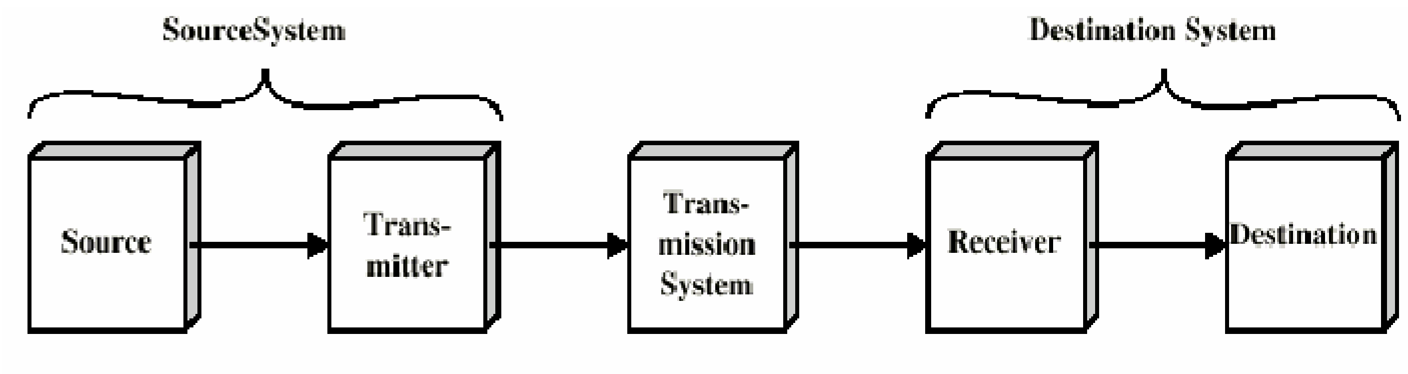
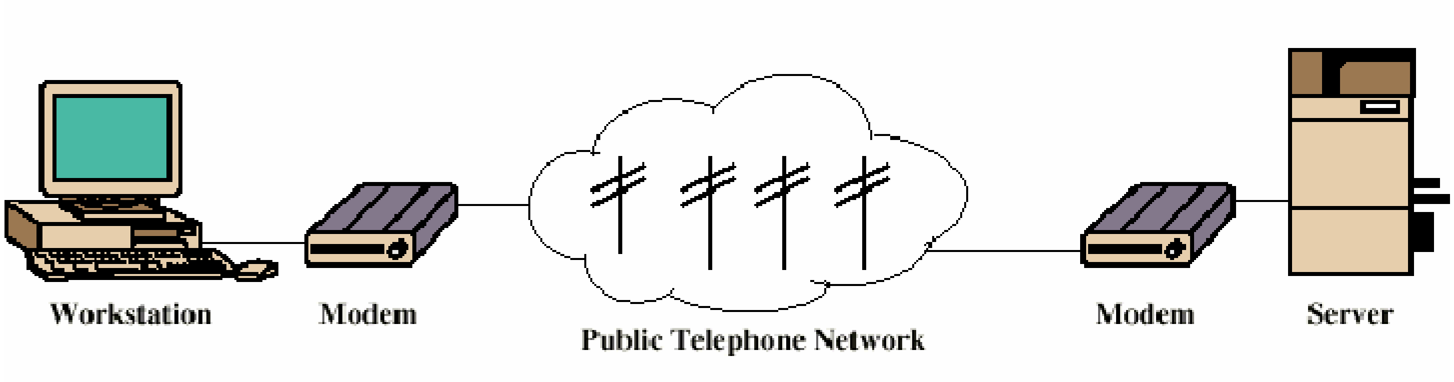
ບົດທີ 3 ເຕັກນິກການສື່ສານຂໍ້ມູນດິຈິຕອນ ແລະ ເຕັກນິກການເຂົ້າລະຫັດ (DIGITAL COMMUNICATION AND ENCODING TECHNIQUE)

ການສົ່ງສັນຍານຂໍ້ມູນ (Data Transmission) ຄືການສົ່ງຂ່າວສານ (Information) ເພື່ອສົ່ງໃຫ້ອຸປະກອນປະມວນຂ່າວສານ (Information Processing Equipment) ທີ່ຮູ້ຈັກກັນດີຄືຄອມພິວເຕີ ດັ່ງນັ້ນ ລະບົບທີ່ເຊື່ອມໂຍງຄອມພິວເຕີກັບອຸປະກອນຮັບສົ່ງຂໍ້ມູນປາຍທາງທີ່ຢູ່ຫ່າງໄກກັນໃຫ້ສາມາດສົ່ງຜ່ານຂໍ້ມູນລະຫວ່າງກັນໄດ້ ຈະຕ້ອງປະກອບດ້ວຍອຸປະກອນທີ່ໃຊ້ຮັບສົ່ງ ແລະ ຕົວກາງນຳສັນຍານ (Media) ແບບຕ່າງໆ.

ໂຄງສ້າງການສື່ສານຂໍ້ມູນ





ຕົວຢ່າງການສື່ສານຂໍ້ມູນ

ສຳລັບອັດຕາຄວາມໄວໃນການສົ່ງຂໍ້ມູນດິຈິຕອນຈະວັດຈາກຈຳນວນບິດຂໍ້ມູນທີ່ສາມາດສົ່ງໄດ້ໄລຍະເວລາ 1 ວິນາທີ (bit per second: bps) ເຊິ່ງເອີ້ນວ່າ ອັດຕາບິດ (Bit Rate/Data Rate) ໃນຂະນະທີ່ ອັດຕາບອດ (Baud Rate) ຈະວັດຈຳນວນຂອງສັນຍານທີ່ຖືກປ່ຽນພາຍໃນ 1 ວິນາທີ.

Bit Rate vs Baud Rate

- **ອັດຕາບິດ (Bit rate: bps)**
  - ແມ່ນຈຳນວນຂອງບິດຕໍ່ວິນາທີ (Number of bits per second)
- ***ອັດຕາບອດ (Baud rate) (signal unit/sec: baud / sec: baud)***
  - ແມ່ນຈຳນວນຂອງກຸ່ມສັນຍານຕໍ່ວິນາທີ (Number of signal units per second)
  - ນ້ອຍກວ່າ ຫຼື ເທົ່າກັບອັດຕາບິດ (less than or equal to the bit rate)

Example

ສິ່ງສັນຍານອະນາລັອກ 4 ບິດ ຂອງແຕ່ລະກຸ່ມສັນຍານ. ຖ້າຫາກວ່າສິ່ງສັນຍານ 1000 ສັນຍານຕໍ່ວິນາທີ, ຈົ່ງຊອກຫາ: ອັດຕາ baud ແລະອັດຕາ bit

Solution

Baud Rate = 1000 bauds per second (baud/s)

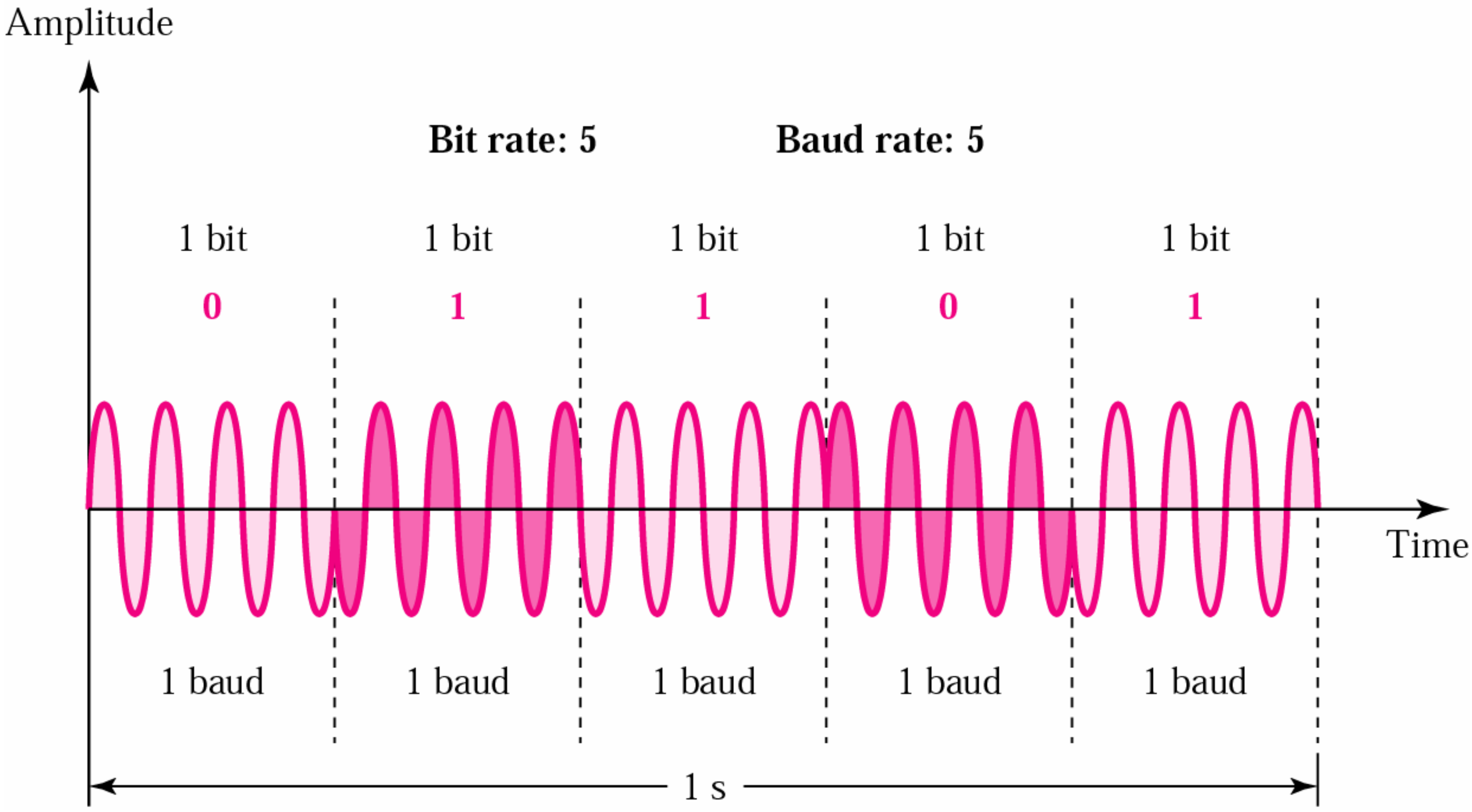
Bit Rate = 1000 x 4 = 4000 bps

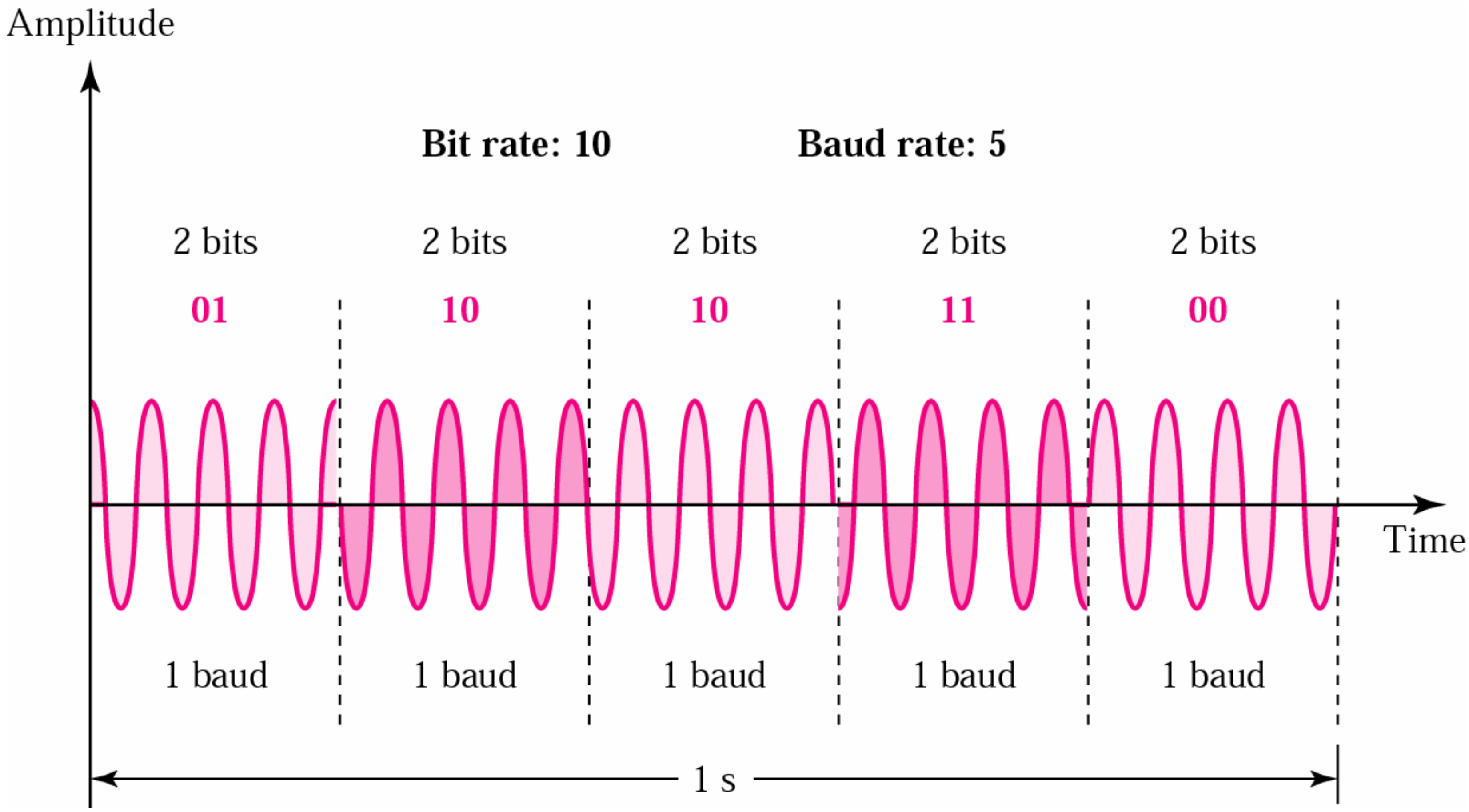
Example

ຈຳນວນອັດຕາບິດຂອງສັນຍານແມ່ນ 3000. ຖ້າຫາກແຕ່ລະກຸ່ມສັນຍານທີ່ສົ່ງອອກໄປແມ່ນ 6 ບິດ. ຖາມວ່າອັດຕາຂອງບອດແມ່ນເທົ່າໃດ

Solution

Baud rate = 3000 / 6 = 500 baud/s


Amplitude
Bit rate: 5
Baud rate: 5
1 bit
1 bit
1 bit
1 bit
1 bit
0
1
1
0
1
Time
1 baud
1 baud
1 baud
1 baud
1 baud
1 s

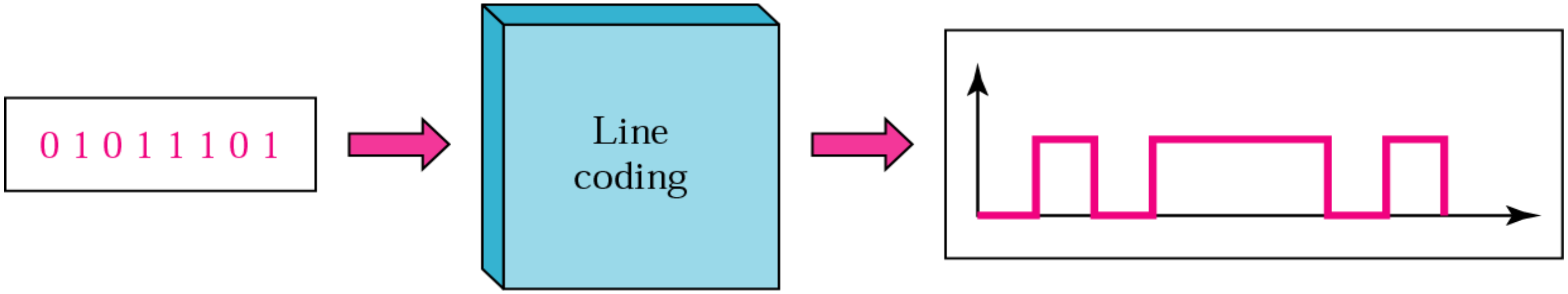

Amplitude
Bit rate: 10
Baud rate: 5
2 bits
01
2 bits
10
2 bits
10
2 bits
11
2 bits
00
Time
1 baud
1 baud
1 baud
1 baud
1 baud
1 s

ລາຍລະອຽດການສົມທຽບອັດຕາຂໍ້ມູນດິຈິຕອນ (BITS RATE COMPARISION)

1 Bit	Binary Digit
8 Bits	1 Byte
1024 Bites	1 Kilobyte
1024 Kilobytes	1 Megabyte
1024 Megabytes	1 Gigabyte
1024 Gigabytes	1 Terabyte
1024 Terabytes	1 Petabyte
1024 Petabytes	1 Exabyte
1024 Exabytes	1 Zettabyte
1024 Zettabytes	1 Yottabyte
1024 Yottabytes	1 Brontobyte
1024 Brontobytes	1 Geopbyte

DIGITAL TRANSMISSION

Actual signal: digital pulse

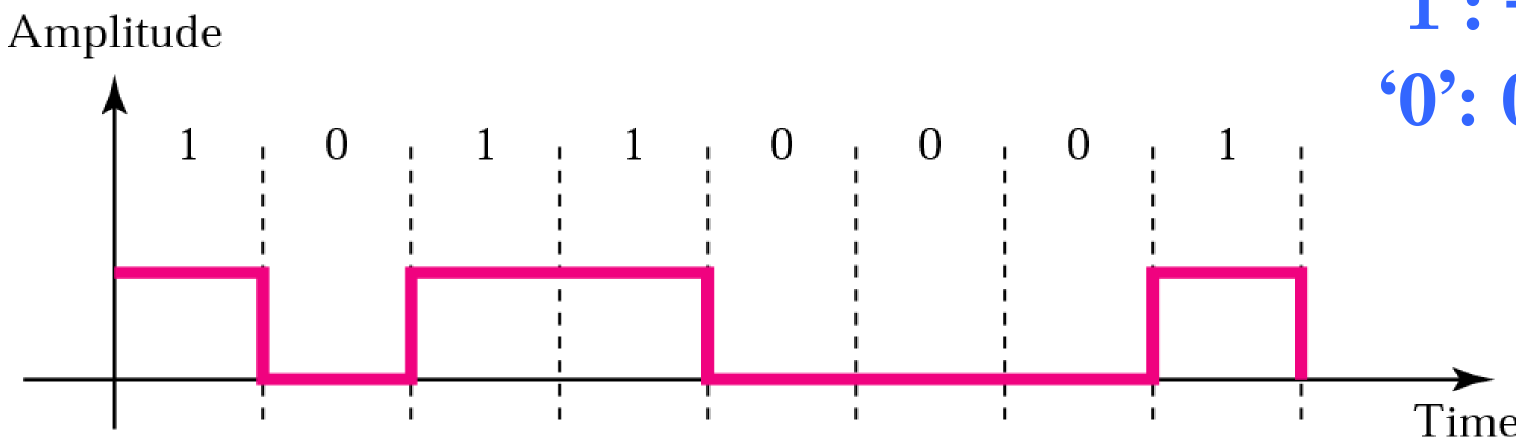


Digital data: Abstract Data

Figure *Signal level versus data level*

'1': +5V

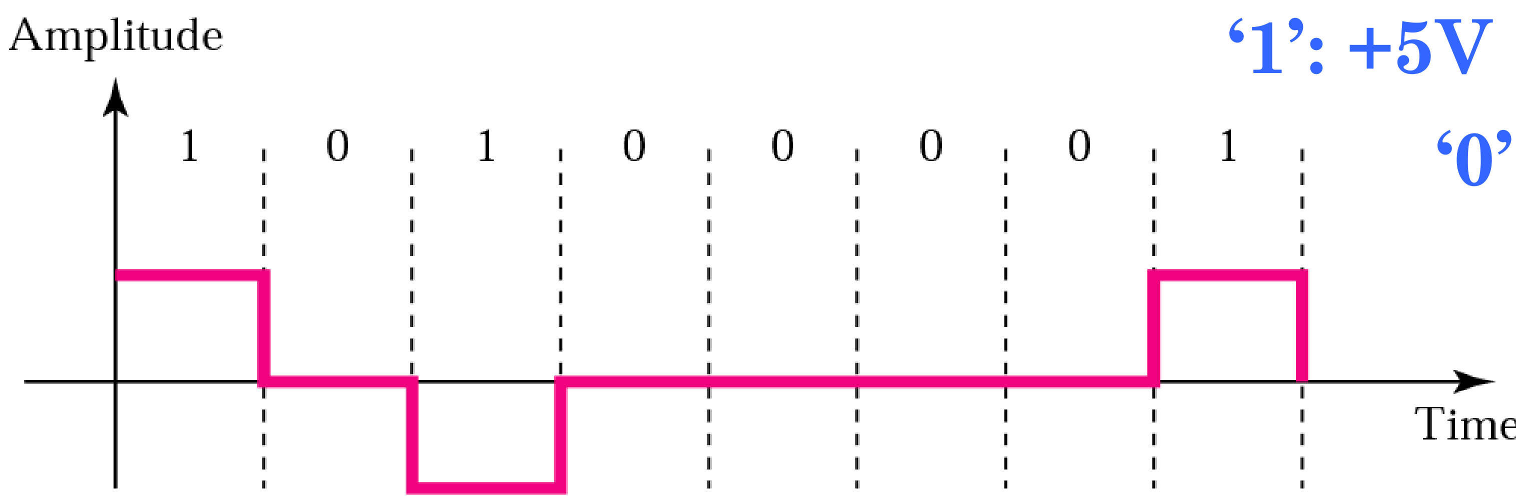
'0': 0V



a. Two signal levels, two data levels

'1': +5V or -5V

'0': 0V



b. Three signal levels, **two** data levels

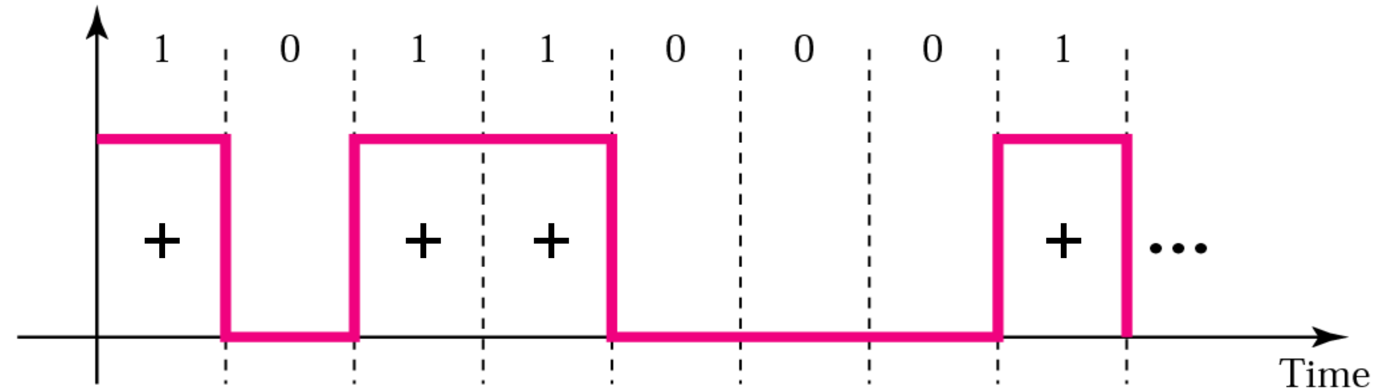
ບັນຫາທີ່ເກີດກັບໃນການແປງສັນຍານຂໍ້ມູນດິຈິຕອນ (PROBLEMS DIGITAL DATA TO DIGITAL SIGNAL CONVERSION)

- DC component
  - ສັນຍານດິຈິຕອນທີ່ມີອົງປະກອບຂອງສັນຍານ DC ເຮັດໃຫ້ລະດັບສັນຍານພົ້ງນ
- Lack of Synchronization
  - ການກວດຈັບບິດຂໍ້ມູນຜິດຕຳແໜ່ງເຮັດໃຫ້ອ່ານຄ່າຂອງລະດັບສັນຍານຜິດໄປ

