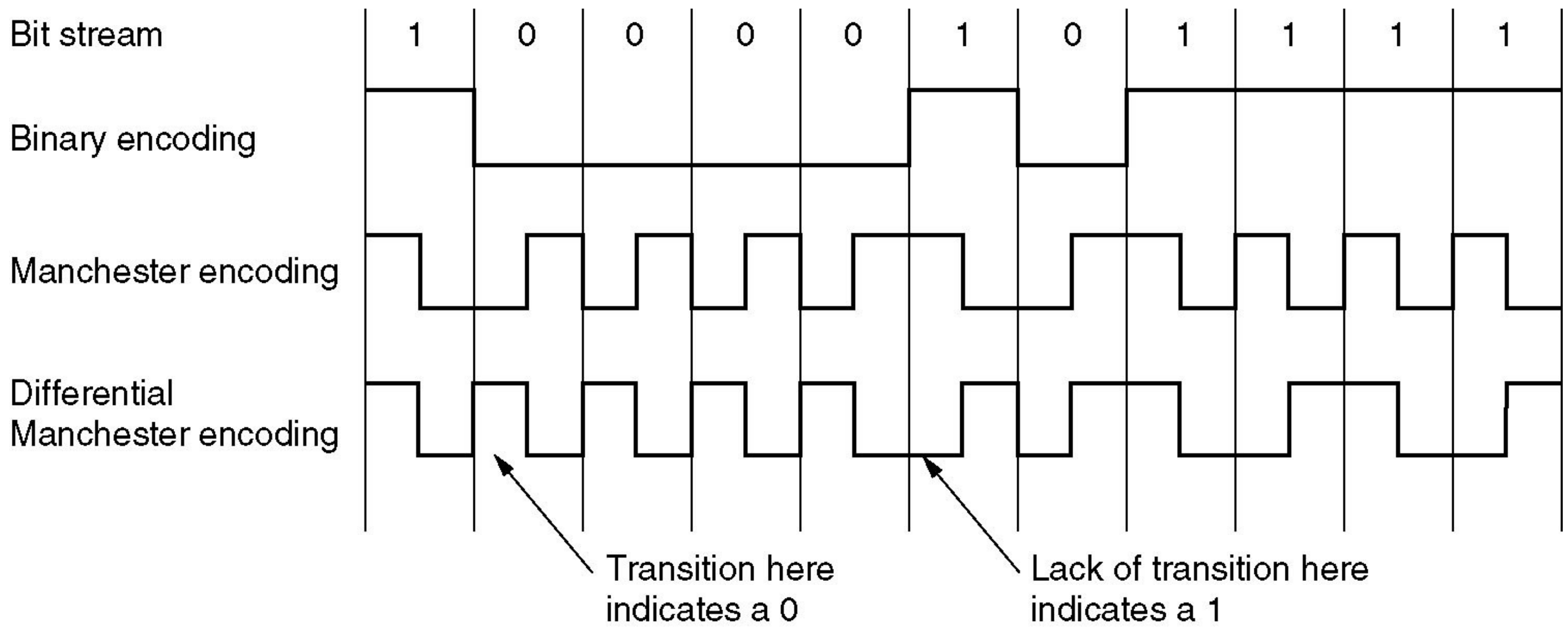
Bipolar AMI

- DC component =0
- Good synchronization when there are many bit 1(0), lost of synchronization when there are many bit 0(1)
- 3 possible signal levels for 1 bit:
  - Not optimal in using transmission line.
  - Receipter needs to distingush 3 levels of signal

