Examples on Analog Transmission

Figure 5.25 *Types of analog-to-analog modulation*

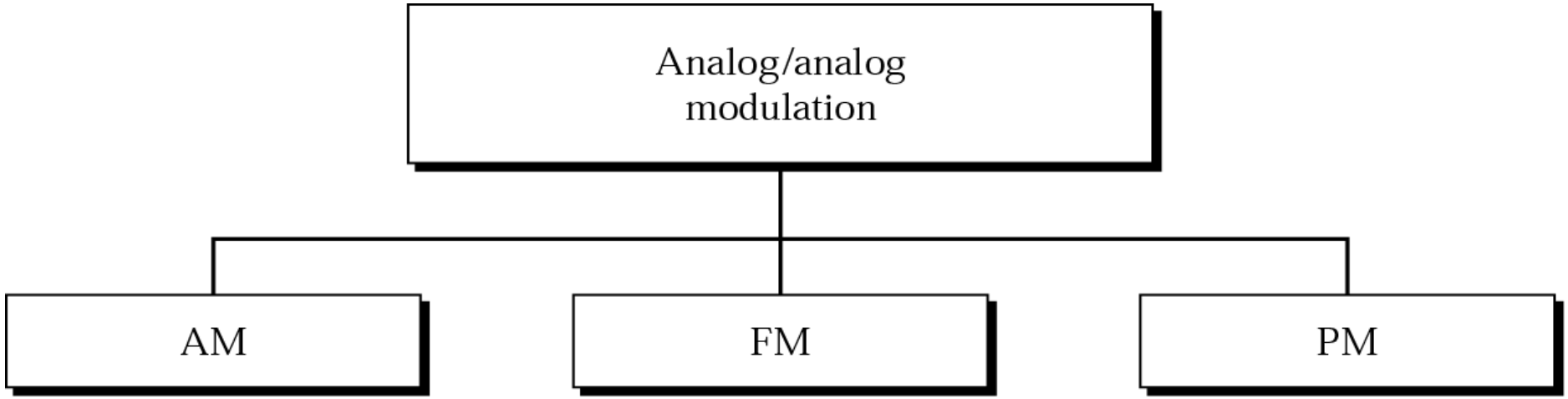


Figure 5.26 *Amplitude modulation*

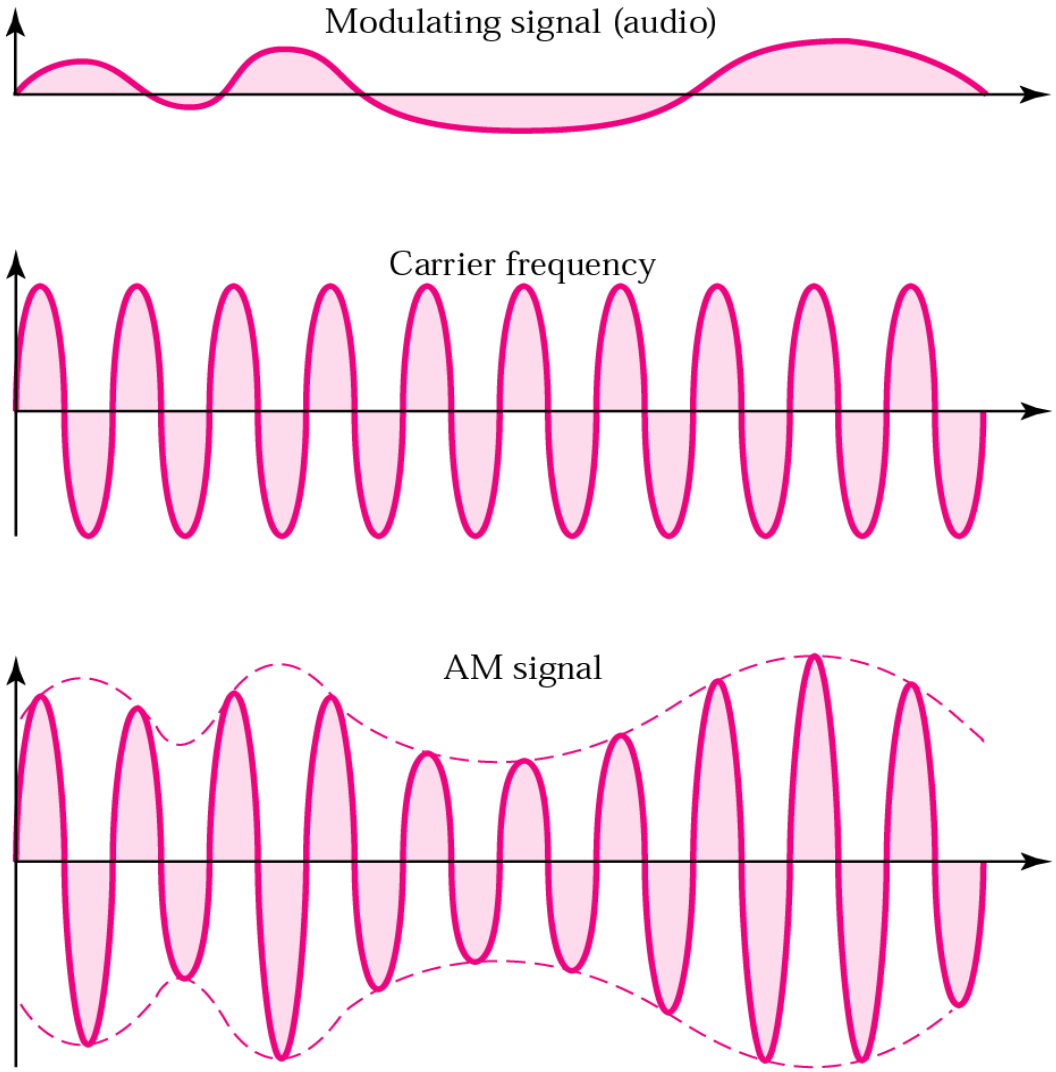
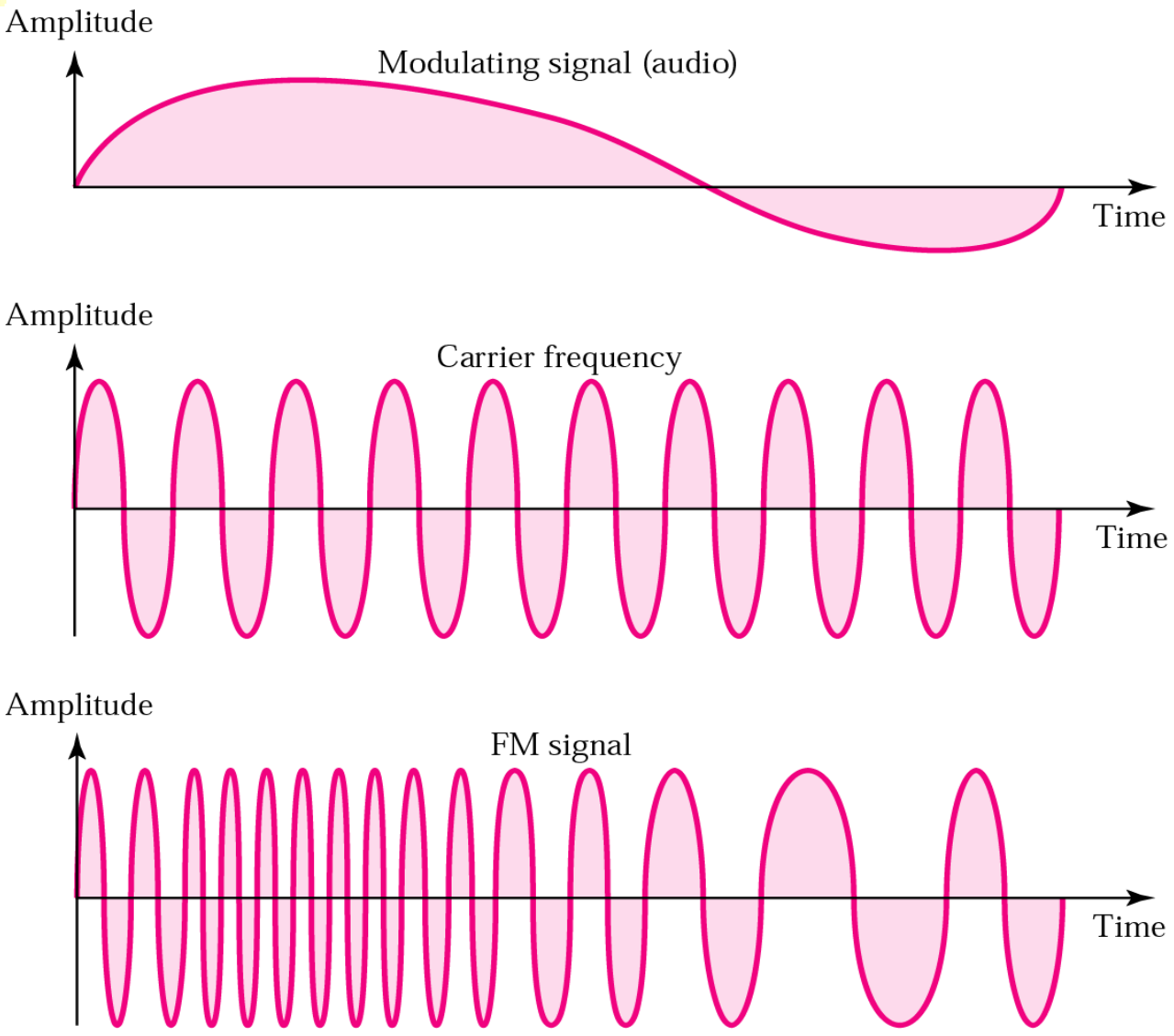


