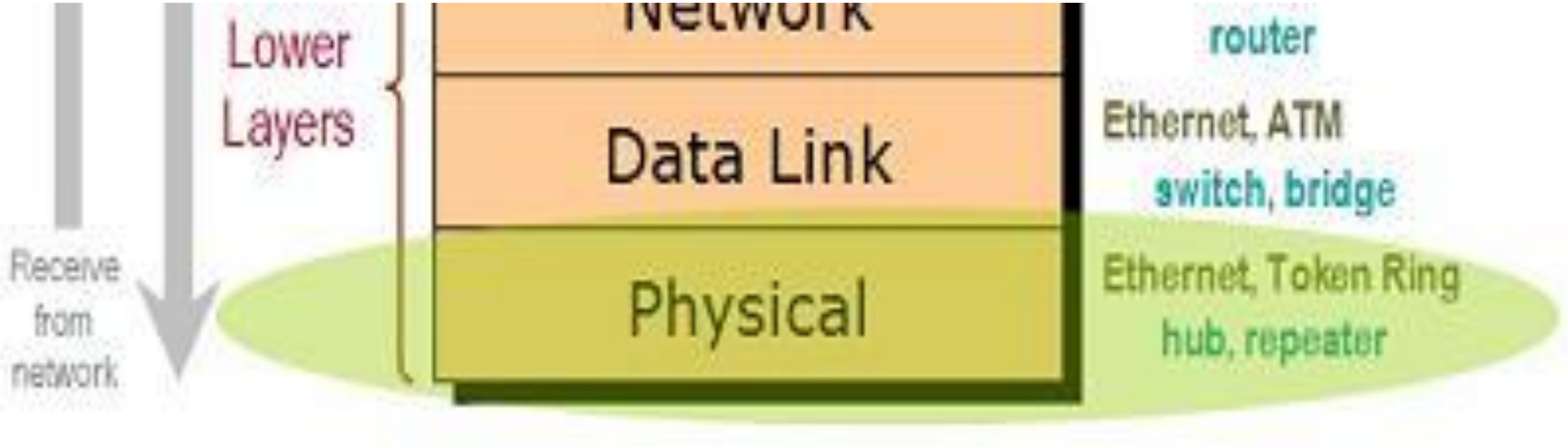
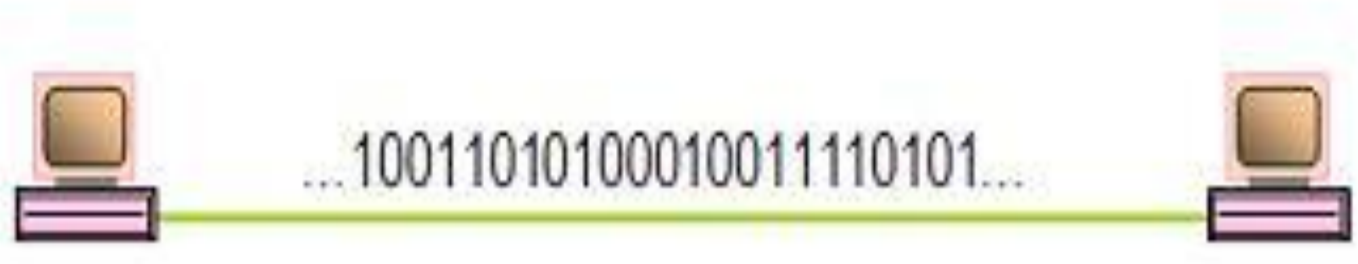
# Data Communication and Networking Presentation


**Presented by:-**

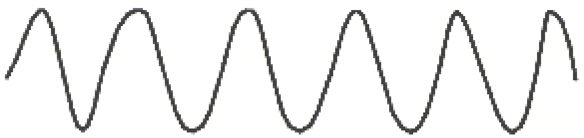
1. Shilpi
2. Ronak
3. Gargi
4. Drishti
5. Dimpy

