CHAPTER 3

PRACTICE SET

Questions

Q3-1. *Fourier series* gives the frequency domain of a periodic signal; *Fourier analysis* gives the frequency domain of a nonperiodic signal.

Q3-2. A *low-pass channel* has a bandwidth that starts from zero. A *band-pass channel* has bandwidth that can start from any frequency.

Q3-3. The period of a signal is the inverse of its frequency and vice versa: $T = 1/f$ and $f = 1/T$.

Q3-4. An alarm system is normally *periodic*. Its frequency domain plot is therefore discrete.

Q3-5. A fiber-optic cable uses light (very high frequency). Since f is very high, the wavelength, which is $\lambda = c / f$, is very low.

Q3-6. This is *baseband transmission* because no modulation is involved.

Q3-7. This is *baseband transmission* because no modulation is involved.

Q3-8. The *Shannon capacity* defines the theoretical highest data rate for a noisy channel.

Q3-9. The *Nyquist theorem* defines the maximum bit rate of a noiseless channel.

Q3-10. *Attenuation* and *noise* are two out of three causes of transmission impairment; distortion is the third one.

Q3-11. The frequency domain of a voice signal is normally *continuous* because voice is a nonperiodic signal.

Q3-12.

- **a.** The *amplitude* of a signal measures the value of the signal at any point.
- **b.** The *frequency* of a signal measures how may times the signal repeats itself in a second.
- **c.** The *phase* of a signal represents the position of the signal with respect to time 0.

Q3-13. *Baseband transmission* means sending a digital or an analog signal without modulation using a low-pass channel. *Broadband transmission* means to modulate signal using a band-pass channel.

Q3-14. A signal is *periodic* if its frequency domain plot is discrete; a signal is *nonperiodic* if its frequency domain plot is continuous.

Q3-15. This is *broadband transmission* because it involves modulation.

Problems

P3-1. The bit duration is the inverse of the bandwidth.We have

(bit length) = (propagation speed) × (bit duration)

- **a.** Bit length = $(2 \times 10^8$ m$) \times [(1 / (10$ Mbps$)] = 20$ m. This means a bit occupies 20 meters on a transmission medium.
- **b.** Bit length = $(2 \times 10^8$ m$) \times [(1 / (100$ Mbps$)] = 2$ m. This means a bit occupies 2 meters on a transmission medium.
- **c.** Bit length = $(2 \times 10^8$ m$) \times [(1 / (1000$ Mbps$)] = 0.2$ m. This means a bit occupies 0.2 meters on a transmission medium.

P3-2. The signal makes 8 cycles in 4 ms. The frequency is 8 /(4 ms) = 2 kHz

P3-3. 480 s × 300,000 km/s = 144,000,000 km

P3-4. To represent 1024 color levels, we need $\log_2 1024 = 10$ bits. The total number of bits are, therefore,

$$\text{Number of bits} = 1600 \times 800 \times 10 = 12{,}800{,}000 \text{ bits}$$

P3-5. We use the Shannon capacity $C = B \log_2 (1 + SNR)$

$$C = 5{,}000 \log_2 (1 + 2{,}000) \approx 54.832 \text{ Kbps}$$

P3-6. Each cycle moves the front of the signal λ meter ahead (definition of the wavelength). In this case, we have

$$1\ \mu\text{m} \times 500 = 500\ \mu\text{m} = 0.5\ \text{mm}$$

P3-7.

a. bit rate = 1/ (bit duration) = 1 / (0.001 s) = 1000 bps = 1 Kbps

b. bit rate = 1/ (bit duration) = 1 / (2 ms) = 500 bps

c. bit rate = 1/ (bit duration) = 1 / (20 μs/10) = 1 / (2 μs) = 500 Kbps

P3-8. The bandwidth of the channel in bits is W_b and the size of the frame is N bits; it takes $t = W_b / N$ seconds to send out the frame. In this case we have

$$t = 1{,}000{,}000 \text{ bits} / 5 \text{ Kbps} = 200 \text{ s}$$

P3-9. We can calculate the attenuation as shown below:

$$\text{dB} = 10 \log_{10} (80 / 100) \approx -0.97 \text{ dB}$$

P3-10. We have dB = $\log_{10} (P_2/P_1)$.