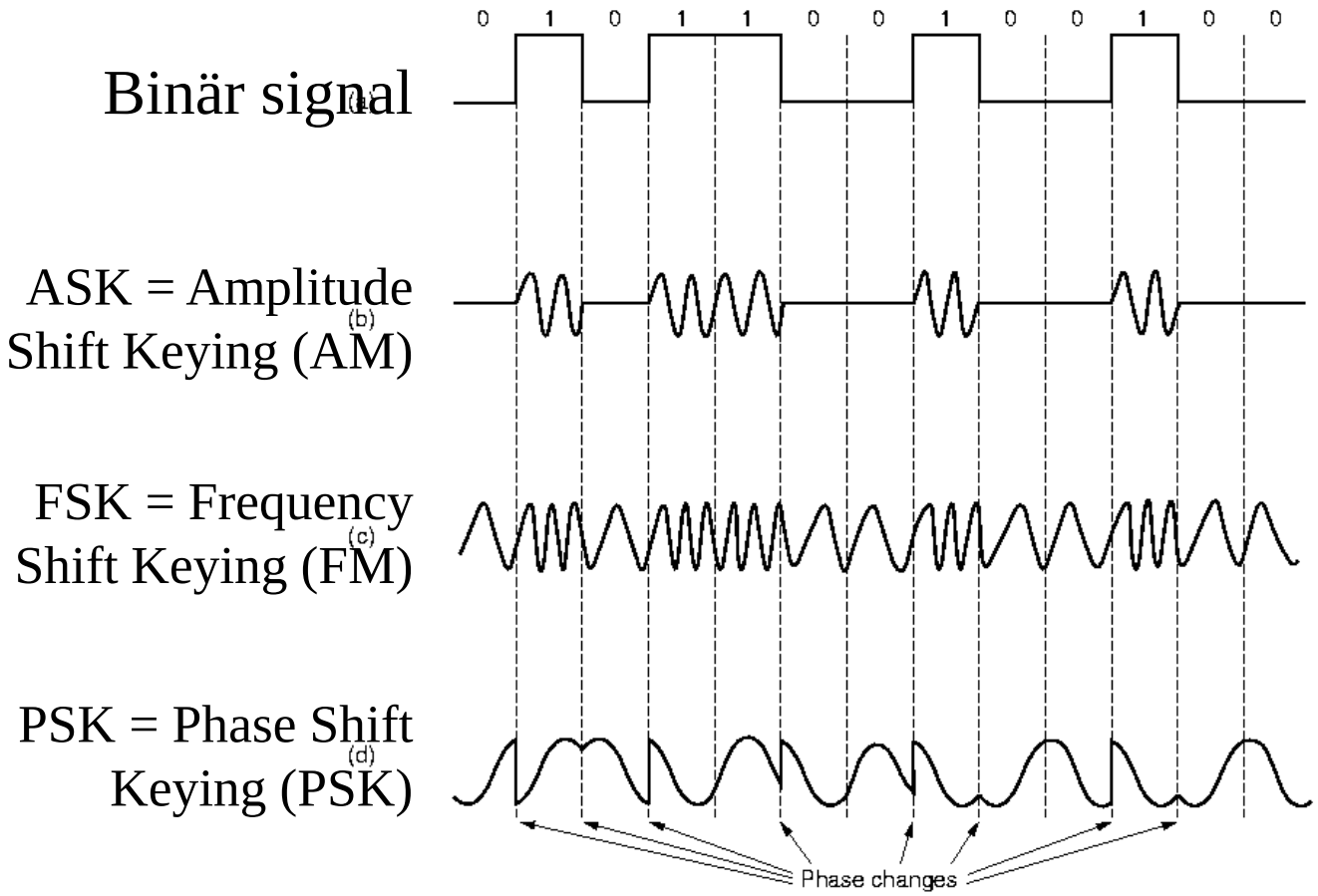
Figure 5.29 *Frequency modulation*



Modulation och demodulation

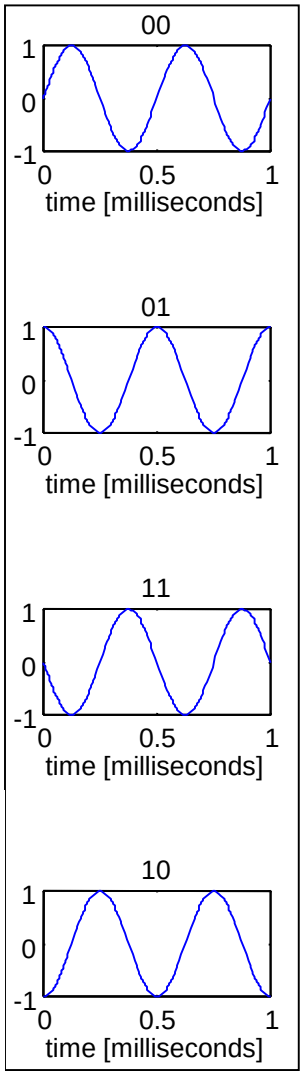
- Baudrate = antal symboler per sekund. Enhet: baud eller symboler/sekund.
- Bitrate = datahastighet. Enhet: bps eller bit/s.
- Vid många modulationsformer t.ex. s.k. ASK, PSK, och QAM är signalens bandbredd = symbolhastigheten.
- Vid FSK är bandbredden vanligen större.

Digitala modulationsmetoder



Exempel 1:

Till höger visas fyra symboler som används av ett s.k. 4PSK-modem (PSK=Phase Shift Keying). De fyra symbolerna representerar bitföljderna 00, 01, 11 resp 10.



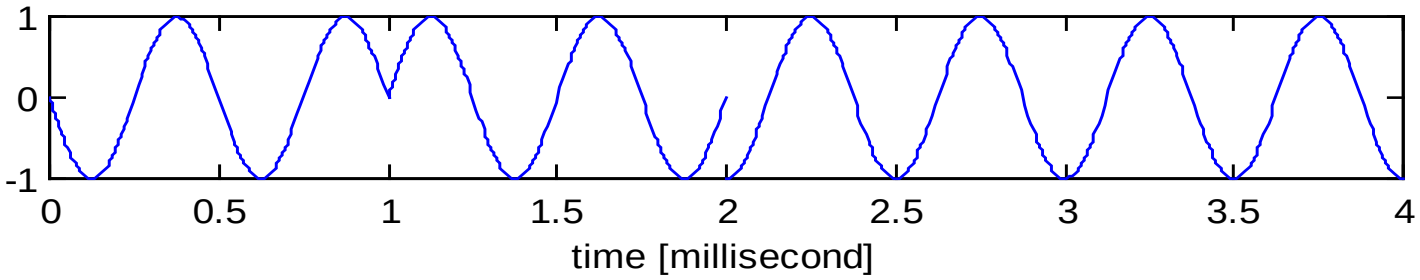
a) Nedan visas utsignalen från det sändande modemet. Vilket meddelande, dvs vilken bitsekvens, överförs?

Svar: 11 00 10 10.

