计算机网络

3.

LONG-DISTANCE COMMUNICATION

厦门大学软件学院

黄炜 助理教授

关于实验一

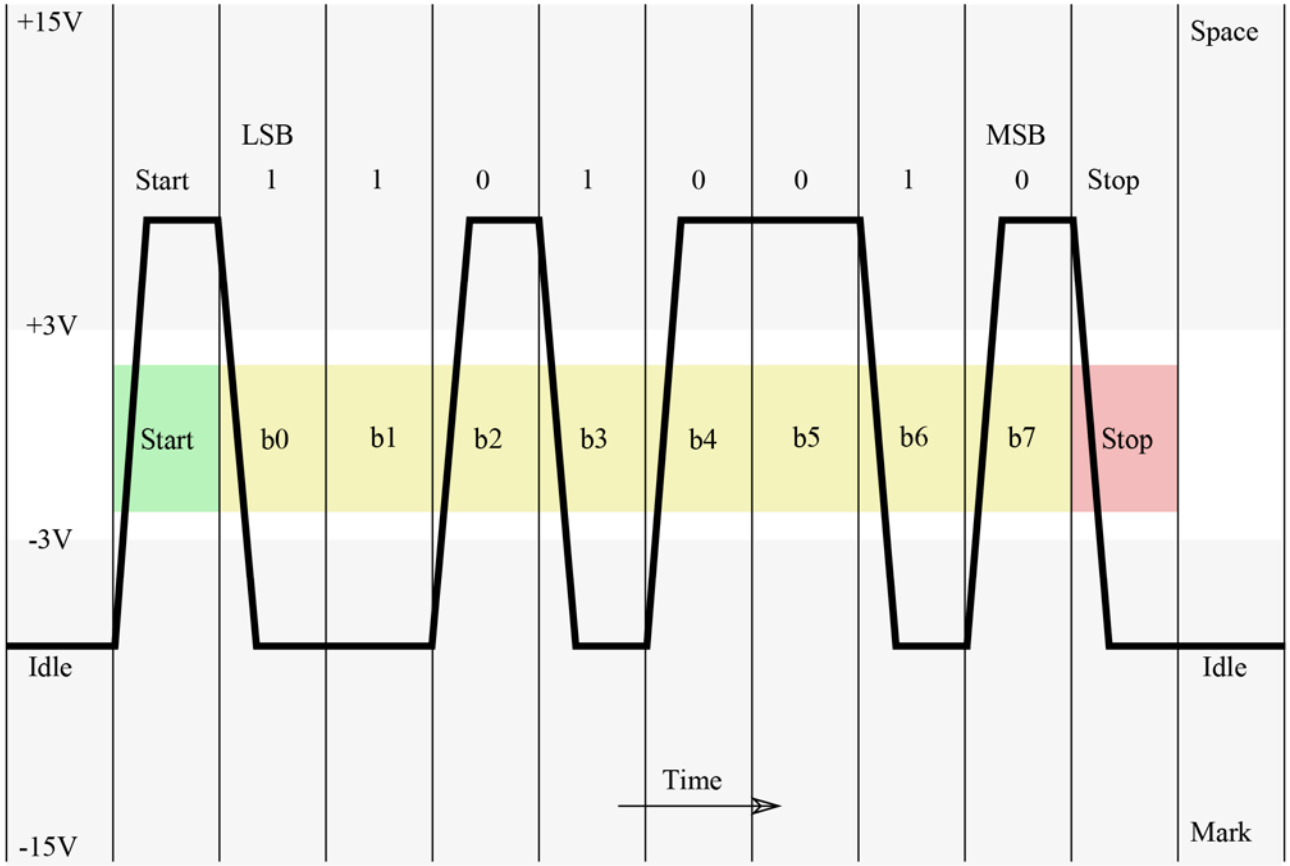
线头顺序正确、连通再压制

废弃物统一交到助教准备的袋子里，完成后椅子放原位

FTP

扩展阅读材料

字符顺序

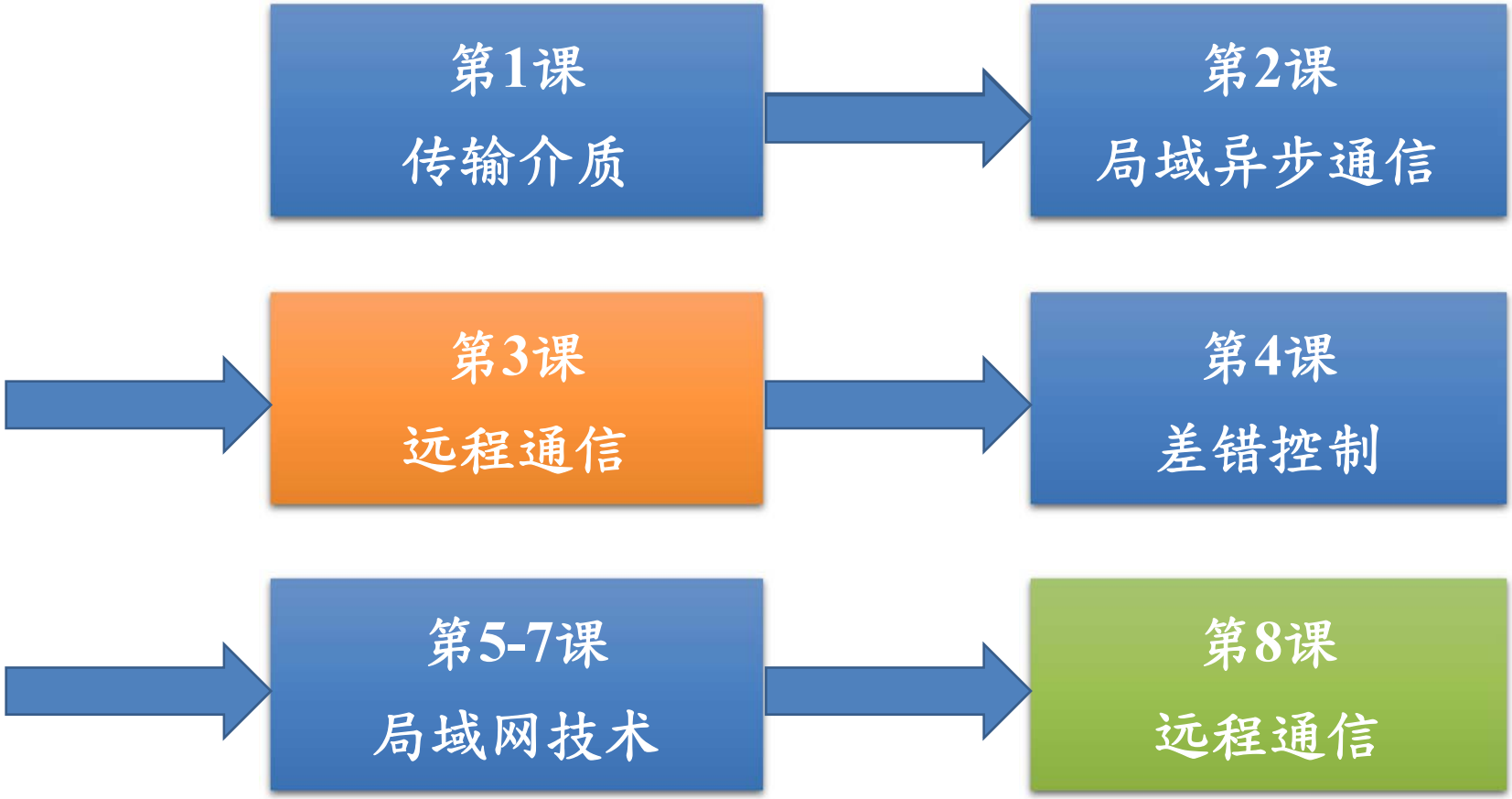

+15V
+3V
-3V
-15V
Idle
Start
LSB
1
1
0
1
0
0
1
MSB
0
Stop
Space
Idle
Mark
Start
b0
b1
b2
b3
b4
b5
b6
b7
Stop
Time