# Physical Layer Numericals

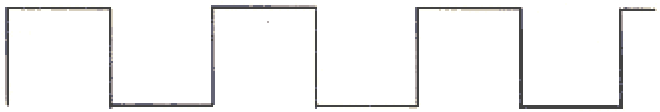


# Chapter – 3 : Data and Signals



Analog Signal



Digital Signal

**Q1. We need to send 265 kbps over a noiseless channel with a bandwidth of 20 kHz. How many signal levels do we need?**

**Sol. We can use the Nyquist formula as shown:**

$$265{,}000 = 2 \times 20{,}000 \times \log_2 L$$

$$\Rightarrow \log_2 L = 6.625$$

$$\Rightarrow L = 2^{6.625} = 98.7 \text{ levels}$$

**Since this result is not a power of 2, we need to either increase the number of levels or reduce the bit rate. If we have 128 levels, the bit rate is 280 kbps. If we have 64 levels, the bit rate is 240 kbps.**

**Q2. Consider an extremely noisy channel in which the value of the signal-to-noise ratio is almost zero. In other words, the noise is so strong that the signal is faint. For this channel the capacity C is calculated as - ??**

**Sol.** $C = B \times \log_2 (1 + SNR)$

$\Rightarrow C = B \times \log_2 (1 + 0)$

$\Rightarrow C = 0$

**This means that the capacity of this channel is zero regardless of the bandwidth. In other words, we cannot receive any data through this channel with any bandwidth.**

**Q3. For practical purposes, when the SNR is very high, we can assume that SNR + 1 is almost the same as SNR. In these cases, the theoretical channel capacity can be simplified to - ??**

**Sol.**

**Formula: $C = B \times \log_2 (1 + SNR)$**

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

$\Rightarrow SNR = 10^{SNR_{db}/10}$

$\Rightarrow C = B \times \log_2 SNR$

$\Rightarrow C = B \times \log_2 10^{SNR_{db}/10}$

$\Rightarrow C = B \times SNR_{db}/10 \times \log_2 10$

Using properties of log (Changing base from 2 to 10)

$\Rightarrow C = B \times SNR_{db}/10 \times \log_{10} 10/\log_{10} 2$

$\Rightarrow C = B \times SNR_{db}/10 \times 1/0.3$

$\Rightarrow C = B \times SNR_{db}/3$

**Q4. We have a channel with a 1-MHz bandwidth. The SNR for this channel is 63. What are the appropriate bit rate and signal level?**

**Sol.** First, we use the Shannon formula to find the upper limit:

$C = B \times \log_2 (l + SNR) = 10^6 \log_2 (1 + 63) = 10^6\ 10g_2\ 64 = 6\ \text{Mbps}$

The Shannon formula gives us 6 Mbps, the upper limit. For better performance we choose something lower, 4 Mbps, for example. Then we use the Nyquist formula to find the number of signal levels.

$$4\ \text{Mbps} = 2 \times 1\ \text{MHz} \times \log_2 L$$

$$\Rightarrow L=4$$

**Q5. We measure the performance of a telephone line (4 KHz of bandwidth). When the signal is 20 V, the noise is 6mV. What is the maximum data rate supported by this telephone line?**

**Given:** $B = 4\ kHz = 4 \times 10^3\ Hz$, Signal Rate = 20 V,

Noise = $6\ mV = 6 \times 10^{-3}\ V$

**To find:** $N_{max}$

**Solution:** $SNR = 20\ V \div 6 \times 10^{-3}\ V = 3300$

By using formula: $\boxed{N_{max} = B \times \log_2 (1 + SNR)}$

$$N_{max} = 4 \times 10^3 \times \log_2(1+3300)$$

$$= 4 \times 10^3 \times \log_2 3301$$

$$= 4 \times 10^3 \times 11.68$$

$$= 11.68\ kbps$$

Q6. A device is sending out data at the rate of 2000 bps.

a. How long does it take to send out 100 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?