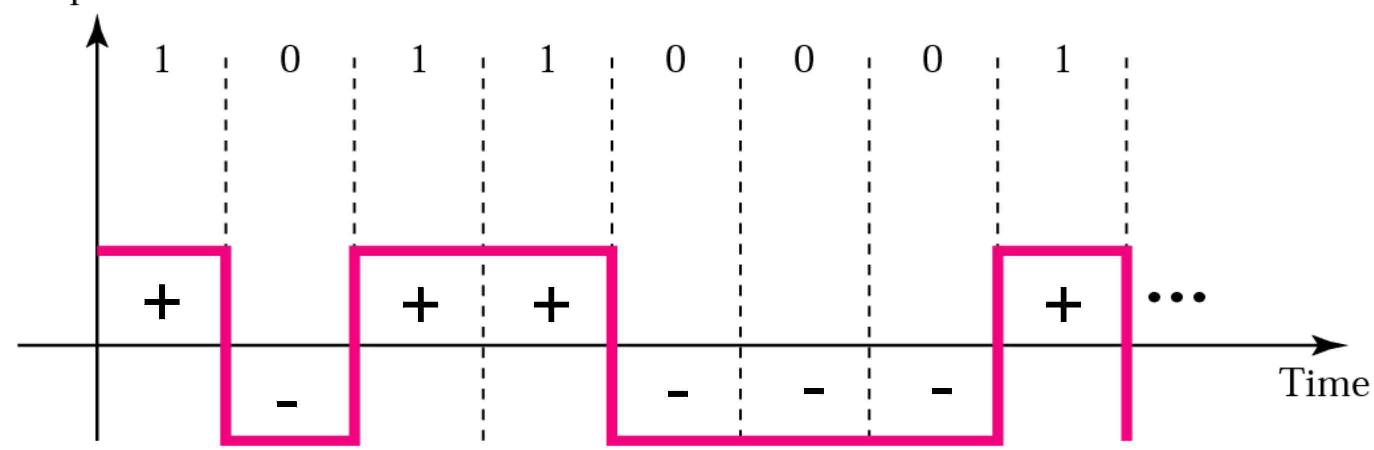
ບັນຫາເຫຼົ່ານີ້ສົ່ງຜົນ

- ຕົວຮັບແປງສັນຍານກັບເປັນບິດຂໍ້ມູນຜິດພ້ຽນໄປ

Figure DC component

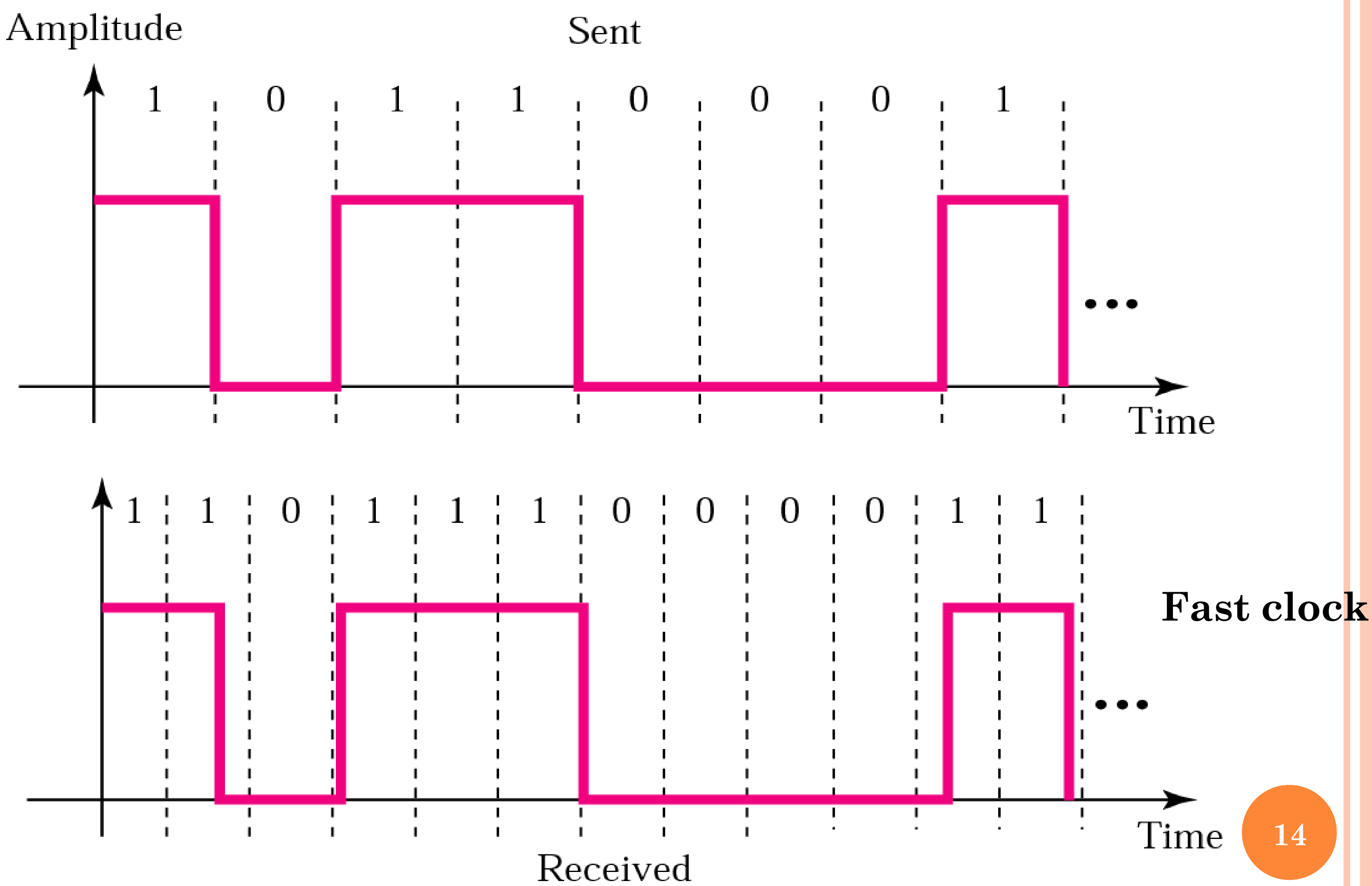


a. A signal with dc component

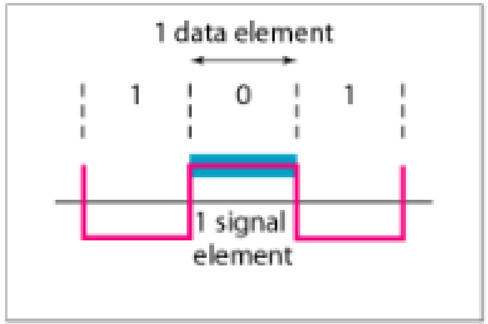


b. A signal without dc component

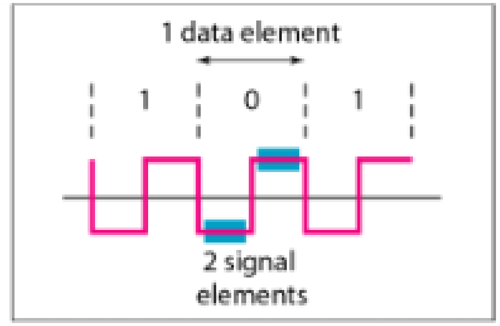
Figure *Lack of synchronization*



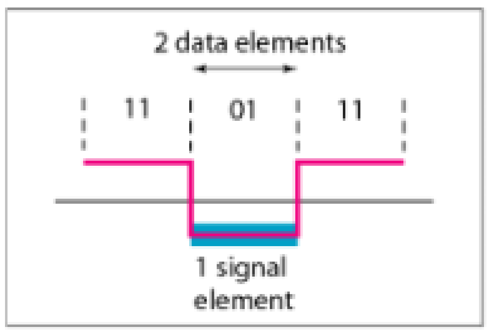
Signal level (Element) versus Data level (Element)



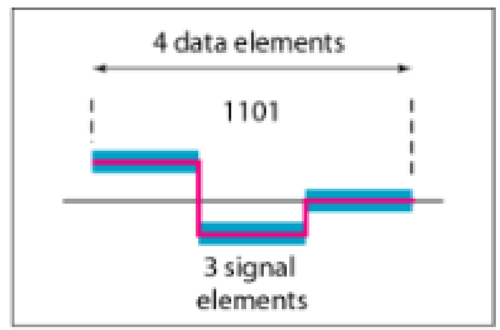
a. One data element per one signal element ($r = 1$)



b. One data element per two signal elements $\left(r = \frac{1}{2}\right)$



c. Two data elements per one signal element ($r = 2$)



d. Four data elements per three signal elements $\left(r = \frac{4}{3}\right)$

$$r = \frac{\#\,data\ element}{\#\,signal\ element}$$

r means number of data elements carried by each signal elem

1. ຮູບແບບການສົ່ງຂໍ້ມູນດິຈິຕອນ (Digital transmission mode)

ສຳລັບການສື່ສານຂໍ້ມູນນັ້ນ ບິດຂໍ້ມູນຈະຖືກລວມກຸ່ມໃຫ້ຢູ່ໃນຮູບແບບຂອງບັອກຂໍ້ມູນ (Packet) ສາເຫດຈຳເປັນຈະຕ້ອງມີການຈັດຂໍ້ມູນໃນລັກສະນະນີ້ກໍ່ເນື່ອງຈາກກຳມະວິທີໃນການສົ່ງ. ແພັກເກັດນັ້ນຈະເປັນກຸ່ມບິດຂໍ້ມູນທີ່ມີຂະໜາດບິດຫຼາຍຂື້ນໂດຍມີໂຄງສ້າງທີ່ແນ່ນອນ ເຊິ່ງຈະປະກອບດ້ວຍຂໍ້ມູນ (Data), ສ່ວນຄວບຄຸມເອີ້ນວ່າ Overhead, ສ່ວນທີ່ຢູ່ Address ແລະ ສ່ວນຄວບຄຸມຄວາມຜິດພາດ (Error Control) ເປັນຕົ້ນ.

Ethernet packet

Source MAC	Destination MAC	Data	CRC

2. ການວັດຄວາມຈຸຂອງຊ່ອງສັນຍານ (Channel Capacity)

ໂດຍທົ່ວໄປຄວາມຈຸຂອງຊ່ອງສັນຍານທີ່ໃຊ້ໃນໂທລະຄົມມະນາຄົມນັ້ນຈະໃຊ້ຄຳວ່າ ແບນວິດ (Bandwidth) ຄ່ານີ້ຈະເປັນຄ່າແຕກຕ່າງຂອງຄວາມຖີ່ສູງສຸດຄວາມຖີ່ຕ່ຳສຸດຂອງຊ່ອງສັນຍານນັ້ນ ຕົວຢ່າງເຊັ່ນ ໃນສັນຍານໂທລະສັບເຊິ່ງໃຊ້ໃນການສົ່ງສັນຍານສຽງ 300Hz ເຖິງ 3100Hz ດັ່ງນັ້ນ ແບນວິດຂອງຊ່ອງສັນຍານຈິ່ງມີຄ່າເທົ່າກັບ 3100-300 ເທົ່າກັບ 2800Hz.

ສຳລັບການສົ່ງສັນຍານຂໍ້ມູນນັ້ນຄວາມຈຸຂອງຊ່ອງສັນຍານຈະຖືກວັດໂດຍຫົວໜ່ວຍເປັນອັດຕາການສົ່ງຂໍ້ມູນຂອງຊ່ອງສັນຍານຕໍ່ວິນາທີ (bps; kbps; Mbps…)

ນອກຈາກນີ້ຍັງມີອີກໜຶ່ງຫົວໜ່ວຍທີ່ໃຊ້ວັດຄວາມຈຸຂອງຊ່ອງສັນຍານຄື: ບອດ (Baud) ເຊິ່ງຫົວໜ່ວຍນີ້ຈະໃຊ້ວັດຄວາມໄວຂອງສັນຍານໃນຊ່ອງສັນຍານຍານນັ້ນ.

ຄວາມຈຸຂອງຊ່ອງສັນຍານໂດຍມີແຖບຄວາມຖີ່ B ແລະມີສັນຍານລົບກວນທີ່ຖືກຈຳກັດຄວາມຖີ່ໄວ້ມີຄ່າບວກຄື

$$C = B\log_2\left(1+\frac{S}{N}\right)$$

C ຄື ຄວາມຈຸຂອງຊ່ອງສັນຍານ (bps)

B ຄື ແຖບຄວາມຖີ່ (Hz)

S/N ຄື ອັດຕາສ່ວນຂອງກຳລັງຂອງສັນຍານຕໍ່ກຳລັງຂອງສັນຍານລົບກວນ dB ແລະກຳລັງຂອງສັນຍານລົບກວນມີຫົວໜ່ວຍເປັນ W

ຖ້າມີແຫຼ່ງກຳເນີດສັນຍາລັກທີ່ກຳເນີດສັນຍາລັກໃນອັດຕາສັນຍາລັກຕໍ່ວິນາທີ ເຮົາສາມາດຫາອັດຕາຂ່າວສານໄດ້ໂດຍ

$$R = rH$$

R ຄື ຈຳນວນສະເລ່ຍຂອງບິດຂ່າວສານຕໍ່ວິນາທີ

r ຄື ອັດຕາການສົ່ງຂໍ້ມູນສູງສຸດ

H ຄື ປະລິມານສະເລ່ຍຂອງຂ່າວສານ/ສັນຍາລັກ

ໂດຍສາມາດຫາປະລິມານສະເລ່ຍຂອງຂ່າວສານ/ສັນຍາລັກໄດ້ໂດຍ

$$H = log_2 M$$

ໂດຍທີ່ M ແມ່ນຈຳນວນຕົວອັກສອນ ຫຼື ຕົວເລກທີ່ກຳລັງສົ່ງ

Example

ກຳນົດໃຫ້ເຄື່ອງປາຍທາງເປັນສະຖານີສົ່ງຂໍ້ມູນທີ່ເປັນຕົວເລກ ແລະຕົວອັກສອນໄປຍັງຄອມພິວເຕີປາຍທາງ ເຊິ່ງເຊື່ອມໂຍງຂໍ້ມູນດ້ວຍສາຍໂທລະສັບແຖບຄວາມຖີ່ 3.4 KHz ແລະ ມີ S/N 10 dB ສົມມຸດວ່າໃຫ້ເຄື່ອງປາຍທາງສົ່ງ 300 ຕົວອັກສອນ ແລະ ຕົວເລກ ຈົ່ງຊອກຫາ

ກ. ຄວາມຈຸຂອງຊ່ອງສັນຍານ

ຂ. ຈົ່ງຫາອັດຕາຂອງຂໍ້ມູນສູງສຸດທີ່ສາມາດສົ່ງຈາກເຄື່ອງປາຍທາງໄປຍັງເຄື່ອງຄອມພິວເຕີໂດຍບໍ່ມີຄວາມຜິດພາດ

ແລະອັດຕາສະເລ່ຍຂອງຂ່າວສານ R = rH ຫາກທຳການສົ່ງຂໍ້ມູນໂດຍບໍ່ມີຄວາມຜິດພາດຈະໃຫ້

$$R = rH < 11.762$$

$$R = 8r < 11.762$$

$$r = 1.470$$

ດັ່ງນັ້ນ ການສົ່ງຂໍ້ມູນທີ່ສູງສຸດໂດຍປາສະຈາກຄວາມຜິດພາດເທົ່າກັບ 1.470 ສັນຍາລັກຕໍ່ວິນາທີ

3. ສັນຍານອະນາລັອກ ແລະສັນຍານດິຈິຕອນ

ສອງສັນຍານນີ້ແມ່ນສັນຍານຫຼັກທີ່ໃຊ້ສຳລັບການສື່ສານແລກປ່ຽນຂໍ້ມູນຕ່າງໆ. ສັນຍານດິຈິຕອນແມ່ນມີຄວາມພິເສດກວ່າສັນຍານອະນາລັອກເພາະວ່າມັນສາມາດທົນຕໍ່ສັນຍານລົບກວນໄດ້ດີກວ່າສັນຍານອະນາລັອກດັ່ງຮູບ

ບົດແກ້ (solution)

ກ. ຄວາມຈຸຂອງຊ່ອງສັນຍານ

ຈະໄດ້ S/N=10

$$C = B\ log_2\left(1+\frac{S}{N}\right)$$

$$= 3400\ log_2(1+10)$$

$$= 11762\ bps$$

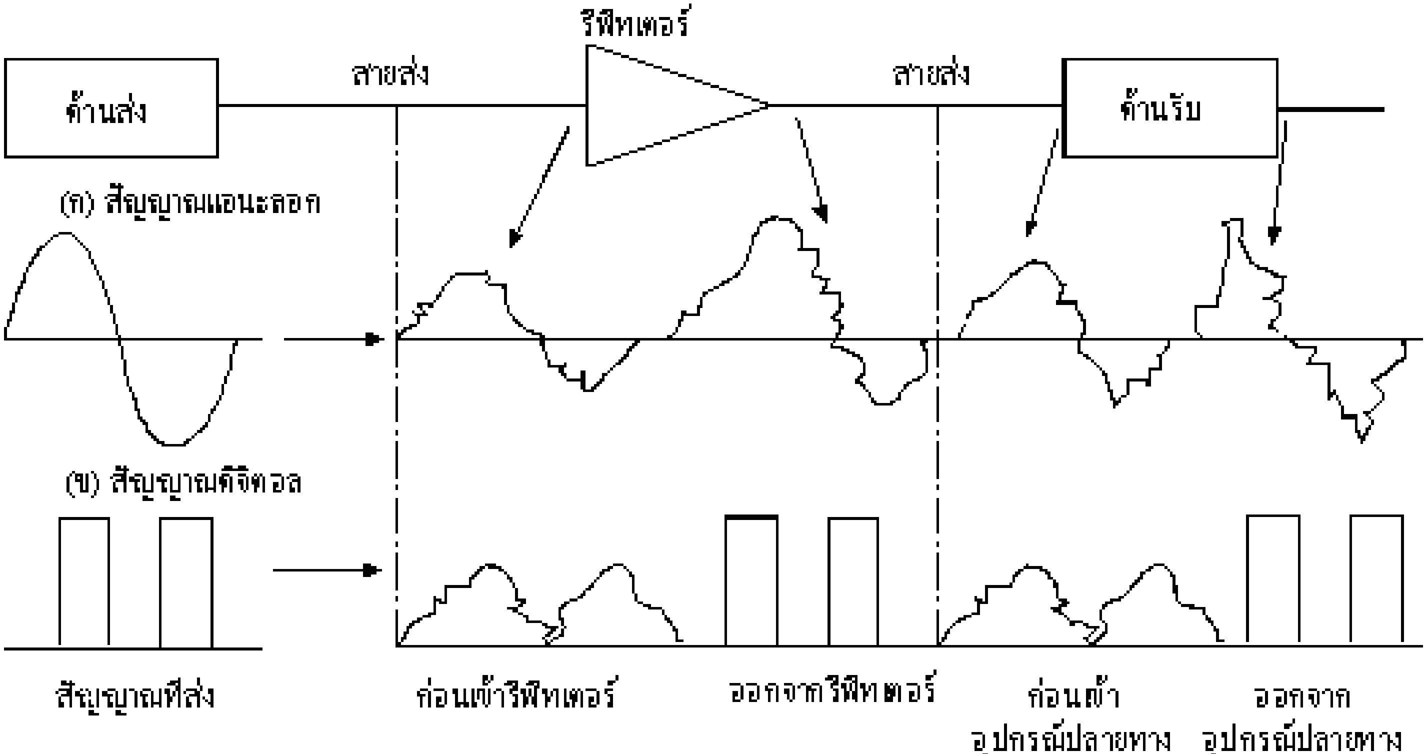
ຂ. ປະລິມານສະເລ່ຍຂອງຂ່າວສານ/ສັນຍາລັກ

$$H = log_2 M$$

$$= log_2(300)$$

= *8 ບິດ/ສັນຍາລັກ*

ສະແດງຄວາມສາມາດຂອງສັນຍານທີ່ທົນຕໍ່ສັນຍານລົບກວນ



4. ການແປງຂໍ້ມູນອະນາລັອກ/ດິຈິຕອນໃຫ້ເປັນສັນຍານ

ຂໍ້ມູນທີ່ຕ້ອງການສື່ສານຈະຢູ່ໃນຮູບແບບຂອງອະນາລັອກ ຫຼືດິຈິຕອນກໍ່ຕາມ ກໍ່ສາມາດສົ່ງຜ່ານຕົວກາງໄປຍັງລະບົບສື່ສານໄດ້ ພຽງແຕ່ຈຳເປັນຕ້ອງມີການປຸ່ງນຮູບແບບຂອງສັນຍານທີ່ເໝາະສົມ ດັ່ງນັ້ນ ເຮົາຈິ່ງສາມາດແປງຂໍ້ມູນ ຫຼືເຂົ້າລະຫັດຂໍ້ມູນໄປມາລະຫວ່າງອະນາລັອກ ຫຼືດິຈິຕອນໄດ້ດັ່ງນີ້:

4.1 ການແປງຂໍ້ມູນອະນາລັອກໃຫ້ເປັນສັນຍານອະນາລັອກ (Analog Data to Analog Signal)

ການແປງຂໍ້ມູນອະນາລັອກໃຫ້ເປັນສັນຍານອະນາລັອກເປັນຮູບແບບທີ່ງ່າຍໂດຍຈະແທນຂໍ້ມູນອະນາລັອກດ້ວຍສັນຍານອະນາລັອກຕົວຢ່າງການສື່ສານວິທະຍຸກະຈາຍສຽງ ສົມມຸດເປີດວິທະຍຸຄື້ນ FM 101.5MHz ເພື່ອຟັງເພງ ໃນຂະນະທີ່ສຽງເວົ້າຂອງມະນຸດຢູ່ທີ່ຍ່ານຄວາມຖີ່ຕ່ຳໃນຊ່ວງ 300-3.400 Hz ແລະສຽງດົນຕີ 30-20.000 Hz ດັ່ງນັ້ນ ເພື່ອໃຫ້ສັນຍານສຽງແລະດົນຕີ ສາມາດສົ່ງອອກໄປໃນຍ່ານຄວາມຖີ່ 101.5 MHz ຈະຕ້ອງມີເທັກນິກວິທີການສົ່ງ.

101.5 MHz ຄື້ນຄວາມຖີ່ສູງນີ້ເອີ້ນວ່າ ຄື້ນພາ (Carrier Signal) ຄຸນສົມບັດຄືສາມາດສົ່ງອອກໄປໄດ້ໄກໆ ແລະຜ່ານຕົວກາງໄດ້ ແລະ ເມື່ອນຳຄື້ນພາຫະມາລວມກັບສັນຍານສຽງດ້ວຍການມໍດູເລດ (Modulate) ກໍ່ໄດ້ຄື້ນໃໝ່ອອກມາພ້ອມສົ່ງໄປຍັງຕົວກາງ ຝັ່ງສະຖານີຮັບກໍ່ມີວິທີການແຍກຄື້ນພາຫະອອກຈາກສັນຍານສຽງຄື: ການດີມໍດູເລດ (Demodulate).

ການມໍດູເລດສັນຍານແບບອະນາລັອກ

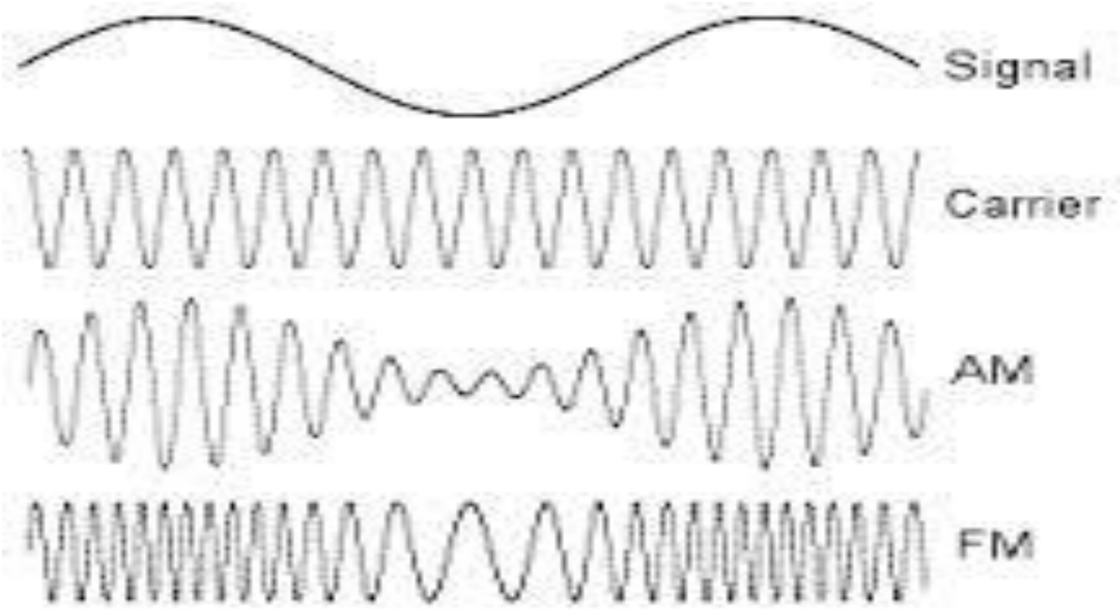
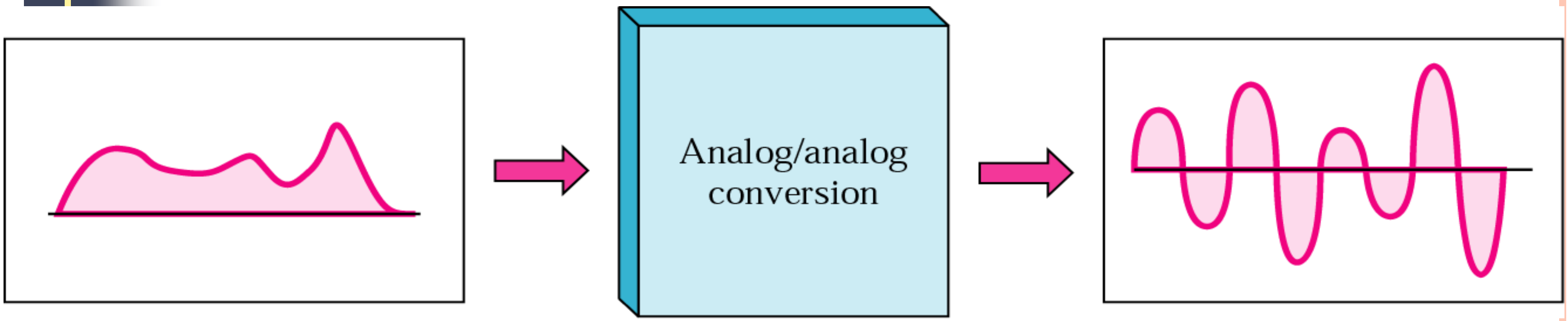
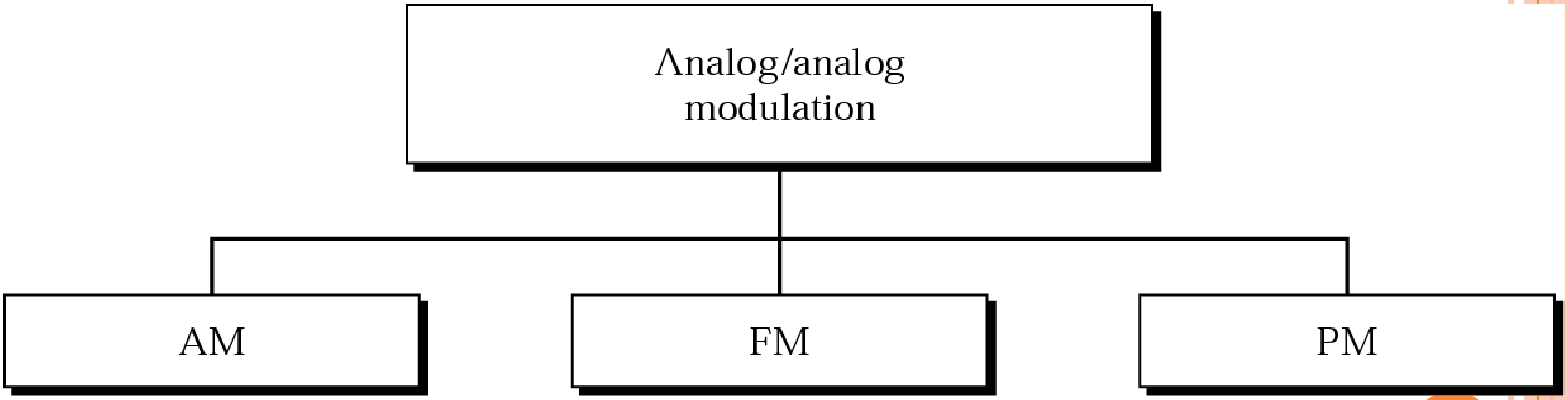
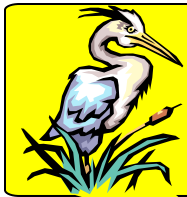


Figure 5.24 *Analog-to-Analog Modulation*







Note:

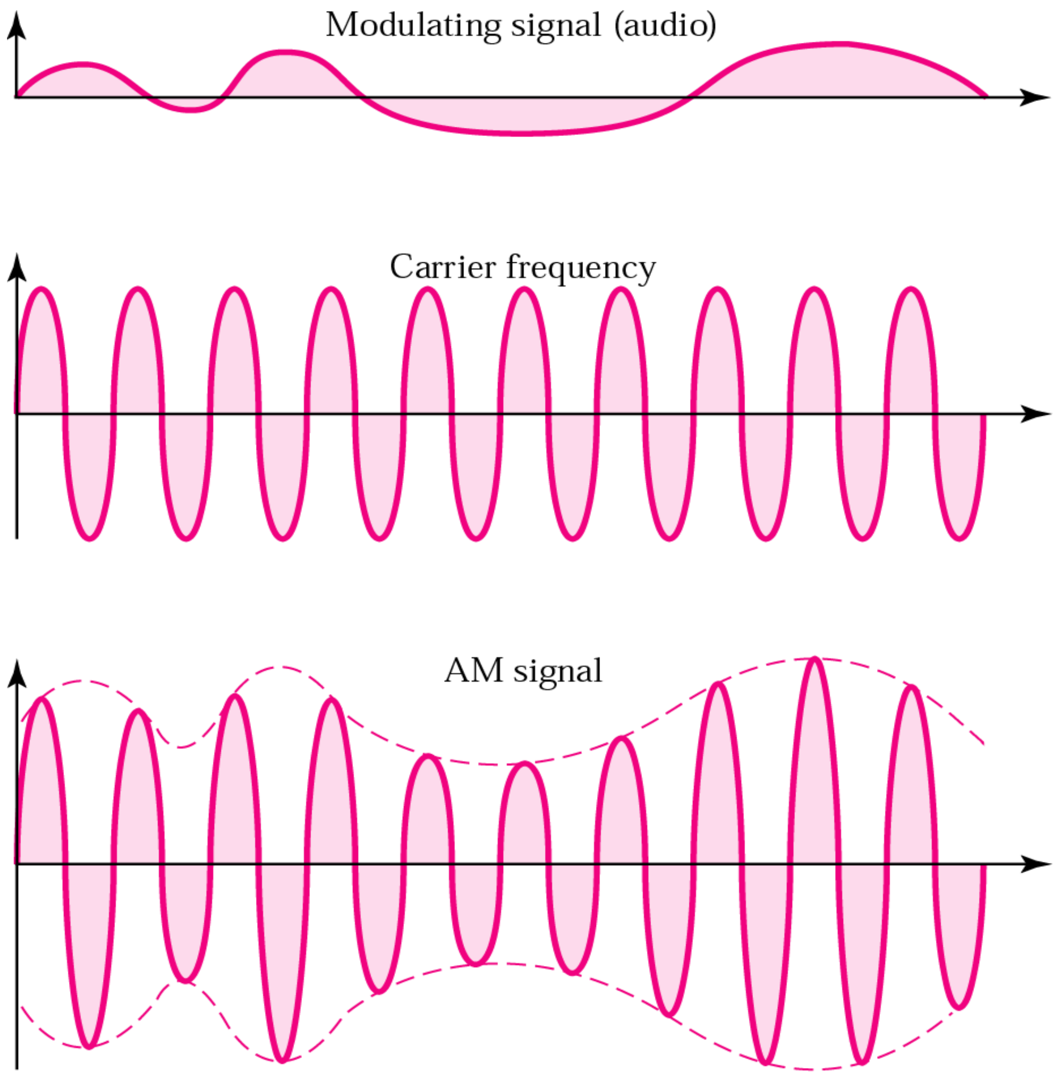
The total bandwidth required for AM can be determined from the bandwidth of the audio signal:

$$BWt = 2 \times BWm.$$

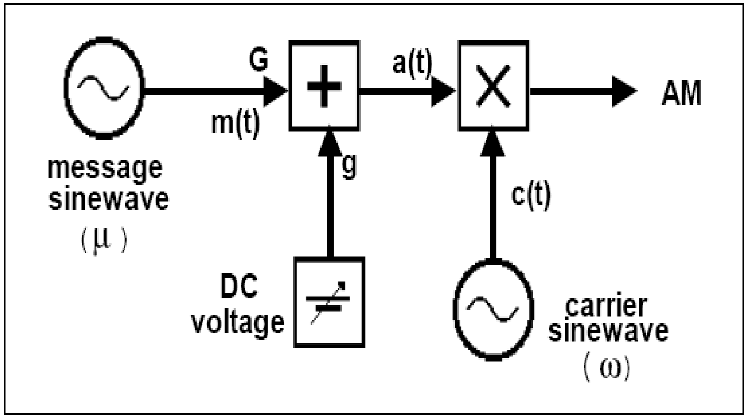
AM bandwidth

Audio bandwidth
(4 KHz)

Figure 5.26 *Amplitude Modulation*



Amplitude Modulation



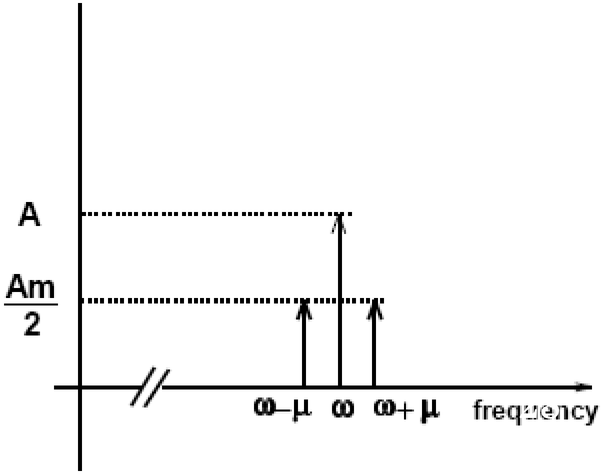
$$AM = \{G[m(t)] + g\}c(t)$$

$$= \{G[\cos(\mu t)] + g\}\cos(\omega t)$$

$$= G\cos(\mu t)\cos(\omega t) + g\cos(\omega t)$$

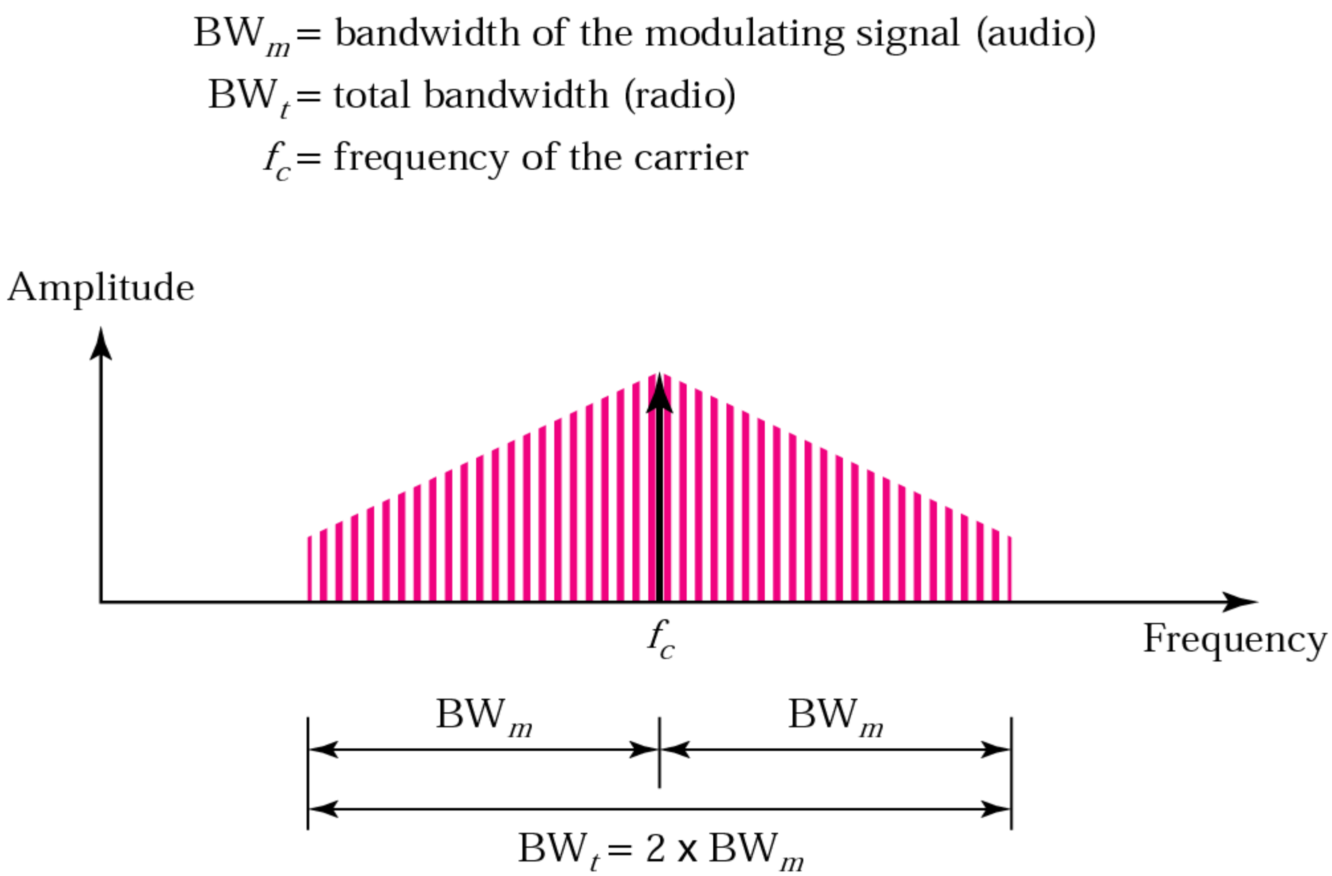
$$\boxed{A\cos(\mu t)\cos(\omega t) = \left(\frac{A}{2}\right)\cos(\omega - \mu)t + \left(\frac{A}{2}\right)\cos(\omega + \mu)t}$$

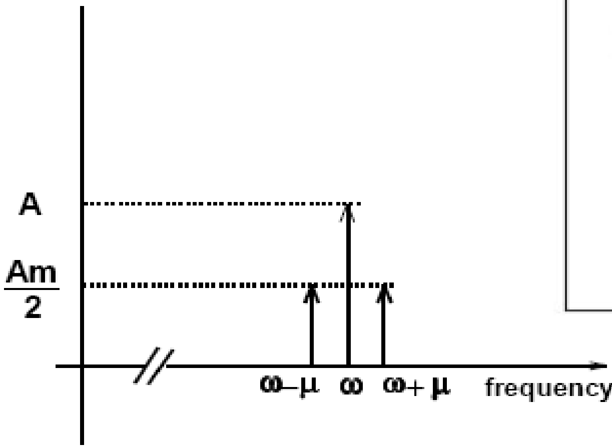
$$= \frac{G}{2}\cos(\omega - \mu)t + \frac{G}{2}\cos(\omega + \mu)t + g\cos(\omega t)$$

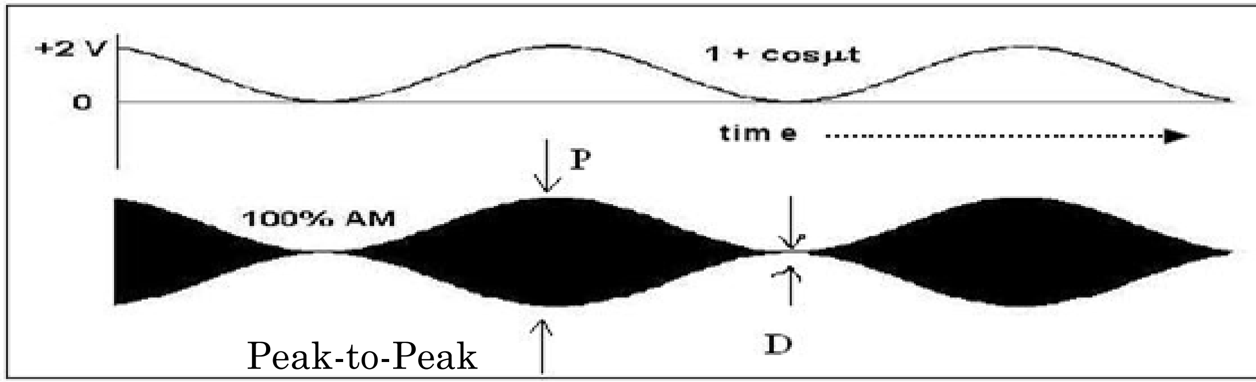


$$\cos A\cos B = \frac{1}{2}[\cos(A+B) + \cos(A-B)]$$

Figure 5.27 *AM bandwidth*

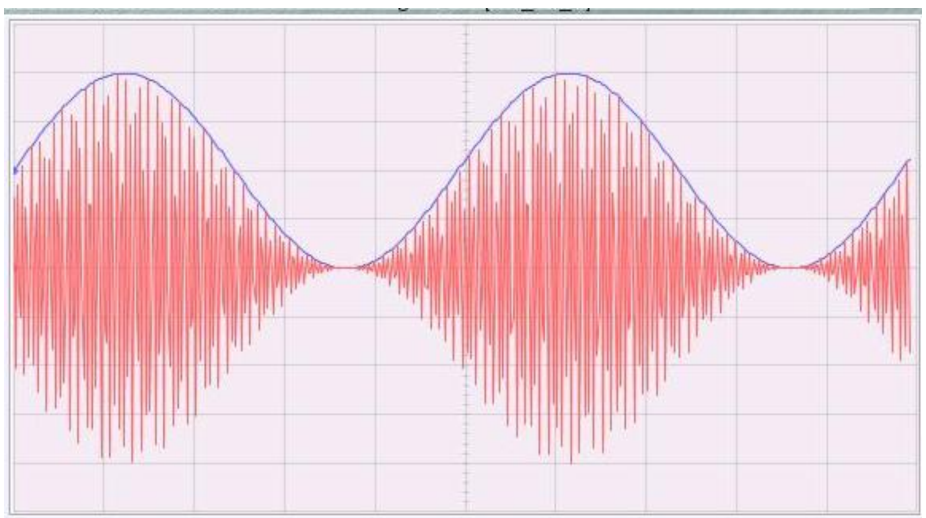






$$m = \frac{P - D}{P + D}$$

m=1 : 100% AM



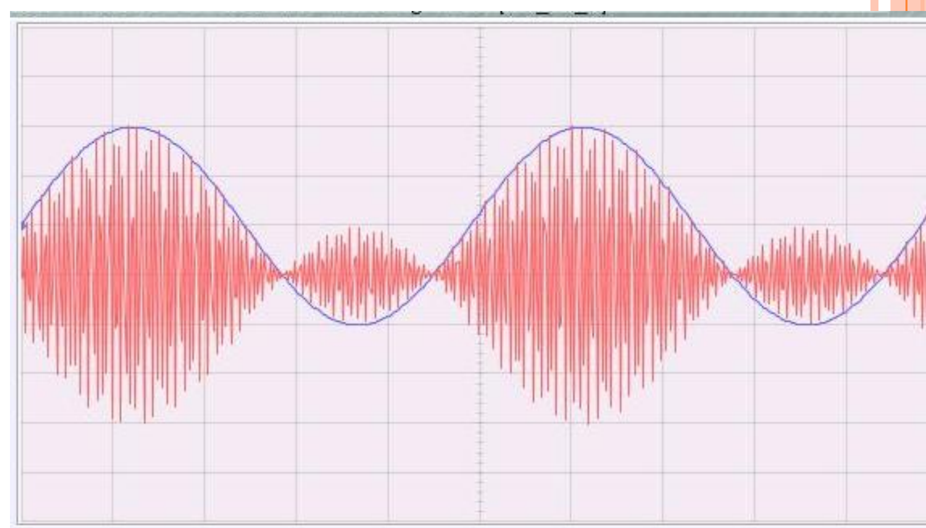
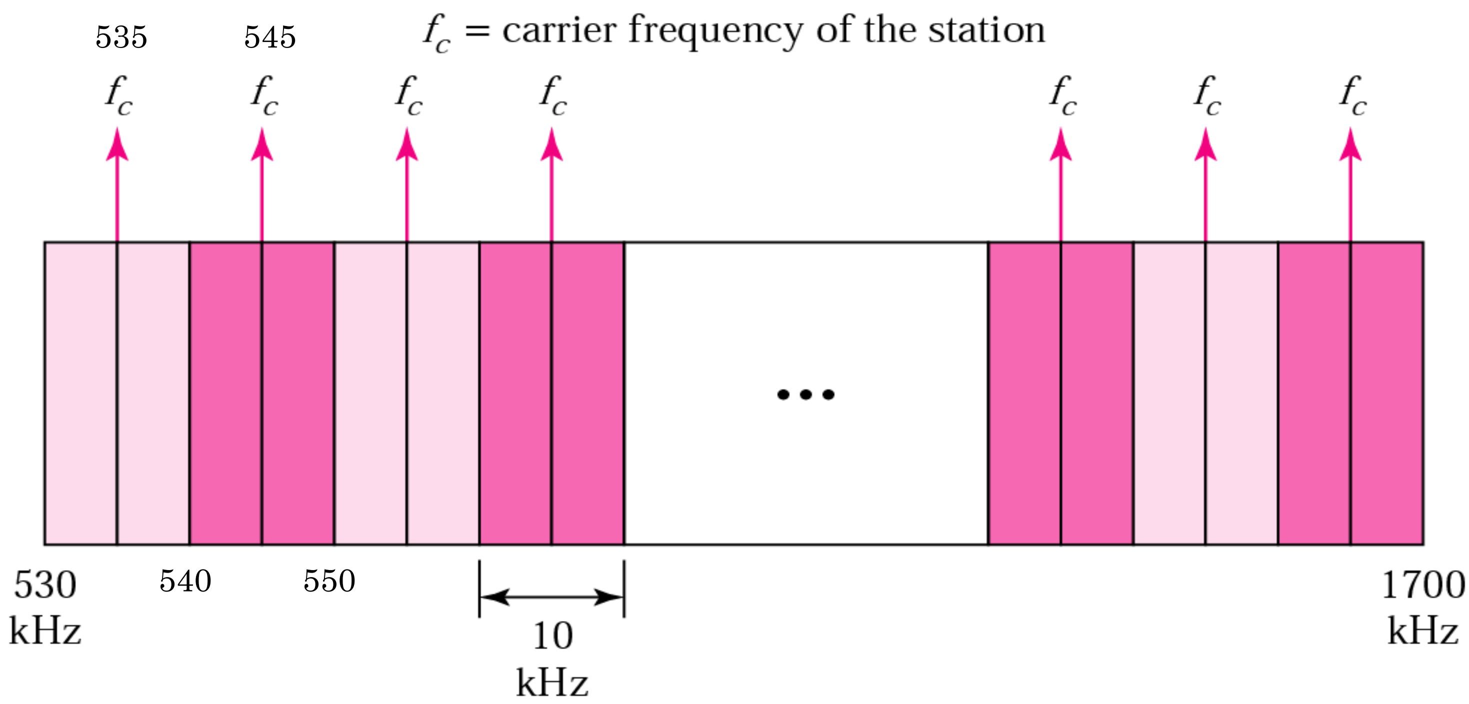


Figure 5.28 *AM band allocation*



Example 13

We have an audio signal with a bandwidth of 4 KHz.

What is the bandwidth needed if we modulate the signal using AM?

Ignore FCC (Federal Communications Commission) regulations.

Solution

$$BWt = 2 \times BWm$$

An AM signal requires twice the bandwidth of the original signal:

$$BW = 2 \times 4 \text{ KHz} = 8 \text{ KHz}$$

Figure 5.29 *Frequency modulation*

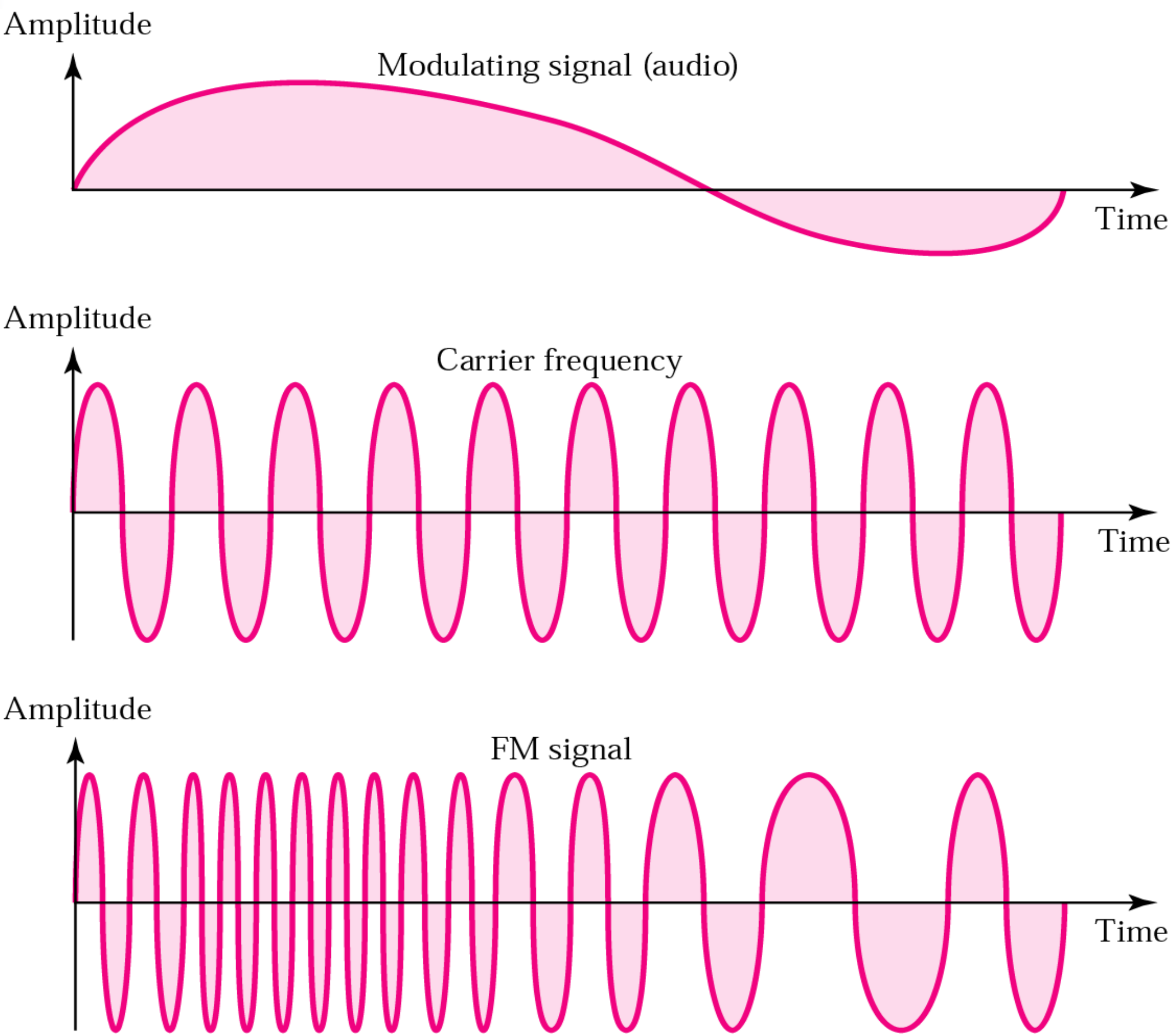


Figure 5.30 *FM bandwidth*

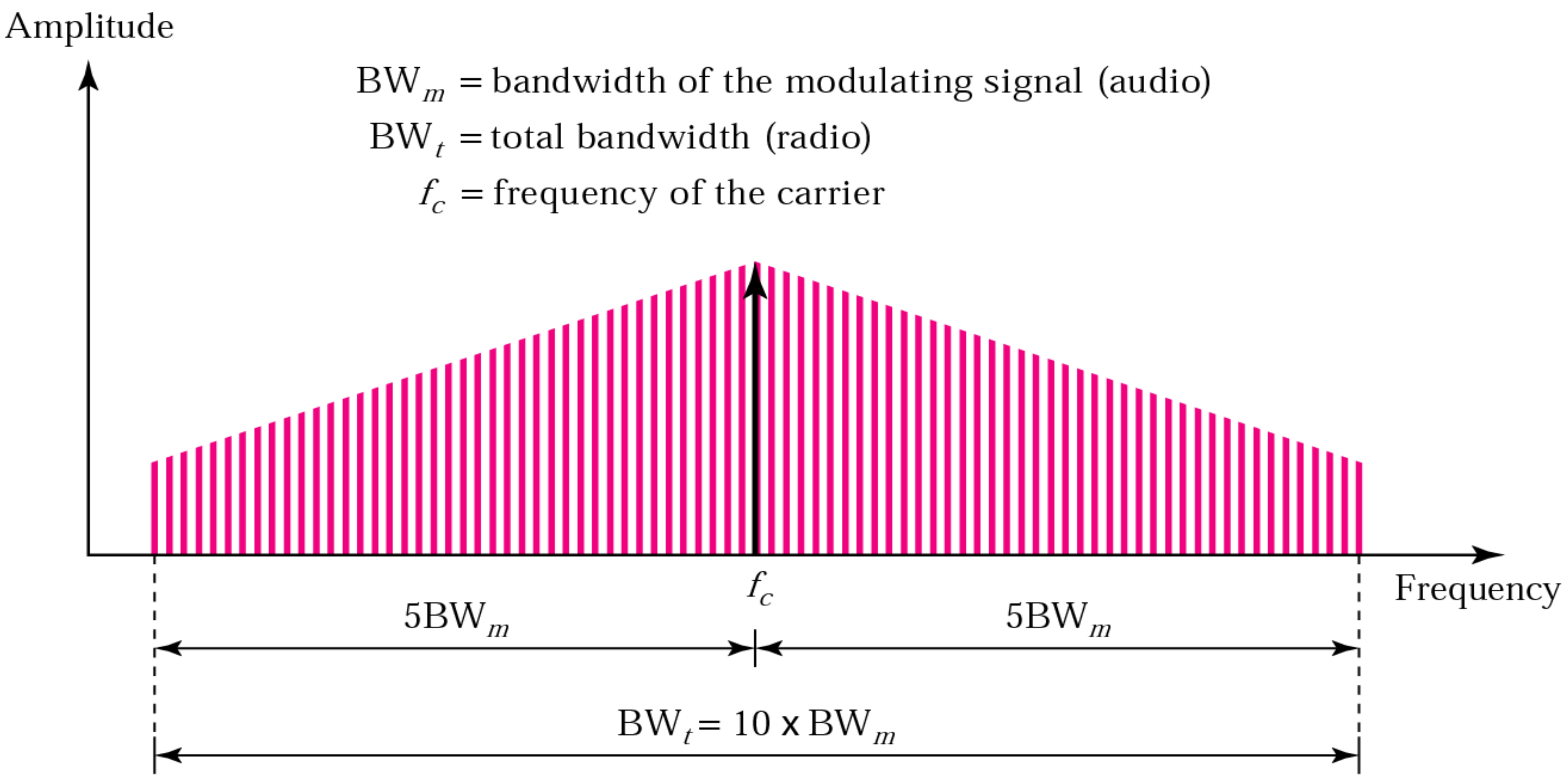
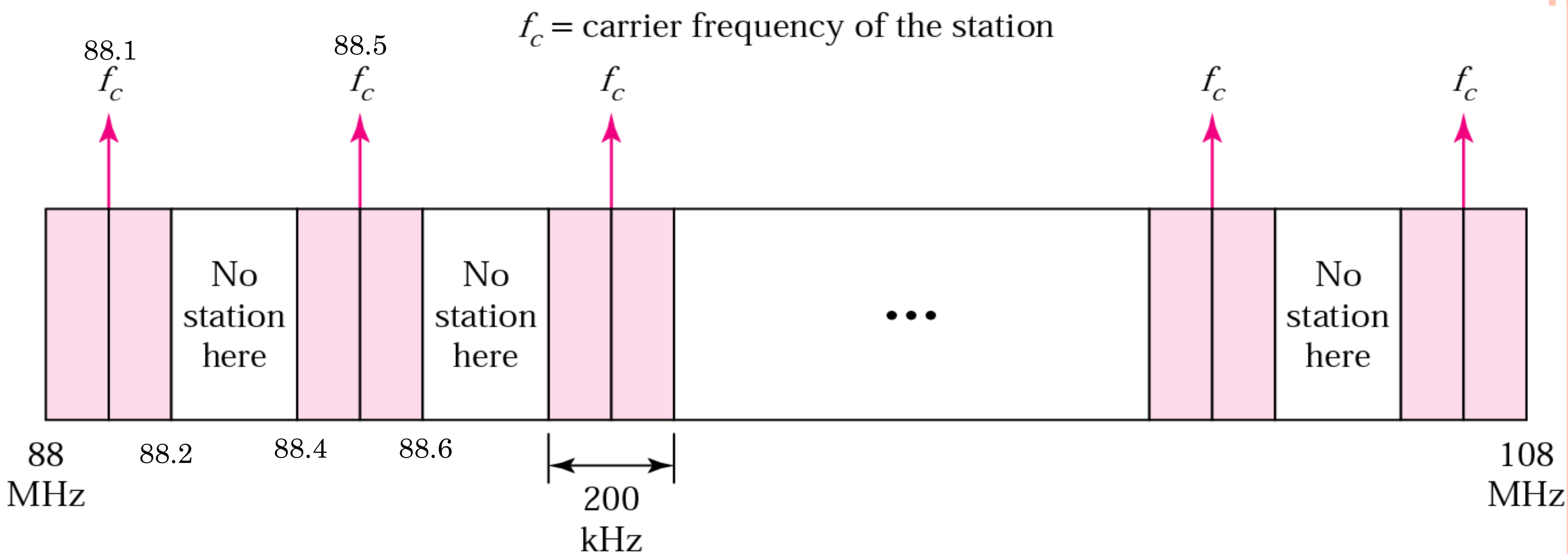


Figure 5.31 *FM band allocation*



Example 14

We have an audio signal with a bandwidth of 4 MHz.