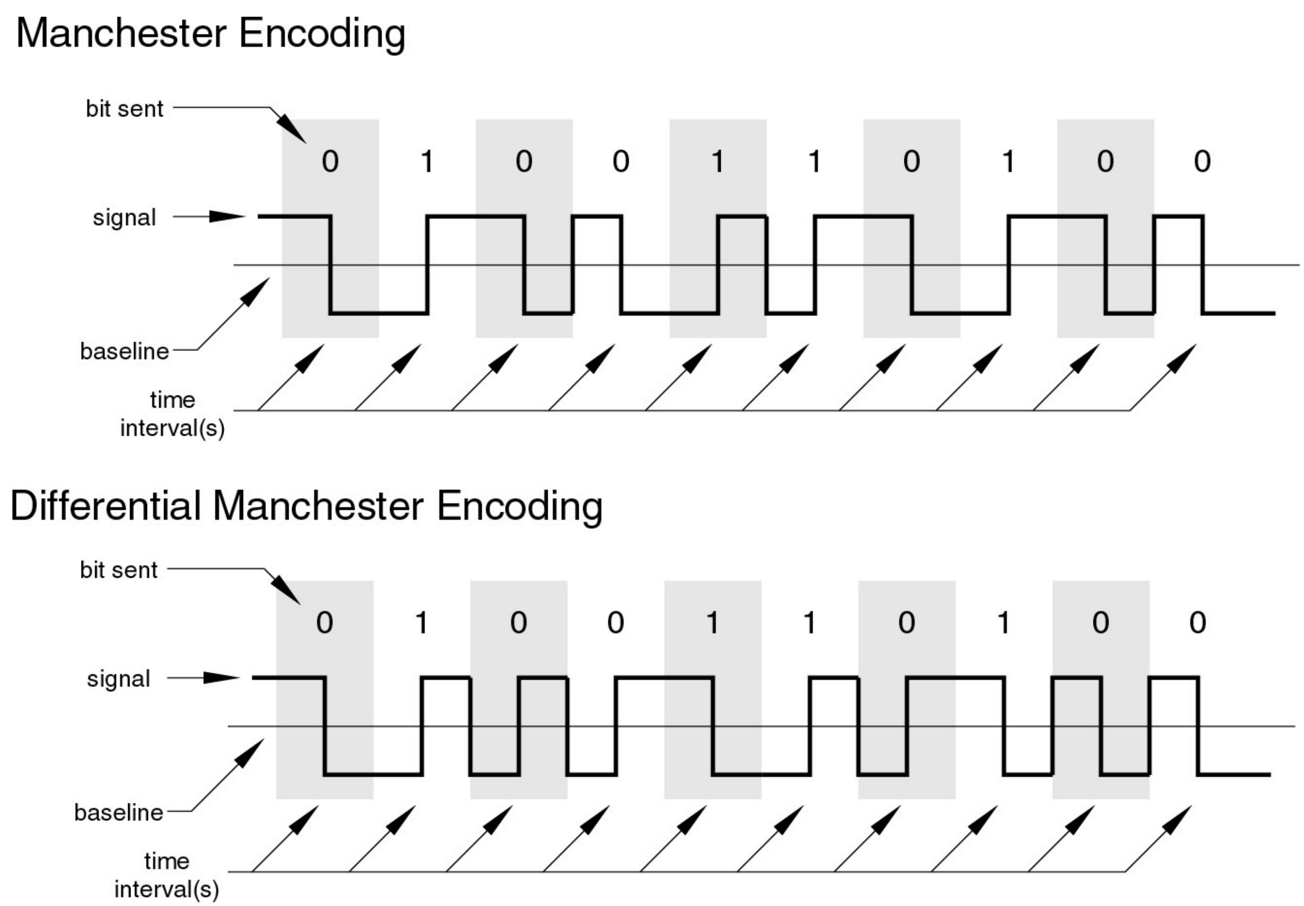
Biphase: Manchester

- Manchester: Always change signal level in the middle of bit time
  - Bit 1: Signal change from low level to high level
  - Bit 0: Signal change from high level to low level
  - Level change provide synchonisation mechanism.
- Differential Manchester:
  - 0: signal level change at the begining of bit
  - 1: **no** signal level change at the begining of bit
  - Always change signal level in the middle of bit time for synchronization purpose