Sol.

a. Bit Duration = 100 bits ÷ 2000 bps = 0.05 sec

b. Bit Duration = 8bits ÷ 2000 bps = 0.004 sec

c. Bit Duration = 100,000 X 8 bits ÷ 2000 bps

= 400 sec

Formula:
Bit Duration
= No. of bits
÷ Bit Rate

Converting
characters
into bits

**Q7. If the bandwidth of the channel is 8 kbps, how long does it take to send a frame of 200,000 bits out of this device?**

$\log_2 L = n_b$

where L = no. of levels

Given: $B = 8$ kbps $= 8 \times 10^3$ Hz, $n_b = 200{,}000$

To find: Bit Duration

Solution: By using Nyquist Theorem, Bit Rate $= 2 \times B \times \log_2 L$

Formula: Bit Duration = No. of bits ÷ Bit Rate

Bit Duration $= 200000 \div (2 \times 8 \times 10^3 \times 200000)$

$= 0.0625$ ms

**Q8. What is the length of a bit in a channel with a propagation speed of 2 X $10^8$ m/s if the channel bandwidth is**

**a. 2 Mbps**

**b. 20 Mbps**

**c. 300 Mbps**

**Sol.** **Using formulae:**

**Bit Length = Propagation Speed X Bit Duration**

**Bit Duration = No. of bits / Bit Rate**

**Bit Rate = 2 X B X $\log_2$ L**

a. $B = 2$ Mbps

$$\text{Bit Length} = 2 \times 10^8 \times \text{No. of bits} \div (2 \times 2 \times 10^6 \times \log_2 L)$$

$$= 2 \times 10^8 \div 4 \times 10^6 = 0.5 \times 10^2 \text{ m} = 50 \text{ m}$$

$\log_2 L$ = no. of bits per level

b. $B = 20$ Mbps

$$\text{Bit Length} = 2 \times 10^8 \times \text{No. of bits} \div (2 \times 20 \times 10^6 \times \log_2 L)$$

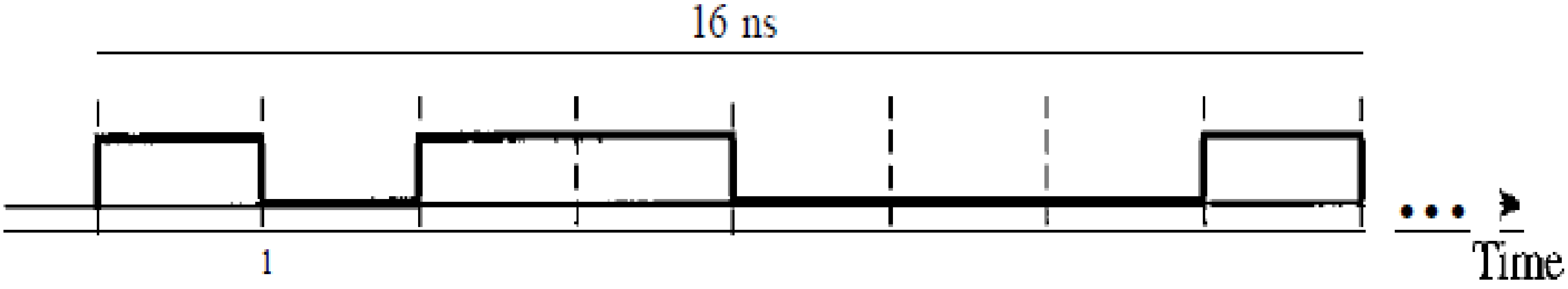
$$= 2 \times 10^8 \div 40 \times 10^6 = 0.05 \times 10^2 \text{ m} = 5 \text{ m}$$

c. $B = 300$ Mbps

$$\text{Bit Length} = 2 \times 10^8 \times \text{No. of bits} \div (2 \times 300 \times 10^6 \times \log_2 L)$$

$$= 2 \times 10^8 \div 6 \times 10^8 = 0.33 \text{ m}$$

**Q9. What is the bit rate for the signal in the following figure?**




**Sol.** **No. of bits = 8, Bit Duration = 16 ns**

**Bit Rate = 8/16 ns = 0.5 X $10^9$ bps = 500 Mbps**

**Q10. What is the bit rate for each of the following signals?**

**a. A signal in which 2 bit lasts 0.001 s**

**b. A signal in which 5 bit lasts 4 ms**

**c. A signal in which 15 bits last 20 µs**

**Sol. a. Bit Rate = 2 ÷ 0.001 s = 2000 bps = 2 Kbps**

**b. Bit Rate = 5 ÷ 4 ms = 1.25 X $10^3$ bps = 1250 Kbps**

**c. Bit Rate = 15 ÷ 20 µs = 0.75 X $10^6$ bps = 750 Kbps**

Formula:
Bit Rate =
No. of bits ÷
Bit Duration

**Q11. A line has a signal-to-noise ratio of 2000 and a bandwidth of 5000 KHz. What is the maximum data rate supported by this line?**

