Signal Transmission Practice Set Solutions

Chapter 5.4 Solutions

1 Questions (Q5.1 - Q5.10)

1.1 Q5-1: Define analog transmission

Answer: Analog transmission is the transmission of analog signals without regard to their content. The signal may represent analog data (human voice) or digital data (binary data converted to analog). The analog signal is amplified at regular intervals to combat signal degradation.

1.2 Q5-2: Define carrier signal and explain its role in analog transmission

Answer: A carrier signal is a high-frequency sinusoidal wave that carries information by being modulated. In analog transmission, the carrier signal serves as a vehicle to transport the information signal over long distances. The information is embedded in the carrier by modifying one of its characteristics (amplitude, frequency, or phase).

1.3 Q5-3: Define digital-to-analog conversion

Answer: Digital-to-analog conversion is the process of converting digital data into analog signals. This is necessary when digital data needs to be transmitted over analog channels. The conversion involves modulating a carrier signal based on the digital bit pattern.

1.4 Q5-4: Which characteristics are changed in digital-to-analog conversions?

For each digital-to-analog conversion technique:

- **ASK (Amplitude Shift Keying):** Amplitude of the carrier signal
- **FSK (Frequency Shift Keying):** Frequency of the carrier signal
- **PSK (Phase Shift Keying):** Phase of the carrier signal
- **QAM (Quadrature Amplitude Modulation):** Both amplitude and phase of the carrier signal

1.5 Q5-5: Most susceptible digital-to-analog conversion technique to noise

Answer: ASK (Amplitude Shift Keying) is the most susceptible to noise because noise primarily affects the amplitude of signals. In ASK, the information is carried in the amplitude variations, making it vulnerable to amplitude-based noise interference.

1.6 Q5-6: Define constellation diagram and its role

Answer: A constellation diagram is a representation of a signal modulated by a digital modulation scheme. It shows the signal as a two-dimensional scatter plot of complex numbers, with the real and imaginary parts plotted on orthogonal axes. Each point represents a possible symbol that can be transmitted. In analog transmission, it helps visualize signal states, analyze signal quality, and determine bit error rates.

1.7 Q5-7: Components of a signal in constellation diagram

Answer: The two components of a signal in a constellation diagram are:

- **In-phase component (I):** Shown on the horizontal axis
- **Quadrature component (Q):** Shown on the vertical axis

1.8 Q5-8: Define analog-to-analog conversion

Answer: Analog-to-analog conversion is the representation of analog information by an analog signal. This involves modulating a carrier signal with the analog information signal. Common techniques include AM (Amplitude Modulation), FM (Frequency Modulation), and PM (Phase Modulation).

1.9 Q5-9: Which characteristics are changed in analog-to-analog conversions?

For each analog-to-analog conversion technique:

- **AM (Amplitude Modulation):** Amplitude of the carrier signal
- **FM (Frequency Modulation):** Frequency of the carrier signal
- **PM (Phase Modulation):** Phase of the carrier signal

1.10 Q5-10: Most susceptible analog-to-analog conversion technique to noise

Answer: AM (Amplitude Modulation) is the most susceptible to noise because noise primarily affects the amplitude of signals. FM and PM are more resistant to noise since they use frequency and phase variations respectively, which are less affected by amplitude-based noise.

2 Practice Problems (P5.1 - P5.12)

2.1 P5-1: Calculate baud rate

The baud rate is calculated using: Baud Rate = Bit Rate / $\log_2(L)$, where L is the number of signal levels.

a) 2000 bps, FSK: L = 2, Baud Rate = $2000/\log_2(2) = 2000/1 = 2000$ baud

b) 4000 bps, ASK: L = 2, Baud Rate = $4000/\log_2(2) = 4000/1 = 4000$ baud

c) 6000 bps, QPSK: L = 4, Baud Rate = $6000/\log_2(4) = 6000/2 = 3000$ baud

d) 36,000 bps, 64-QAM: L = 64, Baud Rate = $36000/\log_2(64) = 36000/6 = 6000$ baud