Manchester encoding



Manchester encoding



Units in transmitting digital data in digital transmission

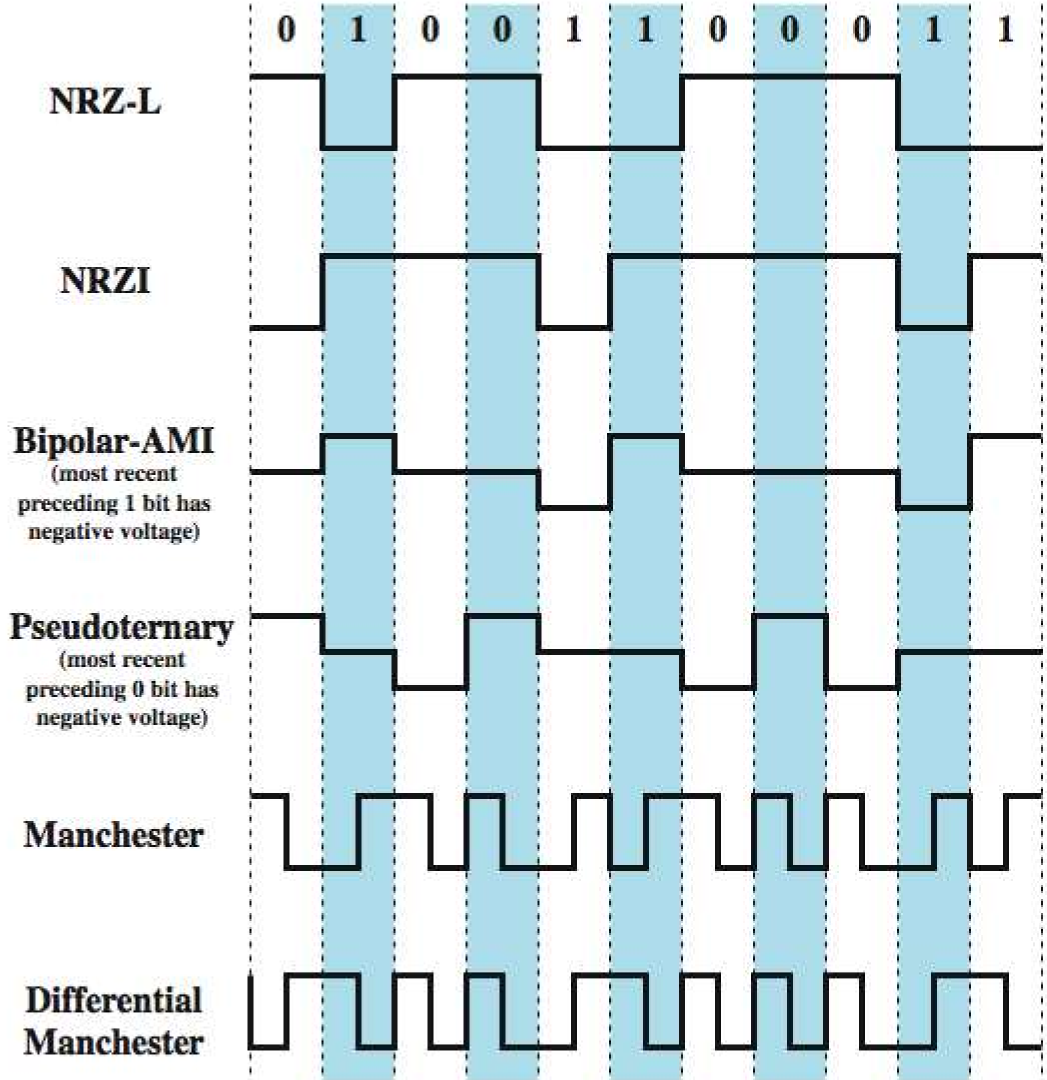
Term	***Units***	***Definition***
Data unit	bit	A single bit, Value 0 or 1
Data rate	bit/s	Rate transmitting bit
Signal unit	Pulse a sinus	Part of the signal correspond to the smallest duration of a symbol
Symbol rate/ Rate of modulation	Number of symbol/s (baud)	Number of symbols generated in a unit of time

Encoding rate: Baud rate

- Number of symbol changes, waveform changes, or signaling events across the transmission medium per unit of time
- Unit: Baud/s = symbol/s

	Minimum	101010…	Maximum
NRZ-L	0 (all 0's or 1's)	1.0	1.0
NRZI	0 (all 0's)	0.5	1.0 (all 1's)
Binary-AMI	0 (all 0's)	1.0	1.0
Pseudoternary	0 (all 1's)	1.0	1.0
Manchester	1.0 (1010…)	1.0	2.0 (all 0's or 1's)
Diff Manchester	1.0 (all 1's)	1.5	2.0 (all 0's)

Line encoding summary

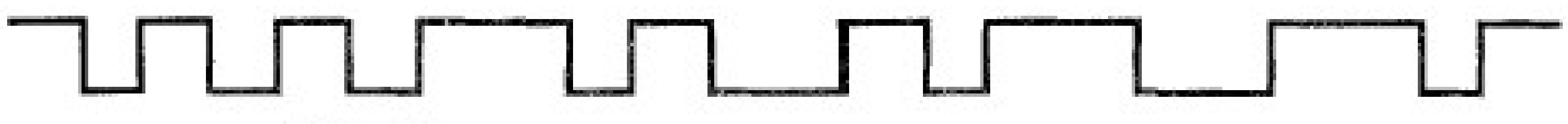


Exercise 1

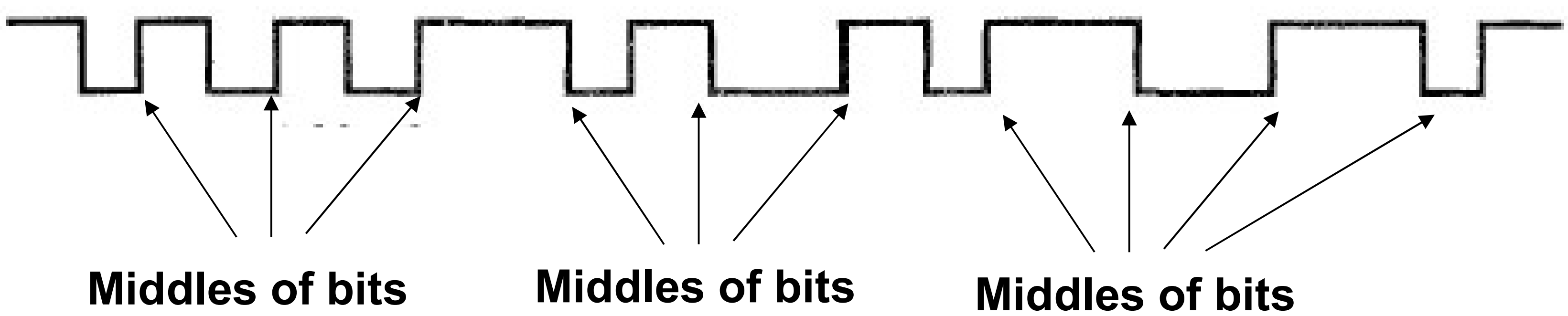
- Present the following bit set by encoding methods
  - 11000000 00000010 11001101 01010101