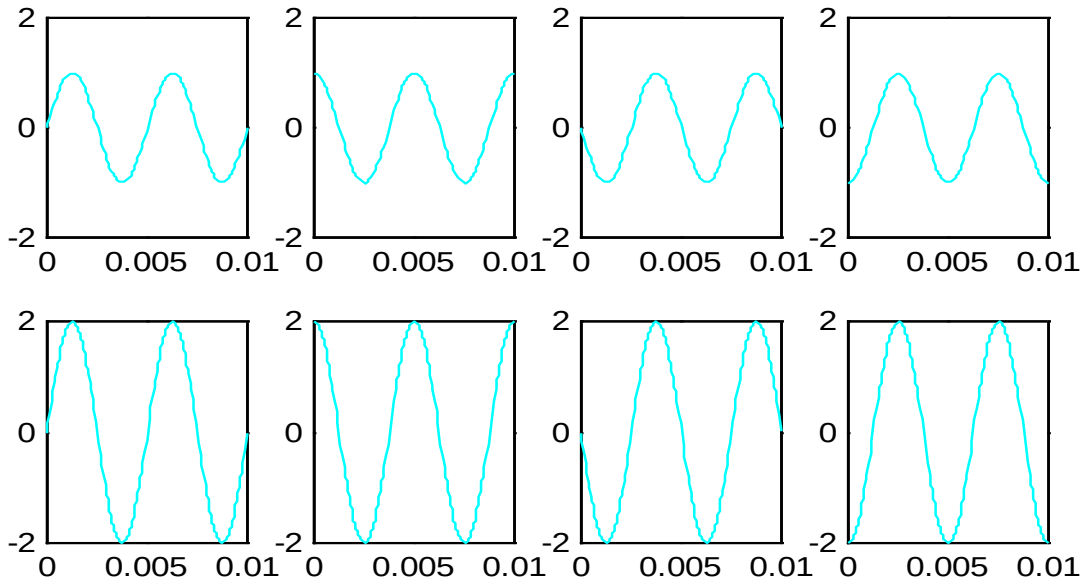
b) Tidsaxeln är graderad i tusendels sekunder. Vad är symbolhastigheten i baud eller symboler/sekund?

Svar: 1/1ms = 1000 symber per sekund = 1kbaud.

c) Vad är bithastigheten i bit per sekund (bps)? Svar: 2000bps.

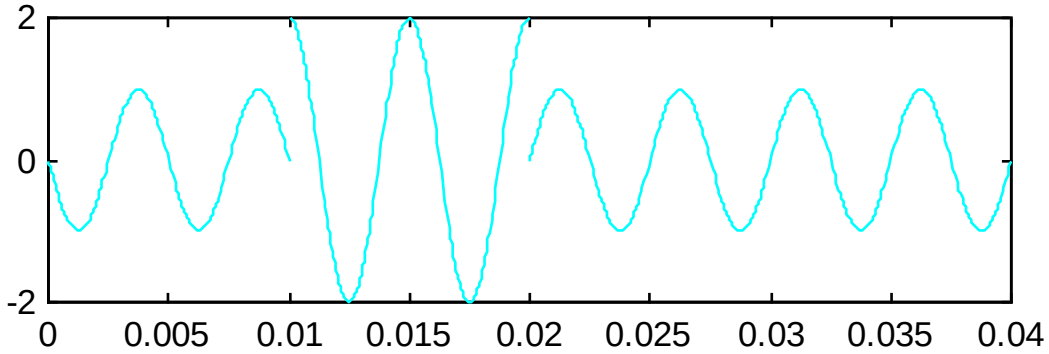


Exempel 2: QAM = kombination av PSK och ASK.
Nedan visas åtta symboler som används av ett s.k. 8QAM-modem (QAM=Quadrature Amplitude Modulation). Symbolerna i övre raden representerar bitföljderna 000, 001, 011 resp 010 (från vänster till höger). Undre raden representerar 100, 101, 111 resp 110.



Forts exempel 2:

a) Nedan visas utsignalen från det sändande modemet. Vilket meddelande, dvs vilken bitsekvens, överförs?



b) Tidsaxlarna är graderad i sekunder. Vad är symbolhastigheten i baud eller symboler/sekund?

c) Vad är bithastigheten i bit per sekund (bps)?

Example 1

An analog signal carries 4 bits in each signal unit. If 1000 signal units are sent per second, find the baud rate and the bit rate

Solution

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

Bit rate = 1000 x 4 = 4000 bps

Figure 5.4 *Relationship between baud rate and bandwidth in ASK*

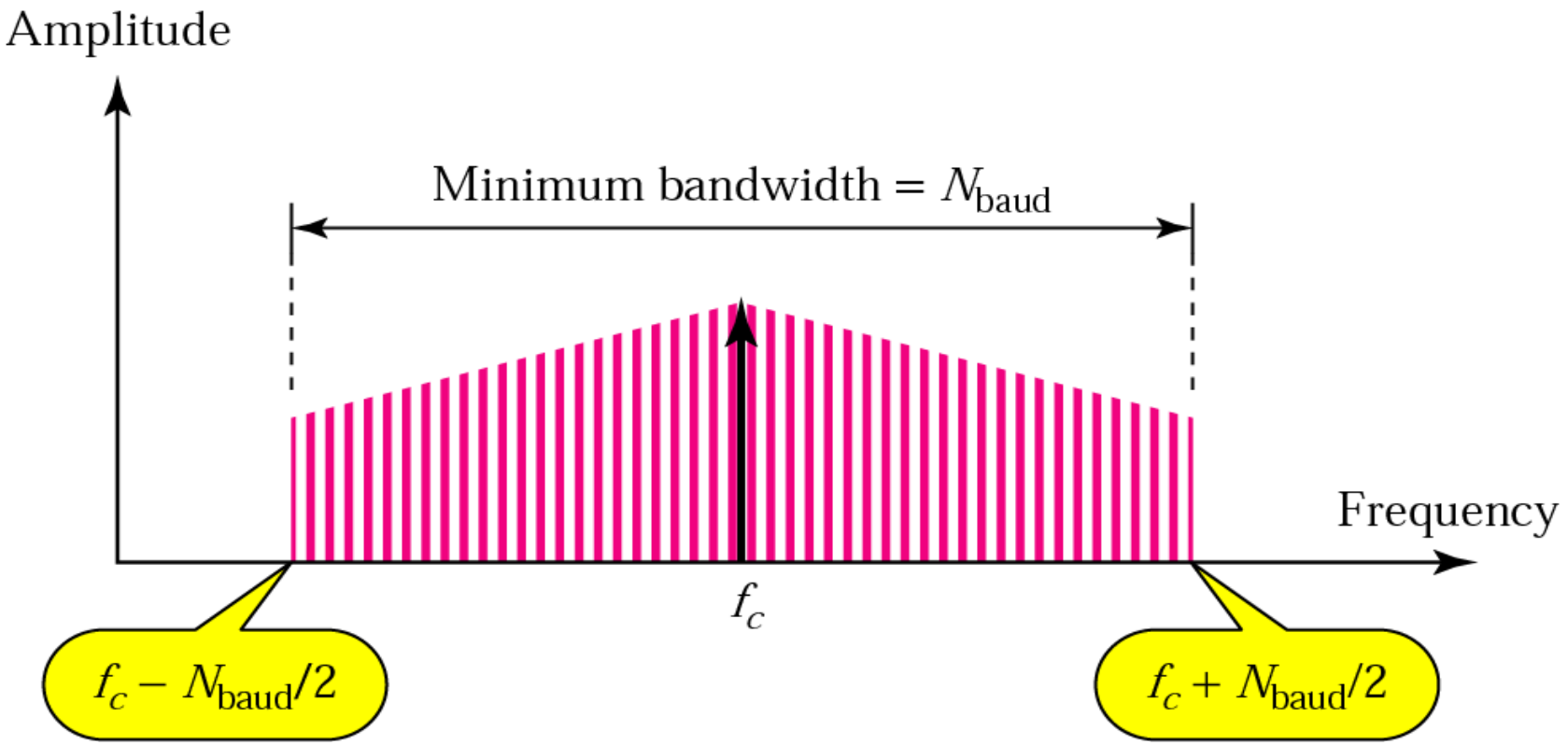
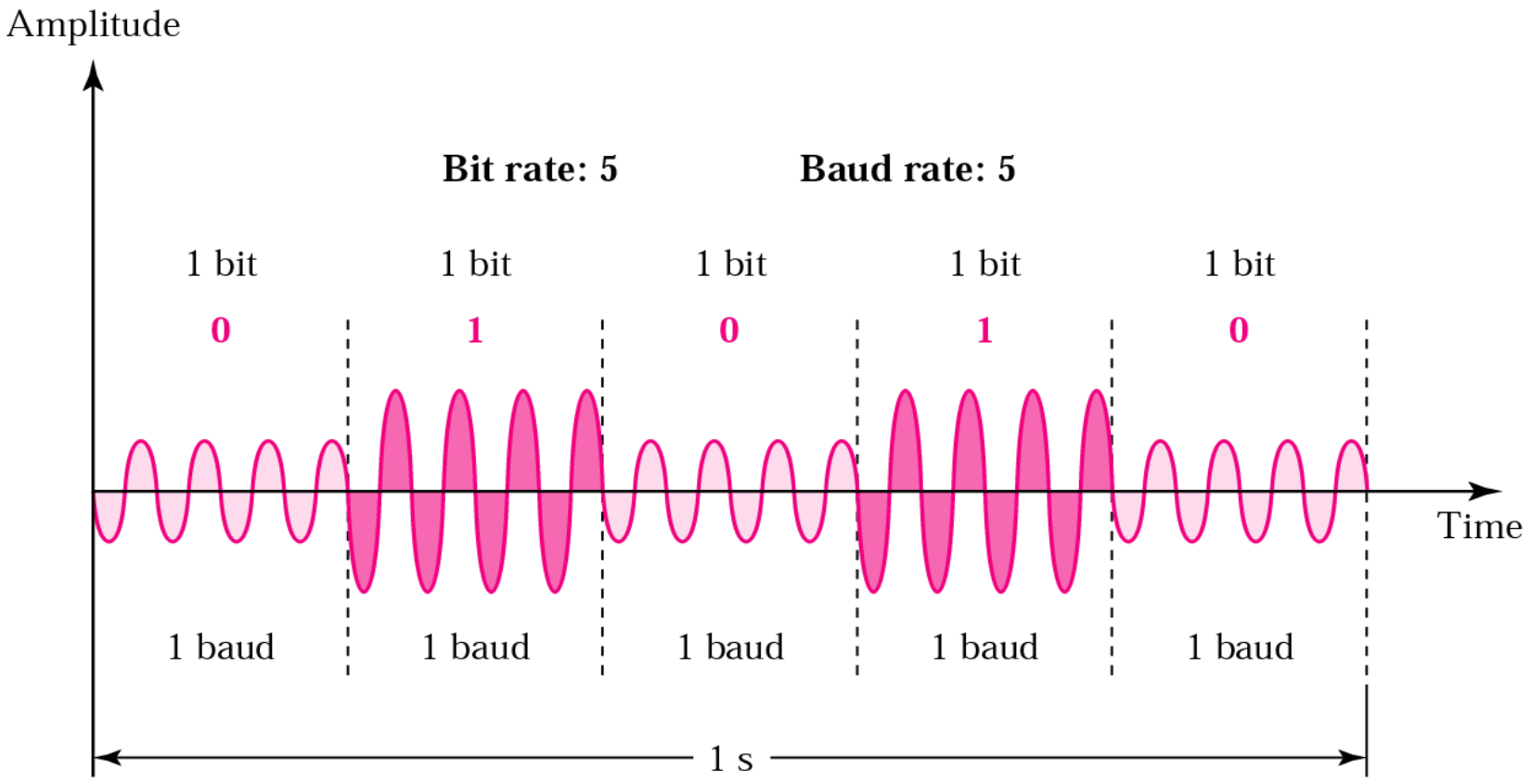


