



Islamic University of Gaza
Faculty of Engineering
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Data Communications Lab

Lab 4

Chapter 3:

Introduction to Physical Layer



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

a. 24 Hz

b. 8 MHz

c. 140 KHz

a. $T = 1 / f = 1 / (24 \text{ Hz}) = 0.0417 \text{ s} = 41.7 \times 10^{-3} \text{ s} = 41.7 \text{ ms}$

b. $T = 1 / f = 1 / (8 \text{ MHz}) = 0.000000125 = 0.125 \times 10^{-6} \text{ s} = 0.125 \mu\text{s}$

c. $T = 1 / f = 1 / (140 \text{ KHz}) = 0.00000714 \text{ s} = 7.14 \times 10^{-6} \text{ s} = 7.14 \mu\text{s}$

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

a. 5 s

b. 12 μs

c. 220 ns

a. $f = 1 / T = 1 / (5 \text{ s}) = 0.2 \text{ Hz}$

b. $f = 1 / T = 1 / (12 \mu\text{s}) = 83333 \text{ Hz} = 83.333 \times 10^3 \text{ Hz} = 83.333 \text{ KHz}$

c. $f = 1 / T = 1 / (220 \text{ ns}) = 4550000 \text{ Hz} = 4.55 \times 10^6 \text{ Hz} = 4.55 \text{ MHz}$

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

a. A sine wave with the maximum amplitude at time zero

b. A sine wave with maximum amplitude after 1/4 cycle

c. A sine wave with zero amplitude after 3/4 cycle and increasing

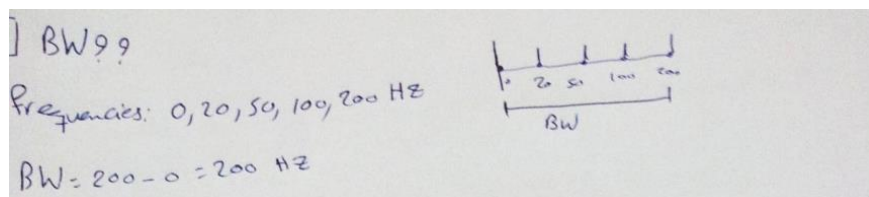
Solution:

a. 90 degrees ($\pi/2$ radian)

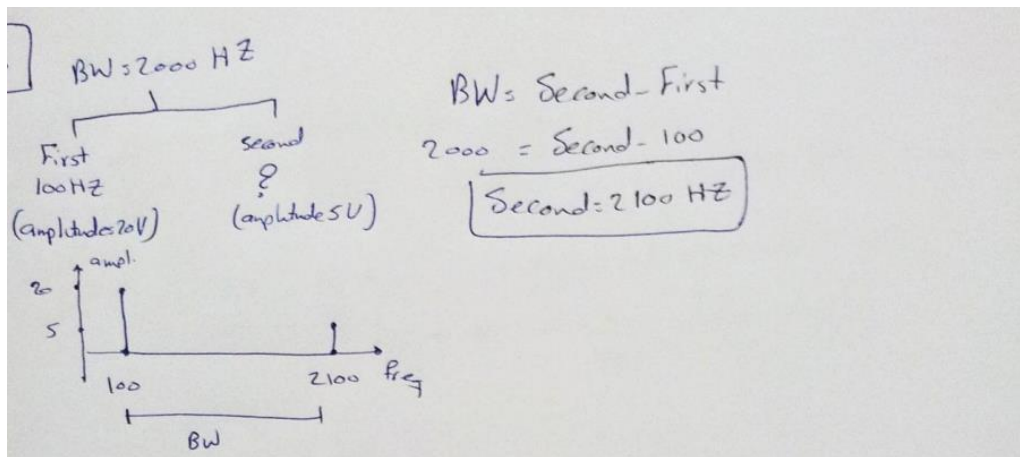
b. 0 degrees (0 radian)

c. 90 degrees ($\pi/2$ radian)

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? All peak amplitudes are the same. Draw the bandwidth.