Exercise 2

- Given a Manchester coding signals as followed
  - Determine the timing of each bit
  - Determine the original bits



Solution for exercise 2



- Original bits: 1110011010

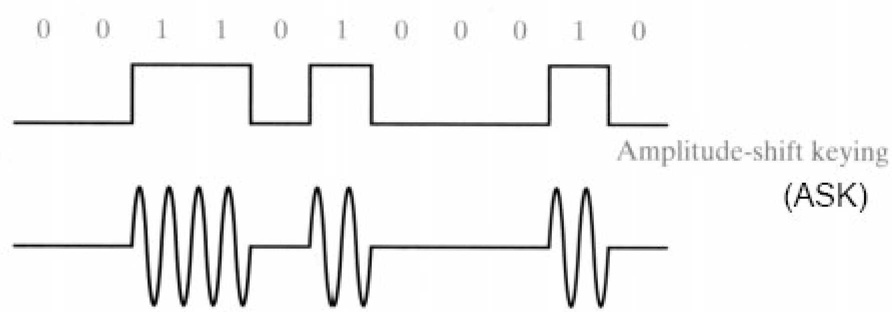
2. Encoding digital data to analogical signal

- Example: transfer data through telephone system
  - Traditional telephone transfer, and forward data from 300Hz to 3400Hz
  - At sources and destination, digital data need to be converted to analog signals to transfer on telephone lines
- Depend on signals, we have 3 different encoding techniques
  - Amplitude shift keying – ASK: Điều chế khóa dịch biên độ
  - Frequency shift keying – FSK: Điều chế khóa dịch pha
  - Phase shift keying – PSK: Điều chế khóa dịch tần số

Amplitude shift keying (ASK)

- 0 and 1 represent with two different amplitute, typical level of one is 0
- Easily impact by noise (1200bps for telephone)
- Hard to sync signals
- Used in optical cables (LED or laser)

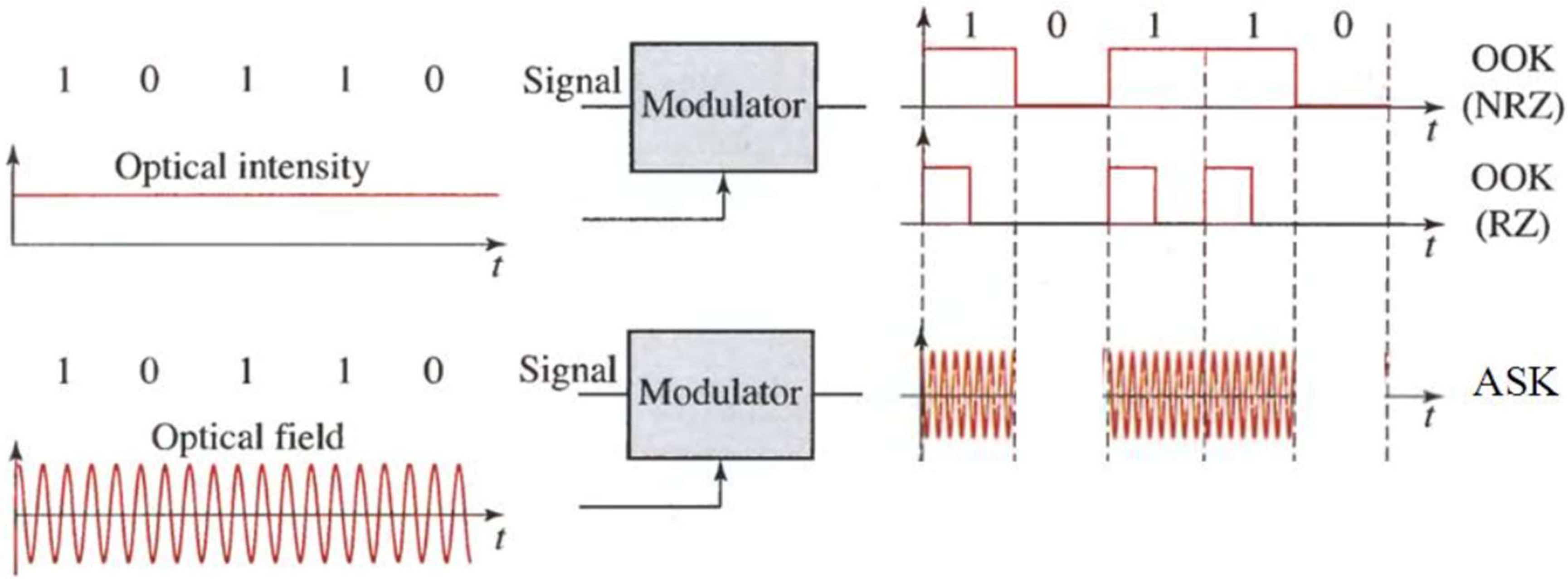
$$s(t) = \begin{cases} A\cos(2\pi ft) \ cho \ 1 \\ 0 \ cho \ 0 \end{cases}$$



On-Off Keying (OOK)

- Used in optical cables
- A type of ASK
  - 1: having light during bit period (ON).
  - 0: no light during bit period (OFF).
- OOK can use different format :
  - NRZ: emit light signal in the whole of bit 1
  - RZ (return-to-zero): only emit light signal in a proportion of bit 1.

