Chapter 2: The Physical Layer

1 What is the basic goal of the physical layer?

2 How to define the physical layer protocols?

3 What is the theoretical basis for the physical layer?

*4 What are the commonly used transmission media?

*5 What are the common physical layer interface standards?

1 The Goals

- To ensure the correctness of the transmitted signals "0" and "1" and the consistency of transmission and reception;
- Bit – transmission mode, speed, duration, and signal distortion;
- Interface design: the number of pins, specifications, functions, etc.;
- Signal transmission procedures: how to arrange the transmission process and the order of events;

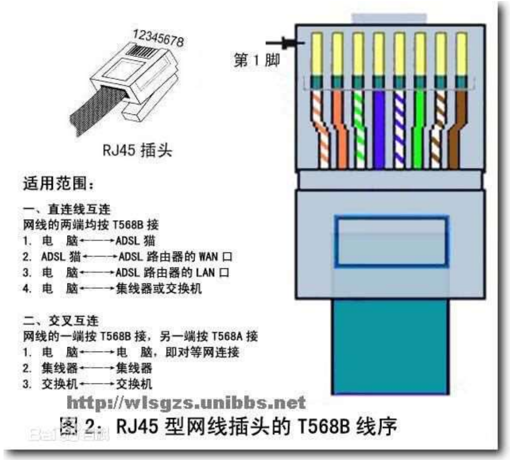
Four Important Characteristics

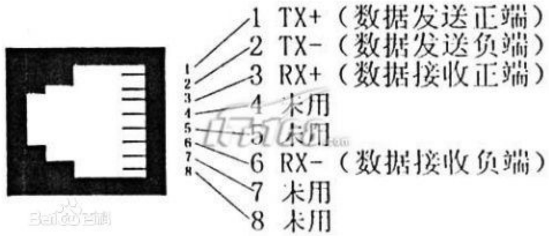
- Mechanical Characteristics
  - Specifies the size of the connector used in the physical connection, the number and arrangement of pins.
- Electrical Characteristics
  - Specifies the transmission mode, voltage level, coding, impedance matching, transmission rate and distance limit when transmitting the binary bit.

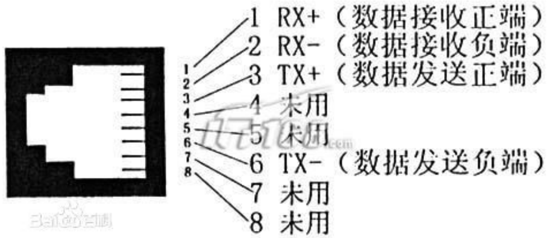
Four Important Characteristics

- Functional Characteristics
  - Define the function of each physical line, indicating the means of a special voltage appears on a line
  - Line functions are divided into four categories: Data, Control, Timing, Power Supply

- Procedural Characteristics
  - Define the working rules and timing relationships for each physical line
  - Signal transmission: simplex, half duplex, full duplex

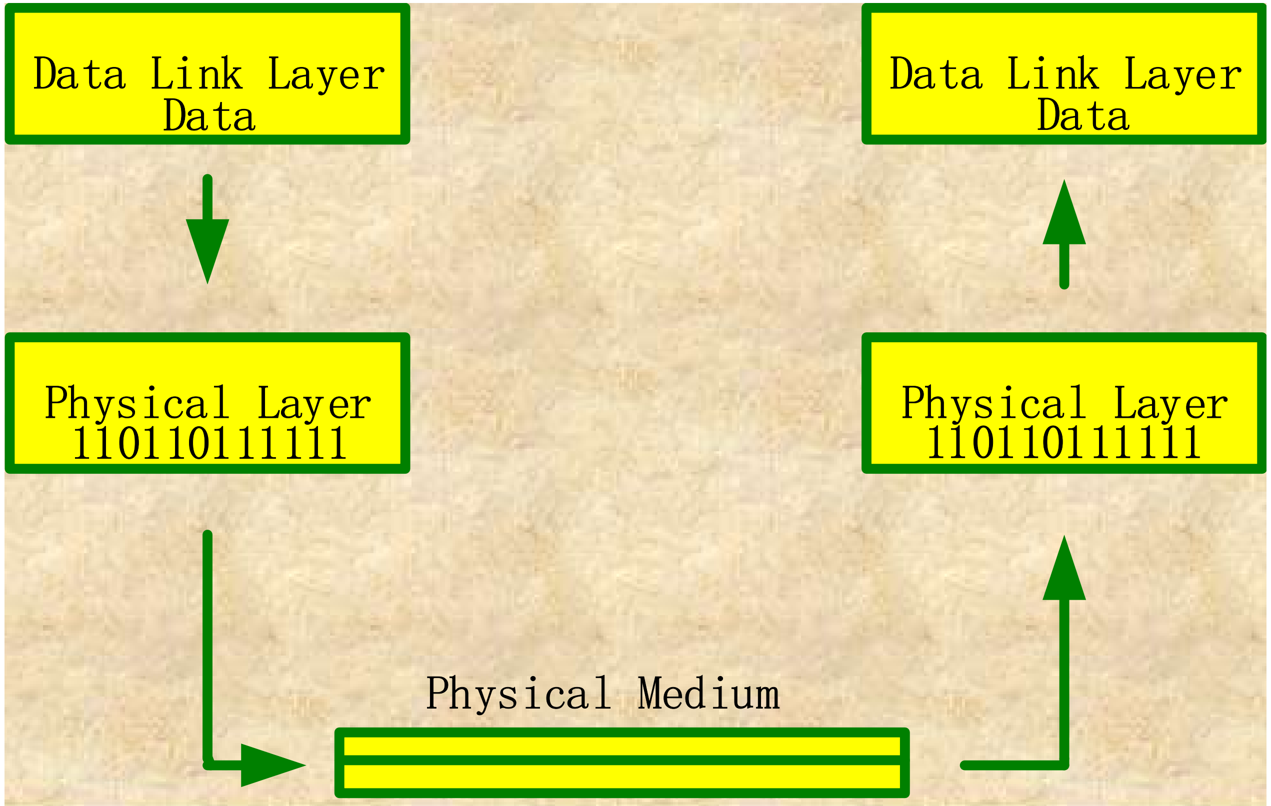

12345678
第 1 脚
RJ45 插头
适用范围：
一、直连线互连
网线的两端均按 T568B 接
1. 电 脑←——→ADSL 猫
2. ADSL 猫←——→ADSL 路由器的 WAN 口
3. 电 脑←——→ADSL 路由器的 LAN 口
4. 电 脑←——→集线器或交换机
二、交叉互连
网线的一端按 T568B 接，另一端按 T568A 接
1. 电 脑←——→电 脑，即对等网连接
2. 集线器←——→集线器
3. 交换机←——→交换机
http://wlsgzs.unibbs.net
图 2：RJ45 型网线插头的 T568B 线序


1 TX+（数据发送正端）
2 TX-（数据发送负端）
3 RX+（数据接收正端）
4 未用
5 未用
6 RX-（数据接收负端）
7 未用
8 未用


1 RX+（数据接收正端）
2 RX-（数据接收负端）
3 TX+（数据发送正端）
4 未用
5 未用
6 TX-（数据发送负端）
7 未用
8 未用

2 Contents of Physical Layer Protocol

- Responsible for reliably transmitting bit data from one end of the physical medium to the other



3 Basic theory of data communication

(1) Basic concepts

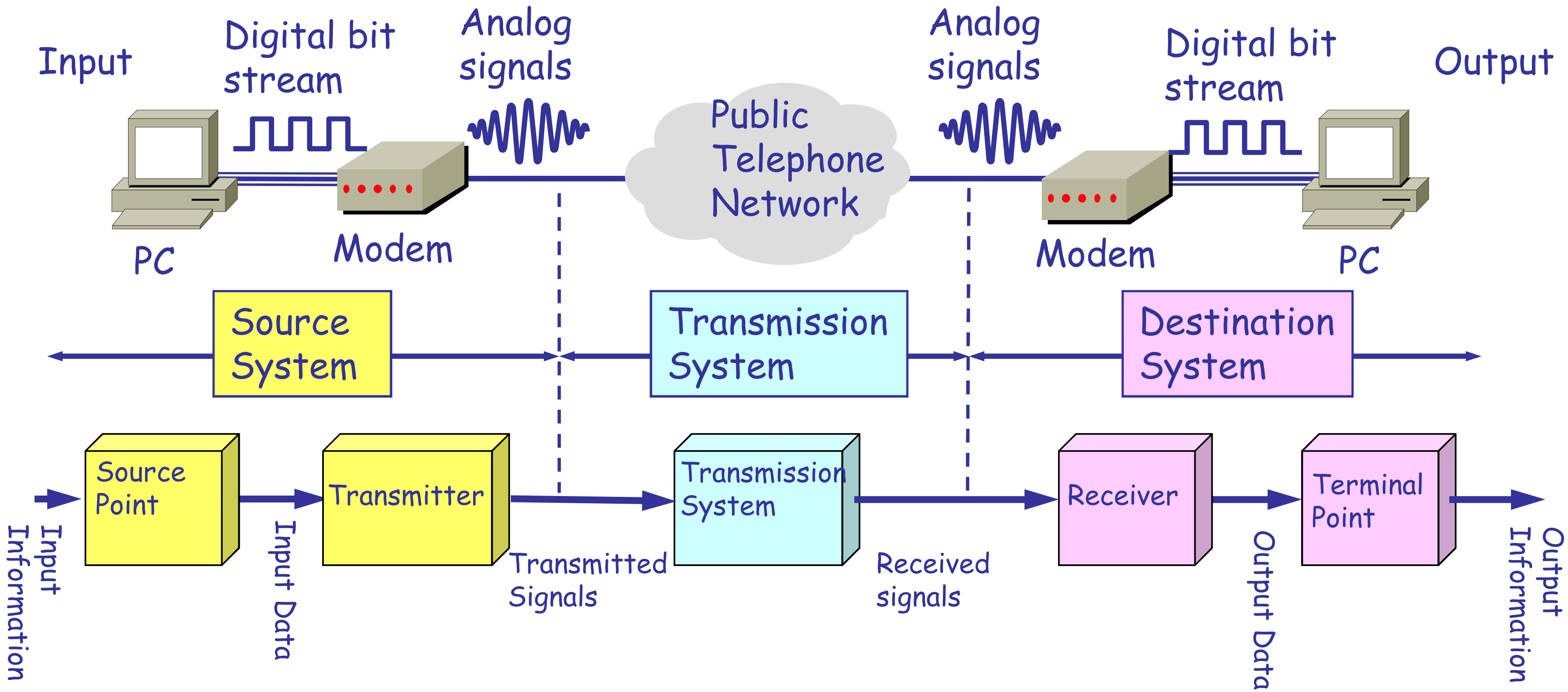
(2) For a specific physical communication channel, what is the maximum transmission rate? Infinite?

(3) How to transmit Bits in specific physical communication channels? Transmission speed, transmission duration, signal distortion?

(4) In order to save communication equipment and costs, how to transmit the information of multiple computers in one physical channel?

(1) Basic concepts

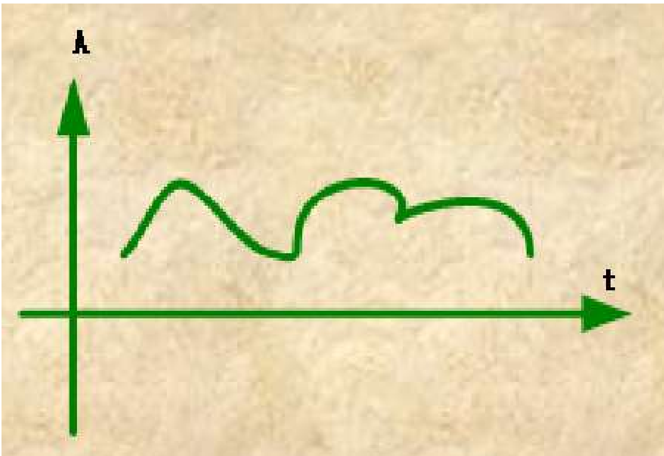
- General Model of Communication System



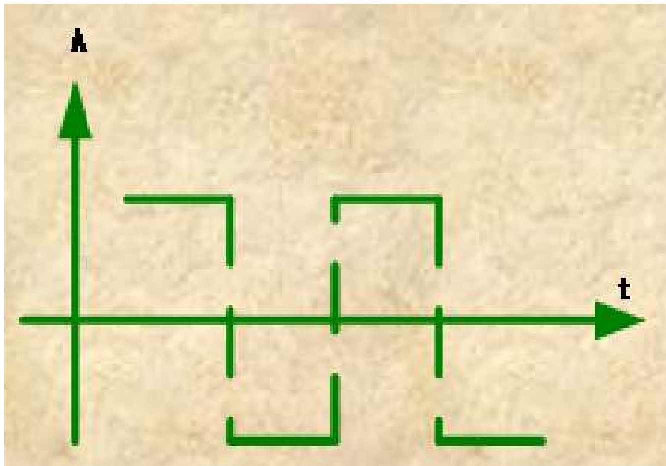
(1) Basic concepts

- Data: Physical symbols describing & documenting objective facts
  - Numbers, text, language, graphics and images.
- Information: collection, meaning and interpretation of Data
- Signal: Form of data transmission process
  - Electronic or electromagnetic coding of data

Analog Signal

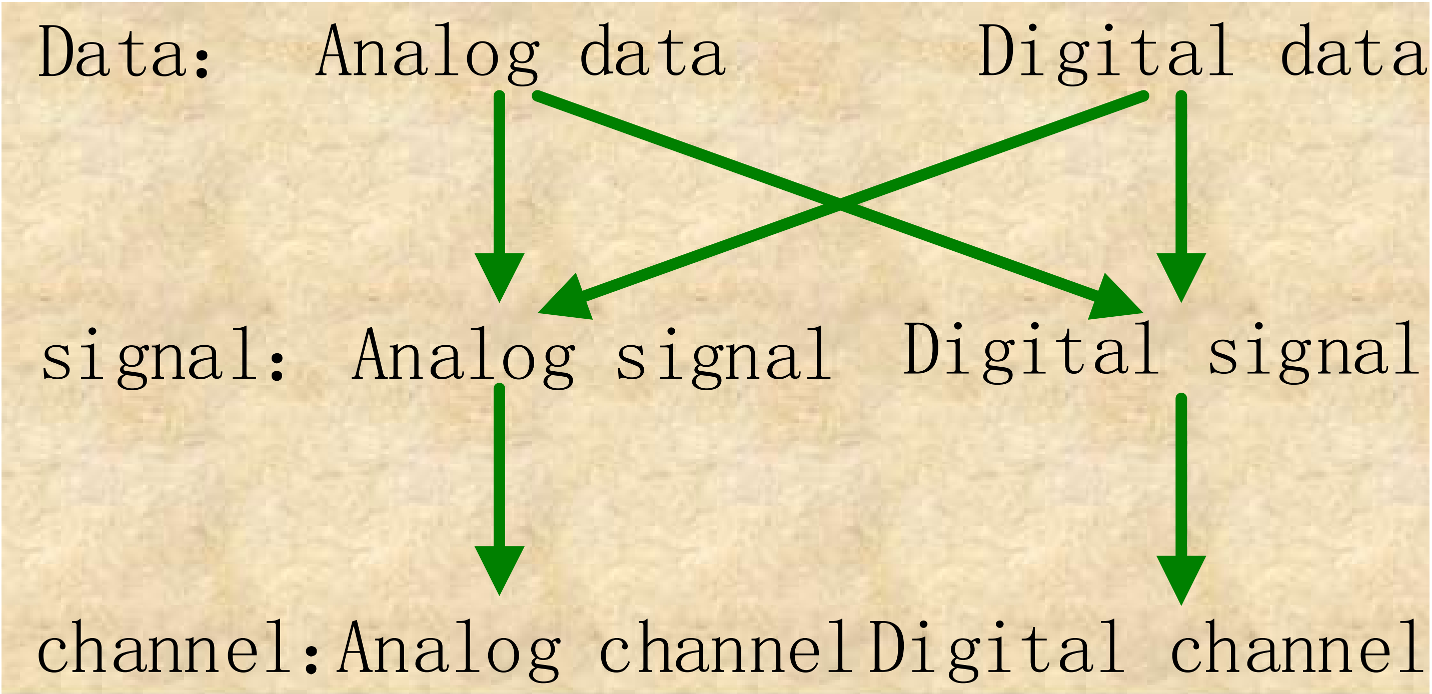


Digital Signal



(1) Basic concepts

- Channel: media that sends information in a certain direction
  - Channel ≠ Circuit