$$-10 = 10 \log_{10} (P_2 / 10) \rightarrow \log_{10} (P_2 / 10) = -1 \rightarrow (P_2 / 10) = 10^{-1} \rightarrow P_2 = 1 \text{ W}$$

P3-11. There are 8 bits in 16 ns. Bit rate is $8 / (16 \times 10^{-9}) = 0.5 \times 10^{9}$ = 500 Mbps

P3-12.

a. (10 / 1000) s = 0.01 s

b. (8 / 1000) s = 0. 008 s = 8 ms

c. ((100,000 × 8) / 1000) s = 800 s

P3-13.

a. 90 degrees (π/2 radians)

b. 0 degrees (0 radians)

c. 90 degrees (π/2 radians) (Note that it is the same wave as in part *a*.)

P3-14. Each signal is a simple signal in this case. The bandwidth of a simple signal is zero. So the bandwidth is the same for both signals.

P3-15. The file contains 3,000,000 × 8 = 24,000,000 bits.

a. With a 56-Kbps channel, it takes 24,000,000/56,000 = 428 s

b. With a 1-Mbps channel, it takes 16,000,000/1,000,000 = 16 s.

P3-16.

a. Number of bits = bandwidth × delay = 1 Mbps × 2 ms = 2000 bits

b. Number of bits = bandwidth × delay = 10 Mbps × 2 ms = 20,000 bits

c. Number of bits = bandwidth × delay = 100 Mbps × 2 ms = 200,000 bits

P3-17. We can approximately calculate the capacity as

a. $C = B \times (SNR_{dB} /3) = 20 \text{ KHz} \times (40 /3) = 267 \text{ Kbps}$

b. $C = B \times (SNR_{dB} /3) = 200 \text{ KHz} \times (4 /3) = 267 \text{ Kbps}$

c. $C = B \times (SNR_{dB} /3) = 1 \text{ MHz} \times (20 /3) = 6.67 \text{ Mbps}$

P3-18.

a. Using the first harmonic, data rate = 2 × 6 MHz = 12 Mbps

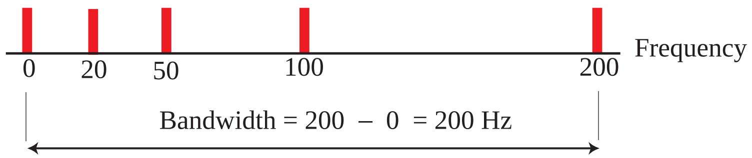
b. Using three harmonics, data rate = (2 × 6 MHz) /3 = 4 Mbps

c. Using five harmonics, data rate = (2 × 6 MHz) /5 = 2.4 Mbps

P3-19. We have

$$SNR = (200 \text{ mW}) / (20 \times 2 \times \mu\text{W}) = 5{,}000$$
$$SNR_{dB} = 10 \log_{10} SNR = 10 \log_{10} 5000 \approx 37$$

P3-20. See below:



P3-21. The bandwidth is 5 × 5 = 25 Hz.

P3-22.

a.	$f = 1 / T$	$= 1 / (5 \text{ s})$	$= 0.2 \text{ Hz}$
b.	$f = 1 / T$	$= 1 / (12\ \mu\text{s})$	$= 83.333 \text{ KHz}$
c.	$f = 1 / T$	$= 1 / (220 \text{ ns})$	$= 4.55 \text{ MHz}$

P3-23. The total gain is 3 × 4 = 12 dB. To find how much the signal is amplified, we can use the following formula:

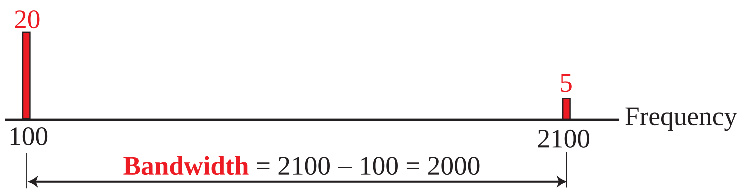
$$12 = 10 \log (P_2/P_1) \quad \rightarrow \quad \log (P_2/P_1) = 1.2 \quad \rightarrow \quad P_2/P_1 = 10^{1.2} = 15.85$$

The signal is amplified almost 16 times.