On-Off Keying (OOK)

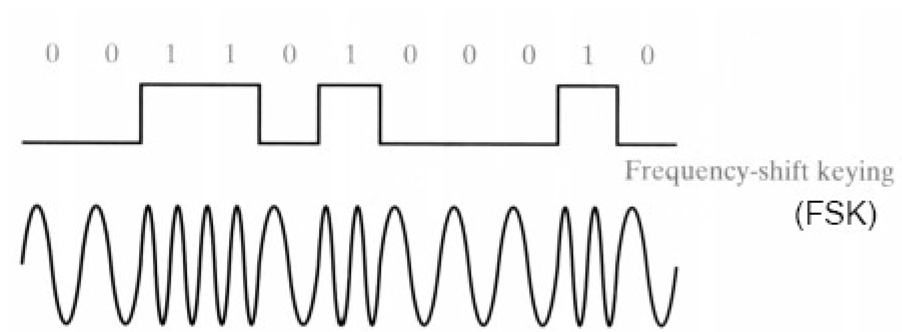


OOK on amplitude view (upper) and light signal (below)

Frequency shift keying (FSK)

$$s(t) = \begin{cases} A\cos(2\pi f_1 t) \\ A\cos(2\pi f_2 t) \end{cases}$$

- Two values of 1 bit are represented as two different frequencies
- Multiple FSK
- Low error rate
- Used to transfer data in telephone lines (low frequencies), or in wireless network (high frequencies)



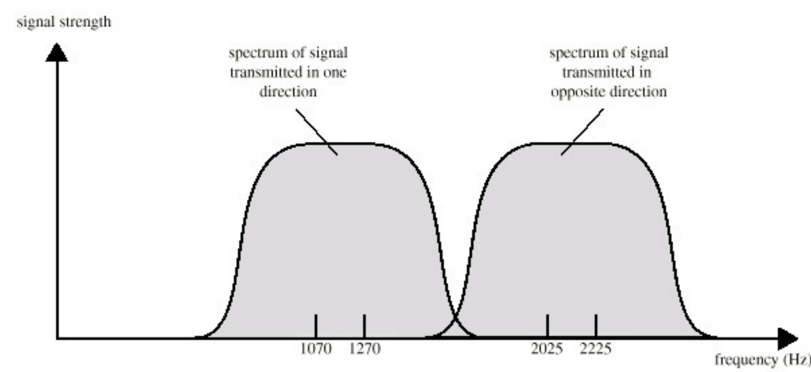
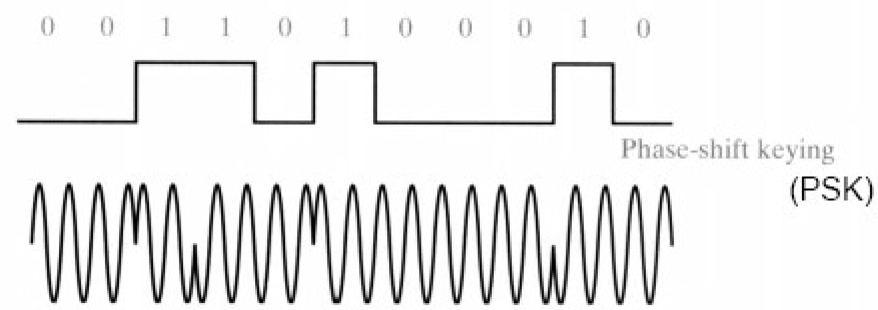


Figure 5.8 Full-Duplex FSK Transmission on a Voice-Grade Line

Phase shift keying (PSK)

- 0,1 are represented by two different phases
- Can be effectively used for encoding multiple bits
- Can be combined with ASK
- If the speed is 9600 bps, what is speed of encoding?