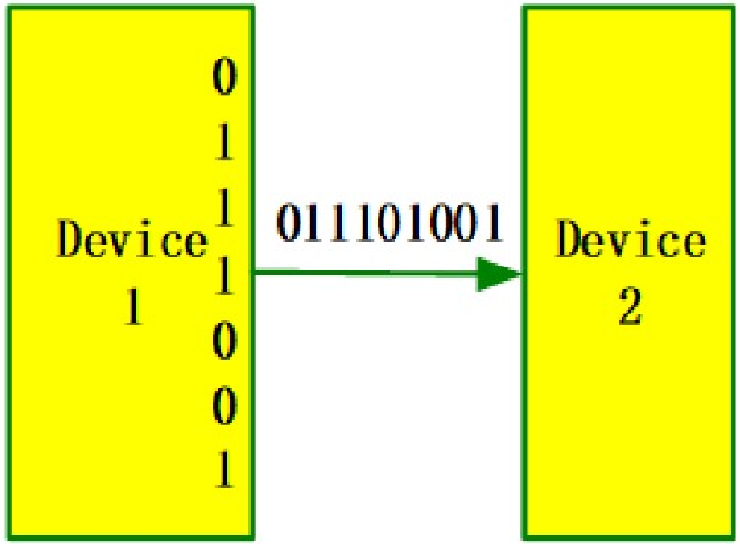
Transmission: Analog VS Digital

Transmission	Analog	Digital
Advantage	• High utilization of the channel	• Signal not distorted, and low bit error rate • Effective use of equipment via multiplexing
Disadvantage	• Signal decays • Signal interfered by noise • Noise amplified when signal amplified	• Wider frequency band required

- Digitalization is the tread
  - Computers can only store and process digital data
  - Digital signals can be compressed and encrypted to improve the efficiency and security of transmission

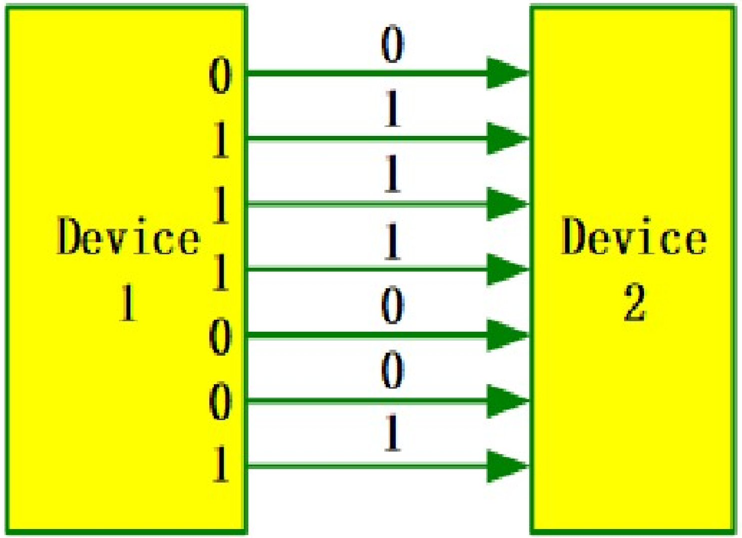
(1) Basic concepts

Serial transmission



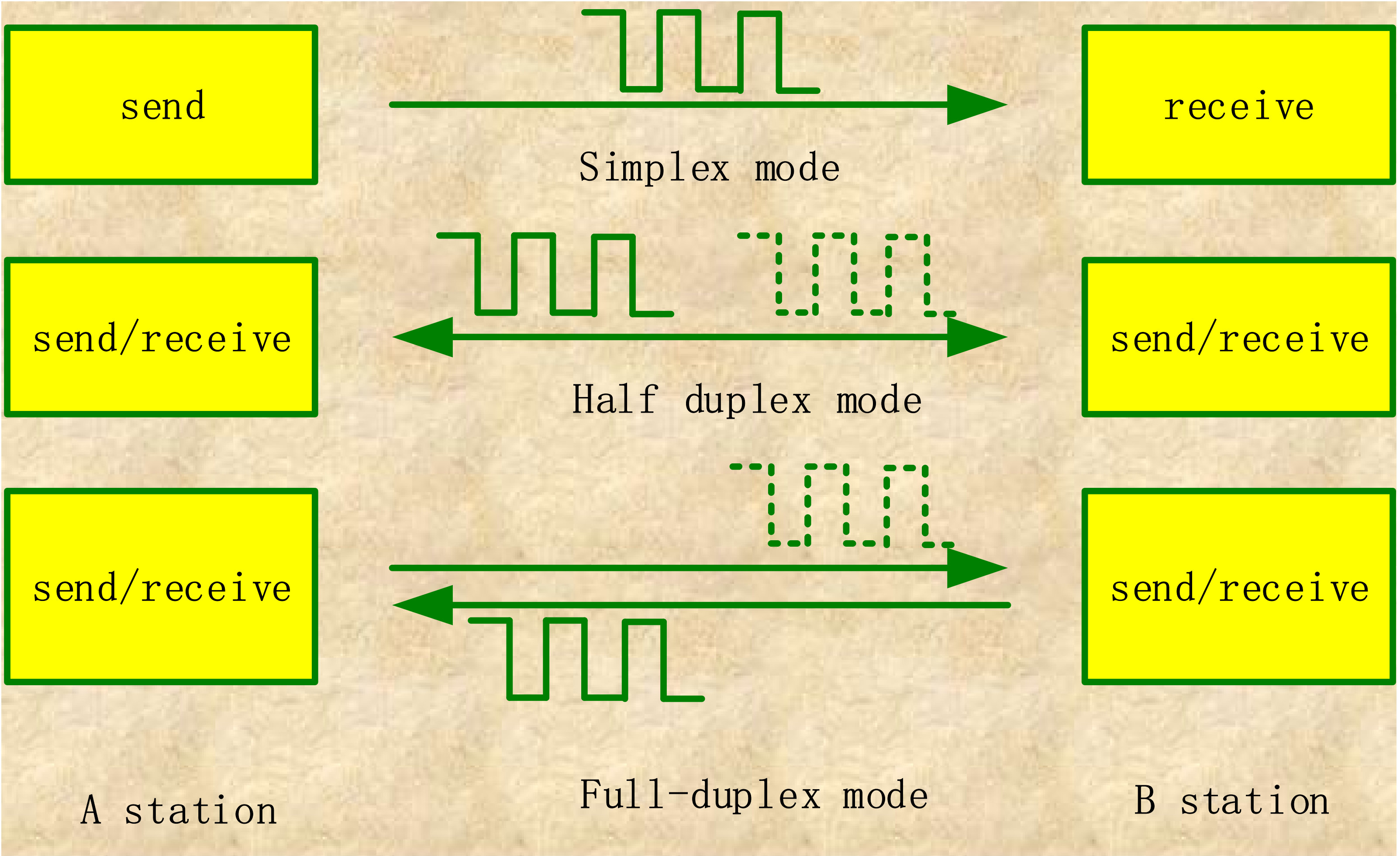
- Suitable for long distance communication

Parallel transmission



- Suitable for short distance communication

(1) Basic concepts



3 Basic theory of data communication

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(2) Channel Characteristics

- Symbol: A digital pulse, which represents the basic waveform of a discrete value
  - ASCII code of letter 'A': 1000001, can be represented by 7 pulses/symbols
- The amount of information carried by a symbol is determined by the number of discrete values taken by the symbol
  - Two discrete values ("0" or "1"): 1 bit
  - Four discrete values for a symbol: 2 bits
  - If N discrete values for a symbol of n (bits), then

$$n = \log_2 N$$

(2) Channel Characteristics

- Baud rate (modulation rate or symbol rate):
  - The number of times the signal changes every second
    - 1 baud sends one symbol per second
- Bit rate:
  - The number of bits transmitted per second
- Relationship between them:
  - If each symbol has n bits: bit rate (b/s) = baud rate * n
  - If each symbol has 3 bits, then the bit rate is three times the baud rate
  - If each symbol has 1 bit, the bit rate and baud rate are the same

(2) Channel Characteristics

- Channel capacity (bandwidth in networks)
  - The maximum number of bits that can be transmitted over a channel per unit time, expressed in bps
- Frequency bandwidth (in communication)
  - Frequency range of the signal allowed by the channel (= maximum frequency - minimum frequency), in Hz
  - E.g., people can hear sound waves of 20Hz ~ 20kHz, i.e., frequency bandwidth of hearing system is19980Hz
- Transmission delay
  - Processing time to send and receive + electrical signal response time + medium transition time

(2) Channel Characteristics

- Nyquist's Law :

  1) For an ideal low-pass channel with the frequency bandwidth of W (Hz), its maximum symbol transmission rate = 2W Baud

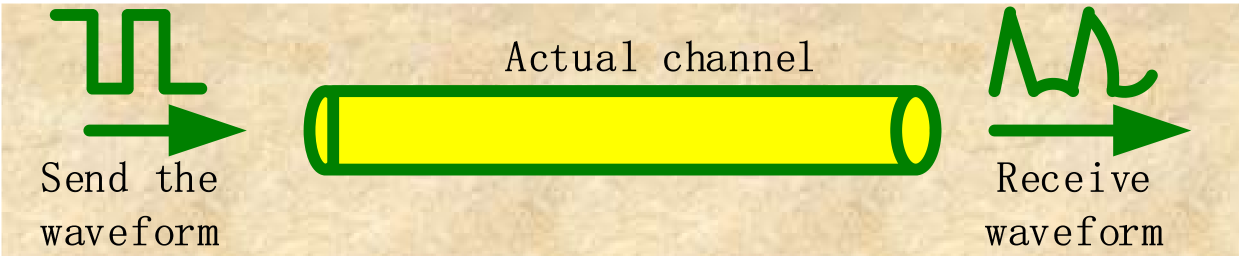
  2) For an ideal band-pass channel with the frequency bandwidth of W (Hz), its maximum symbol transmission rate = W Baud

- Question
  - The frequency band of a standard telephone channel is 300 ~ 3400Hz, i.e., the frequency bandwidth is 3100Hz. What is the maximum symbol transmission rate through the ideal low-pass channel?

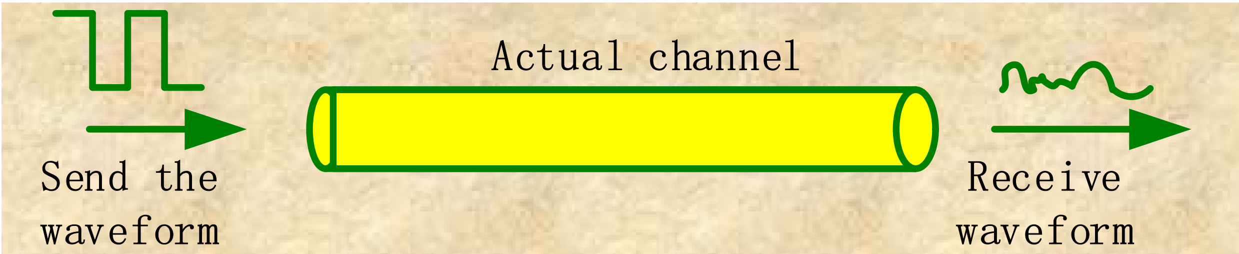
(2) Channel Characteristics

- Actual channels are not ideal – Distortion exists
  - Higher symbol transmission rate
  - Farther signal transmission distance

  } Larger distortion
- Small and recognizable distortion



- Large and unrecognizable distortion



(2) Channel Characteristics

- Shannon's Formula: limit information transmission rate C of channel can be expressed as:

$$C = W\log_2(1+S/N)$$

  - W - Frequency bandwidth in Hz
  - S - Average signal power through the channel
  - N - Gaussian noise power through the channel
  - S/N – related to signal-to-noise ratio
    - Typically in db (decibels): $10 \log_{10} S/N$
- Actual rate much lower than C due to signal loss
- Possible to achieve error-free transmission as long as transmission rate < C

(2) Channel Characteristics

- Example:
  - For the standard telephone channel with frequency bandwidth of 3.1 kHz, if the signal-to-noise ratio S/N = 2500, then can the information transmission rate be 50kb/s?
- Solution:
  - Put W = 3.1kHz, S / N = 2500 into Shannon's Formula
  - The limit information transmission rate is 35kb/s, so it is impossible to reach 50kb/s
- In order to achieve 50kb/s, you can
  - improve the signal-to-noise ratio in the channel
  - or increase the frequency bandwidth

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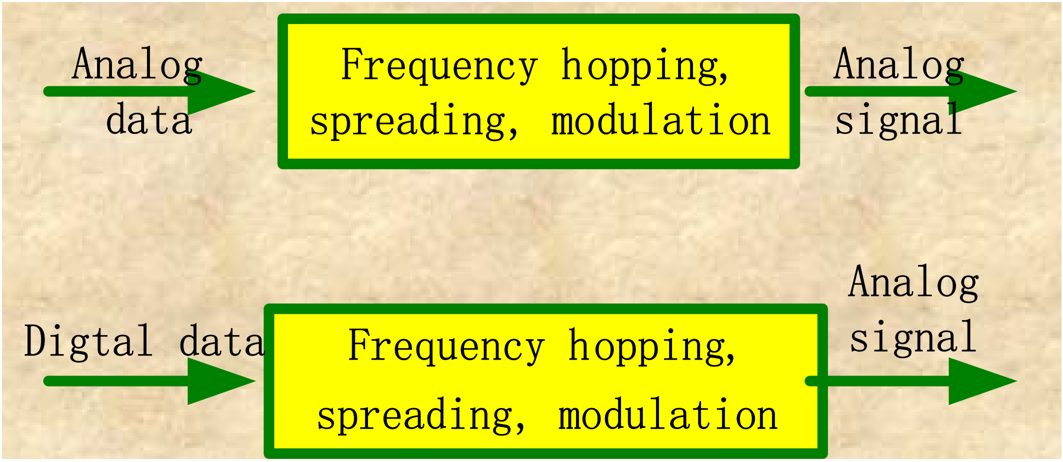
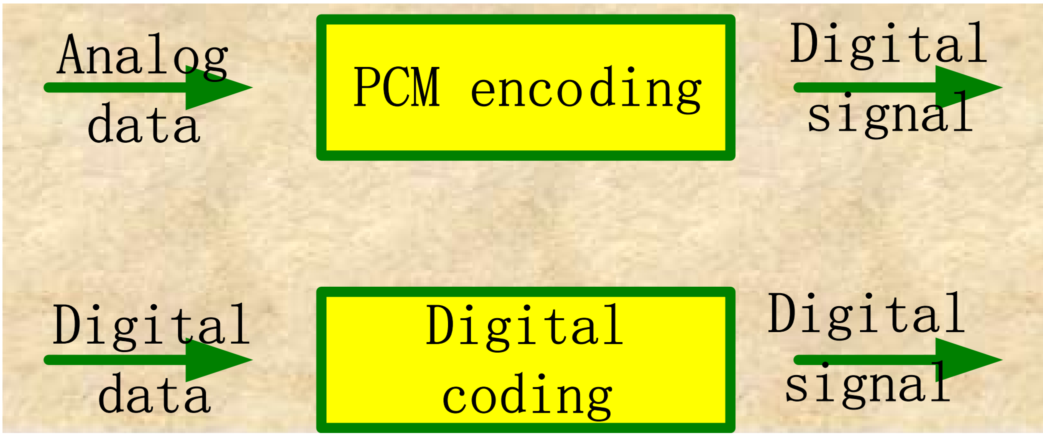
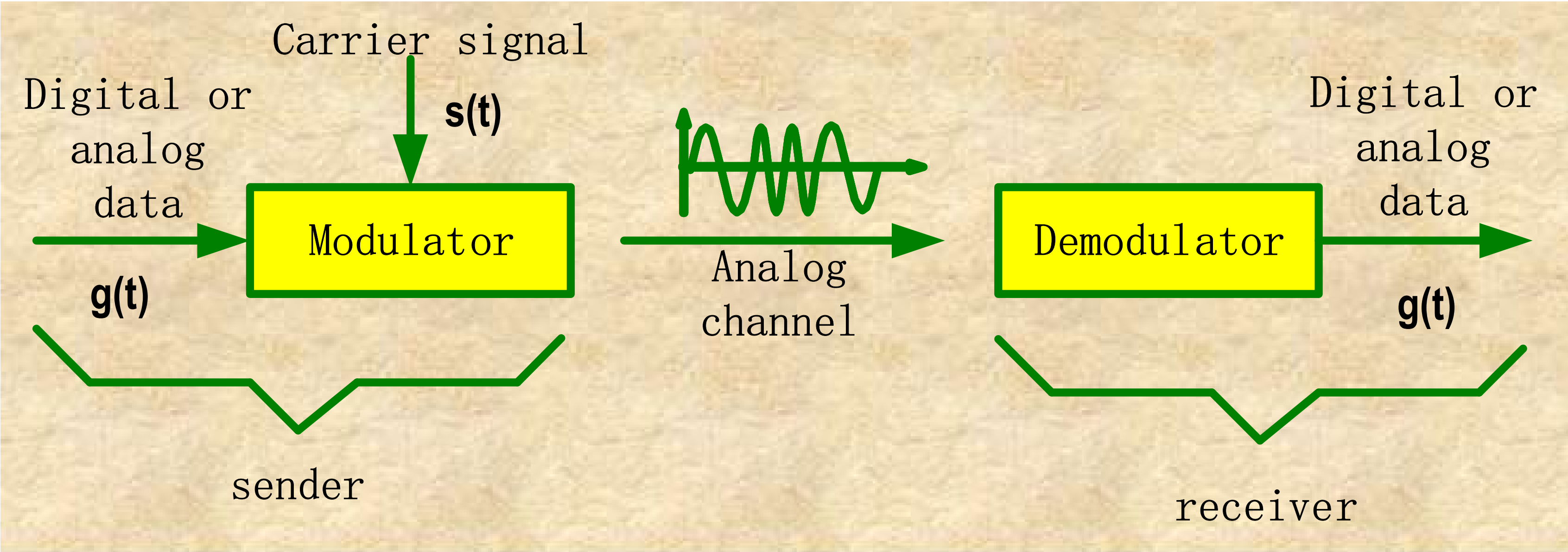
Techniques in analog/digital transmission

