Chapter 2

The Physical Layer
(物理层)

The Physical Layer

- Theoretical Basis(理论基础)
- Transmission Media(传输介质)
- Examples of Communication System(通信系统实例)
  - Communication Satellites
  - Public Switched Telephone System
  - The Mobile Telephone System Cellular Radio
  - Cable Television

Contents

Contents(2)

Contents(3)

2.1 The Theoretical Basis for Data Communication

- Fourier Analysis(傅立叶分析)
- Bandwidth-Limited Signals(有限带宽信号)
- Maximum Data Rate of a Channel(信道的最大传输速率)

2.1.1 Fourier Analysis

$$g(t) = \frac{1}{2}c + \sum_{n=1}^{\infty} a_n \sin(2\pi nft) + \sum_{n=1}^{\infty} b_n \cos(2\pi nft)$$

- f=1/T --基频
- a_n 和 b_n -- n次谐波的振幅
- 对于给定的g(t) 和T,可推导出:

$$a_n = \frac{2}{T}\int_0^T g(t)\sin(2\pi nft)dt$$

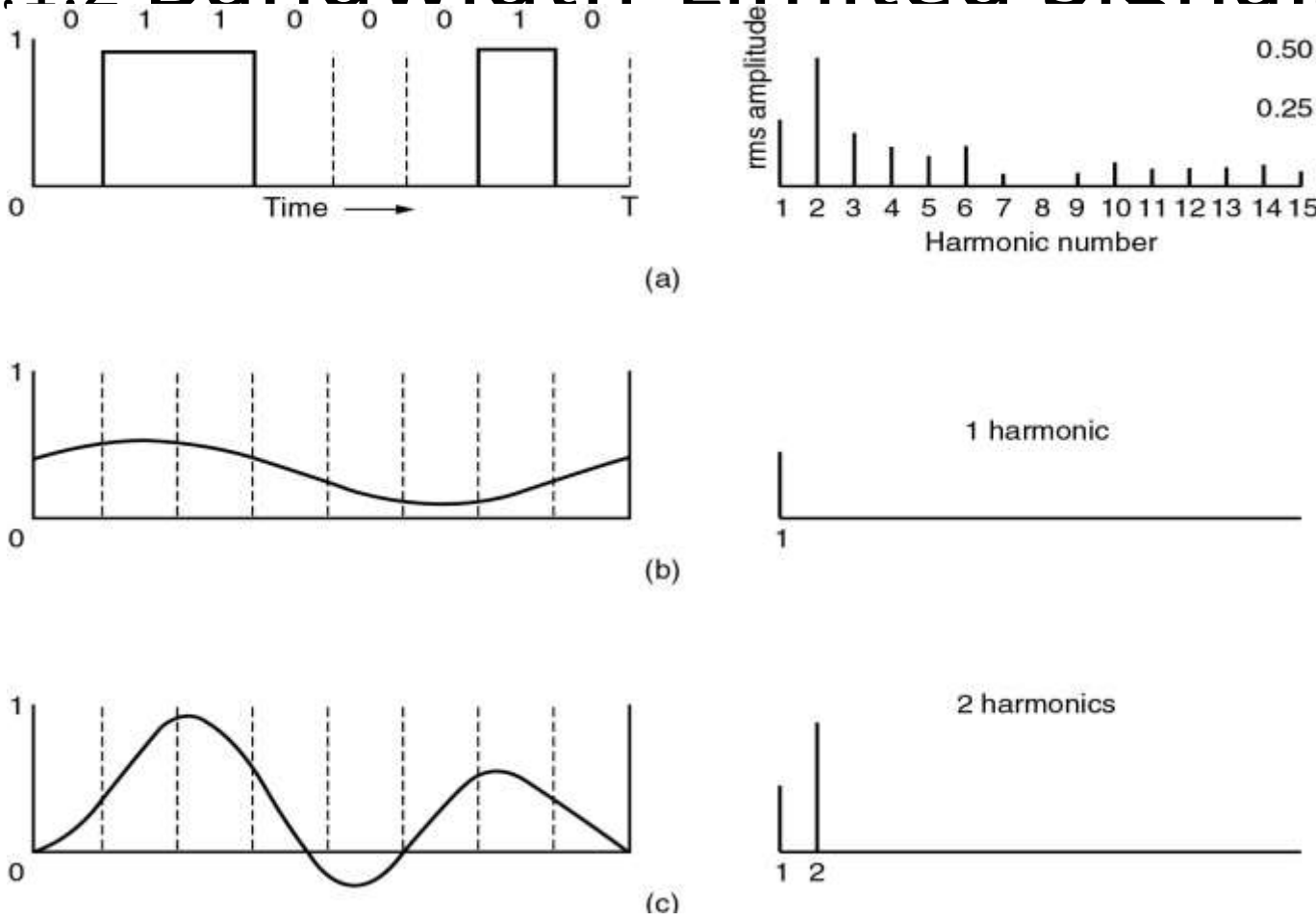
$$b_n = \frac{2}{T}\int_0^T g(t)\cos(2\pi nft)dt$$

$$c = \frac{2}{T}\int_0^T g(t)dt$$

$$\sqrt{a_n^2 + b_n^2}$$

与相应频率处所传输的能量成正比

2.1.2 Bandwidth-Limited Signals

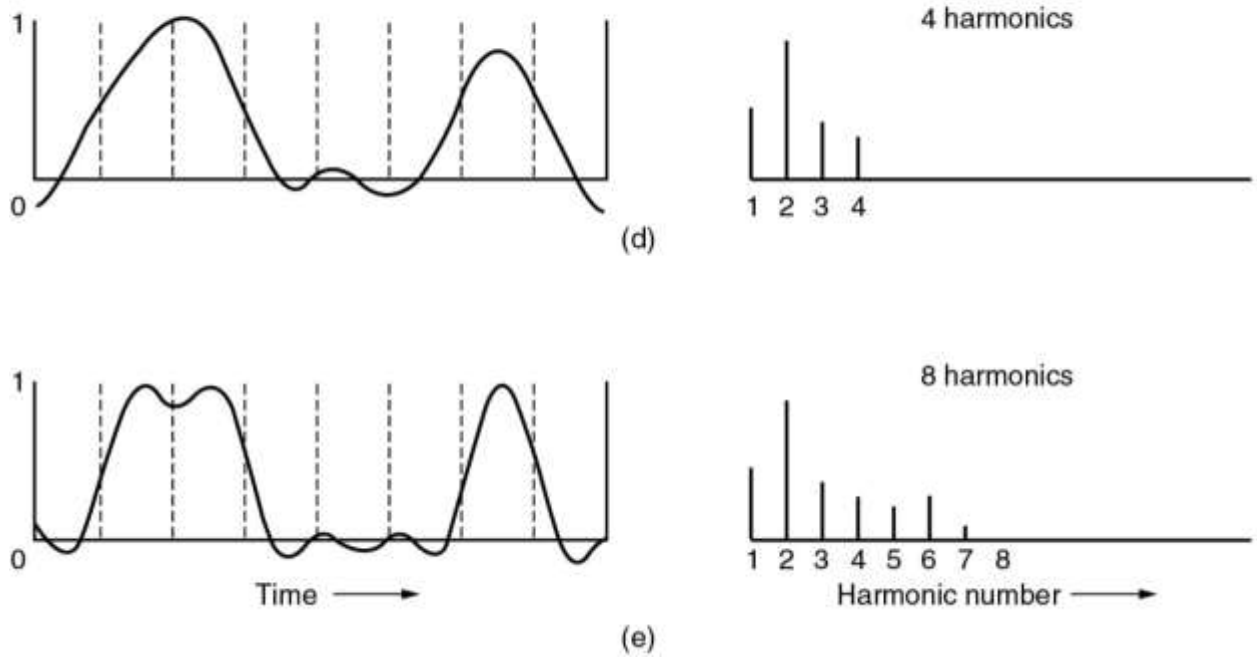


A binary signal and its root-mean-square Fourier amplitudes.

(b) – (c) Successive approximations to the original signal.

Bandwidth-Limited Signals (2)

(d) – (e) Successive approximations to the original signal.



Bandwidth-Limited Signals (3)

第一个谐波　　发送的谐波数

Bps	T (msec)	First harmonic (Hz)	# Harmonics sent
300	26.67	37.5	80
600	13.33	75	40
1200	6.67	150	20
2400	3.33	300	10
4800	1.67	600	5
9600	0.83	1200	2
19200	0.42	2400	1
38400	0.21	4800	0

Relation between data rate and harmonics.

2.1.3 The Maximum Data Rate of a channel

信道的最大传输速率

- 波特（baud)、比特率（bit per second, bps)
- Signal-to-noise ratio S/N
- 分贝（DB) = $10\log_{10}S/N$
- **Nyquist 定理(无噪声信道)：**

  Max速率（b/s) = $2H\log_2V$

  --**H**:bandwidth of a low-pass filter

  --**V**:discrete levels of a signal
- **Shannon 定理(有噪声信道)：**

  Max速率(b/s)= $H\log_2(1+S/N)$

1.A noiseless 3-kHz channel (H)

2.Two level signals (V=2)

=>Max bps

$=2x3kx\log_2 2=6kbps$

2.2 Guided Transmission Data

- **Magnetic Media(磁介质)**
- **Twisted Pair(双绞线)**
- **Coaxial Cable(同轴电缆)**
- **Power lines （电源线）**
- **Fiber Optics(光纤)**

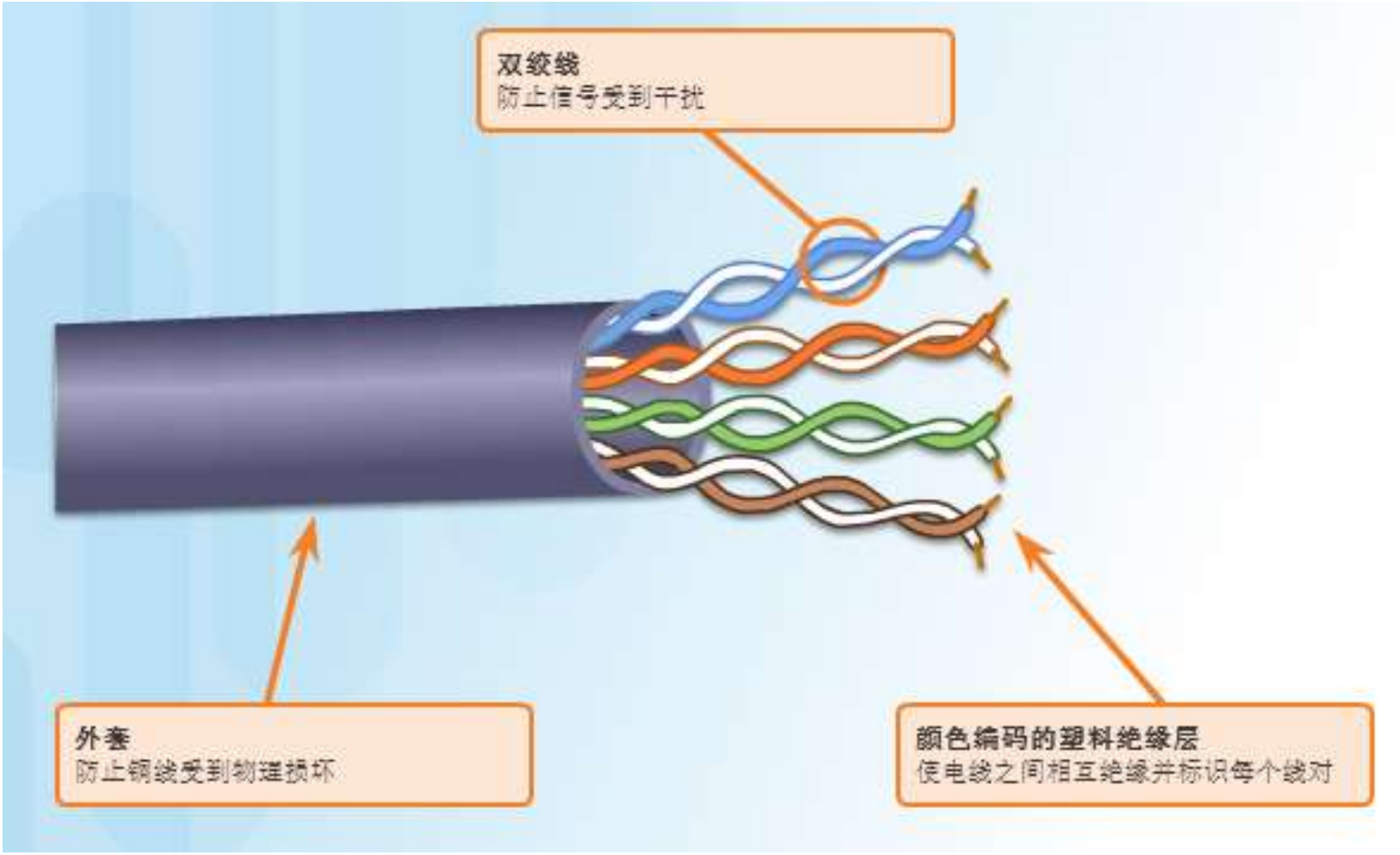
2.2.2 Twisted Pair

(a)

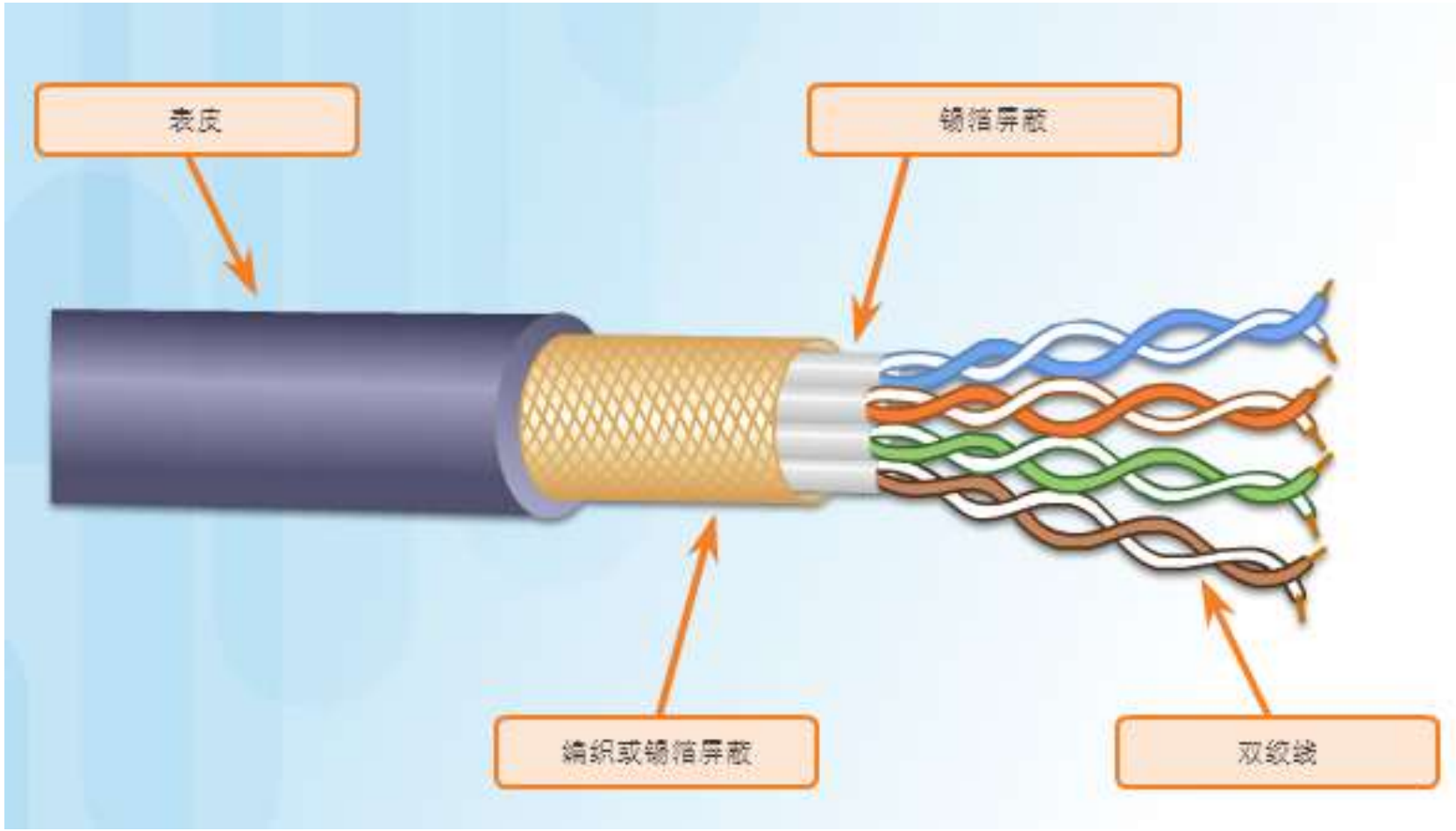
(b)

(a) Category 3 UTP. Prior to 1988
(b) Category 5 UTP.

UTP



STP



RJ-45 UTP

RJ-45 UTP 插头

RJ-45 UTP 插槽

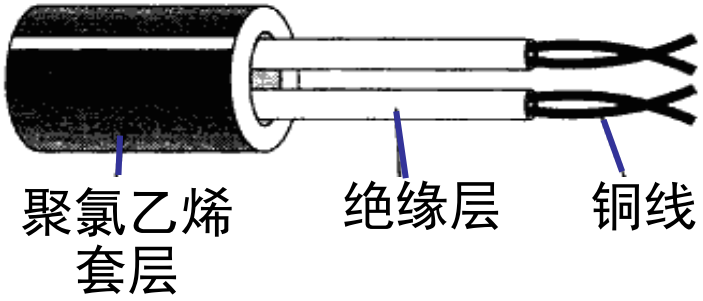
T568A

T568B

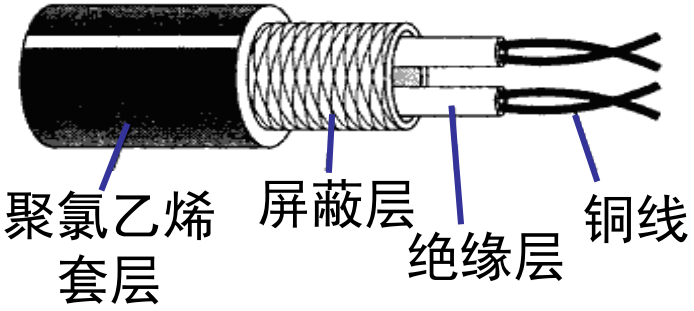
电缆类型	标准	应用
以太网直通电缆	两端均为 T568A 或两端均为 T568B	将网络主机连接到交换机或集线器之类的网络设备。
以太网交叉电缆	一端为 T568A，另一端为 T568B	• 连接两台网络主机 • 连接两台网络中间设备（交换机与交换机或路由器与路由器）

各种电缆

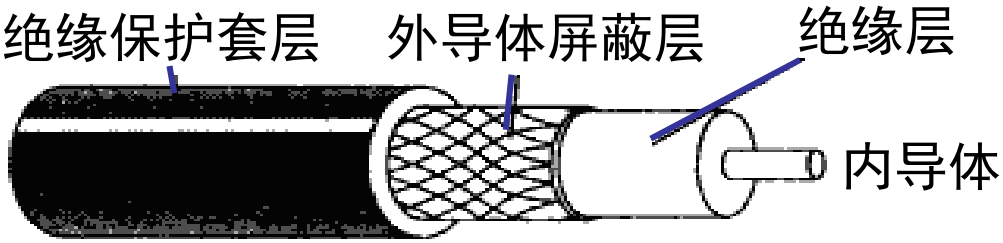
无屏蔽双绞线 UTP



屏蔽双绞线 STP



同轴电缆

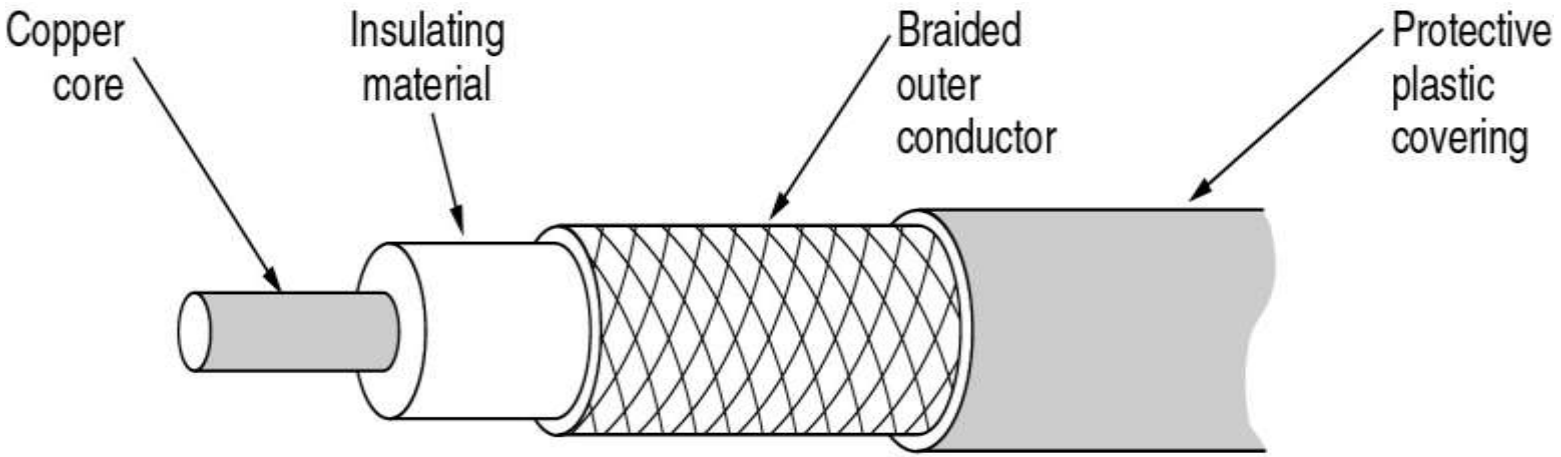


Signal bandwidth

- Cat 3 16MHz
- Cat 5 100MHz
- Cat 6 250MHz
- Cat 7 600MHz

- UTP and STP

2.2.3 Coaxial Cable



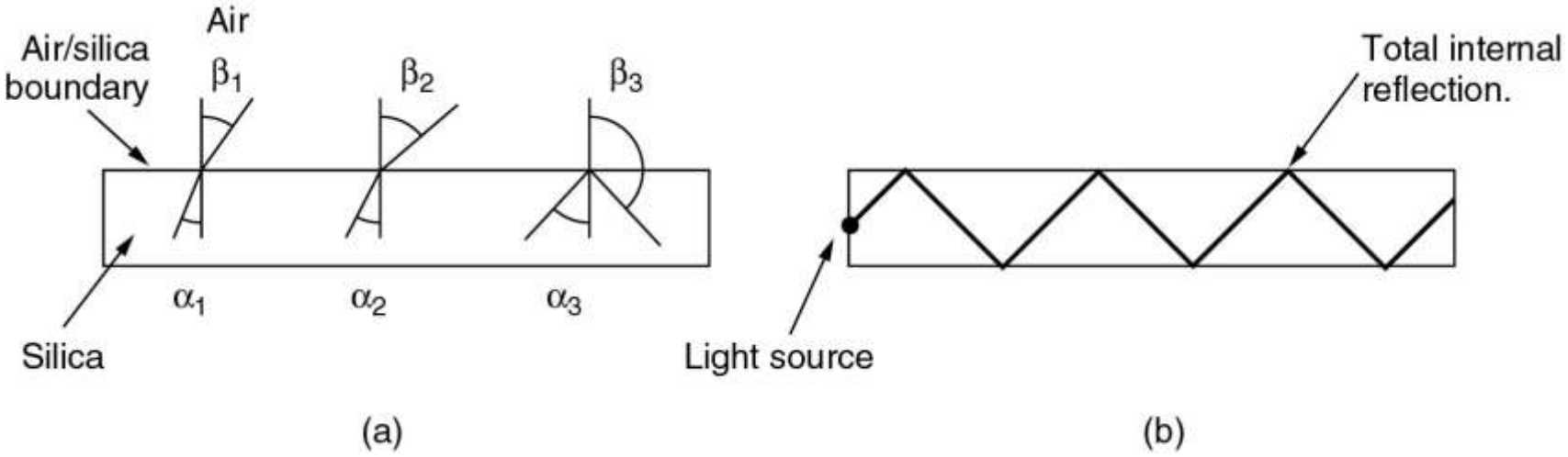
A coaxial cable.

- 基带（baseband)同轴电缆
  - 50Ω电缆– 数字传输
  - 75Ω电缆– 模拟传输
- 宽带(broadband)同轴电缆
  - 75Ω电缆– 模拟传输、有线电视、多信道
  - 宽带网络：双电缆系统、单电缆系统、顶端器

2.2.4 Fiber Optics

- 数据通信：56K->1Gbps→50,000Gb/s
- 多模光纤（multi-mode fiber）
- 单模光纤（single-mode fiber）
- 连接方式:
  - 接头/插座，机械方式钳接， 熔接
- 光源：LED 和 激光
- 光纤网络
- 光纤和铜线的比较：
  - 带宽高、衰减小、抗干扰、轻、安全性高

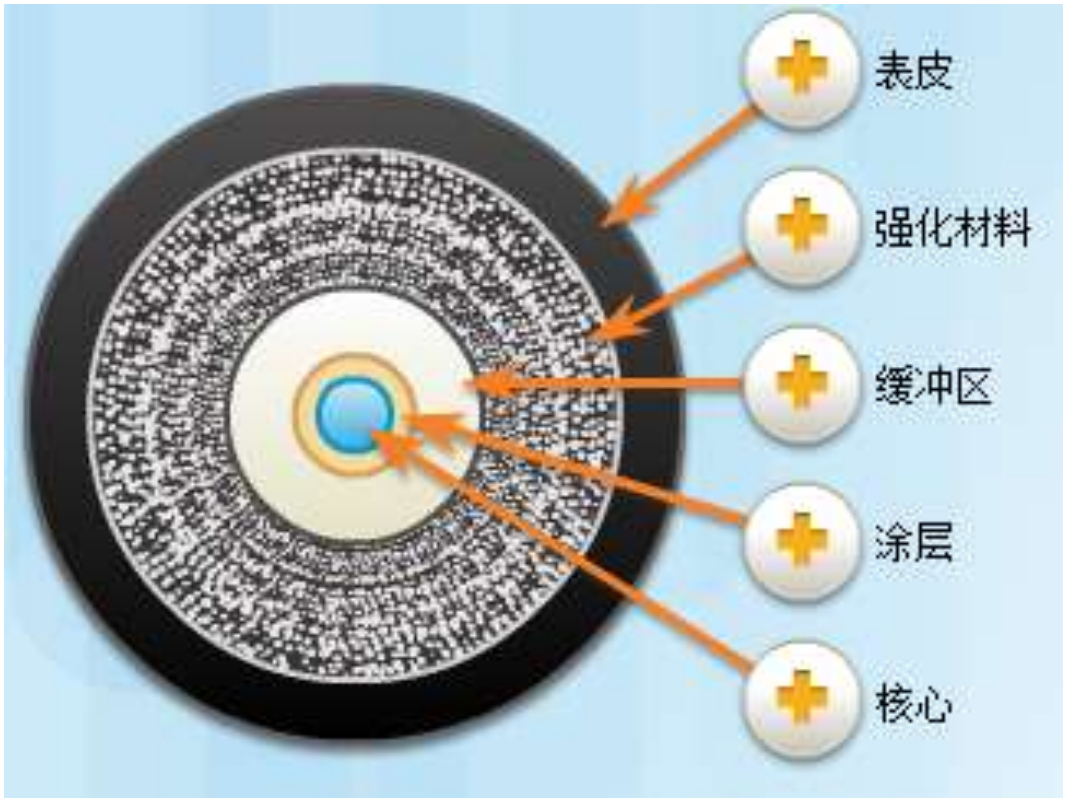
Fiber Optics

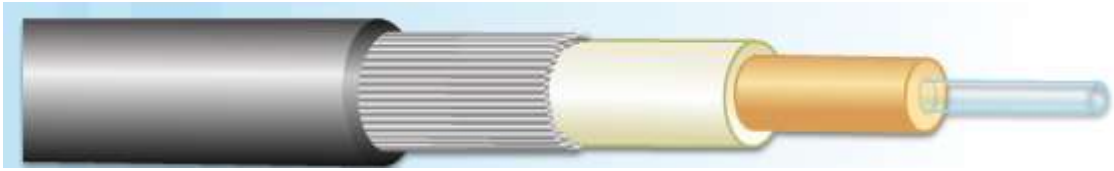


(a) Three examples of a light ray from inside a silica fiber impinging on the air/silica boundary at different angles.