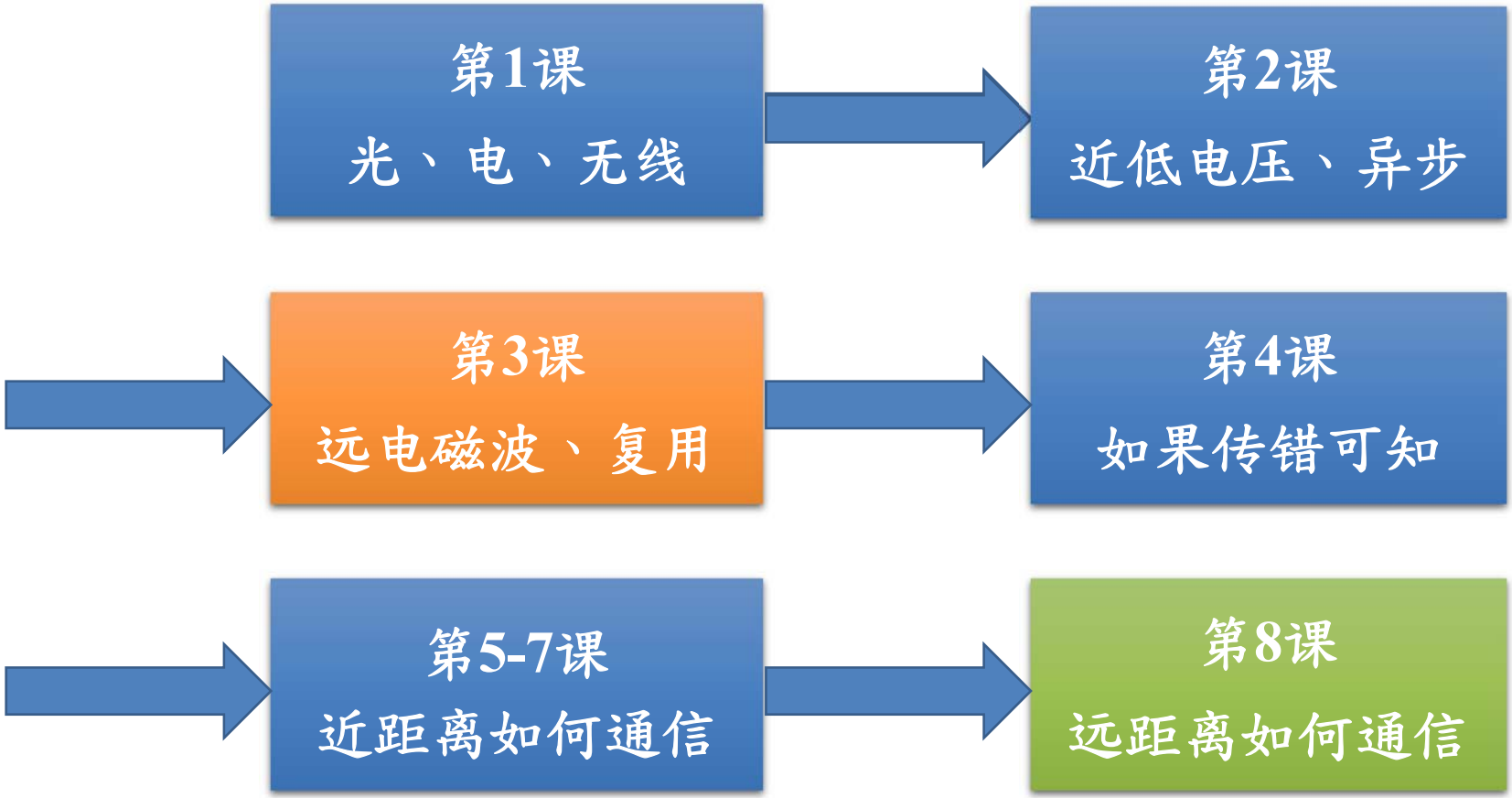
PART I Data Transmission

Ch 6 Long-Distance Communication (Carriers, Modulation, and Modems)

远程通信

(载波，调制和调制解调器)


第1课
传输介质
第2课
局域异步通信
第3课
远程通信
第4课
差错控制
第5-7课
局域网技术
第8课
远程通信


第1课
光、电、无线
第2课
近低电压、异步
第3课
远电磁波、复用
第4课
如果传错可知
第5-7课
近距离如何通信
第8课
远距离如何通信

与上节课的联系

50英尺以外如何通信？

RS-232只能帮你到这里了，以后都要靠自己了。

3~15V不行了，谁顶上？

与上节课的联系

永不消逝的电波

6.2 Sending Signals Across Long Distances

- **An electric current cannot be propagated (传播) an arbitrary distance over copper wire because the current becomes weaker as it travels.**
- **Engineers term the problem signal loss (信号损耗).**
- 原因：导线电阻是的少量的电能转换为内能。
- 结果：误码。

误码的产生

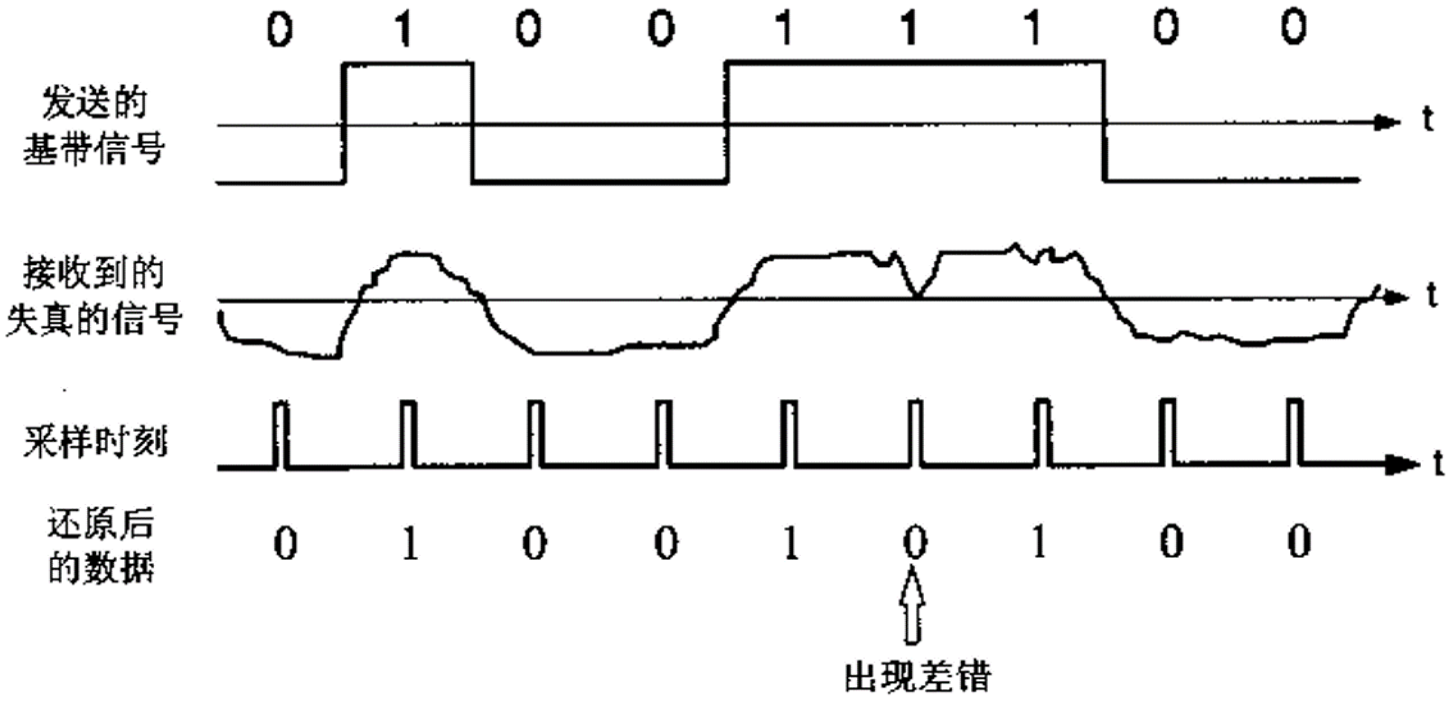


图 3-15　基带信号经电话线路传输后产生误码

本节课的关键技术

Carrier (载波)

连续震荡的电磁波

载波

- **A continuous oscillating (振荡) signal will propagate (传播) farther than other signals.**
- **Instead of transmitting an electric current that only changes when the value of a bit changes, long distance communication systems send a continuously (连续) oscillating (震荡) signal, usually a sine wave (正弦波), called a carrier (载波).**

载波

- **The carrier oscillates (震荡) continuously, even when no data is being sent.**
- **To send data, a transmitter modifies the carrier slightly. Such modification are called modulation (调制).**
- **The transmitter (发射器) generates a continuously oscillating carrier signal, which it modulates according to the data being sent.**

本节课的关键技术

Modulation (调制)

系统根据正在发送的信息

对载波所做的改变

本节课的关键技术

Demodulation (解调)

