Chapter 3 Problem Solution

Q3-1. What is the relationship between period and frequency?

- Period (T) is the duration of one complete cycle of a signal, while frequency (f) is the number of cycles per second. They are inversely related:

$$f=1/T \text{ and } T = 1\backslash f$$

Q3-2. What does the amplitude of a signal measure? What does the frequency of a signal measure? What does the phase of a signal measure?

- **Amplitude:** Measures the strength or intensity of the signal, typically expressed in volts.
- **Frequency:** Measures the number of cycles of a signal per second, expressed in hertz (Hz).
- **Phase:** Measures the position of the waveform relative to time zero, expressed in degrees or radians.

Q3-3. How can a composite signal be decomposed into its individual frequencies?

- A composite signal can be decomposed into its individual frequencies using **Fourier Analysis**. Fourier Transform is used to convert a time-domain signal into its frequency components.

Q3-4. Name three types of transmission impairment.

1. **Attenuation:** Loss of signal strength over distance.
2. **Noise:** Unwanted signals that interfere with the transmission.
3. **Distortion:** Alteration of the original signal due to varying frequencies.

Q3-5. Distinguish between baseband transmission and broadband transmission.

- **Baseband Transmission:** Sends a single signal (digital or analog) through the channel without modulation. Used in LANs.
- **Broadband Transmission:** Transmits multiple signals simultaneously using frequency division multiplexing (FDM) or modulation.

Q3-6. Distinguish between a low-pass channel and a band-pass channel.

- **Low-pass Channel:** Allows signals with frequencies from 0 Hz up to a certain cutoff frequency.
- **Band-pass Channel:** Allows signals within a specific range of frequencies, with a lower and upper cutoff.

Q3-7. What does the Nyquist theorem have to do with communications?

- Nyquist Theorem states that to accurately reconstruct an analog signal, the sampling rate must be **at least twice the highest frequency component** of the signal.

$$fs \geq 2B$$

Where fsf_sfs is the sampling rate and BBB is the bandwidth.

Q3-8. What does the Shannon capacity have to do with communications?

- Shannon Capacity defines the **maximum data rate** that can be transmitted over a noisy channel:

$$C = B \times \log2(1+S/N)$$

Where:

- C is the channel capacity in bits per second (bps)
- B is the bandwidth of the channel
- S/N is the signal-to-noise ratio.

Q3-9. Why do optical signals used in fiber optic cables have a very short wavelength?

- Shorter wavelengths allow **higher data rates** and **less signal dispersion**, which increases the bandwidth and reduces attenuation in fiber optic communication.

Q3-10. Can we say whether a signal is periodic or non-periodic by just looking at its frequency domain plot? How?

- Yes.
- **Periodic signals** have a discrete frequency domain with harmonics at regular intervals.
- **Non-periodic signals** have a continuous frequency domain.

Q3-11. Is the frequency domain plot of a voice signal discrete or continuous?

- A **voice signal** is typically continuous because it is an analog signal with a range of frequencies.

Q3-12. Is the frequency domain plot of an alarm system discrete or continuous?

- An **alarm system** usually generates discrete frequencies, resulting in a **discrete frequency domain plot**.

Q3-13. We send a voice signal from a microphone to a recorder. Is this baseband or broadband transmission?

- **Baseband Transmission:** The voice signal is sent without modulation directly to the recorder.

Q3-14. We send a digital signal from one station on a LAN to another station. Is this baseband or broadband transmission?

- **Baseband Transmission:** LANs typically use baseband to send digital signals.

Q3-15. We modulate several voice signals and send them through the air. Is this baseband or broadband transmission?

- **Broadband Transmission:** Modulated signals with multiple channels are transmitted through the air using broadband.

P3-1. Given the frequencies listed below, calculate the corresponding periods.

The relationship between period and frequency is:

$$T=1/f$$

- **(a)** f = 24Hz

$$T=1/24\approx 0.0417 \text{ seconds (41.7 ms)}$$

- **(b)** f = 8MHz

$$T=1/\ (8\times 10\text{^}6)\ =1.25\times 10-7 \text{ seconds or 125 ns.}$$

- **(c)** f = 140kHz

$$T=1/\ (140\times 10\text{^}3)\ \approx 7.14\ \mu\text{s.}$$

P3-2. Given the following periods, calculate the corresponding frequencies.

The relationship is:

$$f=1/T$$

- **(a)** T = 5s

$$f=1/5=0.2 \text{ Hz.}$$

- **(b)** T = 12μs

$$f=1/\ (12\times 10\text{^-}6)\ \approx 83.33 \text{ kHz.}$$

- **(c)** T = 220ns

$$f=1/(220\times 10\text{^}-9)\approx 4.55 \text{ MHz.}$$

P3-3. What is the phase shift for the following?

- **(a)** A sine wave with the maximum amplitude at time zero → **0° or 0 radians.**
- **(b)** A sine wave with maximum amplitude after 1/4 cycle → **90° or π/2 radians.**
- **(c)** A sine wave with zero amplitude after 3/4 cycle and increasing → **270° or 3π/2 radians.**

P3-4. What is the bandwidth of a signal that can be decomposed into five sine waves with frequencies at 0, 20, 50, 100, and 200 Hz?

- **Bandwidth:**

$$B = \text{Highest frequency} - \text{Lowest frequency}$$

$$B = 200 - 0 = 200\text{Hz}.$$

- **Bandwidth Diagram:**
  The spectrum has components at 0, 20, 50, 100, and 200 Hz.