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.



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?

Solution:

Each signal is a simple signal in this case. The bandwidth of a simple signal is zero. So the bandwidth of both signals are the same.

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

- A signal in which 1 bit lasts 0.001 s
- A signal in which 1 bit lasts 2 ms
- A signal in which 10 bits last 20 μs

Solution:

a. $\text{bit rate} = 1 / (\text{bit duration}) = 1 / (0.001 \text{ s}) = 1000 \text{ bps} = 1 \text{ Kbps}$

b. $\text{bit rate} = 1 / (\text{bit duration}) = 1 / (2 \text{ ms}) = 500 \text{ bps}$

c. $\text{bit rate} = 1 / (\text{bit duration}) = 1 / (20 \mu\text{s} / 10) = 1 / (2 \mu\text{s}) = 500 \text{ Kbps}$

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

- How long does it take to send out 10 bits?
- How long does it take to send out a single character (8 bits)?
- How long does it take to send a file of 100,000 characters?

Solution:

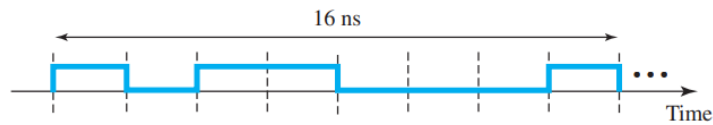
a. $(10 / 1000) \text{ s} = 0.01 \text{ s}$

b. $(8 / 1000) \text{ s} = 0.008 \text{ s} = 8 \text{ ms}$

c. $((100,000 \times 8) / 1000) \text{ s} = 800 \text{ s}$

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

Figure 3.35 Problem P3-9

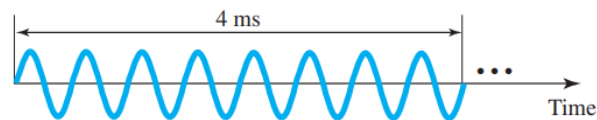


Solution: There are 8 bits in 16 ns.

Bit rate is $8 / (16 \times 10^{-9}) = 0.5 \times 10^9 = 500 \text{ Mbps}$

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

Figure 3.36 Problem P3-10

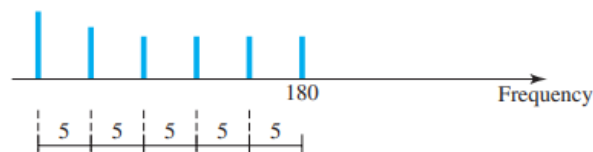


Solution:

The signal makes 8 cycles in 4 ms. The frequency is $8 / (4 \text{ ms}) = 2 \text{ KHz}$

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

Figure 3.37 Problem P3-11



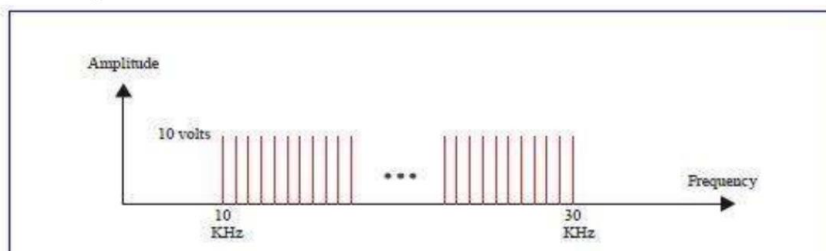
Solution:

$B = 5 + 5 + 5 + 5 + 5 = 25 \text{ Hz}$

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

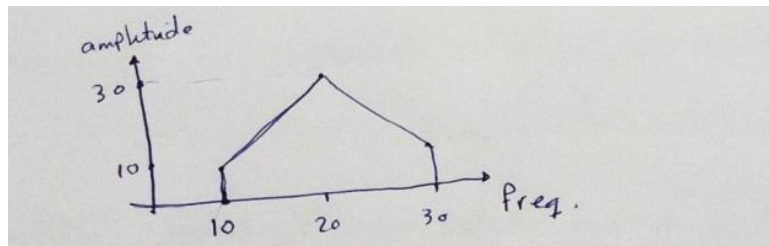
Solution:

The signal is periodic, so the frequency domain is made of discrete frequencies. as shown in Figure.