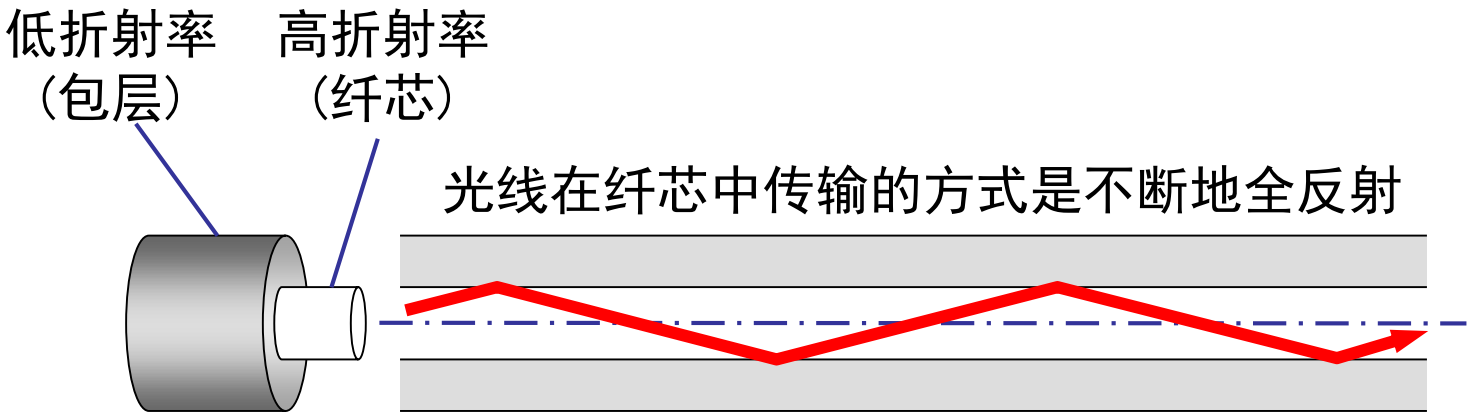
(b) Light trapped by total internal reflection.

光纤Fibre

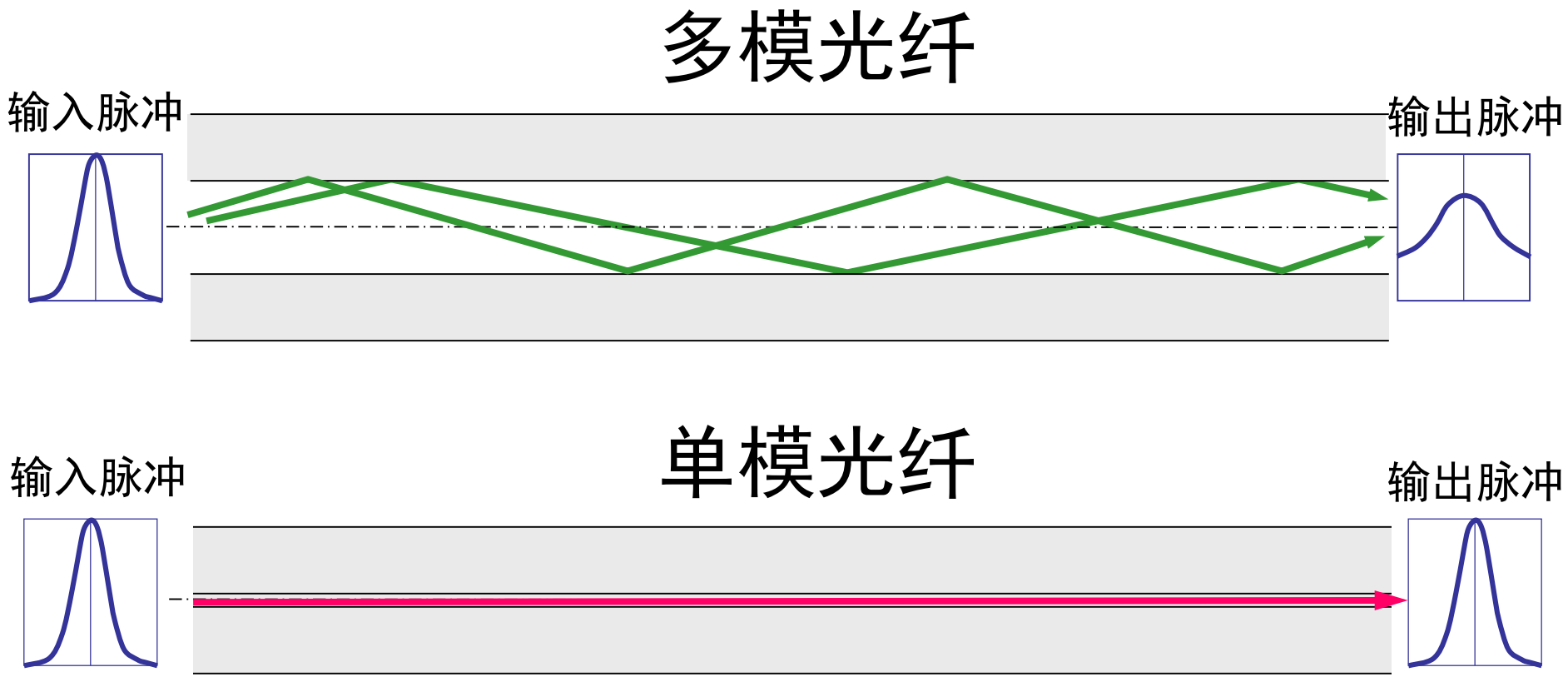




光纤的工作原理



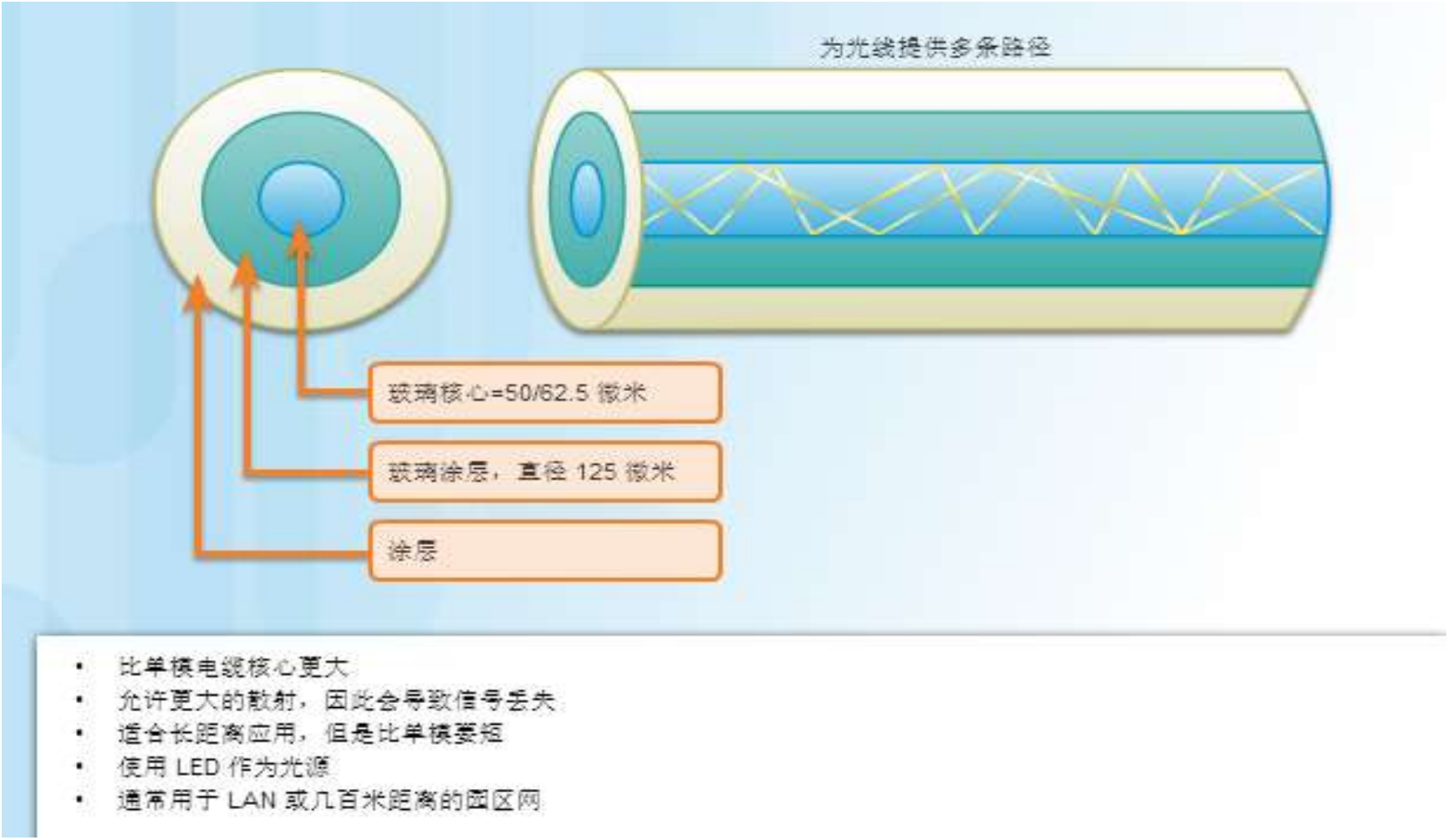
多模光纤与单模光纤



单模Single-Mode

- 小核心
- 散射较小
- 适合长距离应用
- 使用激光作为光源
- 通常用于几千米距离的园区骨干网

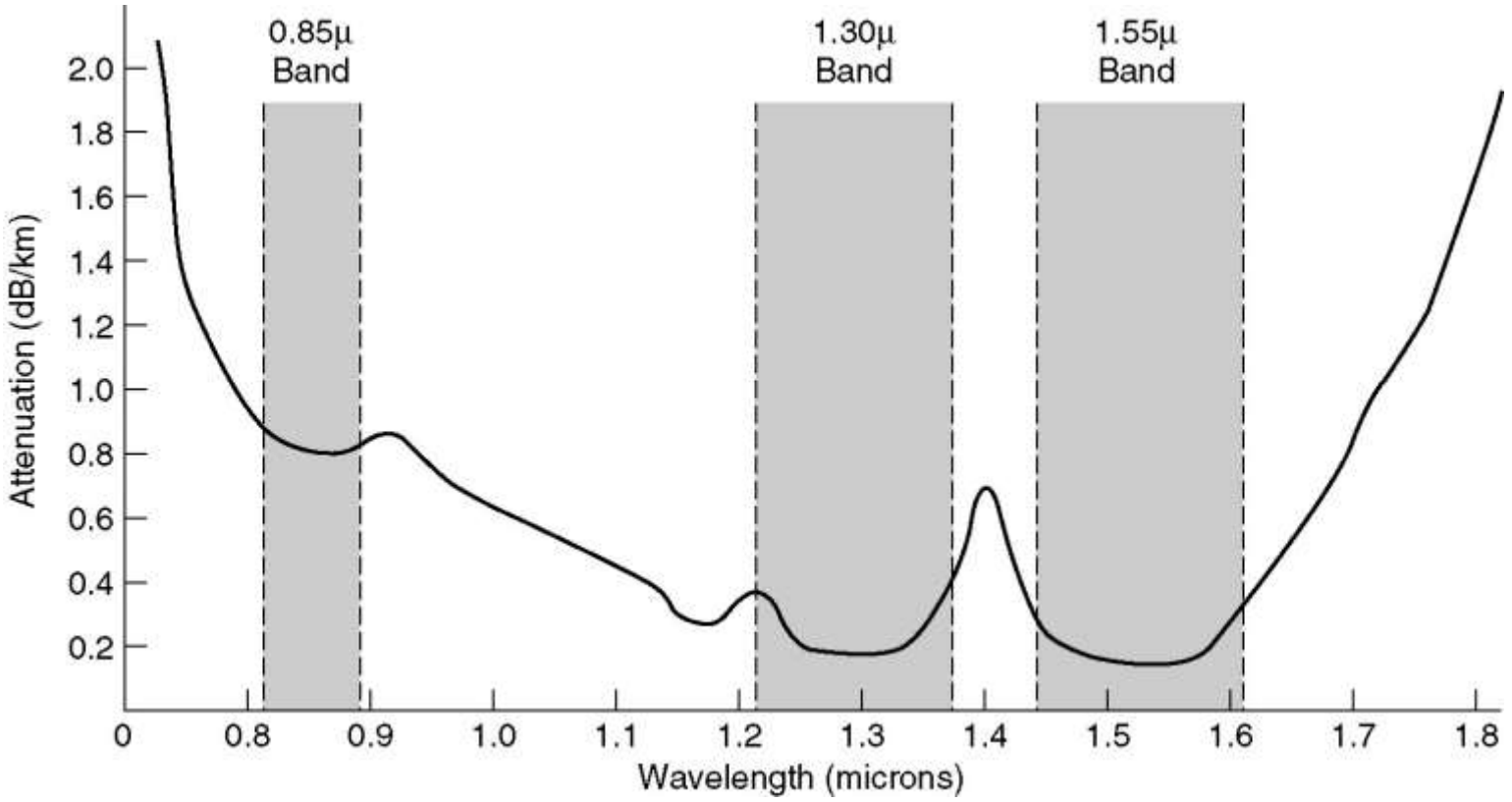
多模Multi-mode



- 比单模电缆核心更大
- 允许更大的散射，因此会导致信号丢失
- 适合长距离应用，但是比单模要短
- 使用 LED 作为光源
- 通常用于 LAN 或几百米距离的园区网

光纤接头

Transmission of Light through Fiber

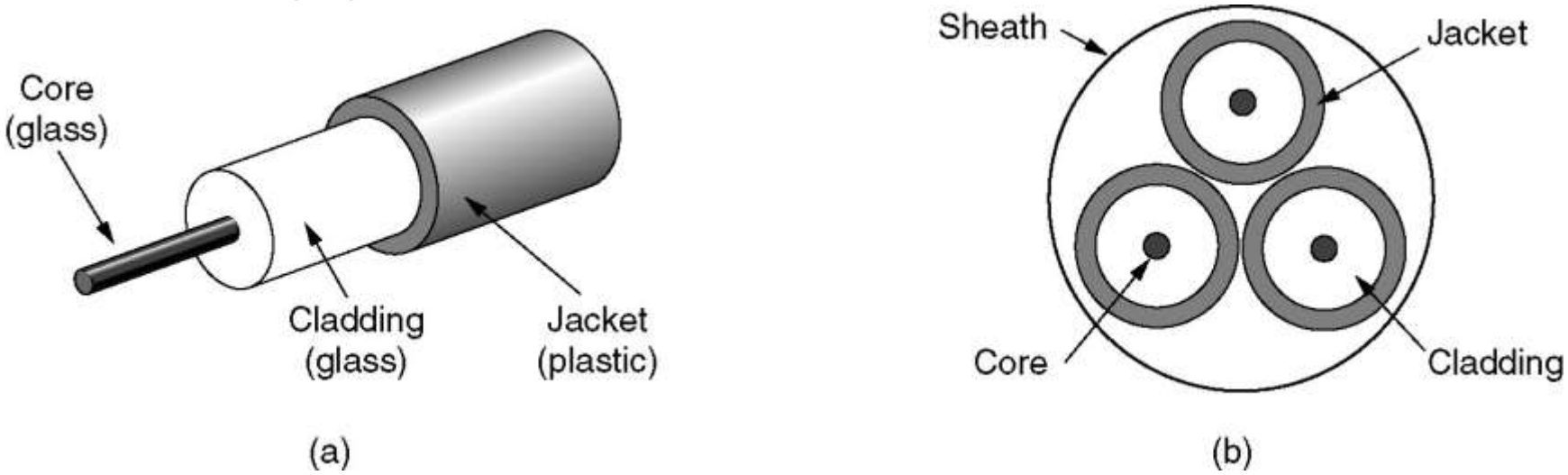


Attenuation of light through fiber in the infrared region.

Fiber Cables

(a) Side view of a single fiber.

(b) End view of a sheath with three



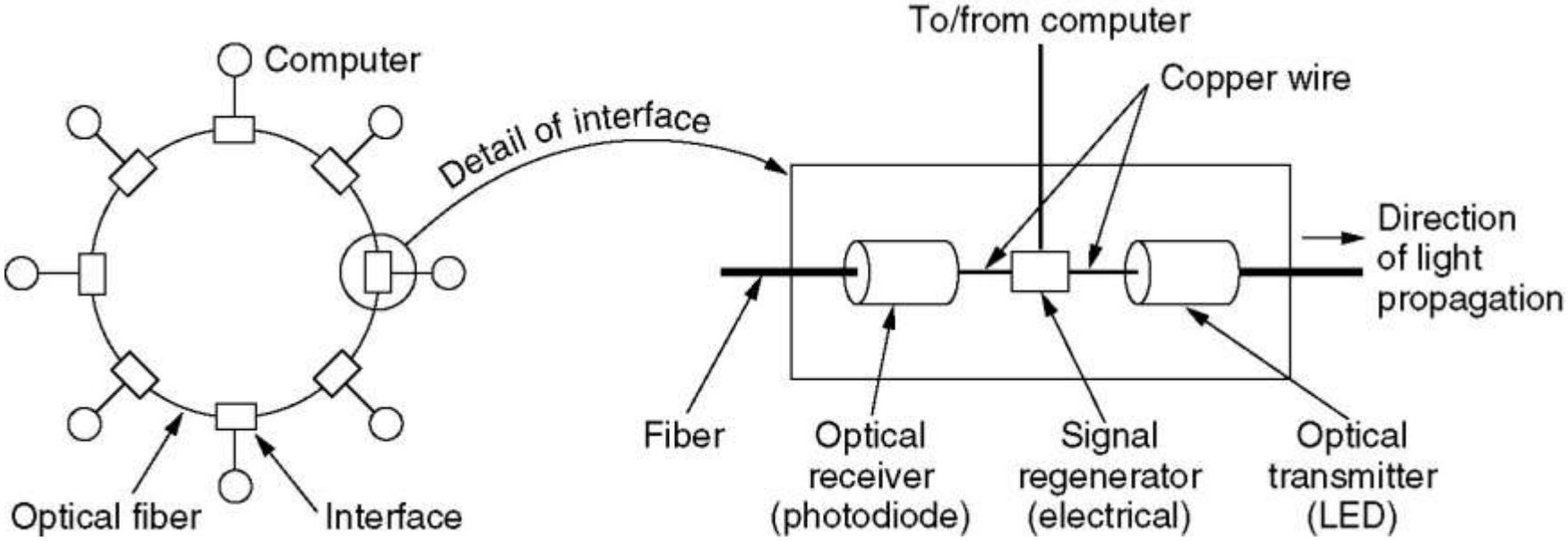
Fiber Cables (2)

A comparison of semiconductor diodes and LEDs as light sources.

Item	LED	Semiconductor laser
Data rate	Low	High
Fiber type	Multimode	Multimode or single mode
Distance	Short	Long
Lifetime	Long life	Short life
Temperature sensitivity	Minor	Substantial
Cost	Low cost	Expensive

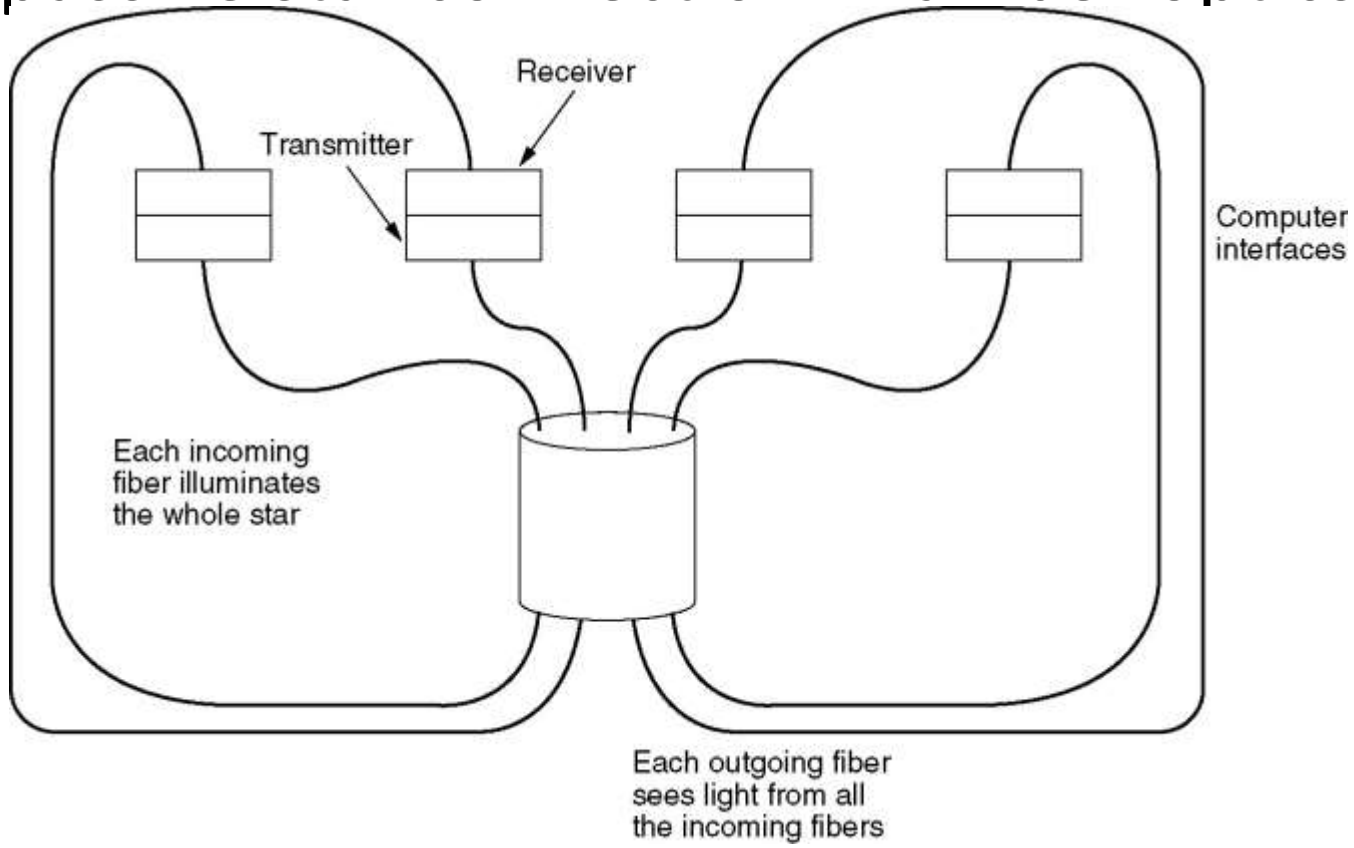
Fiber Optic Networks

A fiber optic ring with active repeaters.

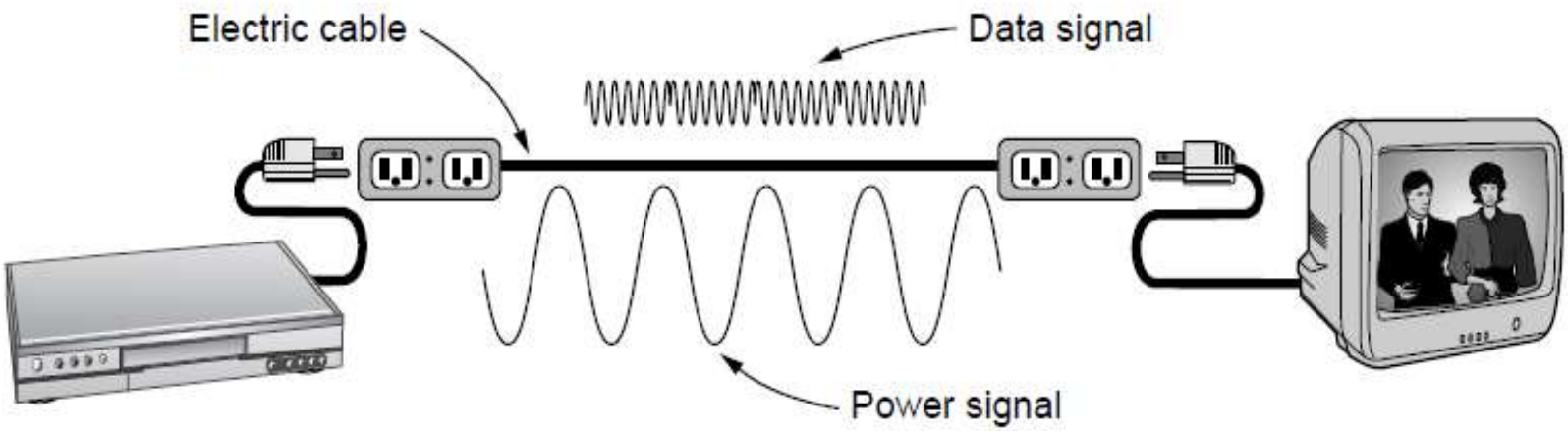


Fiber Optic Networks (2)

A passive star connection in a fiber optics



Power Lines

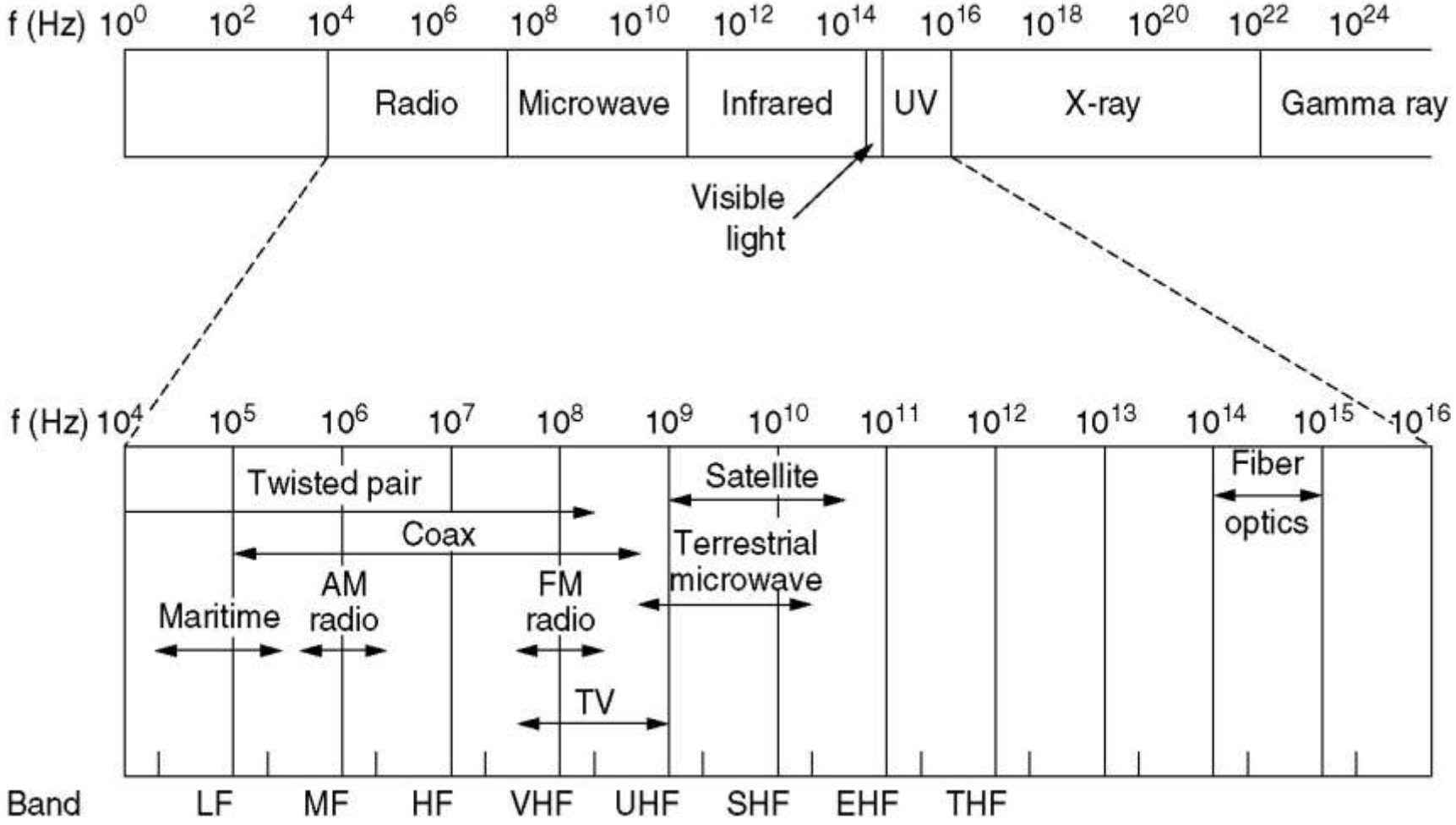


A network that uses household electrical wiring.