What is the bandwidth needed if we modulate the signal using FM?

Ignore FCC (Federal Communications Commission) regulations.

Solution

BWt = 10 x BWm

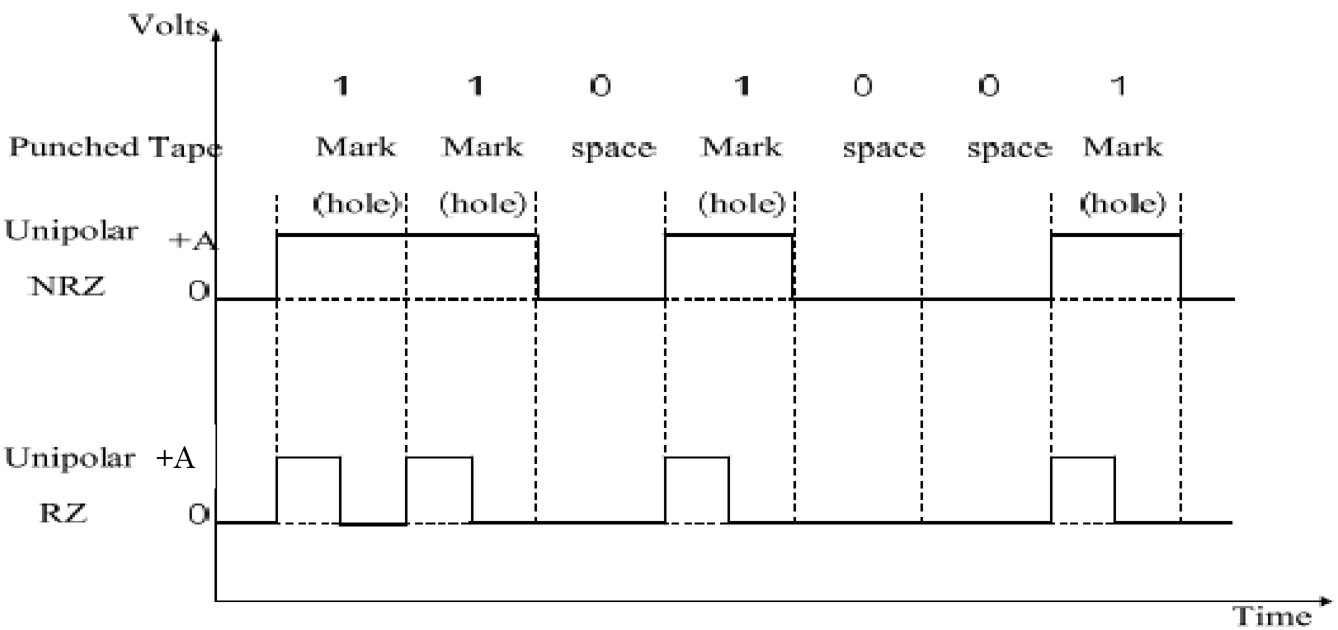
An FM signal requires 10 times the bandwidth of the original signal:

BW = 10 x 4 MHz = 40 MHz

4.2 ການແປງຂໍ້ມູນດິຈິຕອນໃຫ້ເປັນສັນຍານດິຈິຕອນ (Digital Data to Digital Signal)

ການແປງຂໍ້ມູນດິຕອນໃຫ້ເປັນສັນຍານດິຈິຕອນຈະມີວິທີການເຂົ້າລະຫັດສັນຍານດິຈິຕອນຫຼາຍວິທີດ້ວຍກັນ.

+ **Uniporlar Signaling**: ສັນຍານຈະຖືກຈັດລະດັບແຮງດັນເປັນ 2 ລະດັບໂດຍທີ່ສັນຍານທີ່ໄບນາຣີ 1 ສະແດງດ້ວຍລະດັບທີເປັນ High (+A) ສັນຍານທີ່ເປັນ 0 ຈະສະແດງດ້ວຍລະດັບ Low (0V) ເຮົາເອີ້ນສັນຍານແບບນີ້ວ່າ on-off keying.



Punched Tape ຈະສະແດງໃຫ້ຮູ້ວ່າໄບນາຣີ 1 ໃຊ້ແທນດ້ວຍ Mark ແລະ ໄບນາຣີ 0 ໃຊ້ແທນດ້ວຍ space

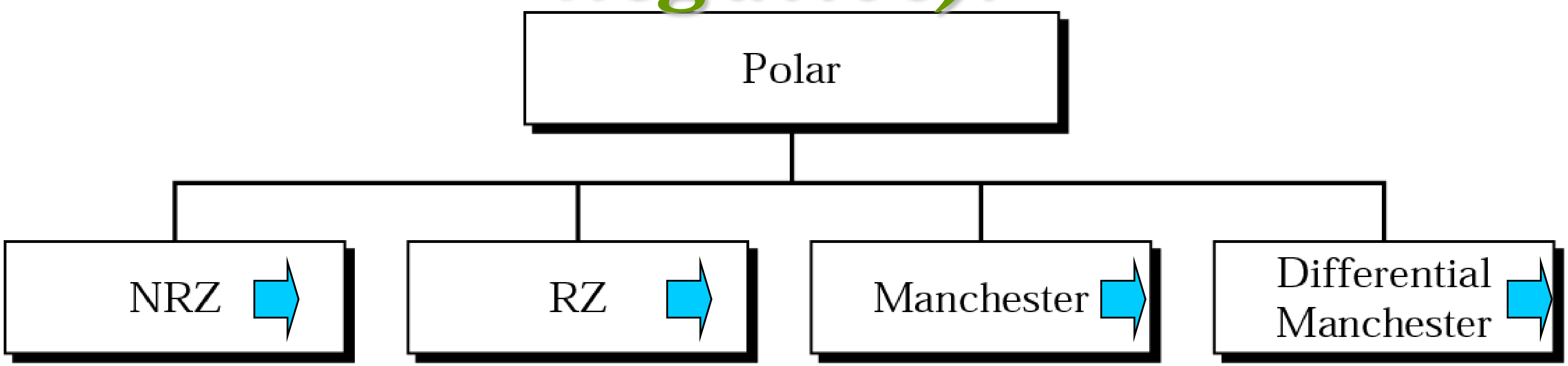
+ Porlar Signaling: ສັນຍານຈະຖືກຈັດລະດັບແຮງດັນເປັນ 2 ລະດັບໂດຍທີ່ສັນຍານທີ່ເປັນໄບນາຣີ 1 ຈະສະແດງດ້ວຍລະດັບ High (+A) ສັນຍານທີ່ເປັນໄບນາຣີ 0 ແມ່ນສະແດງດ້ວຍລະດັບລົບ (-A) ສັນຍານ Porlar ແບ່ງອອກເປັນ RNZ ແລະ RZ.

+ Bipolar Signaling: ຖືກຈັດລະດັບແຮງດັນເປັນ 3 ລະດັບ ສັນຍານທີ່ເປັນ 1 ຈະສະແດງດ້ວຍລະດັບທີ່ເປັນບວກ ແລະລົບສະຫຼັບກັນໄປ ສັນຍານໄບນາຣີທີ່ເປັນ 0 ຈະຖືກແທນດ້ວຍລະດັບ 0 ການທີ່ໃຊ້ການເຂົ້າລະຫັດ 3 ລະດັບແທນສັນຍານຂໍ້ມູນ 2 ລະດັບ ເຮົາເອີ້ນວ່າ Alternate Mark Inversion (AMI) ເຊິ່ງກໍ່ແບ່ງໄດ້ເປັນ NRZ ແລະ RZ.

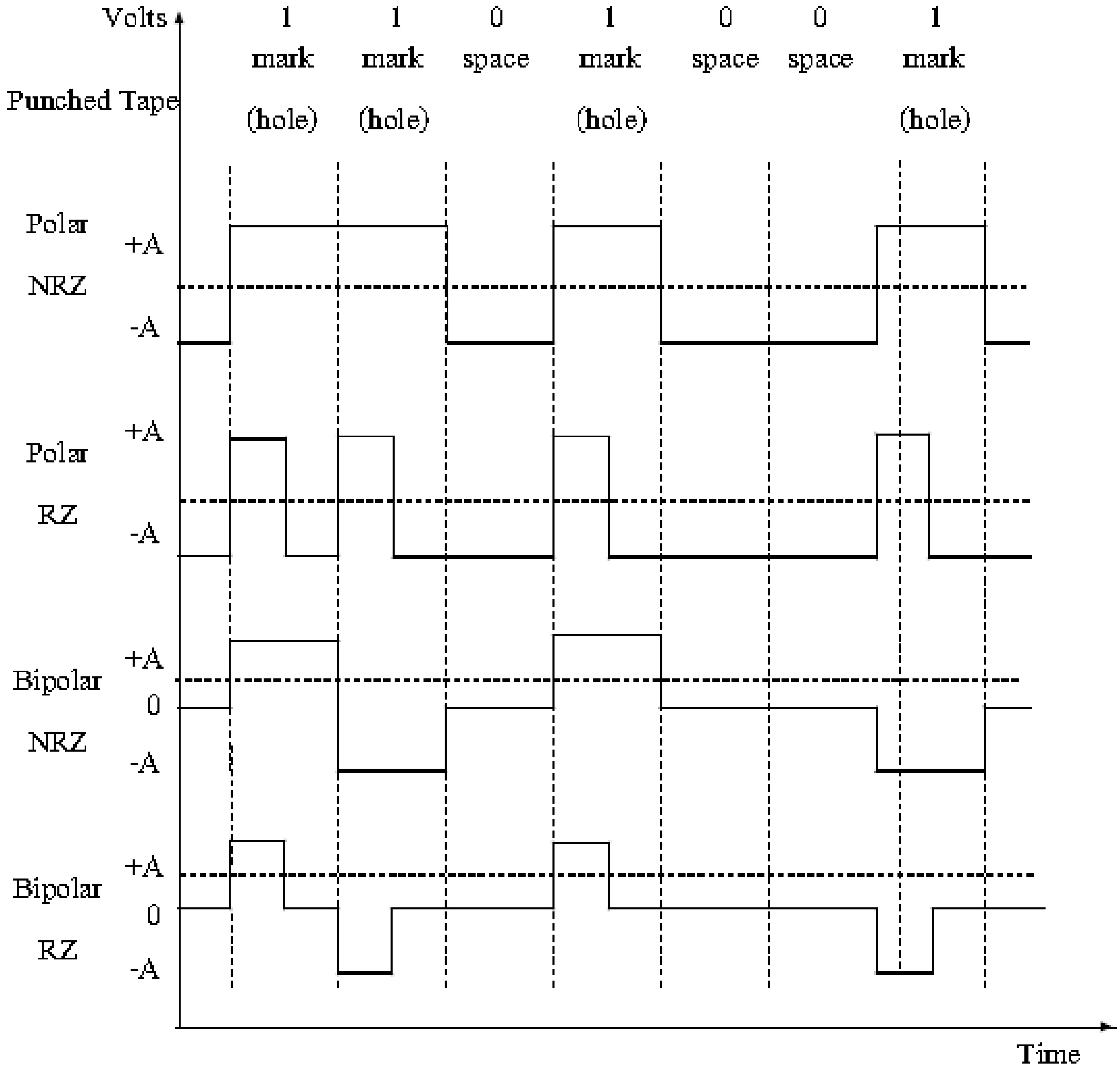
Figure 4.7 *Types of polar encoding*

Note:

Polar encoding uses two voltage levels (positive <u>and</u> negative).



Non-Return-to-ZeroReturn-to-Zero


Volts
1 mark (hole)
1 mark (hole)
0 space
1 mark (hole)
0 space
0 space
1 mark (hole)
Punched Tape
Polar NRZ
+A
-A
Polar RZ
+A
-A
Bipolar NRZ
+A
0
-A
Bipolar RZ
+A
0
-A
Time

+ Manchester Signaling: ສັນຍານຈະຖືກແທນດ້ວຍແຮງດັນອອກເປັນ 2 ລະດັບ ສັນຍານທີ່ເປັນໄບນາຣີ 1 ຈະແທນດ້ວຍບິດທີ່ເປັນບວກເຄິ່ງຄາບເວລາ ແລ້ວຈະຕາມດ້ວຍບິດທີ່ເປັນລົບອີກເຄິ່ງຄາບເວລາທີ່ເຫຼືອ ສັນຍານທີ່ເປັນໄບນາຣີ 0 ຈະສະແດງດ້ວຍບິດທີ່ເປັນລົບເຄິ່ງຄາບເວລາແລ້ວຕາມດ້ວຍບິດທີ່ເປັນບວກອີກເຄິ່ງຄາບເວລາສ່ວນທີ່ເຫຼືອ

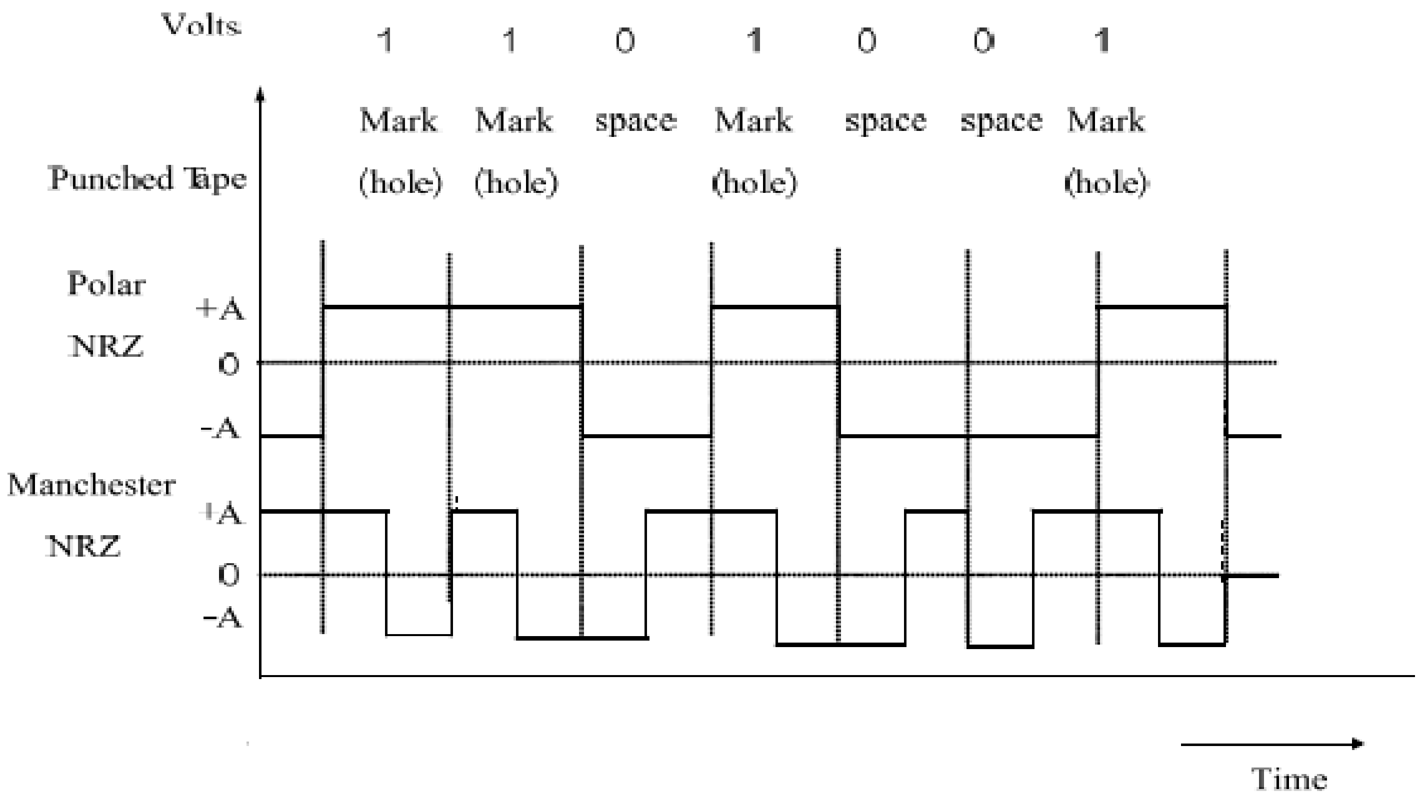
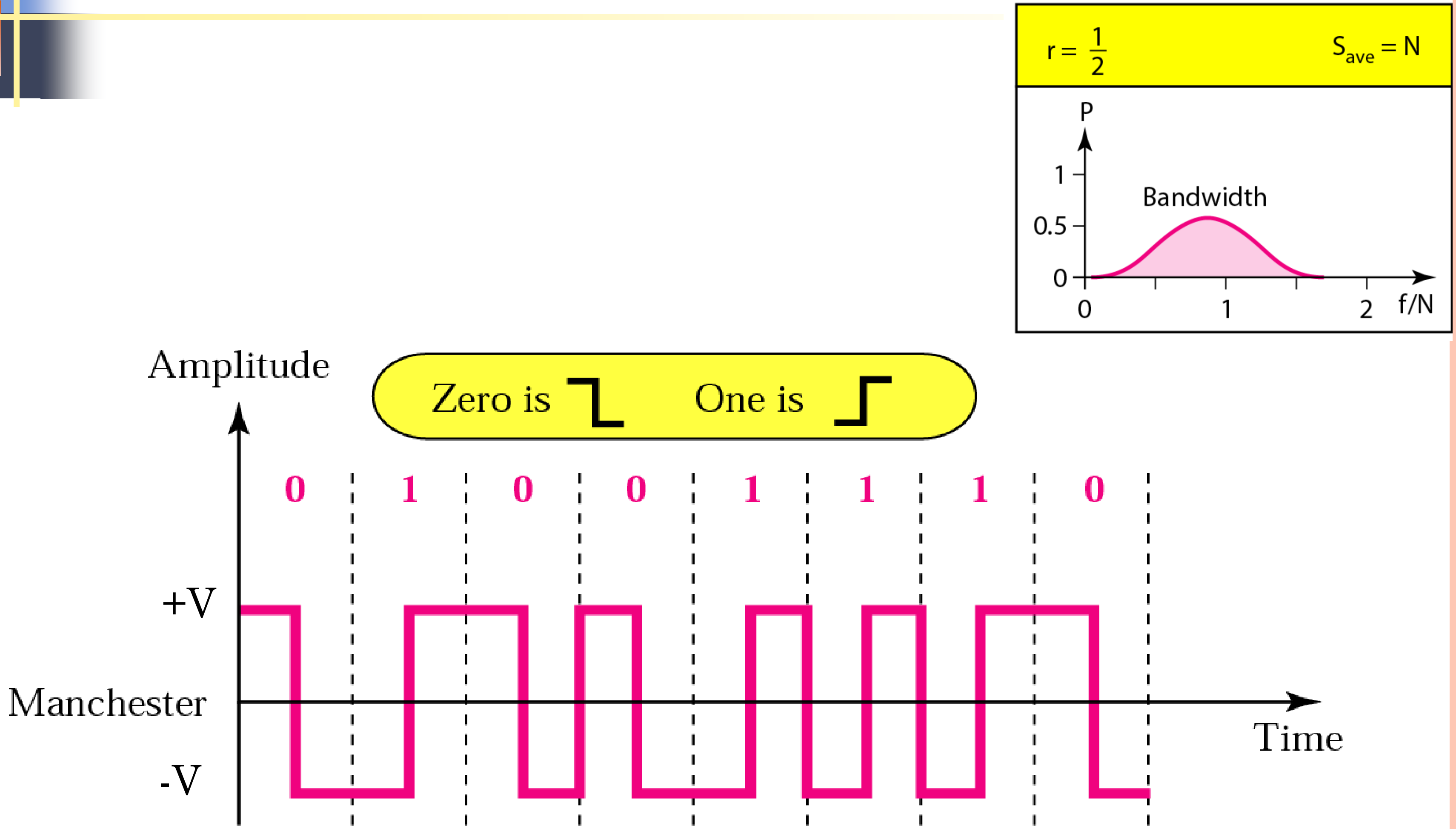


Figure 4.10 *Manchester encoding*

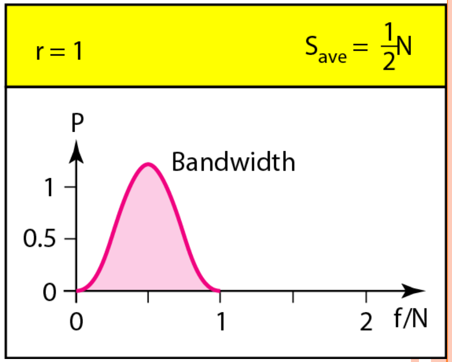


Applications of Line Coding

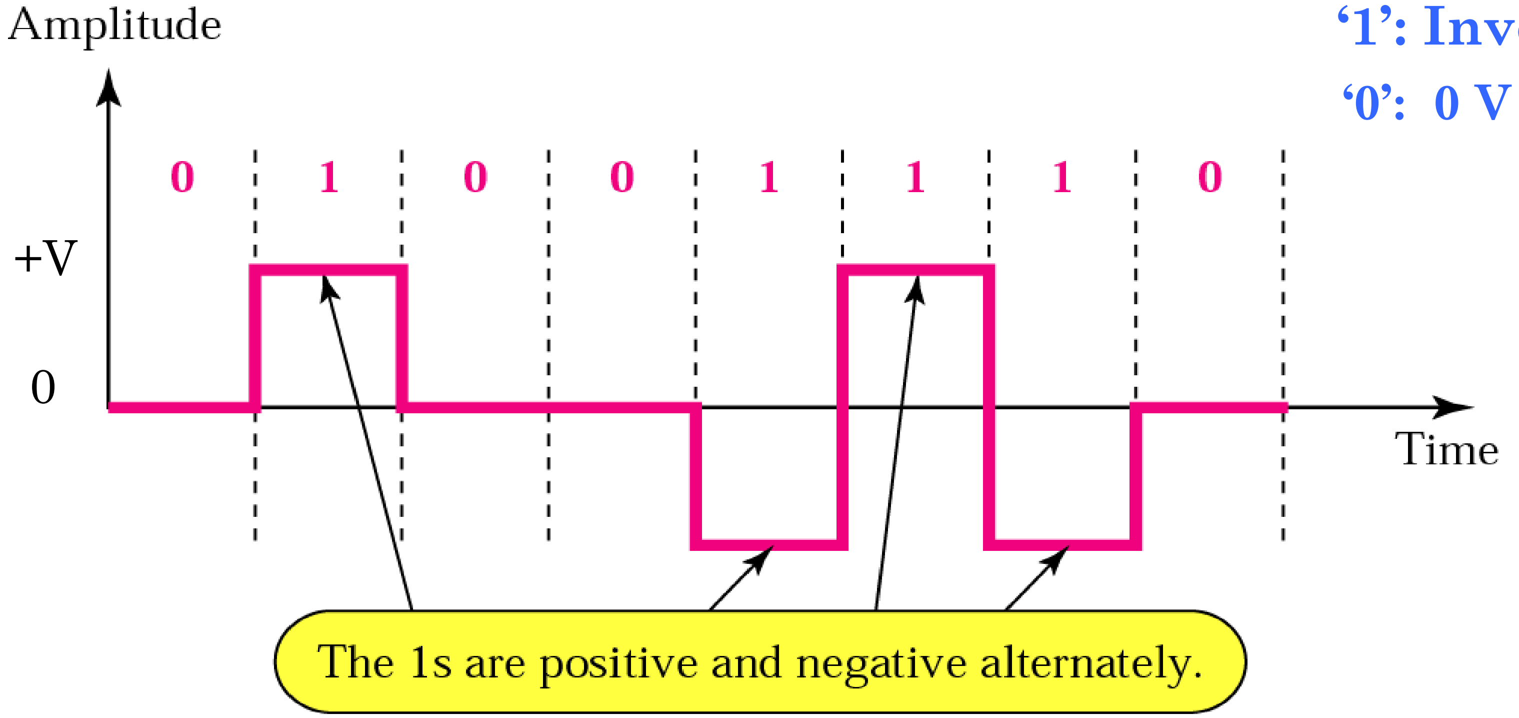
- NRZ encoding:
  - RS232 based protocols
- Manchester encoding:
  - Ethernet networks
  - Hard drive
- Differential Manchester encoding:
  - token-ring networks
- NRZ-Inverted encoding:
  - Fiber Distributed Data Interface (FDDI)

Figure 4.12 *Bipolar AMI encoding*

AMI stands for **Alternate Mark Inversion**,
Variation of AMI is **Pseudoternary**



In bipolar encoding, we use three levels: positive, zero, and negative.