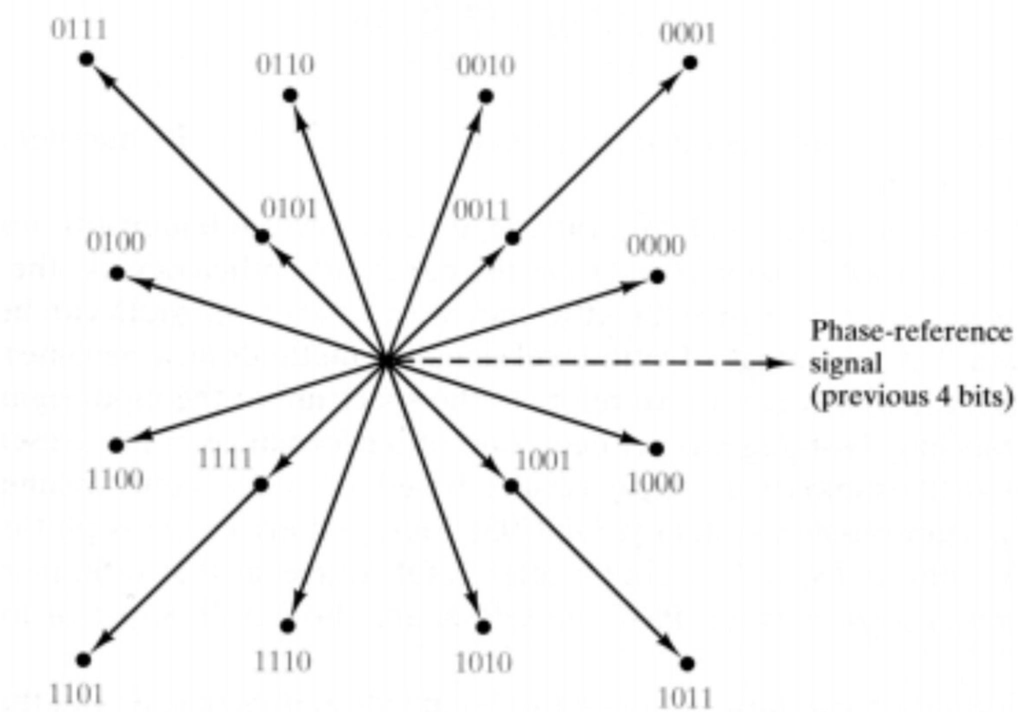
$$s(t) = \begin{cases} A\cos(2\pi f_c t + \pi) & \text{binary 1} \\ A\cos(2\pi f_c t) & \text{binary 0} \end{cases}$$



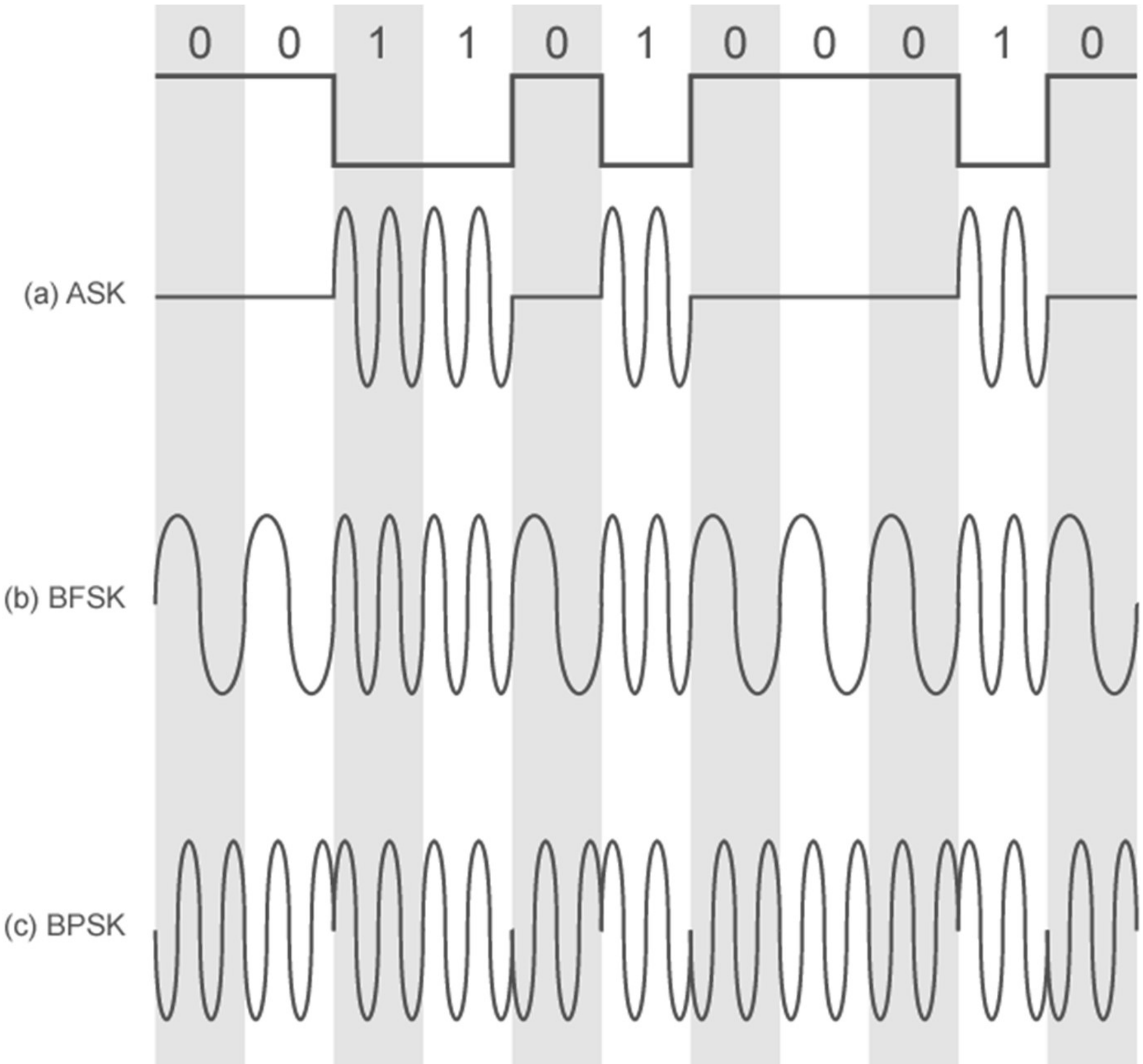
$$s(t) = \begin{cases} A\cos(2\pi f_c t + 45°) & 11 \\ A\cos(2\pi f_c t + 135°) & 10 \\ A\cos(2\pi f_c t + 225°) & 00 \\ A\cos(2\pi f_c t + 315°) & 01 \end{cases}$$