2.3 Wireless Transmission

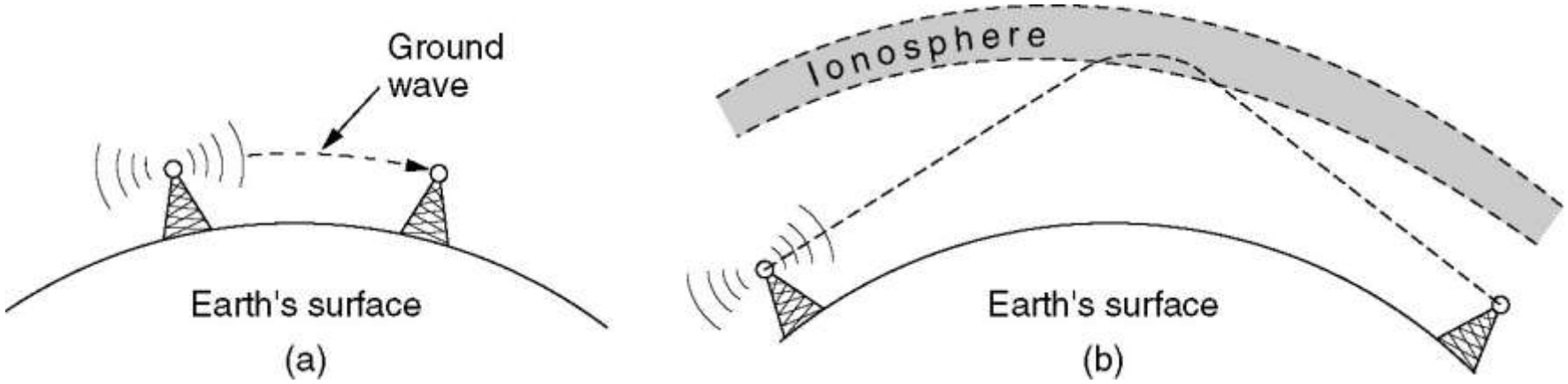
- The Electromagnetic Spectrum(电磁波谱)
- Radio Transmission(无线传输)
- Microwave Transmission(微波传输)
- Infrared and Millimeter Waves(红外线和毫米波)
- Lightwave Transmission (光波传输)

2.3.1 The Electromagnetic Spectrum



The electromagnetic spectrum and its uses for communication.

2.3.2 Radio Transmission



(a) In the VLF, LF, and MF bands, radio waves follow the curvature of the earth.

特点: 穿透力强, 但传输距离近

(b) In the HF band, they bounce off the ionosphere.

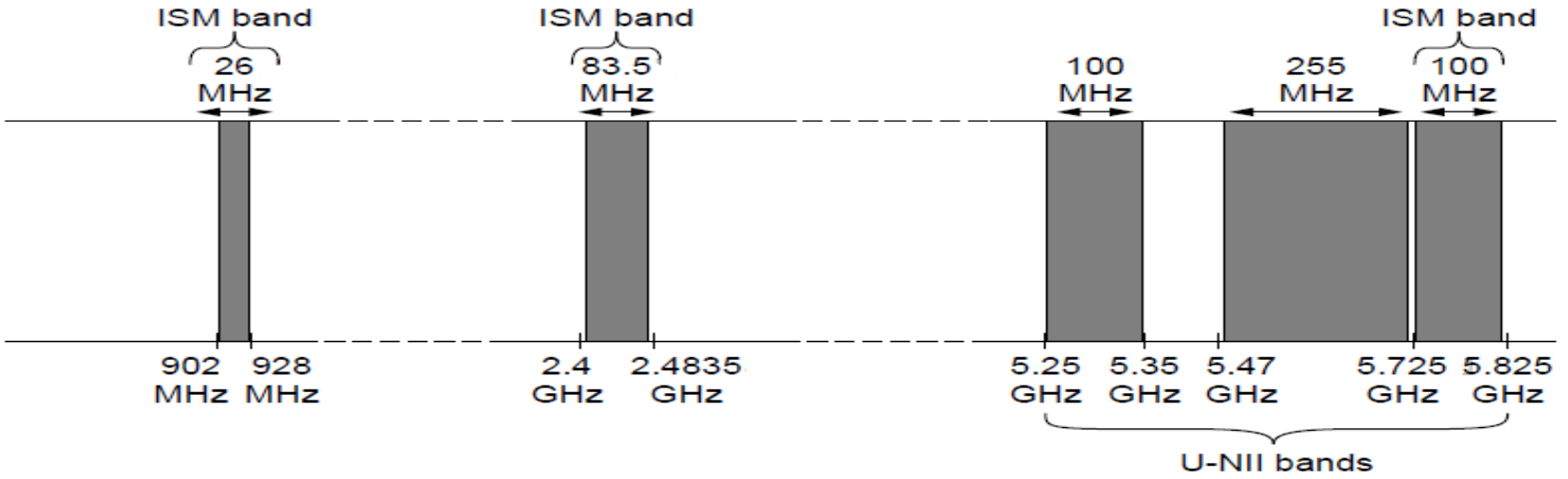
特点: 直线传输,遇到障碍物反射

2.3.3 Microwave Transmission

- 100MHz以上，直线传输，可集中于一点(方向性好)
- Inexpensive
- Problem at about 4GHz : absorption by water

- **MCI**(Microwave Communications, Inc), ←> **Sprint**
- WorldCom

Politics of the Electromagnetic Spectrum



The ISM bands in the United States.

(ISM:Industrial, Scientific, Medical)

900MHz band: works best, but crowded, not available

2.4GHz band: available, but interference from microwave ovens and radar installations

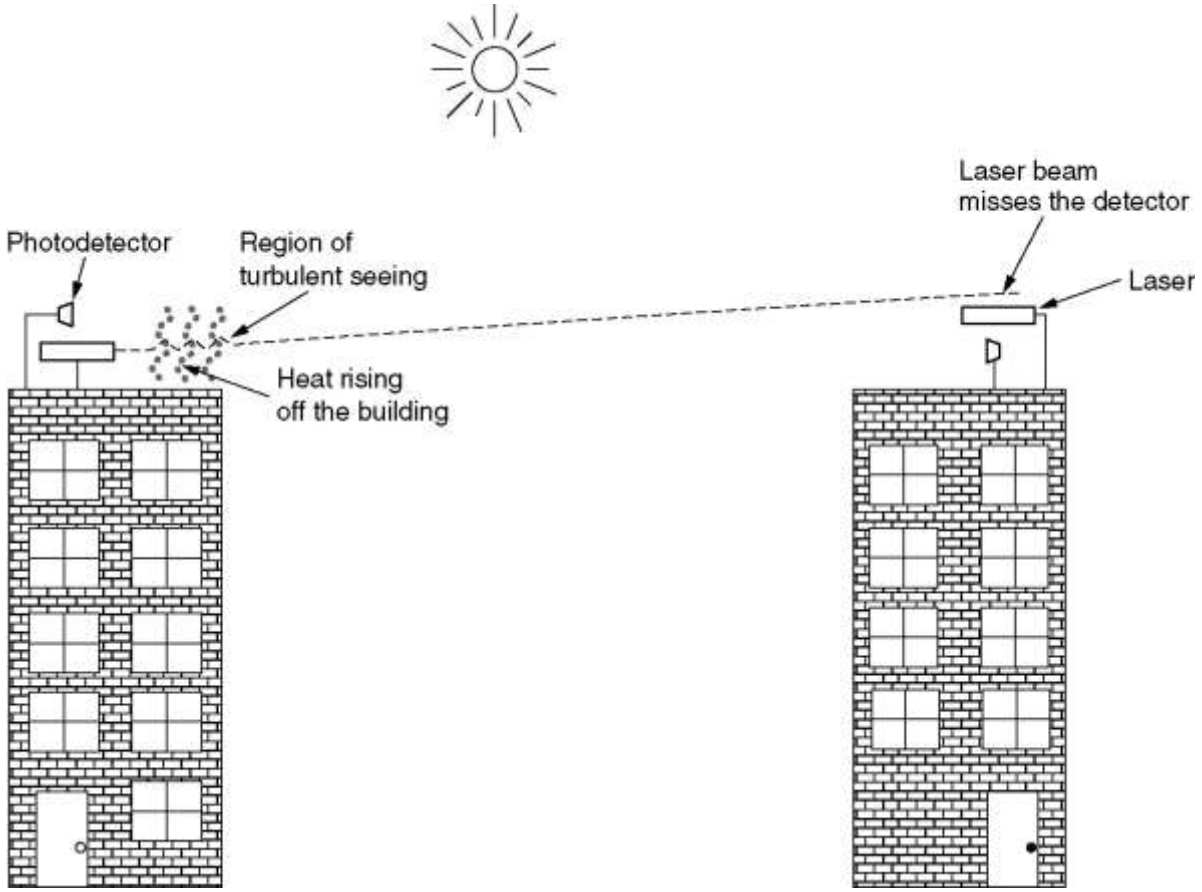
5.7GHz band: new and relatively undeveloped, equipment expensive, 802.11a

ITU-R ←不一致→ FCC(Federal Communication Commission)

2.3.4 Infrared and Millimeter Waves

- Short range communication
- Drawback: they do not pass through solid objects
  - 但同时也是优点

2.3.5 Lightwave Transmission



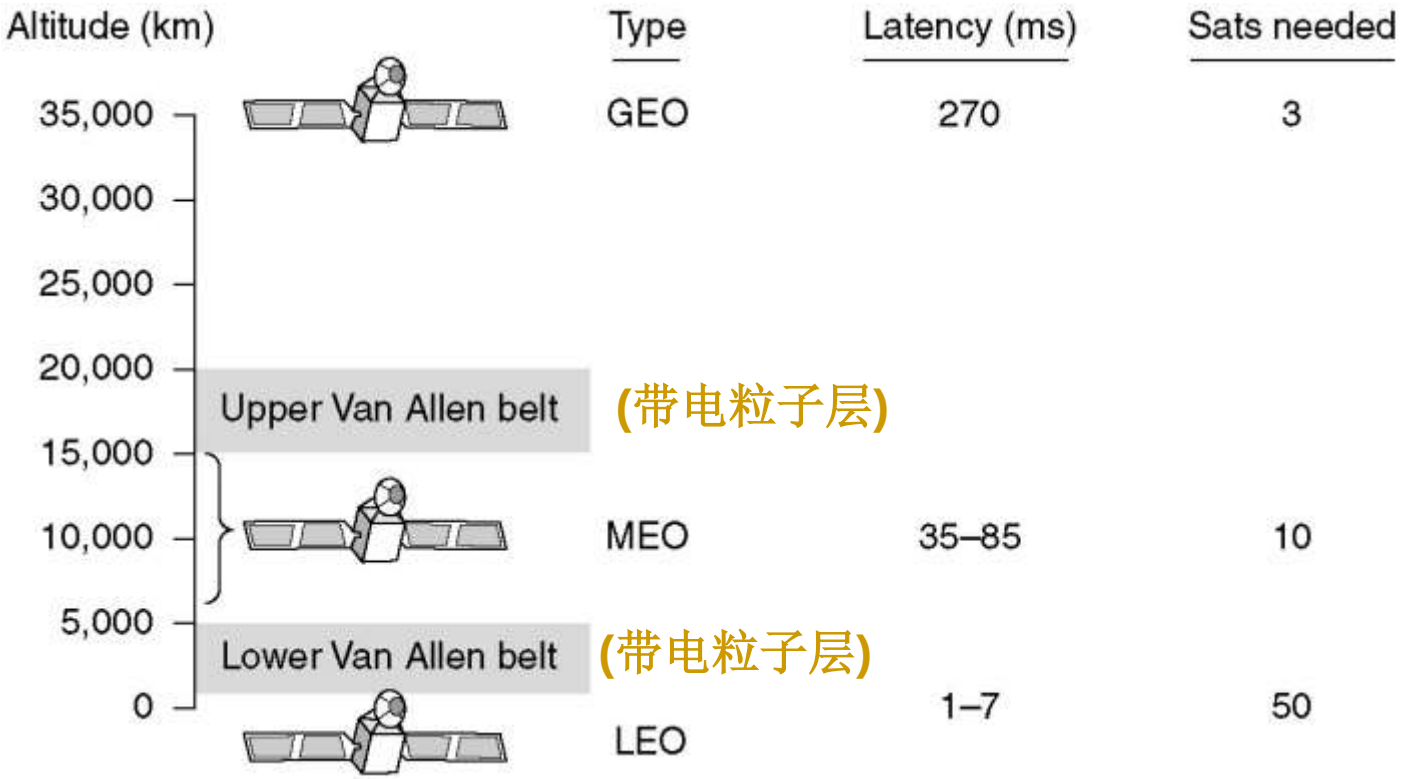
Convection currents can interfere with laser communication systems.

A bidirectional system with two lasers is pictured here.

2.4 Communication Satellites

- Geostationary Satellites(地球同步卫星)
- Medium-Earth Orbit Satellites (中轨道卫星)
- Low-Earth Orbit Satellites(低轨道卫星)
- Satellites versus Fiber(卫星与光纤的比较)

Communication Satellites



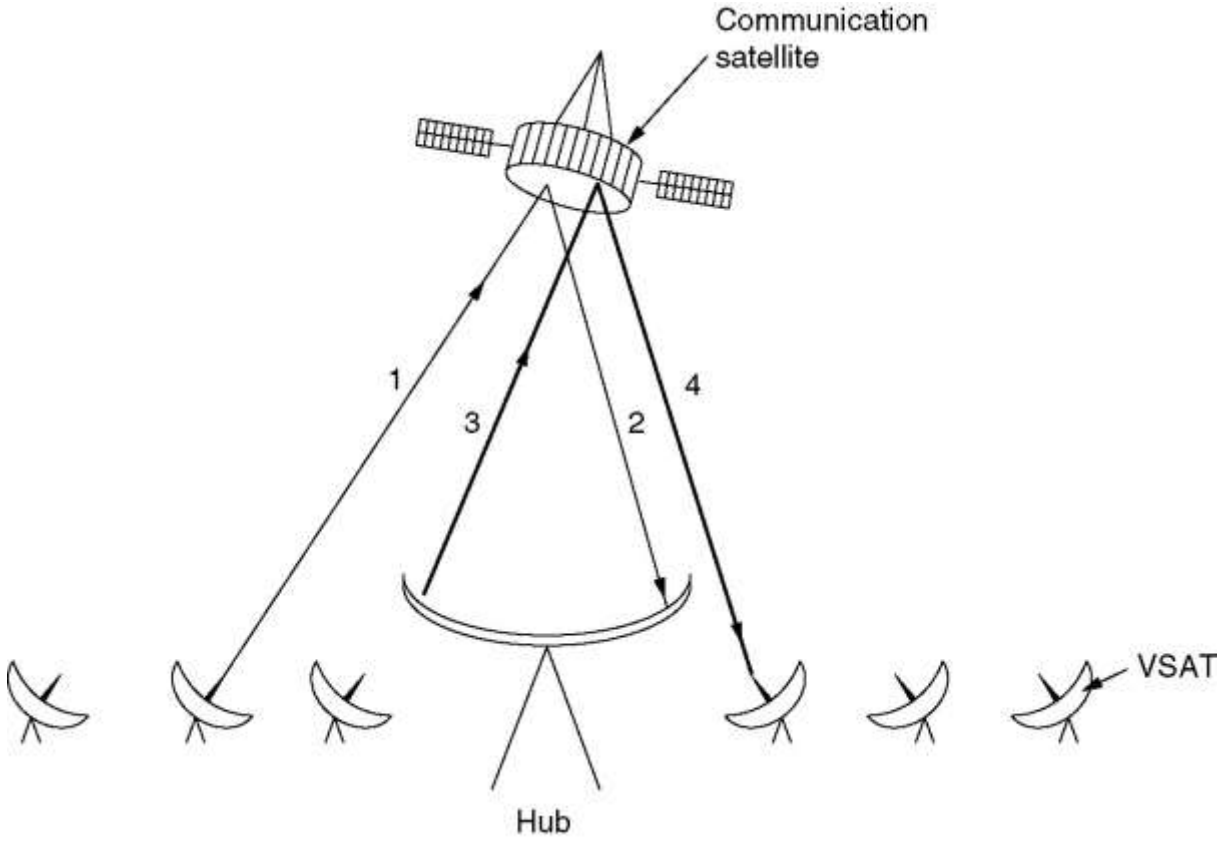
Communication satellites and some of their properties, including altitude above the earth, round-trip delay time and number of satellites needed for global coverage.

Communication Satellites (2)

Band	Downlink	Uplink	Bandwidth	Problems
L	1.5 GHz	1.6 GHz	15 MHz	Low bandwidth; crowded
S	1.9 GHz	2.2 GHz	70 MHz	Low bandwidth; crowded
C	4.0 GHz	6.0 GHz	500 MHz	Terrestrial interference
Ku	11 GHz	14 GHz	500 MHz	Rain
Ka	20 GHz	30 GHz	3500 MHz	Rain, equipment cost

The principal satellite bands.

Communication Satellites (3)



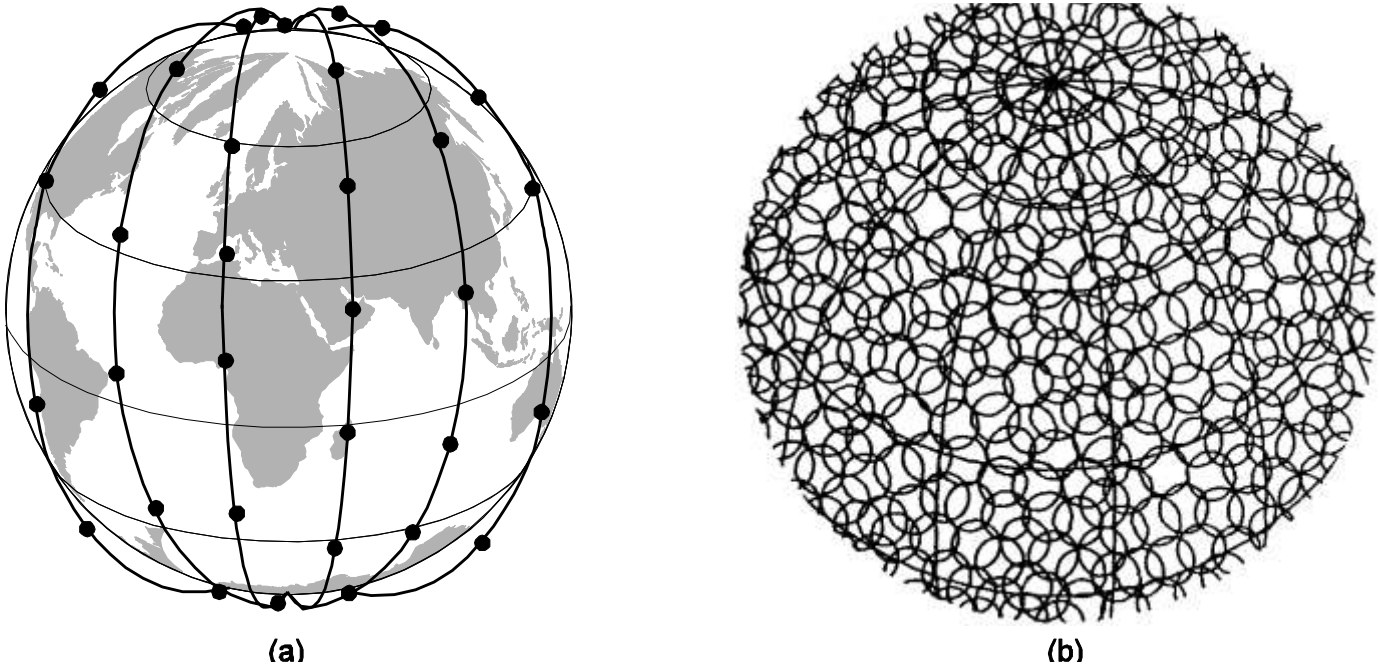
VSATs(小孔终端) using a hub.

2.4.2 Medium-Earth Orbit Satellites

Examples:

- 24 GPS(Global Positioning System,全球定位系统) satellites
  - Orbiting at about 18,000km

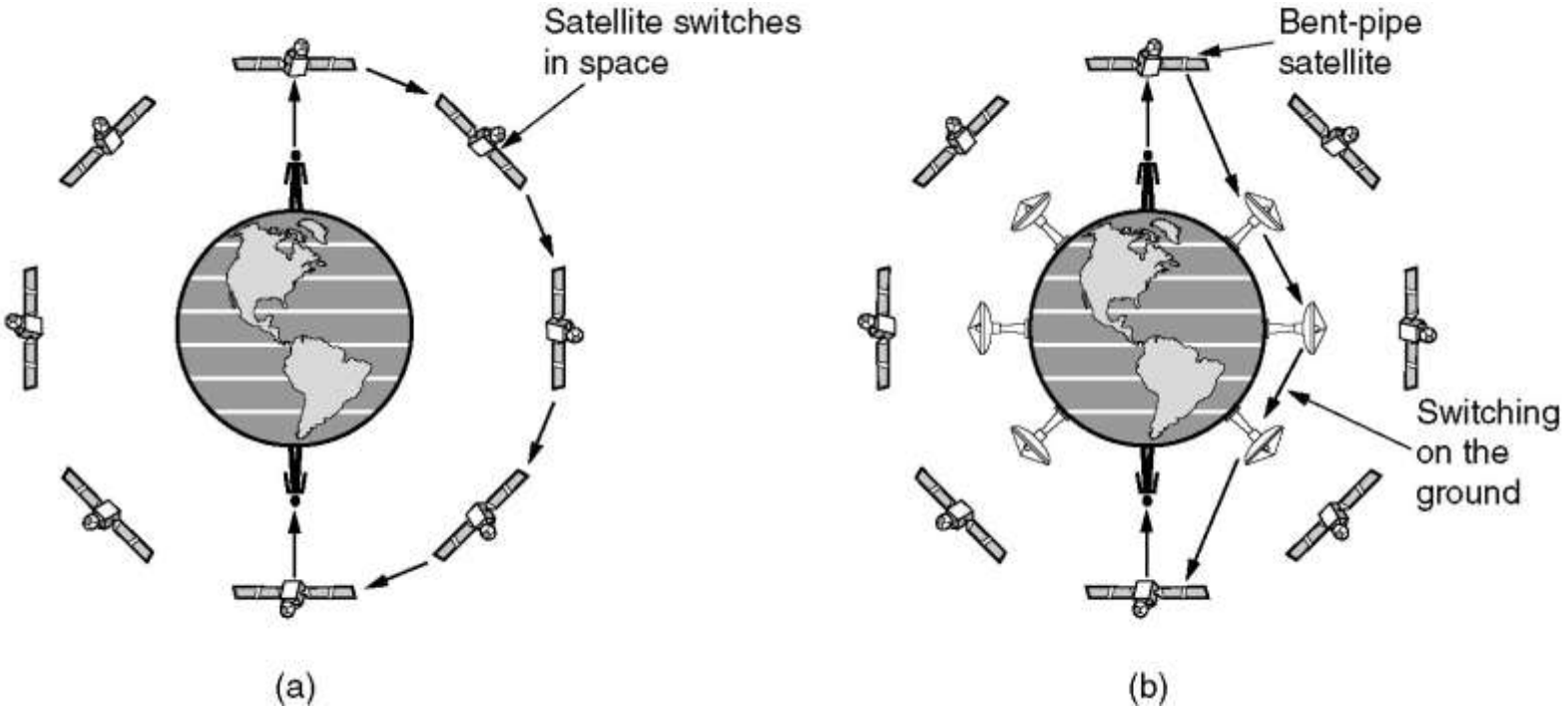
2.4.3 Low-Earth Orbit Satellites
Iridium



(a) The Iridium(铱77) satellites from six necklaces around the earth. [actually 66 satellites, so renamed Dysprosium (element 镝66)]

(b) 1628 moving cells cover the earth. (each satellite has a max of 48 cells)

Another example: Globalstar (47 LEO satellites)



(a) Relaying in space. (Used in **Iridium**)

(b) Relaying on the ground. (Used in **Globalstar**)

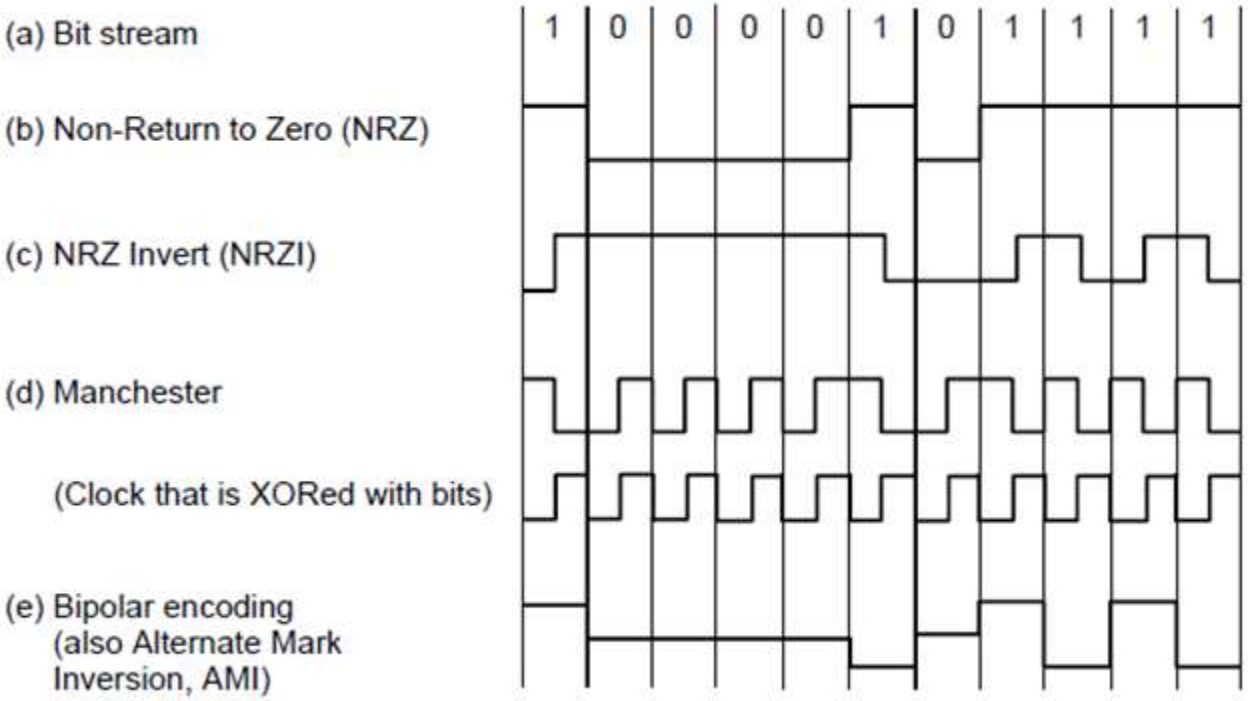
2.4.4 Satellites vs Fiber

- 卫星与光纤的比较
  - 带宽
  - 成本
  - 地域
- 卫星的市场
  - 移动通信
  - 广播
  - 恶劣环境的地方
  - 光纤无法铺设或太昂贵的地方
  - 快速展开需求的地方, 如战时

2.5 DIGITAL MODULATION AND MUTIPLEXING

- Baseband Transmission
- Passband Transmission
- Frequency Division Multiplexing
- Time Division Multiplexing
- Code Division Multiplexing

2.5.1Baseband Transmission



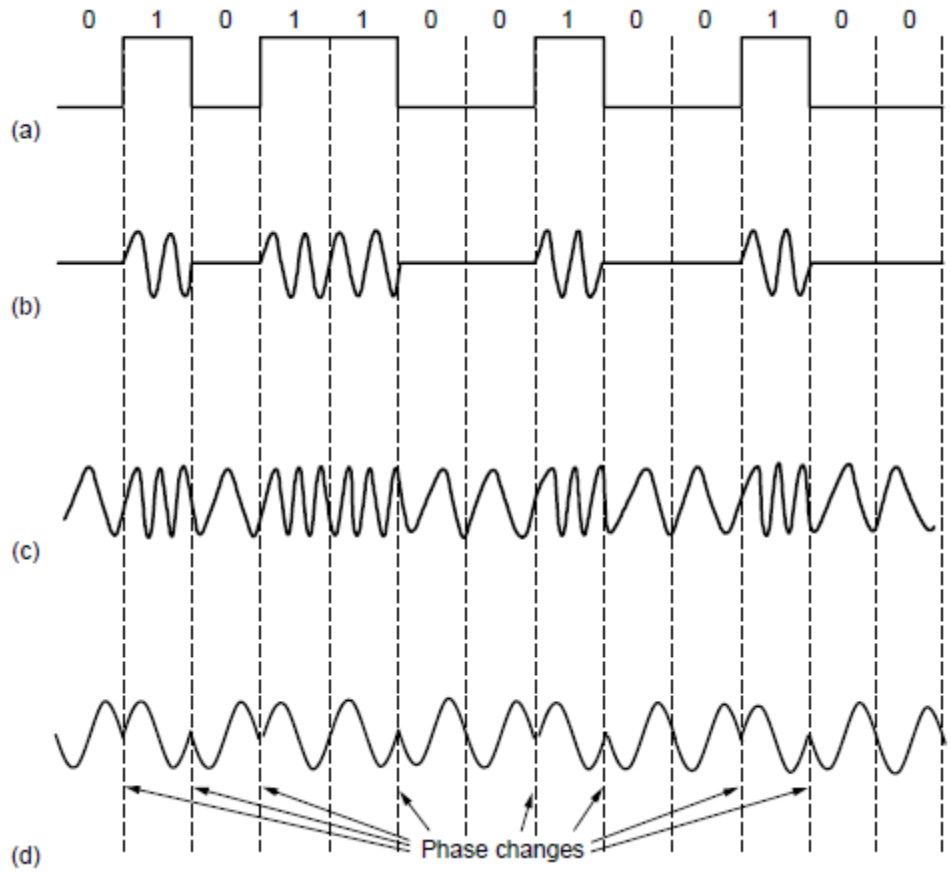
Line codes: (a) Bits, (b) NRZ, (c) NRZI, (d) Manchester, (e) Bipolar or AMI.