**Sol.** **Given: $B = 5000\ kHz = 5000 \times 10^3\ Hz$, $SNR = 2000$**

**To find: $N_{max}$**

**Solution:** $\boxed{N_{max} = B \times \log_2 (1 + SNR)}$

$$N_{max} = 5000 \times 10^3 \times \log_2(1+2000)$$

$$= 5000 \times 10^3 \times \log_2 2001$$

$$= 5000 \times 10^3 \times 10.96$$

$$= 54.8\ Mbps$$

**Q12. 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?**

**Sol.** **Given: Length of the packet = 2 million bytes, B = 300 Kbps**

**To find: Transmission time**

**Solution: Transmission time = 2000000 / (300 X 1000)**

**= 20/3**

**= 6.66 secs**

Formula: Transmission Time = Length / Bandwidth

**Q13. 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 $SNR_{dB}$ = 6**

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

**Sol:** a. $C = 20 \times 10^3 \times 40/3 = 266.6$ Kbps

b. $C = 200 \times 6/3 = 400$ Kbps

c. $C = 1 \times 20/3 = 6.67$ Mbps

**Formula:**

**Bitrate = B X $SNR_{dB}$ /3**

**Q14. We have a channel with 5 KHz bandwidth. If we want to send data at 150 Kbps, what is the minimum $SNR_{dB}$? What is SNR?**