2.2 P5-2: Calculate bit rate

The bit rate is calculated using: Bit Rate = Baud Rate $\times \log_2(L)$

a) 1000 baud, FSK: L = 2, Bit Rate = $1000 \times \log_2(2) = 1000 \times 1 = 1000$ bps

b) 1000 baud, ASK: L = 2, Bit Rate = $1000 \times \log_2(2) = 1000 \times 1 = 1000$ bps

c) 1000 baud, BPSK: L = 2, Bit Rate = $1000 \times \log_2(2) = 1000 \times 1 = 1000$ bps

d) 1000 baud, 16-QAM: L = 16, Bit Rate = $1000 \times \log_2(16) = 1000 \times 4 = 4000$ bps

2.3 P5-3: Number of bits per baud

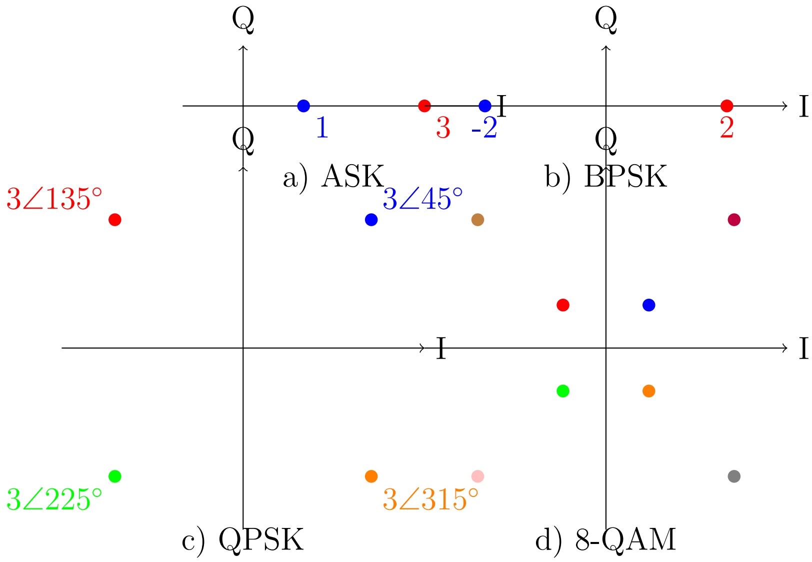
a) ASK with four different amplitudes: $\log_2(4) = 2$ bits per baud

b) FSK with eight different frequencies: $\log_2(8) = 3$ bits per baud

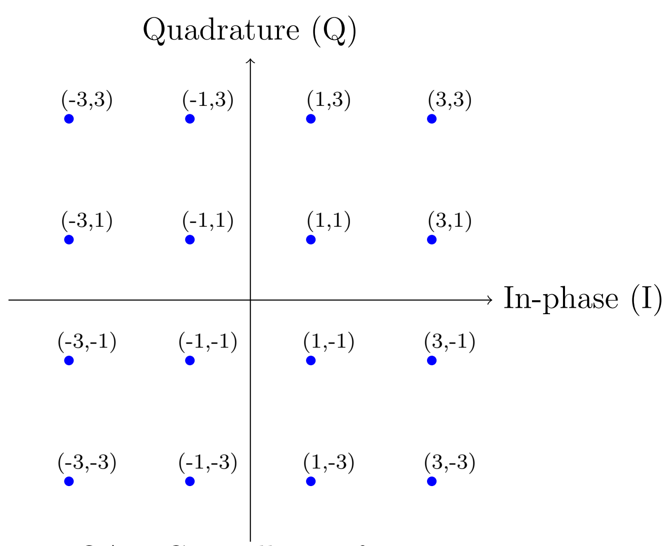
c) PSK with four different phases: $\log_2(4) = 2$ bits per baud

