

IUG - Faculty of Engineering
Department of Computer Engineering
Data communications Lab
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Data Communications

Lab 7

Chapter 5

Analog Transmission

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- P5-1.** Calculate the baud rate for the given bit rate and type of modulation.
- a. 2000 bps, FSK
 - b. 4000 bps, ASK
 - c. 6000 bps, QPSK
 - d. 36,000 bps, 64-QAM

Solution:

We use the formula $S = (1/r) \times N$, but first we need to calculate the value of r for each case.

- a. $r = \log_2 2 = 1 \rightarrow S = (1/1) \times (2000 \text{ bps}) = 2000 \text{ baud}$
- b. $r = \log_2 2 = 1 \rightarrow S = (1/1) \times (4000 \text{ bps}) = 4000 \text{ baud}$
- c. $r = \log_2 4 = 2 \rightarrow S = (1/2) \times (6000 \text{ bps}) = 3000 \text{ baud}$
- d. $r = \log_2 64 = 6 \rightarrow S = (1/6) \times (36,000 \text{ bps}) = 6000 \text{ baud}$

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- P5-2.** Calculate the bit rate for the given baud rate and type of modulation.
- a. 1000 baud, FSK
 - b. 1000 baud, ASK
 - c. 1000 baud, BPSK
 - d. 1000 baud, 16-QAM

Solution:

We use the formula $N = r \times S$, but first we need to calculate the value of r for each case.

- a. $r = \log_2 2 = 1 \rightarrow N = (1) \times (1000 \text{ baud}) = 1000 \text{ bps}$
- b. $r = \log_2 2 = 1 \rightarrow N = (1) \times (1000 \text{ baud}) = 1000 \text{ bps}$
- c. $r = \log_2 2 = 1 \rightarrow N = (1) \times (1000 \text{ baud}) = 1000 \text{ bps}$
- d. $r = \log_2 16 = 4 \rightarrow N = (4) \times (1000 \text{ baud}) = 4000 \text{ bps}$

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- P5-3.** What is the number of bits per baud for the following techniques?
- a. ASK with four different amplitudes
 - b. FSK with eight different frequencies
 - c. PSK with four different phases
 - d. QAM with a constellation of 128 points

Solution:

We use the formula $r = \log_2 L$ to calculate the value of r for each case.

- a. $\log_2 4 = 2 \text{ bits/baud}$
- b. $\log_2 8 = 3 \text{ bits/baud}$

- c. $\log_2 4 = 2$ bits/ baud
- d. $\log_2 128 = 7$ bits/ baud

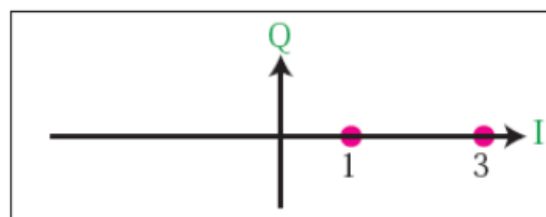
P5-4. Draw the constellation diagram for the following:

- a. ASK, with peak amplitude values of 1 and 3
- b. BPSK, with a peak amplitude value of 2
- c. QPSK, with a peak amplitude value of 3
- d. 8-QAM with two different peak amplitude values, 1 and 3, and four different phases

Solution:

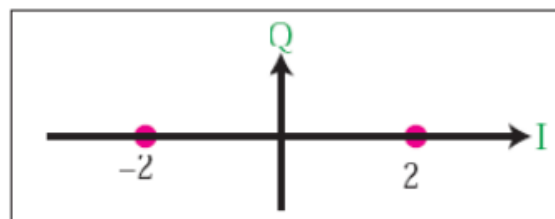
a. We have two signal elements with peak amplitudes 1 and 3. The phase of both signal elements are the same, which we assume to be 0 degrees.

a. ASK

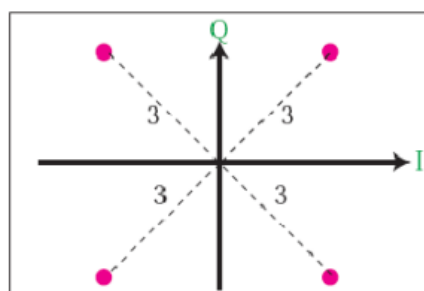


b. We have two signal elements with the same peak amplitude of 2. However, there must be 180 degrees difference between the two phases. We assume one phase to be 0 and the other 180 degrees.

b. BPSK

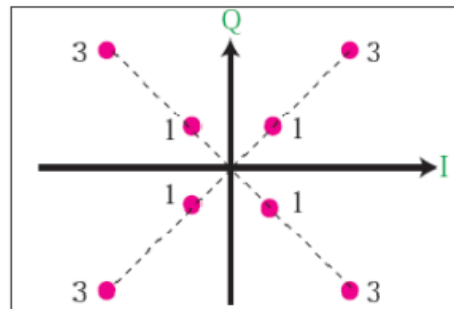


c. We have four signal elements with the same peak amplitude of 3. However, there must be 90 degrees difference between each phase. We assume the first phase to be at 45, the second at 135, the third at 225, and the fourth at 315 degrees. Note that this is one out of many configurations. The phases can be at 0, 90, 180, and 270. As long as the differences are 90 degrees, the solution is satisfactory.



c. QPSK

d. We have four phases, which we select to be the same as the previous case. For each phase, however, we have two amplitudes, 1 and 3 as shown in the figure. Note that this is one out of many configurations. The phases can be at 0, 90, 180, and 270. As long as the differences are 90 degrees, the solution is satisfactory.