Figure 5.3 *ASK*



Example 3

Find the minimum bandwidth for an ASK signal transmitting at 2000 bps. The transmission mode is half-duplex.

Solution

In ASK the baud rate and bit rate are the same. The baud rate is therefore 2000. An ASK signal requires a minimum bandwidth equal to its baud rate. Therefore, the minimum bandwidth is 2000 Hz.

Example 4

Given a bandwidth of 5000 Hz for an ASK signal, what are the baud rate and bit rate?

Solution

In ASK the baud rate is the same as the bandwidth, which means the baud rate is 5000. But because the baud rate and the bit rate are also the same for ASK, the bit rate is 5000 bps.

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

For FSK

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

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

Example 7

Find the maximum bit rates for an FSK signal if the bandwidth of the medium is 12,000 Hz and the difference between the two carriers is 2000 Hz. Transmission is in full-duplex mode.

Solution

Because the transmission is full duplex, only 6000 Hz is allocated for each direction.

BW = baud rate + fc1 – fc0

Baud rate = BW – (fc1 – fc0) = 6000 – 2000 = 4000

But because the baud rate is the same as the bit rate, the bit rate is 4000 bps.

Figure 5.8 *PSK*

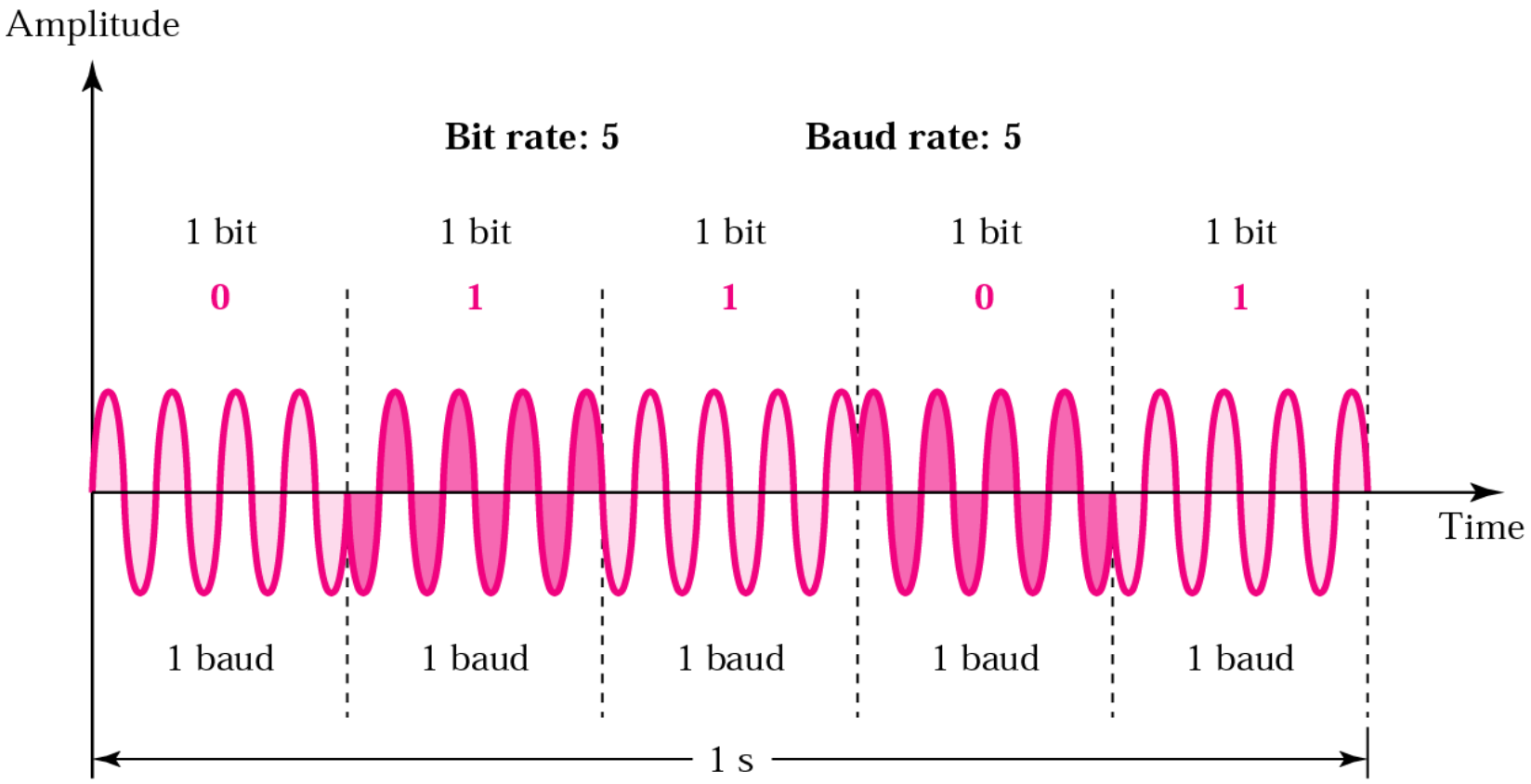


Figure 5.5 *Solution to Example 5*

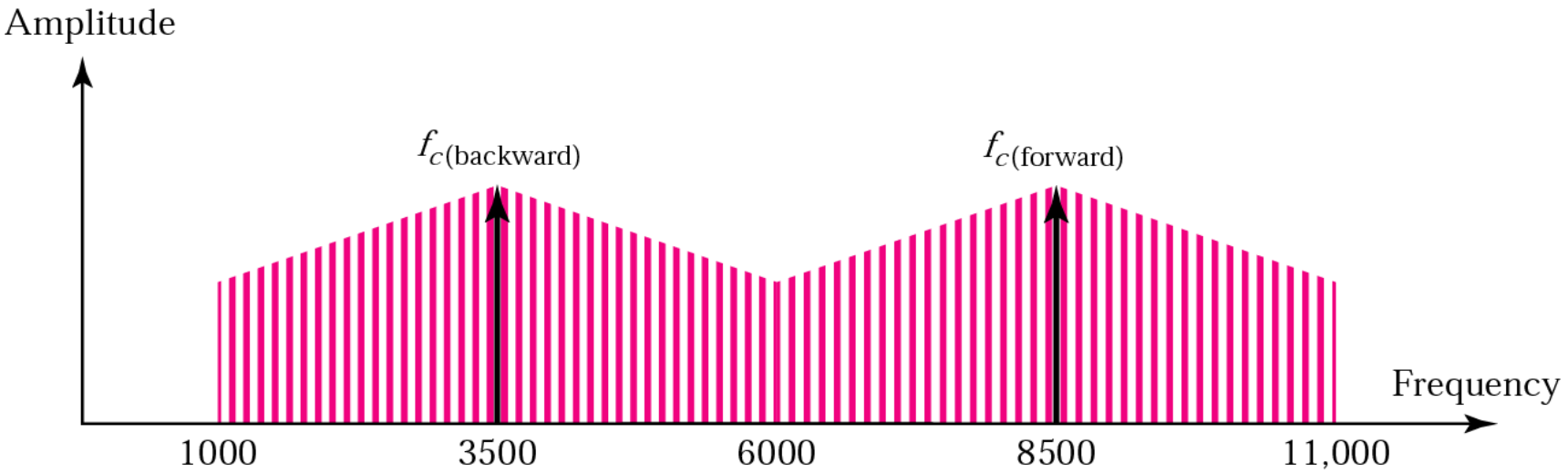


Figure 5.6 *FSK*

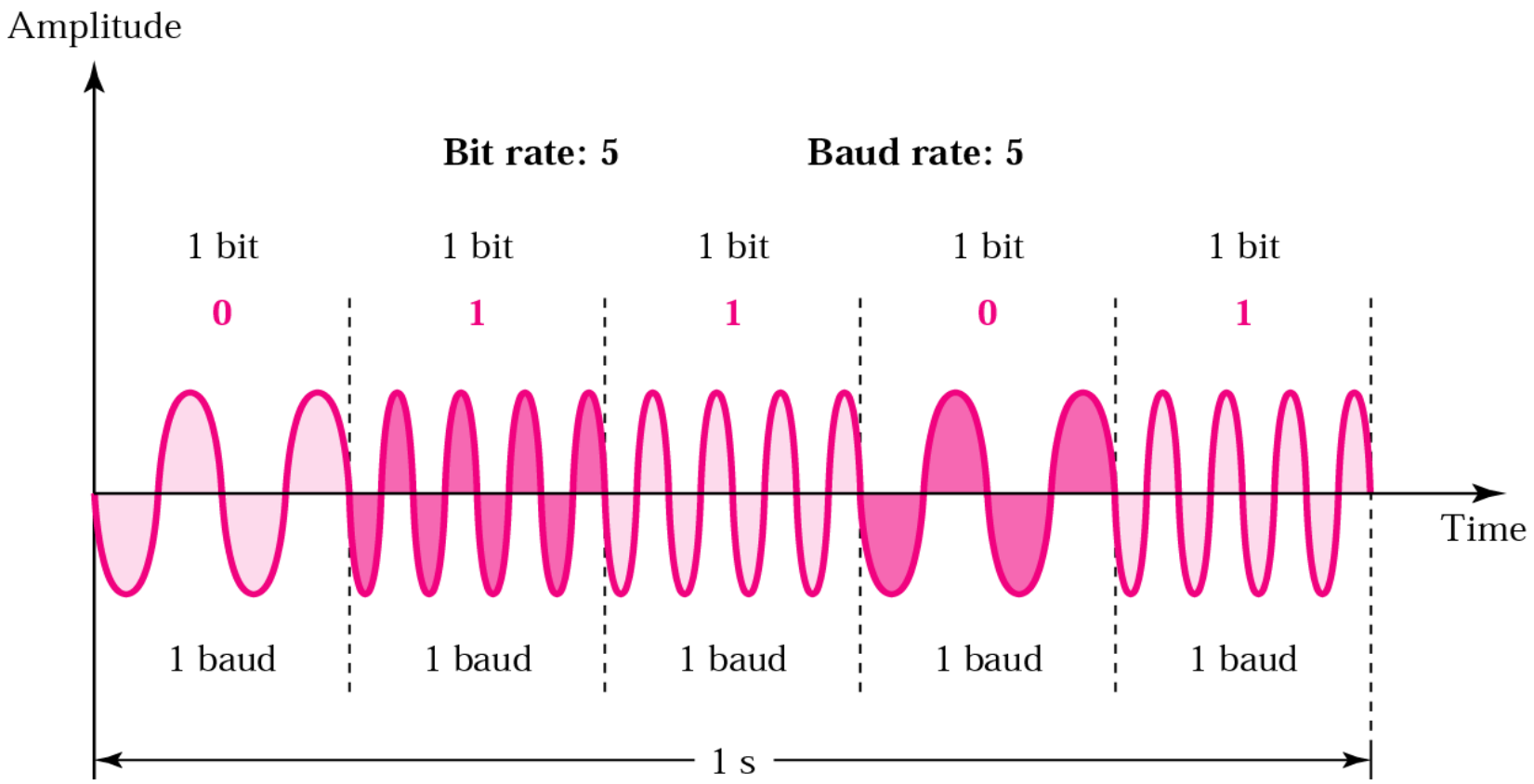
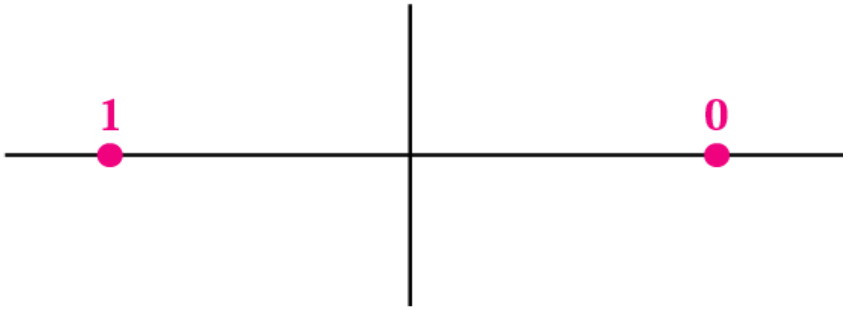