d) QAM with constellation of 128 points: $\log_2(128) = 7$ bits per baud

2.4 P5-4: Constellation diagrams



2.5 P5-5: Constellation diagrams for given points



16-QAM Constellation for P5-5

2.6 P5-6: Bits per baud for different constellation points

a) 2 points: $\log_2(2) = 1$ bit per baud

b) 4 points: $\log_2(4) = 2$ bits per baud

c) 16 points: $\log_2(16) = 4$ bits per baud

d) 1024 points: $\log_2(1024) = 10$ bits per baud

2.7 P5-7: Required bandwidth for 4000 bps

Given: Bit rate = 4000 bps, d = 1 (ideal case)
Bandwidth formula: $B = \frac{\text{Baud Rate}}{2d} = \frac{\text{Baud Rate}}{2}$

a) ASK: Baud Rate = 4000, $B = 2000$ Hz = 2 kHz

b) FSK with $2\Delta f = 4$ kHz: $B = 2\Delta f + 2 \times \frac{\text{Baud Rate}}{2} = 4000 + 4000 = 8000$ Hz = 8 kHz

c) QPSK: Baud Rate = 2000, $B = 1000$ Hz = 1 kHz

d) 16-QAM: Baud Rate = 1000, $B = 500$ Hz = 0.5 kHz

2.8 P5-8: Maximum bits with 4 kHz bandwidth

Given: Bandwidth = 4 kHz, d = 0 (practical case)
For d = 0: Baud Rate = Bandwidth

a) ASK: Baud Rate = 4000, Bit Rate = $4000 \times 1 = 4000$ bps

b) QPSK: Baud Rate = 4000, Bit Rate = $4000 \times 2 = 8000$ bps

c) 16-QAM: Baud Rate = 4000, Bit Rate = $4000 \times 4 = 16000$ bps

d) 64-QAM: Baud Rate = 4000, Bit Rate = $4000 \times 6 = 24000$ bps

2.9 P5-9: QAM technology analysis

Given: 1-MHz bandwidth (lowpass), 10 independent channels, minimum 10 Mbps each
Total bit rate needed = 10×10 Mbps = 100 Mbps
Available baud rate per channel = 1 MHz / 10 = 100 kbaud
Required bits per baud = 100 Mbps/(10×100 kbaud) = 10 bits per baud
Required constellation points = $2^{10} = 1024$
Therefore: 1024-QAM is needed, with 1024 points in the constellation diagram for each channel.

2.10 P5-10: Cable TV digital communication

Given: Bandwidth = 6 MHz, 64-QAM technique
For 64-QAM: bits per symbol = $\log_2(64) = 6$ bits
Baud rate = Bandwidth = 6×10^6 baud
Data rate = Baud rate $\times$ bits per symbol = $6 \times 10^6 \times 6 = 36$ Mbps
Available data rate for each resident = 36 Mbps

2.11 P5-11: Bandwidth for analog modulation of 5-kHz voice

Given: Voice signal = 5 kHz

a) AM: $B = 2 \times f_m = 2 \times 5 = 10$ kHz

b) FM ($\beta = 5$): $B = 2(\beta + 1) \times f_m = 2(5 + 1) \times 5 = 60$ kHz

c) PM ($\beta = 1$): $B = 2(\beta + 1) \times f_m = 2(1 + 1) \times 5 = 20$ kHz

2.12 P5-12: Total channels allocated by FCC

a) AM:

- Frequency range: 535–1605 kHz
- Total bandwidth: $1605 - 535 = 1070$ kHz
- Channel bandwidth: 10 kHz
- Number of channels: $1070/10 = 107$ channels

b) FM:

- Frequency range: 88–108 MHz
- Total bandwidth: $108 - 88 = 20$ MHz $= 20{,}000$ kHz
- Channel bandwidth: 200 kHz
- Number of channels: $20000/200 = 100$ channels