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

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 Hz) = 0.0417 s = 41.7 × 10^-3 s = 41.7 ms

b. T = 1 / f = 1 / (8 MHz) = 0.000000125 = 0.125 × 10^-6 s = 0.125 μs

c. T = 1 / f = 1 / (140 KHz) = 0.00000714 s = 7.14 × 10^-6 s = 7.14 μs

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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 s) = 0.2 Hz

b. f = 1 / T = 1 / (12 μs) =83333 Hz = 83.333 × 103 Hz = 83.333 KHz

c. f = 1 / T = 1 / (220 ns) = 4550000 Hz = 4.55× 106 Hz = 4.55 MHz

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

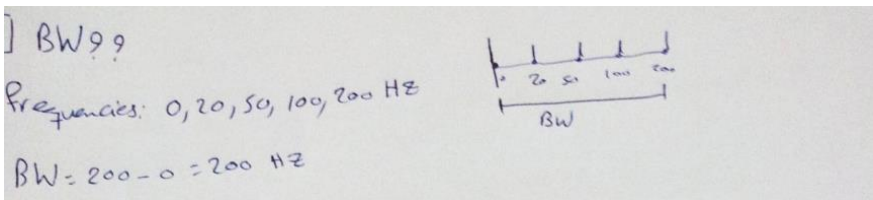
a. A sine wave with the maximum amplitude at time zero

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

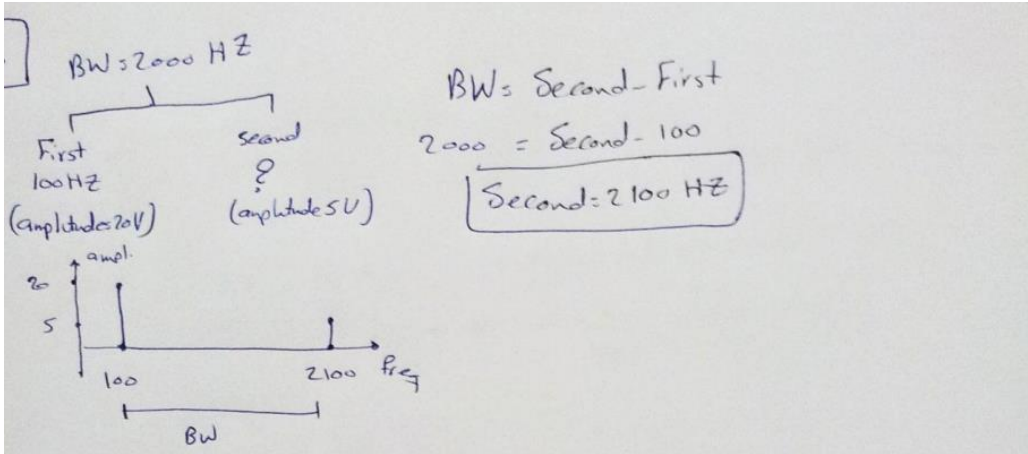
c. A sine wave with zero amplitude after 3/4 cycle and increasing

Solution:
a. 90 degrees (π/2 radian)
b. 0 degrees (0 radian)
c. 90 degrees (π/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. A signal in which 1 bit lasts 0.001 s

b. A signal in which 1 bit lasts 2 ms

c. A signal in which 10 bits last 20 µs

Solution:
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

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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?

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

c. How long does it take to send a file of 100,000 characters?

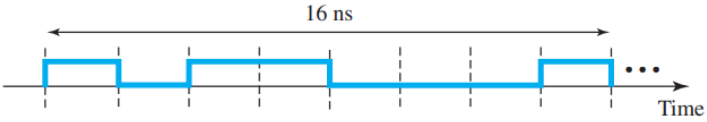
Solution:
a. (10 / 1000) s = 0.01 s

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

c. ((100,000 × 8) / 1000) s = 800 s

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

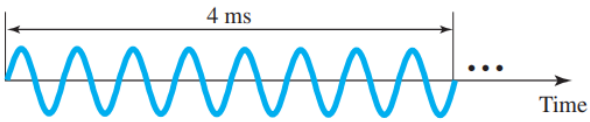
Figure 3.35 *Problem P3-9*



Solution: There are 8 bits in 16 ns.
Bit rate is 8 / (16 × 10^−9) = 0.5 × 10^−9 = 500 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 ms) = 2 KHz

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

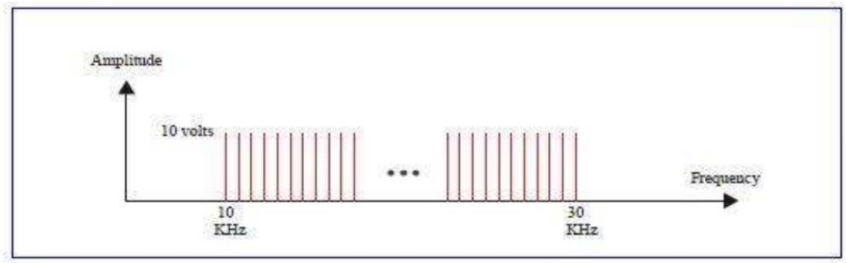
Figure 3.37 *Problem P3-11*

Solution:
B = 5 + 5+ 5+ 5+ 5 = 25 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.