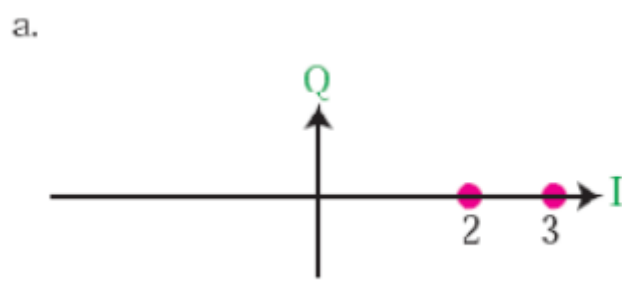
d. 8-QAM

P5-5. Draw the constellation diagram for the following cases. Find the peak amplitude value for each case and define the type of modulation (ASK, FSK, PSK, or QAM). The numbers in parentheses define the values of I and Q respectively.

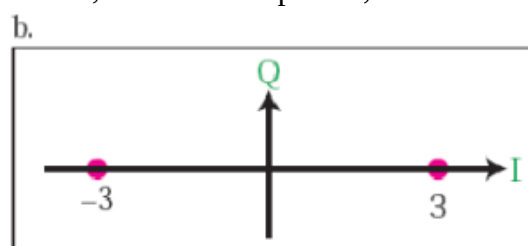
- a. Two points at (2, 0) and (3, 0)
- b. Two points at (3, 0) and (-3, 0)
- c. Four points at (2, 2), (-2, 2), (-2, -2), and (2, -2)
- d. Two points at (0, 2) and (0, -2)

Solution:

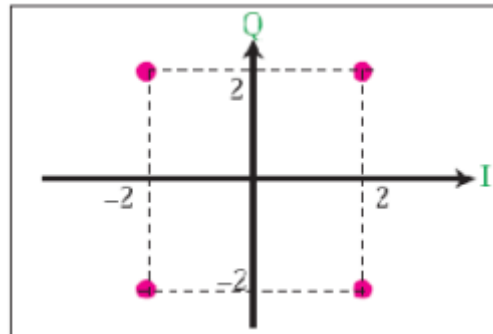
- a. This is ASK. There are two peak amplitudes both with the same phase (0 degrees). The values of the peak amplitudes are $A_1 = 2$ (the distance between the first dot and the origin) and $A_2 = 3$ (the distance between the second dot and the origin).



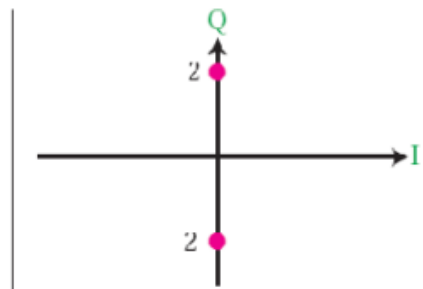
- b. This is BPSK, there is only one peak amplitude (3). The distance between each dot and the origin is 3. However, we have two phases, 0 and 180 degrees.



- c. This can be either QPSK (one amplitude, four phases) or 4-QAM (one amplitude and four phases). The **amplitude** is the distance between a point and the origin, which is $\sqrt{2^2 + 2^2} = 2.83$



- d. This is also BPSK. The **peak amplitude is 2**, but this time the phases are 90 and 270 degrees.



d.

P5-6. How many bits per baud can we send in each of the following cases if the signal constellation has one of the following number of points?

- a. 2 b. 4 c. 16 d. 1024

Solution:

The number of points define the number of levels, L . The number of bits per baud is the value of r . Therefore, we use the formula $r = \log_2 L$ for each case.

- a. $\log_2 2 = 1$
b. $\log_2 4 = 2$
c. $\log_2 16 = 4$
d. $\log_2 1024 = 10$

P5-7. What is the required bandwidth for the following cases if we need to send 4000 bps? Let $d = 1$.