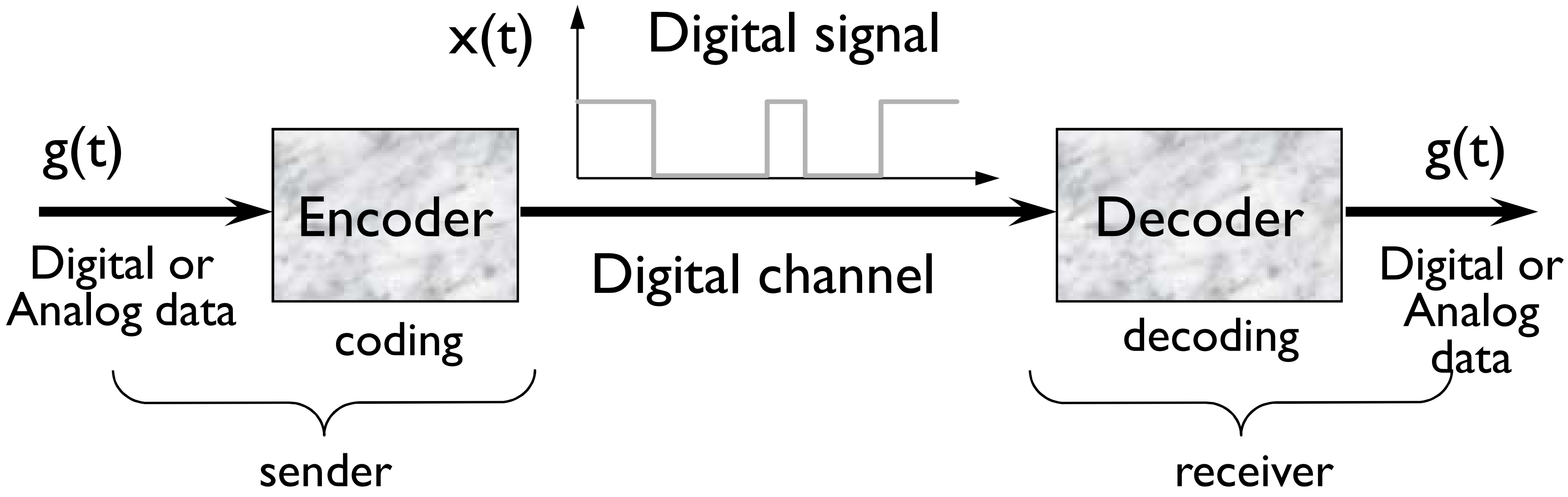




Modulation / demodulation system model

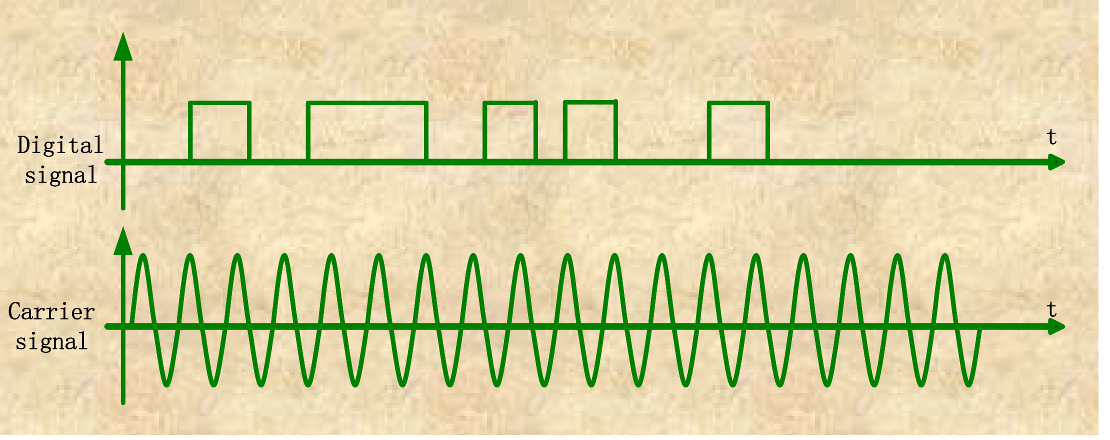


Coding / decoding system model

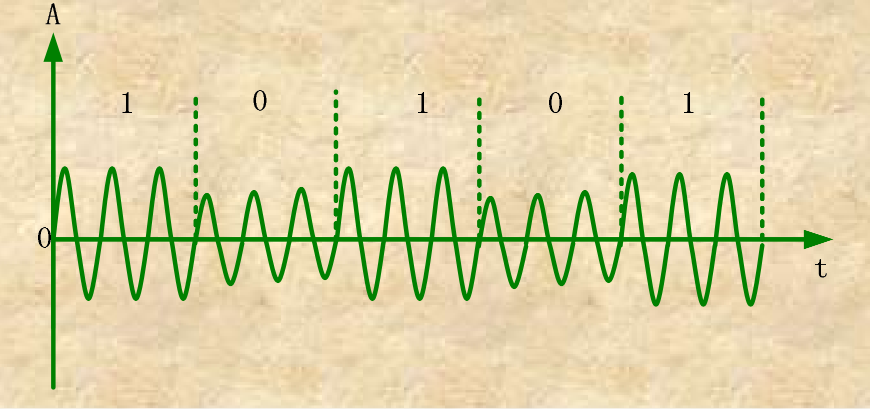


Modulation
(digital data to analog signals)

- Digital and carrier signals

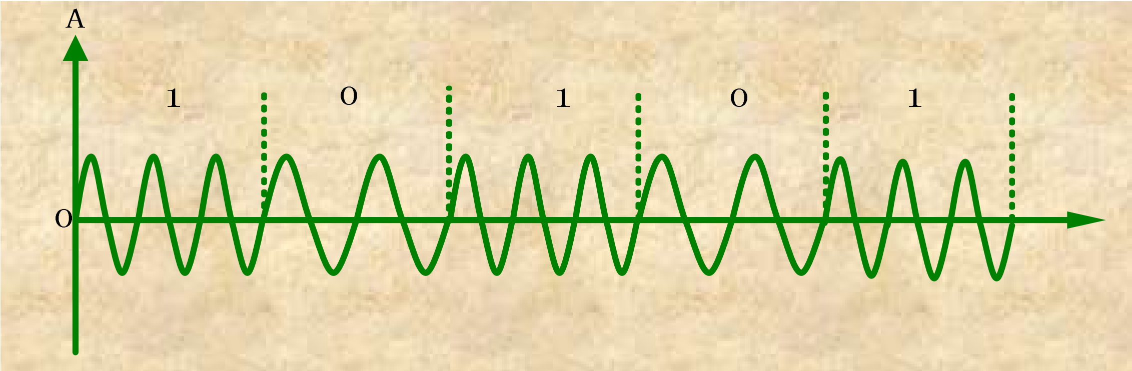


- Amplitude Modulation (AM)

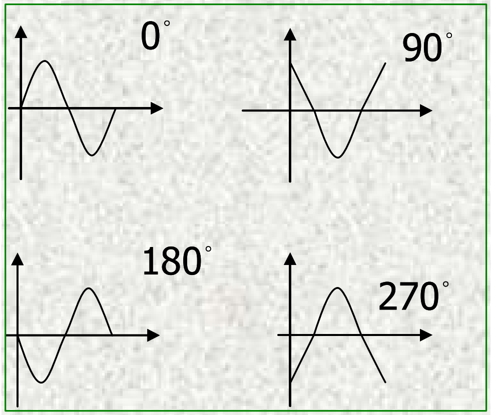


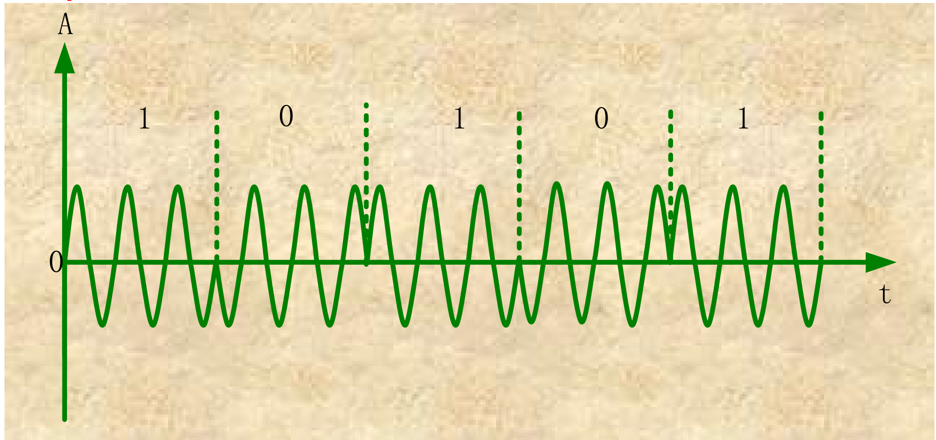
Modulation
(digital data to analog signals)

- Frequency Modulation (FM)



- Phase Modulation (PM)

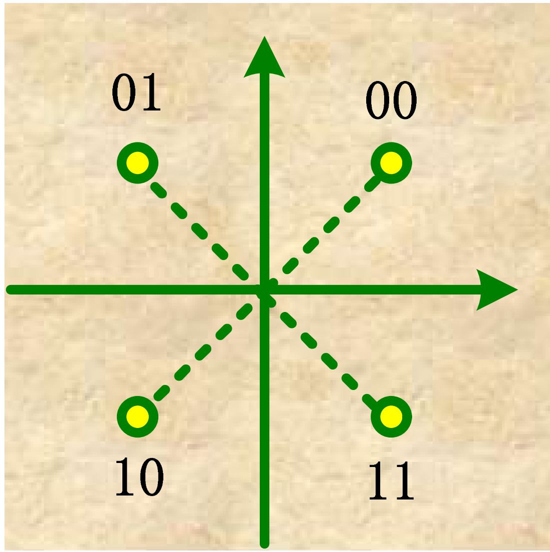


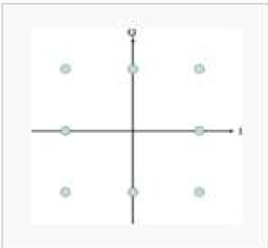


Modulation
(digital data to analog signals)

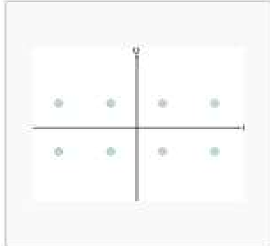
- Quadrature Amplitude Modulation (QAM)
  - PM and AM techniques
  - If there are x changes in phase and y changes in amplitude, then there are x * y combined changes

4-QAM constellation table

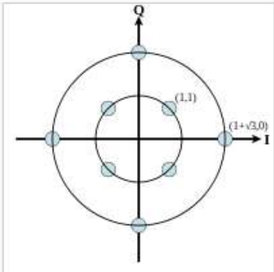




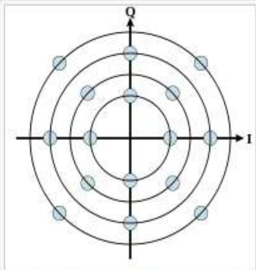
Constellation diagram for rectangular 8-QAM.



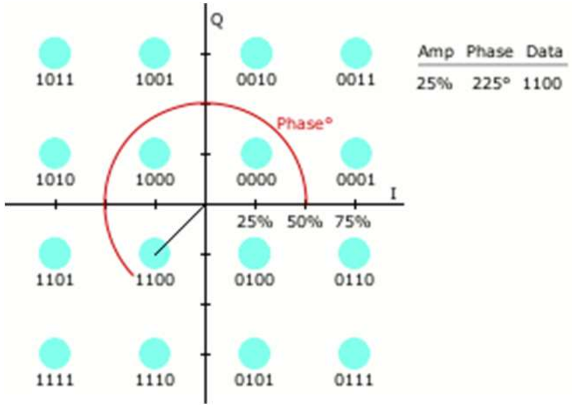
Alternative constellation diagram for rectangular 8-QAM.



Constellation diagram for circular 8-QAM.

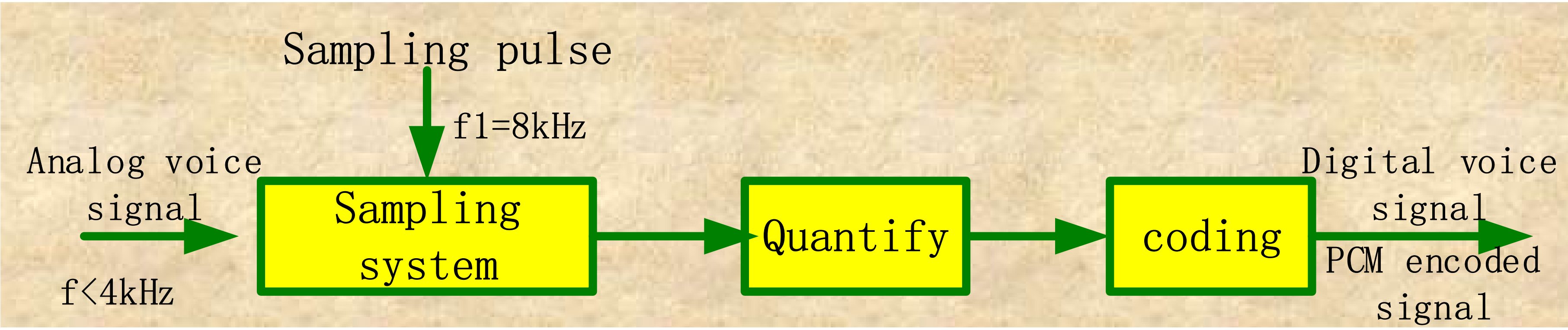


Constellation diagram for circular 16-QAM.