Figure 5.9 *PSK constellation*

Bit	Phase
0	0
1	180

Bits



Constellation diagram

Figure 5.10 *The 4-PSK method*

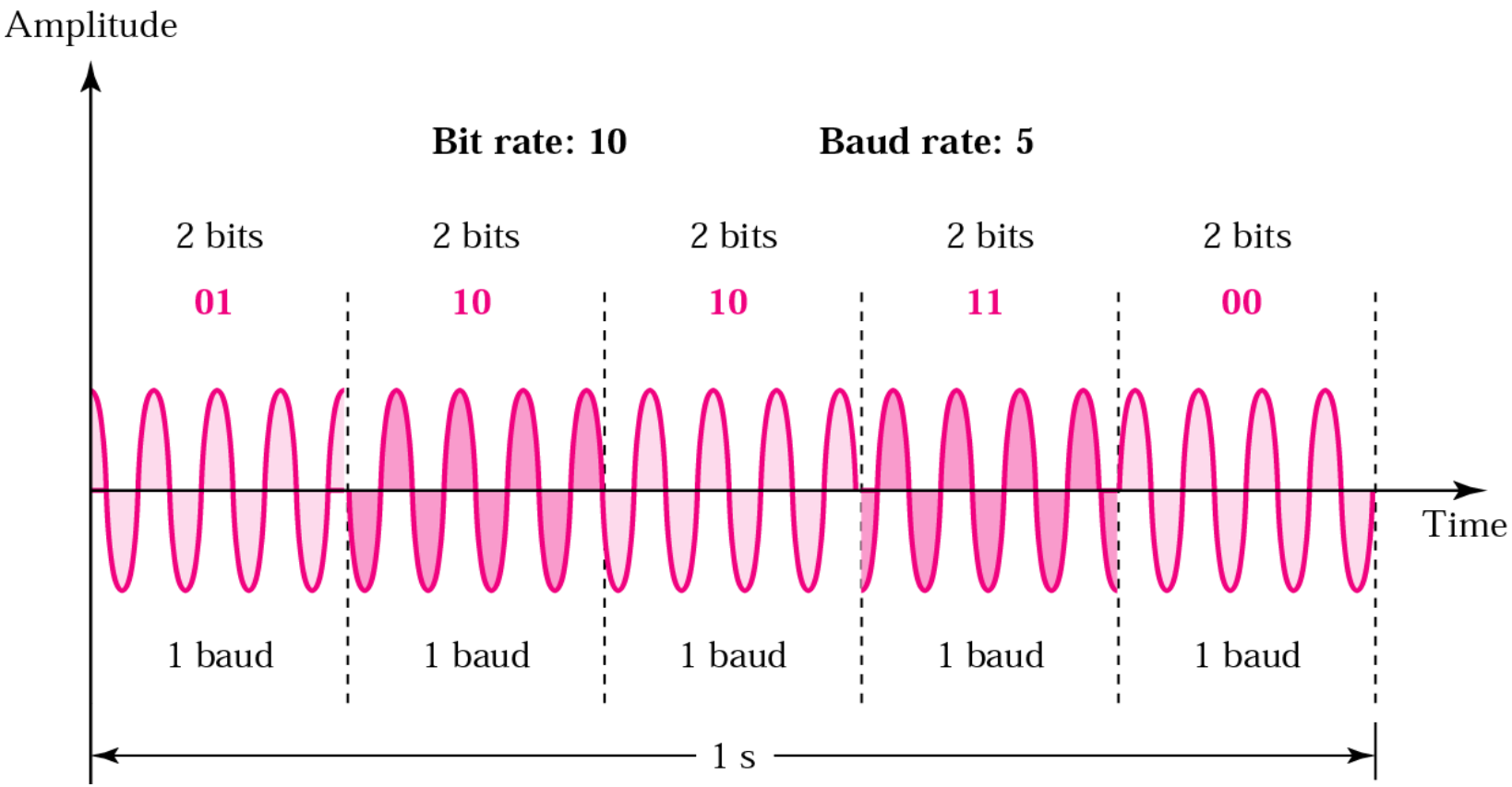
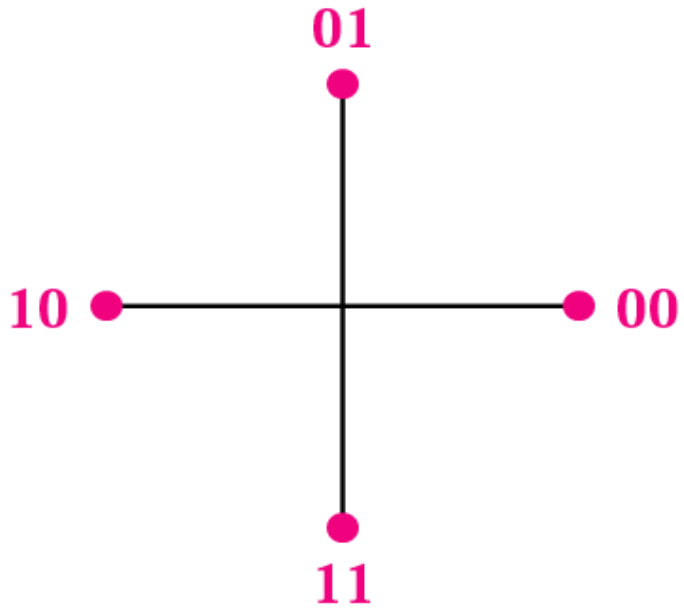


Figure 5.11 *The 4-PSK characteristics*

Dibit	Phase
00	0
01	90
10	180
11	270

Dibit
(2 bits)

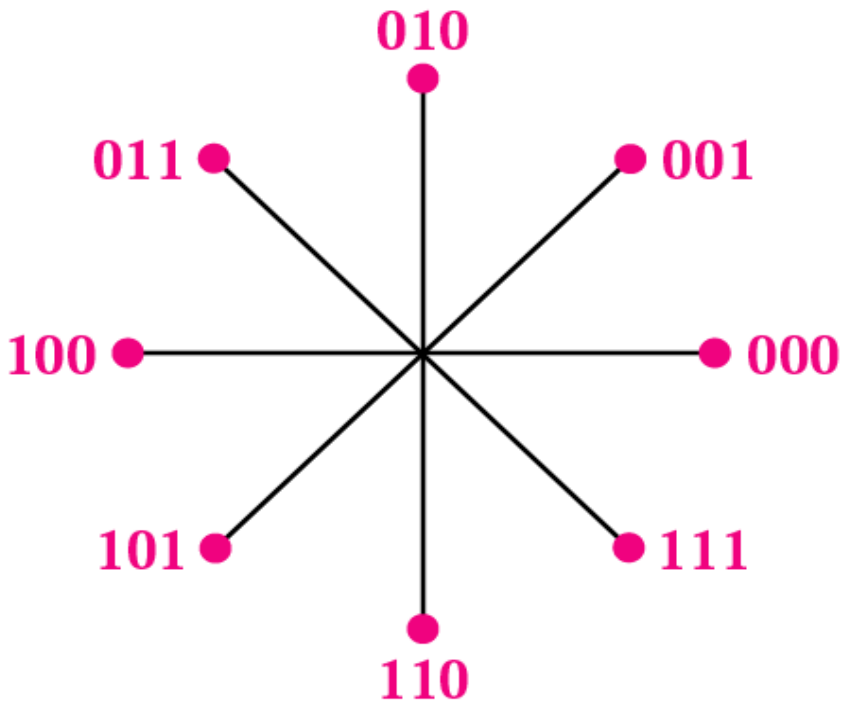


Constellation diagram

Figure 5.12 The 8-PSK characteristics

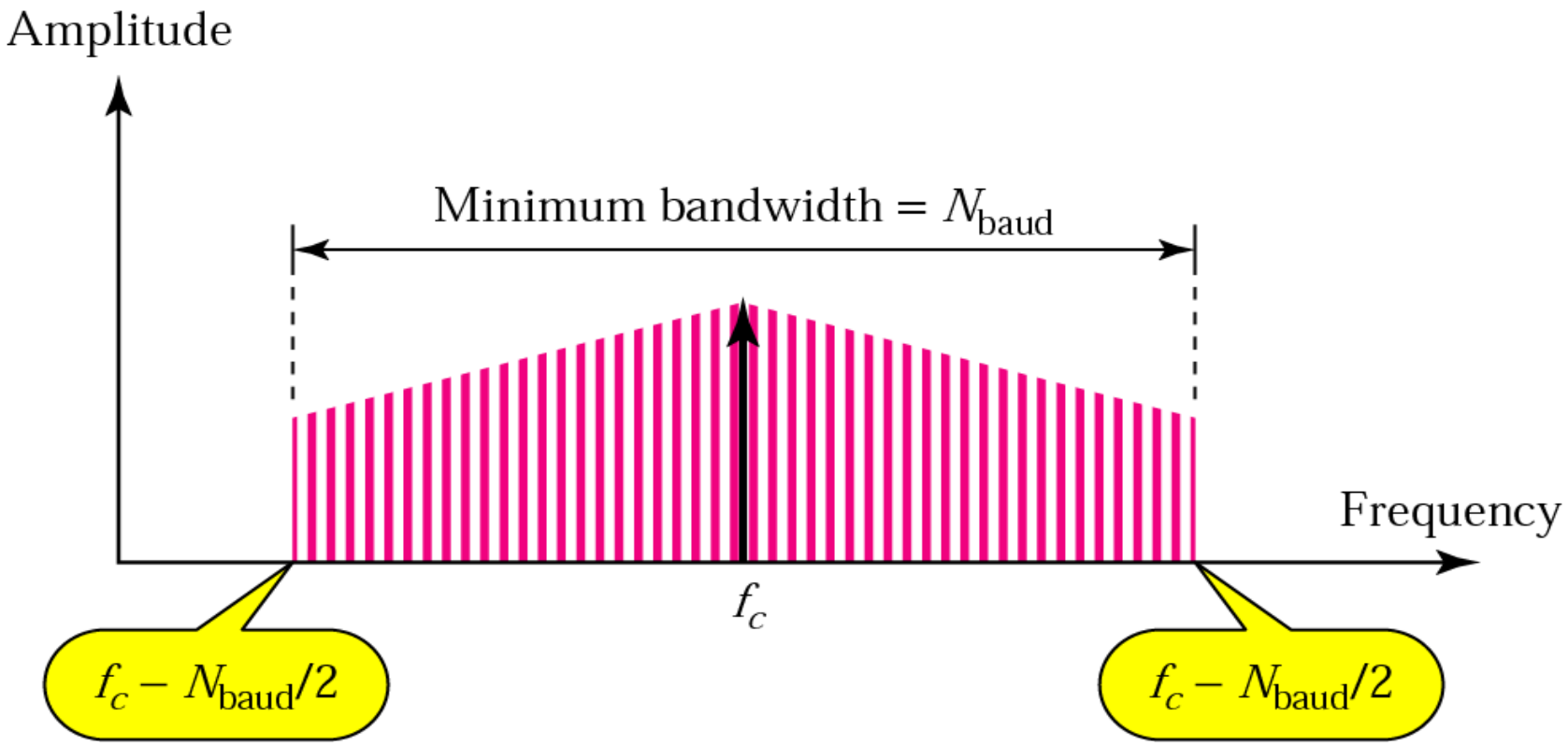
Tribit	Phase
000	0
001	45
010	90
011	135
100	180
101	225
110	270
111	315

Tribits
(3 bits)



Constellation diagram

Figure 5.13 *Relationship between baud rate and bandwidth in PSK*

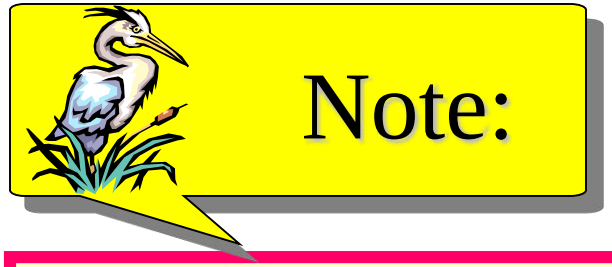


Example 9

Given a bandwidth of 5000 Hz for an 8-PSK signal, what are the baud rate and bit rate?