Clock Recovery

Data (4B)	Codeword (5B)	Data (4B)	Codeword (5B)
0000	11110	1000	10010
0001	01001	1001	10011
0010	10100	1010	10110
0011	10101	1011	10111
0100	01010	1100	11010
0101	01011	1101	11011
0110	01110	1110	11100
0111	01111	1111	11101

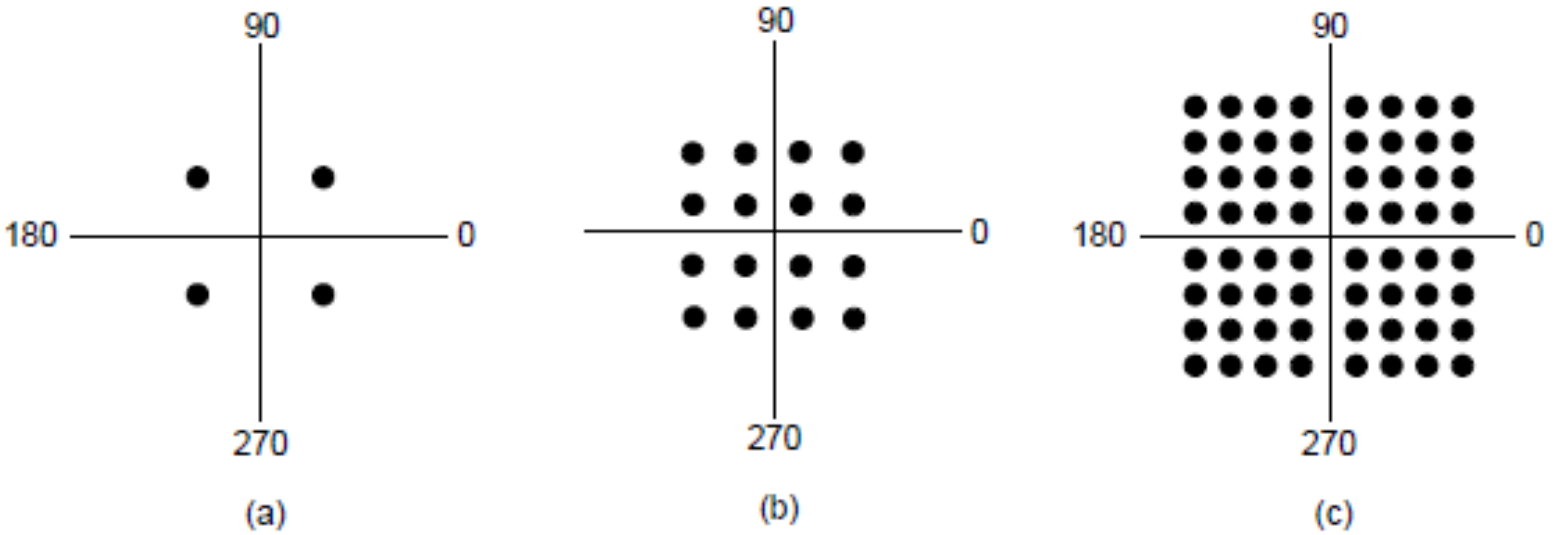
4B/5B mapping.

2.5.2Passband Transmission (1)



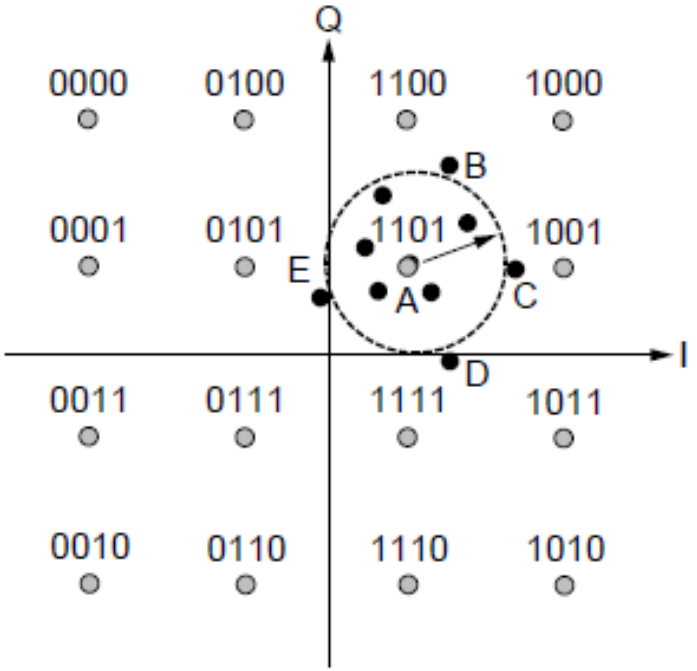
(a) A binary signal. (b) Amplitude shift keying. (c) Frequency shift keying. (d) Phase shift keying.

Passband Transmission (2)



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

2.5.3 Frequency Division Multiplexing (1)

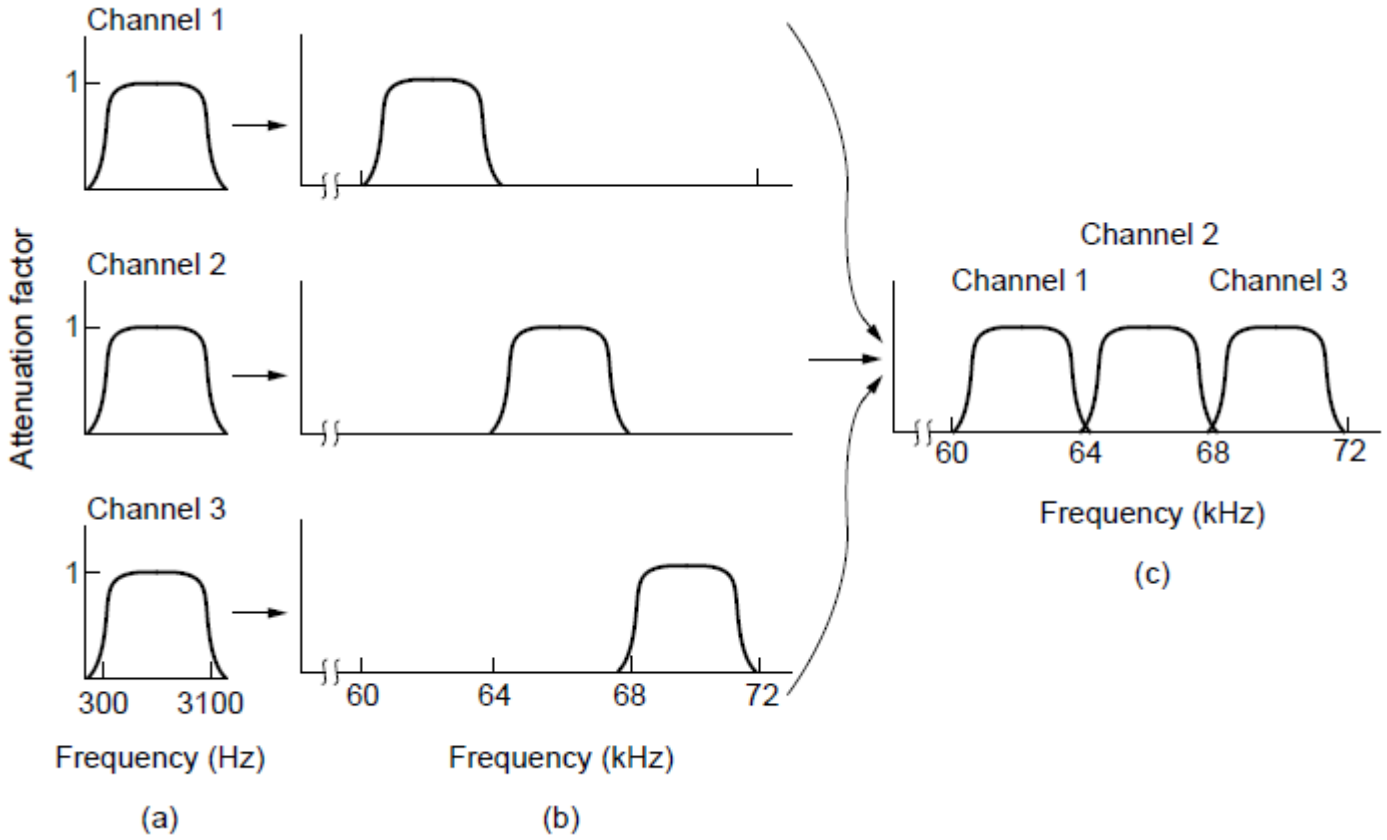


When 1101 is sent:

Point	Decodes as	Bit errors
A	1101	0
B	1100	1
C	1001	1
D	1111	1
E	0101	1

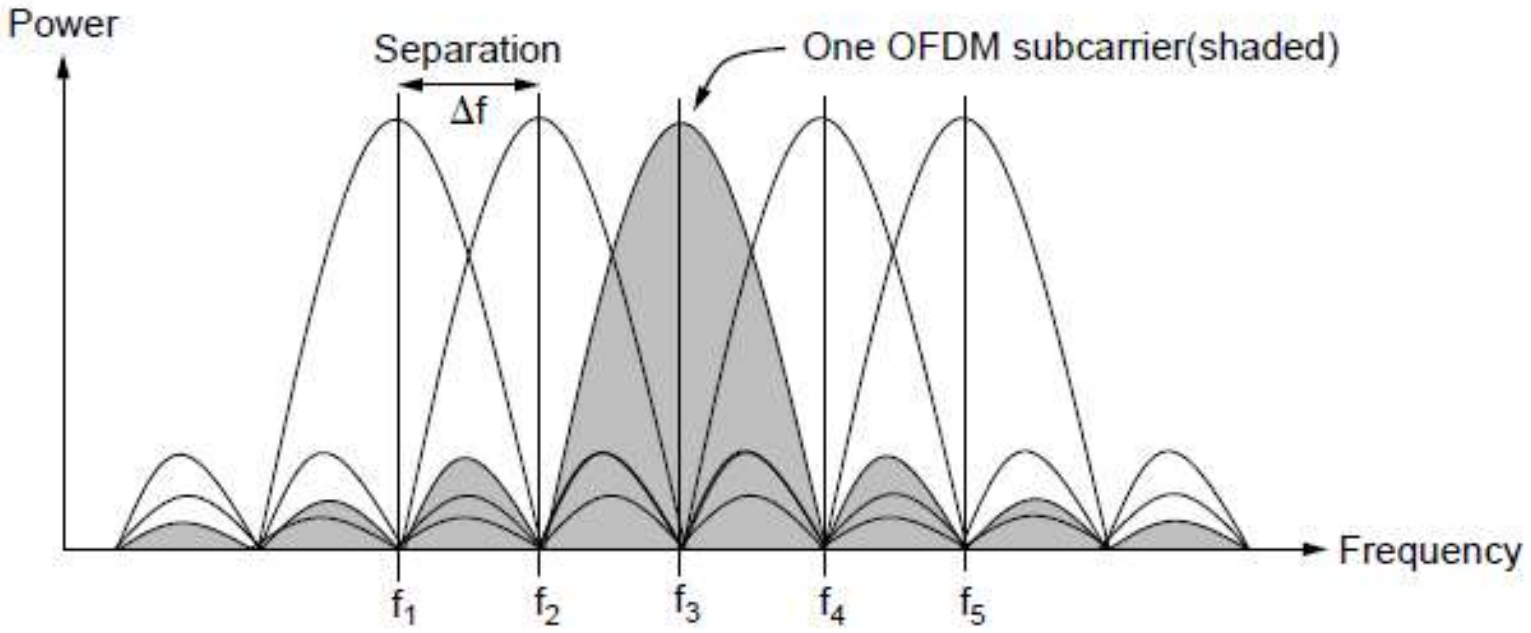
Gray-coded QAM-16.

Frequency Division Multiplexing (2)



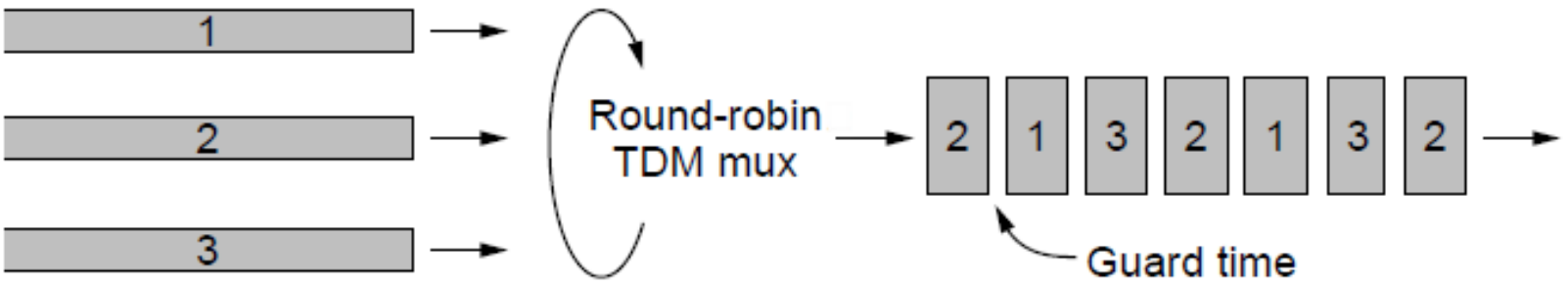
Frequency division multiplexing. (a) The original bandwidths. (b) The bandwidths raised in frequency. (c) The multiplexed channel.

Frequency Division Multiplexing (3)



Orthogonal frequency division multiplexing (OFDM).

2.5.4 Time Division Multiplexing

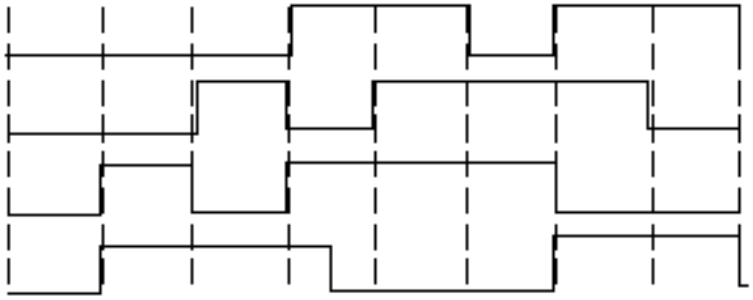


Time Division Multiplexing (TDM).

2.5.5 Code Division Multiplexing (1)

A = (–1 –1 –1 +1 +1 –1 +1 +1)
B = (–1 –1 +1 –1 +1 +1 +1 –1)
C = (–1 +1 –1 +1 +1 +1 –1 –1)
D = (–1 +1 –1 –1 –1 –1 +1 –1)

(a)



(b)

(a) Chip sequences for four stations.
(b) Signals the sequences represent

Code Division Multiplexing (2)

$S_1 = C = (-1 +1 -1 +1 +1 +1 -1 -1)$

$S_2 = B+C = (-2 \ 0 \ 0 \ 0 +2 +2 \ 0 -2)$

$S_3 = A+\overline{B} = (0 \ 0 -2 +2 \ 0 -2 \ 0 +2)$

$S_4 = A+\overline{B}+C = (-1 +1 -3 +3 +1 -1 -1 +1)$

$S_5 = A+B+C+D = (-4 \ 0 -2 \ 0 +2 \ 0 +2 -2)$

$S_6 = A+B+\overline{C}+D = (-2 -2 \ 0 -2 \ 0 -2 +4 \ 0)$

(c)

$S_1 \bullet C = [1+1-1+1+1+1-1-1]/8 = 1$

$S_2 \bullet C = [2+0+0+0+2+2+0+2]/8 = 1$

$S_3 \bullet C = [0+0+2+2+0-2+0-2]/8 = 0$

$S_4 \bullet C = [1+1+3+3+1-1+1-1]/8 = 1$

$S_5 \bullet C = [4+0+2+0+2+0-2+2]/8 = 1$

$S_6 \bullet C = [2-2+0-2+0-2-4+0]/8 = -1$

(d)

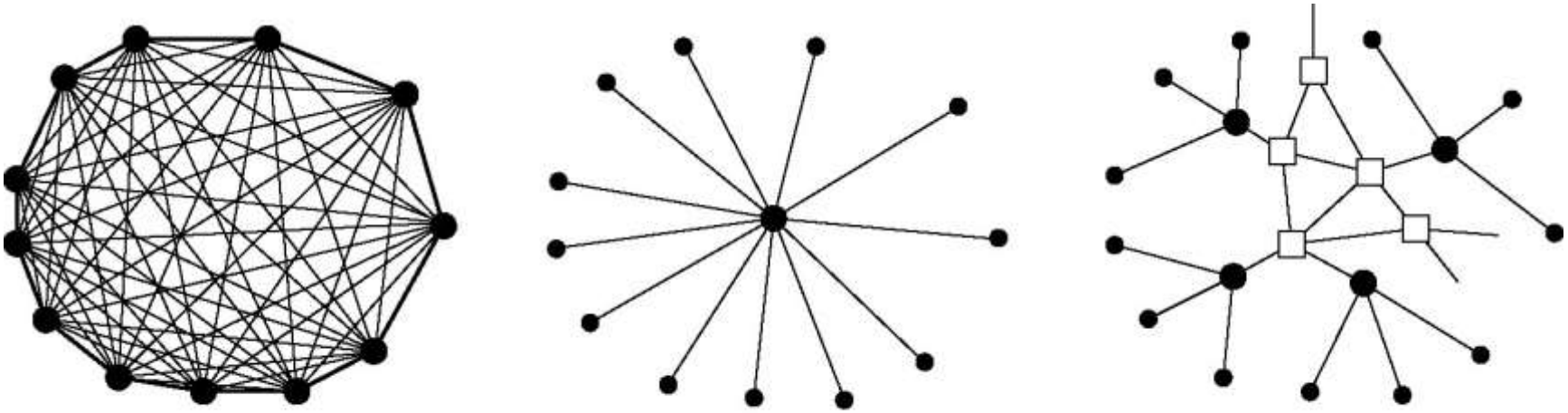
(a) Six examples of transmissions.

(b) Recovery of station C's

2.6 Public Switched Telephone System

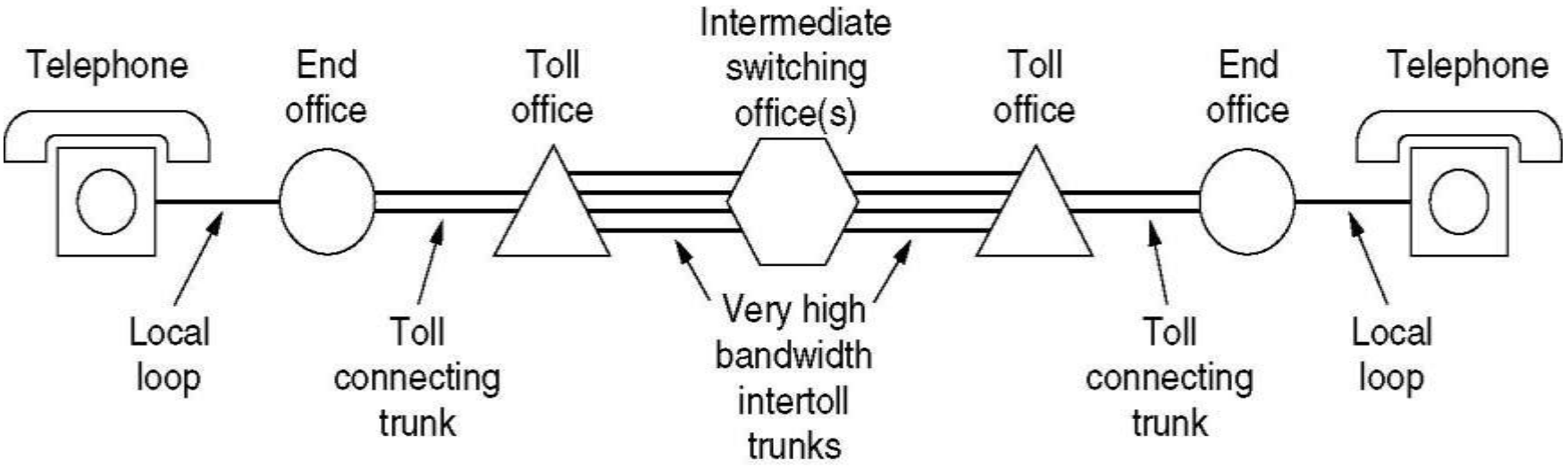
- **PSTN**(Public Switched Telephone Network,公用电话交换网)
- Structure of the Telephone System(电话系统的结构)
- The Politics of Telephones(电话的政治学)
- The Local Loop(本地回路): Modems, ADSL and Wireless
- Trunks and Multiplexing(主干和多路复用)
- Switching(交换)

2.6.1 Structure of the Telephone System



(a) Fully-interconnected network.
(b) Centralized switch.
(c) Two-level hierarchy.

Structure of the Telephone System (2)



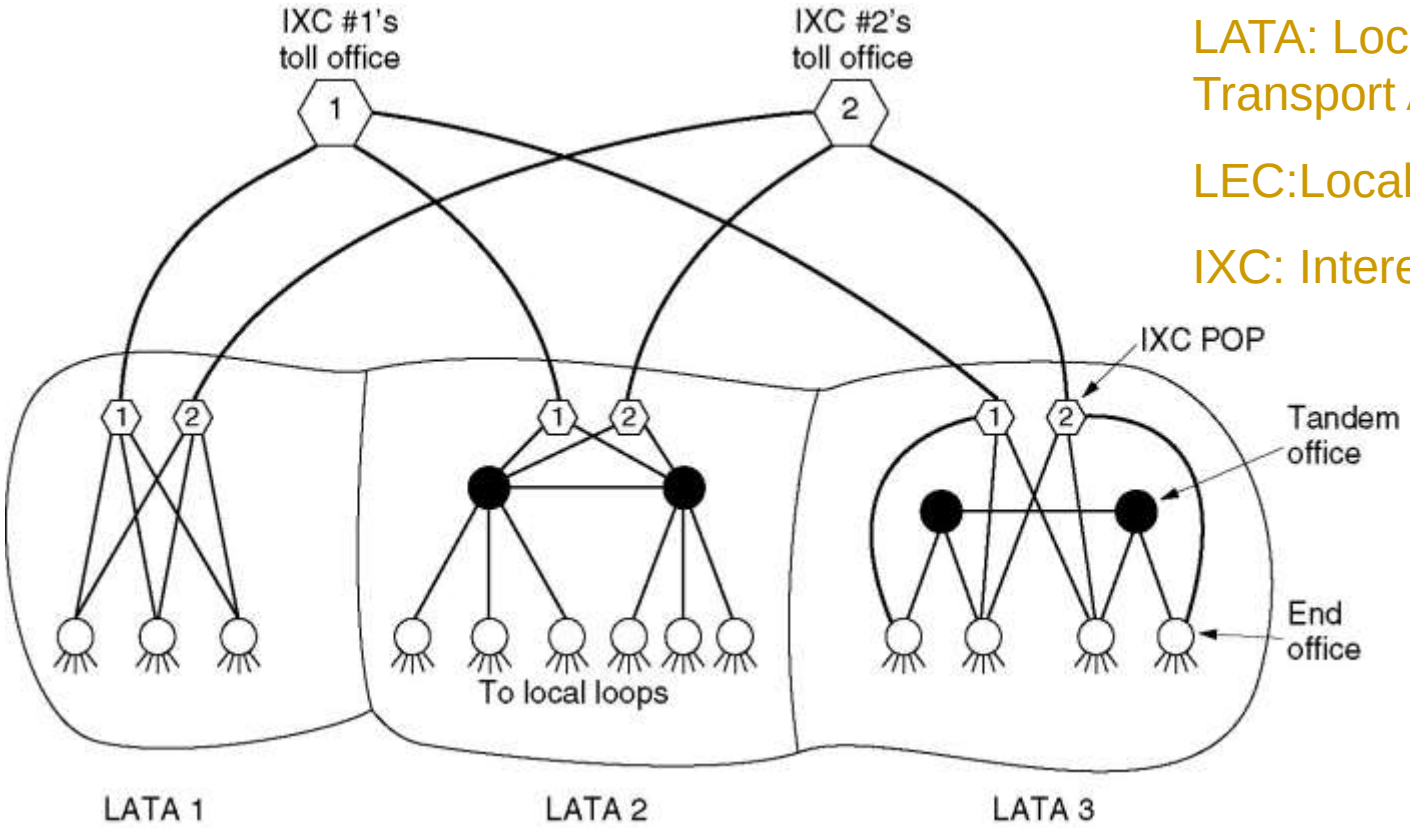
A typical circuit route for a medium-distance call.