系统将被调制到载波上的信息

重新生成出来

模拟和数字的数据和信号转换

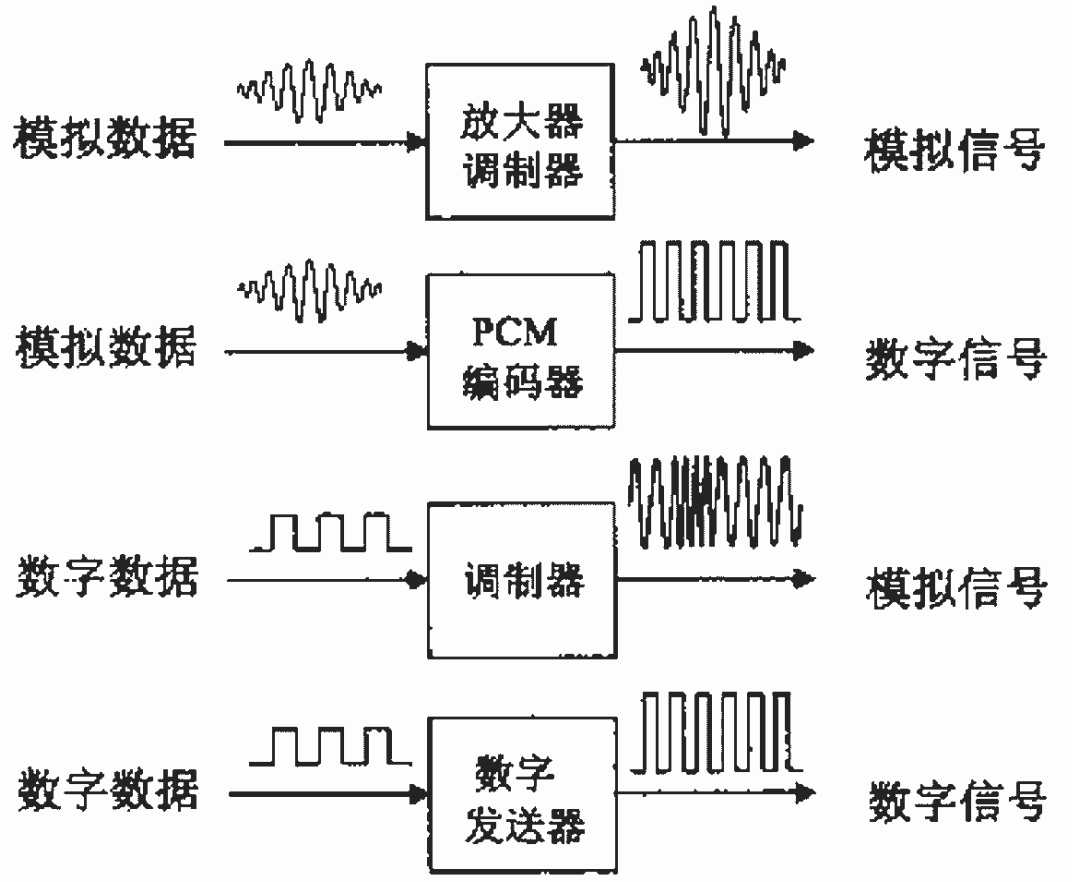


图 3-2　模拟数据、模拟信号、数字数据和数字信号

Modulation

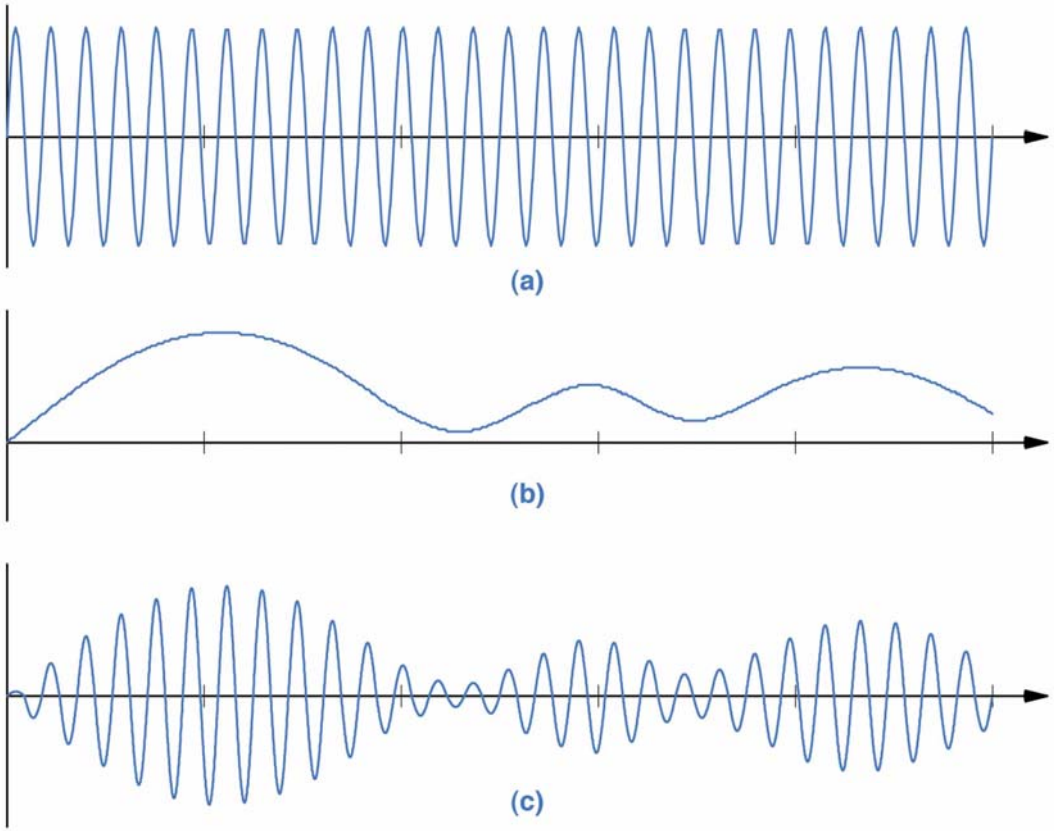


Figure 10.2 Illustration of (a) an unmodulated carrier wave, (b) an analog information signal, and (c) an amplitude modulated carrier.

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载波

- **The receiver on a long-distance communication link must be configured to recognize the carrier that the sender uses.**
- **The receiver monitors the incoming carrier, detects modulation, reconstructs (重建) the original data, and discards the carrier.**

Modulation techniques

- **Network technologies use a variety of modulation techniques, including：**
  - **amplitude modulation (AM调幅),**
  - **frequency modulation (FM调频),**
  - **phase shift modulation (PM调相).**

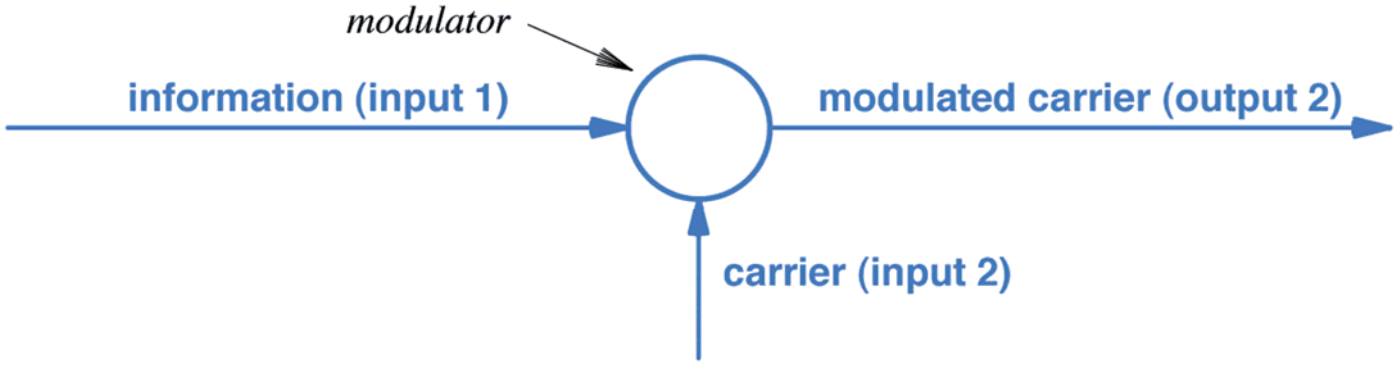

Figure 10.1 The concept of modulation with two inputs.