Solution

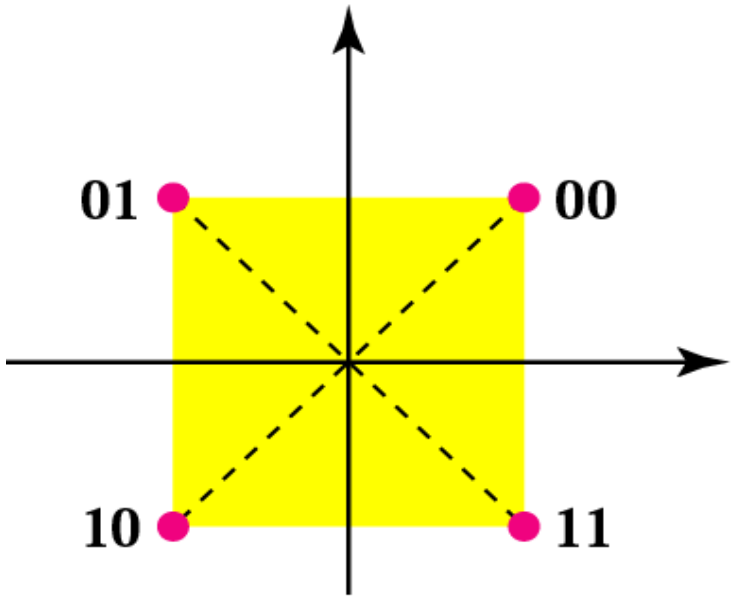
For PSK the baud rate is the same as the bandwidth, which means the baud rate is 5000. But in 8-PSK the bit rate is 3 times the baud rate, so the bit rate is 15,000 bps.



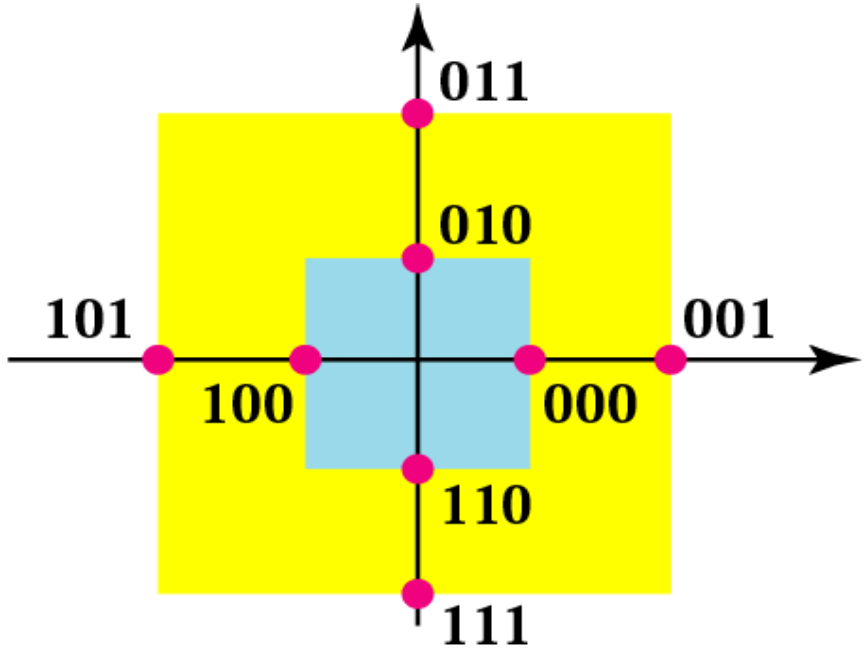
Note:

Quadrature amplitude modulation is a combination of ASK and PSK so that a maximum contrast between each signal unit (bit, dibit, tribit, and so on) is achieved.