- End office(端局)、 Toll office(长途局) Tandem office(汇接局) **Intermediate switching office(中心交换局)**、Toll connecting trunk(准长途干线)
- **电话系统的组成：**本地回路、干线、交换局

Major Components of the Telephone System

- Local loops
  - Analog twisted pairs going to houses and businesses
- Trunks
  - Digital fiber optics connecting the switching offices
- Switching offices
  - Where calls are moved from one trunk to another

2.6.2 The Politics of Telephones



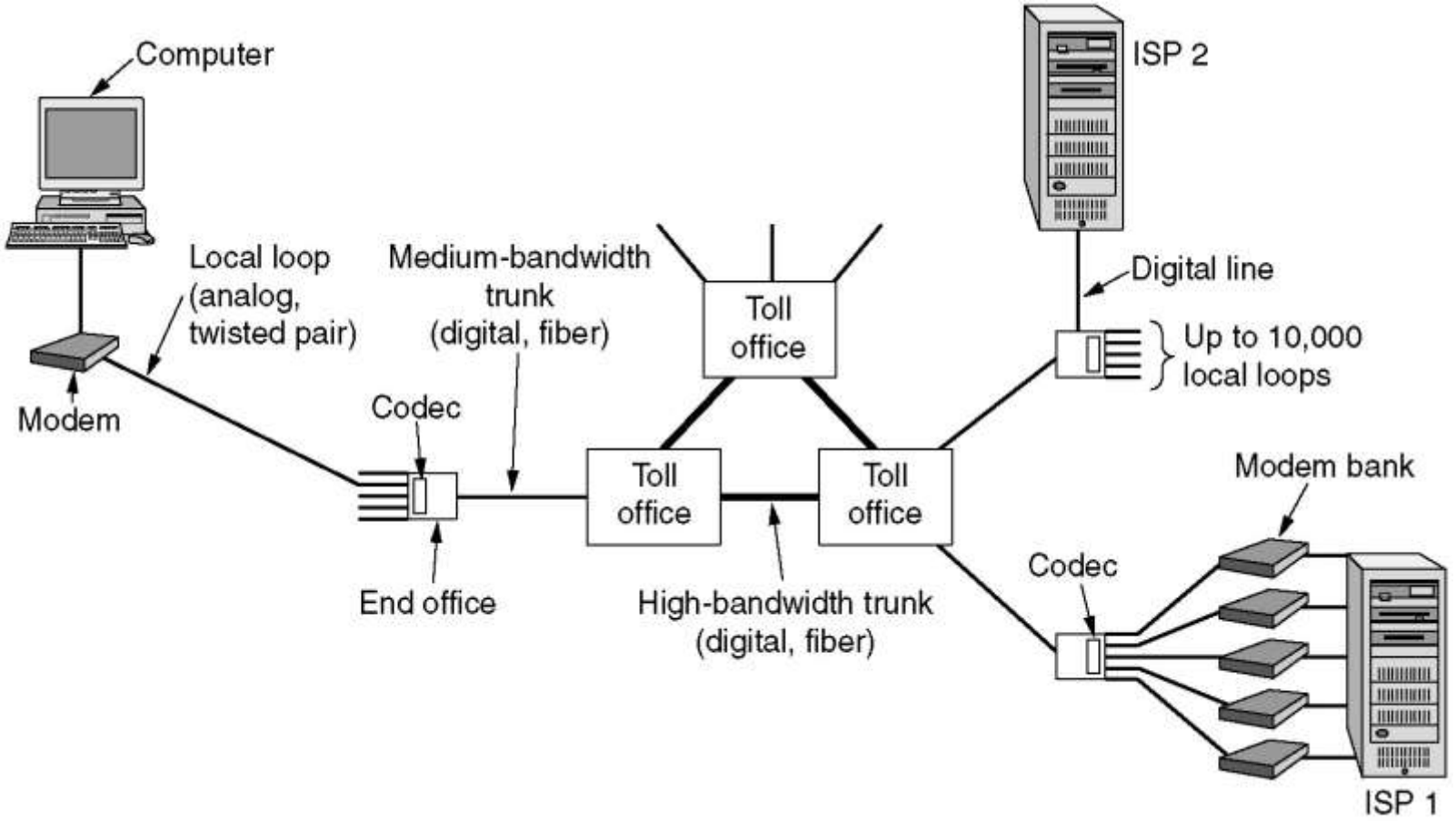
LATA: Local Access and Transport Areas

LEC:Local Exchange Carrier

IXC: IntereXchange Carrier

The relationship of LATAs, LECs, and IXCs. All the circles are LEC switching offices. Each hexagon belongs to the IXC whose number is on it.

2.6.3 The Local Loop: Modems, ADSL, and Wireless



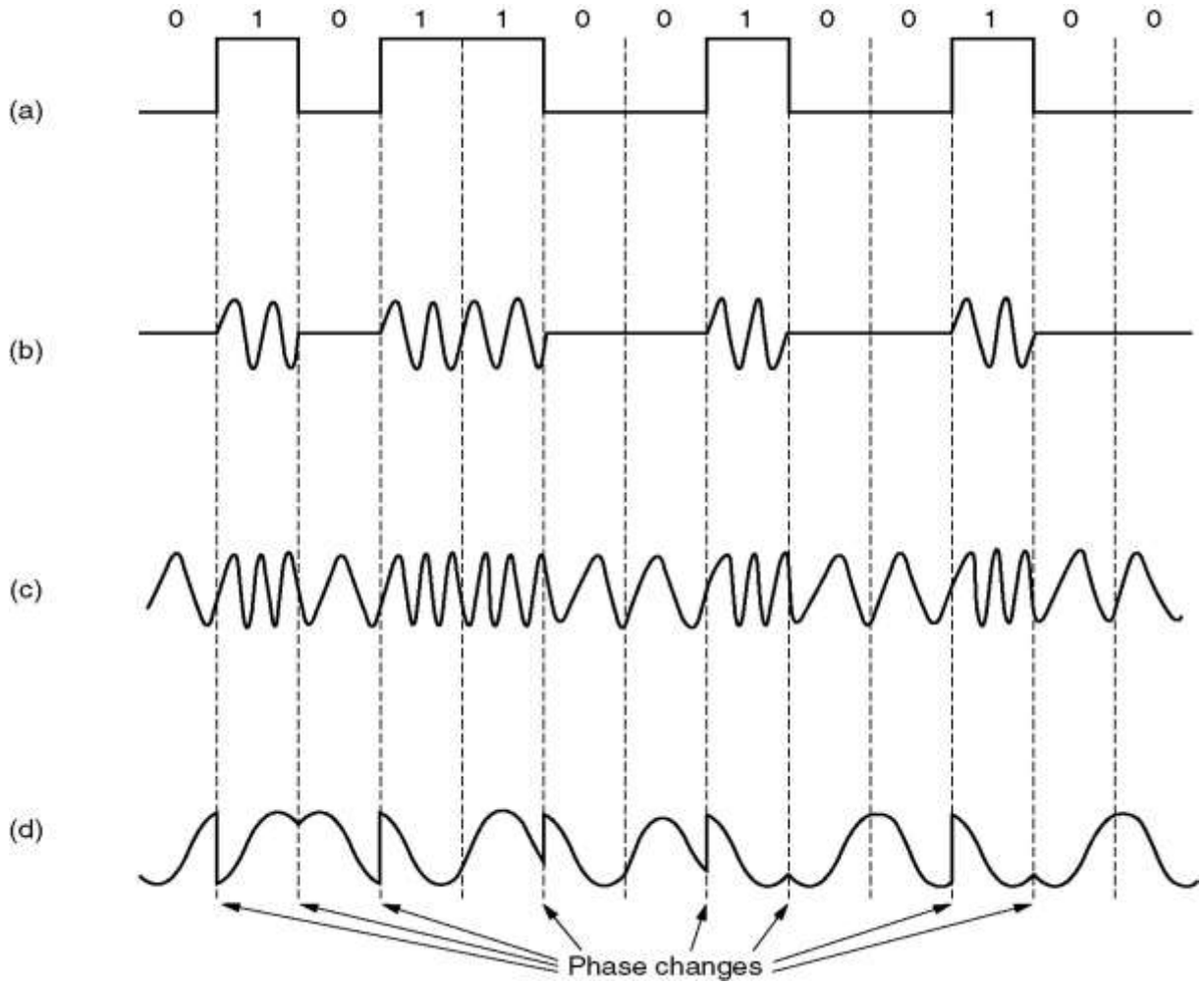
The use of both analog and digital transmissions for a computer to computer call. Conversion is done by the modems and codecs.

Modems

本地回路

- 计算机-(M)-模拟-解调-数字(干线)-解调-模拟-(M)-计算机
- （模拟的）传输损害
  - 衰减、延迟变形、噪音

Modems(1)



(a) A binary signal

(b) **Amplitude** modulation(调幅)

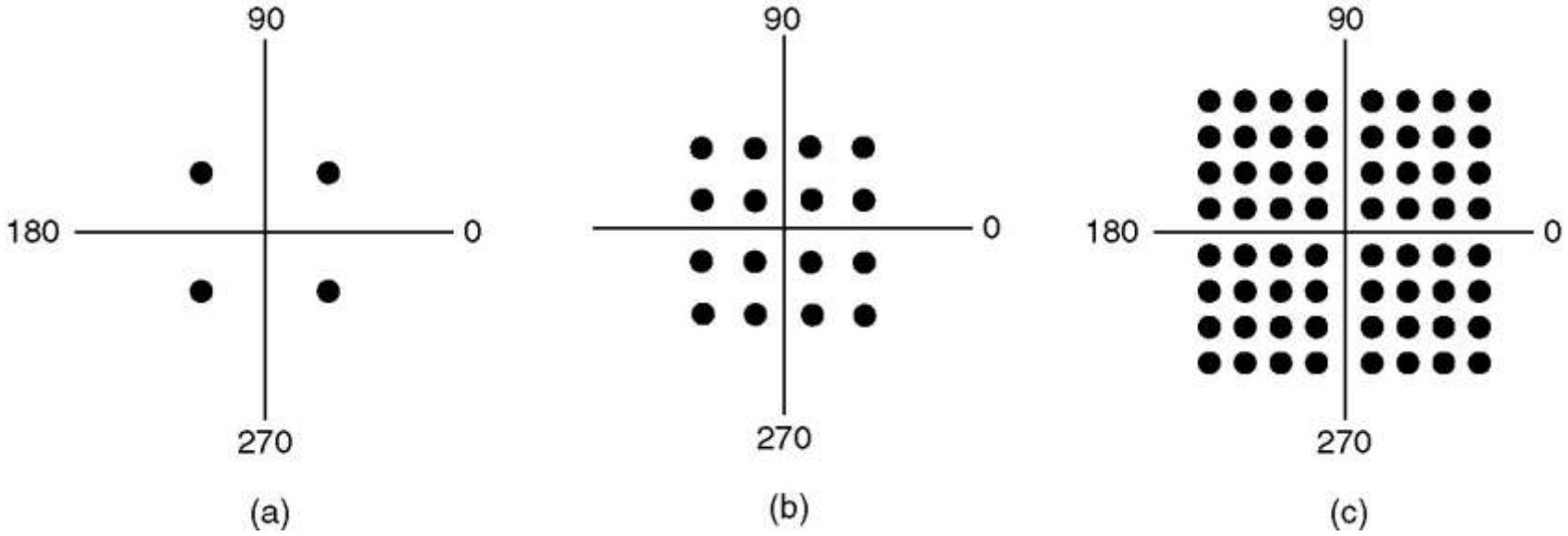
(c) **Frequency** modulation(调频)

(d) **Phase** modulation(调相)

Modems(2)

- **Baud** – the number of samples per second
- 2400-baud => 416.667 usec/symbol
- If the symbol consists of 0v for 0 and 1v for 1, the bit rate is 2400 bps
- If the voltages 0,1,2, and 3 volts are used, every symbol consists of 2 bits, so a 2400-baud line can transmit 2400 symbol/sec at a data rate of 4800 bps
- Similarly, with four possible phase shifts, there are also 2 bits/symbol, so again the bit rate is twice the baud rate ➔widely used and called **QPSK** (Quadrature Phase Shift Keying,正交相移键控)

Modems (3)

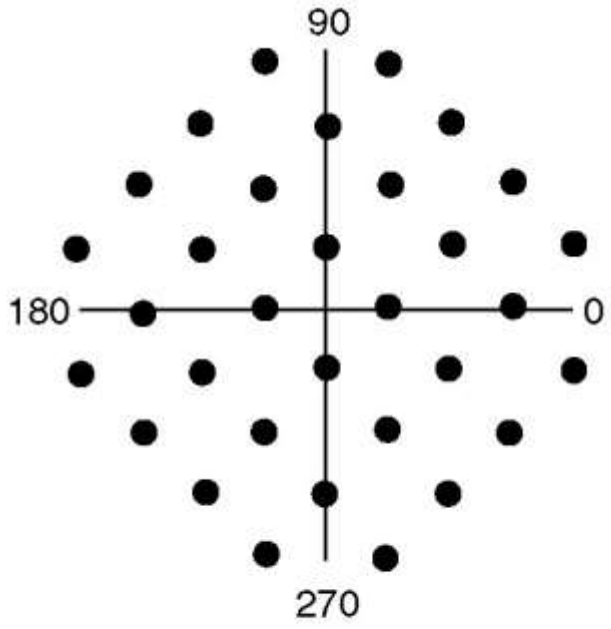


(a) QPSK (Quadrature Phase Shift Keying,正交相移键控)
--2 bits/symbol

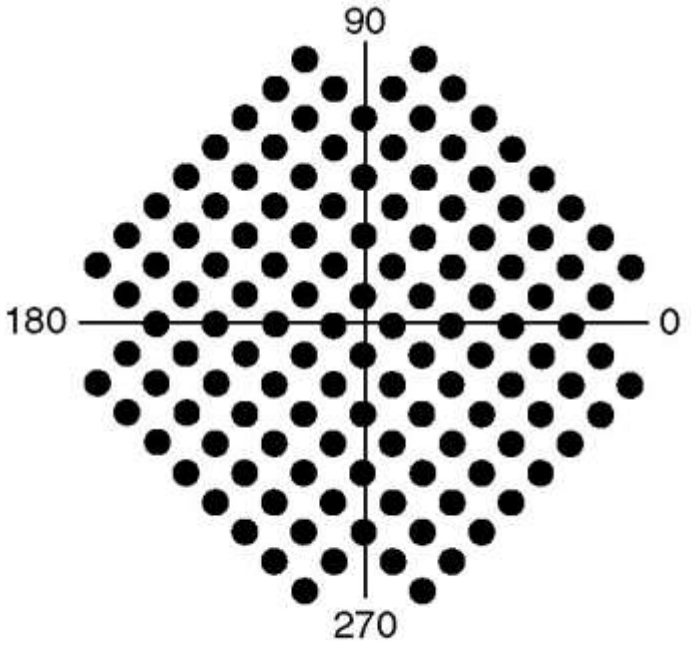
(b) QAM-16.(Quadrature Amplitude Modulation, 正交振幅调制)
--4 bits/symbol

(c) QAM-64. --6 bits/symbol

Modems (4)



(a)



(b)

TCM(Trellis Code Modulation)

(a) V.32 for 9600 bps. --5 bits/symbol(4data bits, 1 parity bit)

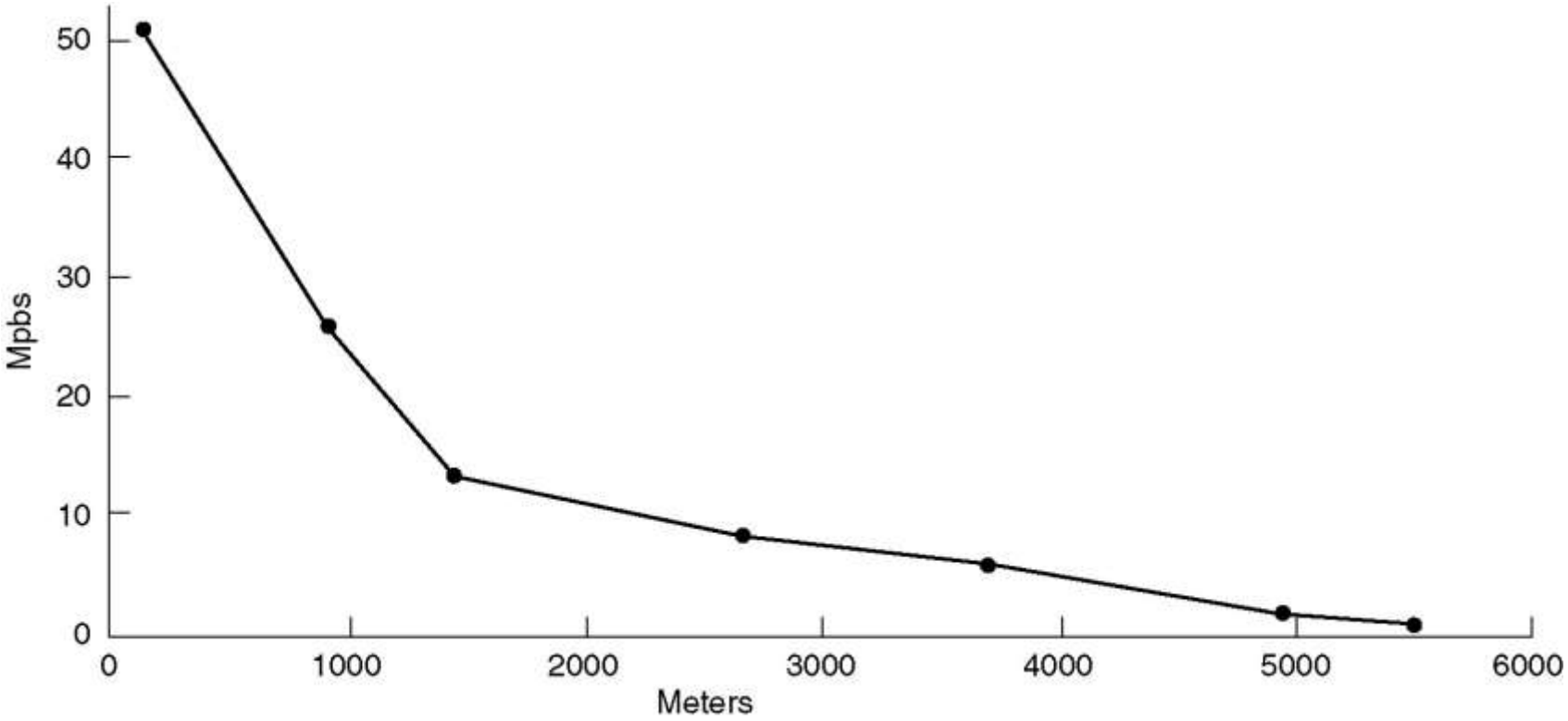
(b) V32 bis for 14,400 bps. --7 bits/symbol(6data bits, 1 parity bit)

Modems (5)

- V.90 for 33.6kbps
- V.92 for 48kbps
- 56kbps (the reason for choosing this speed?)

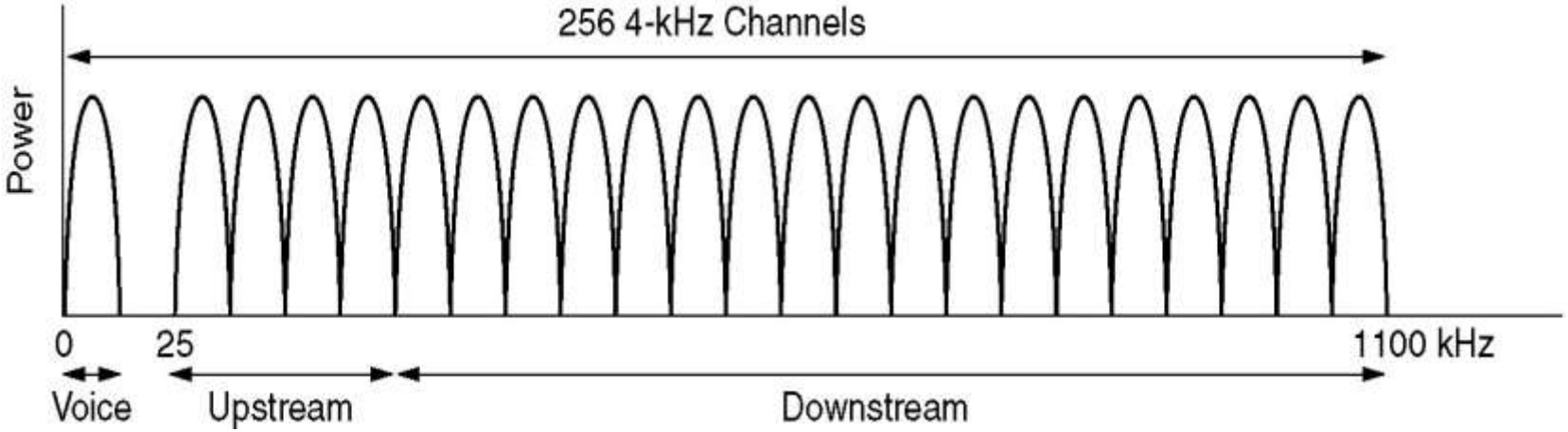
- Full duplex
- Half duplex
- Simplex

Digital Subscriber Lines



Bandwidth versus distanced over category 3 UTP for DSL.

Digital Subscriber Lines (2)



Operation of ADSL using DMT (Discrete MultiTone) modulation.

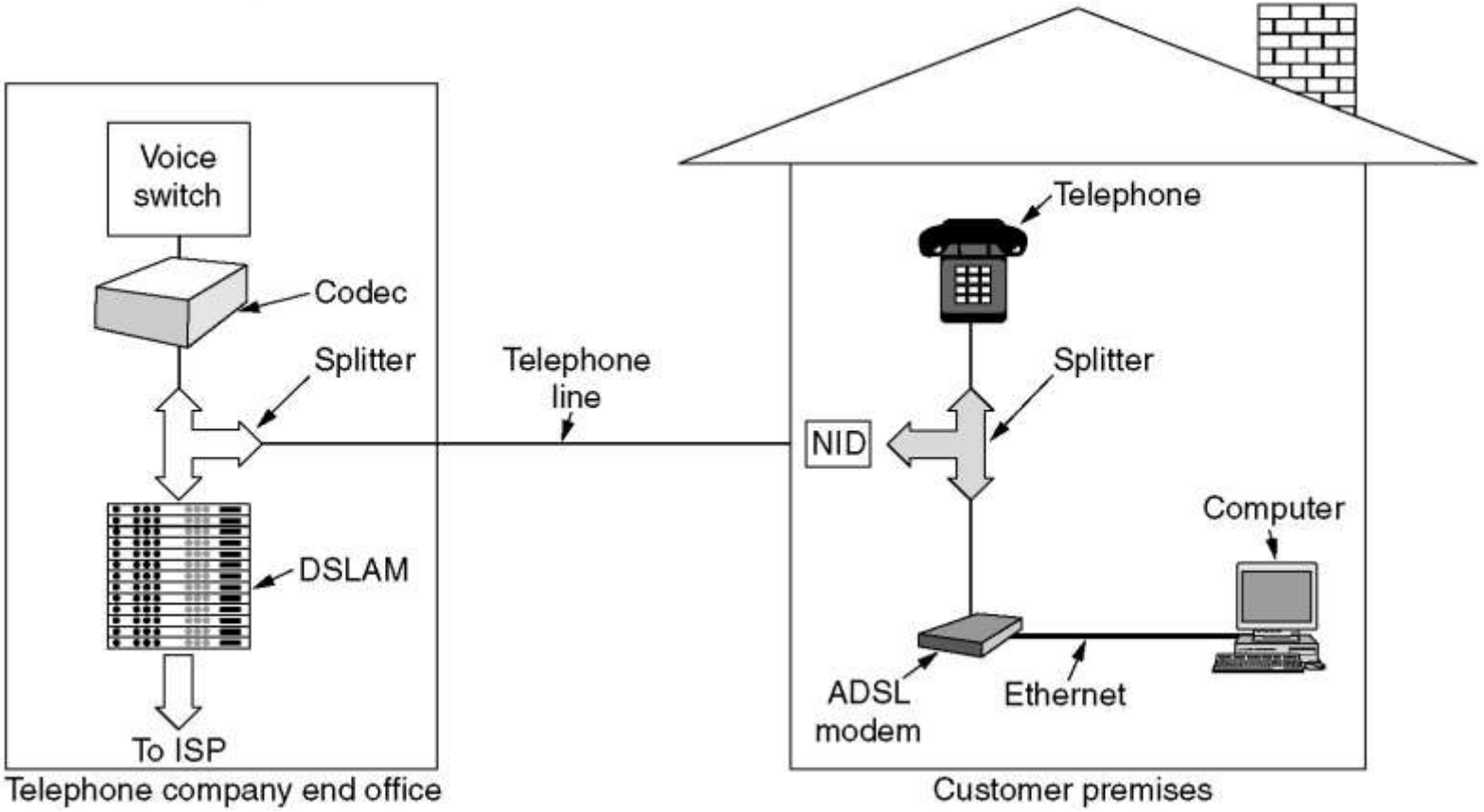
3 frequency bands:

- **POTS**(Plain Old Telephone Service)
- **Upstream**(user to end office)
- **Downstream**(end office to user)

Digital Subscriber Lines (3)

- ADSL standard:
  - ANSI T.1413, ITU G.992.1
  - 8Mbps Downstream
  - 1Mbps Upstream

Digital Subscriber Lines (4)



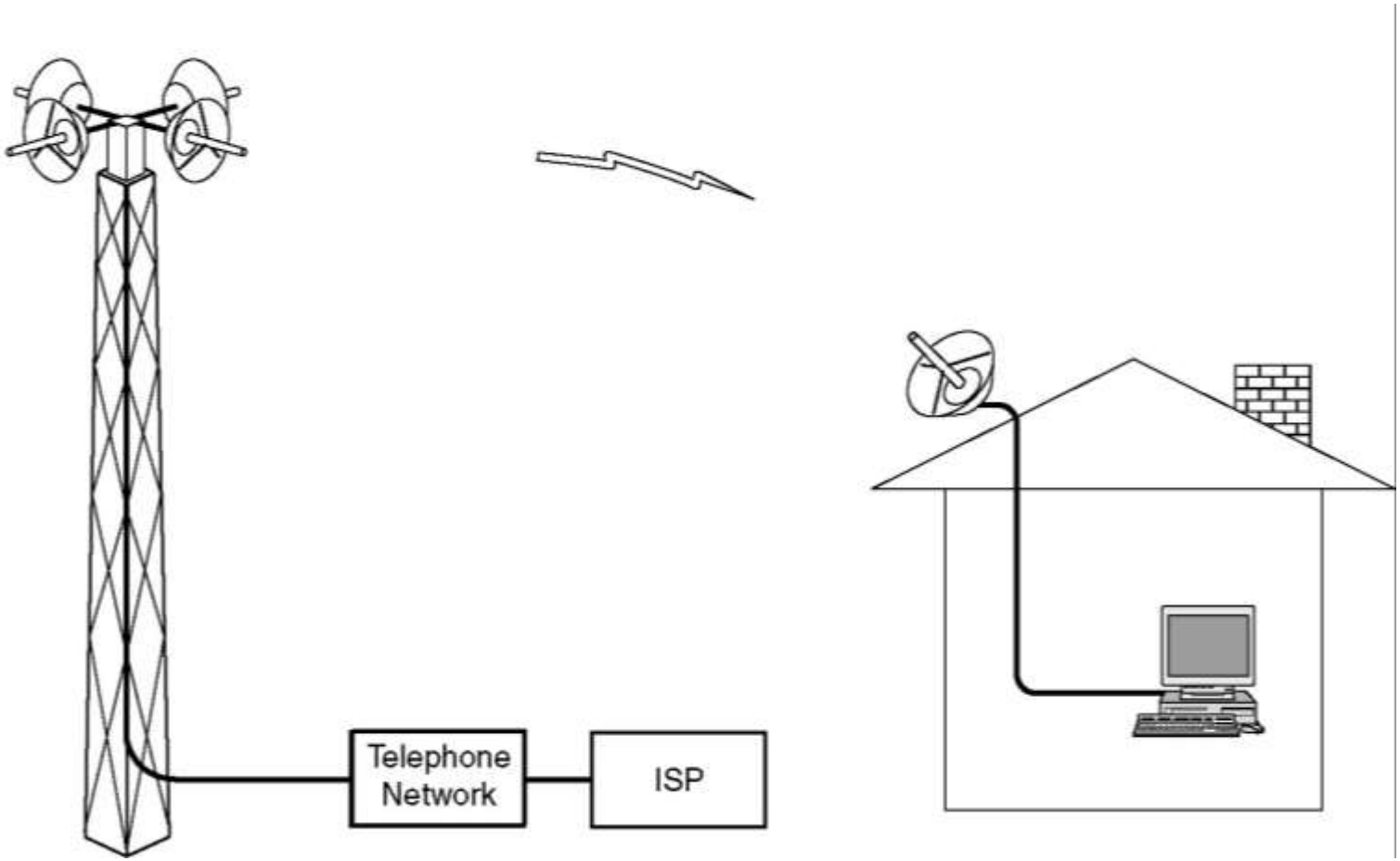
A typical ADSL equipment configuration.

NID:Network Interface Device

Splitter: an analog filter that separates the 0-4000Hz band used by POTS from the data

DSLAM (Digital Subscriber Line Access Multiplexer)

Wireless Local Loops



Architecture of an LMDS system
(Local Multipoint Distribution Service).