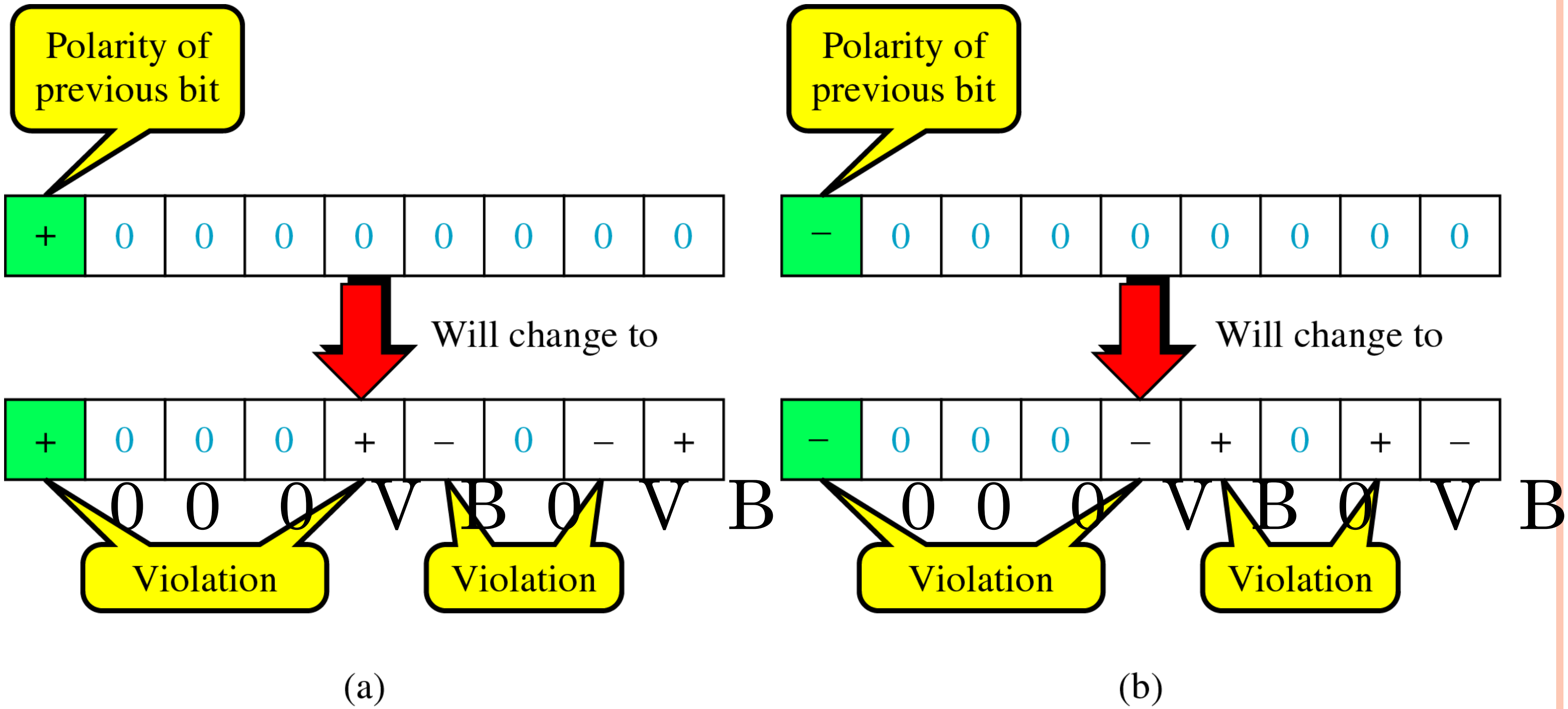


'1': Inversion

'0': 0 V

Figure 5-11

B8ZS Encoding (Bipolar with Eight-Zero Substitution)

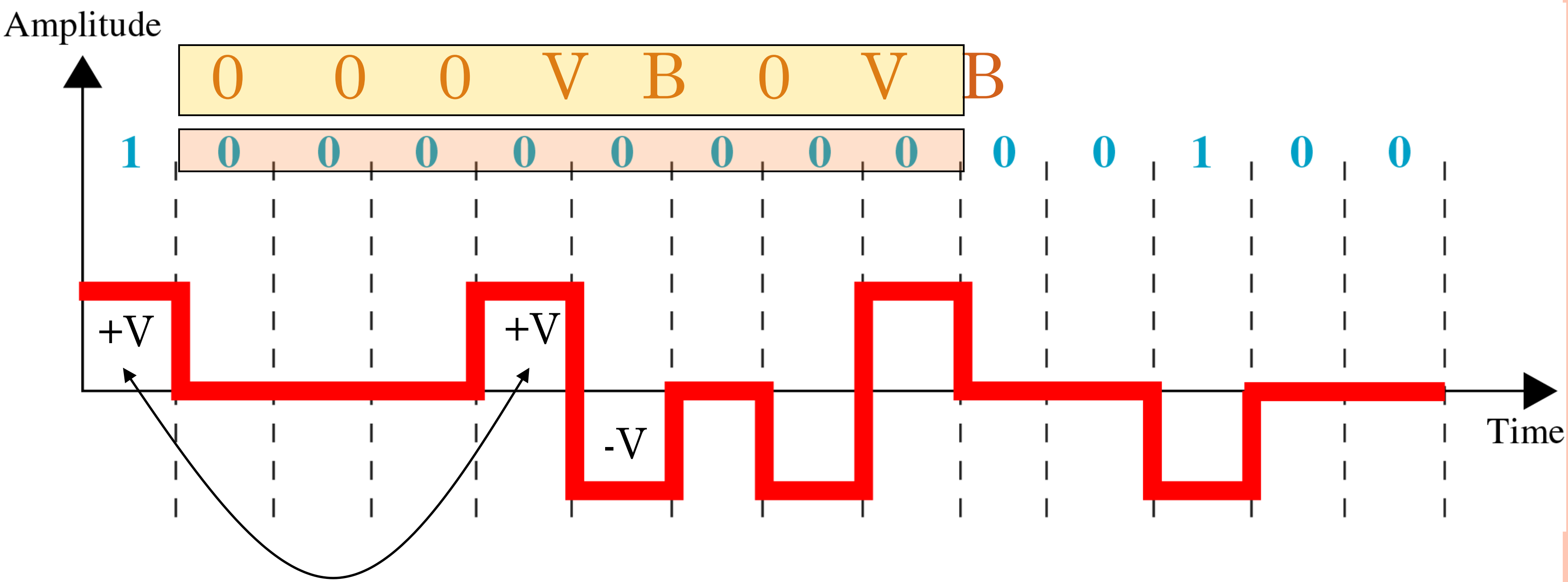


0 0 0 V B 0 V B

V = Violation, B = Bipolar

Figure 5-13

Example: B8ZS Encoding



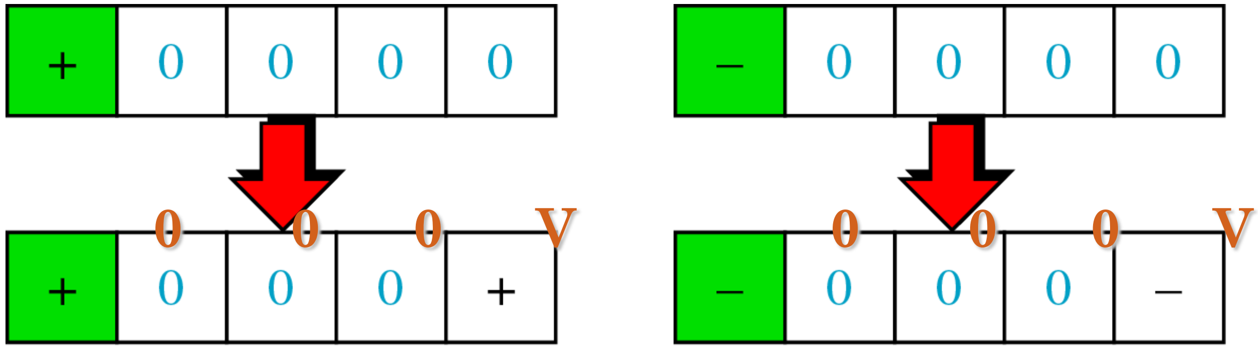
V = Violation, B = Bipolar

Figure 5-12

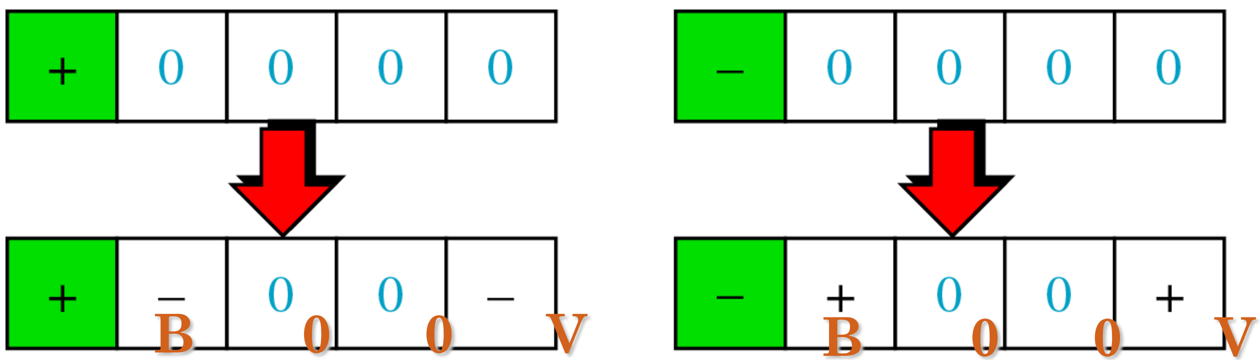
Pattern 1 : 0 0 0 V

Pattern 2 : B 0 0 V

HDB3 Encoding (High Density Bipolar 3-zero Encoding)



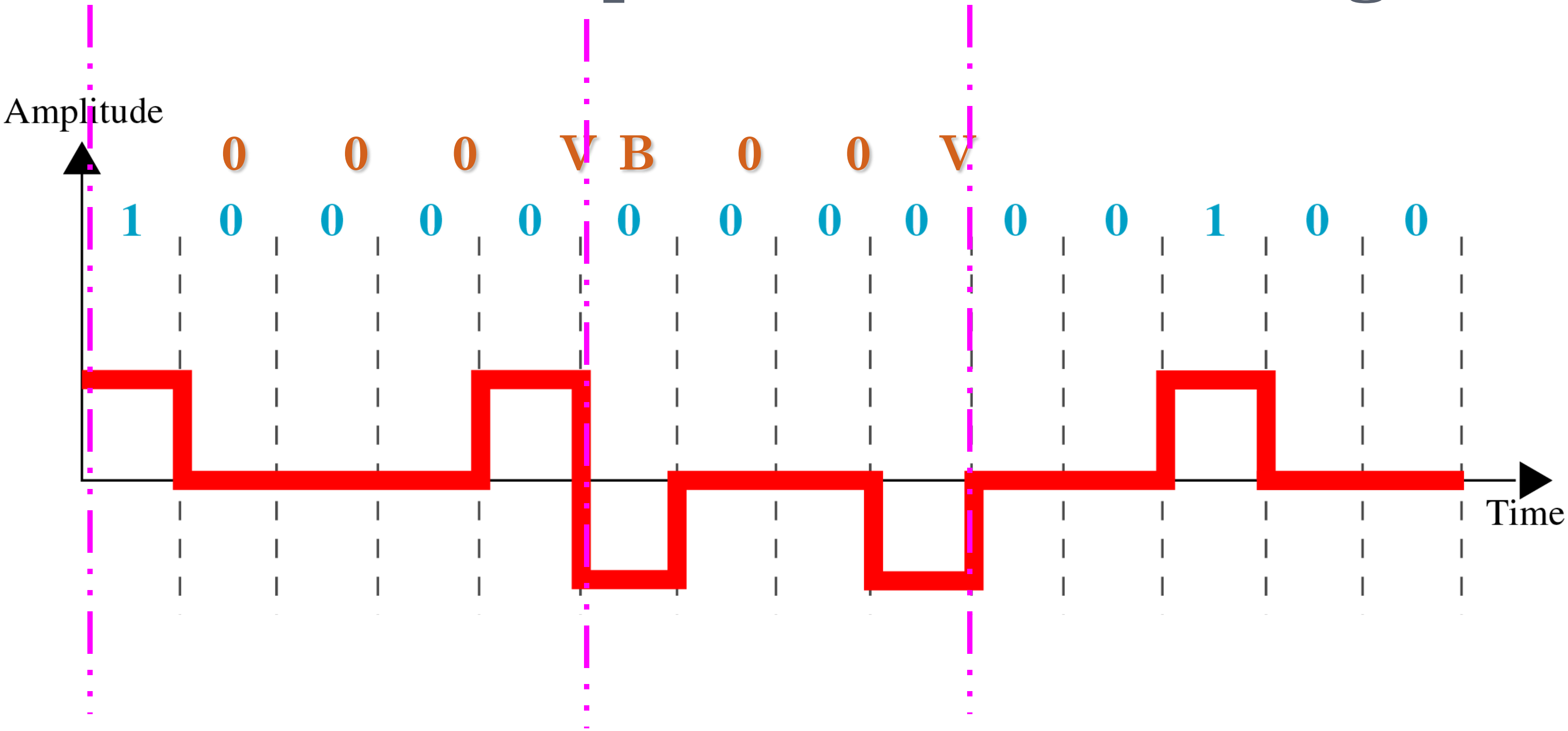
(a) If the number of 1s since the last substitution is odd



(b) If the number of 1s since the last substitution is even

Figure 5-14

Example: HDB3 Encoding



Length of binary pattern

Binary data

Length of signal pattern

Number of Level in the signaling

$$2^m \le L^n \cdot \quad \boxed{\underline{mB}} \quad \boxed{\underline{nL}}$$

Data Elements

Signal Elements

B (binary) for L=2
T(trenary) for L=3
Q(quaternary) for L=4

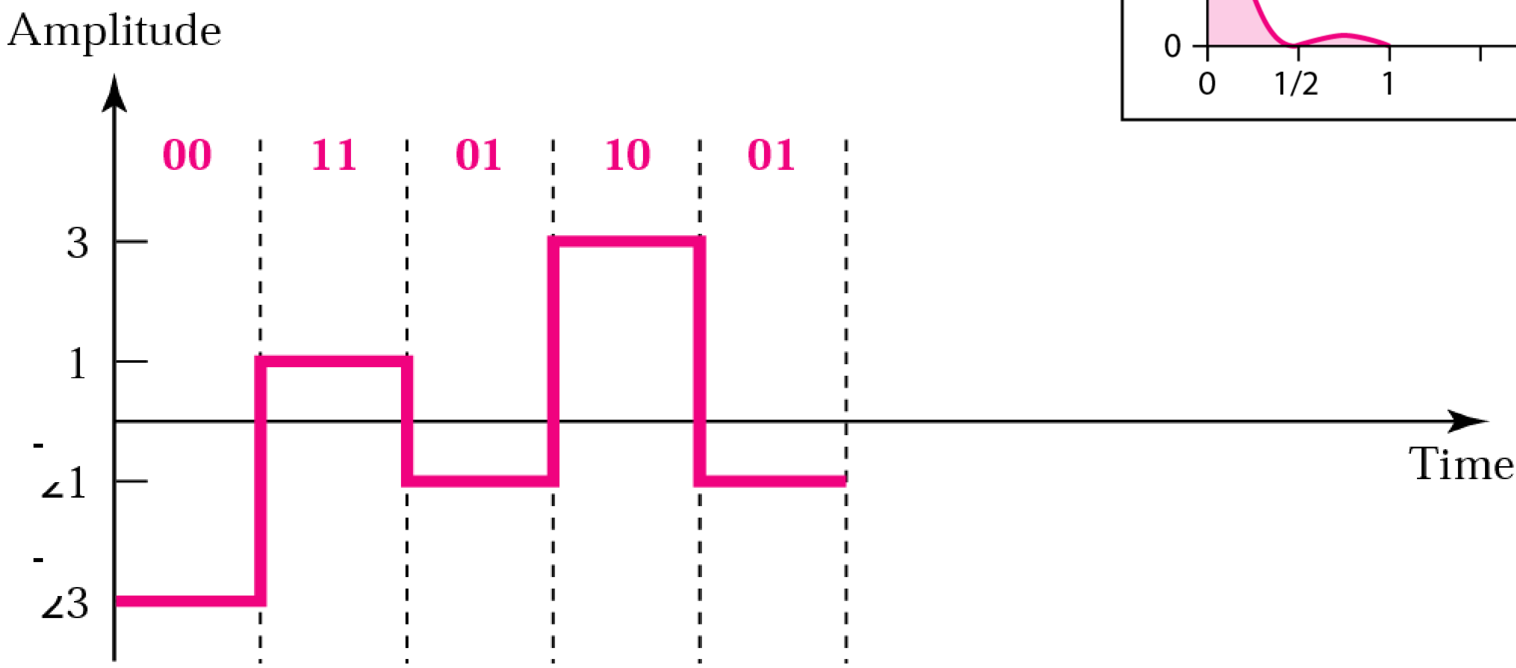
LINE CODING

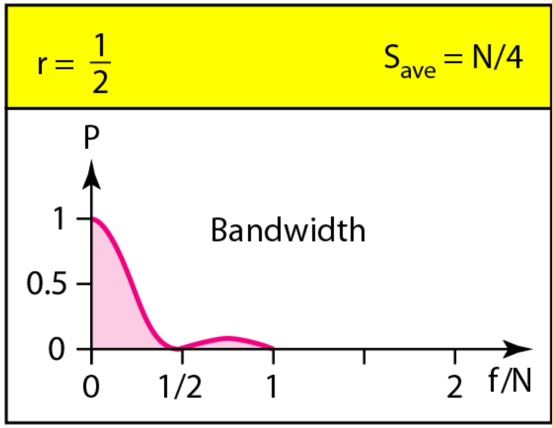
Multi-level coding

1) 2B1Q (2 Binary 1 Quaternary)
2) 8B/6T (8 data bits as six ternary)
3) MLT-3 (Multi-Level Transition 3

Figure 4.13 *2B1Q*

(2 Binary 1 Quaternary)





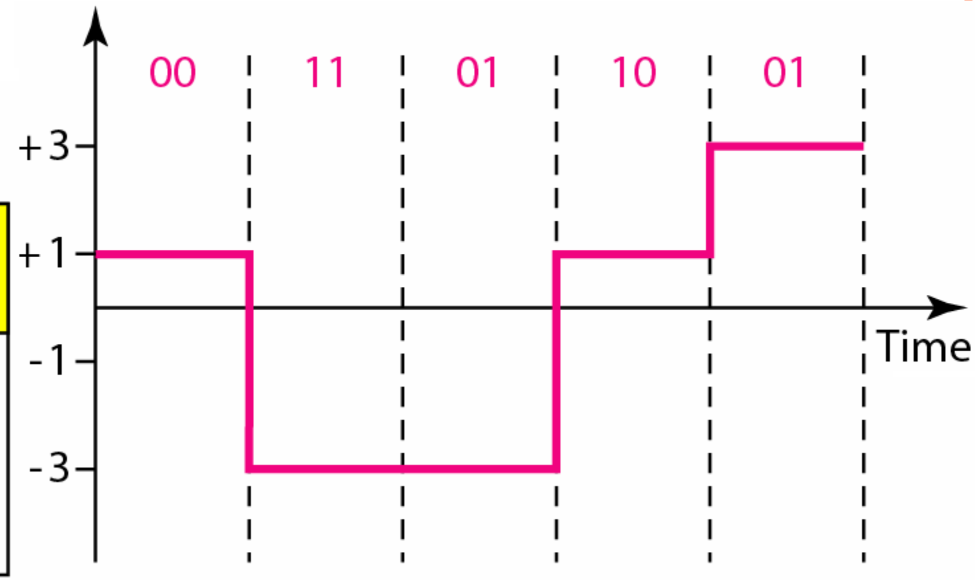
Used in ISDN 64 kbps or 128 kbps via telephone line

2B1Q (TWO BINARY, ONE QUATERNARY)

- Uses data patterns of size 2
- one signal element belonging to four-level signal

Next bits	Previous level: positive Next level	Previous level: negative Next level
00	+1	-1
01	+3	-3
10	-1	+1
11	-3	+3

Transition table



Assuming positive original level

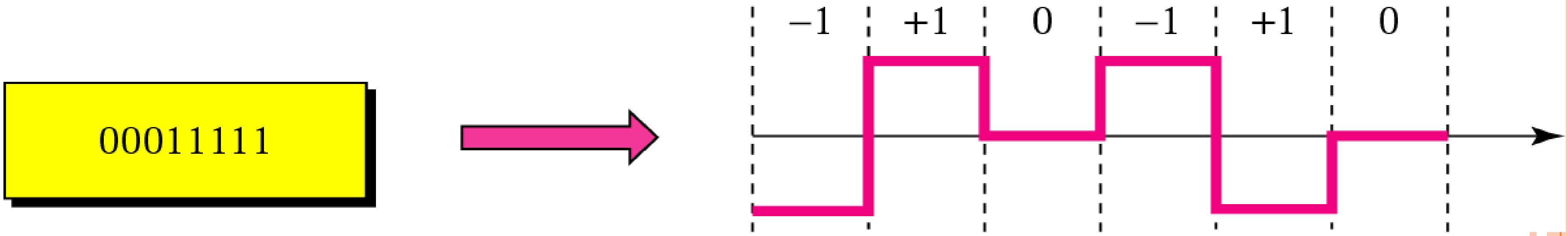
- 2B1Q is used in DSL (Digital Subscriber Line) technology

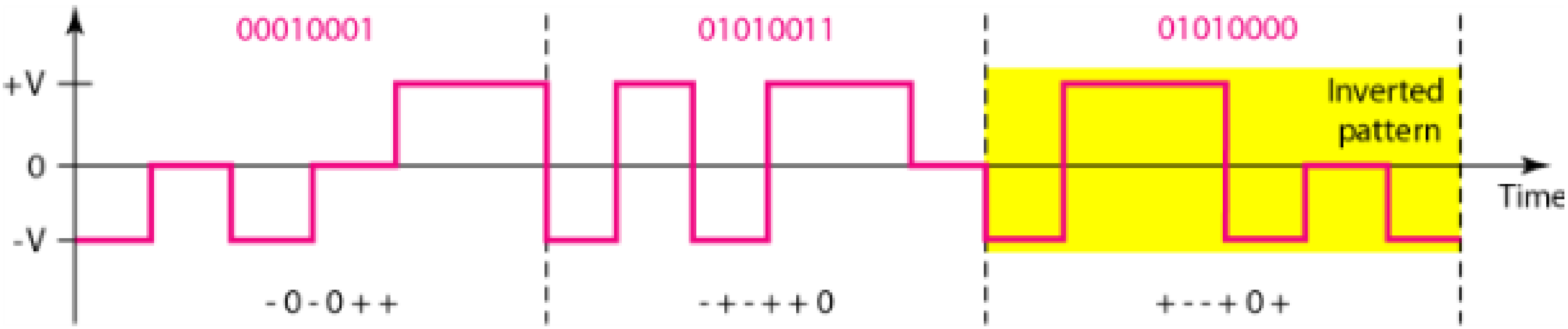
Figure 4.17 *Example of 8B/6T* *ncoding*

2^8=256 different data patter
3^6=478 different signal patt

Data 8 Bits
ความยาวของ Signal = 6
ใช้ Signal 3 ระดับ

478-256=222
redundant signal elemen

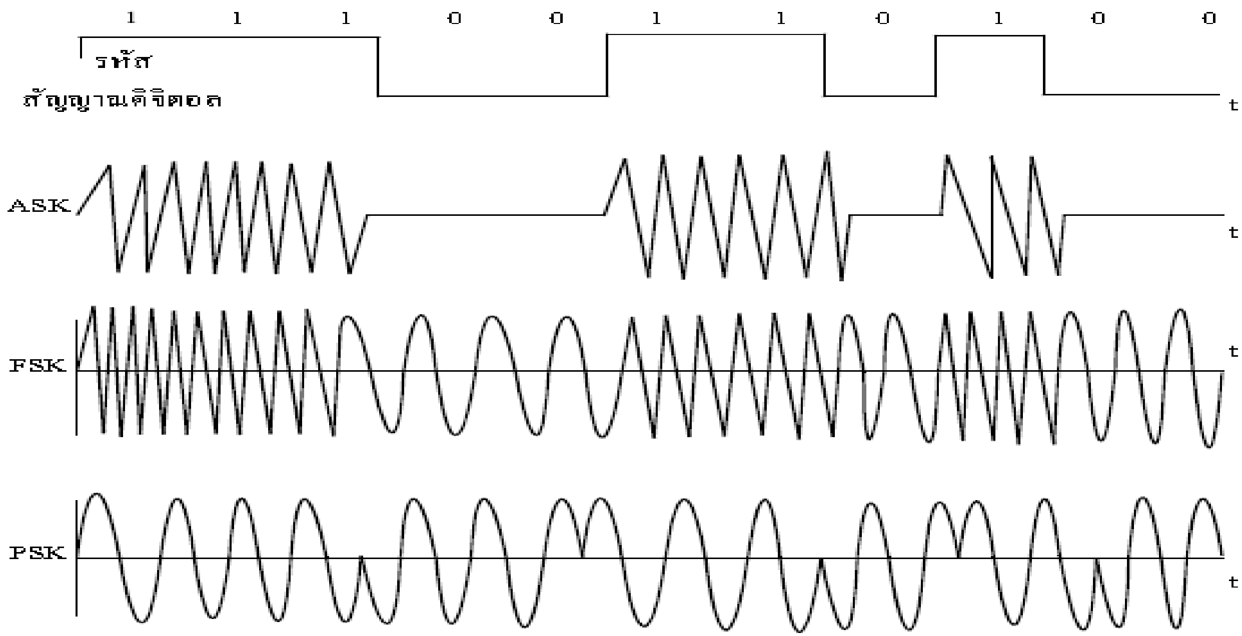


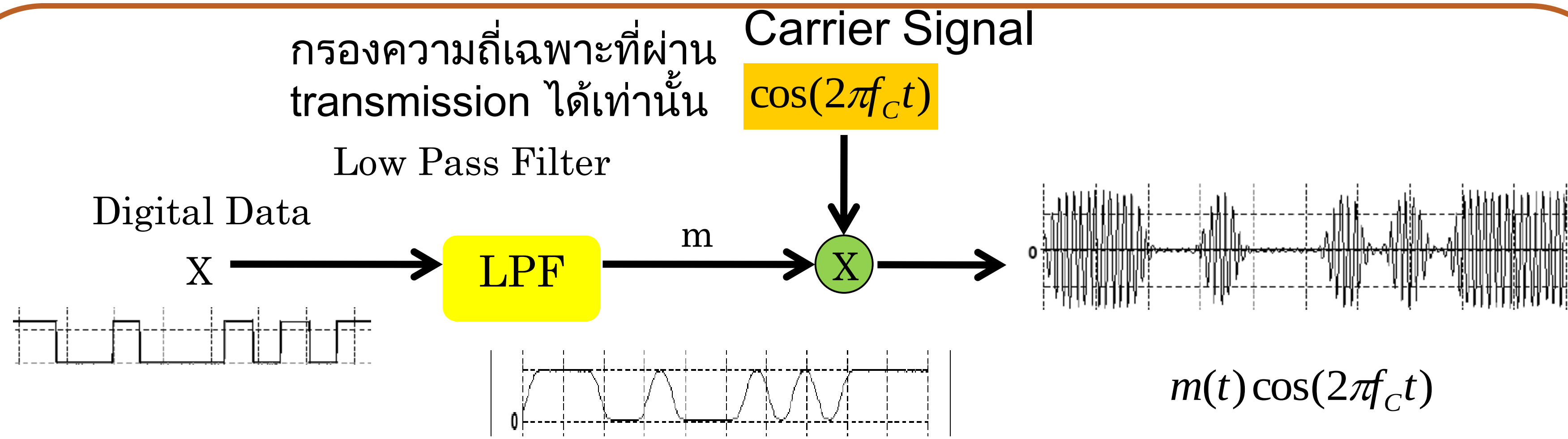


Used in **100BASET4 Ethernet** (100 Mbps) via UTP in Star Topology

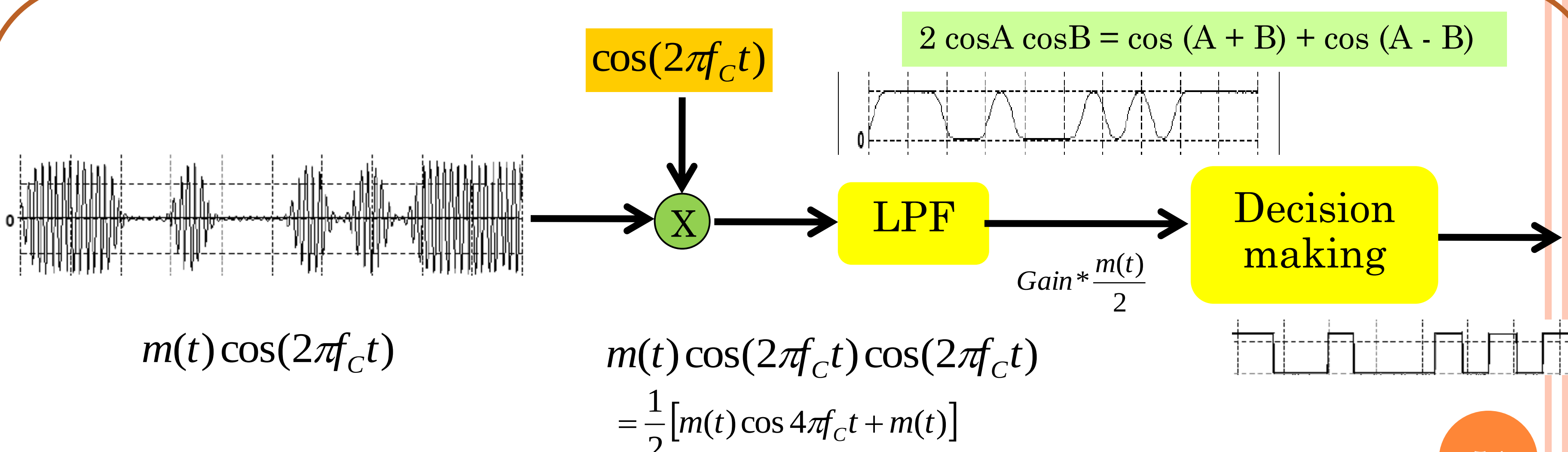
4.3 ການແປງຂໍ້ມູນດິຈິຕອນໃຫ້ເປັນສັນຍານອະນາລັອກ (Digital Data to Analog Signal)

ສຳລັບການແປງຂໍ້ມູນດິຈິຕອນໃຫ້ເປັນສັນຍານອະນາລັອກຈະໃຊ້ອຸປະກອນທີ່ເອີ້ນວ່າ: ໂມເດັມ (Modem) ເຊິ່ງເປັນອຸປະກອນເຮັດໜ້າທີ່ແປງສັນຍານດ້ວຍການ ມໍດູເລດ (Modulate) ໂດຍປະກອບດ້ວຍການມໍດູເລດດ້ວຍວິທີ ASK (Amplitude Shift Keying), FSK (Frequency Shift Keying) ແລະ PSK (Phase Shift Keying).