振幅、频率、相位

$$F(t) = A\sin(2\pi ft + \alpha)$$

A：振幅

f：频率

α：相位

Three Types of Modulation

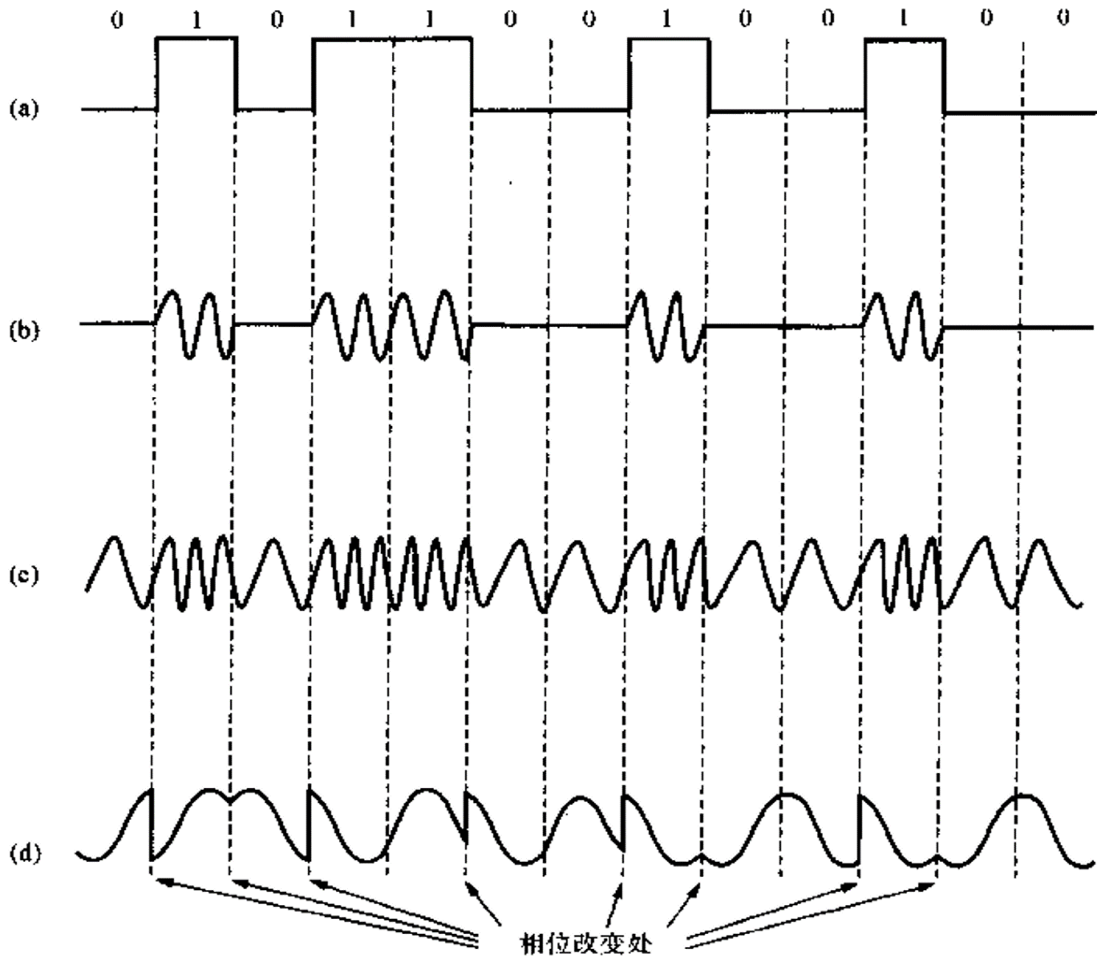

图 2-18 （a）一个二进制信号；（b）振幅调制；（c）频率调制；（d）相位调制。

Three Types of Modulation

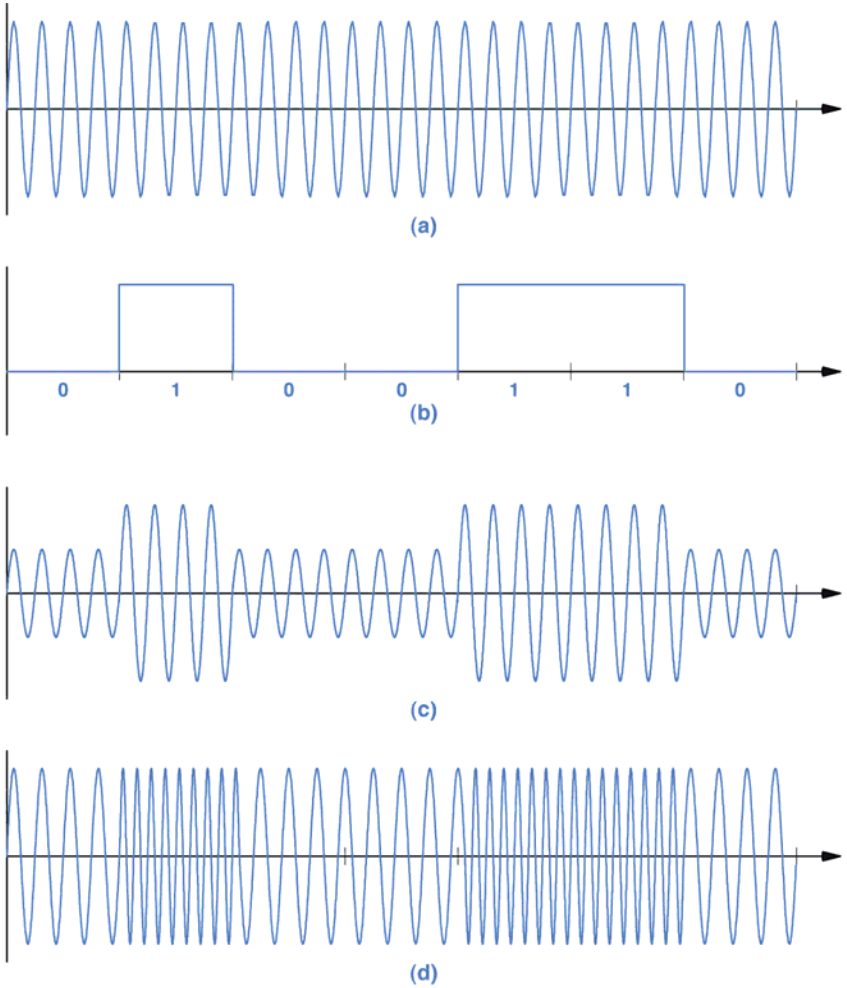

Figure 10.4 Illustration of (a) a carrier wave, (b) a digital input signal, (c) amplitude shift keying, and (d) frequency shift keying.

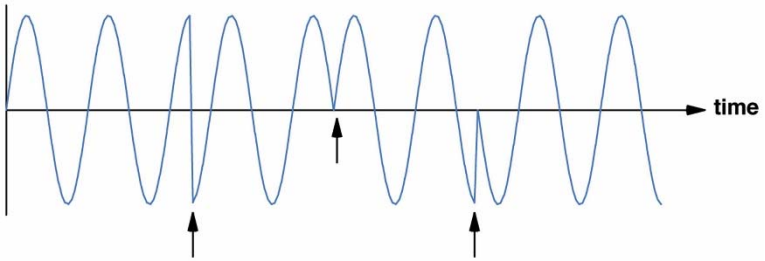

Figure 10.5 An illustration of phase shift modulation with arrows indicating times at which the carrier abruptly jumps to a new point in the sine wave cycle.

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6.3 Modem Hardware Used for Mo & Dem

- A hardware circuit (回路) that accepts a sequence of data bits and applies modulation to a carrier wave according to the bits is called a **modulator** (调制器).
- A hardware circuit that accepts a modulated carrier wave and recreates the sequence of data bits that was used to modulate the carrier is called a **demodulator** (解调器).

Modem

- Transmission of data across a long distance requires a modulator at one end of the transmission line and a demodulator at the other.
- Most network systems are full duplex, each location needs both a modulator and a demodulator.
- Manufactures combine both circuits into a single device called a modem (调制解调器).

Computer to Tel. to Computer

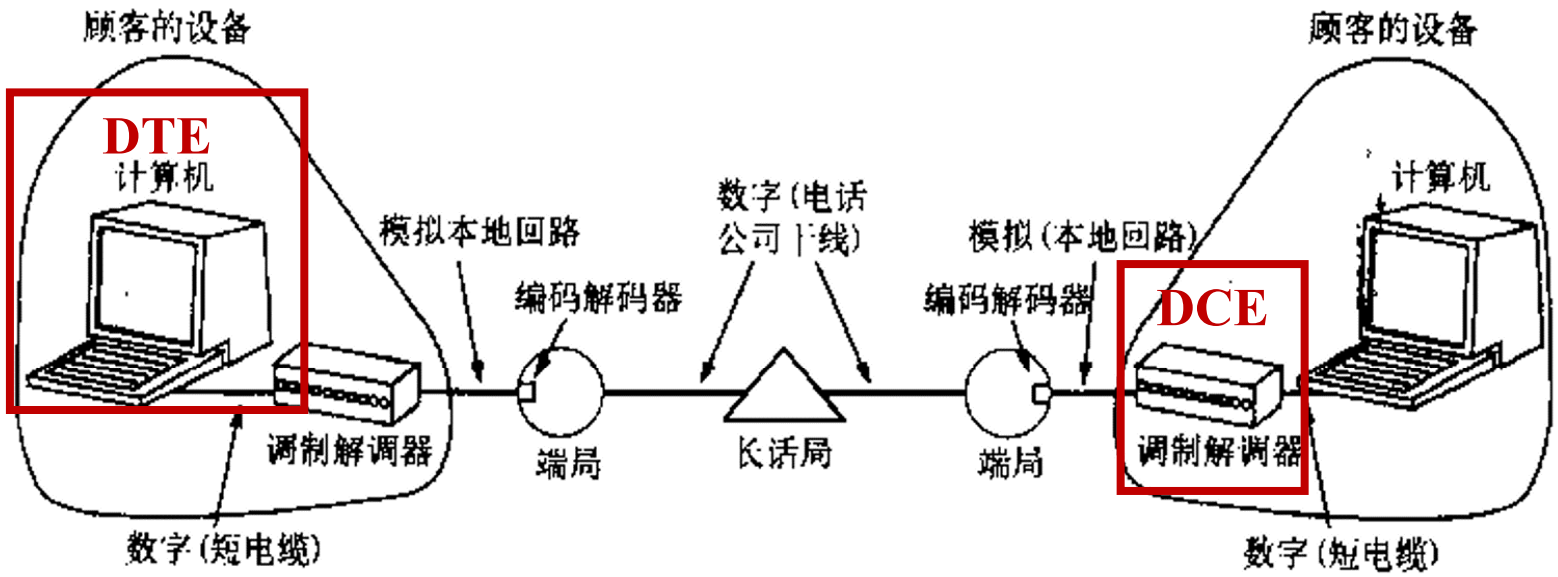

图 2-17　计算机与计算机之间的呼叫必须使用模拟及数字两种传输；其转换工作由调制解调器(modem)及编码解码器(codec)完成。

Two modems using 4-wire conn.

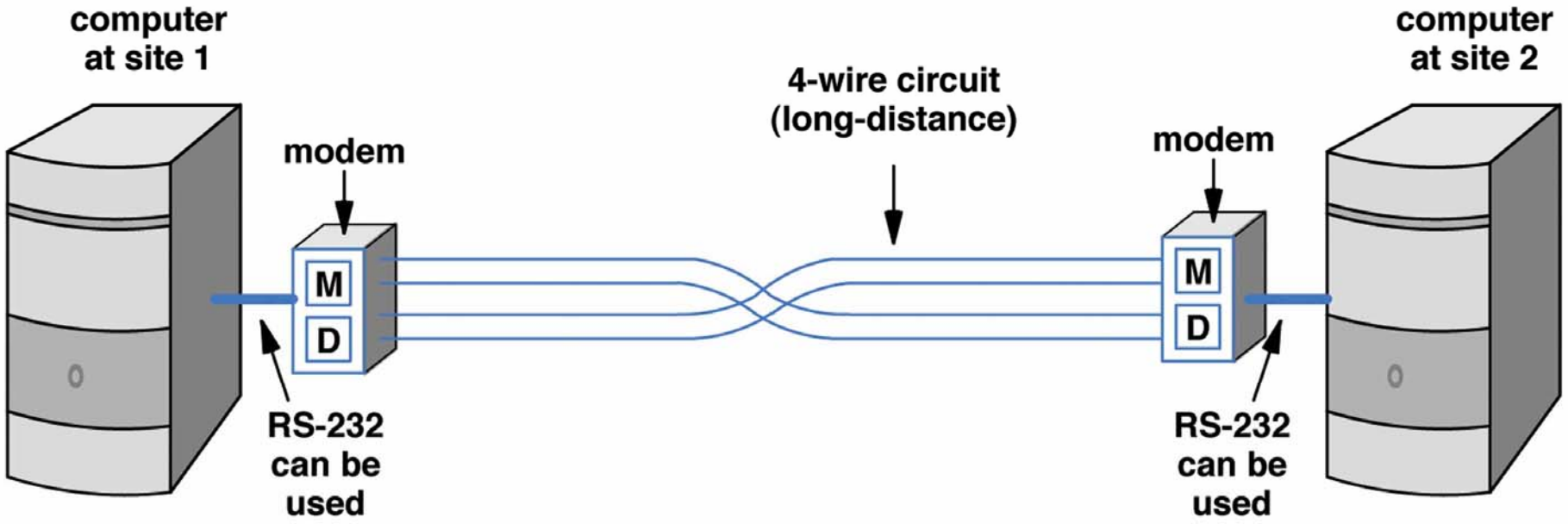

Figure 10.9 Illustration of two modems that use a 4-wire connection.