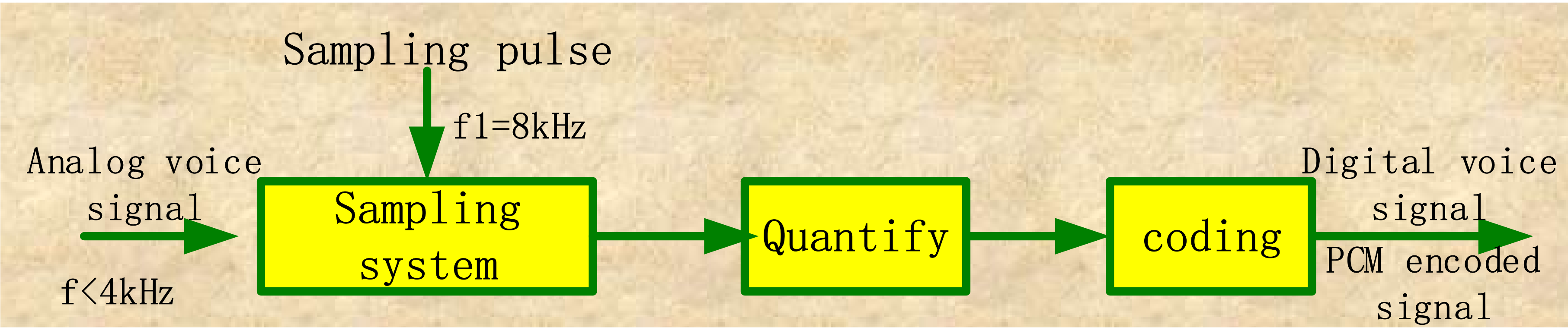
Pulse Code Modulation (PCM)
(analog data to digital signals)

- Sampling Theorem
  - As long as the sampling frequency is not less than twice the maximum frequency of the signal, the original signal can be recovered from the sampling pulse without distortion
- PCM system model



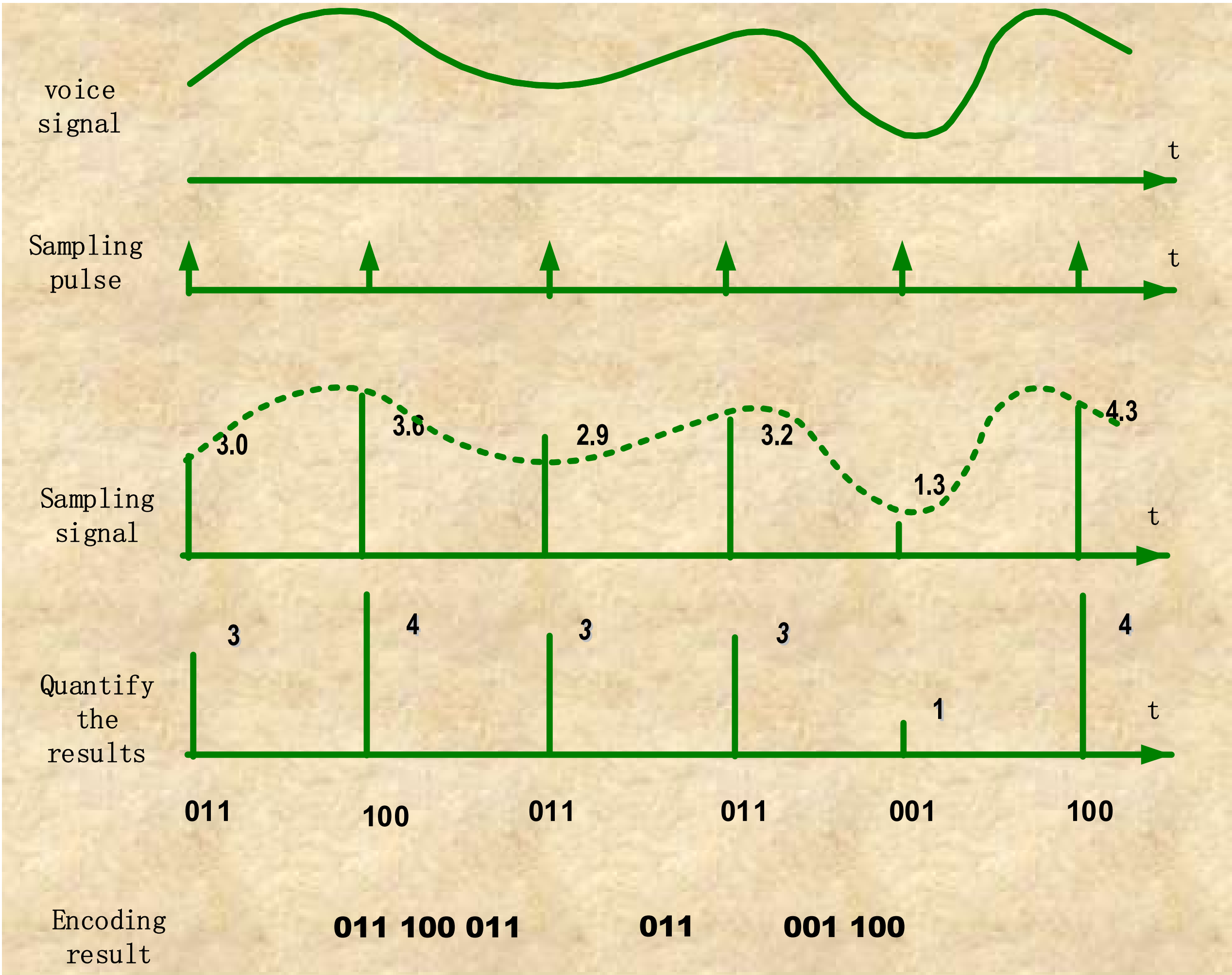
Pulse Code Modulation (PCM)
(analog data to digital signals)

- Voice signal digitization
  - Voice frequency bandwidth f <4kHz
  - Sampling clock frequency: 8kHz (> 2 times the maximum voice frequency)
  - Sample quantization series: 256 (8bit / per sample)
  - Data rate: 8000 times / s * 8bit = 64kb / s
  - The rate of each PCM signal = 64kb / s



Pulse Code Modulation (PCM)
(analog data to digital signals)

PCM coding process example

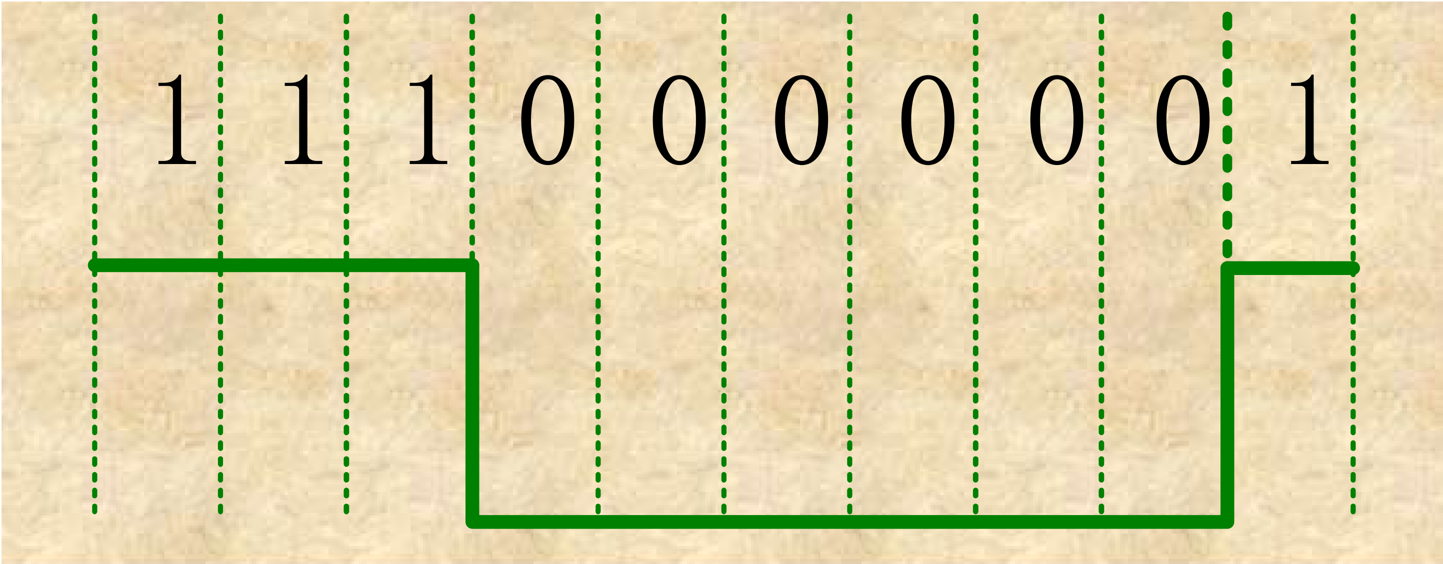


Digital signal coding
(digital data to digital signals)

- Non-Return-to-Zero (NRZ)
- Manchester encoding
- Differential Manchester encoding
- Block encoding (4B / 5B, 8B / 10B)

Digital signal coding
(digital data to digital signals)

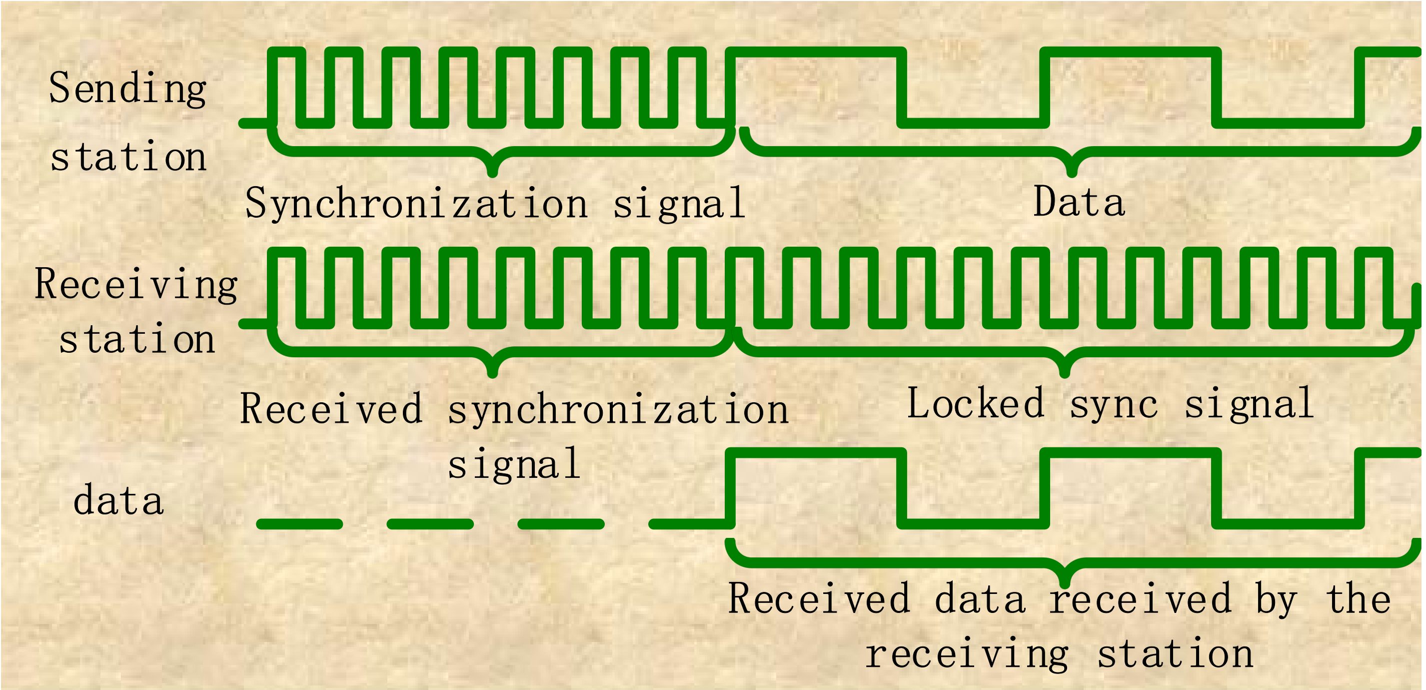
- Non-Return-To-Zero Level (NRZ-L) Coding



Digital signal coding
(digital data to digital signals)

- Disadvantages of NRZ-L
  - Difficult to tell the end of one and the beginning of another
  - The sender and the receiver must have clock synchronization
  - If the signal "0" or "1" appears continuously, the signal DC component will accumulate
  - Prone to propagation errors

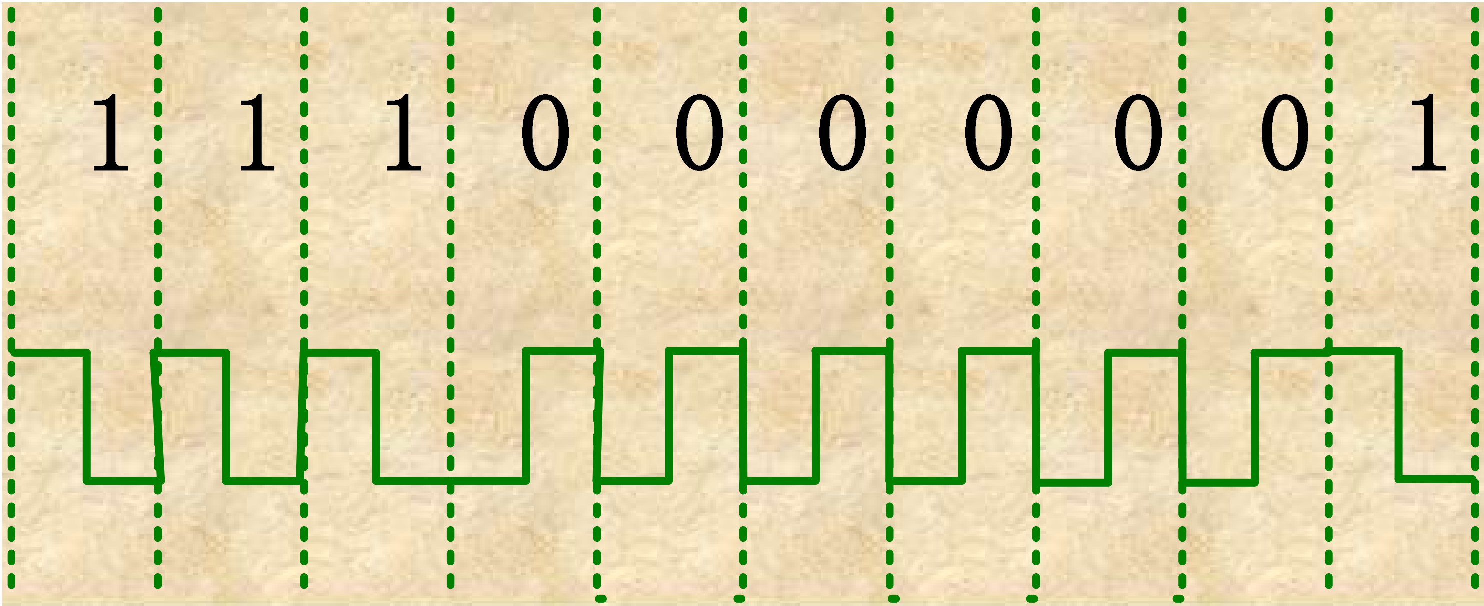
- Bit synchronization
  - The purpose is to synchronize each bit of information received by the receiver with the sender
- External synchronization



- Self-synchronization

Digital signal coding
(digital data to digital signals)

- Manchester Coding
  - Each symbol is divided into two equal intervals
    - "1": the previous interval is high and the next low
    - "0": the previous interval is low and the next high
  - Feature: A level hop in the middle time of each symbol



Digital signal coding (digital data to digital signals)

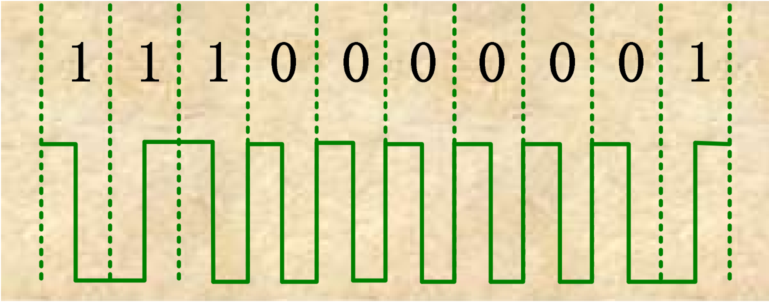
- Advantages
  - Overcoming the disadvantages of the NRZ Coding
  - Each jump in the middle of a symbol can be used as data, and also as a clock for self-synchronization
- Disadvantages
  - Doubling the frequency bandwidth requirement of the transmission channel
  - High-frequency noise also increases – susceptible to noise interference
  - Ambiguous

Digital signal coding
(digital data to digital signals)

- Differential Manchester Coding
  - "1": the level of the first half of the symbol is the same as the level of the second half of the previous symbol
  - "0": the level of the first half of the symbol is opposite to the level of the second half of the previous symbol
- Regardless of whether the previous bit is 1 or 0