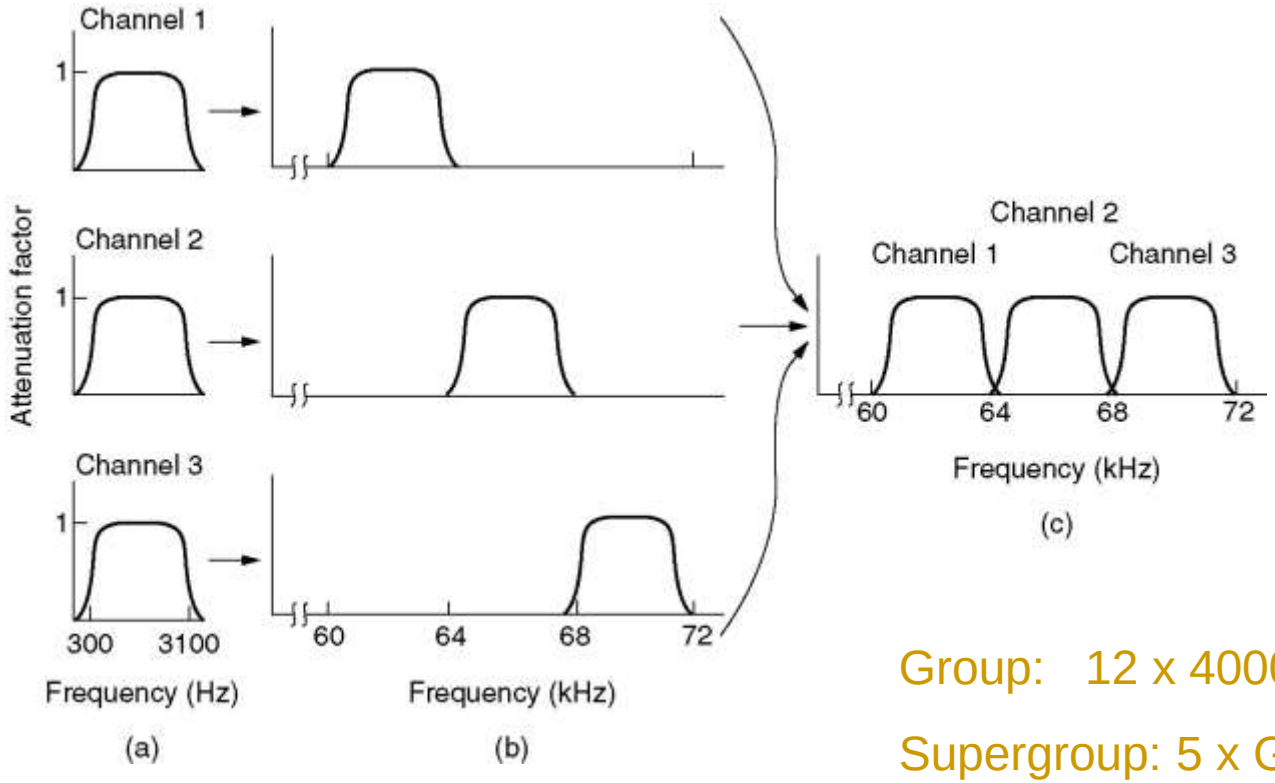
Wireless Local Loops(2)

- **Fixed wireless**
- **LMDS**
  - Each antenna defines a sector, independent of the other ones
  - The range is 2-5km
  - Asymmetric bandwidth allocation like ADSL
    - 36Gbps downstream
    - 1Mbps upstream
  - **Problems**:
    - Millimeter waves propagate in straight lines, clear line of sight is necessary
    - Leaves absorb these waves
    - Rain also absorb these waves
- **IEEE 802.16** , a standard for LMDS, published in April 2002
  - A wireless MAN standard

2.6.4 Trunks and Multiplexing

- **FDM**: Frequency Division Multiplexing
  - **WDM**: Wave Division Multiplexing
  - **DWDM**: Dense Wave Division Multiplexing
- **TDM**: Time Division Multiplexing

Frequency Division Multiplexing



Group: 12 x 4000Hz channels

Supergroup: 5 x Groups

Mastergroup: 5/10 x Supergroups

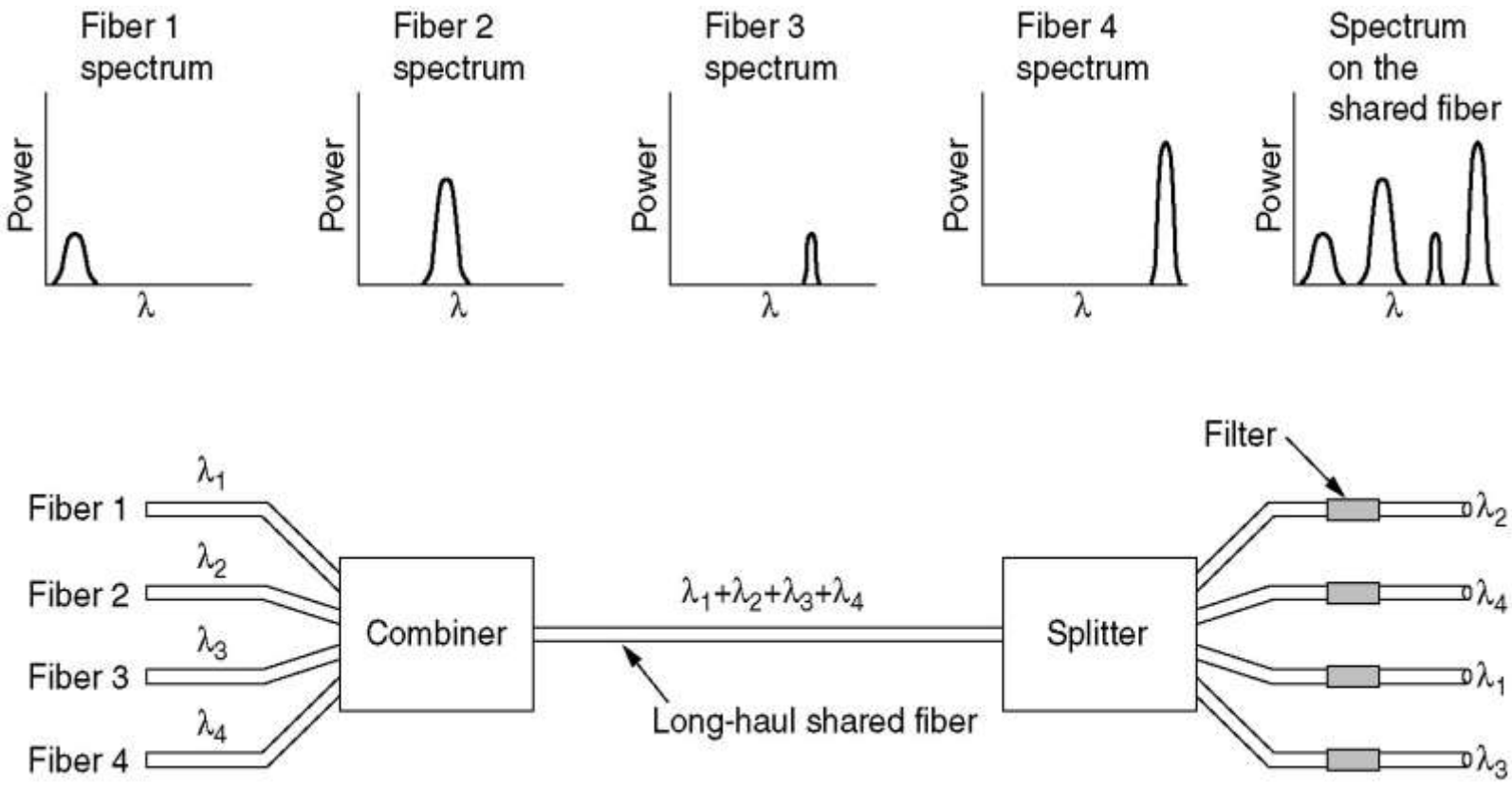
(a) The original bandwidths.

(b) The bandwidths raised in frequency.

(b) The multiplexed channel.

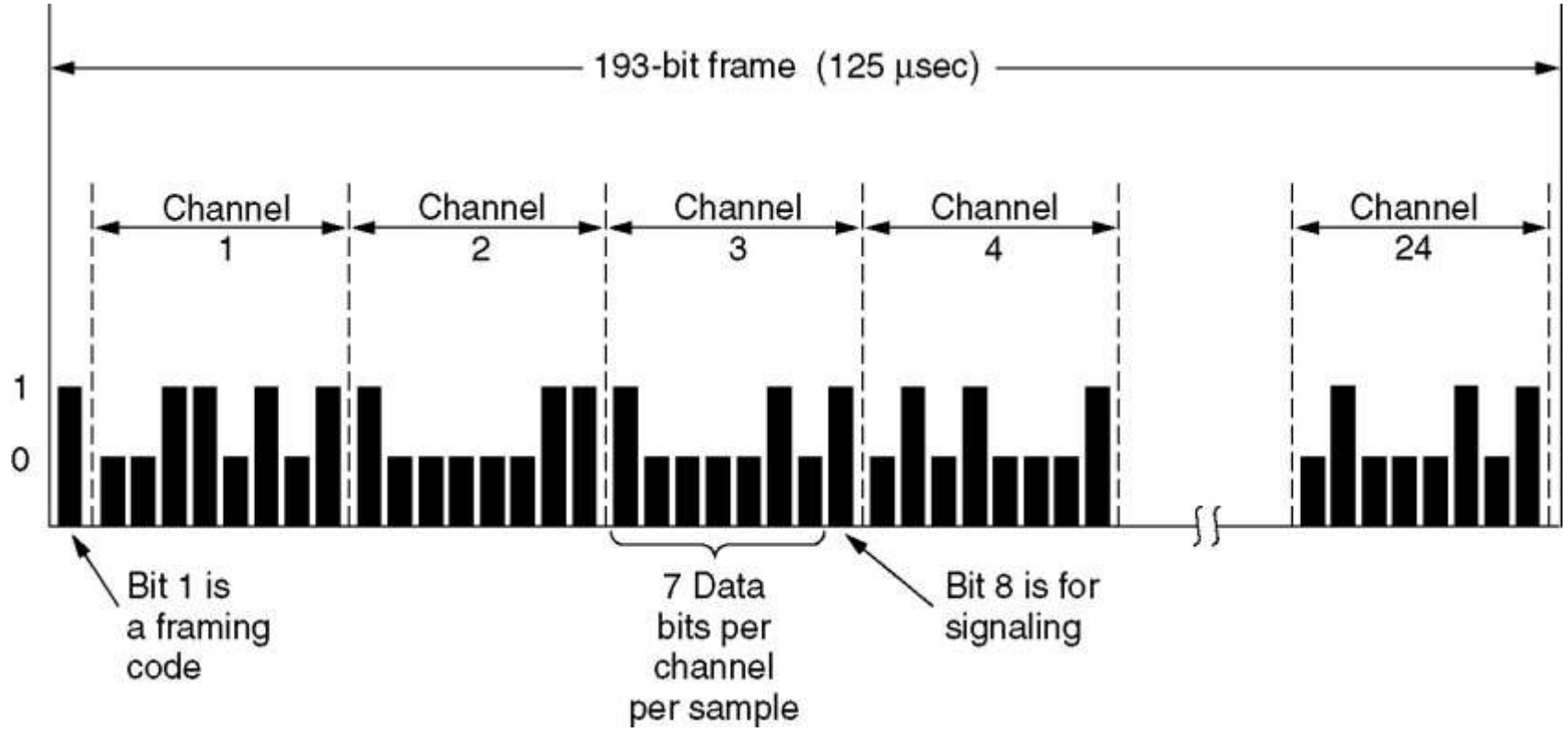
频分复用

Wavelength Division Multiplexing



Wavelength division multiplexing.

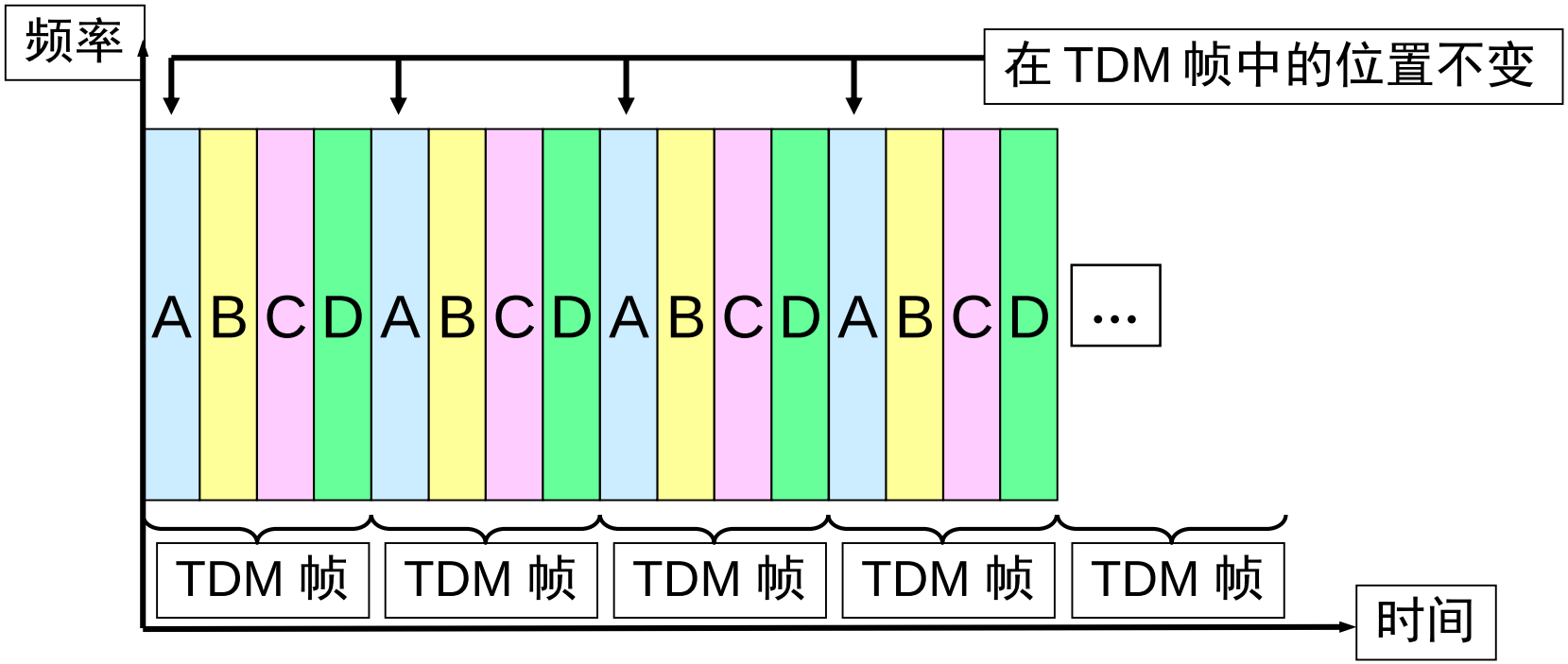
Time Division Multiplexing



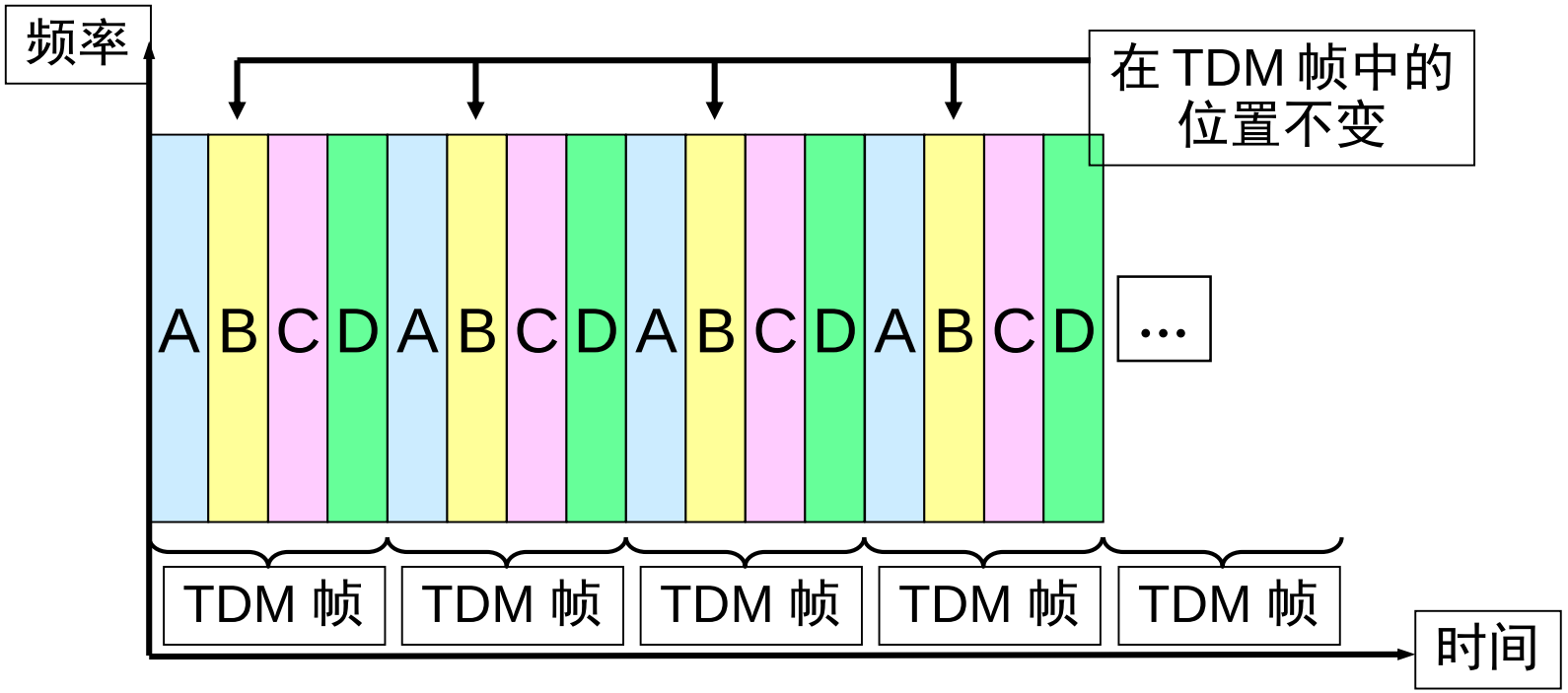
The T1 carrier (1.544 Mbps).

PCM、T1(1.544Mbps)、E1(2.048Mbps)、T2/T3/T4...

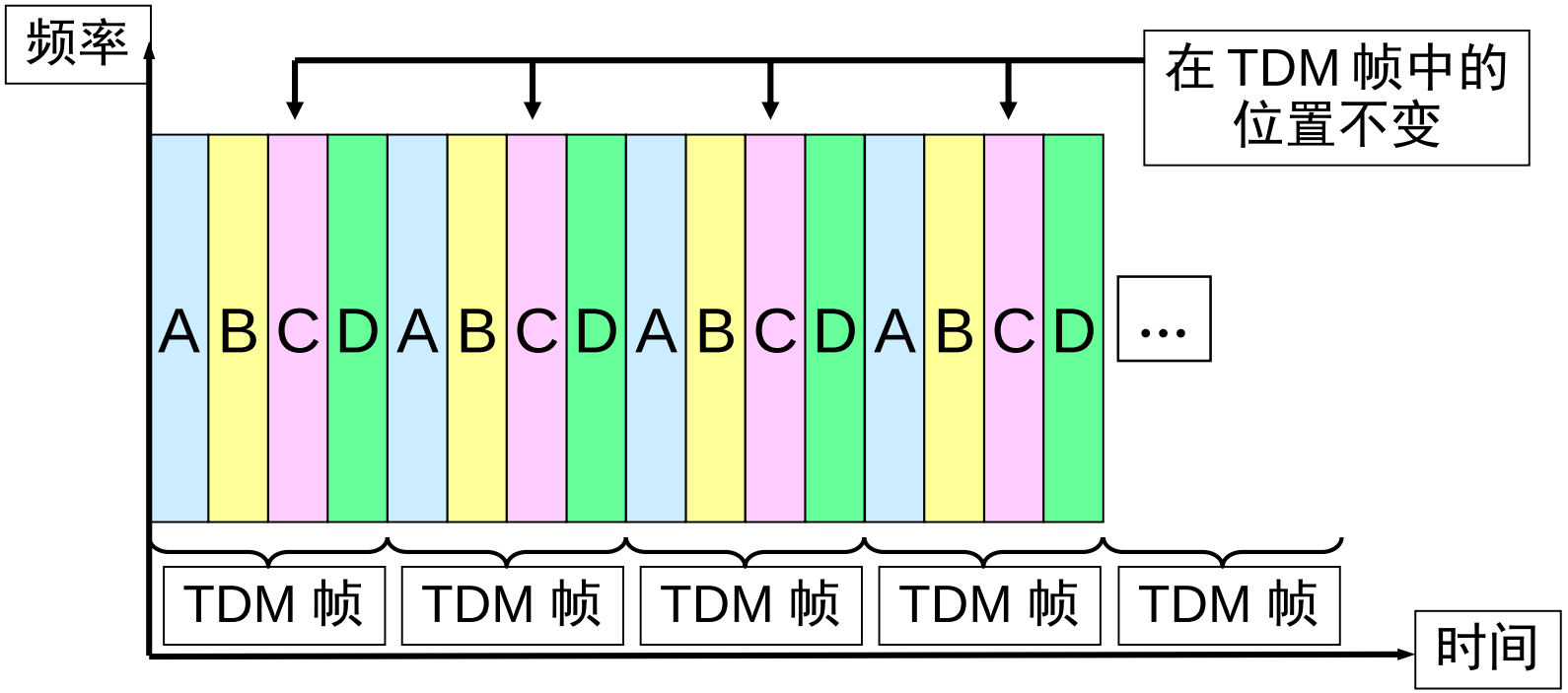
时分复用


频率
在 TDM 帧中的位置不变
A B C D A B C D A B C D A B C D
…
TDM 帧
TDM 帧
TDM 帧
TDM 帧
TDM 帧
时间

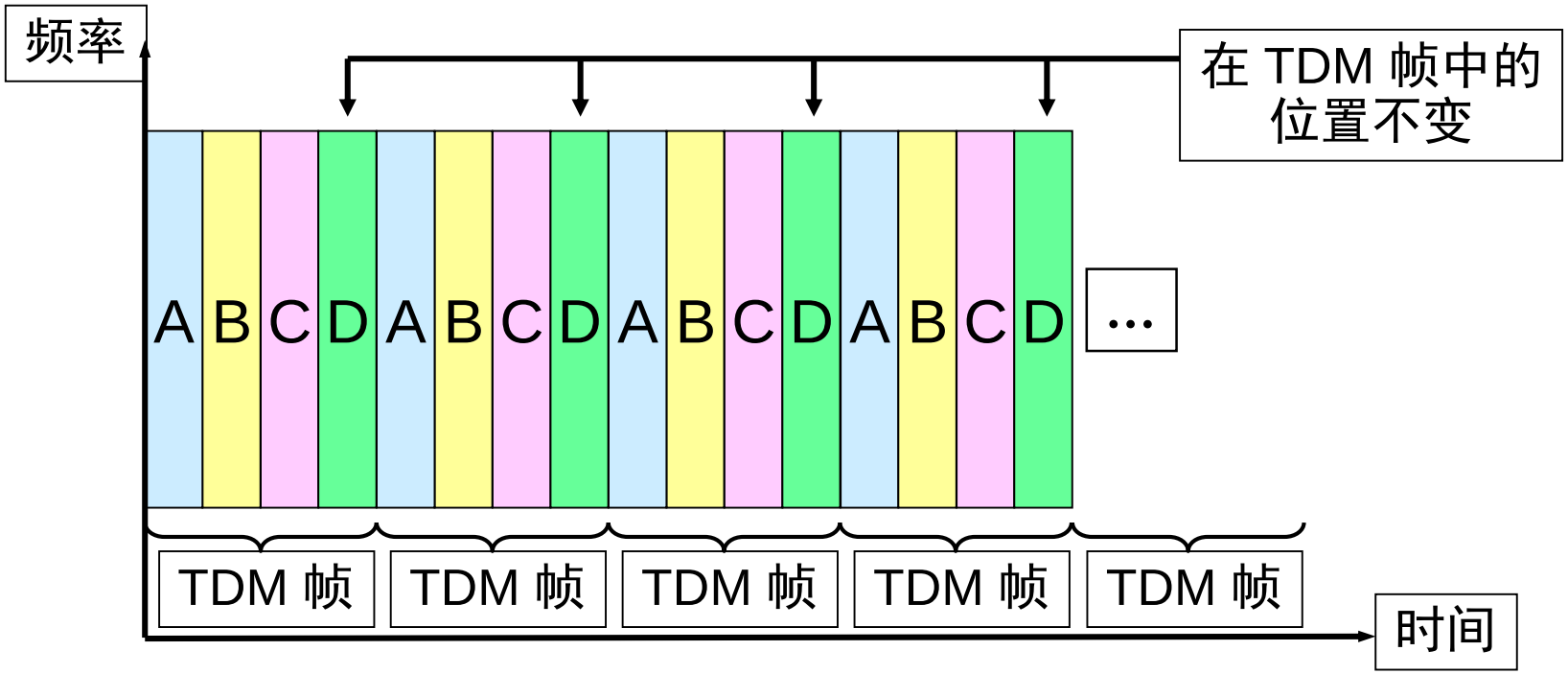
时分复用


频率
在 TDM 帧中的
位置不变
A B C D A B C D A B C D A B C D
…
TDM 帧
TDM 帧
TDM 帧
TDM 帧
TDM 帧
时间

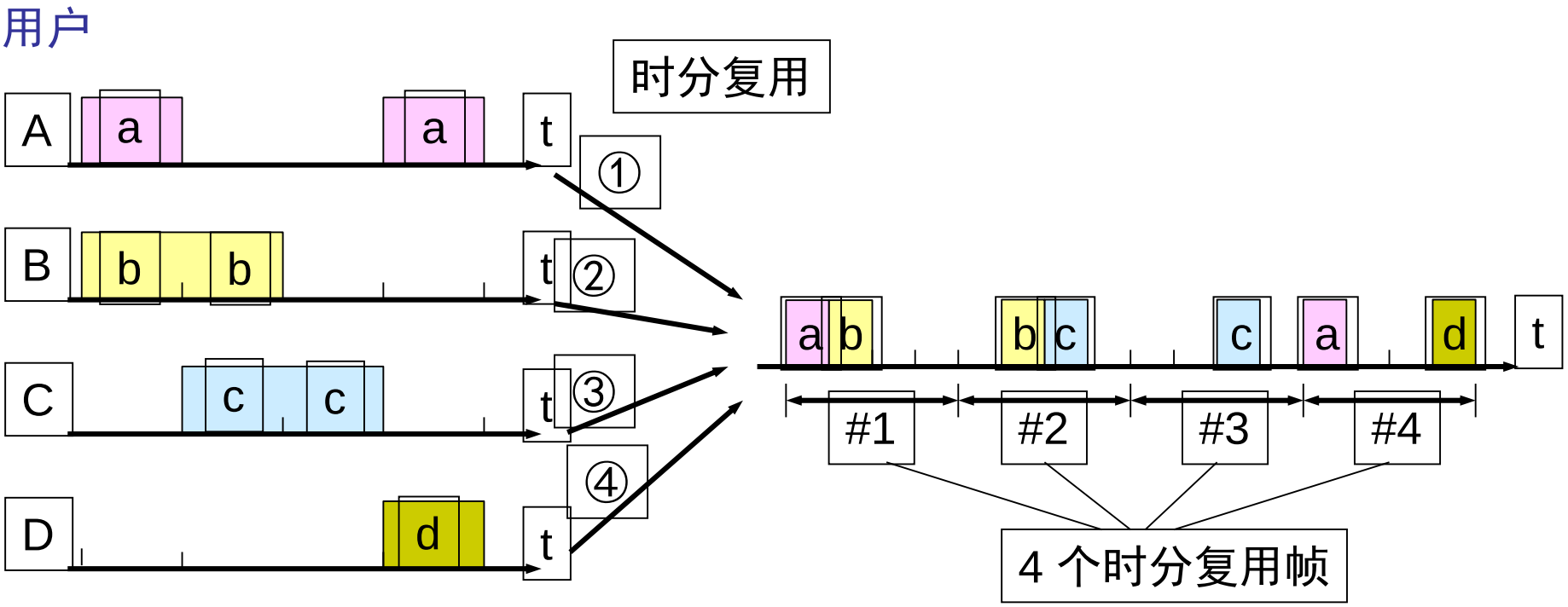
时分复用


频率
在 TDM 帧中的
位置不变
A B C D A B C D A B C D A B C D
…
TDM 帧
TDM 帧
TDM 帧
TDM 帧
TDM 帧
时间