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虚调制解调器

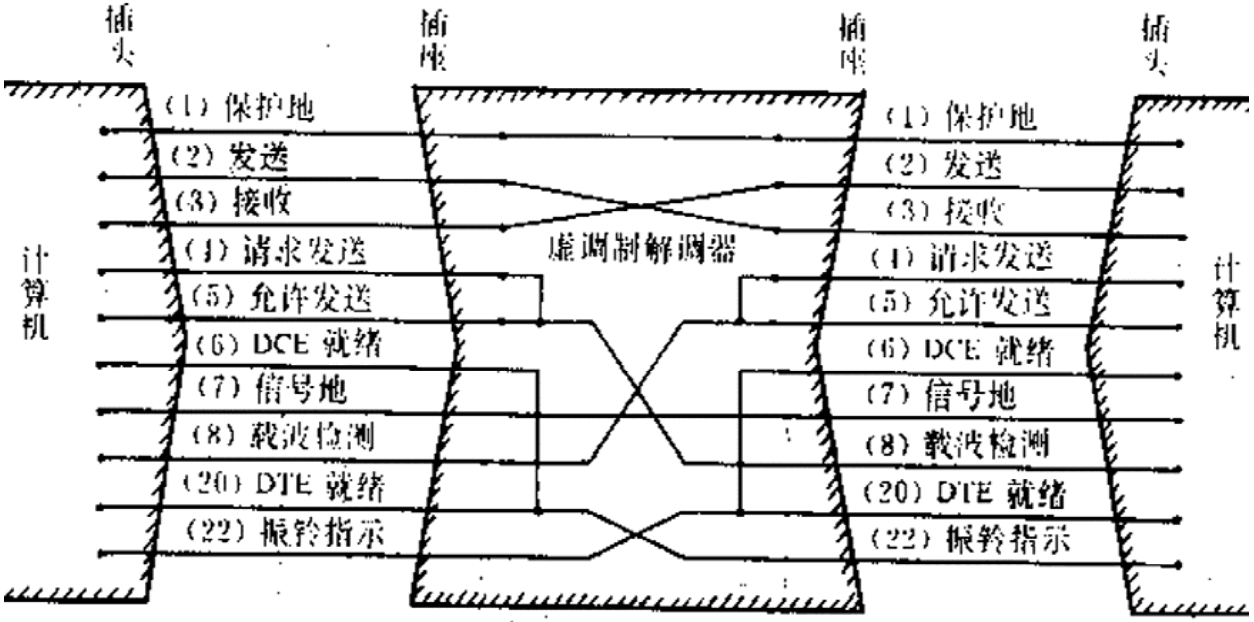

图 4-14 利用虚调制解调器使两台计算机相连

6.4 Leased Analog Data Circuits

- When the circuit connects two location at a single site, the company can install the necessary wires itself. Private companies cannot install circuits across long distance. (私人企业无法远距离安装电路)
- The necessary wiring can be obtained from a telephone company. Telephone companies allow companies to lease (租用) a circuit between any two locations.

6.4 Leased Analog Data Circuits

- Once a connection has been leased from the phone company, a modem must be installed at each end before communication is possible.
- After that, the leased line is available to send data.
  - Advantage: data can be sent at any time.
  - Disadvantage: the limited connectivity and cost.

6.5 Optical, Radio Frequency, Dialup Modems

- In addition to dedicated wires, modems are also used with other media, including RF transmission, glass fibers, and conventional telephone connections.
- A dialup modem contains circuitry that mimics a telephone----the modem can simulate lifting the handset, dialing, or hanging up the phone.

10.13 Optical and Radio Frequency Modems

- Modems are also used with other media including Radio Frequency transmission and optical fibers
  - A pair of RF modems can be used to send data via radio
  - A pair of optical modems can be used to send data across a pair of optical fibers
- Modems can use entirely different media, but the principle remains the same:
  - at the sending end, a modem modulates a carrier
  - at the receiving end, data is extracted from the modulated carrier

Digital and analog signals

- Term **internal modem** to denote an embedded device
- Term **external modem** to denote a separate physical device

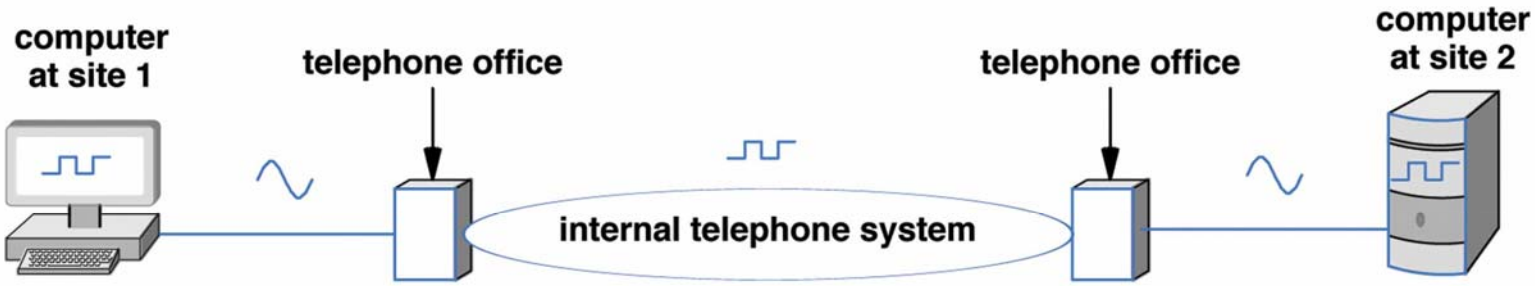

Figure 10.10 Illustration of digital and analog signals (denoted by a square wave and a sine wave) that occur when a dialup modem is used to send data from one computer to another.

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信道很贵

本节课的关键技术

Multiplexing (复用)

多个信源的信息流组合在一条共享介质上传输

11.2 The Concept of Multiplexing

- **Multiplexing (复用) to refer to the combination of information streams from multiple sources for transmission over a shared medium**
  - **Multiplexor is a mechanism that implements the concept**
- **Demultiplexing (解复用) to refer to the separation of a combination back into separate information streams**
  - **Demultiplexor to refer to a mechanism that implements the concept**

Multiplexing

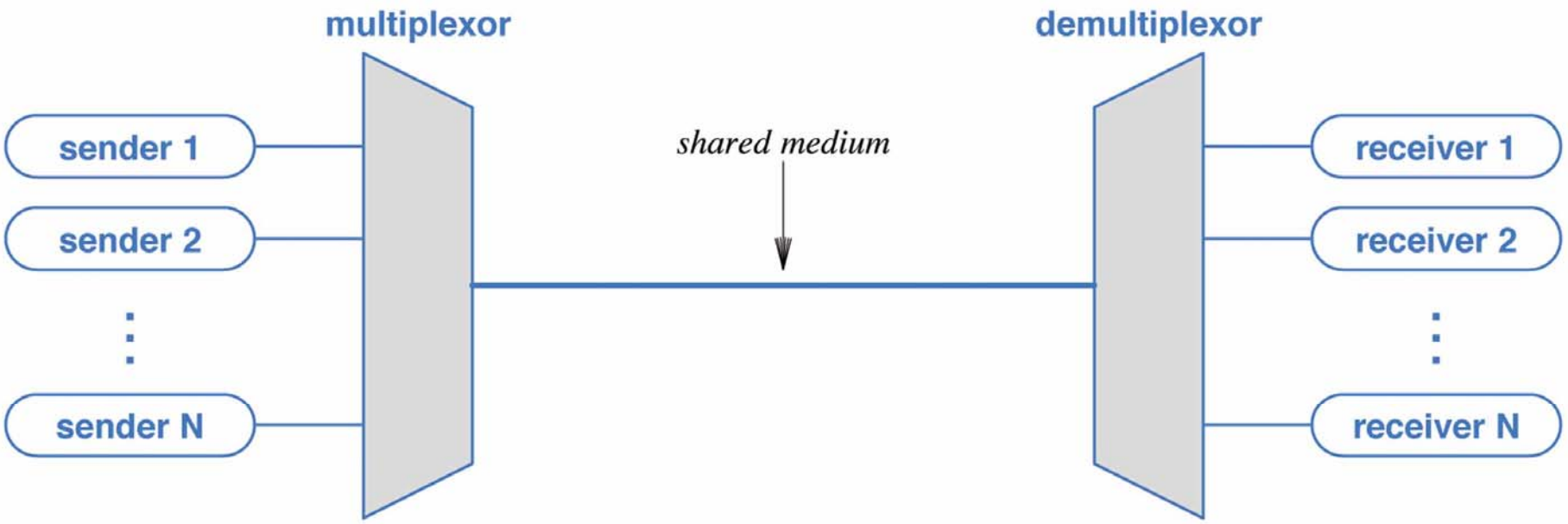

Figure 11.1 The concept of multiplexing in which independent pairs of senders and receivers share a transmission medium.

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11.3 The Basic Types of Multiplexing

- There are four basic approaches to multiplexing that each have a set of variations and implementations
  - Frequency Division Multiplexing (FDM 频分多路复用)
  - Wavelength Division Multiplexing (WDM 波分多路复用)
  - Time Division Multiplexing (TDM 时分多路复用)
  - Code Division Multiplexing (CDM 码分多路复用)
- TDM and FDM are widely used
- WDM is a form of FDM used for optical fiber
- CDM is a mathematical approach used in cell phone mechanisms

三大运营商的相关技术

- 中国移动
  - GSM，TD-SCDMA，TD-LTE
- 中国联通
  - GSM，WCDMA，FDD-LTE
  - TD-LTE
- 中国电信
  - CDMA2000
  - TD-LTE，FDD-LTE

FDD制式4G网络能实现实时的上传与下载，而TD制式4G网络需要通过信号灯切换改变上传与下载通道，对于用户而言，FDD的网络体验相对来说会更胜一筹。

多重奏

6.6 Carrier Frequency And Multiplexing

- **Each television station is assigned a channel number on which it broadcasts a signal.**
- **A channel number is merely shorthand for the frequency at which the station's carrier oscillates.**
- **The signal for one channel does not interfere with the signal for another.**

6.6 Carrier Frequency And Multiplexing

- **Computer networks use the principle of separate channels to permit multiple communication to share a single, physical connection.**
- **Each sender transmits a signal using a particular carrier frequency.**
- **Multiple carriers can pass over the same wire at the same time without interference.**

Frequency division multiplexing

- **Frequency division multiplexing (FDM频分多路复用)：multiple carrier frequencies to allow independent signal to travel through a medium.**
- **FDM allows multiple pairs of senders and receivers to communication over a shared medium simultaneously. The carrier used by each pairs operates at a unique frequency that does not interfere with the others.**