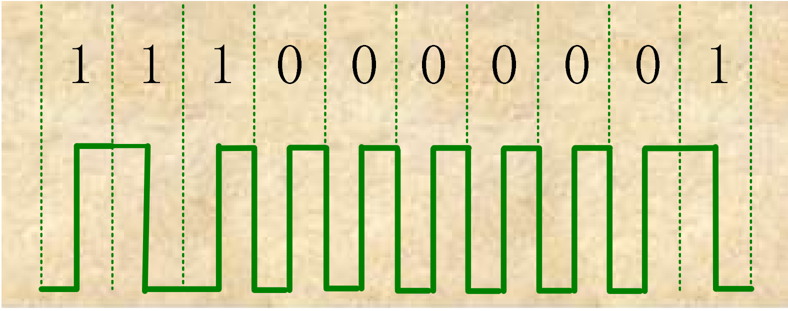
Waveform 1

Assuming the previous bit rises from low to high



Waveform 2

Assuming the previous bit drops from high to low



Digital signal coding
(digital data to digital signals)

- Advantages
  - Regardless of whether the symbol is "1" or "0", there must be a level hop in the middle of each symbol => better anti–interference performance
  - Separation between bit clock and data => easy data extraction
  - Transition uniquely determined by the second half of the previous symbol => ambiguity eliminated
- Disadvantages
  - Doubling the frequency bandwidth requirement of the transmission channel
  - High-frequency noise also increases – susceptible to noise interference

Digital signal coding
(digital data to digital signals)

- Exercise:

  Draw the waveform of "001101" with
  - NRZ-L
  - Manchester Coding
  - Differential Manchester Coding

Digital signal coding
(digital data to digital signals)

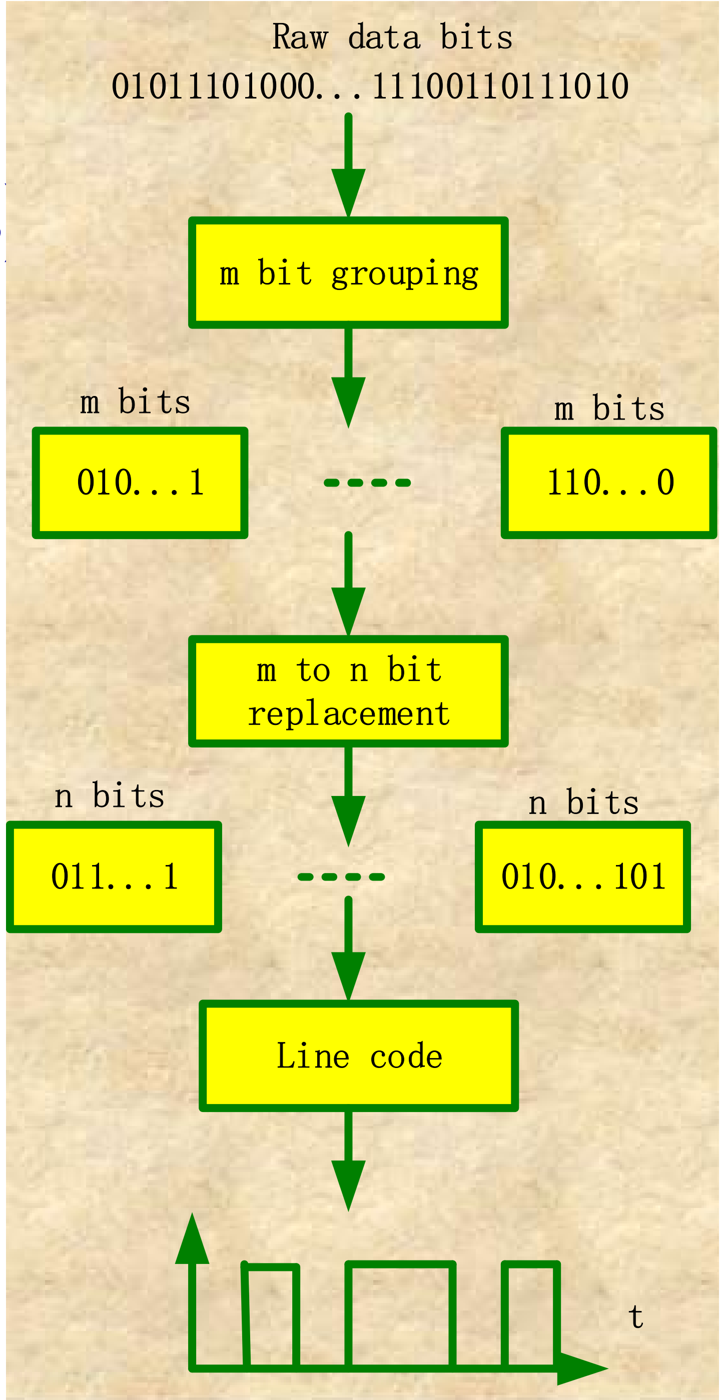
- Block Coding
  - Advantages
    - Can improve the coding efficiency, reduce the modulation rate, and reduce the transmission line requirements
    - Some redundant bits can be added for error detection or synchronization
  - Applications
    - 4B / 5B (FDDI, 100M Fast Ethernet)
    - 8B / 10B (Gigabit Ethernet)

Digital signal coding
(digital data to digital signals)

Steps (mB / nB, m < n) :

- Grouping
- Substitution
  - The extra bit sequence can be used for
    - error detection
    - synchronization
    - or other controls

    or not used
- Line coding



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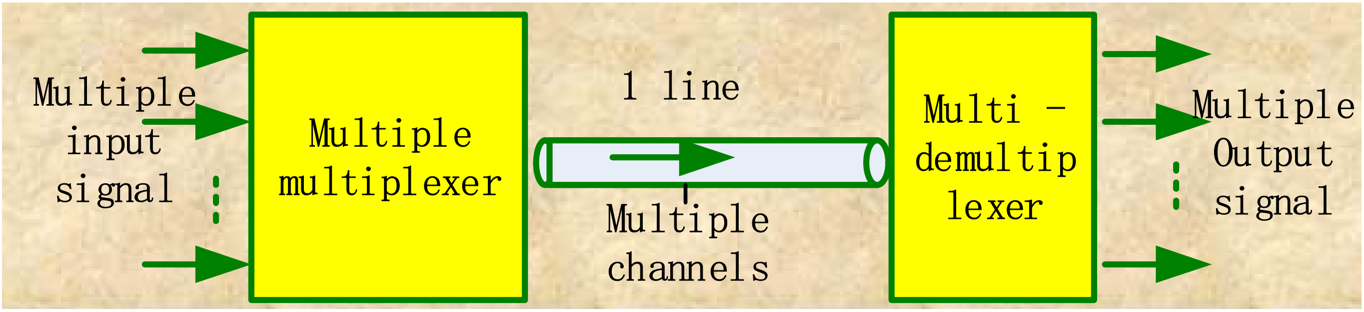
Multiplexing (Multi-pass)

- To send multiple sources of information in one physical channel at the same time

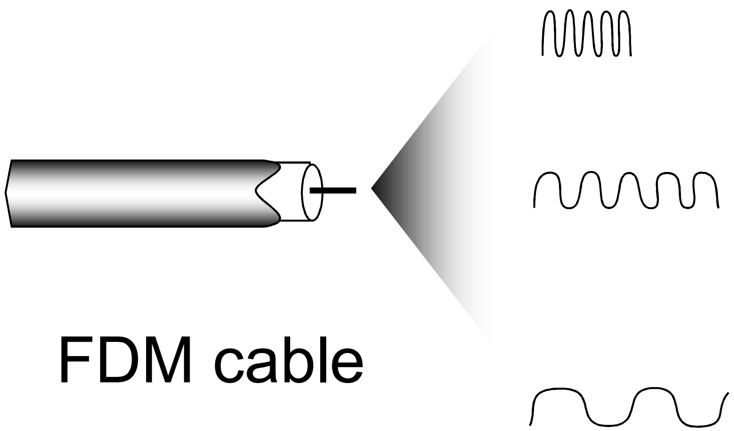


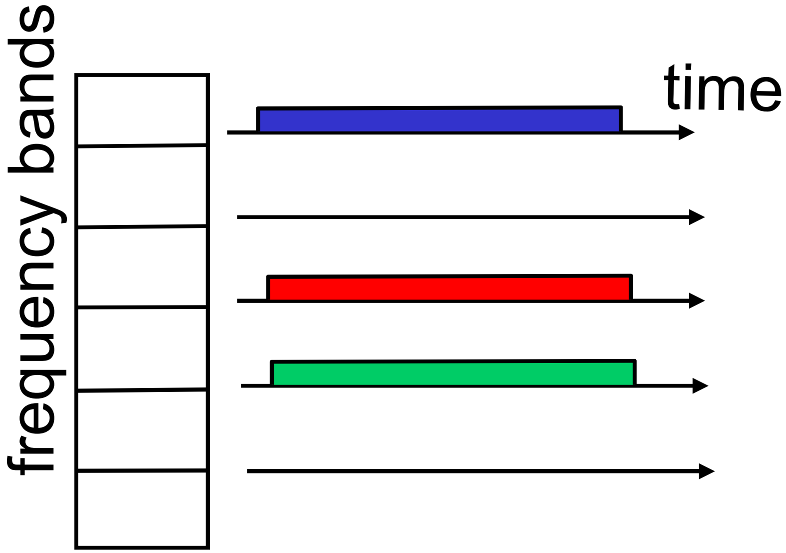
- Commonly used techniques
  - Frequency division multiplexing (FDM)
  - Time division multiplexing (TDM)
  - Wavelength division multiplexing (WDM)
  - Code division multiplexing (CDM)

Multiplexing : FDMA

FDMA: frequency division multiple access

- channel spectrum divided into frequency bands
- each station assigned fixed frequency band
- unused transmission time in frequency bands go idle
- example: 6-station LAN, 1,3,4 have pkt, frequency bands 2,5,6 idle



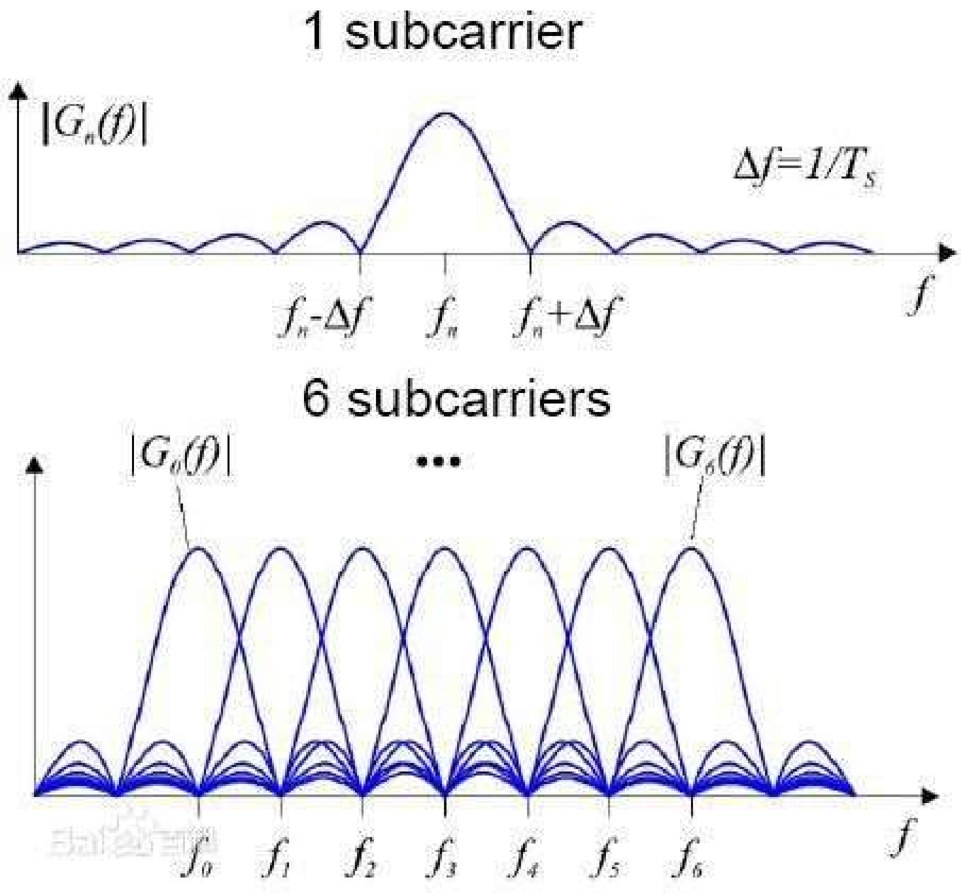


Orthogonal frequency division multiplexing (OFDM) technology

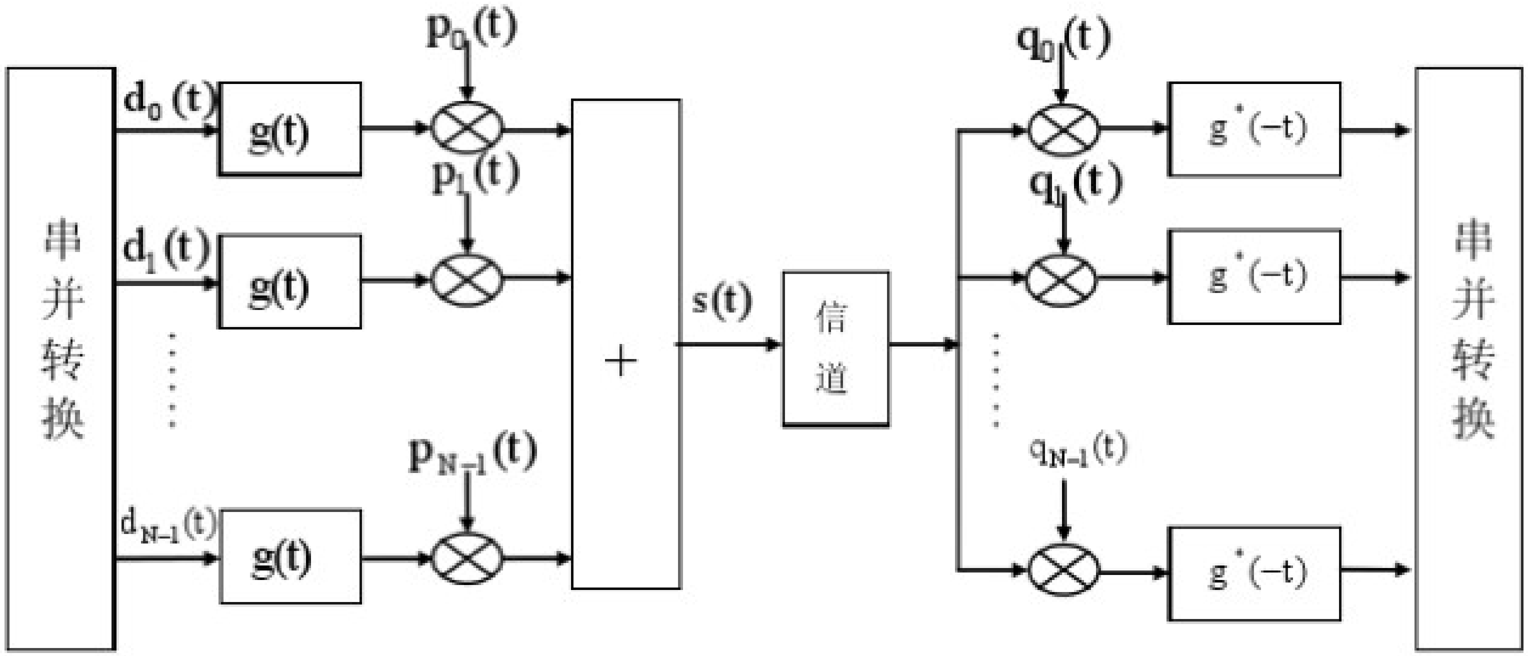
- Basic principle:
  - Dividing the channel into a number of orthogonal sub-channels;
  - The high-speed serial data is decomposed into multiple parallel low-speed data, the use of multi-carrier FDM method to transfer, that is, the data allocated to a large number of sub-channels for transmission.

- Suitable for the high-speed data transmission through wireless channel under the presence of multipath propagation and Doppler shift.