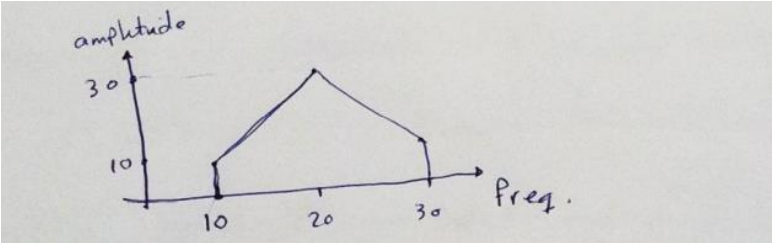
Solution:

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 × 6 MHz = **12 Mbps**
Using three harmonics, data rate = (2 × 6 MHz) /3 = **4 Mbps**
Using five harmonics, data rate = (2 × 6 MHz) /5 = **2.4 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:

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

dB = 10 $\log_{10}$ (90 / 100) = **−0.46 dB**

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

Solution:

$dB=10\log_{10}\frac{P2}{p1}$ → $-10=10\log_{10}\frac{P2}{5}$

$\log_{10}\frac{P2}{5}=-1$

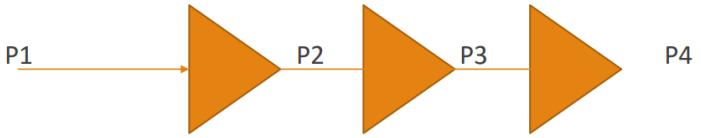
$\frac{P2}{5}=10^{-1}$

→ P2 = 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?

Solution:

Total gain = 4dB + 4dB + 4dB = 12dB



For power gain of the first stage:

$4dB = 10 * \log_{10} \frac{P2}{P1}$

$\frac{P2}{P1} = \left(10^{\left(\frac{4}{10}\right)}\right) = 2.512$

For power gain of three stages: or $12dB = \log_{10} \frac{P4}{P1} \rightarrow \frac{P4}{P1} = \left(10^{\left(\frac{12}{10}\right)}\right) = 15.85$

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

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

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 = velocity of light × time taken to reachlight form sun to earth

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

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)

Distance = 1 µm *1000= 1000µm =1 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 =4000KHz , SNR=1000

So, We Know the Shannon capacity

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

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

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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:

Given , BW= 4 KHz , Signal=10V , Noise= 5mV ,

SNR= $\frac{10}{0.005} = 2000$

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

Capacity =4000* $\log_2(\mathbf{1} + \mathbf{2000})$=43866 bps

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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 × 8 = 16,000,000 bits. With a 56-Kbps channel, it takes 16,000,000/56,000 = **289 s**. With a 1-Mbps channel, it takes **16 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

we need = log2 1024 = $10 bits$

Total number of bit = 1200*1000*10 = 12000,000 bit = 12 million bit

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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 SNRdB?

Solution:

Given, Signal =200 mW= 0.2 W

Total Noise = 10*2 *10^{-6}=2*10^{-5}

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

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

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:

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

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

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

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

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:

$$\text{Capacity} = BW * \left(\frac{SNR\ dB}{3}\right)$$

C = B × (SNR_{dB} /3) = 20 KHz × (40 /3) = **267 Kbps**

C = B × (SNR_{dB} /3) = 200 KHz × (4 /3) = **267 Kbps**

C = B × (SNR_{dB} /3) = 1 MHz × (20 /3) = **6.67 Mbps**

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

a. How is the rate improved if we double the bandwidth?

b. How is the rate improved if we double the SNR?

Solution:

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

$$C2=2*\mathbf{BW1}*\log_2(\mathbf{1}+\boldsymbol{SNR})$$

The data rate is doubled (C2 =2*C1)

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

$$C2=\mathbf{BW1}*\log_2(\mathbf{1}+\mathbf{2}*\boldsymbol{SNR})$$

$$C2=BW1*\log_2(\mathbf{2}*\boldsymbol{SNR})$$

$$C2=BW1*\log_2(\mathbf{2})+\mathbf{BW1}*\log_2(\boldsymbol{SNR})$$

C2=BW1+ C1

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:

$$\text{Capacity} = BW * \left(\frac{\text{SNR dB}}{3}\right)$$

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

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

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

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

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.

$$\textbf{Bit length}=\frac{propagation\ speed}{Bandwith}$$

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

b. Bit length = (2 ×10^8) × [(1 / (10 Mbps)] = **20 m**.

c. Bit length = (2 ×10^8) × [(1 / (100 Mbps)] = **2 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 × 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**

P3-33. 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 μs and a processing time of 1 μs. 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 × 1 μs = 10 μs = **0.000010 s**

Queuing time = 10 × 2 μs = 20 μs = **0.000020 s**

Transmission time = 5,000,000 / (5 Mbps) = **1 s**

Propagation time = (2000 Km) / (2 × 10^8) = **0.01 s**

Latency = 0.000010 + 0.000020 + 1 + 0.01 = 1.01000030 s