Frequency division multiplexing

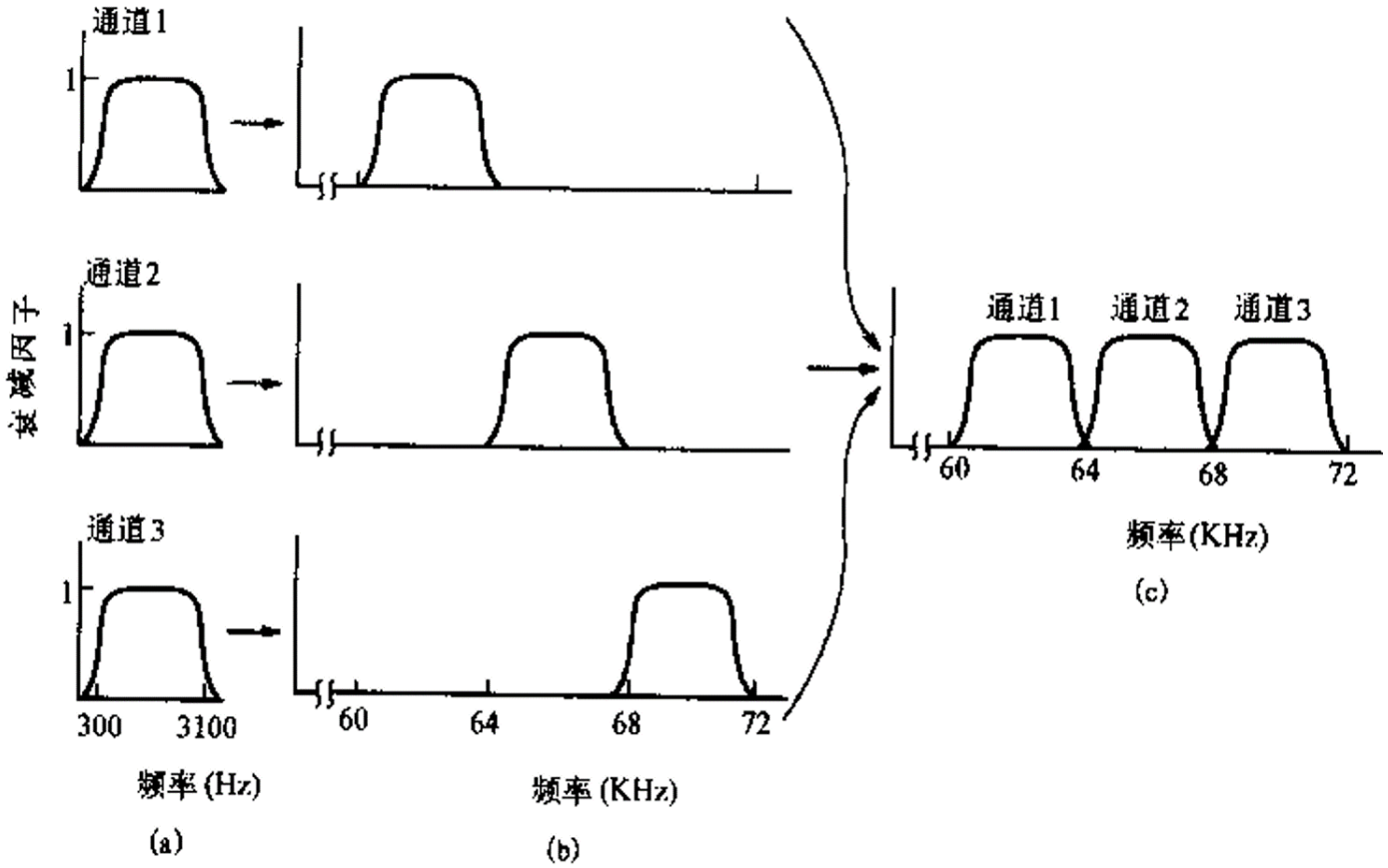

图 2-24　频分多路复用

(a) 原来的带宽；(b) 带宽被升频；(c) 多路复用的通道。

Guard band

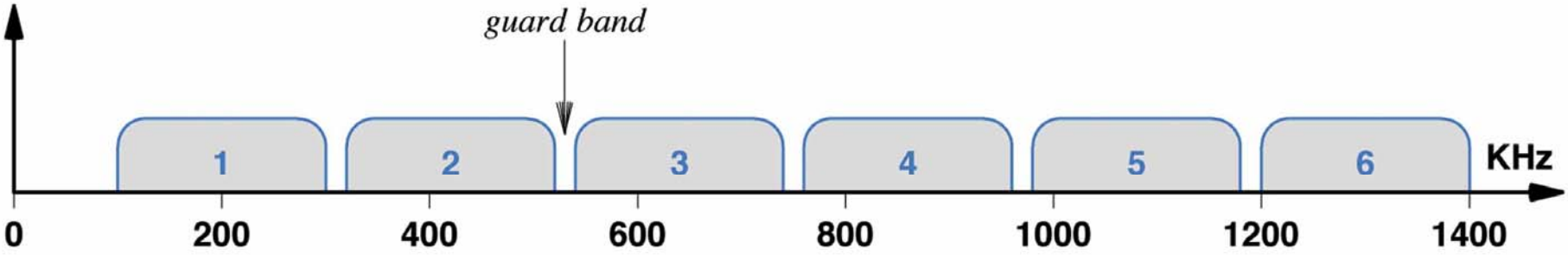

Figure 11.5 A frequency domain plot of the channel allocation from Figure 11.4 with a guard band visible between channels.

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6.7 Baseband and Broadband technology

- The primary motivation for using Frequency division multiplexing (FDM) arises from the desire for high throughput (吞吐量).
- To achieve higher throughput, the underlying hardware uses a larger part of the electromagnetic spectrum (频谱) (i.e., a larger bandwidth)

Broadband (宽带技术)

- The term broadband (宽带) refers to the wide bandwidth characteristics of a transmission medium and its ability to transport multiple signals and traffic types simultaneously.
  - The medium can be coax, optical fiber, twisted pair or wireless.
- In contrast, baseband describes a communication system in which information is transported across a single channel.

基带信号和宽带信号

- 基带信号就是将数字信号1或0直接用两种不同的电压来表示，然后送到线路上去传输。
- 宽带信号是将基带信号进行调制后形成的频分复用模拟信号。
- 基带信号进行调制后，其频谱被移到较高的频率处，每一路基带信号的频谱被移到不同的频段，因此合在一起不会互相干扰。
- 因此，一条电缆中可以同时传送多路的数字信号，从而提高了线路的利用率。

6.8 Wave Division Multiplexing

- Technically, optical FDM is known as Wave Division Multiplexing (WDM).
- WDM operates by sending multiple light waves across a single optical fiber.
- At the receiving end, an optical prism is used to separate the frequencies.

波分多路复用

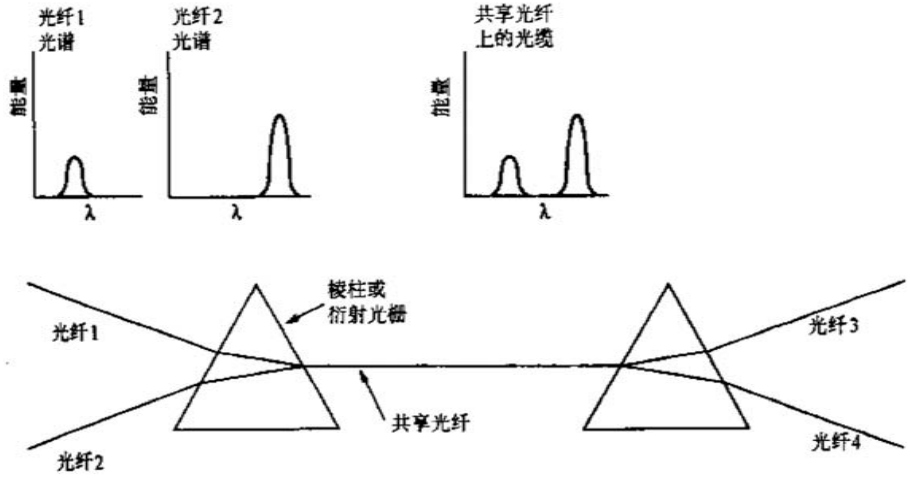

图 2-25 波分多路复用

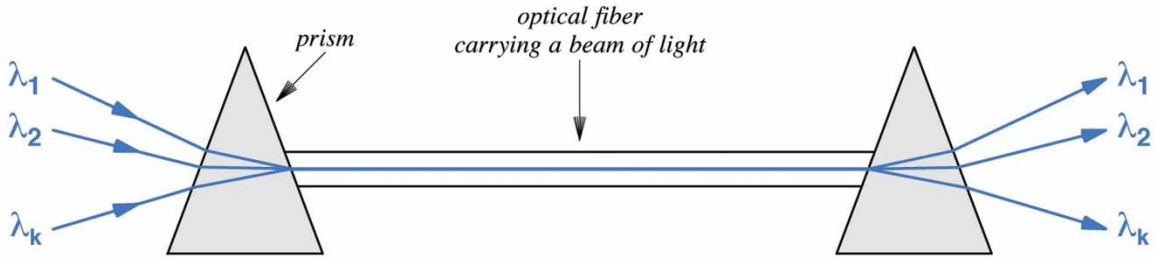

Figure 11.7 Illustration of prisms used to combine and separate wavelengths of light in wavelength division multiplexing technologies.