Orthogonal frequency division multiplexing (OFDM) technology



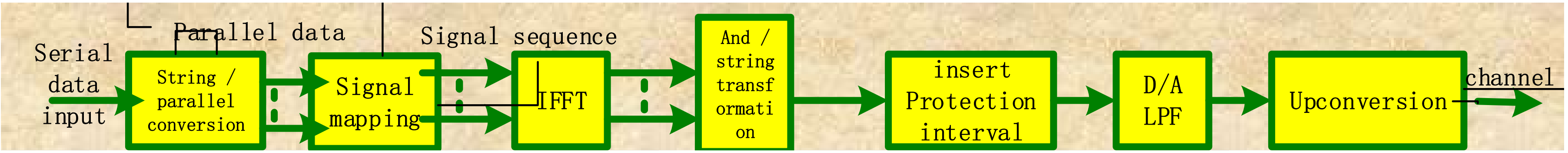
Orthogonal frequency division multiplexing (OFDM) technology



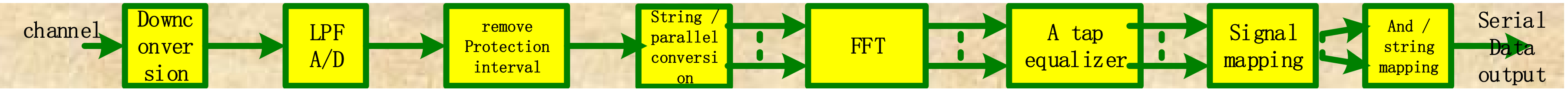
$$\int_0^{T_s} P_m(t) q_m(t) dt = c\delta_{mn} = \begin{cases} 0 & m \neq n \\ C & m = n \end{cases}$$

Orthogonal frequency division multiplexing (OFDM) technology

- FFT based OFDM Transmit System



- FFT based OFDM Receiving System



Orthogonal frequency division multiplexing (OFDM) technology

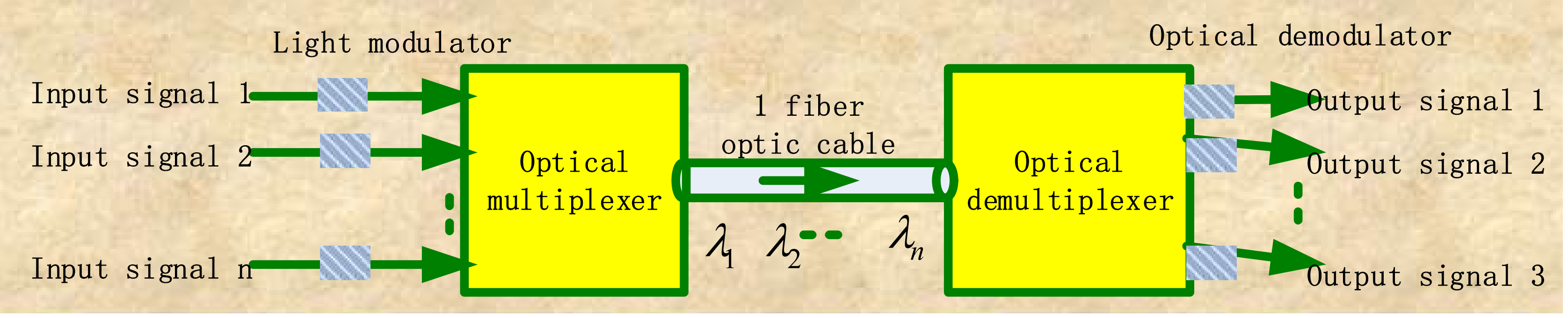
- Advantages:
  - Reduce the influence of inter-symbol interference;
  - Reduce the effect of frequency selective fading;
  - Improve the band utilization, to avoid the crosstalk between sub-channels;
  - Nearly eliminate inter-symbol interference;
  - Anti-interference coding technology can be used to effectively recover the error;
  - The parallel data can be modulated and demodulated by discrete Fourier transform DFT, which reduces the complexity of system implementation.

Orthogonal frequency division multiplexing (OFDM) technology

- Applications of OFDM technology:
  - ADSL
  - Digital Audio Broadcasting (DAB)
  - HDTV
  - Wireless LAN (WLAN)
  - Broadband radio access network
  - 3G mobile communication network and other fields.

Multiplexing : Wavelength division multiplexing (WDM)

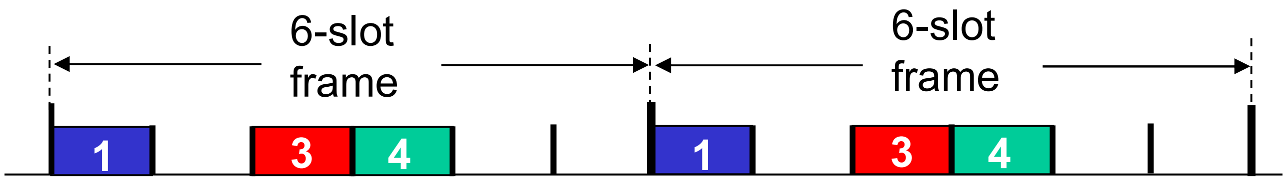
- Transmission of multiple optical carriers with different wavelengths in a fiber at the same time
- WDM is actually a variant of FDM for fiber channel multiplexing.

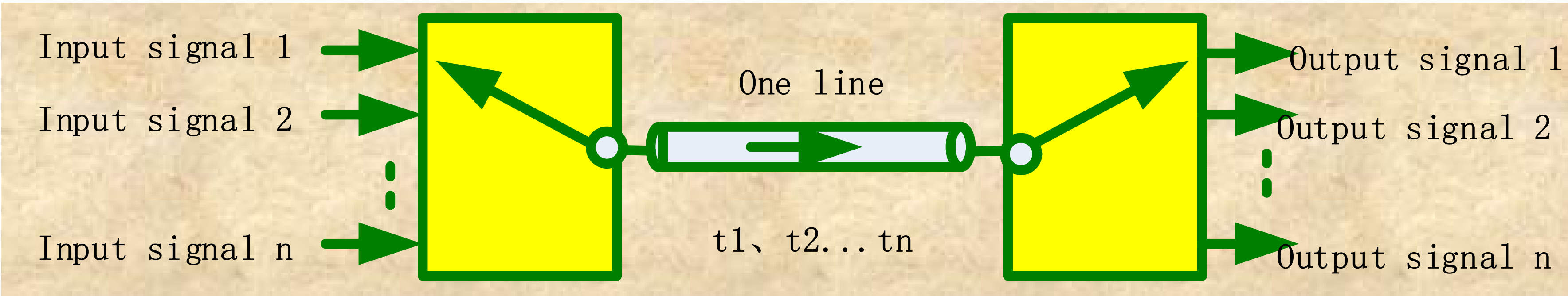


Multiplexing : TDMA

TDMA: time division multiple access

- access to channel in "rounds"
- each station gets fixed length slot (length = pkt trans time) in each round
- unused slots go idle
- example: 6-station LAN, 1,3,4 have pkt, slots 2,5,6 idle





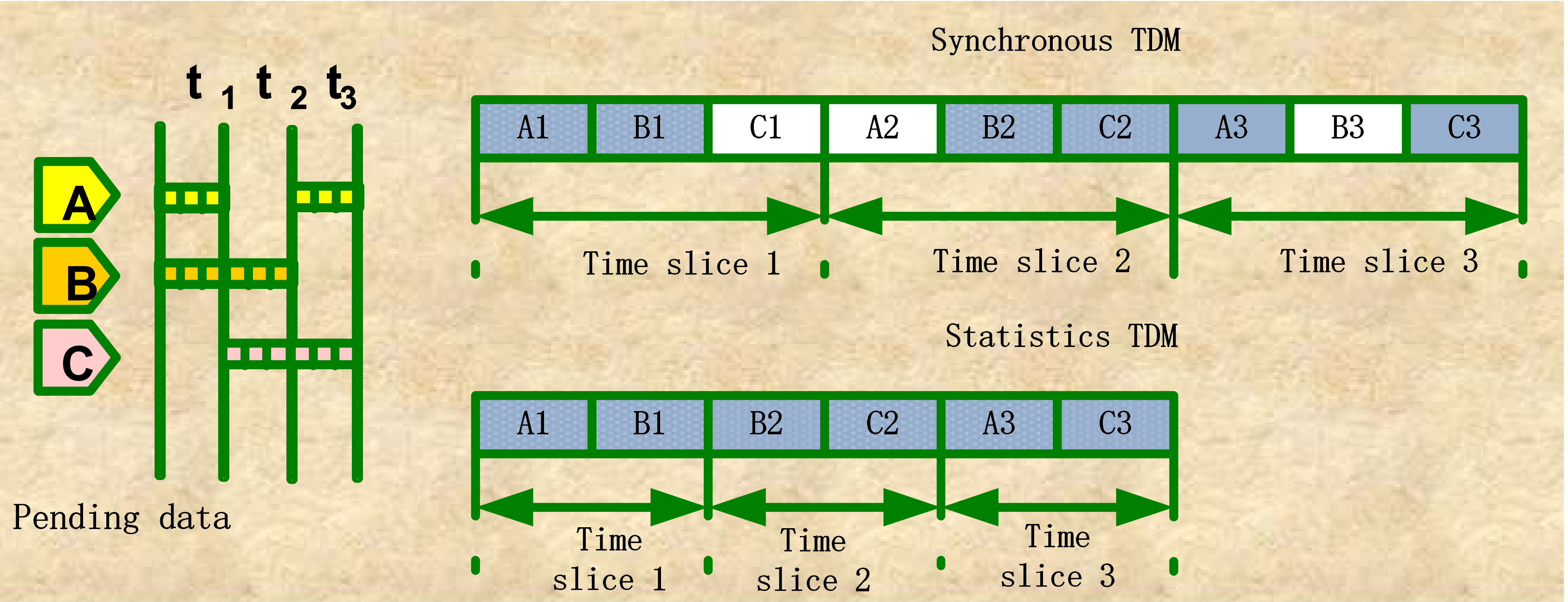
Multiplexing : TDMA

- Classification of TDM
  - Synchronous TDM:
    - Time slice fixed allocation, suitable for fixed rate transmission
    - The time slice of the physical channel is fixedly allocated to several users for data transmission, and each user uses the channel for data transmission when its corresponding time slice arrives.
  - Advantages: **simple implementation.**
  - Disadvantages: **there is a waste of bandwidth.**
  - **Synchronous TDM technology is suitable for fixed rate data communication system.**

Multiplexing : TDMA

- Asynchronous TDM:
  - The time slot of the physical channel is fixedly allocated for several, and the user does not occupy a certain time slice.
  - When a user needs to carry out data transmission, to assign a time slice;
  - If the user does not have the data transmission requirements, the system does not allocate the time slice to the user, the corresponding time slice can be allocated to other users.
- Advantages: **On-demand distribution of channel time slices, high utilization rate.**
- Disadvantages: **complex implementation.**
- **Asynchronous TDM technology is suitable for variable rate communication systems.**

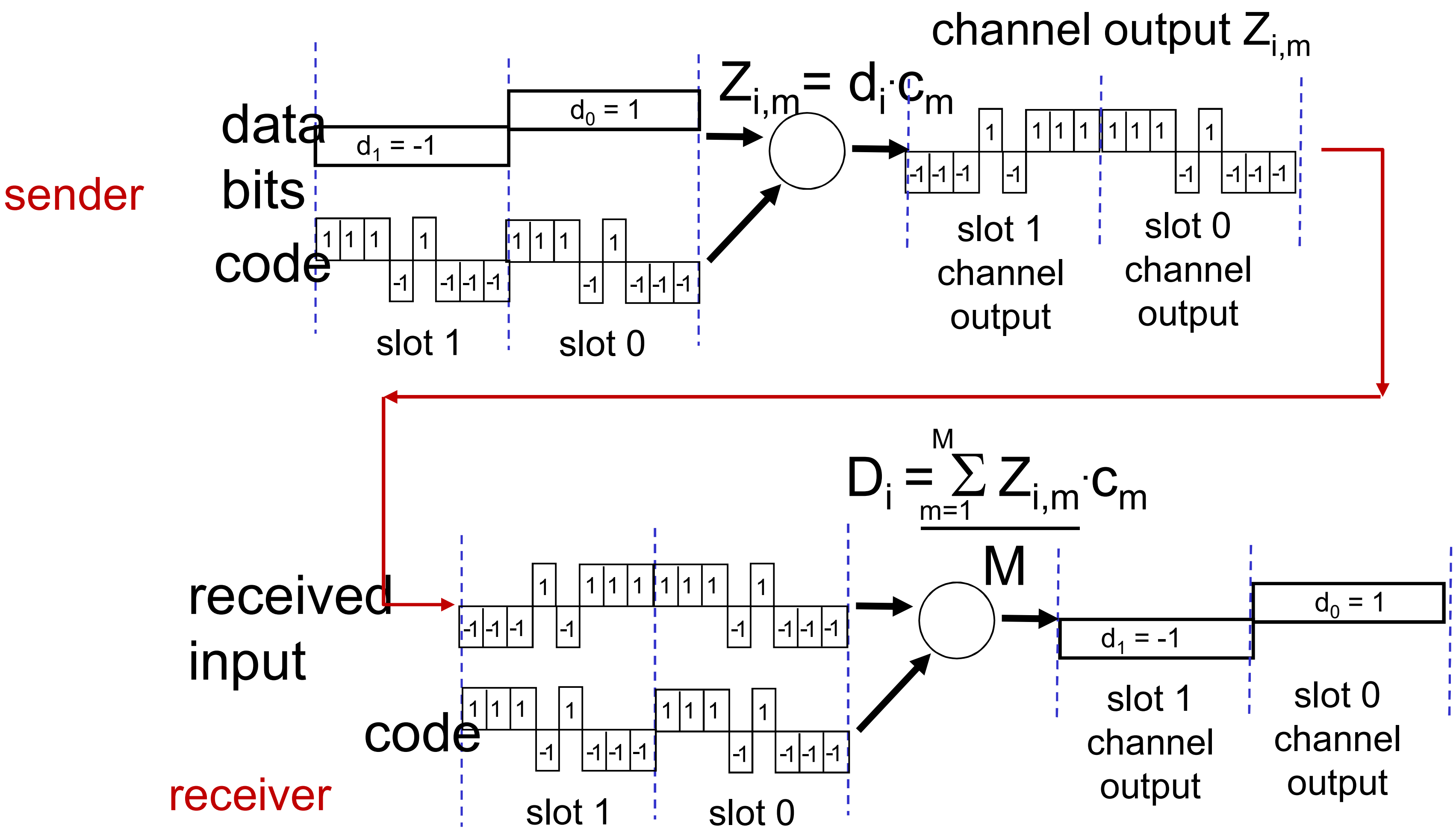
Multiplexing : TDMA



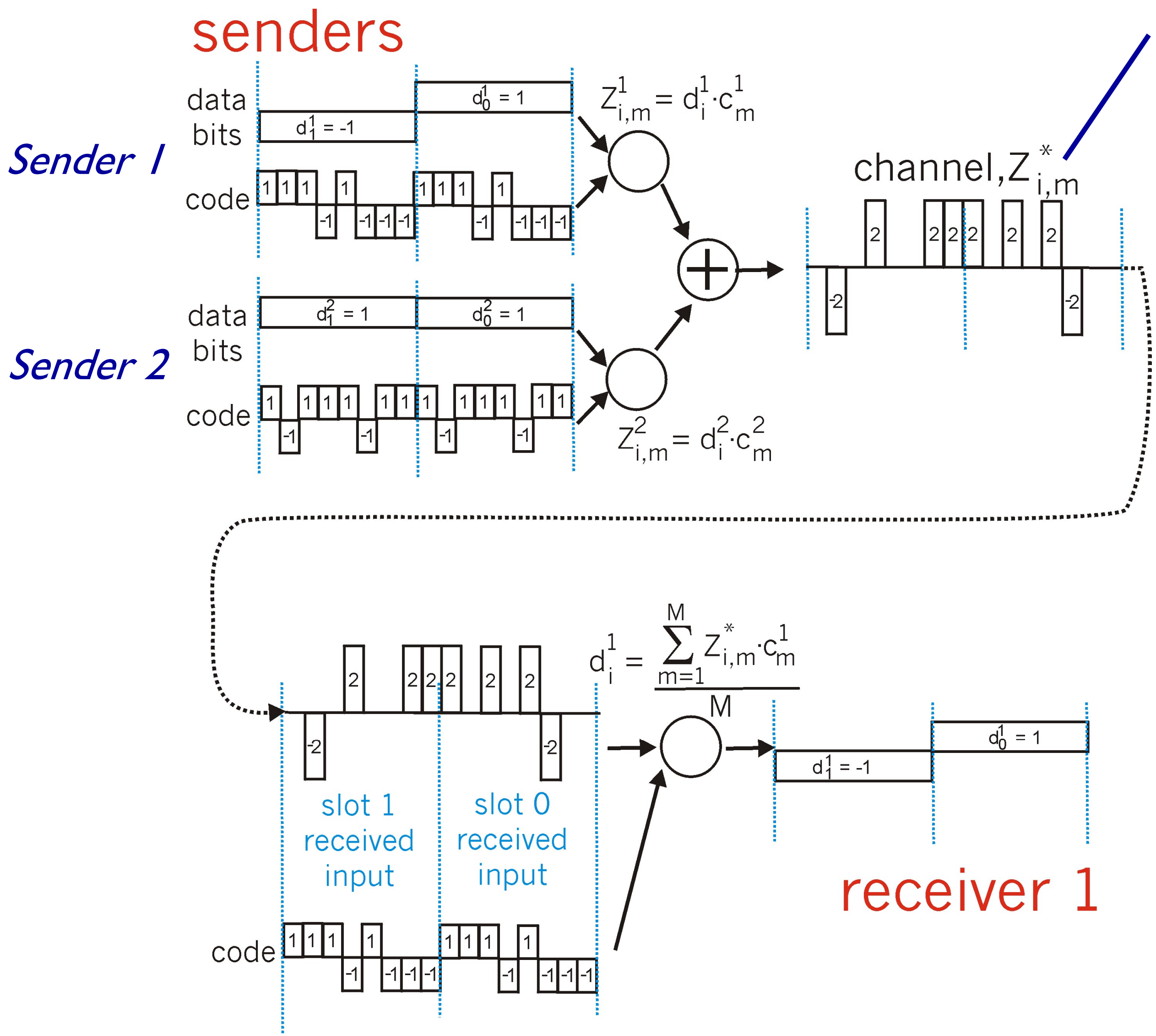
Multiplexing : Code Division Multiple Access (CDMA)

- unique "code" assigned to each user; i.e., code set partitioning
  - all users share same frequency, but each user has own "chipping" sequence (i.e., code) to encode data
  - allows multiple users to "coexist" and transmit simultaneously with minimal interference (if codes are "orthogonal")
- *encoded signal* = (original data) X (chipping sequence)
- *decoding:* inner-product of encoded signal and chipping sequence

CDMA encode/decode



CDMA: two-sender interference



channel sums together transmissions by sender 1 and 2

using same code as sender 1, receiver recovers sender 1's original data from summed channel data!