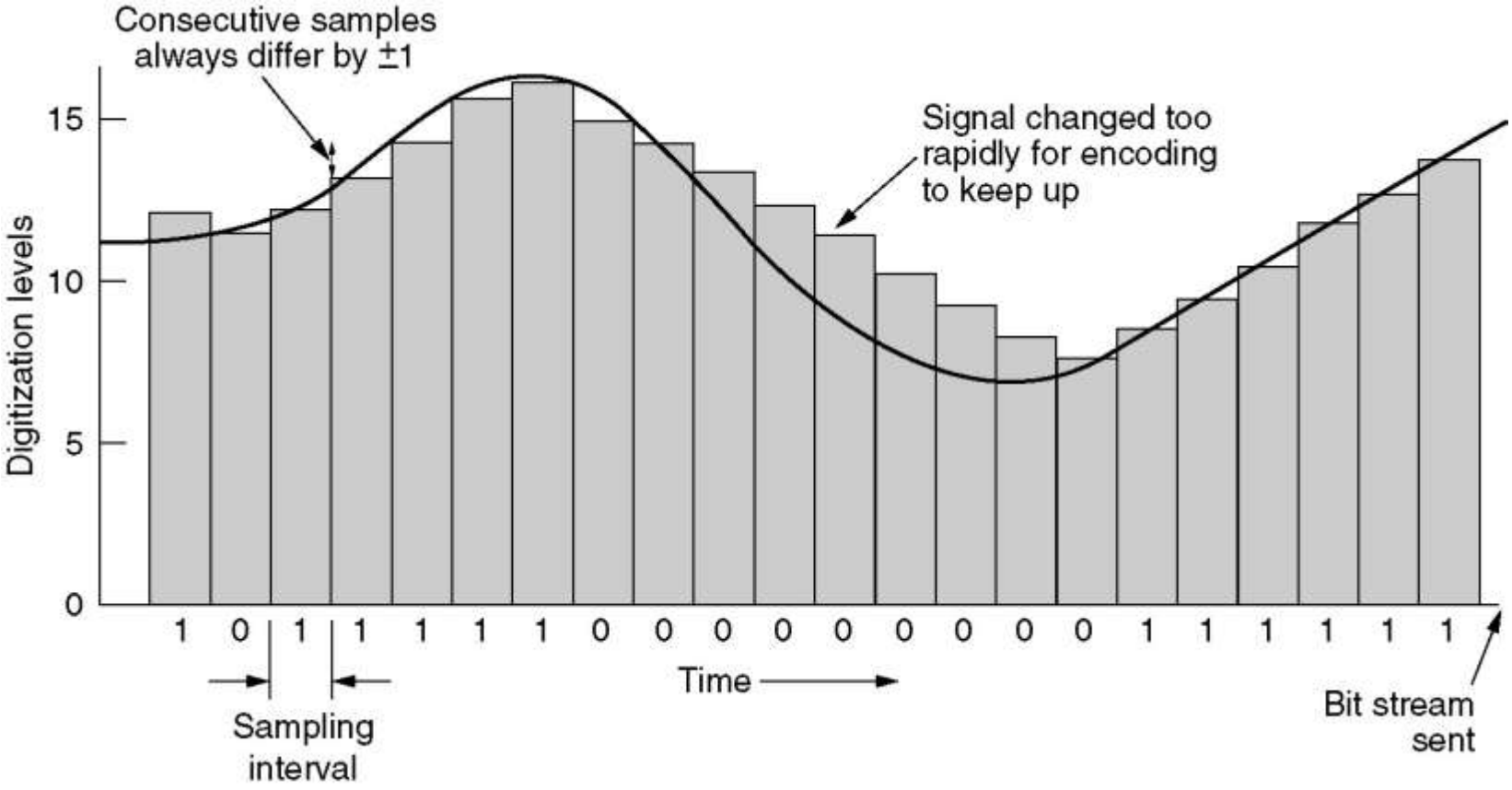
时分复用


频率
在 TDM 帧中的
位置不变
A B C D A B C D A B C D A B C D
…
TDM 帧
TDM 帧
TDM 帧
TDM 帧
TDM 帧
时间

时分复用可能会造成线路资源的浪费



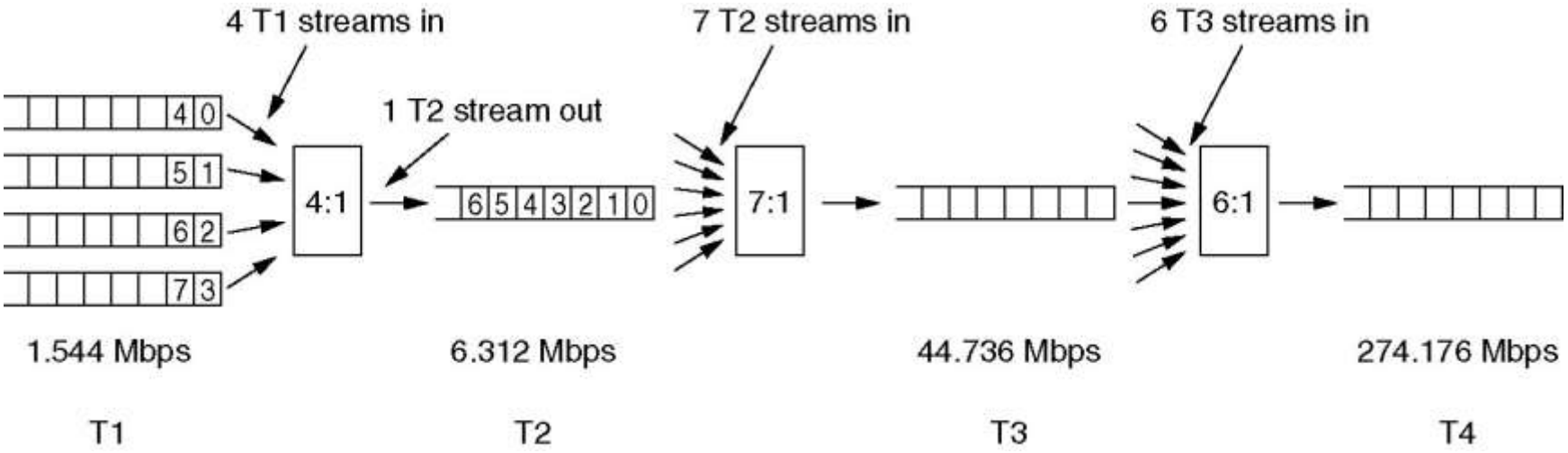
Time Division Multiplexing (2)



Delta modulation.

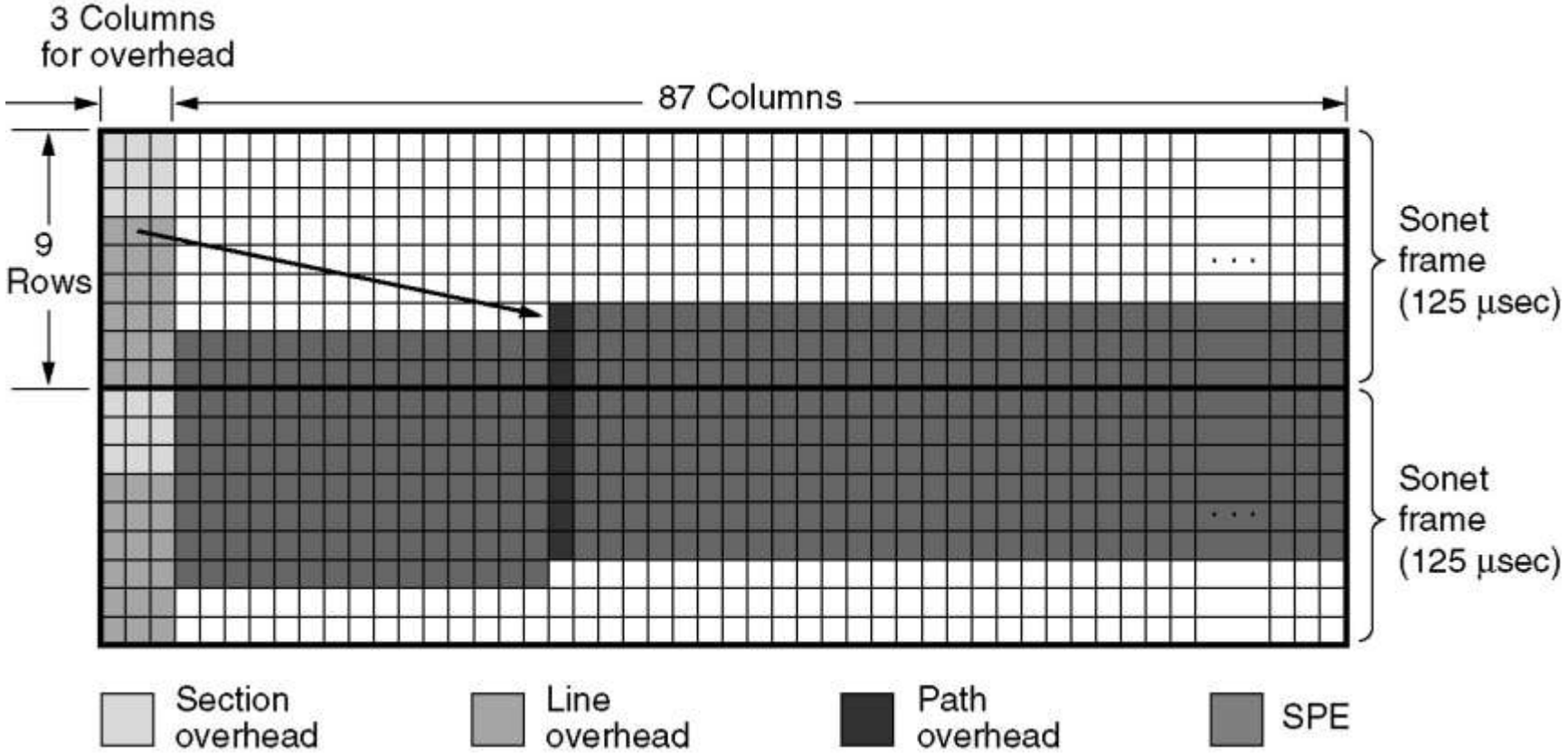
(Differential pulse code modulation for voice channel digitalized)

Time Division Multiplexing (3)



Multiplexing T1 streams into higher carriers.
T1→T2: 4 T1, 6.312Mbps, not 6.176Mbps,
(extra bits for framing and recovery in case the carrier slips)
T2→T3: 7 T2, 44.736Mbps
T3→T4: 6 T3, 274.176Mbps

Time Division Multiplexing (4)



Two back-to-back SONET frames.

Basic frame is a block of 810bytes / 126us

SONET: Synchronous Optical NETwork

SDH: Synchronous Digital Hierarchy, CCITT

SPE(Synchronous Payload Envelope): 87x9x8x8000=50.112Mbps

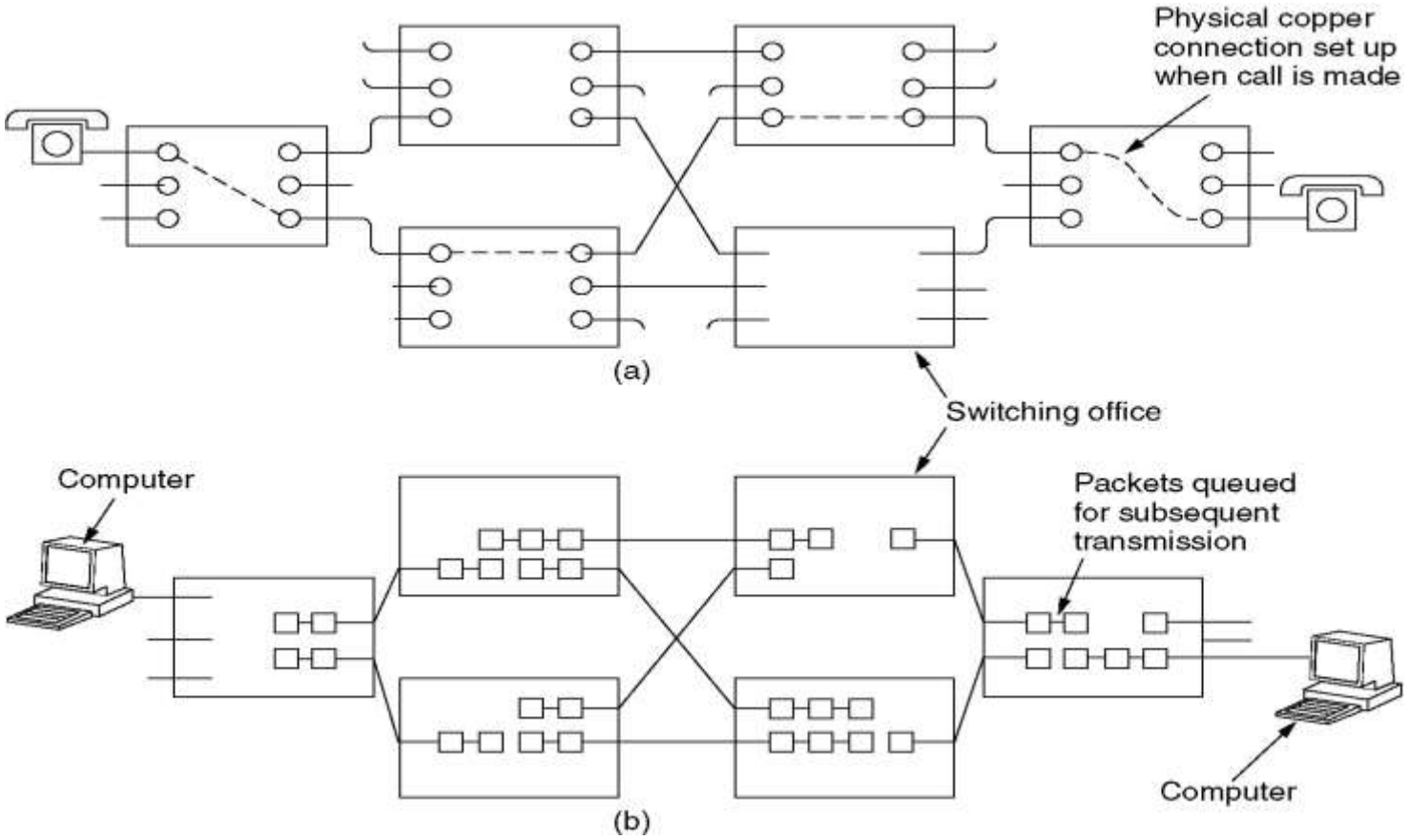
Time Division Multiplexing (5)

SONET		SDH	Data rate (Mbps)		
Electrical	Optical	Optical	Gross	SPE	User
STS-1	OC-1		51.84	50.112	49.536
STS-3	OC-3	STM-1	155.52	150.336	148.608
STS-9	OC-9	STM-3	466.56	451.008	445.824
STS-12	OC-12	STM-4	622.08	601.344	594.432
STS-18	OC-18	STM-6	933.12	902.016	891.648
STS-24	OC-24	STM-8	1244.16	1202.688	1188.864
STS-36	OC-36	STM-12	1866.24	1804.032	1783.296
STS-48	OC-48	STM-16	2488.32	2405.376	2377.728
STS-192	OC-192	STM-64	9953.28	9621.504	9510.912

SONET and SDH multiplex rates.

OC-3 and OC-3c (c– concatenated, non-channelized)

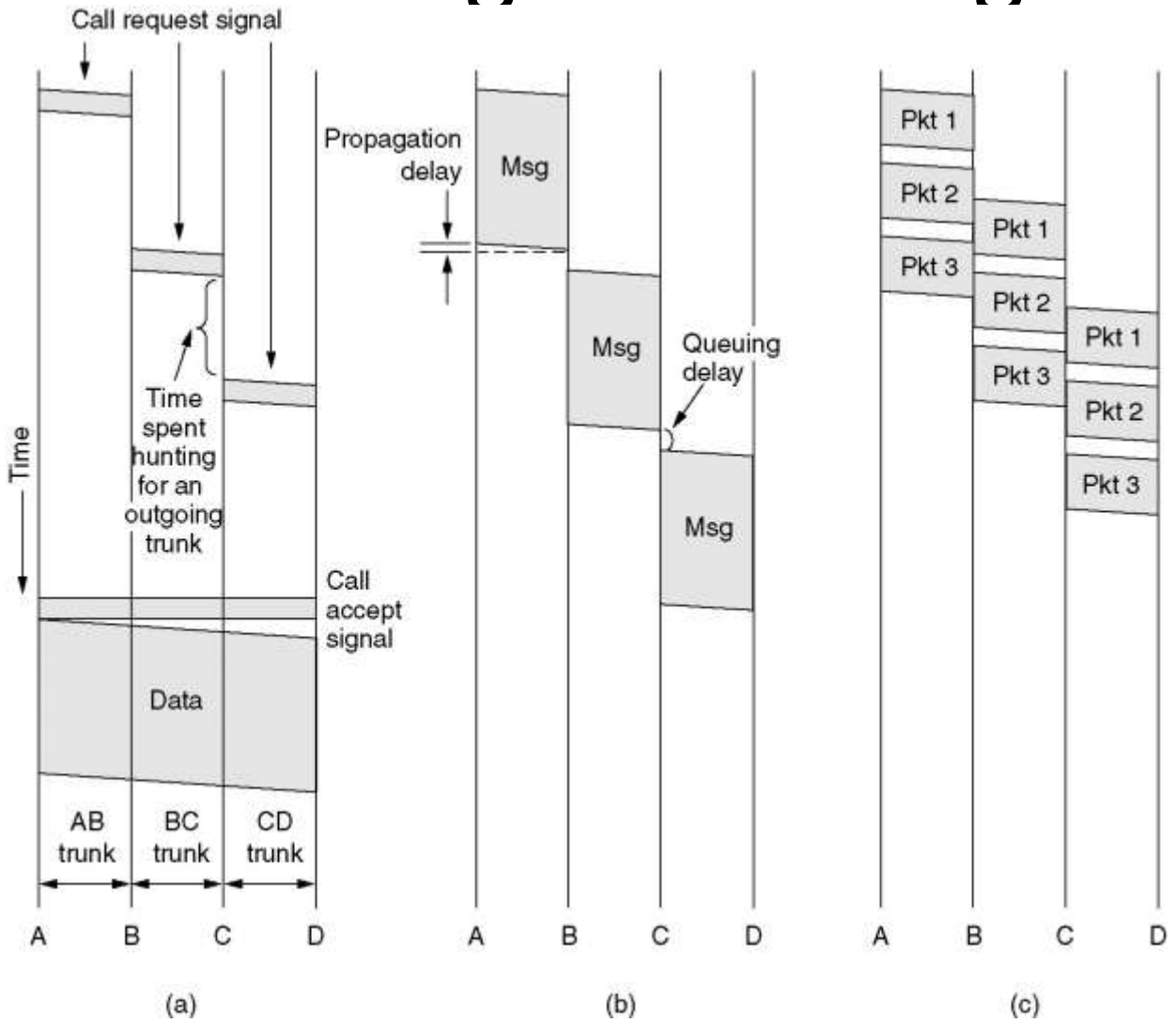
2.6.5 Circuit Switching



(a) Circuit switching.

(b) Packet switching.(store-and-forward)

Message Switching



(a) Circuit switching (b) Message switching (c) Packet switching

Packet Switching

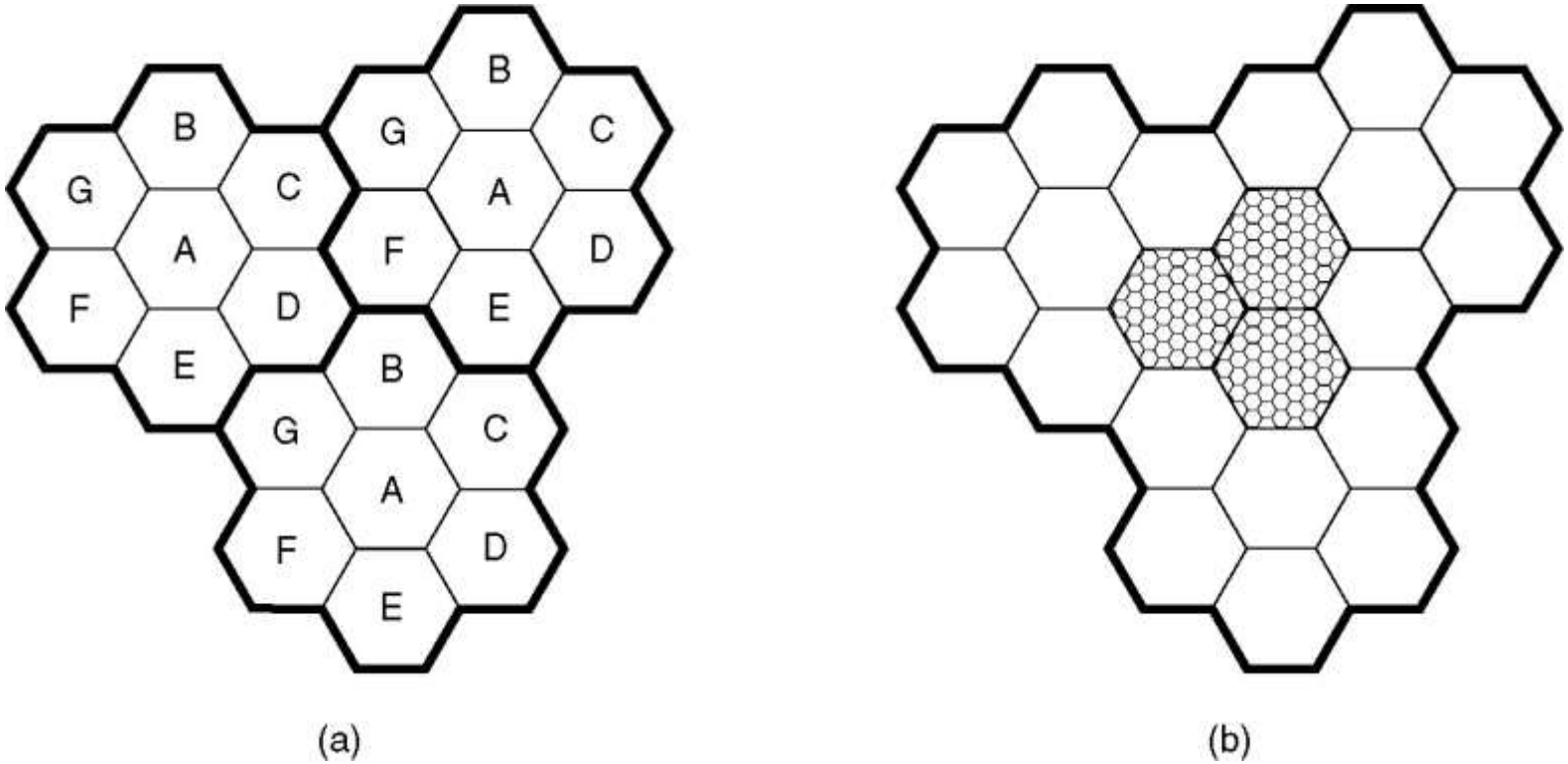
Item	Circuit-switched	Packet-switched
Call setup	Required	Not needed
Dedicated physical path	Yes	No
Each packet follows the same route	Yes	No
Packets arrive in order	Yes	No
Is a switch crash fatal	Yes	No
Bandwidth available	Fixed	Dynamic
When can congestion occur	At setup time	On every packet
Potentially wasted bandwidth	Yes	No
Store-and-forward transmission	No	Yes
Transparency	Yes	No
Charging	Per minute	Per packet

A comparison of circuit switched and packet-switched networks.

2.7 The Mobile Telephone System

- First-Generation Mobile Phones: Analog Voice
- Second-Generation Mobile Phones: Digital Voice
- Third-Generation Mobile Phones: Digital Voice and Data

2.7.1 Advanced Mobile Phone System



(a) Frequencies are not reused in adjacent cells.

(b) To add more users, **smaller cells (microcells)** can be used.

Channel Categories

The 832 channels are divided into four categories:

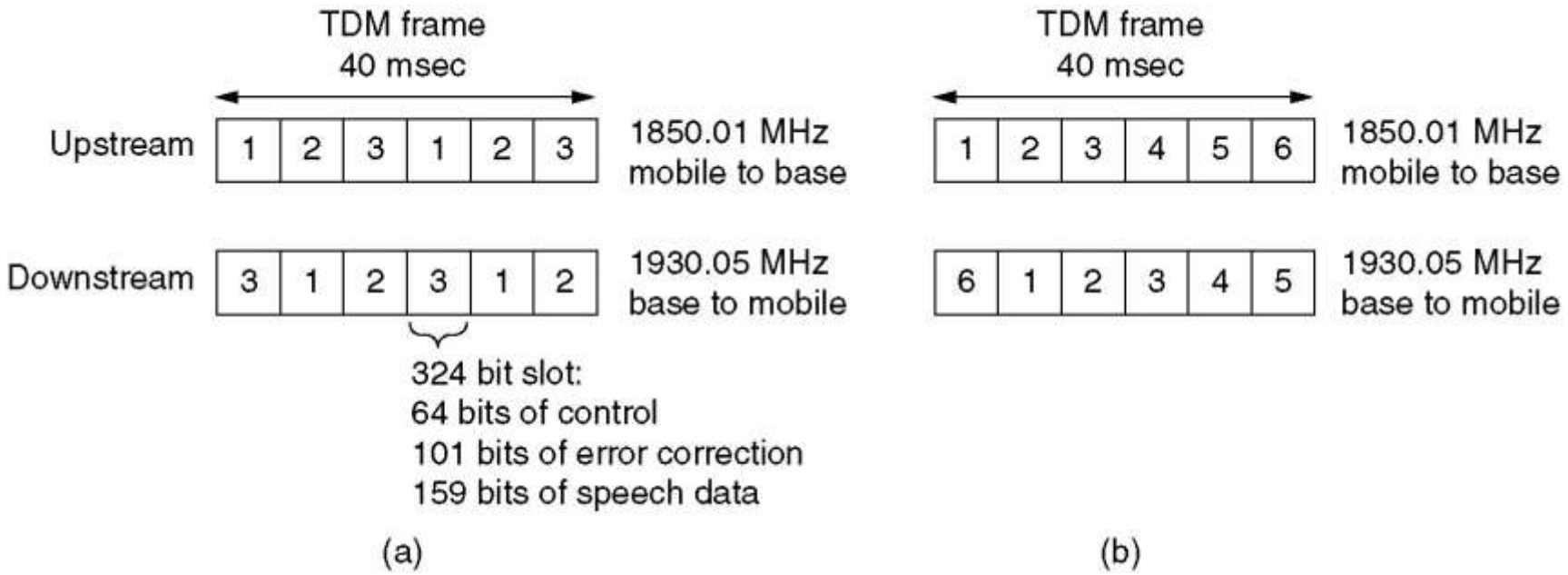
- Control (base to mobile) to manage the system
- Paging (base to mobile) to alert users to calls for them
- Access (bidirectional) for call setup and channel assignment
- Data (bidirectional) for voice, fax, or data

- **PROM中：32bit序列号、10位数电话号码**
- 安全问题:非常不安全、空中窃贼

2.7.2 Second-Generation Mobile Phones: Digital Voice

- D-AMPS, IS-54 and IS-136, used in U.S. and Japan, 30kHz/channel
- GSM, used in Europe and other area , 200kHz/channel
- CDMA
- PDC only in Japan
- 数字传输的优点：
  - 数字、声音和传真三合一
  - 声音压缩比高
  - 纠错、高质量
  - 安全

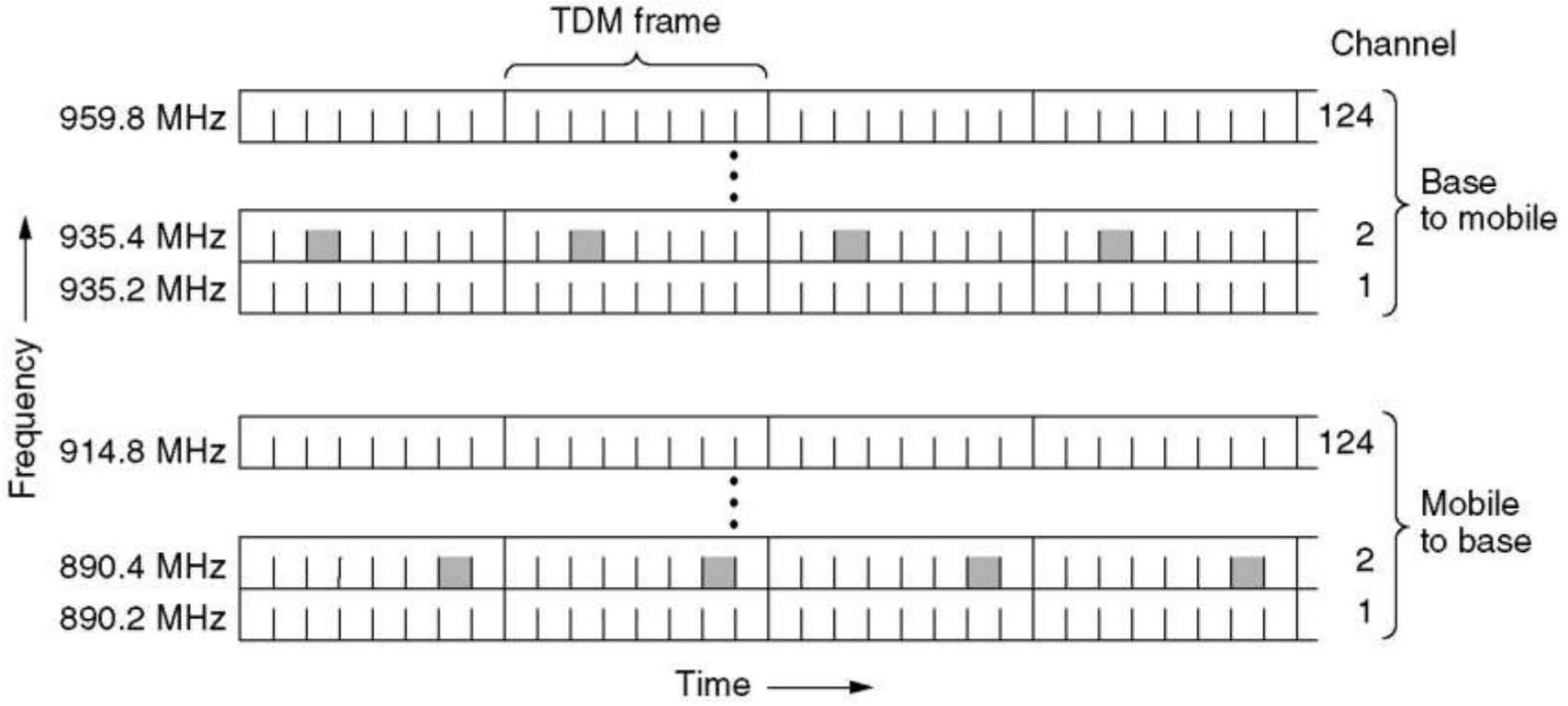
D-AMPS
Digital Advanced Mobile Phone System



(a) A D-AMPS channel with three users.