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EDAF

- **EDAF: 光纤放大器，直接对光信号进行放大。**

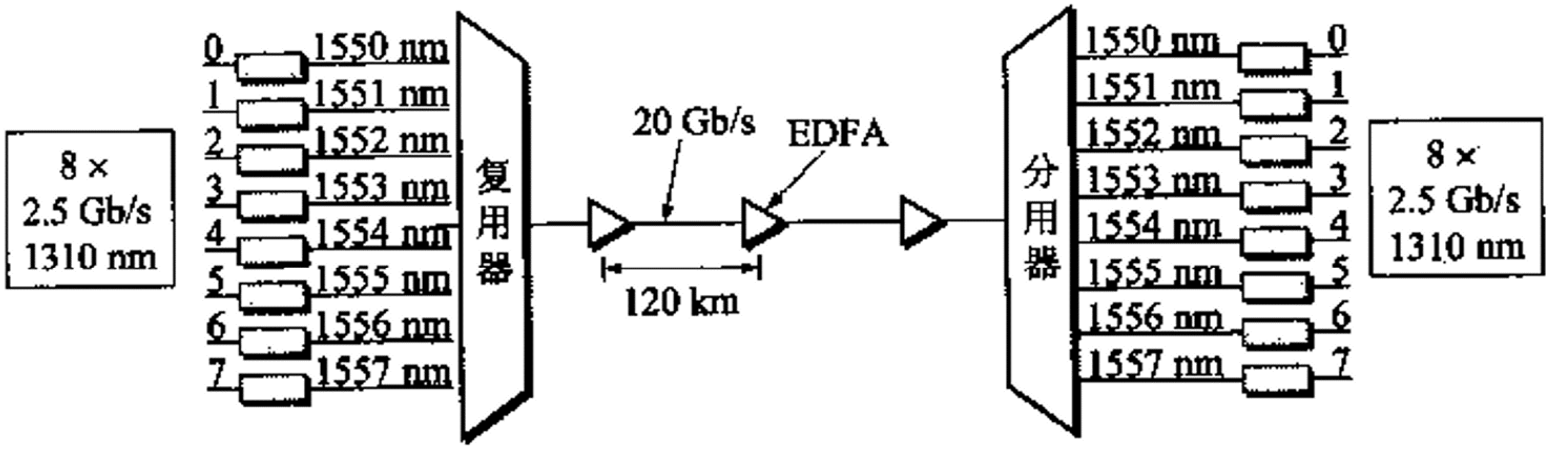


图 3-24　波分复用的概念

DWDM

- 由于光载波的频率很高，因此习惯上用波长表示光载波。
- 现在可以在一根光纤上复用80路或更多路数的光载波信号，即密集波分复用DWDM (dense wavelength division multiplexing)。

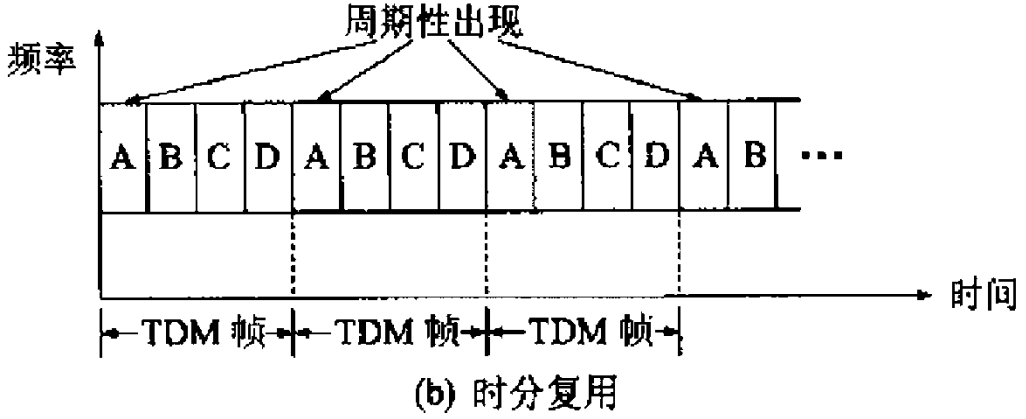
6.9 Spread Spectrum 扩散频谱

- A transmitter sends the same signal on a set of carrier frequencies.
- A receiver is configured to check all carrier frequencies and to use whichever is working at present.
- Some modems select a set of carrier frequencies and use them simultaneously.
- If interference damages one or more of the carriers, the modem can extract the data from the others.

6.10 Time Division Multiplexing

- **Time Division Multiplexing (TDM).**
- **There are two types of TDM:**
  - **Synchronous Time Division Multiplexing (STDM，同步时分多路复用).**
  - **Statistical Multiplexing (统计多路复用).**

TDM



(b) 时分复用

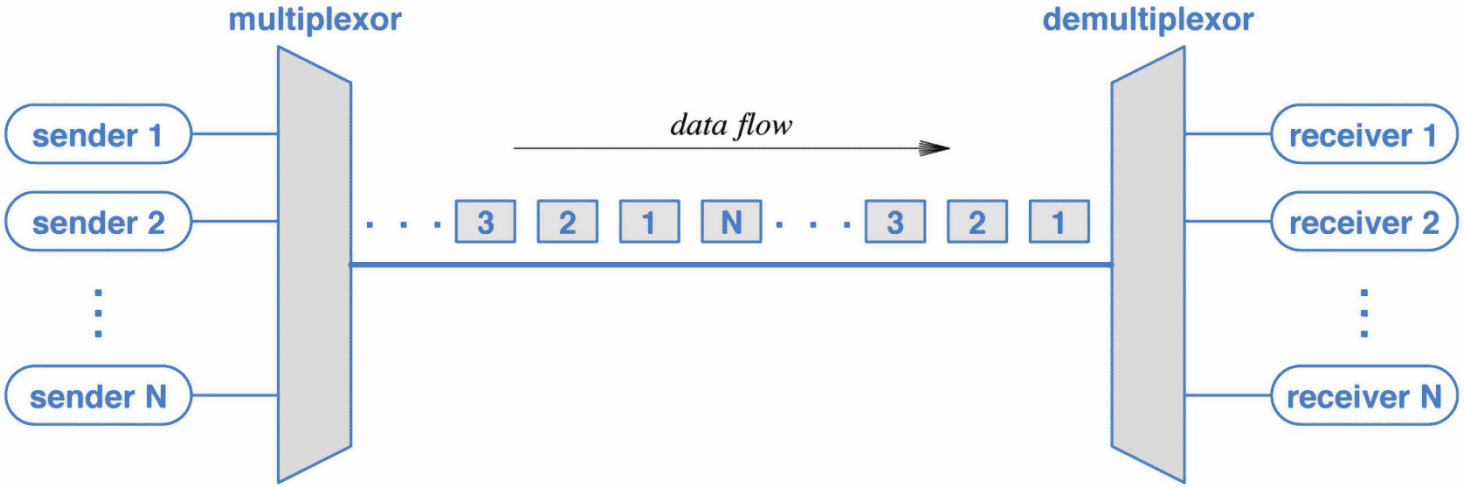


Figure 11.8 Illustration of the Time Division Multiplexing (TDM) concept with items from multiple sources sent over a shared medium.

TDM

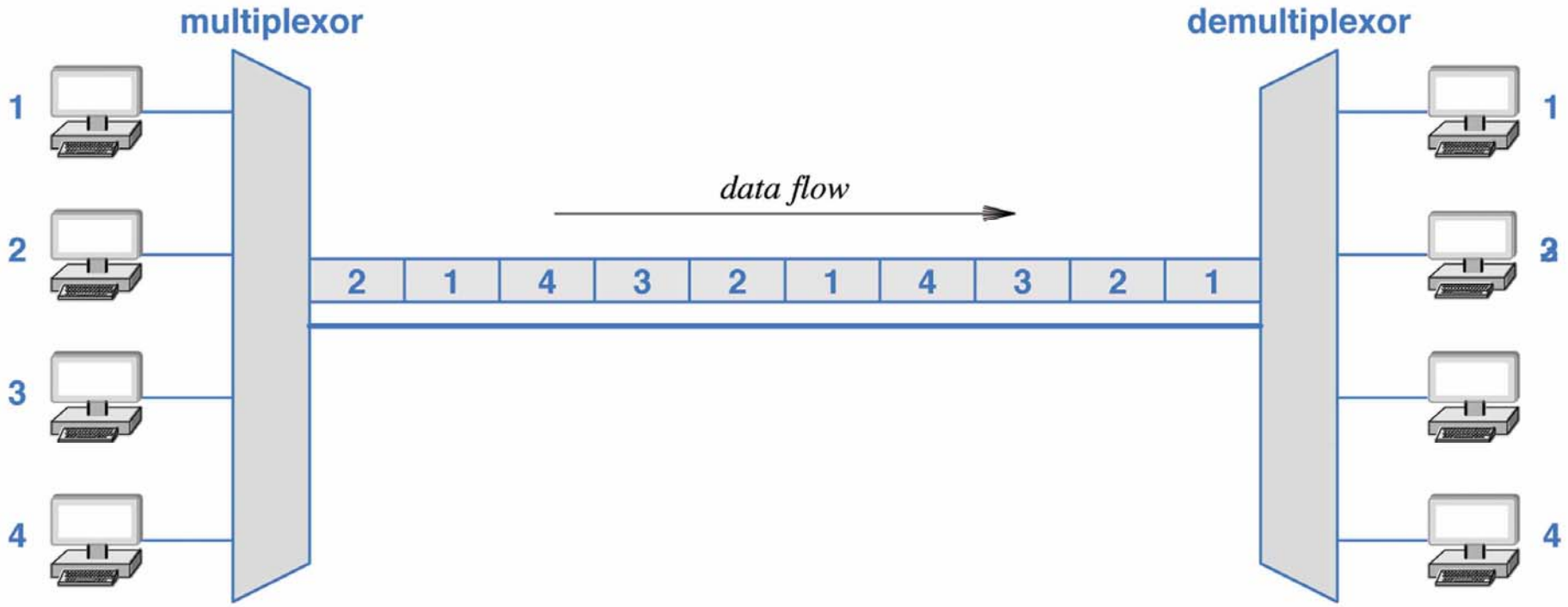


Figure 11.9 Illustration of a Synchronous Time Division Multiplexing system with four senders.