TDM—Digital Carrier Standard

- **T-standard**
  - **North America, Japan**
- **E-standard**
  - **Europe, China, South America**
- **Synchronous Fiber Network SONET**
- **Synchronous Digital Hierarchy SDH**

T- standard

- T1 standard line bandwidth calculation:
  - Taking the T1 carrier of the Bell system as an example, the Bell system multiplexes 24 audio channels together.
  - According to Nyquist theorem, the frequency bandwidth of 4KHz audio channel, as long as 8000 times per second sampling (that is, 125us mining once) can capture all of its information.
  - Each time the sample is quantized to generate a 7-bit data, 24 audio channels of a sampling data into a frame, the frame length of 193bit, each logical channel 8bit (7bit data, 1bit control signal), the first 193bit In frame synchronization.
  - T1 carrier to send 8,000 such frames per second, so the physical channel capacity is greater than 193 * 8000bit / s = 1.544Mbit / s

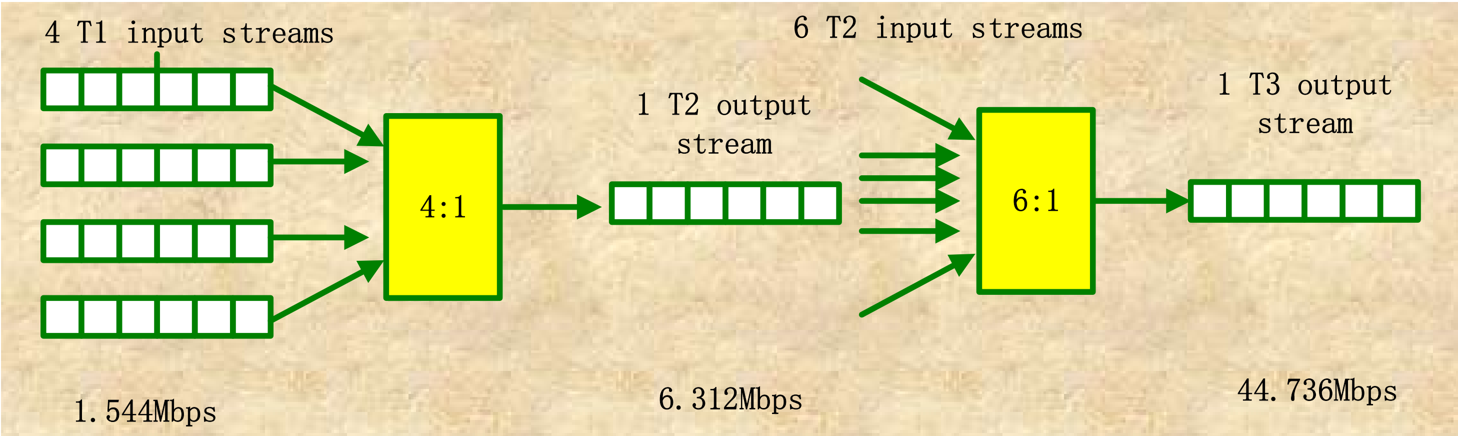
E- standard

- E1 standard line bandwidth calculation:
  - Every 125us for a time slice, each film time is divided into 32 channels (for 32 users in turn use), then each channel occupies 125us / 32 = 3.90625us
  - Each channel transfers 8 bits of binary data at a time, that is, each bit occupies 3.90625 / 8 = 0.48828125us
  - So the E1 rate = 1 / 0.48828125 = 2.048Mb / s

T-standard

- 4 T1 channels can be multiplexed into the T2 channel; 6 T2 streams can be multiplexed into the T3 channel; 7 T3 streams can be combined into the T4 channel.

- The multiplexing on T2 and higher lines is carried out in bits.
  - T2 line data transmission rate of 6.312Mbps
  - T3 line data transmission rate of 44.736Mbps
  - T4 line data transmission rate of 274.176Mbps.



T- standard and E-standard

- There are many drawbacks to the digital transmission system defined by the T and E standards:
  - The use of electrical media, signal distortion, poor anti-interference performance, poor confidentiality.
  - The rate standard is not uniform
  - Not synchronous transmission

Synchronous optical network SONET

- **SONET standard: Four design goals**
  - **Different lines can be interconnected and work reliably;**
  - **Unified the digital system standards of United States, Europe and Japan and other regions;**
  - **Capable of multiplexing multiple digital channels together;**
  - **Support operation, management and maintenance.**

Synchronous optical network SONET

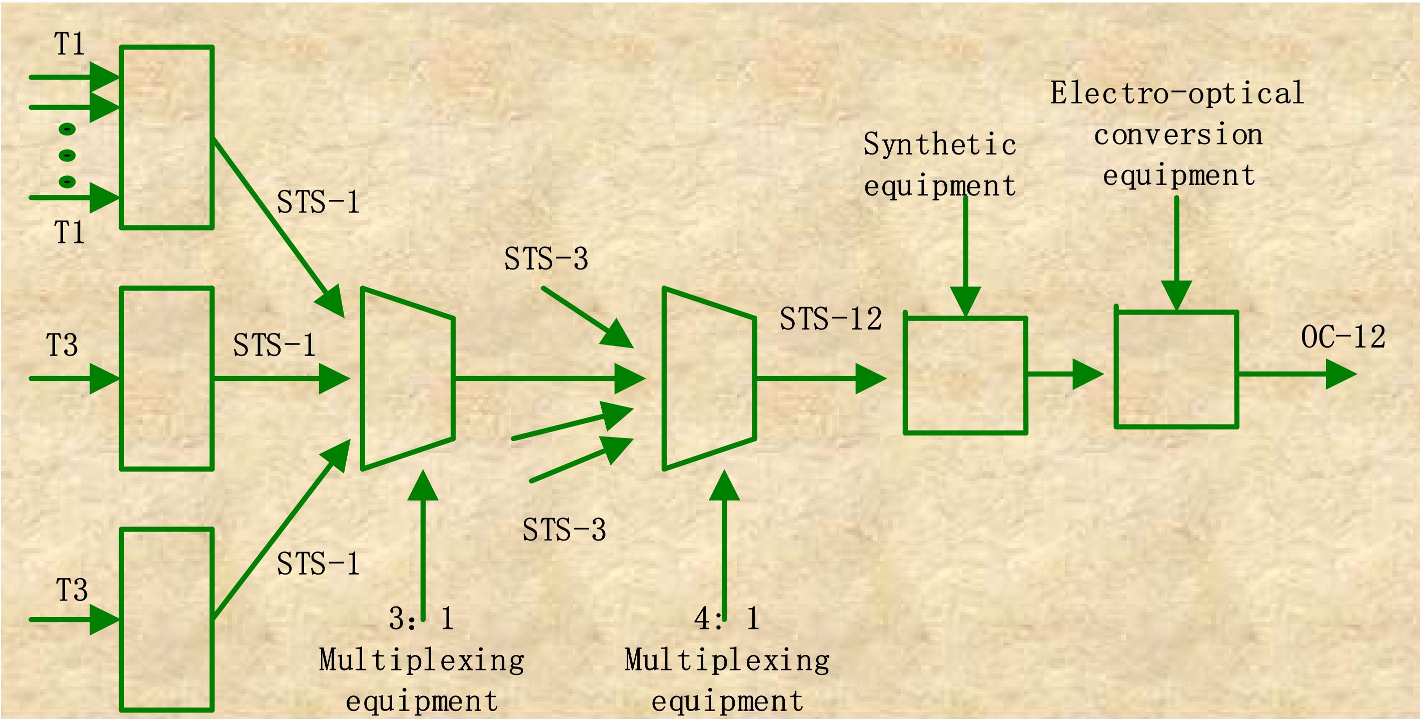
- **TDM based optical fiber multiplexing system.**
- **Synchronous system.**
- **The clocks at all levels come from a very precise master clock.**
- **SONET system consists of switches, multiplexing equipment and repeaters, and use optical fiber in connection.**

Synchronous optical network SONET

- **The basic SONET frame is 810 bytes, the sampling frequency is 8000 times / sec, the system uses synchronous TDM technology, therefore, the total data transfer rate:**
- $$810 \times 8 \times 8000 = 51.84 Mb/s$$
- **The basic SONET channel is also known as the synchronous transmission signal STS-1.**
- **SONET defines the rate from STS-1 to STS-48, and the fiber line corresponding to STS-n is called OC-n.**

Synchronous optical network SONET

- **Multiplexing of multiple data streams**



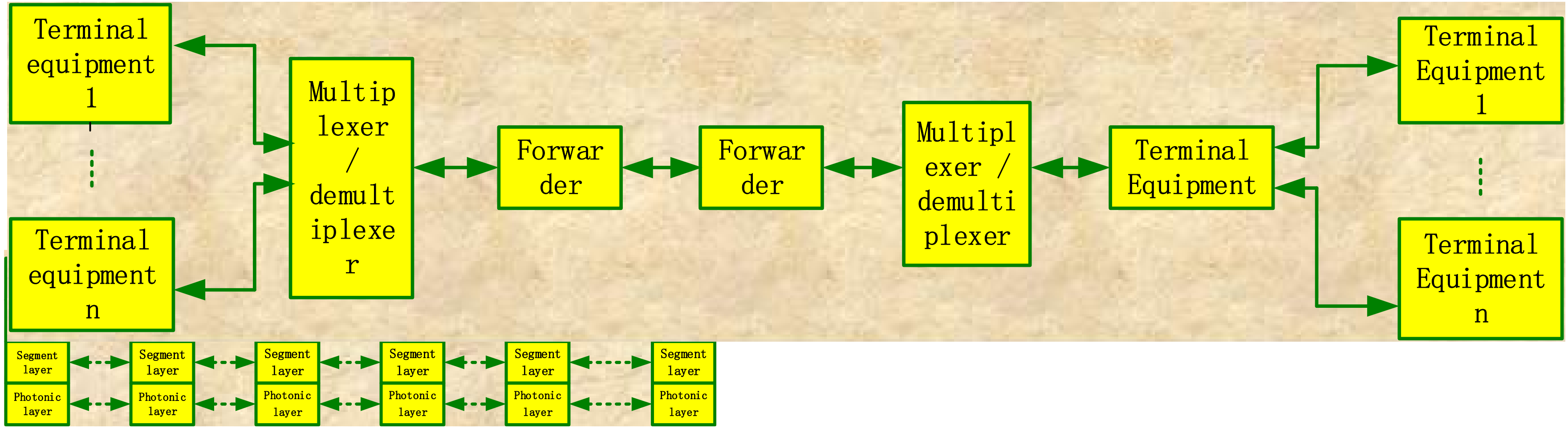
Synchronous digital hierarchy SDH

- **ITU-T based on the US standard SONET, developed the international standard synchronous digital series SDH (Synchronous Digital Hierarchy).**
- **The basic rate of SDH is 155.52 Mb/s, which is called the Synchronous Transfer Module (STM-1), equivalent to the OC-3 rate in the SONET system.**

Commonly used rate in SONET system

Line rate（Mb/s）	SONET symbol	ITU-T symbol	Represents a common approximation of line rates
51.840	OC-1/STS-1	---	
155.520	OC-3/STS-3	SMT-1	155Mb/s
466.560	OC-9/STS-9	SMT-3	
622.080	OC-12/STS-12	SMT-4	622Mb/s
933.120	OC-18/STS-18	SMT-6	
1244.160	OC-24/STS-24	SMT-8	
2488.320	OC-48/STS-48	SMT-16	2.5Gb/s
4976.640	OC-96/STS-96	SMT-32	
9953.280	OC-192/STS-192	SMT-64	10Gb/s
39813.120	OC-768/STS-768	SMT-256	40Gb/s

The architecture of SONET



The significance of SDH/SONET standards

- So the different digital transmission standards in North America, Japan and Europe and other regions are unified in the STS-1 level.
- Truly realizing the worldwide digital transmission standard for the first time, and is of great significance to the development of the world telecommunication networks.

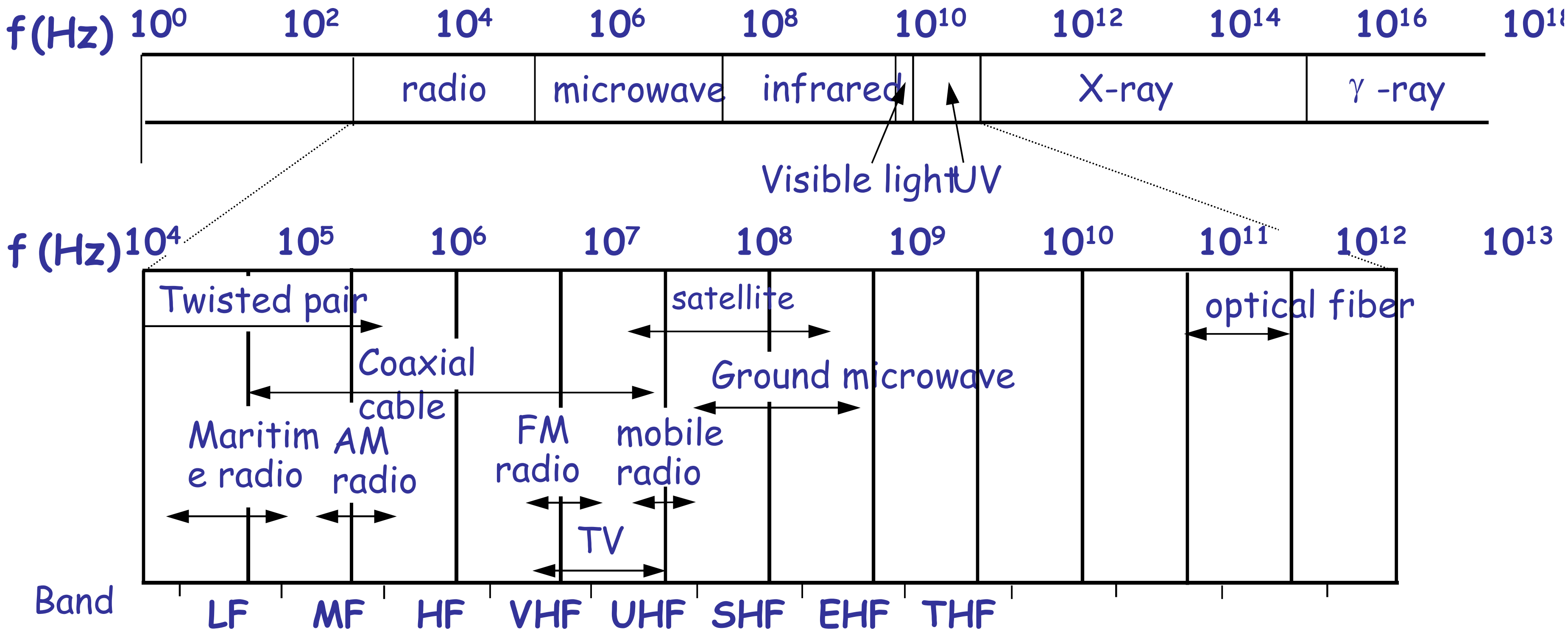
Chapter 2 The physical layer

3 What is the theoretical basis for the physical layer?

4 What are the commonly used transmission media?

5 The commonly used physical layer interface standards

The spectrum of electromagnetic waves used in Telecommunications



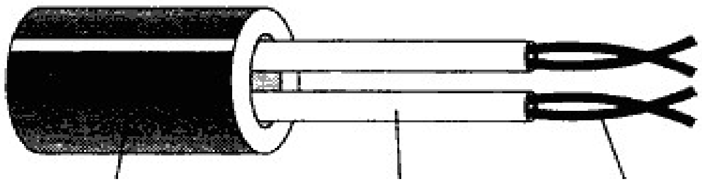
Transmission medium (guided transmission medium)