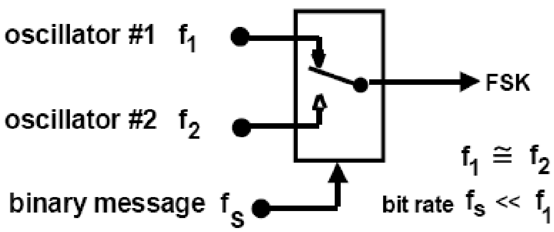
ASK Modulation



ASK Demodulation

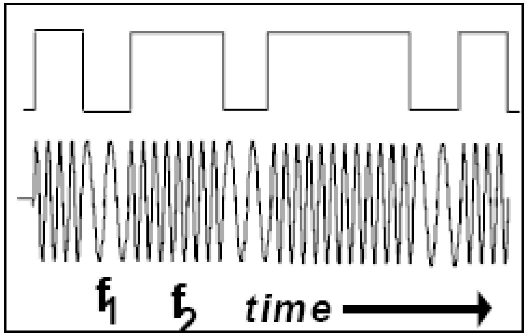
Voltage Controlled Oscillator

VCO



FSK Modulation

- **Bit representation**
  - Changing **Frequency** of Carrier Sigr
  - One bit, One signal unit
    - Ex '0' -> f_1
      '1' -> f_2



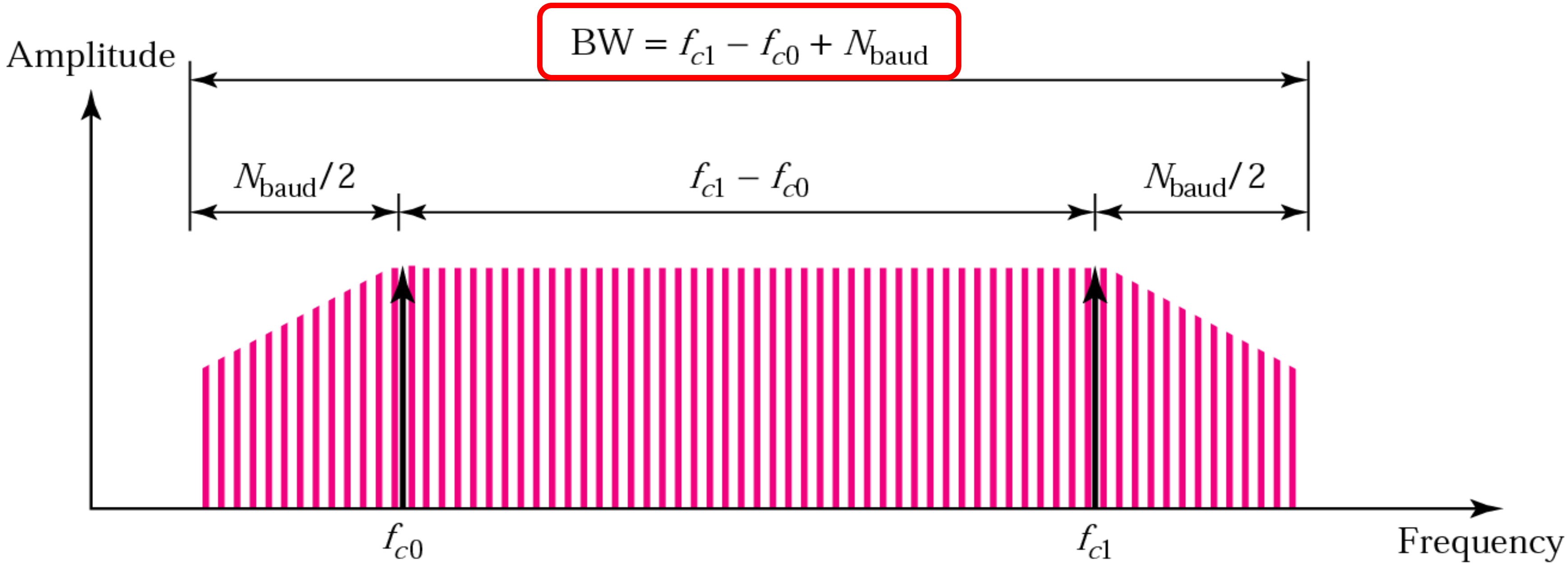
- **Benefit**
  - Less effected by noise
    - Normally used in high frequency radio transmission or coaxial cable
- **Disadvantage**
  - Require Large Bandwidth

Figure 5.7 *Relationship between baud rate and bandwidth in FSK*

$$BW = (1+d)S + (f_{C1} - f_{C0})$$

$$BW\min = S + (f_{C1} - f_{C0})$$

$$BW\max = 2S + (f_{C1} - f_{C0})$$



Example 6

Find the minimum bandwidth for an FSK signal transmitting at 2000 bps.

Transmission is in half-duplex mode, and the carriers are separated by 3000 Hz.

Solution

Bit Rate = Baud Rate

For FSK

$$BW = \text{Baud rate} + f_{c1} - f_{c0}$$

$$BW = \text{Bit rate} + fc1 - fc0 = 2000 + 3000 = 5000 \text{ Hz}$$

Figure 5.8 *PSK*

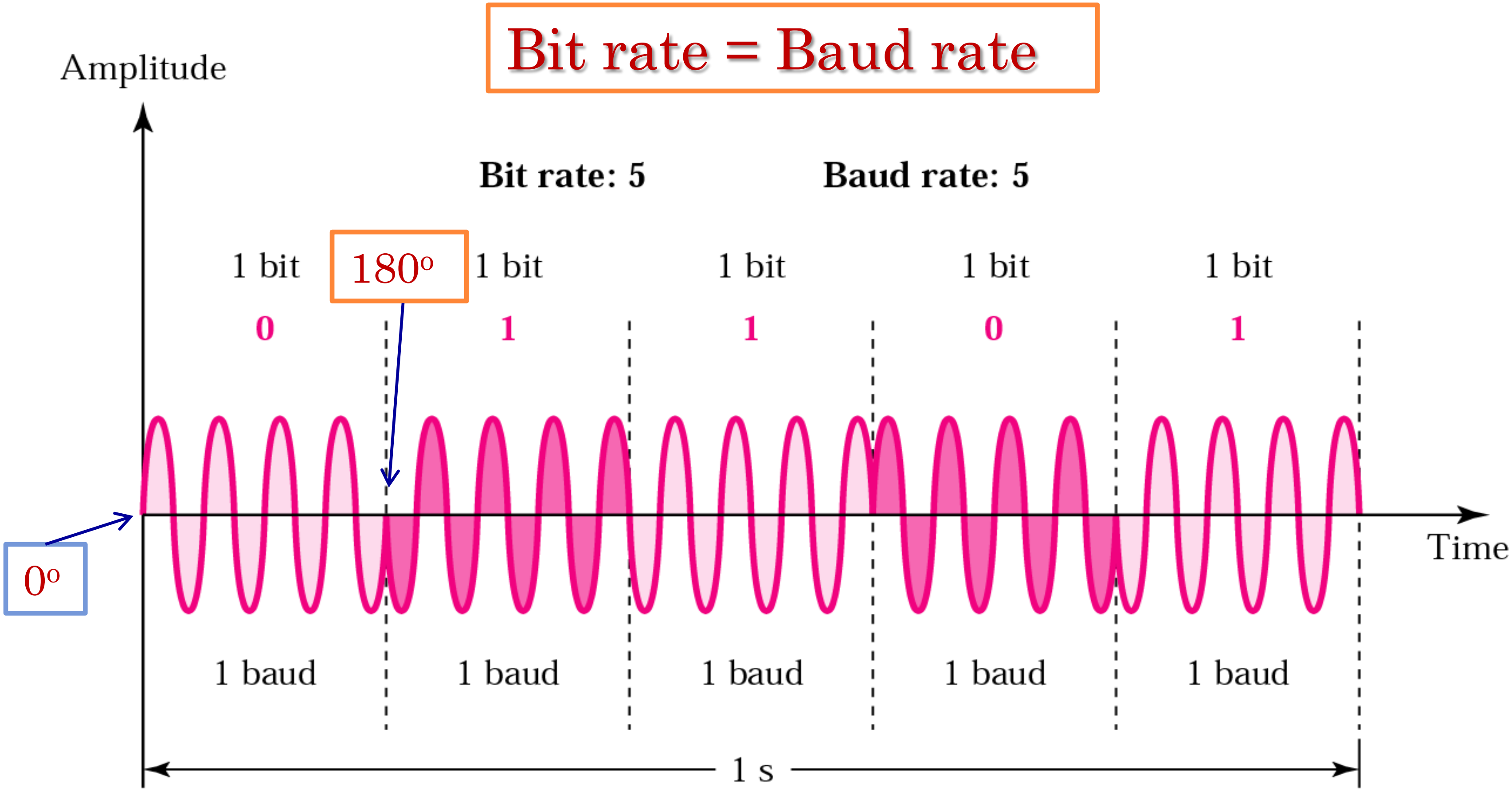
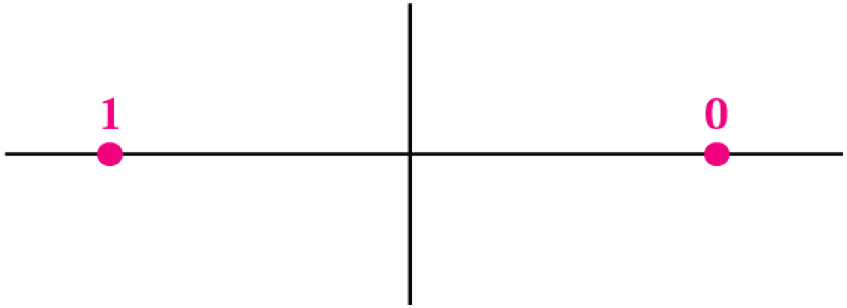


Figure 5.9 *PSK constellation*

Bit	Phase
0	0
1	180

Bits



Constellation diagram

Figure 5.10 *The 4-PSK method*

4-PSK = 2^n-PSK=2^2-PSK

Bit rate = n x baud rate

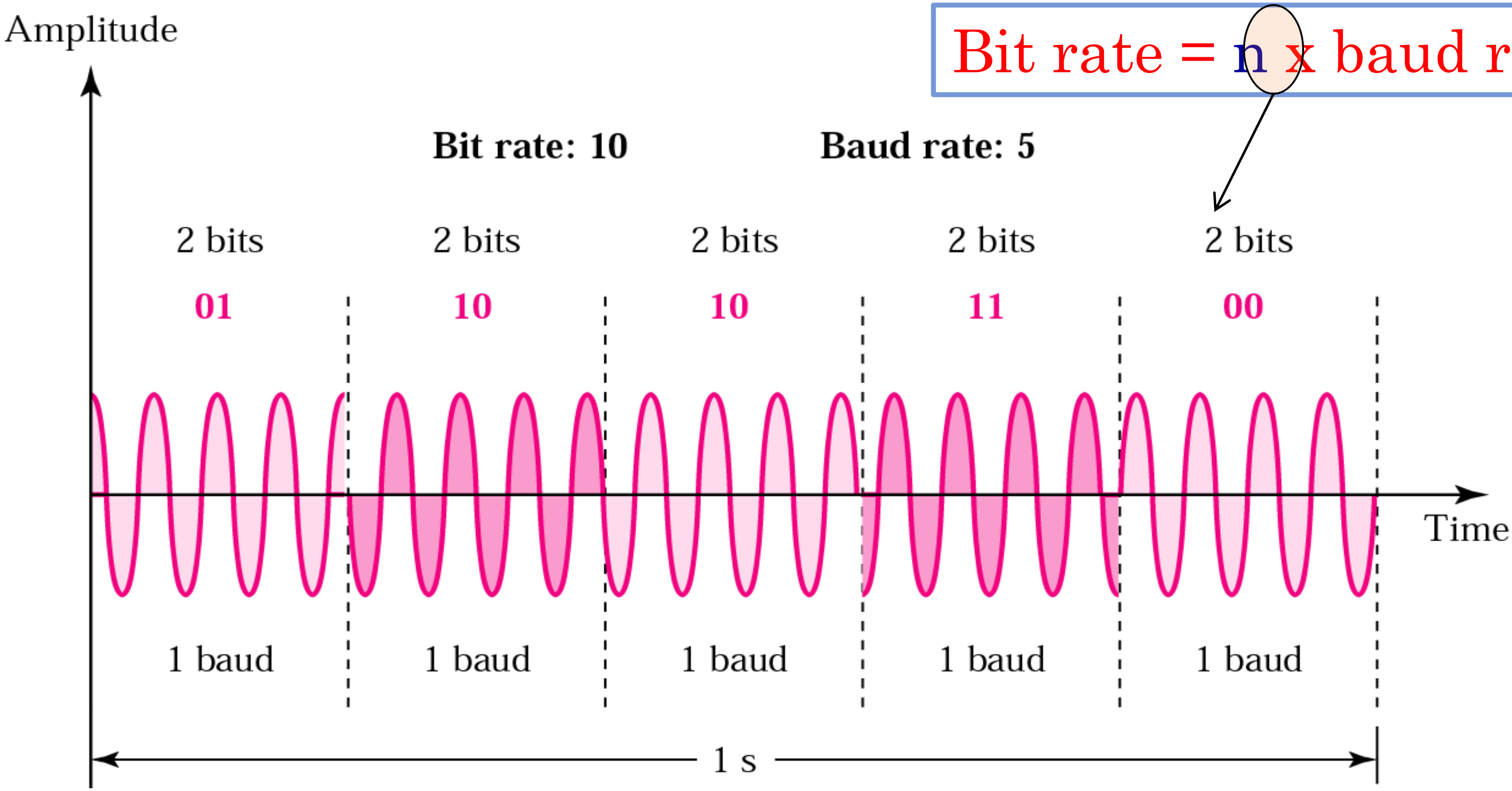
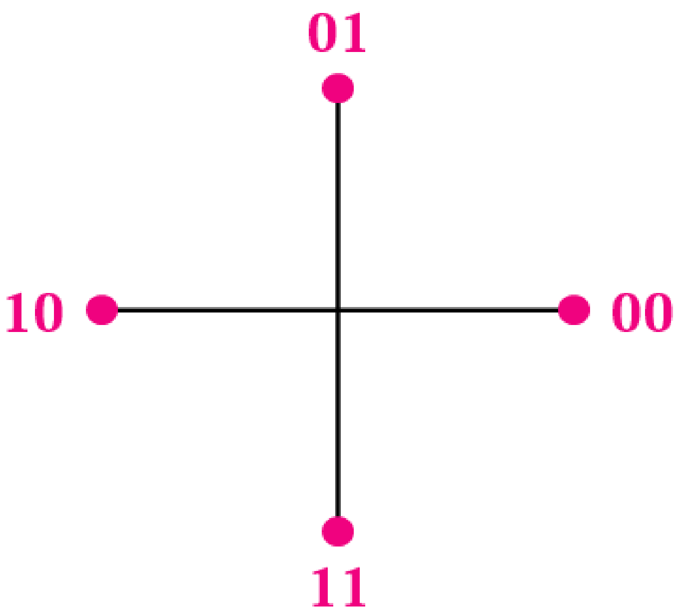


Figure 5.11 *The 4-PSK characteristics*

Dibit	Phase
00	0
01	90
10	180
11	270

Dibit
(2 bits)



Constellation diagram

Figure 5.12 The 8-PSK characteristics

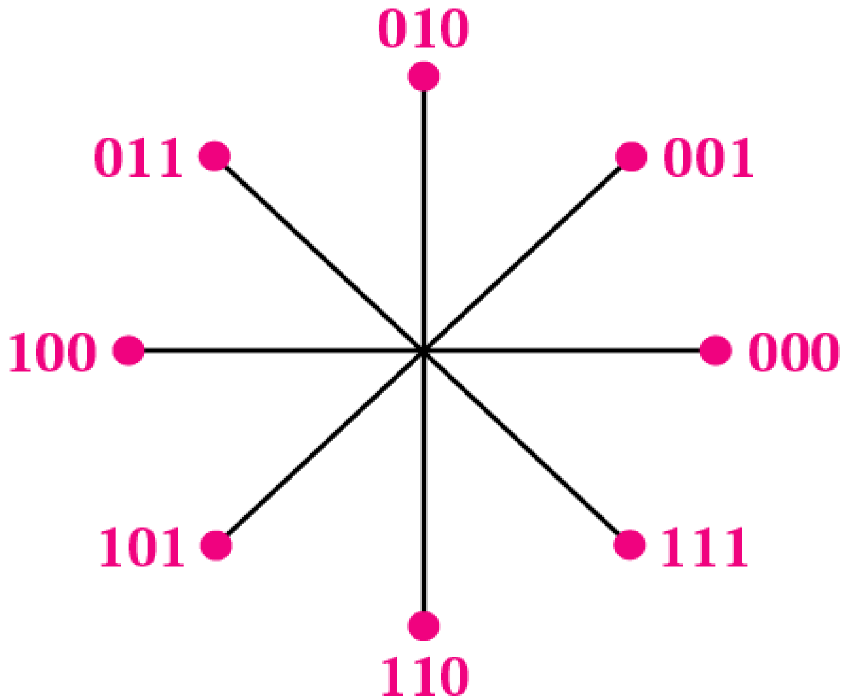
4-PSK = 2^n-PSK=2^3-PSK

Bit rate = n x Baud rate

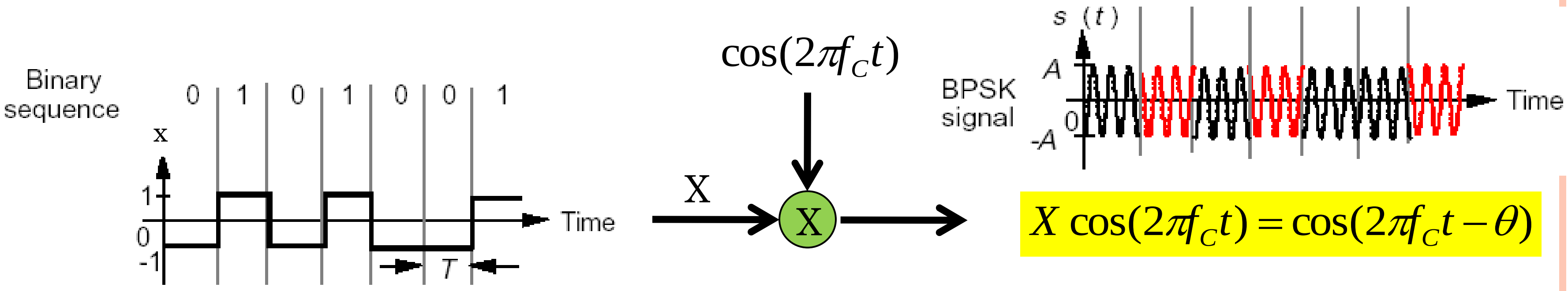
Bit rate = 3 x Baud rate

Tribit	Phase
000	0
001	45
010	90
011	135
100	180
101	225
110	270
111	315

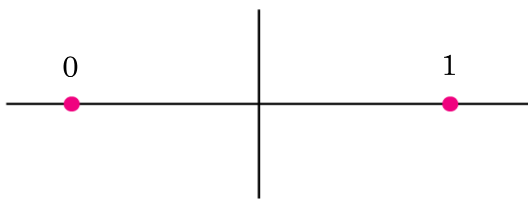
Tribits
(3 bits)



Constellation diagram



$$X\cos(2\pi f_C t) = \cos(2\pi f_C t - \theta)$$



Constellation diagram

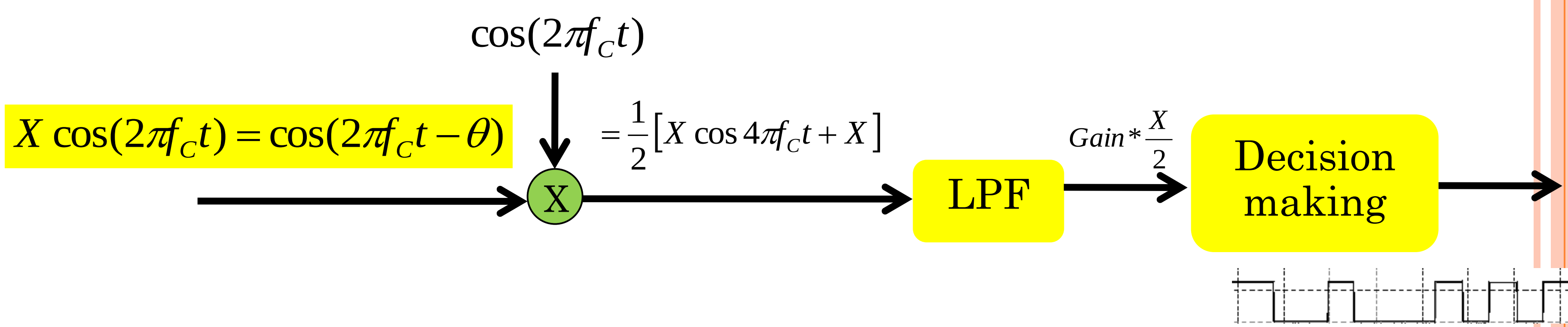
$$s(t) = \begin{cases} A\cos(2\pi f_c t - \pi); & binary \quad '0' \\ A\cos(2\pi f_c t); & binary \quad '1' \end{cases}$$

Pulse

Data

X		$X\cos(2\pi f_C t)$	$\cos(2\pi f_C t - \theta)$
[0,1]	[-1,1]		
0	-1	$-\cos(2\pi f_C t)$	$\cos(2\pi f_C t - \pi)$
1	1	$\cos(2\pi f_C t)$	$\cos(2\pi f_C t - 0)$

BPSK Modulation



2 cosA cosB = cos (A + B) + cos (A - B)

$$X\cos(2\pi f_C t)\cos(2\pi f_C t) = X\left(\frac{1}{2}\left[\cos 2(2\pi f_C t) + \cos(0)\right]\right)$$

$$= \frac{1}{2}\left[X\cos 4\pi f_C t + X\right]$$

BPSK Demodulation

QUADRATURE AMPLITUDE MODULATION (QAM)

- **Bit representation**
  - Combination of ASK and PSK
  - Changing Amplitude & Phase of Career Signal
  - One bit, One signal unit
    - Ex ‘0’ -> A_1, Φ_1

      ‘1’ -> A_2, Φ_2
- **Benefit**
  - Less effected by noise compared to ASK
  - Require less bandwidth
- **Disadvantage**
  - Complex demodulation technique