**Sol.** Given: B = 5 KHz, N = 150 Kbps

To find: $SNR_{dB}$ & SNR

Solution: $150X10^3 = 5X10^3 X SNR_{dB}/3$

$\Rightarrow 150X3/5 = SNR_{dB}$

$\Rightarrow 90 = SNR_{dB}$

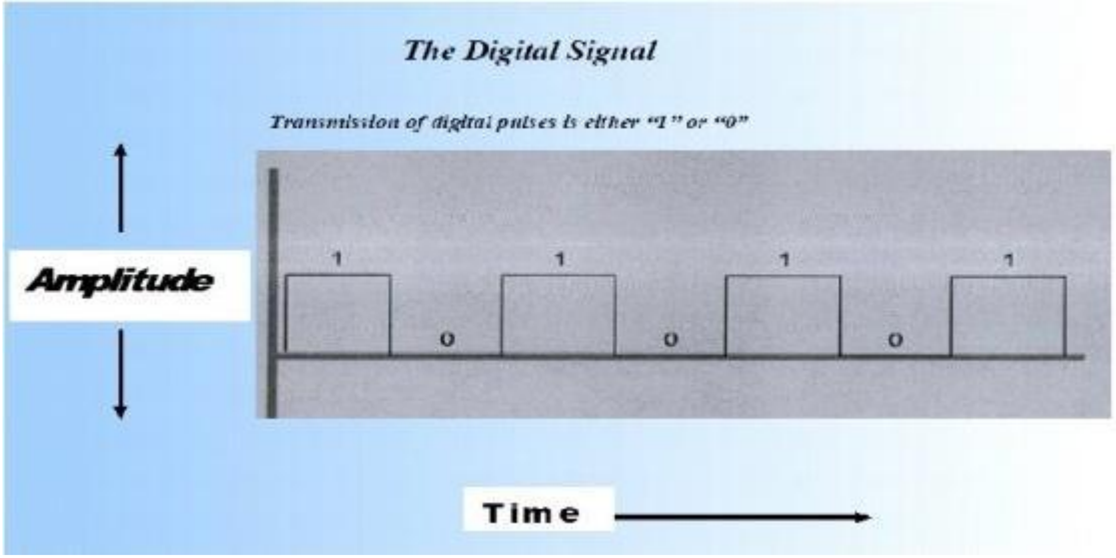
$SNR_{dB} = 10 X \log_{10} SNR$

$\Rightarrow 90 = 10x\log_{10} SNR$

$\Rightarrow SNR = 10^9$

**Formula:**
**Bitrate =**
**$B X SNR_{dB} /3$**

# Chapter – 4 : Digital Transmission

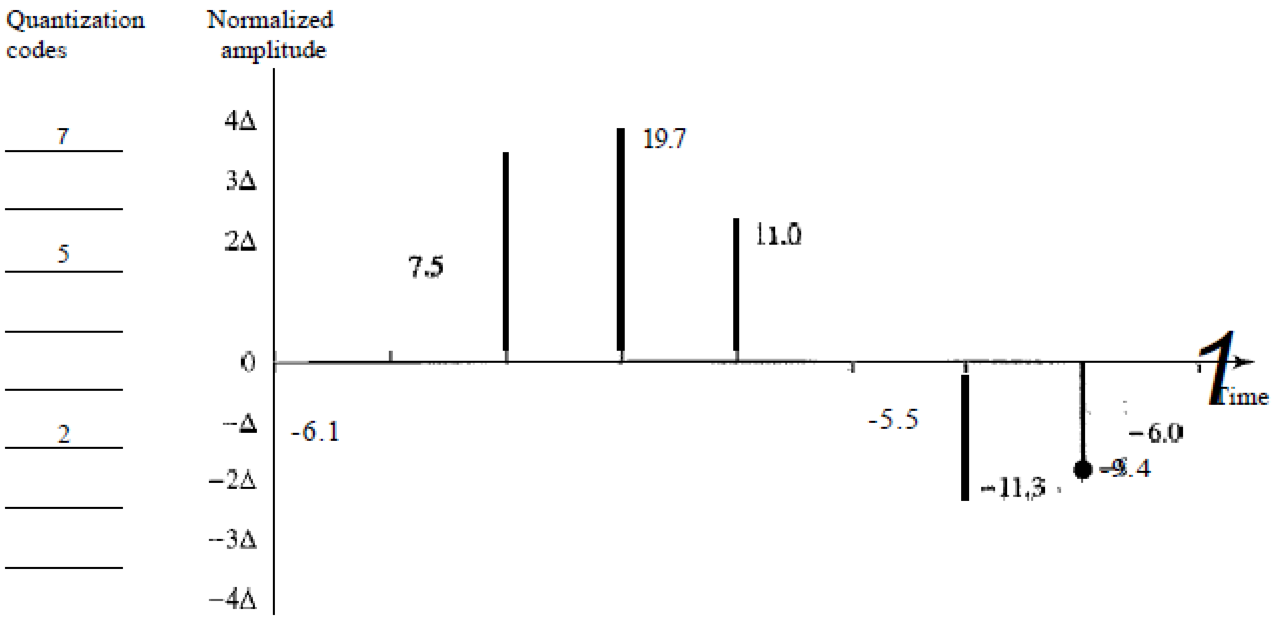


**Q15. The maximum data rate of a channel is $N_{max} = 2 \times B \times \log_2 L$ (defined by the Nyquist formula). Does this agree with the formula for $N_{max} = 1/c \text{ X } B \text{ X } r$?**

**Sol. A signal with L levels actually can carry $\log_2 L$ bits per level. If each level corresponds to one signal element and we assume the average case ($c = 1/2$), then we have**

$$\boxed{N_{max} = \frac{1}{c} \times B \times r = 2 \times B \times \log_2 L}$$

# Q16. What is the $SNR_{dB}$ in the example of Figure 4.26?




| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Normalized PAM values | -1.22 | 1.50 | 3.24 | 3.94 | 2.20 | -1.10 | -2.26 | -1.88 | -1.20 |
| Normalized quantized values | -1.50 | 1.50 | 3.50 | 3.50 | 2.50 | -1.50 | -2.50 | -1.50 | -1.50 |
| Normalized error | -0.38 | O | +0.26 | -0.44 | +0.30 | -0.40 | -0.24 | +0.38 | -0.30 |
| Quantization code | 2 | 5 | 7 | 7 | 6 | 2 | | 2 | 2 |
| Encoded words | 010 | 101 | 111 | 111 | 110 | 010 | 001 | 010 | 0W |

Sol.