- Twisted Pair
  - Can be used for both analog and digital transmission
  - Bandwidth depends on the wire diameter and the transmission distance
  - UTP (Unshielded Twisted Pair)
    - Twisted pair without any shielding
    - Divided into Category 1 to Category 7
    - Category 3 : transmission characteristics 16MHz, the data rate up to 16Mbps
    - Category 5 : transmission characteristics of 100MHz, the data rate of up to 100Mbps

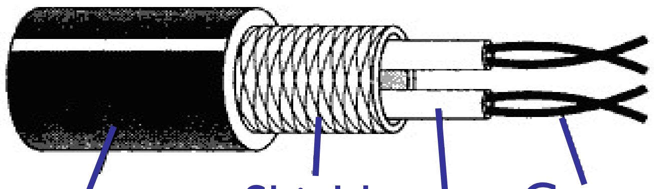
Transmission medium (guided transmission medium)

- Twisted Pair
  - Shielded twisted pair STP (Shielded Twisted Pair)
    - Twisted pair is wrapped by the aluminum foil, used to shield the interference signal
    - The price is relatively expensive, mainly for IBM network products

Unshielded Twisted Pair

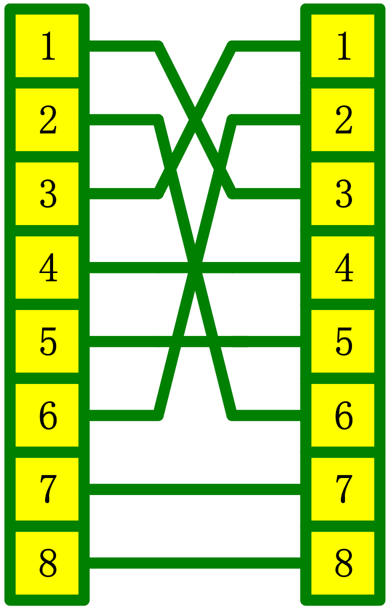


Shielded twisted

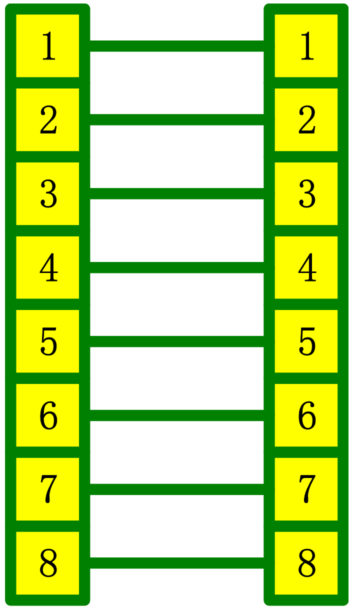


- **Connection standard for twisted pair**
  - **Cross line:**
    - **Switch - Switch, PC-PC, HUB-HUB (standard port)**
  - **Straight line:**
    - **PC / router - switch / HUB, HUB-HUB (cascade port)**

Line pair	Color code
1	White blue, blue
2	White orange, orange
3	White green, green
4	White brown, brown



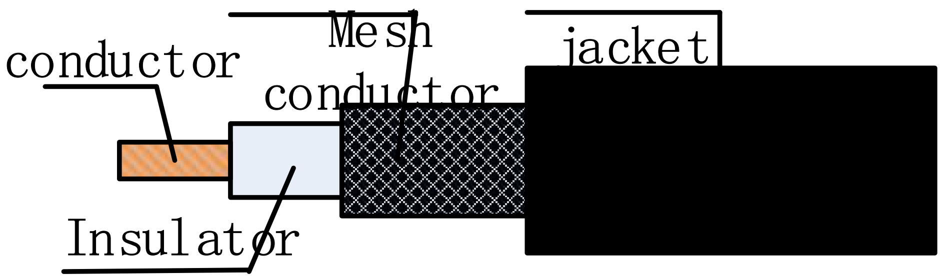
Cross line
EIA-568B



Direct line
EIA-568A

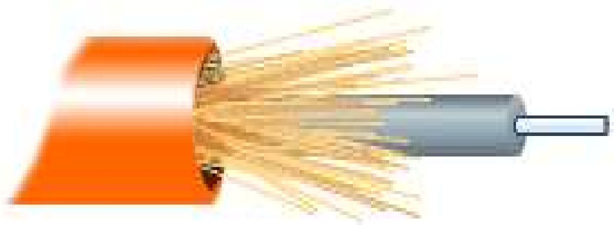
Transmission medium (guided transmission medium)

- **Coaxial cable**
  - **Baseband Coaxial Cable**
    - **Transmit digital signal, one channel**
    - **Impedance 50 Ω, rate 10Mbps**
  - **Broadband Coaxial Cable**
    - **Transmission of different frequencies of analog signals**
    - **Impedance 75 Ω, 300M or 450Mbps, 100km**
  - **Thick Cable， Thin Cable**

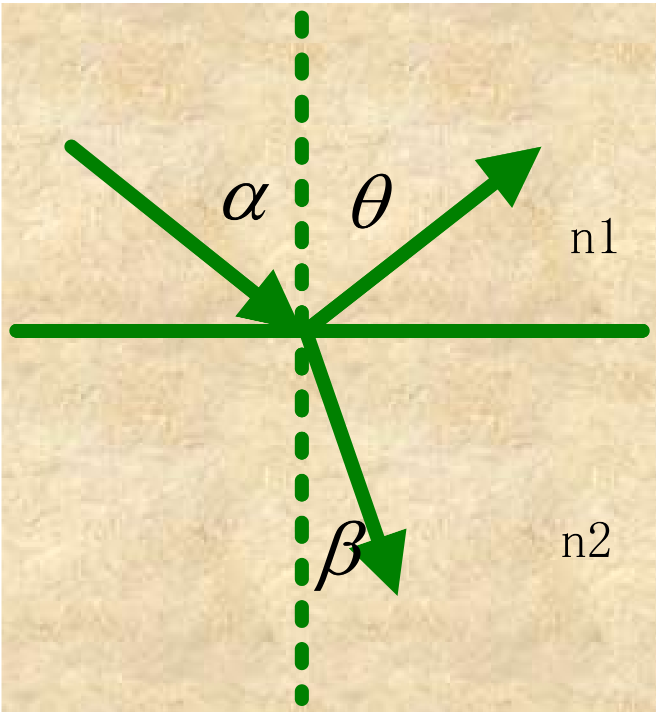


Transmission medium (guided transmission medium)

- **Fiber Optics**
  - **Features**
    - **Use light to carry information**
    - **High transmission rate, large communication capacity**
    - **Transmission loss is small, suitable for long distance transmission**
    - **Anti-lightning and electromagnetic interference performance is good, good confidentiality**
    - **light**

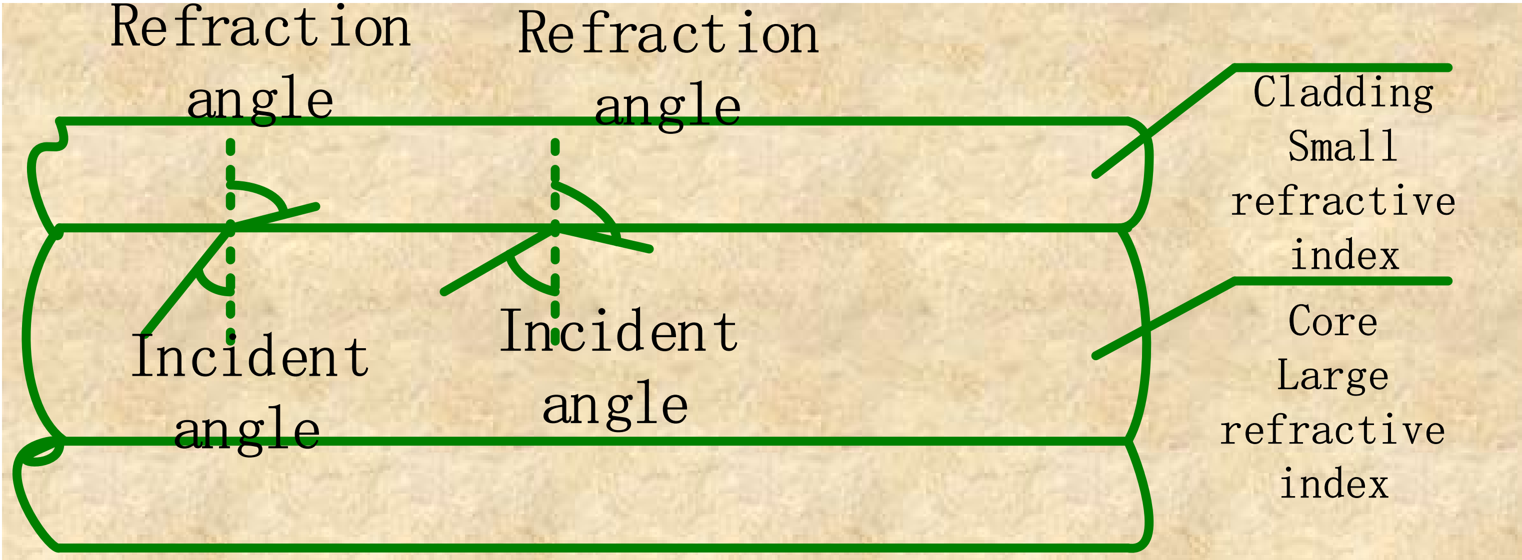


The law of refraction and the law of reflection of light

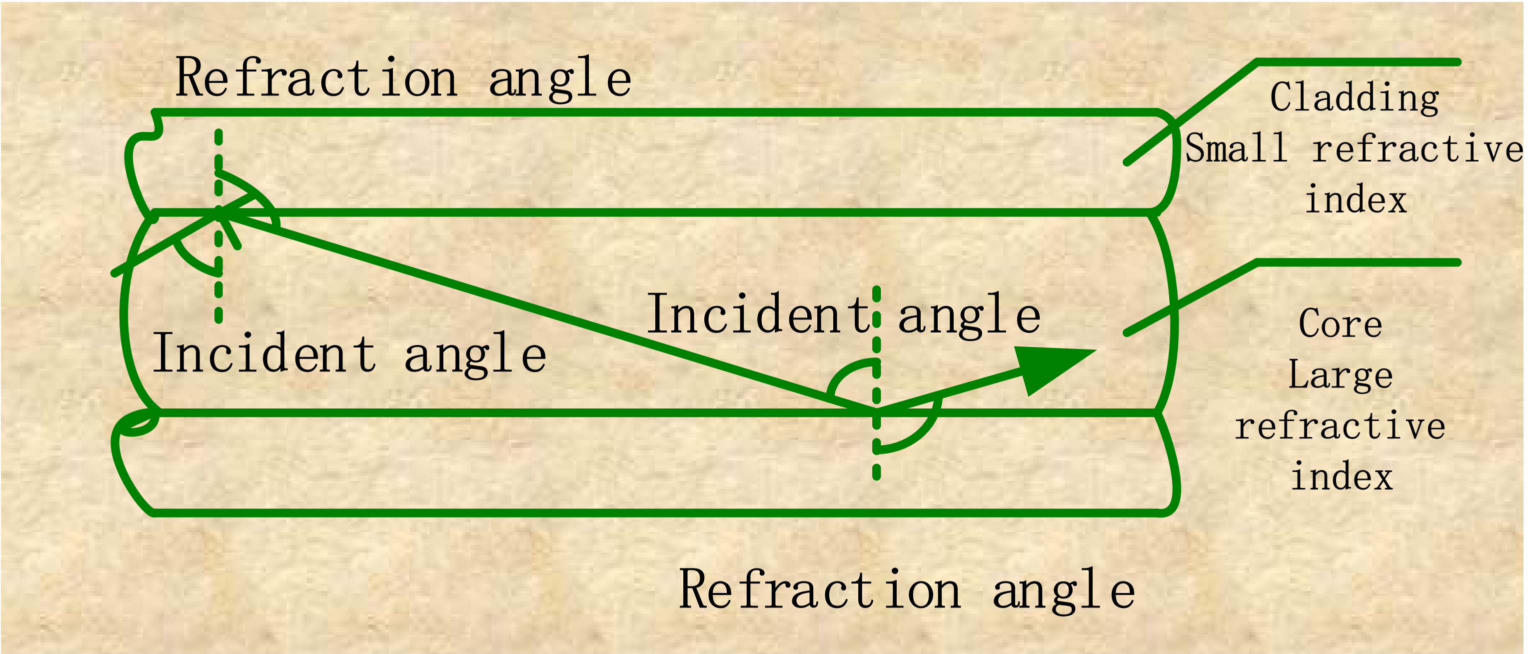


$$\frac{\sin(\alpha)}{\sin(\beta)} = \frac{n2}{n1}$$

Refraction and reflection of light in an optical fiber



Propagation of light in optical fiber



Transmission medium (unguided transmission medium)

- **Wireless media**
  - **Use electromagnetic waves or light to carry information**
- **Advantages and disadvantages:**
  - **No physical connection required**
  - **Applicable to long distance or inconvenient wiring occasions**
  - **Susceptible to interference**
  - **Reflex, obstructed by obstacles**
- **Main types:**
  - **Radio, ground microwave**
  - **Communication satellite**
  - **Infrared**

Transmission medium (unguided transmission medium)

- **Radio**
  - **The communication between the base station and the terminal uses a wireless link**
  - **Application areas: mobile communications, wireless local area network (WLAN)**
- **Ground microwave**
  - **Through the ground station between the relay transmission**
  - **Distance between relay stations: 50 -100 km**
  - **Rate: 45 Mb/s per channel**

Transmission medium (unguided transmission medium)

- **Earth Synchronous Satellite**
  - **Position is fixed relative to the ground station**
  - **Three satellites can cover the worldwide communication**
  - **Transmission delay time is long (≈270ms)**
  - **Broadcast transmission**
  - **Application areas:**
    - **TV**
    - **Long-distance call**
    - **Dedicated network**
    - **WAN**

Comparison of commonly used media

Transmission medium	Transfer method	Rate/ Band	Transmission distance	Performance	Price	Application
Twisted pair	Broadband Baseband	≤1Gb/s	Anolog：10km digtal：500m	Better	Low	Analog / digital signal transmission
50Ω Coaxial cable	Baseband	10Mb/s	<3km	Better	Lower	Baseband digital signal
75Ω Coaxial cable	Broadband	≤450MHz	100km	Better	Lower	Analog TV, data and audio
Optical fiber	Baseband	40Gb/s	20km以上	Very good	Higher	Long - distance high - speed data transmission
Microwave	Broadband	4-6GHz	Several hundred km	Good	Medium	Remote communication
Satellite	Broadband	1-10GHz	18000 km	Very good	High	Remote communication

Chapter 2 The physical layer

3 What is the theoretical basis for the physical layer?

4 What are the commonly used transmission media?

5 The commonly used physical layer interface standards

Commonly used physical layer interface standards

- EIA-232-E interface standard
- RS-449 interface standard
- RS-485 interface standard
- CAN interface standard
- PROFIBUS interface standard
- ....

Recap of the Physical Layer

- The function of the physical layer and the issues to be considered
- Four important characteristics of the physical layer
- The contents of the physical layer protocol
- Some Basic Concepts in Data Communication
- Multiplexing technology and signal coding technology
- Nyquist's Law and Shannon's Formula
- Commonly used transmission medias
- Commonly used physical layer interface standards