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



4-QAM
1 amplitude, 4 phases



8-QAM
2 amplitudes, 4 phases

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

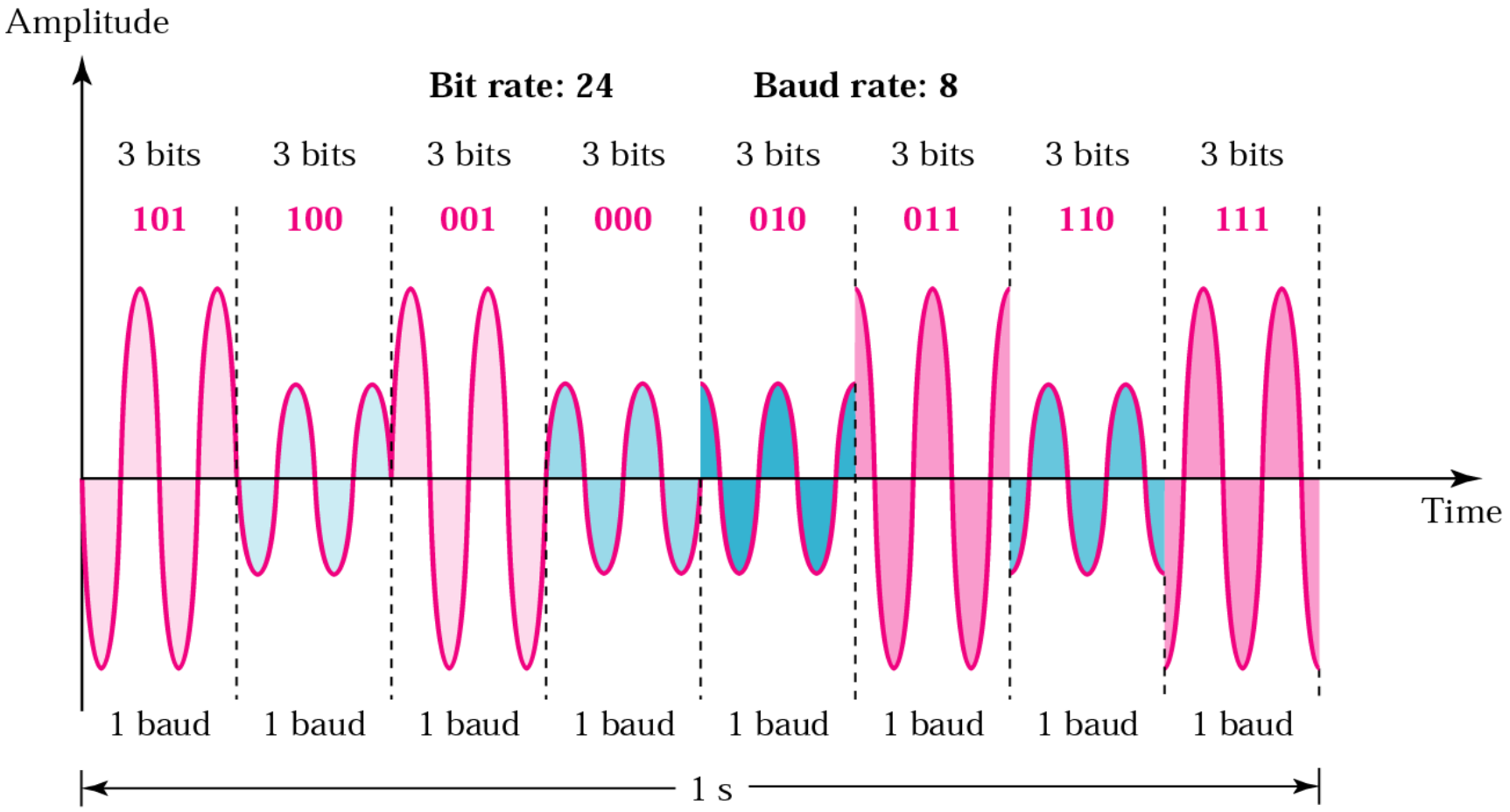


Figure 5.16 *16-QAM constellations*

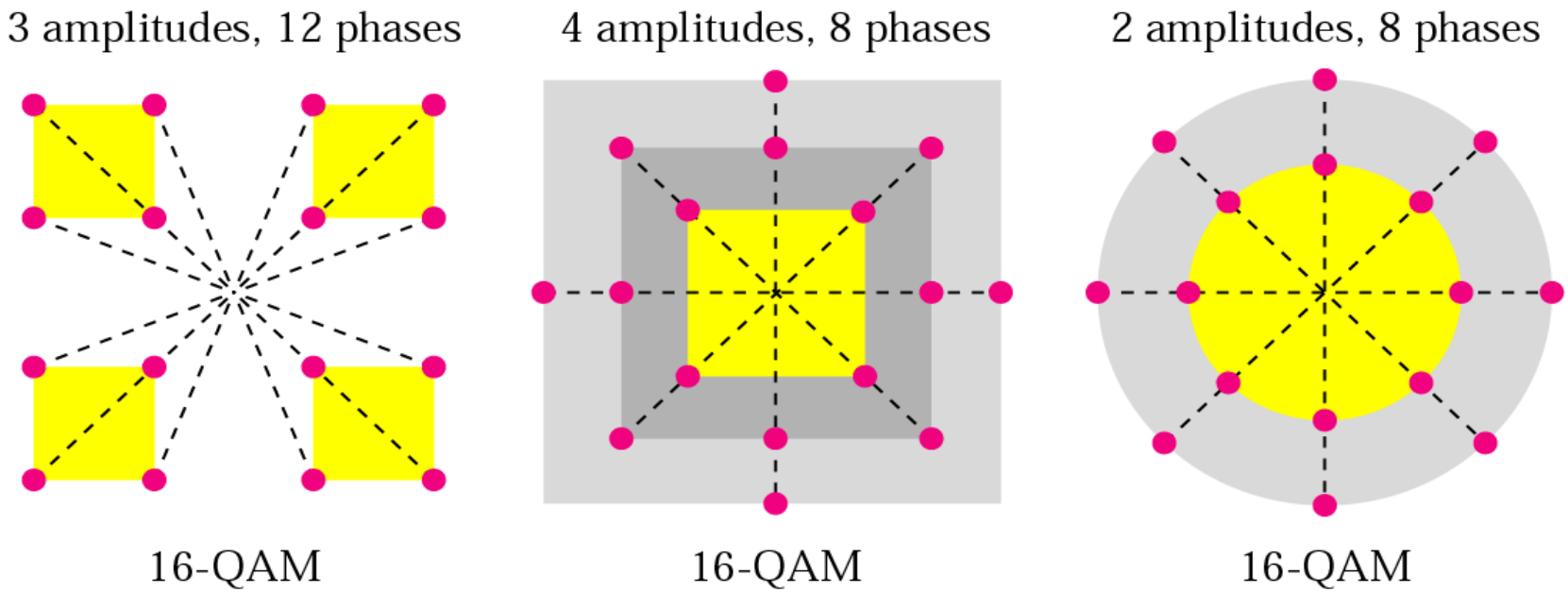


Figure 5.17 *Bit and baud*

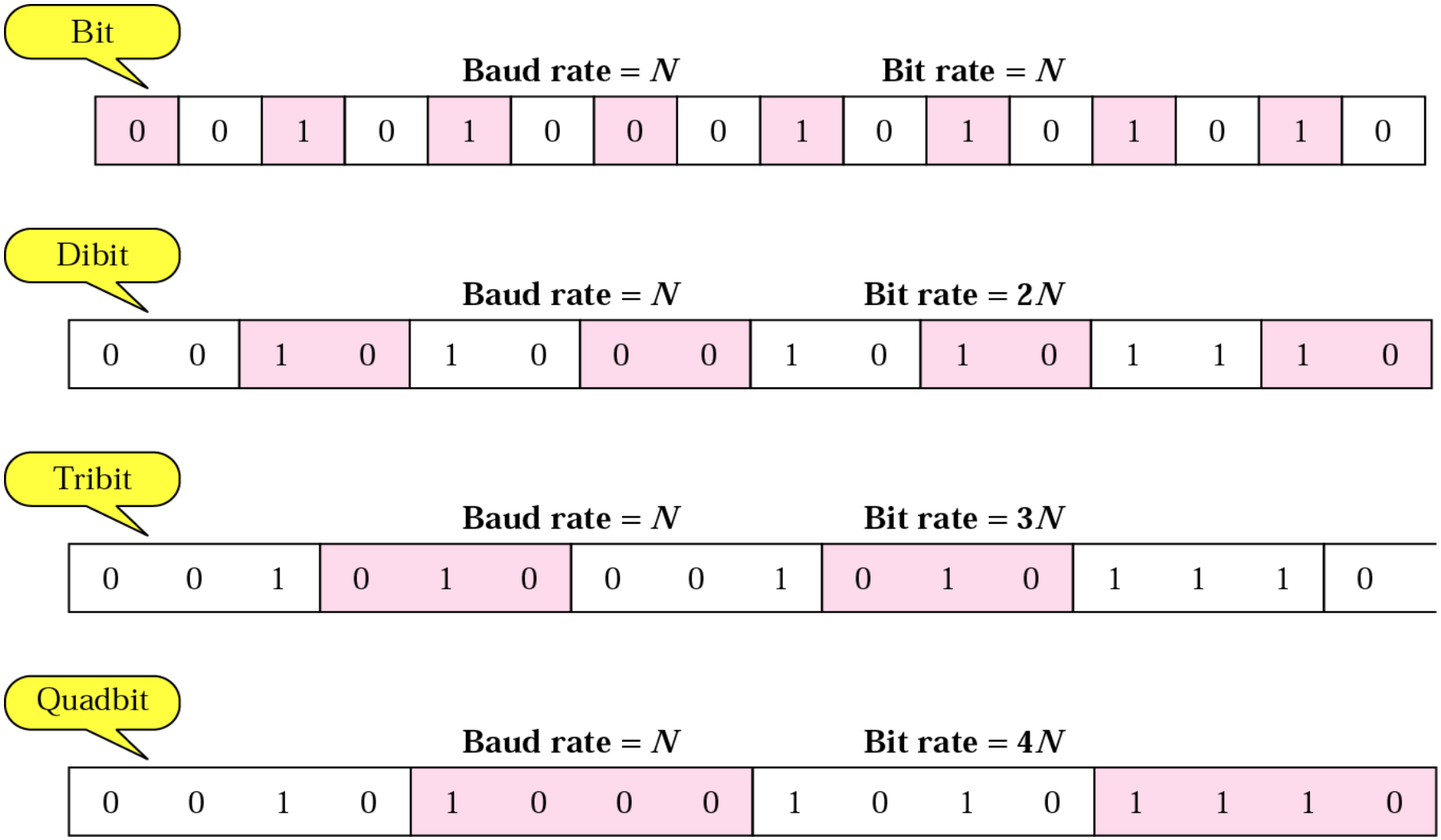


Table 5.1 Bit and baud rate comparison

Modulation	Units	Bits/Baud	Baud rate	Bit Rate
ASK, FSK, 2-PSK	Bit	1	N	N
4-PSK, 4-QAM	Dibit	2	N	2N
8-PSK, 8-QAM	Tribit	3	N	3N
16-QAM	Quadbit	4	N	4N
32-QAM	Pentabit	5	N	5N
64-QAM	Hexabit	6	N	6N
128-QAM	Septabit	7	N	7N
256-QAM	Octabit	8	N	8N

Example 10

A constellation diagram consists of eight equally spaced points on a circle. If the bit rate is 4800 bps, what is the baud rate?

Solution

The constellation indicates 8-PSK with the points 45 degrees apart. Since $2^3 = 8$, 3 bits are transmitted with each signal unit. Therefore, the baud rate is

$$4800 / 3 = 1600 \text{ baud}$$

Example 11

Compute the bit rate for a 1000-baud 16-QAM signal.

Solution

A 16-QAM signal has 4 bits per signal unit since

$$\log_2 16 = 4.$$

Thus,

$$1000 \cdot 4 = 4000 \text{ bps}$$

Example 12

Compute the baud rate for a 72,000-bps 64-QAM signal.

Solution

A 64-QAM signal has 6 bits per signal unit since

$$\log_2 64 = 6.$$

Thus,

$$72000 / 6 = 12{,}000 \text{ baud}$$