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时分复用

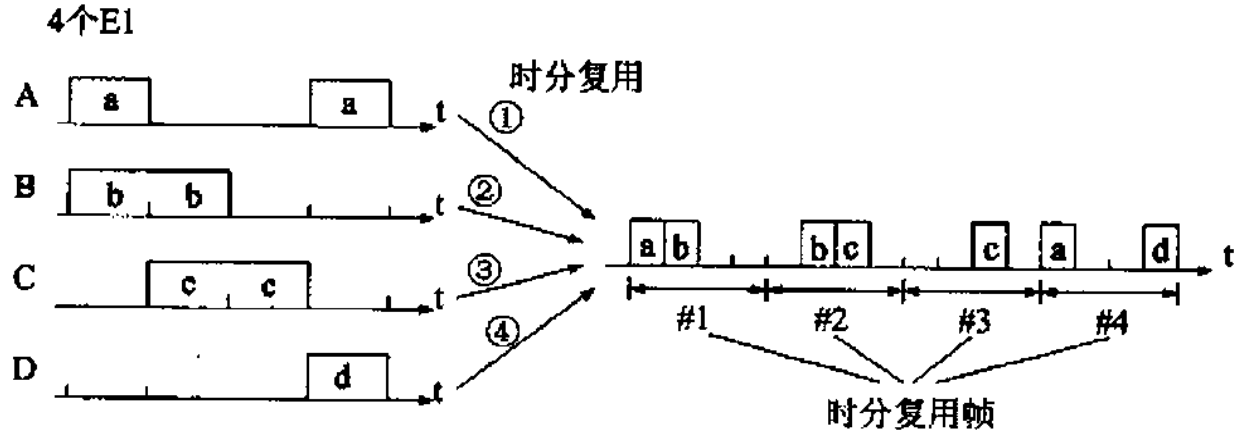

图 3-22　时分复用可能会造成线路资源的浪费

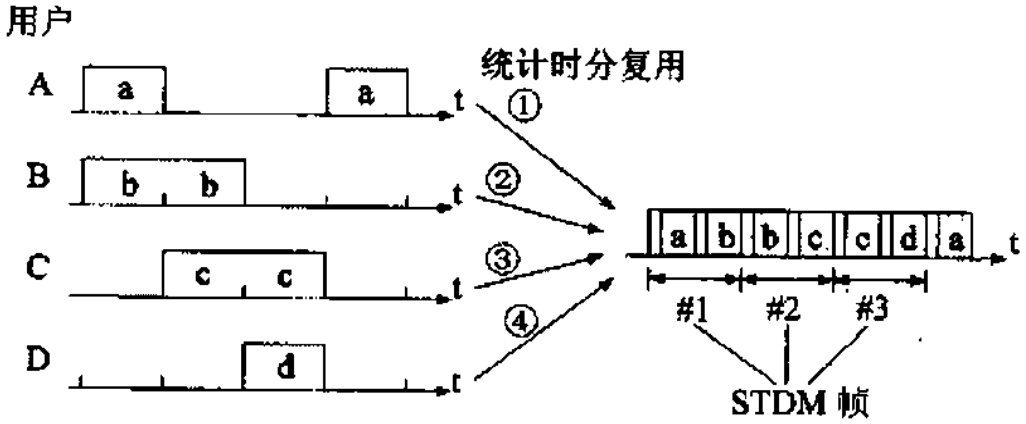

图 3-23　统计时分复用的工作原理

Statistical Multiplexing in TDM

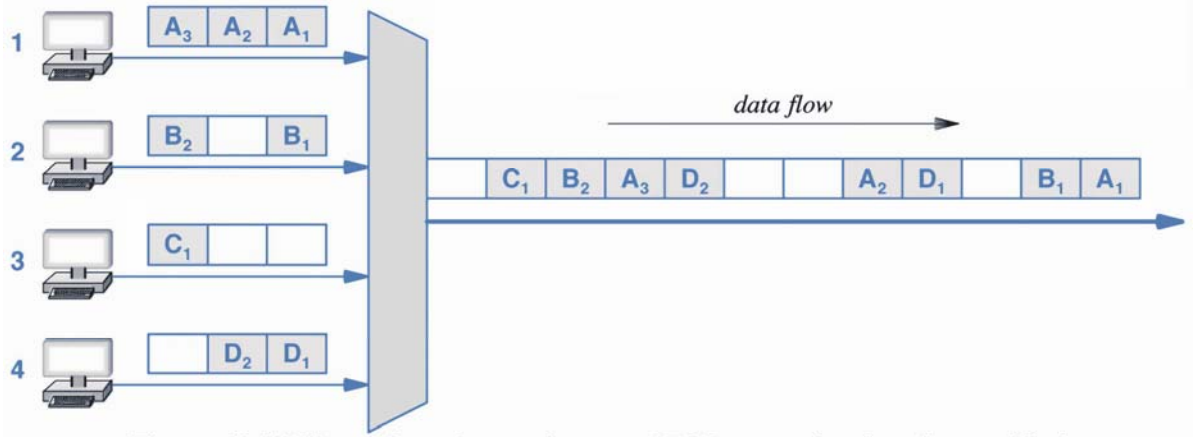

Figure 11.12 Illustration of a synchronous TDM system leaving slots unfilled when a source does not have a data item ready in time.

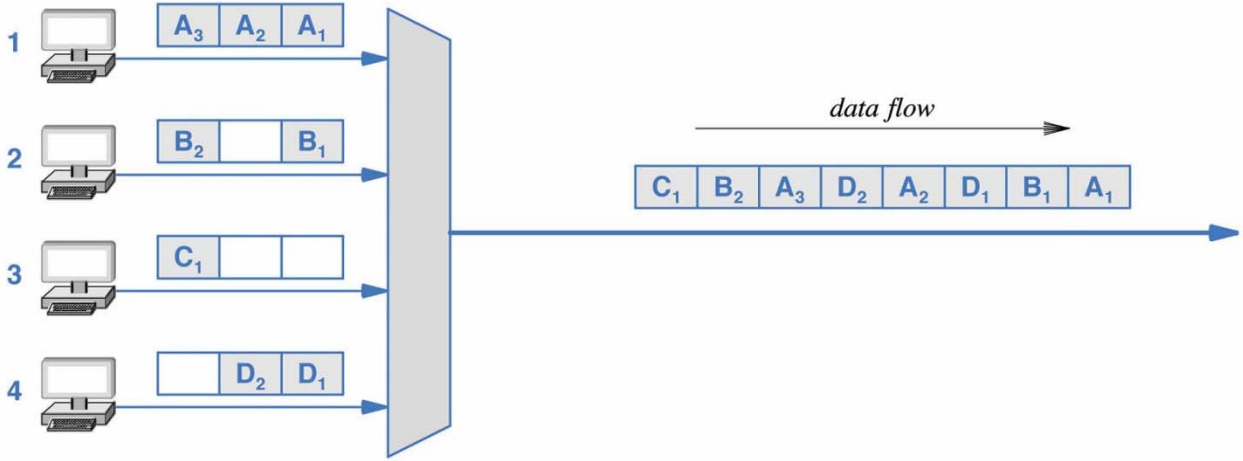

Figure 11.13 Illustration that shows how statistical multiplexing avoids unfilled slots and takes less time to send data.

E1的时分复用帧

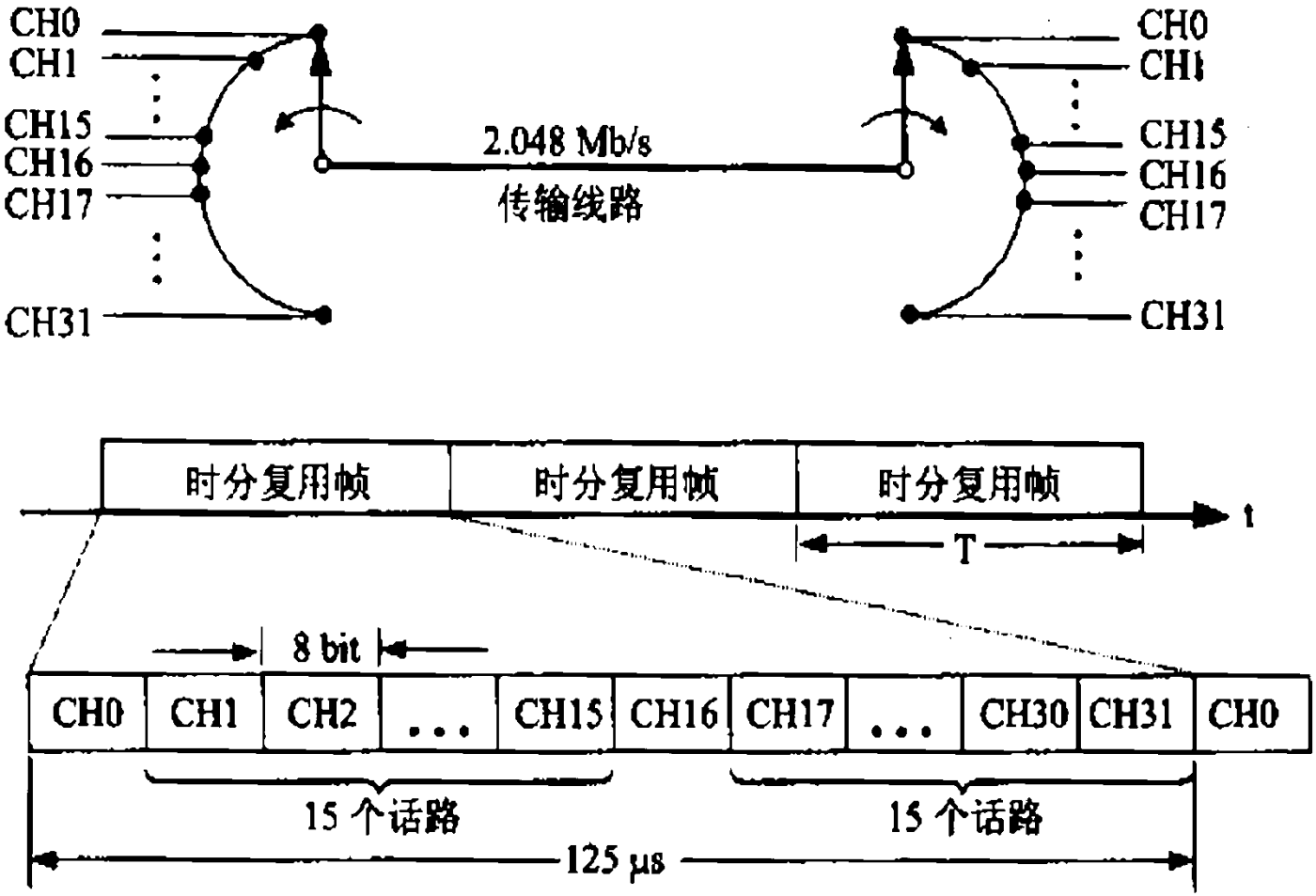

图 3-20　E1 的时分复用帧

什么是CDMA？

Code Division Multiple Access

中国电信的手机网络通讯技术

码分复用

- 详见课本11.15

Sender	Chip Sequence	Data Value
A	1 0	1 0 1 0
B	1 1	0 1 1 0

Figure 11.15 Example values for use with code division multiplexing.

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码分复用

- 思考题：中国电信、中国移动、中国联通的2G～4G都使用了何种通信技术？

下一节

逐步走向软件

怎么传输多个位

如何才能传的对

计算机网络

3.

THANK YOU.

厦门大学软件学院

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