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.

Solution:



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

Solution: first: $B=N/2$, three $B= 3N/2$, five = $5N/2$

Using the first harmonic, data rate = $2 \times 6 \text{ MHz} = \mathbf{12 \text{ Mbps}}$

Using three harmonics, data rate = $(2 \times 6 \text{ MHz}) / 3 = \mathbf{4 \text{ Mbps}}$

Using five harmonics, data rate = $(2 \times 6 \text{ MHz}) / 5 = \mathbf{2.4 \text{ Mbps}}$

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?

Solution:

$$\text{dB} = 10 \log_{10} \frac{P_2}{P_1}$$

$$\text{dB} = 10 \log_{10} (90 / 100) = \mathbf{-0.46 \text{ dB}}$$

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

Solution:

$$\text{dB} = 10 \log_{10} \frac{P_2}{P_1} \rightarrow -10 = 10 \log_{10} \frac{P_2}{5}$$

$$\log_{10} \frac{P_2}{5} = -1$$

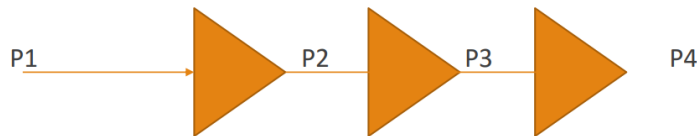
$$\frac{P_2}{5} = 10^{-1}$$

$$\rightarrow P_2 = 0.5 \text{ W}$$

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?

Solution:

$$\text{Total gain} = 4\text{dB} + 4\text{dB} + 4\text{dB} = 12\text{dB}$$



For power gain of the first stage:

$$4\text{dB} = 10 * \log_{10} \frac{P_2}{P_1}$$

$$\frac{P_2}{P_1} = \left(10^{\left(\frac{4}{10}\right)}\right) = 2.512$$

For power gain of three stages:

$$\text{or } 12\text{dB} = \log_{10} \frac{P_4}{P_1} \rightarrow \frac{P_4}{P_1} = \left(10^{\left(\frac{12}{10}\right)}\right) = 15.85$$

$$2.512 * 2.512 * 2.512 = 15.851$$

P3-18. If the bandwidth of the channel is 5 Kbps, how long does it take to send a frame of 100,000 bits out of this device?

Solution:

Given ,bandwidth 5000 bps , Frame 100,000 bit

$$\rightarrow \frac{100000 \text{ b}}{5000 \text{ bps}} = 20\text{sec}$$

P3-19. The light of the sun takes approximately eight minutes to reach the earth. What is the distance between the sun and the earth?

Solution:

The distance between the earth and the sun $d = \text{velocity of light} \times \text{time taken to reach light from sun to earth}$

$$\text{or } d = (3 \times 10^8 \text{ m/s}) \times (8 \times 60\text{s}) = 144 \times 10^9 \text{ m} = 144 \times 10^6 \text{ km}$$

P3-20. A signal has a wavelength of 1 μm in air. How far can the front of the wave travel during 1000 periods?

Solution:

Given , wavelength = 1 μm , periods= 1000

*Wavelength = propagation speed * period (For one period)*

$$\text{Distance} = 1 \mu\text{m} * 1000 = 1000 \mu\text{m} = 1 \text{ mm}$$

P3-21. A line has a signal-to-noise ratio of 1000 and a bandwidth of 4000 KHz. What is the maximum data rate supported by this line?