We can use the formula to find the quantization. We have eight levels and 3 bits per sample, so

$SNR_{dB} = 6.02(3) + 1.76 = 19.82$ dB.

Increasing the number of levels increases the SNR.

**Q17. A telephone subscriber line must have an $SNR_{dB}$ above 40. What is the minimum number of bits per sample?**

**Sol. We can calculate the number of bits as**

$$SNR_{db} = 6.02n_b + 1.76$$

$$\Rightarrow 40 = 6.02n_b + 1.76$$

$$\Rightarrow n_b = 6.35$$

**Telephone companies usually assign 7 or 8 bits per sample.**

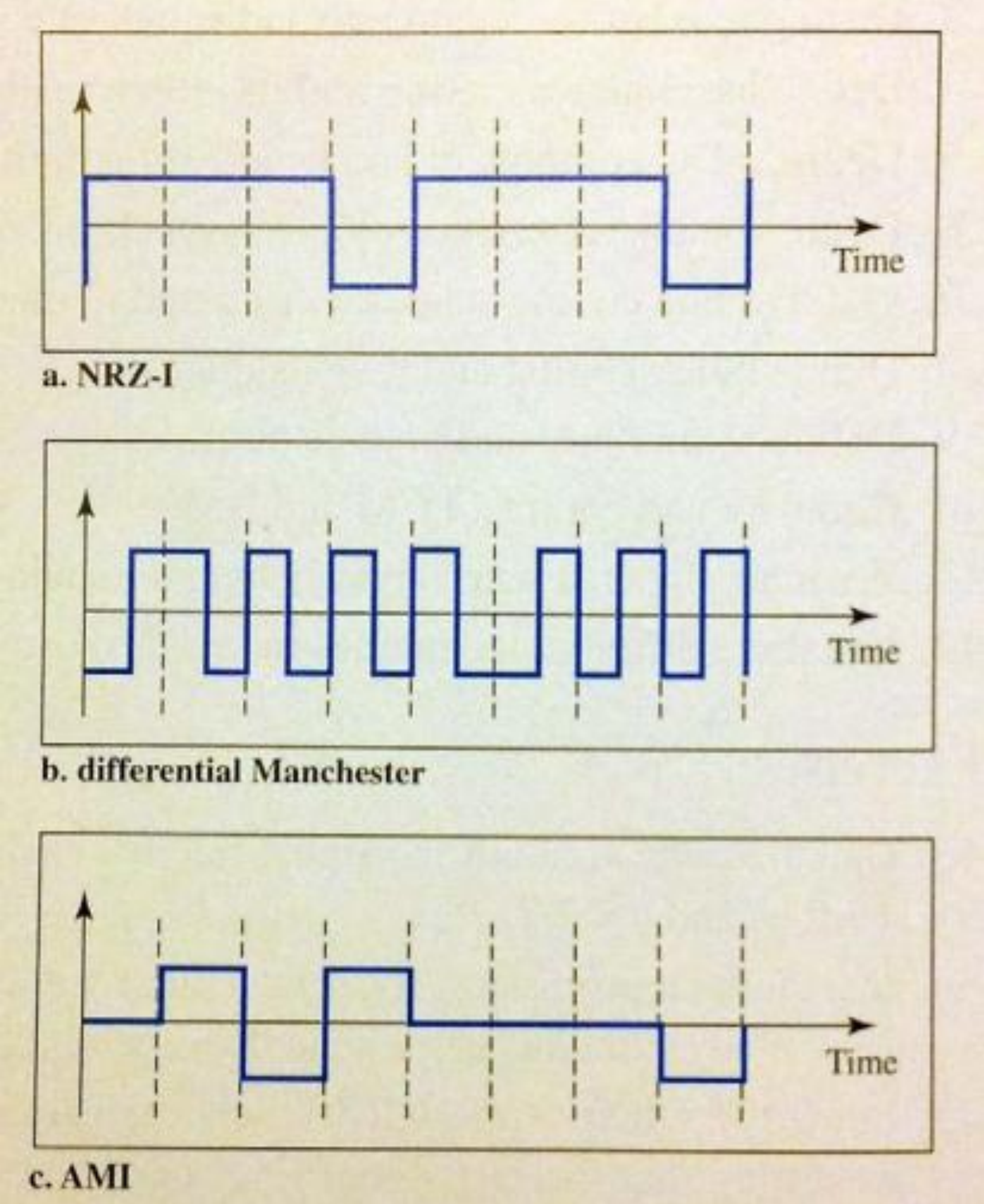
**Q18. Find the 8-bit data stream for each case depicted in the following figure.**