P3-24. We have **SNR = (signal power)/(noise power).** However, power is proportional to the square of voltage. This means we have

$$SNR = [(\text{signal voltage})^2] / [(\text{noise voltage})^2] = 20^2 = 400$$
$$SNR_{dB} = 10 \log_{10} SNR = 10 \log_{10} 400 = 26$$

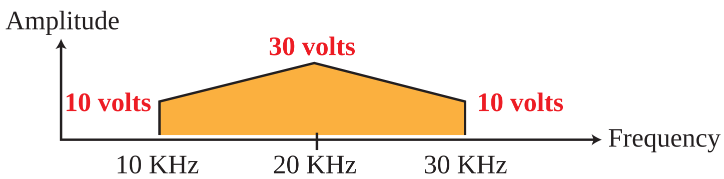
P3-25. We know the bandwidth is 2000. The highest frequency must be 100 + 2000 = 2100 Hz. See below:



P3-26. SNR is the ratio of the powers. The power is proportion to the voltage square ($P = V^2/R$). Therefore, we have $SNR = (10)^2 / (10 \times 10^{-3})^2 = 10^6$. We then use the Shannon capacity to calculate the maximum data rate.

$$C = 4{,}000 \log_2 (1 + 10^6) \approx 80 \text{ Kbps}$$

P3-27. The signal is nonperiodic, so the frequency domain is made of a continuous spectrum of frequencies as shown below:



P3-28.

a. The data rate is doubled ($C_2 = 2 \times C_1$).

b. When the SNR is doubled, the data rate increases slightly. We can say that, approximately, ($C_2 = C_1 + 1$).

P3-29. We can use the approximate formula

$$C = B \times (SNR_{dB} /3) \text{ or } SNR_{dB} = (3 \times C) / B$$

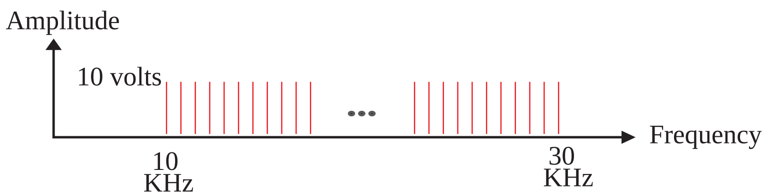
We can say that the minimum of SNR_{dB} is

$$SNR_{dB} = 3 \times 100 \text{ Kbps} / 4 \text{ KHz} = 75$$

This means that the minimum

$$SNR = 10\ SNR_{dB}/10 = 107.5 \approx 31{,}622{,}776$$

P3-30. The signal is periodic, so the frequency domain is made of discrete frequencies with the bandwidth of 30 – 10 = 20 kHz. See below:



P3-31.

a.	$T = 1/f$	$= 1 / (24 \text{ Hz})$	$= 0.0417$ s	$= 41.7$ ms
b.	$T = 1/f$	$= 1 / (8 \text{ MHz})$	$= 0.000000125$ s	$= 0.125$ ms
c.	$T = 1/f$	$= 1 / (140 \text{ kHz})$	$= 7.14 \times 10^{-6}$ s	$= 7.14$ ms

P3-32. We have

transmission time = (packet length in bits)/(bandwidth) =
(8,000,000 bits) / (200,000 bps) = 40 s

P3-33. We have Latency = $Delay_{pr} + Delay_{qu} + Delay_{tr} + Delay_{pg}$

$Delay_{pr} = 10 \times 1\ \mu s = 10\ \mu s$ **// Processing delay**

$Delay_{qu} = 10 \times 2\ \mu s = 20\ \mu s$ **// Queuing delay**

$Delay_{tr} = 5{,}000{,}000 / (5 \text{ Mbps}) = 1$ s **// Transmission delay**

$Delay_{pg} = (2000 \text{ Km}) / (2 \times 10^8) = 0.01$ s **// Propagation delay**

This means

Latency = $10\ \mu s + 20\ \mu s + 1s + 0.01\ s \approx 1.01$ s

The transmission time is dominant here because the packet size is huge.