Solution:

Given

Bandwidth = 4000 KHz, SNR = 1000

So, We Know the Shannon capacity

$$\text{Capacity} = BW * \log_2(1 + SNR)$$

$$\text{Capacity} = 4000K * \log_2(1 + 1000) = 40 \text{ Kbps}$$

P3-22. We measure the performance of a telephone line (4 KHz of bandwidth). When the signal is 10 V, the noise is 5 mV. What is the maximum data rate supported by this telephone line?

Solution:

Q3.22 :

$$B = 4k, \text{ Signal} = 10 \text{ v}, \text{ Noise} = 5 \text{ mV}$$

$$SNR = \frac{(10)^2}{(0.005)^2} = 4M$$

$$\begin{aligned} \text{Capacity} &= B \log_2(1 + SNR) \\ &= 4k \log_2(1 + 4 \times 10^6) \\ &= 87.7 \text{ Kbps} \end{aligned}$$

P3-23. A file contains 2 million bytes. How long does it take to download this file using a 56-Kbps channel? 1-Mbps channel?

Solution:

The file contains $2,000,000 \times 8 = 16,000,000$ bits. With a 56-Kbps channel, it takes $16,000,000 / 56,000 = \mathbf{289 \text{ s}}$. With a 1-Mbps channel, it takes $\mathbf{16 \text{ s}}$.

P3-24. A computer monitor has a resolution of 1200 by 1000 pixels. If each pixel uses 1024 colors, how many bits are needed to send the complete contents of a screen?

Solution:

To represent 1024 color

$$\text{we need} = \log_2 1024 = 10 \text{ bits}$$

$$\text{Total number of bit} = 1200 * 1000 * 10 = 12,000,000 \text{ bit} = 12 \text{ million bit}$$

P3-25. A signal with 200 milliwatts power passes through 10 devices, each with an average noise of 2 microwatts. What is the SNR? What is the SNR_{dB}?

Solution:

Given, Signal = 200 mW = 0.2 W

Total Noise = $10 \times 2 \times 10^{-6} = 2 \times 10^{-5}$

$$\text{We Know, SNR} = \frac{\text{average signal power}}{\text{average noise power}} = \frac{0.2}{2 \times 10^{-5}} = 10000$$

$$\text{SNR dB} = 10 \log_{10}(\text{SNR})$$

$$\text{SNR dB} = 10 \log_{10}(10000) = 40$$

P3-26. If the peak voltage value of a signal is 20 times the peak voltage value of the noise, what is the SNR? What is the SNR_{dB}?

Solution:

$$\text{SNR} = \frac{\text{signal power}}{\text{noise power}}$$

$$\text{SNR} = \frac{(\text{signal voltage})^2}{(\text{noise voltage})^2} = 20^2 = 400$$

$$\text{SNR dB} = 10 \log_{10}(\text{SNR})$$

$$\text{SNR dB} = 10 \log_{10}(400) = 26.021$$

P3-27. What is the theoretical capacity of a channel in each of the following cases?

a. Bandwidth: 20 KHz SNR_{dB} = 40

b. Bandwidth: 200 KHz SNR_{dB} = 4

c. Bandwidth: 1 MHz SNR_{dB} = 20

Solution:

سؤال 3.27

Capacity = ??

Solution:

(a) $BW = 20\text{K}$ $SNR_{dB} = 40$

لأن $SNR_{dB} < 30$ علينا ان نستخدم
القانون :

$$C = BW * \frac{SNR_{dB}}{3} \rightarrow 40$$

20K

(b) & (c)

في هذه الحالة $SNR_{dB} > 30$ لذلك
سنستخدم القانون

$$C = B \log_2 (1 + SNR)$$

B ←
SNR ←

$$SNR_{dB} = 10 \log_{10} SNR$$

$$SNR = 10^{SNR_{dB}/10}$$

P3-28. We need to upgrade a channel to a higher bandwidth. Answer the following questions:

- How is the rate improved if we double the bandwidth?
- How is the rate improved if we double the SNR?