P3-5. A periodic composite signal with a bandwidth of 2000 Hz is composed of two sine waves. The first one has a frequency of 100 Hz with a maximum amplitude of 20 V; the second one has a maximum amplitude of 5 V. Draw the bandwidth.

- **Bandwidth:**

$$B = 2000\text{Hz}.$$

- **Bandwidth Diagram:**
  The spectrum shows one component at 100 Hz with an amplitude of 20V and another at a higher frequency (implied by bandwidth) with 5V amplitude.

P3-6. Which signal has a wider bandwidth, a sine wave with a frequency of 100 Hz or a sine wave with a frequency of 200 Hz?

- **Answer:** Both signals are sine waves and have zero bandwidth. However, if modulated or transmitted, the **200 Hz signal** will occupy a wider frequency range.

P3-7. What is the bit rate for each of the following signals?

- **(a)** A signal in which 1 bit lasts 0.001 s:

$$\text{Bit rate} = 1/0.001 = 1000\ \text{bps}.$$

- **(b)** A signal in which 1 bit lasts 2 ms:

$$\text{Bit rate} = 1/0.002 = 500\ \text{bps}.$$

- **(c)** A signal in which 10 bits last 20 μs:

$$\text{Bit rate} = 10/(20 \times 10\text{^}{-6}) = 500{,}000\ \text{bps or } 500\ \text{Kbps}.$$

P3-8. A device is sending out data at the rate of 1000 bps.

- **(a)** How long does it take to send out 10 bits?

  Time=Number of bits/Bit rate=10/1000=0.01 seconds or 10 ms.

- **(b)** How long does it take to send out a single character (8 bits)?

  Time=8/1000=0.008 seconds or 8 ms.

- **(c)** How long does it take to send a file of 100,000 characters?
  Each character has 8 bits, so:

  Total bits=100,000×8=800,000 bits.

  Time=800,000/1000=800 seconds or approximately 13.3 minutes.

P3-9. What is the bit rate for the signal in Figure 3.35?

- The figure shows a digital signal where 1 bit lasts **16 ns**.
- Bit rate formula:

  Bit rate=1/bit duration=1/(16×10^−9)=62.5×106 bps or 62.5 Mbps.

P3-10. What is the frequency of the signal in Figure 3.36?

- The signal has a **period of 4 ms**.
- Frequency formula:

  f=1/T=1/ (4×10^−3) =250 Hz.

P3-11. What is the bandwidth of the composite signal shown in Figure 3.37?

- The diagram shows frequency components spaced by **5 Hz**, with the highest frequency component at **180 Hz**.
- Bandwidth formula:

  B=Highest frequency−Lowest frequency=180−5=175 Hz.

P3-12. A periodic composite signal contains frequencies from 10 to 30 KHz, each with an amplitude of 10 V. Draw the frequency spectrum.

- **Frequency Range:** 10 kHz to 30 kHz
- **Amplitude:** 10 V for all frequencies
- **Type:** Periodic signal

The frequency spectrum will consist of vertical lines at equal intervals between 10 kHz and 30 kHz, each having an amplitude of 10 V.

P3-13. A nonperiodic composite signal contains frequencies from 10 to 30 KHz. The peak amplitude is 10 V for the lowest and the highest signals and is 30 V for the 20-KHz signal.

Assuming that the amplitudes change gradually from the minimum to the maximum, draw the frequency spectrum.

- **Frequency Range:** 10 kHz to 30 kHz
- **Amplitude:**
    - 10 V at 10 kHz and 30 kHz
    - 30 V at 20 kHz
- **Type:** Nonperiodic signal

The frequency spectrum will be a continuous curve (triangular shape), starting at 10 V at 10 kHz, peaking at 30 V at 20 kHz, and returning to 10 V at 30 kHz.

P3-14. A TV channel has a bandwidth of 6 MHz. If we send a digital signal using one harmonic, three harmonics, and five harmonics, what are the data rates?

- **Formula (Nyquist Theorem):**

$$\text{Bit rate}=2\times B\times N$$

Where:

- $B=6\times10^6$ Hz.
- NNN = Number of harmonics
- **For 1 harmonic:**

$$\text{Bit rate}=2\times6\times10^6\times1=12\ \text{Mbps}.$$

- **For 3 harmonics:**

$$\text{Bit rate}=2\times6\times10^6\times3=36\ \text{Mbps}.$$

- **For 5 harmonics:**

$$\text{Bit rate}=2\times6\times10^6\times5=60\ \text{Mbps}.$$

P3-15. A signal travels from point A to point B. At point A, the signal power is 100 W. At point B, the power is 90 W. What is the attenuation in decibels?

- **Formula:**

$$\text{Attenuation (dB)}=10\times\log(P1/P2)$$

$$\text{Attenuation}=10\times\log\,(100/90)=10\times\log\,(1.11)\approx0.46\ \text{dB}.$$

P3-16. The attenuation of a signal is −10 dB. What is the final signal power if it was originally 5 W?

- **Formula:**

$$\text{Attenuation (dB)}=10\times\log(P2/P1)$$

$$-10=10\times\log(P2/5)$$

$$P2/5=10^{-1}=0.1$$

$$P2=5\times0.1=0.5\ W.$$

P3-17. A signal has passed through three cascaded amplifiers, each with a 4 dB gain. What is the total gain? How much is the signal amplified?

- **Total Gain:**

$$\text{Total Gain}=3\times4=12\ dB.$$

- **Amplification Factor:**

$$\text{Amplification Factor}=10^{(Gain/10)}=10^{(12/10)}=15.85.$$

The signal is amplified by approximately **15.85 times.**