Figure 5.14 *The 4-QAM and 8-QAM constellations*

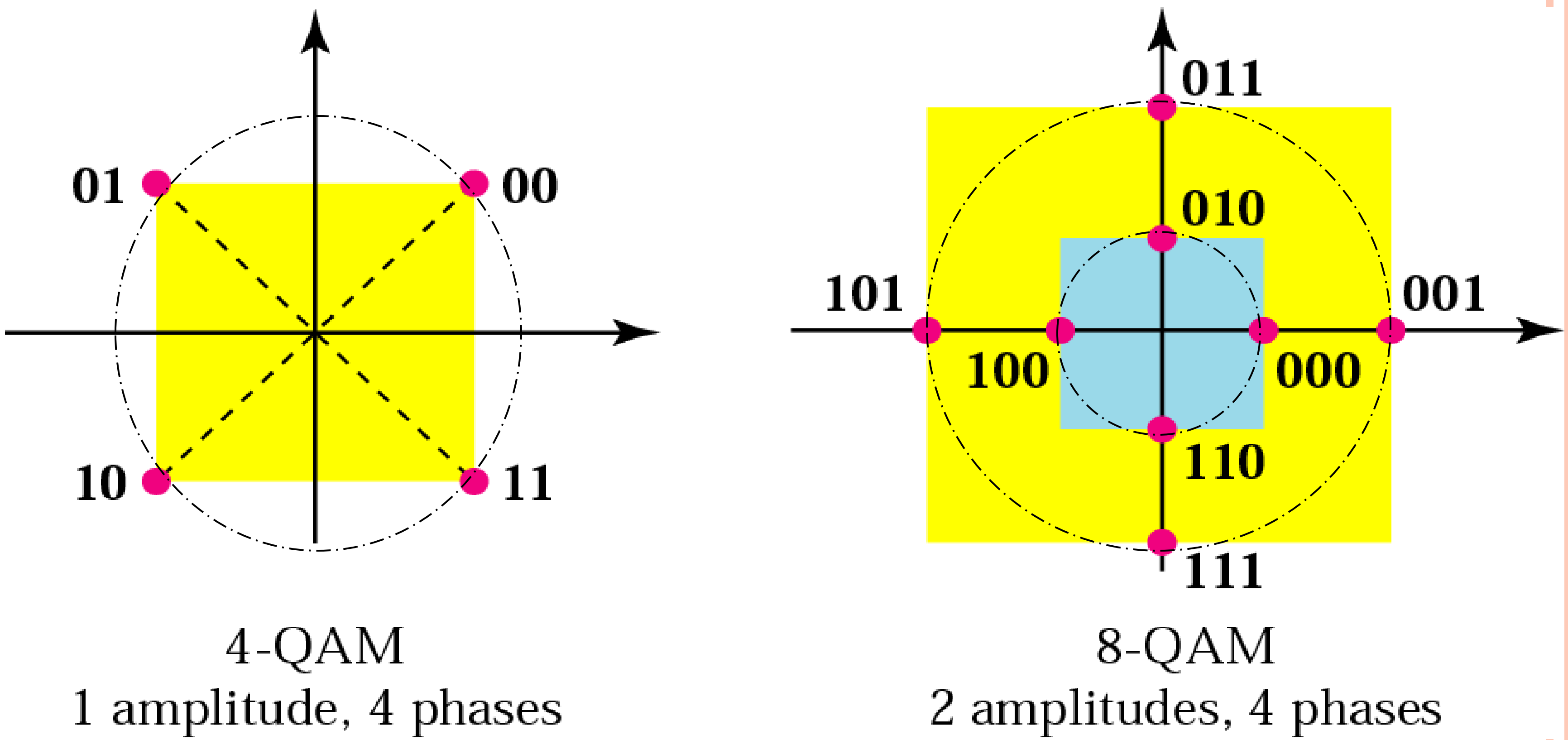


Figure 5.15 *Time domain for an 8-QAM signal*

8-QAM = 2^n-QAM=2^3-QAM

Bit rate = n x Baud rate

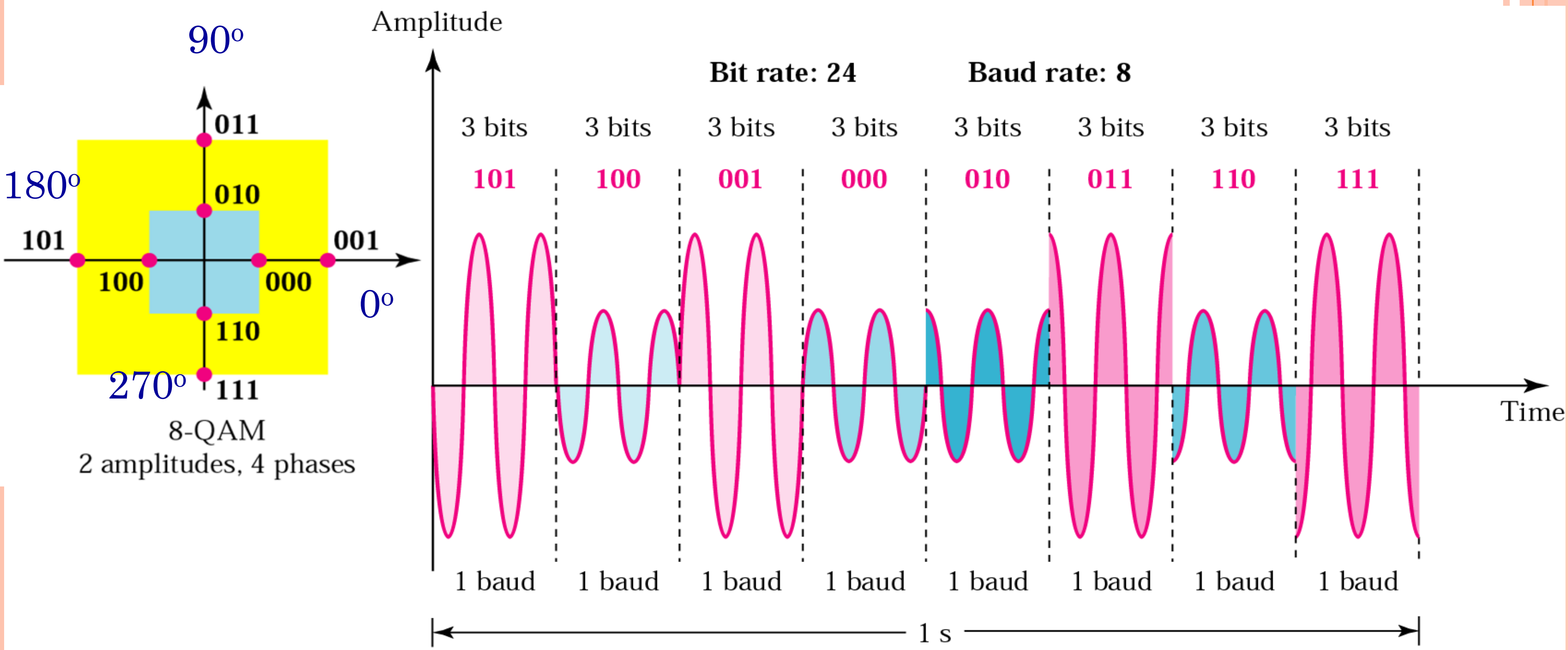
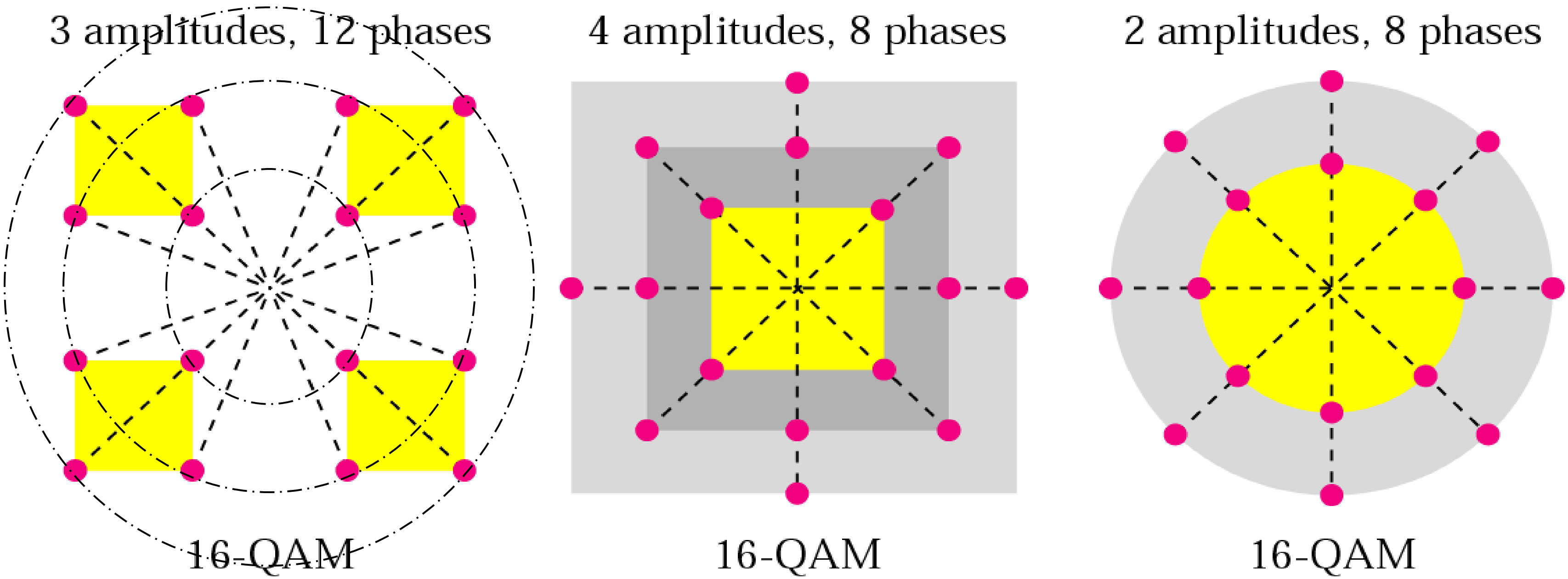


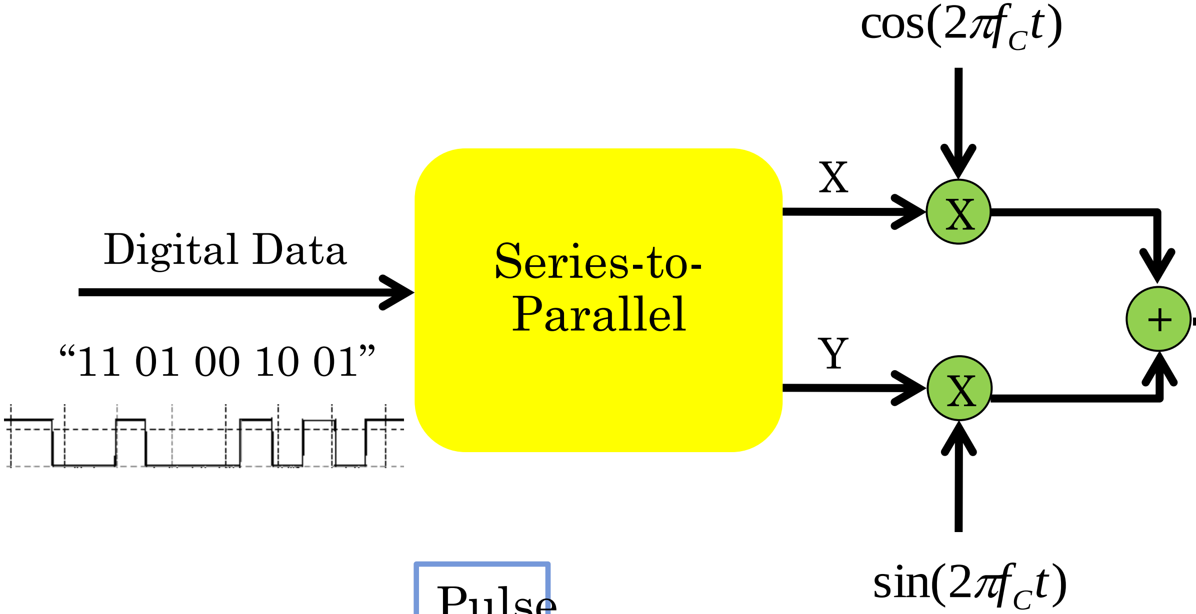
Figure 5.16 *16-QAM constellations*

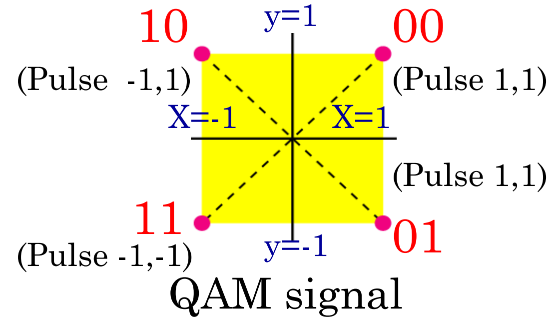


ITU-T recommendation

OSI recommendation

QAM Modulation



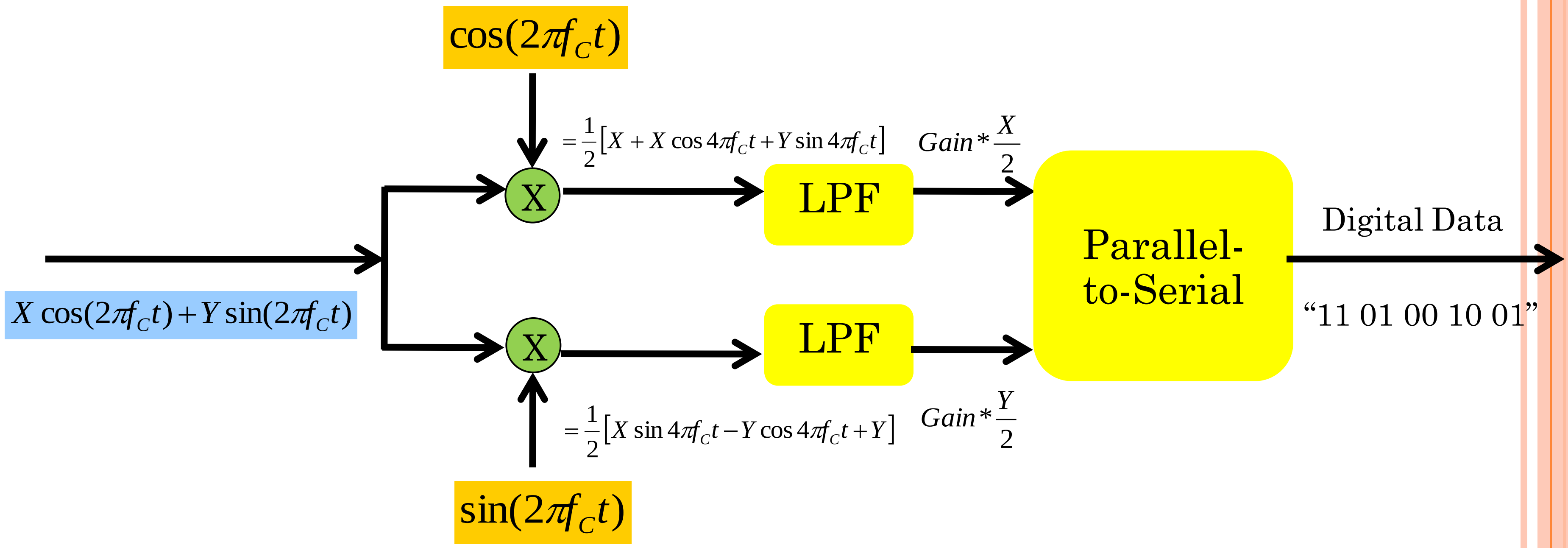


$$X\cos(2\pi f_C t) + Y\sin(2\pi f_C t)$$
$$= \cos B \cos A + \sin B \sin A$$
$$= \cos(A - B)$$
$$(2\pi f_C t)$$

Pulse

X		Y		XcosA + YsinA =	cos(A-B)	Θ
[0,1]	[1,-1]	[0,1]	[1,-1]	cosAcosB + sinAsinB		
0	1	0	1	"1" cosA + "1" sinA	cos(A-45)	45
0	1	1	-1	"1" cosA + "-1" sinA	cos(A+45)	-45
1	-1	0	1	"-1" cosA + "1" sinA	cos(A-135)	135
1	-1	1	-1	"-1" cosA + "-1" sinA	cos(A+135)	-135

Digital Data



$$[X\cos(2\pi f_C t) + Y\sin(2\pi f_C t)]\cos(2\pi f_C t)$$
$$= [X\cos(2\pi f_C t)\cos(2\pi f_C t) + Y\sin(2\pi f_C t)\cos(2\pi f_C t)]$$
$$= X\left(\frac{1}{2}[\cos 2(2\pi f_C t) + \cos(0)]\right) + Y\left(\frac{1}{2}\sin 2(2\pi f_C t)\right)$$
$$= \frac{1}{2}[X + X\cos 4\pi f_C t + Y\sin 4\pi f_C t]$$

2 cosA cosB = cos (A + B) + cos (A - B)

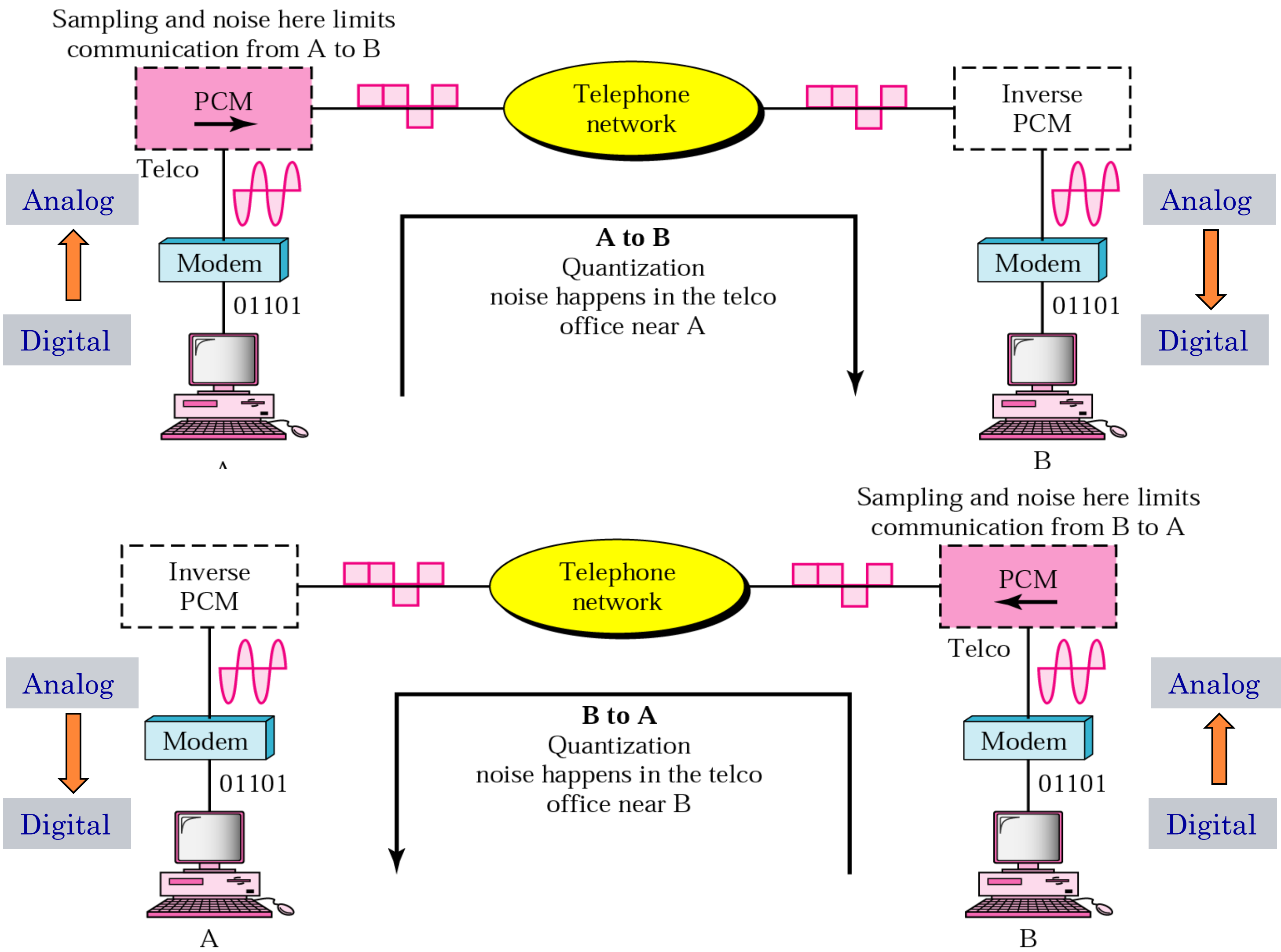
$$[X\cos(2\pi f_C t) + Y\sin(2\pi f_C t)]\sin(2\pi f_C t)$$
$$= [X\cos(2\pi f_C t)\sin(2\pi f_C t) + Y\sin(2\pi f_C t)\sin(2\pi f_C t)]$$
$$= X\left(\frac{1}{2}[\sin 2(2\pi f_C t)]\right) + Y\left(\frac{1}{2}[-\cos 2(2\pi f_C t) + \cos(0)]\right)$$
$$= \frac{1}{2}[X\sin(4\pi f_C t) - Y\cos(4\pi f_C t) + Y]$$

2 sinA sinB = - cos (A + B) + cos (A - B)

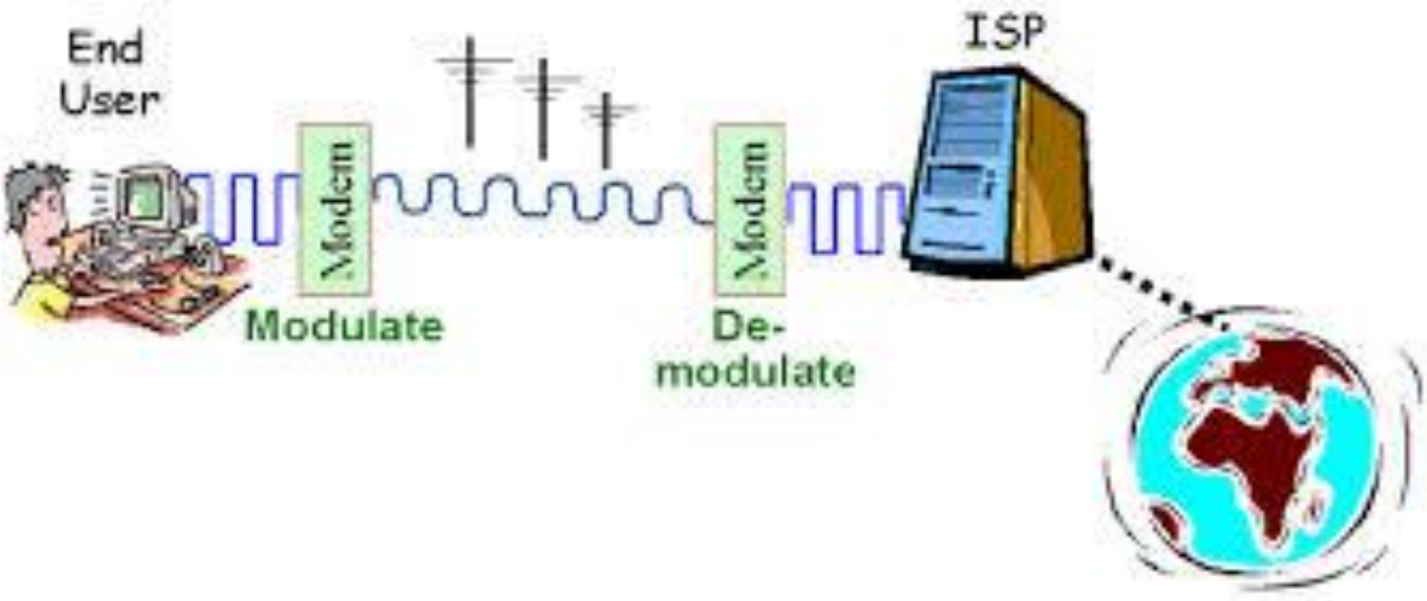
2 sinA cosB = sin (A + B) + sin (A - B)

QAM Demodulation

Figure 5.22 *Traditional modems*



ຮູບແບບການທຳງານຂອງໂມເດັມ (MODEM)



4.4 ການແປງຂໍ້ມູນອະນາລັອກໃຫ້ເປັນສັນຍານດິຈິຕອນ (Analog Data to Digital Signal)

ອຸປະກອນທີ່ເອີ້ນວ່າ ໂຄດເດັກ (Codec: Coder/Decoder) ຈັດເປັນອຸປະກອນທີ່ສຳຄັນສຳລັບໃນການແປງຂໍ້ມູນອະນາລັອກໃຫ້ເປັນສັນຍານດິຈິຕອນດ້ວຍເທັກນິກ PCM (Pulse Code Modulation) ໃນຂະນະດຽວກັນກໍ່ສາມາດແປງມາເປັນສັນຍານອະນາລັອກໄດ້ ຕົວຢ່າງອຸປະກອນໂຄດເດັກ ເຊັ່ນ ຊາວນ໌ກາດ, ສະແກນເນີ ເປັນຕົ້ນ.

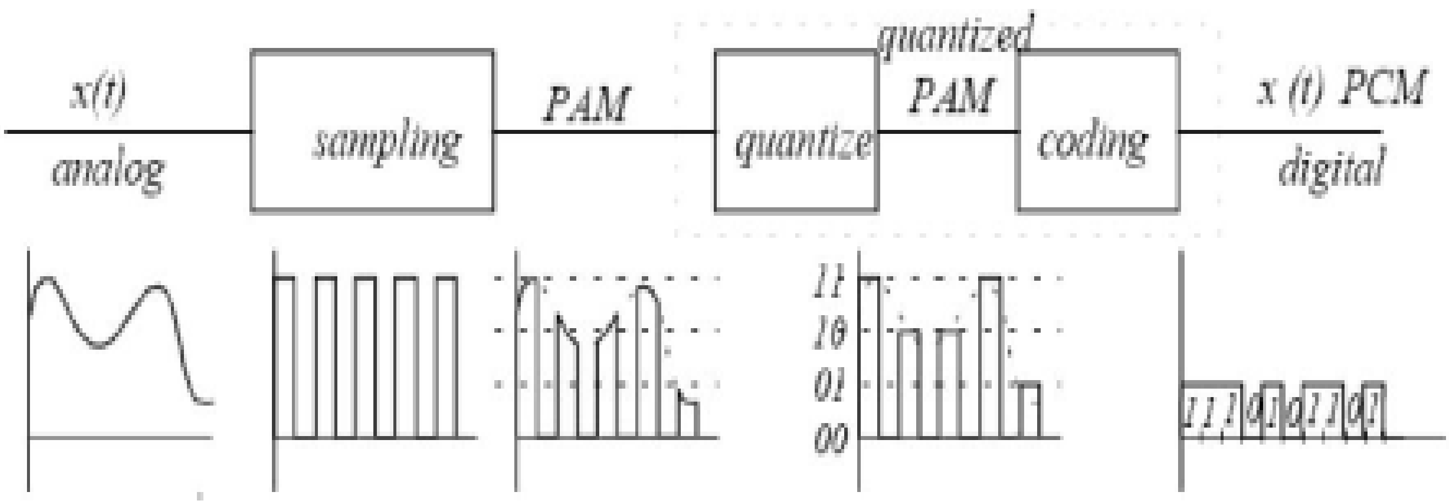
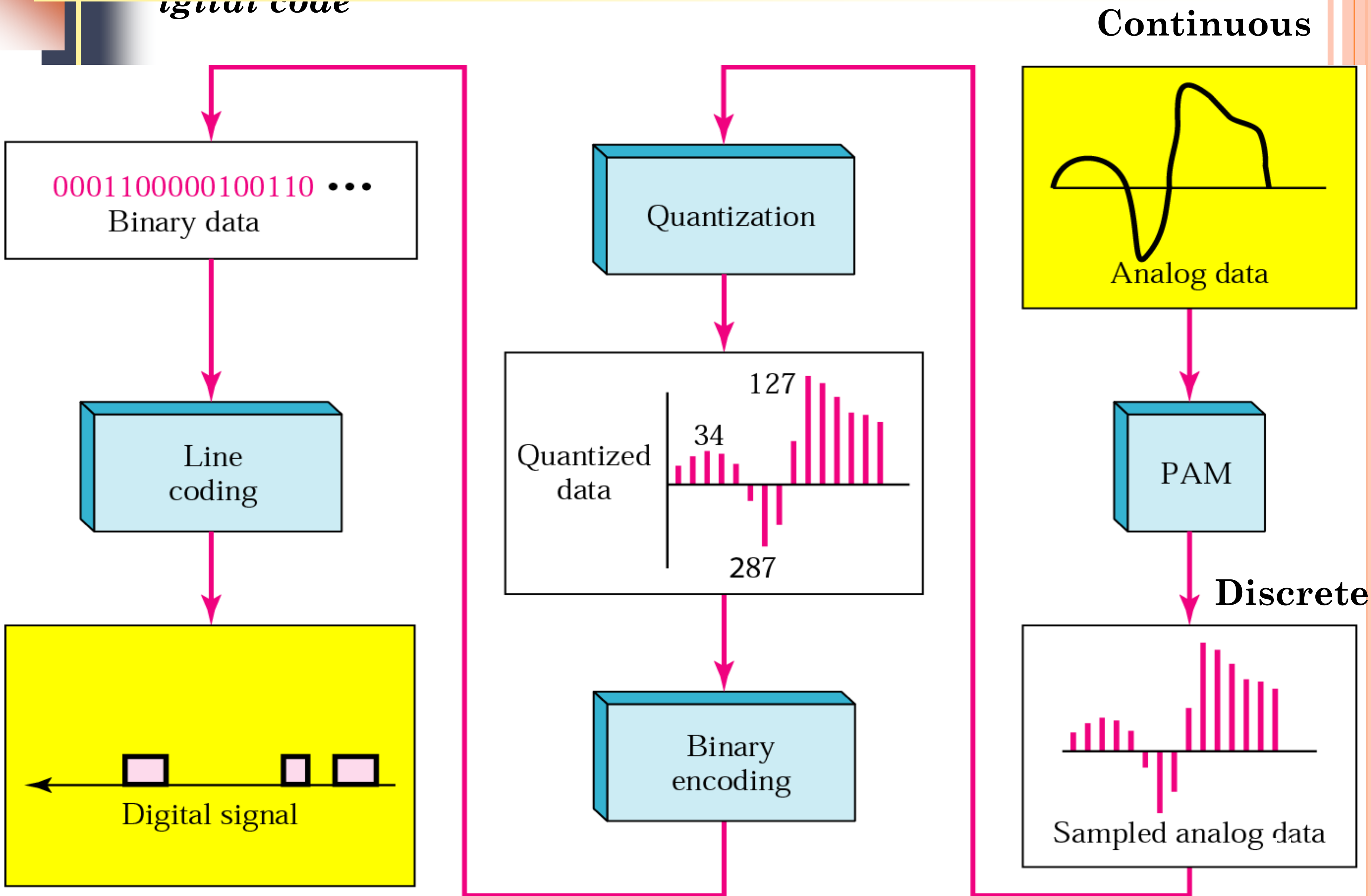
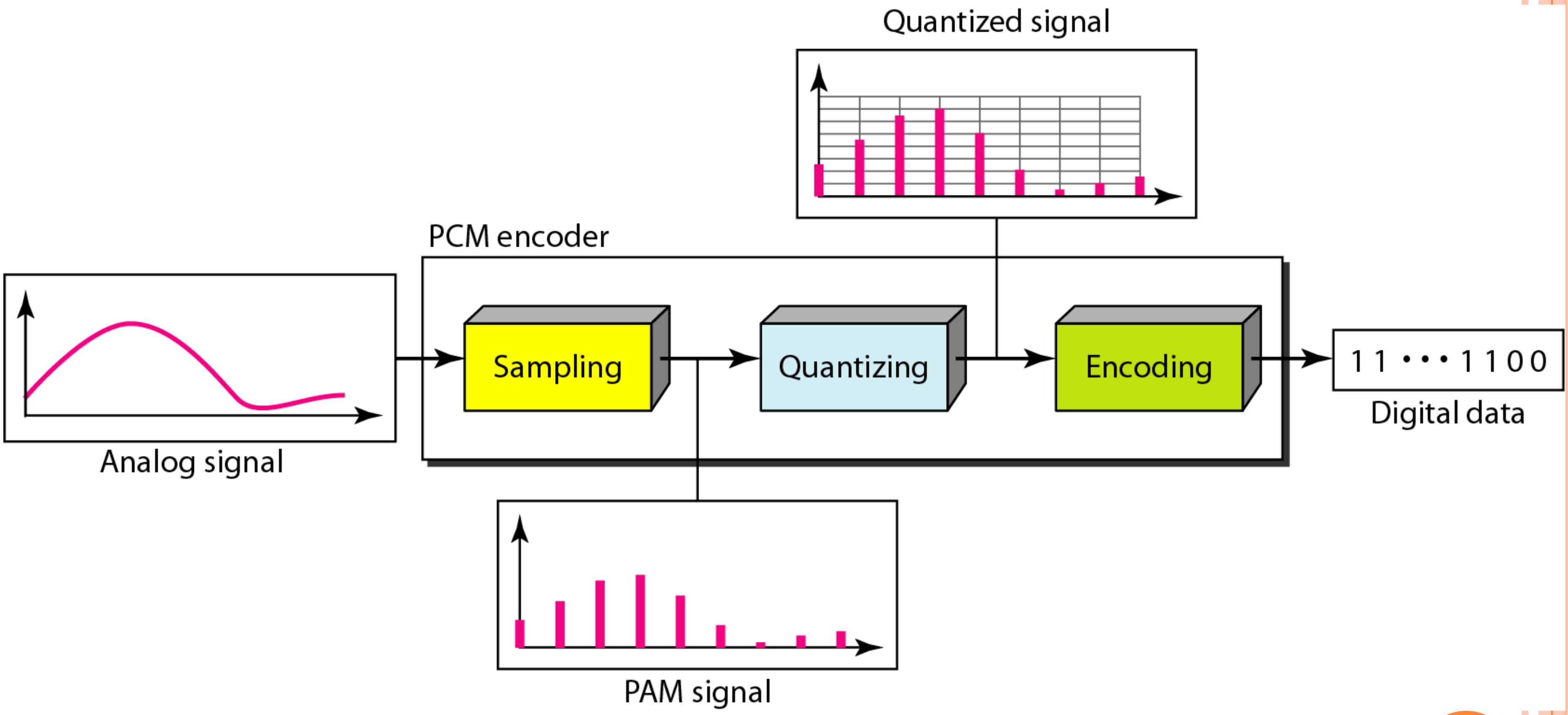