- a. ASK
b. FSK with $2\Delta f = 4$ KHz
c. QPSK
d. 16-QAM

Solution:

a. ASK

$$r = \log_2 2 = 1$$

$$B = (1+d) S = (1+d) N/r = (1+1) 4000 = 8000 \text{ Hz}$$

b. FSK with $2\Delta f = 4 \text{ KHz}$

$$r = \log_2 2 = 1$$

$$B = (1+d) S + 2\Delta f = (1+1) 4000 + 4000 = 12000 \text{ Hz}$$

c. QPSK

$$r = \log_2 4 = 2$$

$$B = (1+d) S = (1+d) N/r = (1+1) 4000/2 = 4000 \text{ Hz}$$

d. 16-QAM

$$r = \log_2 16 = 4$$

$$B = (1+d) S = (1+d) N/r = (1+1) 4000/4 = 2000 \text{ Hz}$$

P5-8. The telephone line has 4 KHz bandwidth. What is the maximum number of bits we can send using each of the following techniques? Let $d = 0$.

a. ASK

b. QPSK

c. 16-QAM

d. 64-QAM

Solution:

We use the formula $N = [1/(1 + d)] \times r \times B$, but first we need to calculate the value of r for each case.

a. $r = \log_2 2 = 1 \rightarrow N = [1/(1 + 0)] \times 1 \times (4 \text{ KHz}) = 4 \text{ kbps}$

b. $r = \log_2 4 = 2 \rightarrow N = [1/(1 + 0)] \times 2 \times (4 \text{ KHz}) = 8 \text{ kbps}$

c. $r = \log_2 16 = 4 \rightarrow N = [1/(1 + 0)] \times 4 \times (4 \text{ KHz}) = 16 \text{ kbps}$

d. $r = \log_2 64 = 6 \rightarrow N = [1/(1 + 0)] \times 6 \times (4 \text{ KHz}) = 24 \text{ kbps}$

P5-9. A corporation has a medium with a 1-MHz bandwidth (lowpass). The corporation needs to create 10 separate independent channels each capable of sending at least 10 Mbps. The company has decided to use QAM technology. What is the minimum number of bits per baud for each channel? What is the number of points in the constellation diagram for each channel? Let $d = 0$.

Solution:

∴ channel BW 10

channel BW = 1 MHz = 100 kHz

channels 25

∴ channel BW = 100 kHz

$$B = (1+d) S$$

$$= (1+0) \frac{N}{r}$$

$$B = \frac{N}{r}$$

$$\therefore r = \frac{N}{B} = \frac{10 M}{100 K} = 100$$

of points in constellation (L) = $2^r = 2^{100} =$

of levels

P5-10. A cable company uses one of the cable TV channels (with a bandwidth of 6 MHz) to provide digital communication for each resident. What is the available data rate for each resident if the company uses a 64-QAM technique?

Solution:

$$B = 6 \text{ MHz } r = \log_2 64 = 6$$

Let $d = 0$

$$N = \frac{1}{(1+d)} * r * B = 1 * 6 * 6M = 36 \text{ Mbps}$$

P5-11. Find the bandwidth for the following situations if we need to modulate a 5-KHz voice.

a. AM

b. FM ($\beta = 5$)

c. PM ($\beta = 1$)

Solution:

a. AM

$$B_{AM} = 2B = 2 * 5K = 10 \text{ KHz}$$

b. FM ($\beta = 5$)

$$B_{FM} = 2(1 + \beta)B = 2(1 + 5) * 5K = 60 \text{ KHz}$$

c. PM ($\beta = 1$)

$$B_{PM} = 2(1 + \beta)B = 2(1 + 1) * 5K = 20 \text{ KHz}$$

P5-12. Find the total number of channels in the corresponding band allocated by FCC.

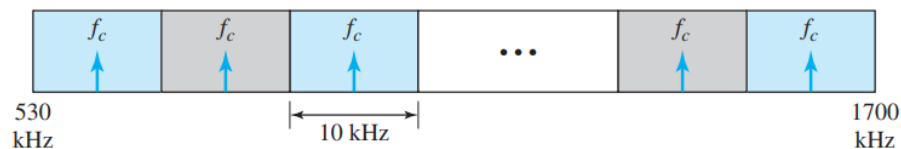
a. AM

b. FM

Solution:

a.

Figure 5.17 AM band allocation

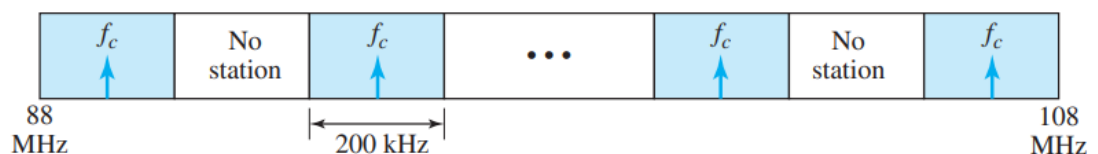


AM stations are allowed carrier frequencies anywhere between 530 and 1700 kHz (1.7 MHz). However, each station's carrier frequency must be separated from those on either side of it by at least 10 kHz (one AM bandwidth) to avoid interference.

$$n = (1700 - 530) \text{ k} / 10 \text{ k} = 117$$

b.

Figure 5.19 FM band allocation



$$n = (108 - 88) \text{ M} / 200 \text{ k} = 10$$