Solution:

1) How is the rate improved if we double the bandwidth?

$$C_2 = 2 \cdot BW_1 \cdot \log_2(1 + SNR)$$

The data rate is doubled ($C_2 = 2 \cdot C_1$)

2) How is the rate improved if we double the SNR?

$$C_2 = BW_1 \cdot \log_2(1 + 2 \cdot SNR)$$

$$C_2 = BW_1 \cdot \log_2(2 \cdot SNR)$$

$$C_2 = BW_1 \cdot \log_2(2) + BW_1 \cdot \log_2(SNR)$$

$$C_2 = BW_1 + C_1$$

P3-29. We have a channel with 4 KHz bandwidth. If we want to send data at 100 Kbps, what is the minimum SNR_{dB} ? What is the SNR?

Solution:

$$\text{Capacity} = BW \cdot \left(\frac{SNR_{dB}}{3} \right)$$

$$\text{so minimum SNR}_{dB} = \frac{3 \cdot \text{Capacity}}{BW} = \frac{3 \cdot 100,000}{4000} = 75$$

$$\text{Minimum SNR} = 10^{\frac{SNR_{dB}}{10}} = 10^{\frac{75}{10}}$$

P3-30. What is the transmission time of a packet sent by a station if the length of the packet is 1 million bytes and the bandwidth of the channel is 200 Kbps?

Solution:

Given, Packet length = 1 million byte = 8 million bit

$$\text{Transmission time} = \frac{\text{packet length}}{\text{bandwidth}} = \frac{8,000,000}{200,000} = 40 \text{ sec}$$

P3-31. What is the length of a bit in a channel with a propagation speed of 2×10^8 m/s if the channel bandwidth is

a. 1 Mbps?

b. 10 Mbps?

c. 100 Mbps?

Solution: a.

$$\text{Bit length} = \frac{\text{propagation speed}}{\text{Bandwidth}}$$

$$\text{Bit length} = \frac{2 \cdot 10^8 \text{ m/s}}{10^6 \text{ b/s}} = 200 \text{ m}$$

b. Bit length = $(2 \times 10^8) \times [(1 / (10 \text{ Mbps}))] = 20 \text{ m}$.

c. Bit length = $(2 \times 10^8) \times [(1 / (100 \text{ Mbps}))] = 2 \text{ m}$.

P3-32. How many bits can fit on a link with a 2 ms delay if the bandwidth of the link is

a. 1 Mbps?

b. 10 Mbps?

c. 100 Mbps?

Solution:

a. Number of bits = bandwidth $\times$ delay = 1 Mbps $\times$ 2 ms = **2000 bits**

b. Number of bits = bandwidth $\times$ delay = 10 Mbps $\times$ 2 ms = **20,000 bits**

c. Number of bits = bandwidth $\times$ delay = 100 Mbps $\times$ 2 ms = **200,000 bits**

P3-33. What is the total delay (latency) for a frame of size 5 million bits that is being sent on a link with 10 routers each having a queuing time of 2 μ s and a processing time of 1 μ s. The length of the link is 2000 Km. The speed of light inside the link is 2×10^8 m/s. The link has a bandwidth of 5 Mbps. Which component of the total delay is dominant? Which one is negligible?

Solution:

**Latency = processing time + queuing time +
transmission time + propagation time**

Processing time = $10 \times 1 \mu\text{s} = 10 \mu\text{s} = \mathbf{0.000010 \text{ s}}$

Queuing time = $10 \times 2 \mu\text{s} = 20 \mu\text{s} = \mathbf{0.000020 \text{ s}}$

Transmission time = $5,000,000 / (5 \text{ Mbps}) = \mathbf{1 \text{ s}}$

Propagation time = $(2000 \text{ Km}) / (2 \times 10^8) = \mathbf{0.01 \text{ s}}$

Latency = $0.000010 + 0.000020 + 1 + 0.01 = 1.01000030 \text{ s}$