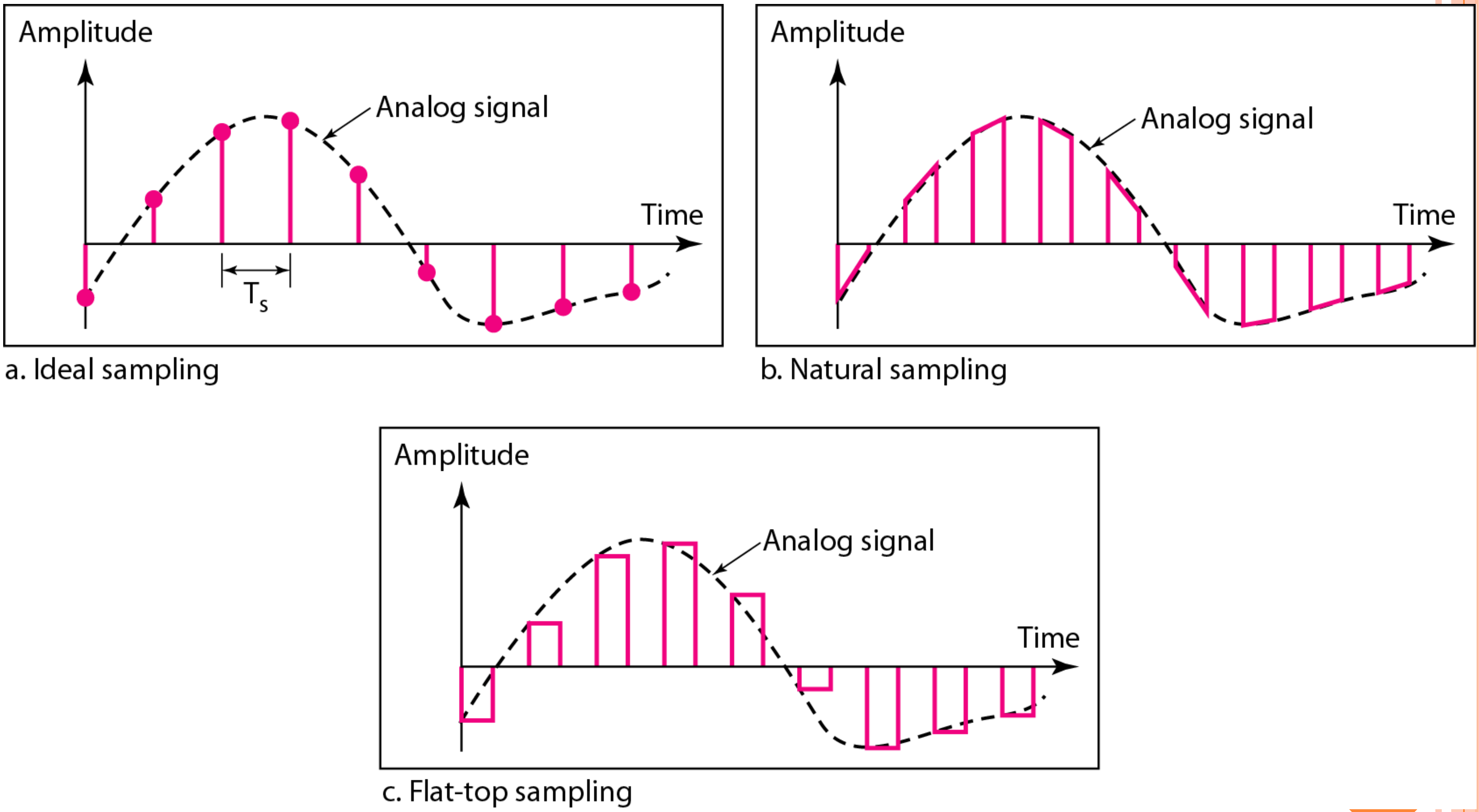
Figure 4.22 *From analog signal to PCM digital code*



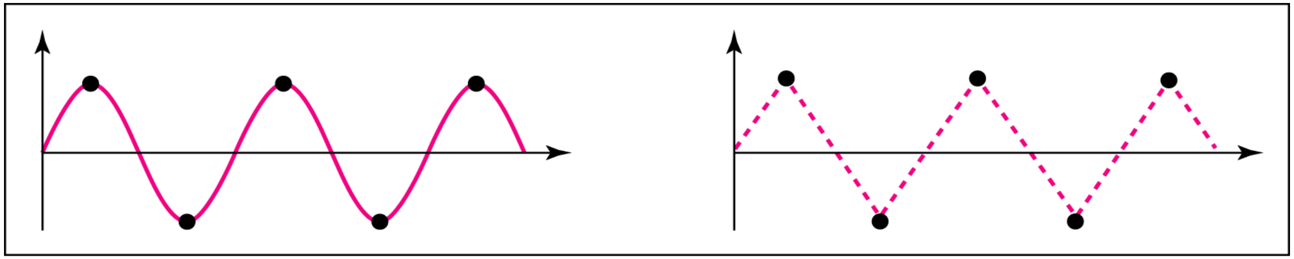
Components of PCM encoder



Three different sampling methods for PCM

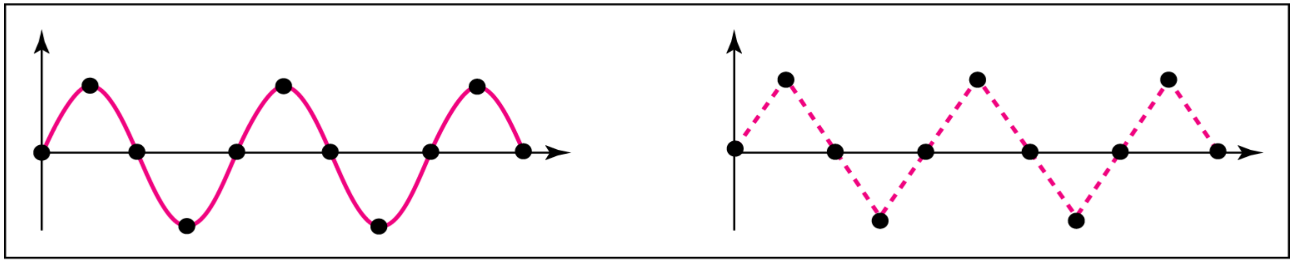


Recovery of a sampled sine wave for different sampling rates



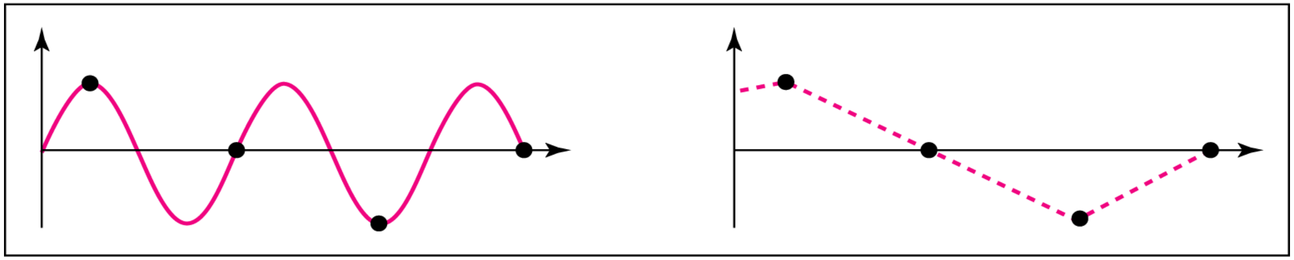
a. Nyquist rate sampling: $f_s = 2f$

Sampling at the Nyquist rate can create a good approximation of the original sine wave.



b. Oversampling: $f_s = 4f$

Oversampling can also create the same approximation, but is redundant and unnecessary.

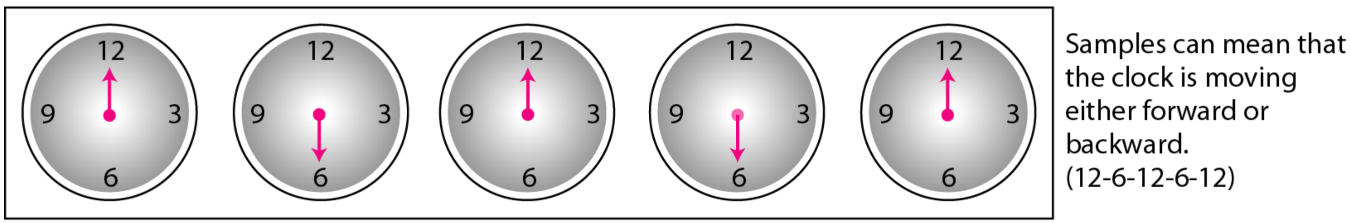


c. Undersampling: $f_s = f$

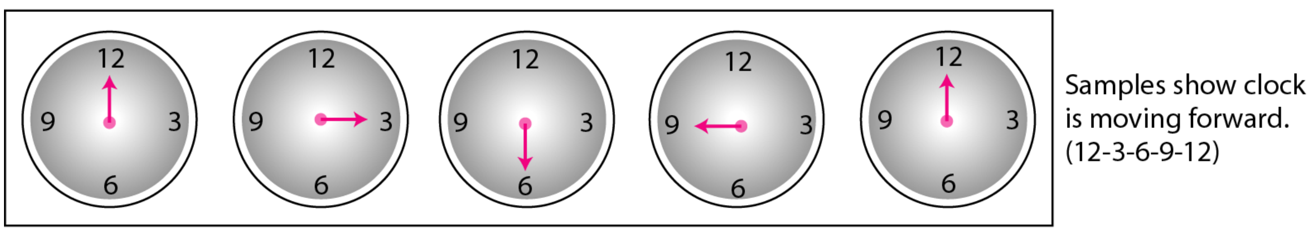
Sampling below the Nyquist rate does not produce a signal that looks like the original sine wave.

Sampling of a clock with only one hand

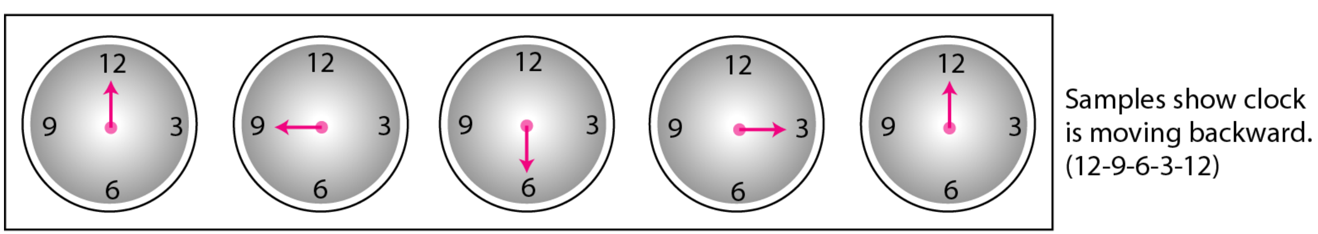
The second hand of a clock has a period of 60 s.
According to the Nyquist theorem, we need to sample hand every 30 s



a. Sampling at Nyquist rate: $T_s = T\frac{1}{2}$

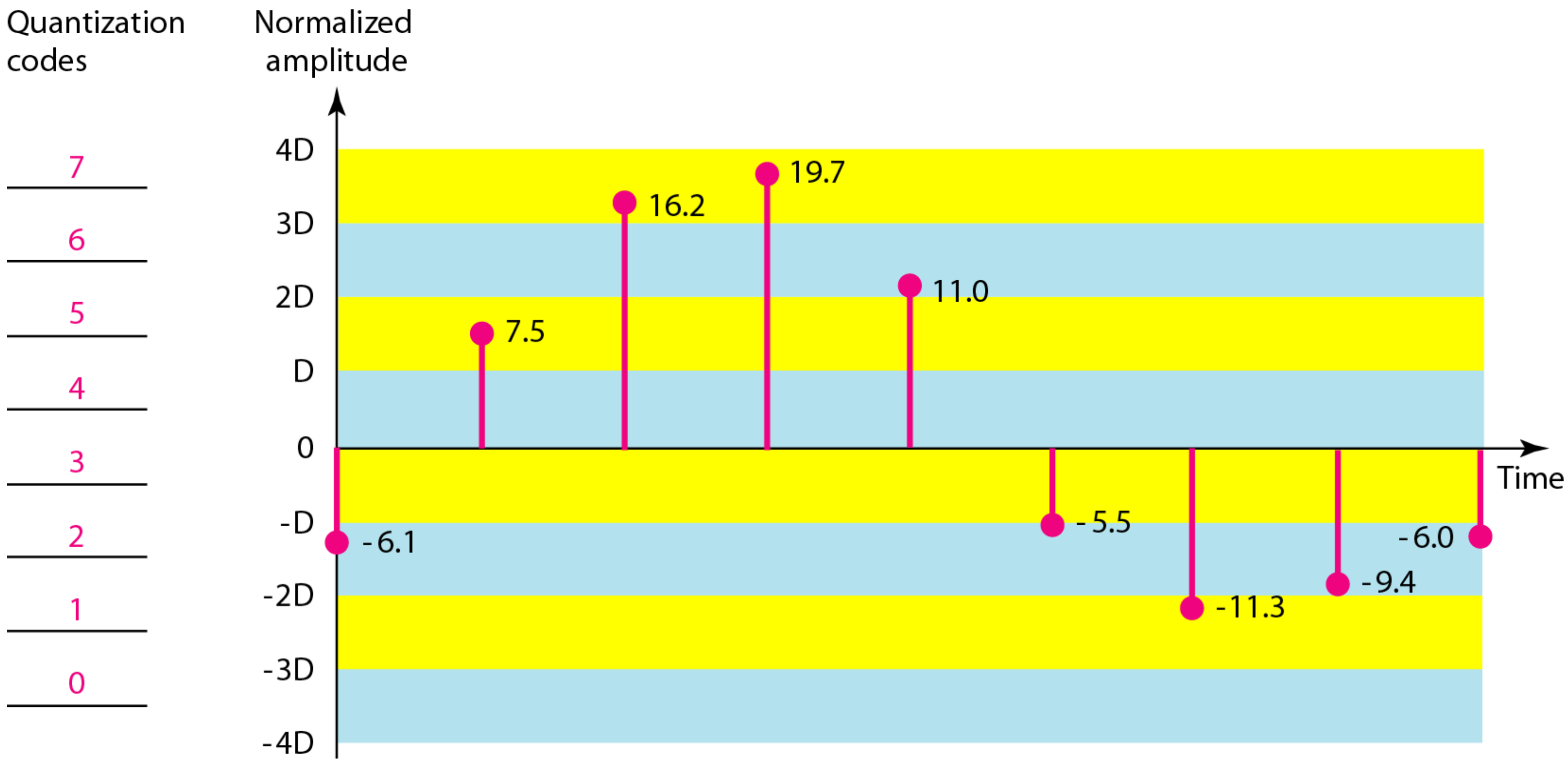


b. Oversampling (above Nyquist rate): $T_s = T\frac{1}{4}$



c. Undersampling (below Nyquist rate): $T_s = T\frac{3}{4}$

Quantization and encoding of a sampled signal



Normalized PAM values	-1.22	1.50	3.24	3.94	2.20	-1.10	-2.26	-1.88	-1.20
Normalized quantized values	-1.50	1.50	3.50	3.50	2.50	-1.50	-2.50	-1.50	-1.50
Normalized error	-0.38	0	+0.26	-0.44	+0.30	-0.40	-0.24	+0.38	-0.30
Quantization code	2	5	7	7	6	2	1	2	2
Encoded words	010	101	111	111	110	010	001	010	010

Figure 4.19 *Quantized PAM signal*

** Signed Integer **

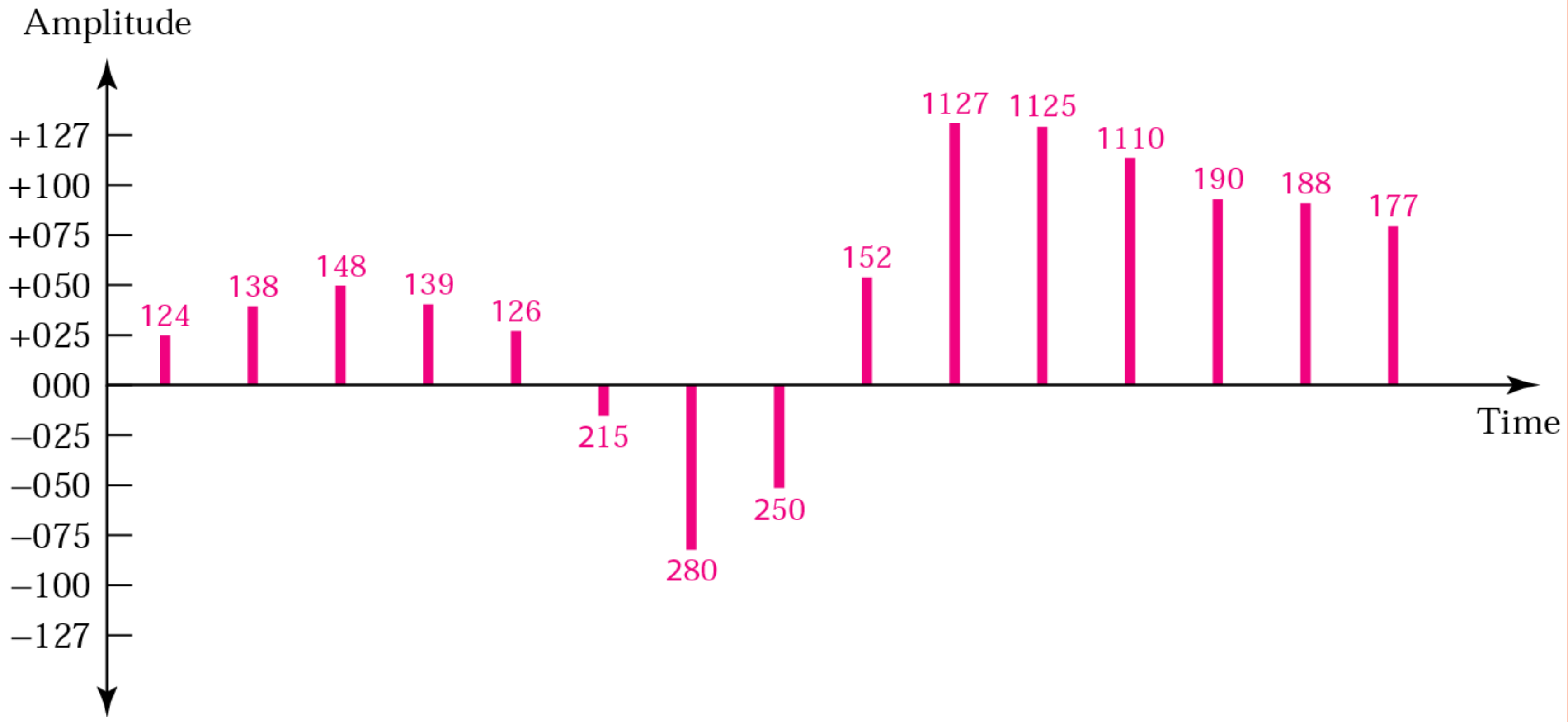
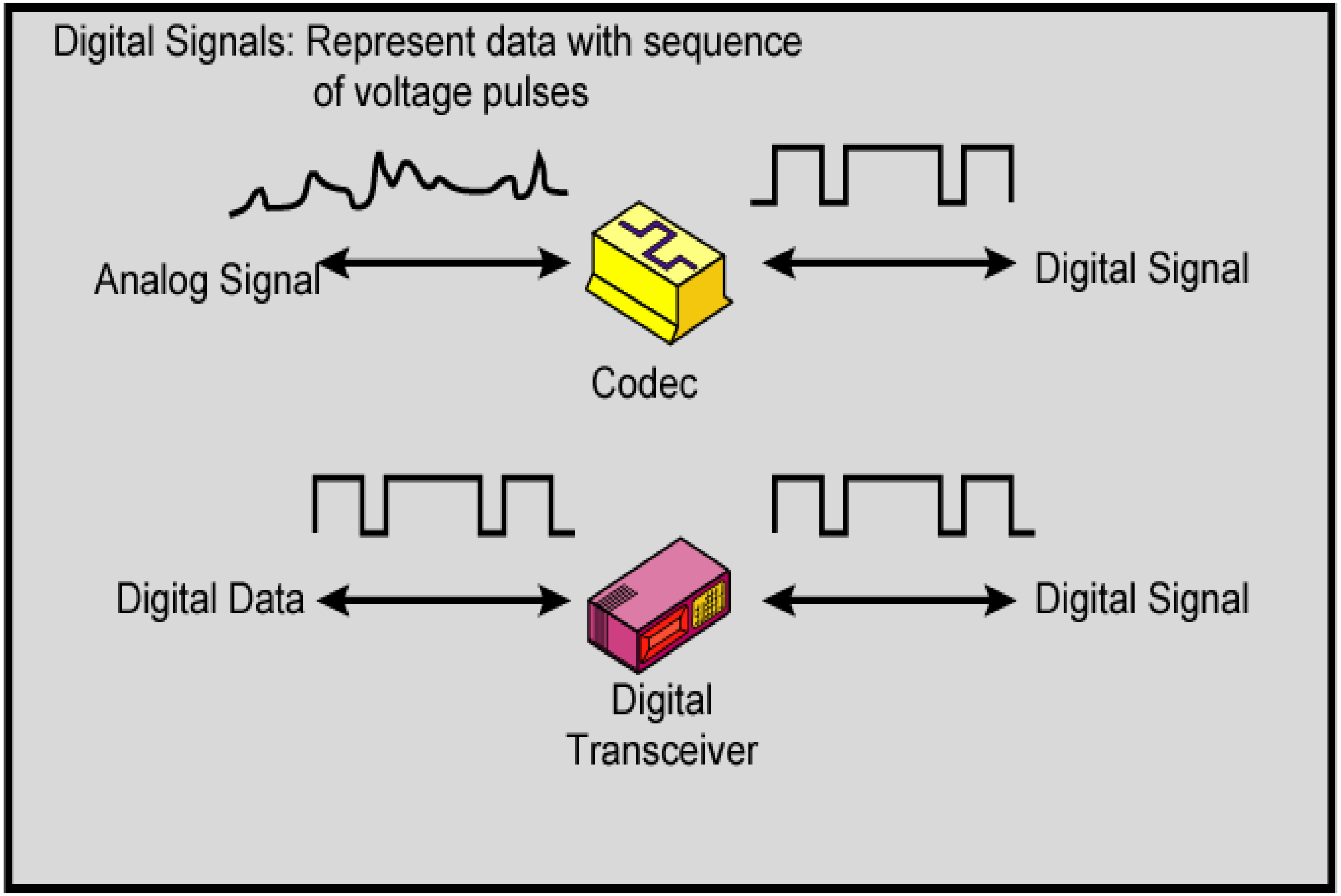


Figure 4.20 *Quantizing by using sign and magnitude*

+024	**0**0011000	–015	**1**0001111	+125	**0**1111101
+038	**0**0100110	–080	**1**1010000	+110	**0**1101110
+048	**0**0110000	–050	**1**0110010	+090	**0**1011010
+039	**0**0100111	+052	**0**0110110	+088	**0**1011000
+026	**0**0011010	+127	**0**1111111	+077	**0**1001101

Sign bit
+ is 0 – is 1

Codec & Digital transceiver



ລາຍລະອຽດຂະນິດຂໍ້ມູນທີ່ແປງເປັນສັນຍານຕ່າງໆກັບຕົວຢ່າງການໃຊ້ງານ

Data	Signal	Common Conversion Technique	Common Device	Common Systems
Analog	Analog	Amplitude Modulation Frequency Modulation	Radio tuner TV tuner	Telephone Cable TV Broadcast TV AM&FM Radio
Digital	Digital	NRZ-L NRZ-I Manchester Differential Manchester	Digital encoder	Local Area Network Digital Telephone Systems
Digital	Analog	Amplitude Modulation Frequency Modulation Phase Modulation	Modem	Home Internet Access
Analog	Digital	Pulse Code Modulation	Codec	Telephone systems Music systems