Amplitude and phase-shift keying (APSK)

– 9,600 bps modem (2,400 baud x 4)



Encoding digital-to-analogue

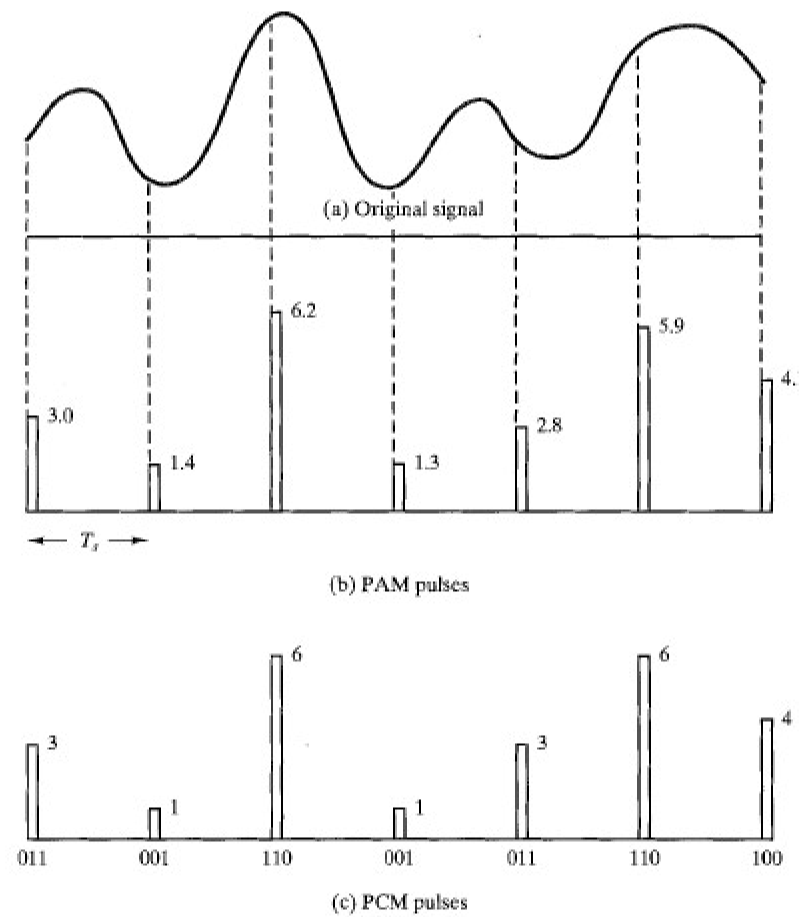


3. Encoding analog data to digital data

- Encoding analog data to digital data,
  - Convert to digital signals
    - Direcly by NRZ-L
    - Or other digital-digital encoding
  - Convert to analog signals
    - Presented digital-analog encoding
- Two main encoding methods
  - Pulse Code Modulation
  - Delta Modulation