(b) A D-AMPS channel with six users.

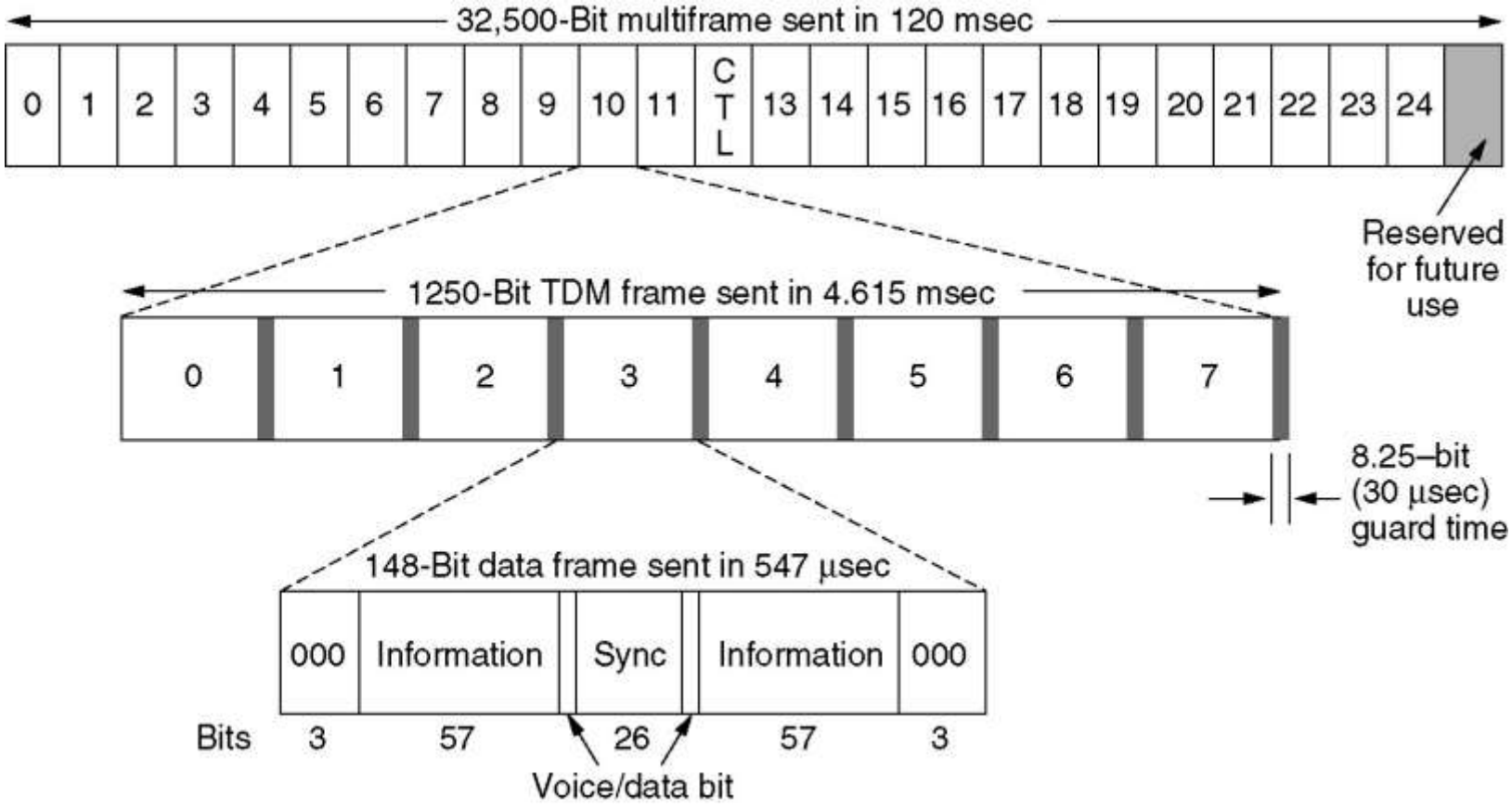
GSM
Global System for Mobile Communications



GSM uses 124 frequency channels, each of which uses an eight-slot TDM system

- 欧洲GSM（900MHz波段、1800MHz）
- GSM使用124个频率信道。每个均使用8隙TDM系统，支持8个独立的连接

GSM (2)



A portion of the GSM framing structure.

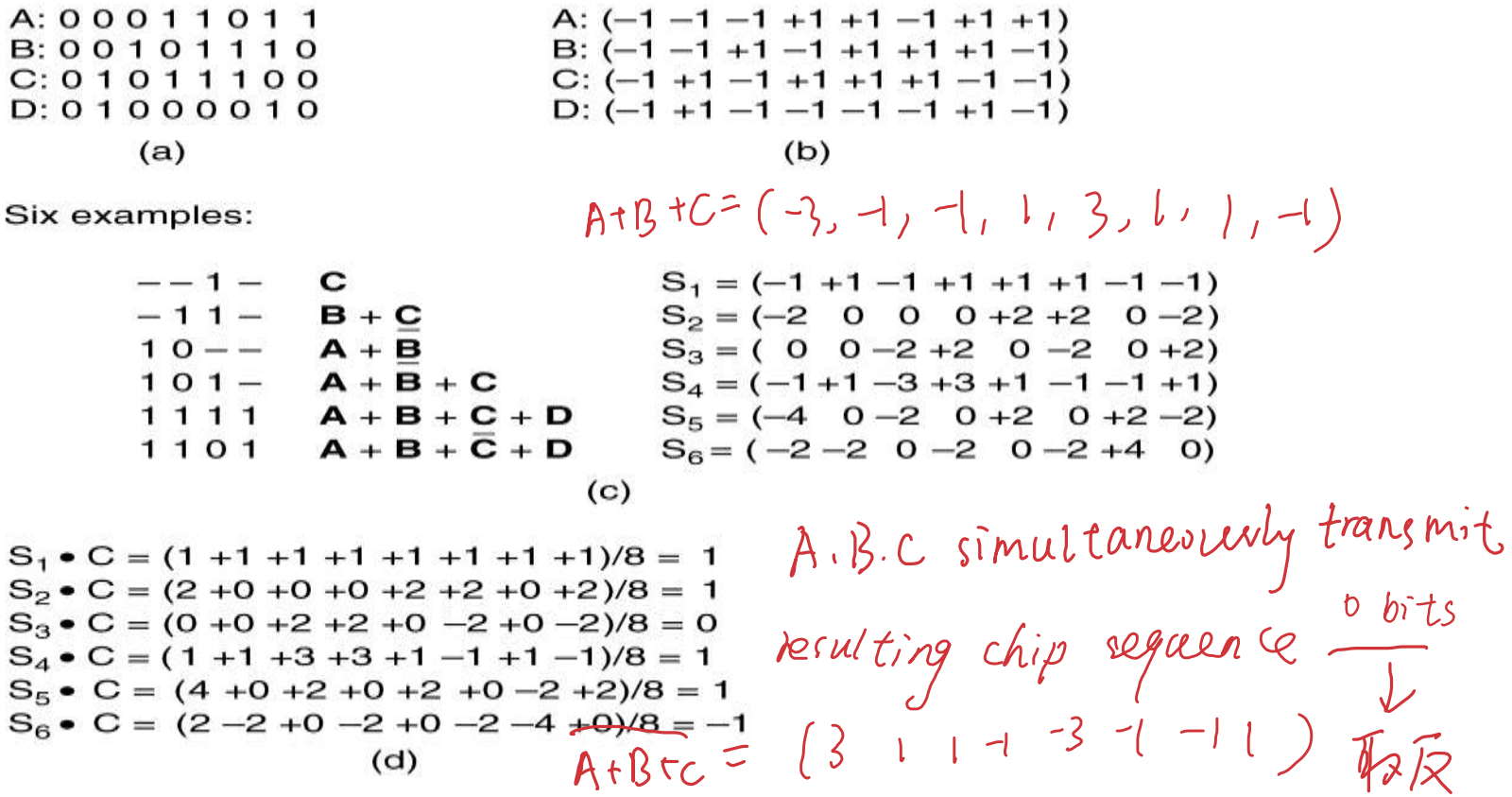
GSM(3)

- 许多管理信道：
  - 广播控制信道、专用控制信道、公用控制信道（呼叫、随机访问和访问授权子信道）
- GSM:复杂系统
  - 运用：分隙ALOHA、FDM、TDM控制信道

CDMA – Code Division Multiple Access

- CDMA—码分多址(Code Division Multiple Access)
  - 特点：允许所有站点同时在整个频段上传输，多路的同时传输编码原理加以区分
  - 每站点一个唯一的m位代码（或芯片序列）
  - 原理： -[see next figure]
  - 带宽利用率高
  - 新一代通信系统的重要标准

CDMA – Code Division Multiple Access(2)



(a) Binary chip sequences for four stations
(b) Bipolar chip sequences
(c) Six examples of transmissions
(d) Recovery of station C's signal

2.7.3 Third-Generation Mobile Phones: Digital Voice and Data

Basic services an IMT-2000 network should provide

- High-quality voice transmission
- Messaging (replace e-mail, fax, SMS, chat, etc.)
- Multimedia (music, videos, films, TV, etc.)
- Internet access (web surfing, w/multimedia.)

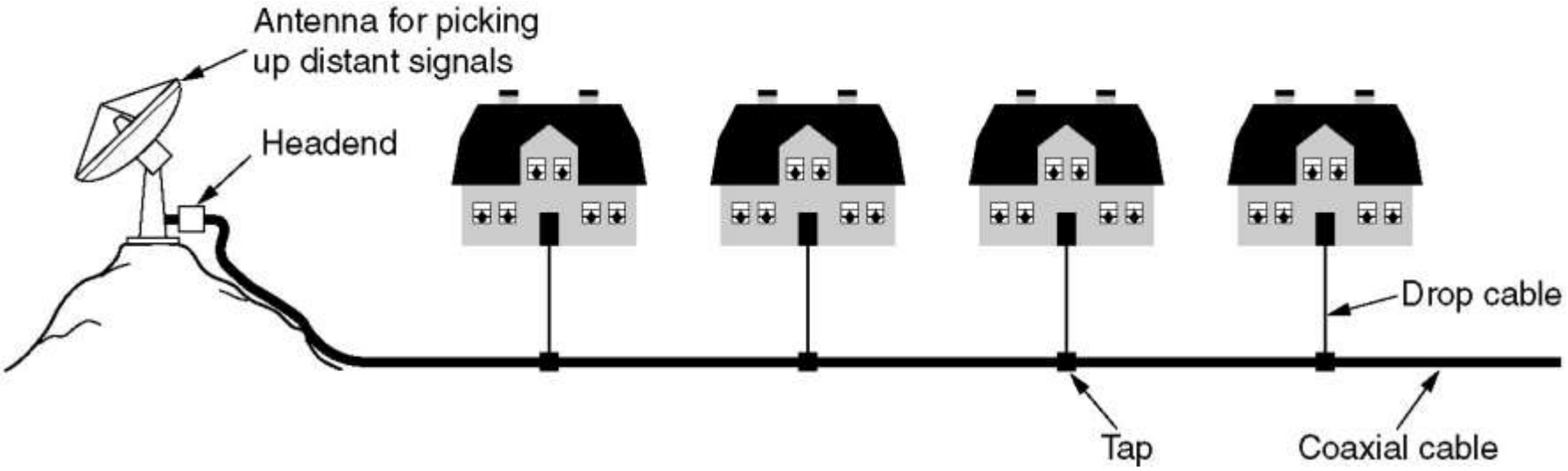
Third-Generation Mobile Phones

- Proposals:
  - W-CDMA(Wideband CDMA), proposed by Ericsson
  - CDMA2000, proposed by Qualcomm
  - TD-CDMA, proposed by Datang Tele,China
- 3G
- 2.5G (2.1G)
  - **EDGE** (Enhanced Data rates for GSM Evolution)
  - **GPRS**(General Packet Radio Service)
    - An overlay packet network on top of D-AMPS or GSM
- **4G**, now

2.8 Cable Television

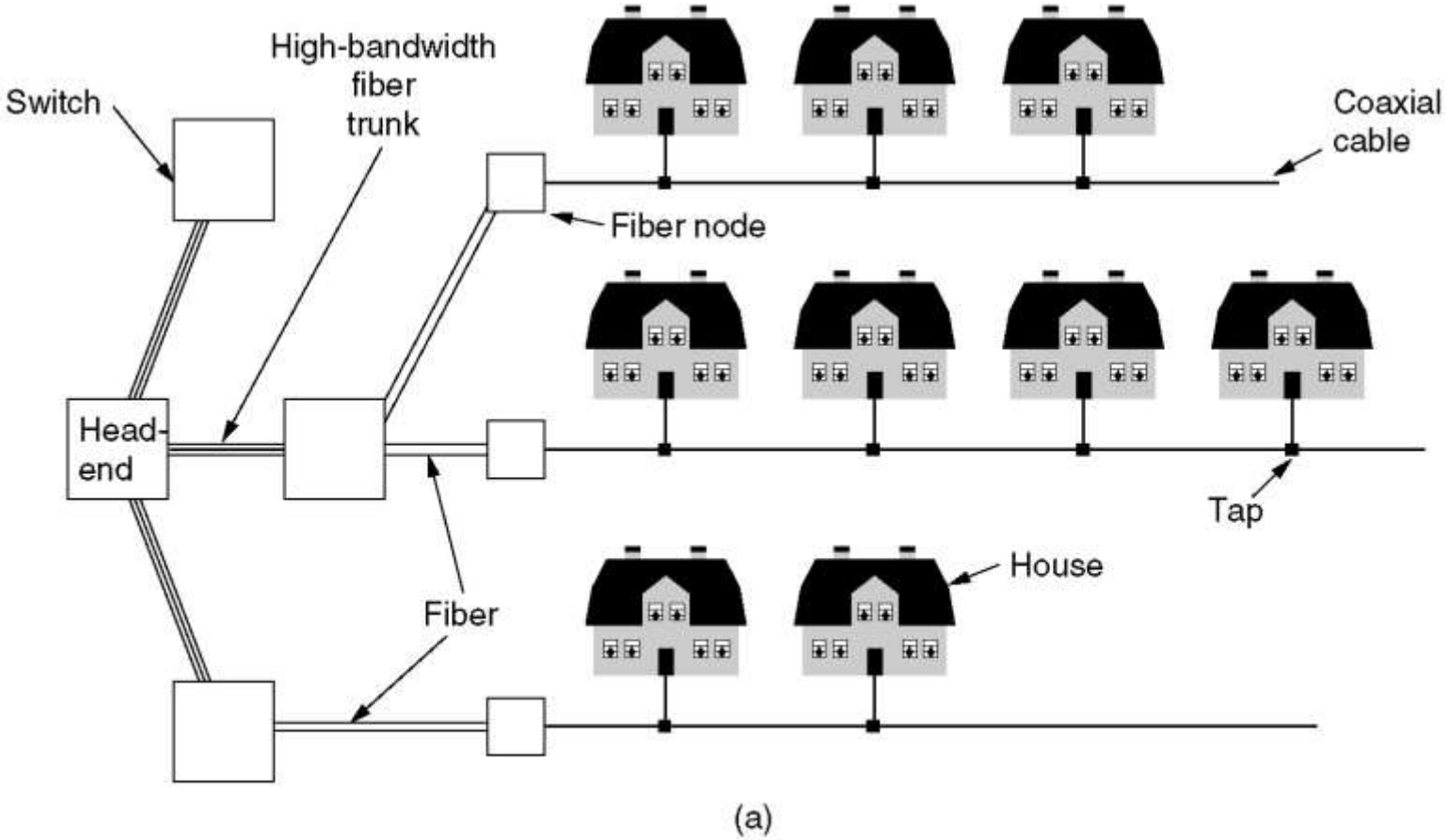
- **Community Antenna Television(共用天线电视)**
- **Internet over Cable**
- **Spectrum Allocation(光谱分配）**
- **Cable Modems**
- **ADSL versus Cable**

2.8.1 Community Antenna Television



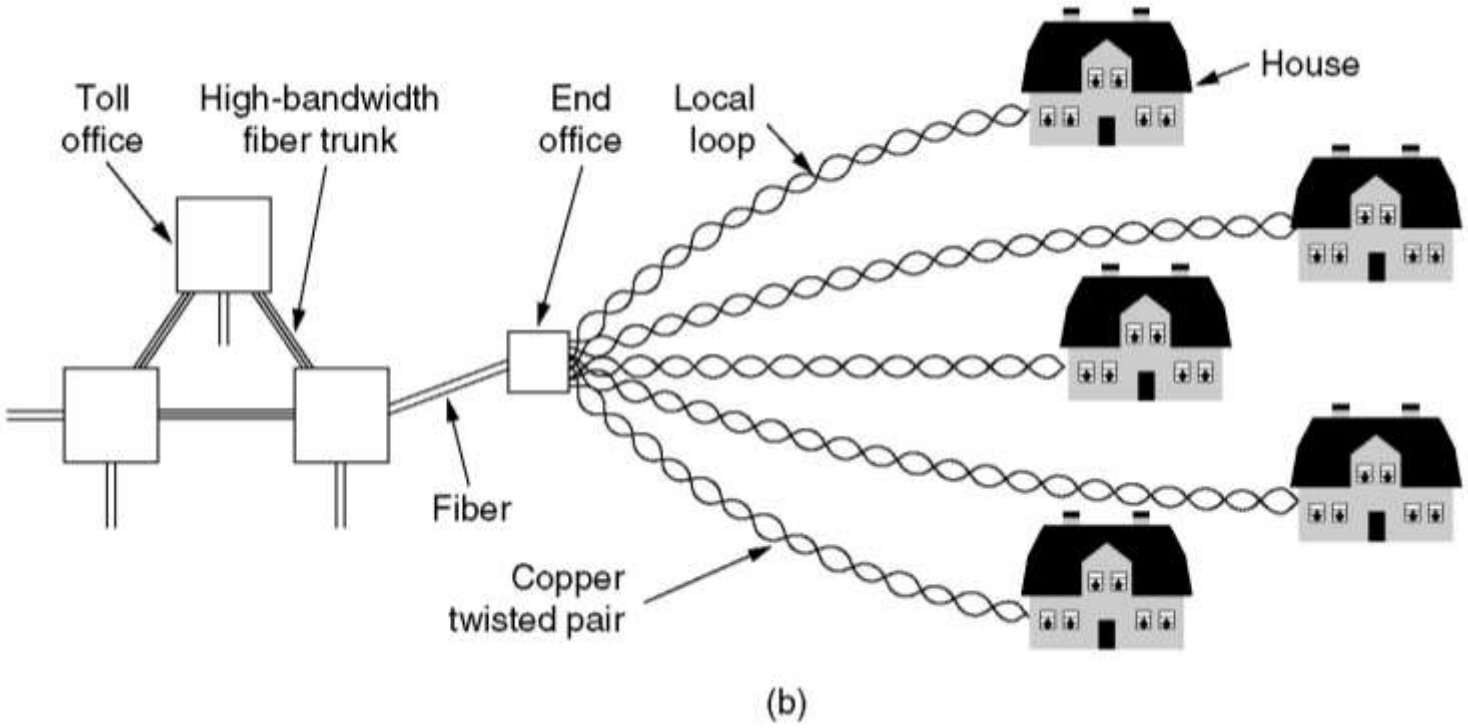
An early cable television system.

2.8.2 Internet over Cable



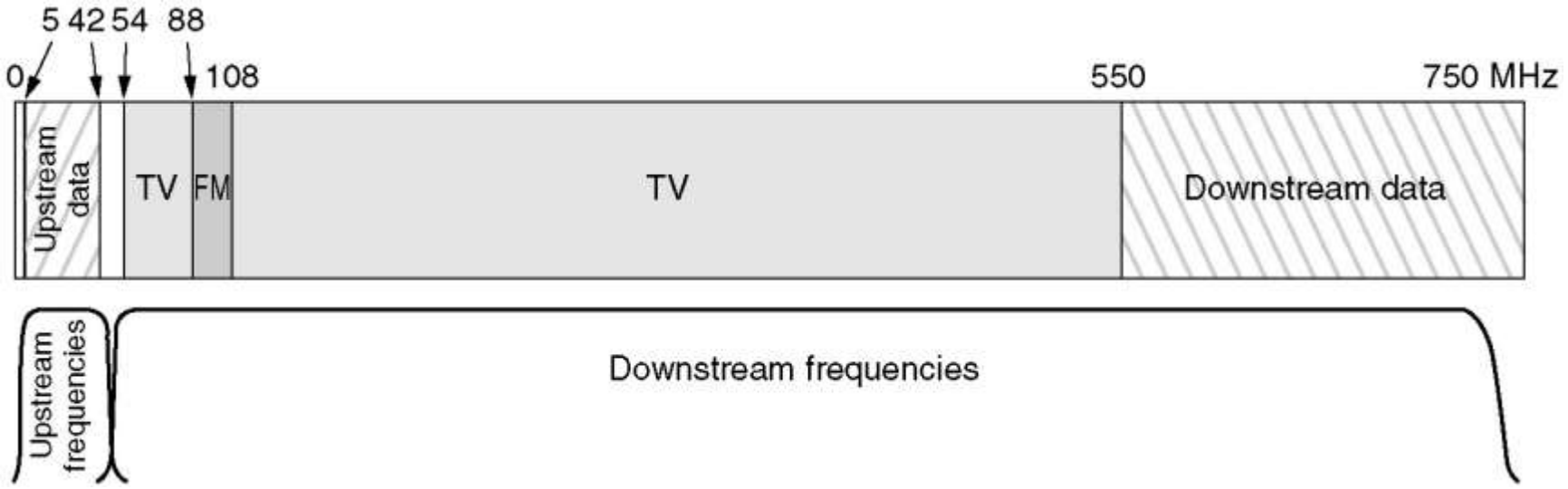
Cable television

Internet over Cable (2)



The fixed telephone system.

2.8.3 Spectrum Allocation

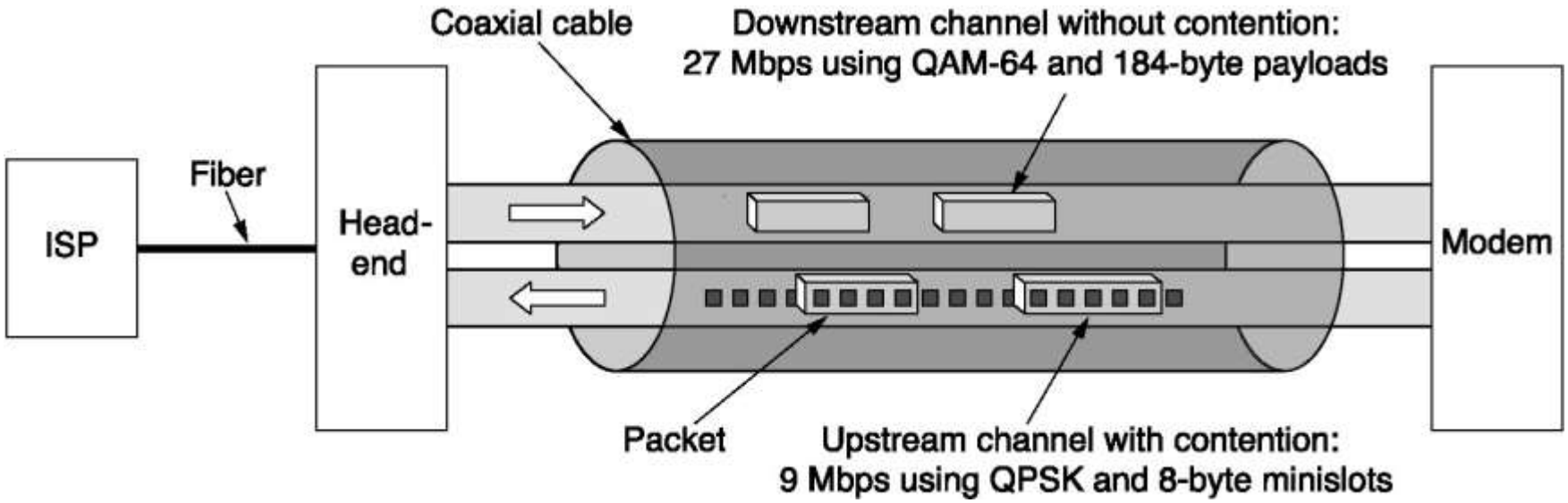


Frequency allocation in a typical cable TV system used for Internet access

2.8.4 Cable Modems

- **Interface Standards:**
  - **DOCSIS**:Data Over Cable Service Interface Specification
  - **EuroDOCSIS**
- **Modem-to-computer interface**
  - **10Mbps Ethernet or USB**
- **Modem-to-Headend**
  - **Complicated**
- **Fixed packet size of 204bytes**
  - **Compatiable with digital television using MPEG-2**

Cable Modems (2)



Typical details of the upstream(**with contention**) and downstream(**without contention**) channels in North America.

DOCSIS:Data Over Cable Service Interface Specification

EuroDOCSIS

2.8.5 ADSL versus Cable

- **Which is better?**
- **Cable uses coax, ADSL uses twisted pair**
- **Effective capacity**
- **Availability**
- **Security**
- **Reliable**
- **Choice of ISPs**

2.9 Summary

- **Theoretical basis of data communication**
  - **Fourier, Nyquist limit and Shannon limit**
- **Transmission media**
  - **Guided: twisted pair, coaxial cable and fiber optics**
  - **Unguided: radio, microwaves, infrared, laser and satellite (LEO, MEO, GEO)**
- **Telephone network**
  - **Local loops, trunks and switches**
  - **ADSL, Wireless**
  - **TDM,FDM,WDM, DWDM**
- **Mobile**
  - **AMPS, D-AMPS, GSM, CDMA, W-CDMA**
- **Cable television**

Exerciese

In 4th Edition：

- 2，3，4，5，
- 22，28，39，55

In 5th Edition：

- 2，3，4，6，15
- 25，26，47，50