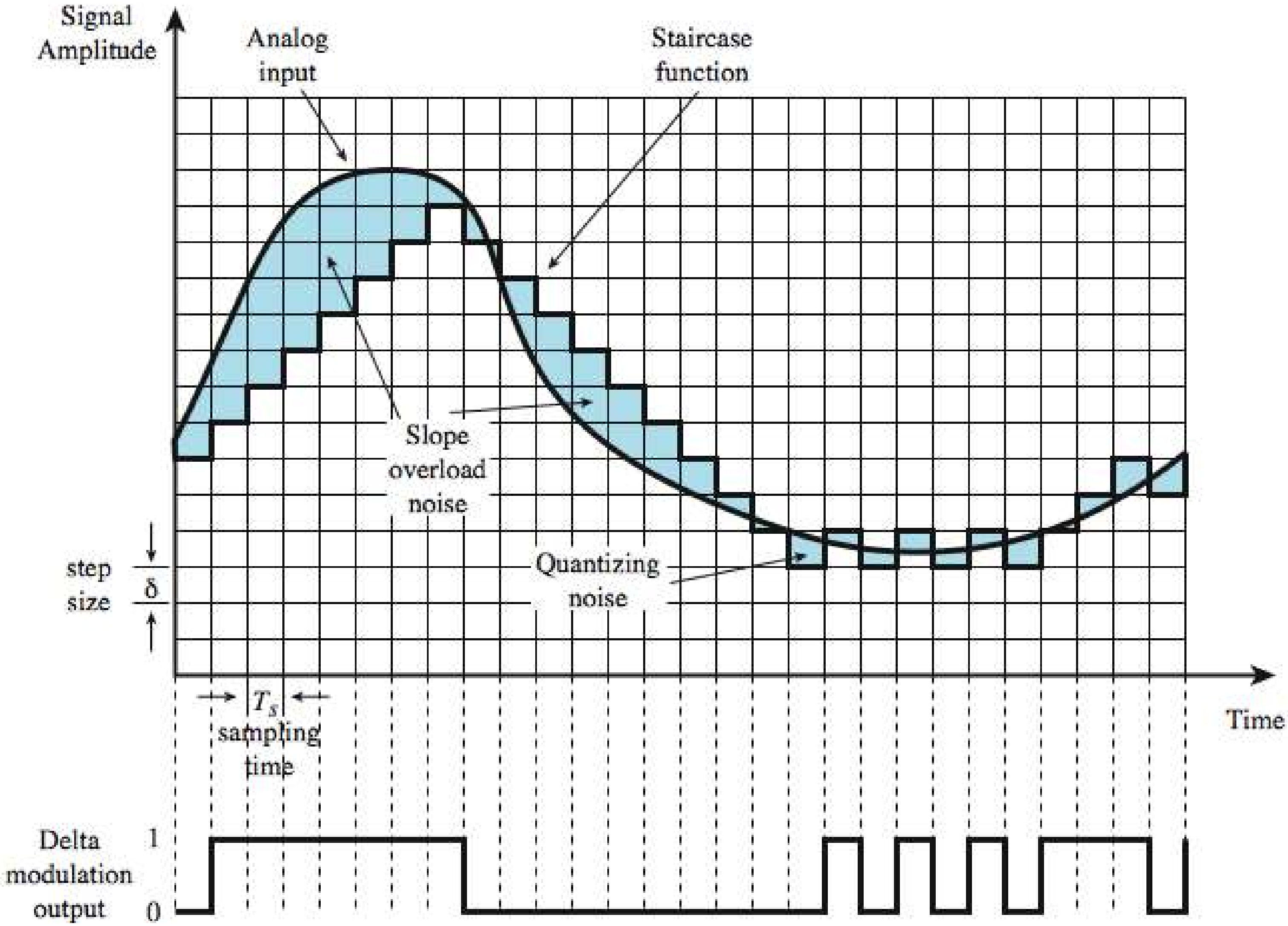
Pulse Code Modulation (PCM)

- Pulse Code Modulation
- Shannon sampling theorem
  - the sampling rate is be equal to or greater than twice the highest frequency in the signal, the original is intact
  - Example: voice has maximum frequency of 4300Hz, sampling rate should be minimum at 8600Hz
- Two steps
  - Sampling (Pulse-amplitude modulation)
  - Quantization
- Differential pulse-code modulation
  - Only sampling the differences



Delta Modulation

- Use a staircase function (hàm bậc thang)
  - The approximation falls below the signal → 1
  - The approximation lies above the signa → 0
  - Increase or decrease the approximation "delta" depending on 1 (increase) or 0 (decrease)
- In general
  - 1-bit per sampling period based on derivative
- Parameters
  - Delta / step-size
  - Sampling rate
- Noise/ Error/ Distortion
  - Slow-change signal/ small delta: quantization error / granular noise
  - Fast-change signal/ large delta: Slope Over load distortion


Signal Amplitude
Analog input
Staircase function
Slope overload noise
step size
δ
Quantizing noise
T_s
sampling time
Time
Delta modulation output
1
0

Delta Modulation

- Delta modulation requires a sampling rate much greater than the Nyquist rate (commonly four or five times the Nyquist rate)
- Close to DPCM

Analog data to analog signals

- Combine signal m(t) and carrier into a single combined signal around the frequency Fc
  - Radio
- Allow to carry signals on a more suitable frequency
- Allow to multiplex channels by diferent carrier frequencies
- There are 3 different modulation methods based on signal characteristics
  - Amplitute modulation
  - Frequency modulation
  - Phase modulation