**Sol.**

**a. NRZ-I = 100110011**

**b. Differential Manchester = 110001000**

**c. AMI = 01110001**



**Q19. We have a baseband channel with a 2-MHz bandwidth. What is the data rate for this channel if we use one of the following line coding schemes?**

**a. NRZ-L**

**b. Manchester**

**Sol.** $B = 2 \times 10^6$ Hz $= S$

$N = ??$

For NRZ-L, $S = N \div 2$

$\Rightarrow N = 2 \times S = 2 \times 2 \times 10^6$ bps $= 4$ Mbps

For Manchester, $S = N$

$\Rightarrow N = 2 \times 10^6$ bps $= 2$ Mbps

Bandwidth is proportional to the Signal Rate

**Q20. What is the Nyquist sampling rate for each of the following signals?**

**a. A low-pass signal with bandwidth of 300 KHz?**

**b. A band-pass signal with bandwidth of 300 KHz if the lowest frequency is 100 KHz?**

**Sol.**

**a. In low-pass signal $B = f_{max} = 300$ kHz**

**Nyquist Sampling Rate = 2 X 300 kHz**

**= 600000 samples per second**

**b. $f_{max} = 100 + 300$ kHz = 400 kHz**

**Nyquist Sampling Rate = 2 X 400 kHz**

**= 800000 samples per second**

Nyquist Sampling Rate $= 2 \times f_{max}$

**Q21. A Manchester signal has a data rate of 300 Kbps. Calculate the value of the normalized energy (P) for frequencies at 0 Hz, 50 KHz, 100 KHz.**

**Formula:**
**P = Frequency ÷ Data Rate**

**Sol.**

**Data Rate = 300 kbps**

**a. Frequency = 0 kHz**

**P = 0**

**b. Frequency = 50 kHz => P = 50 kHz ÷ 300 kbps = 0.15**

**c. Frequency = 100 kHz => P = 100kHz ÷ 300 kbps = 0.33**

**Q22. An analog signal has a bandwidth of 40 KHz. If we sample this signal and send it through a 50 Kbps channel what is the $SNR_{dB}$ ?**

**Sol. Given: $B = 40 \times 10^3$ Hz, $N = 50 \times 10^3$ bps**

**To find: $SNR_{dB}$**

**Solution: $N = B \times SNR_{dB} \div 3$**

$$50 \times 10^3 = 40 \times 10^3 \times SNR_{dB} \div 3$$

$$\Rightarrow SNR_{dB} = 3.75 \text{ dB}$$

**Q23. An NRZ-I signal has a data rate of 100 Kbps. Calculate the value of the normalized energy (P) for frequencies at 0 Hz, 50 KHz, and 100 KHz.**

**Formula:**
**P =**
**Frequency ÷ Data Rate**

**Sol.**

**Data Rate = 100 kbps**

**a. Frequency = 0 kHz => P = 1**

**For NRZ-I, When f/N = 0, power is taken as 1**

**b. Frequency = 50 kHz => P = 50 kHz ÷ 100 kbps = 0.5 X $10^{-3}$**

**c. Frequency = 100 kHz => P = 100 kHz ÷ 100 kbps = 1**

**Q24. We have sampled a low-pass signal with a bandwidth of 300 KHz using 1024 levels of quantization.**

**a. Calculate the bit rate of the digitized signal.**

**b. Calculate the $SNR_{dB}$ for this signal.**

$n_b = \log_2 1024$

$= \log_2 2^{10}$

$= 10$ S

Sol. $B = f_{max} = 300 \text{ X } 10^3$ Hz, $L = 1024$

$f_s = 2 \text{ X } f_{max}$

a. Bit Rate $= f_s \text{ X } n_b$

$= 2 \text{ X } 300 \text{ X } 10^3 \text{ X } 10$

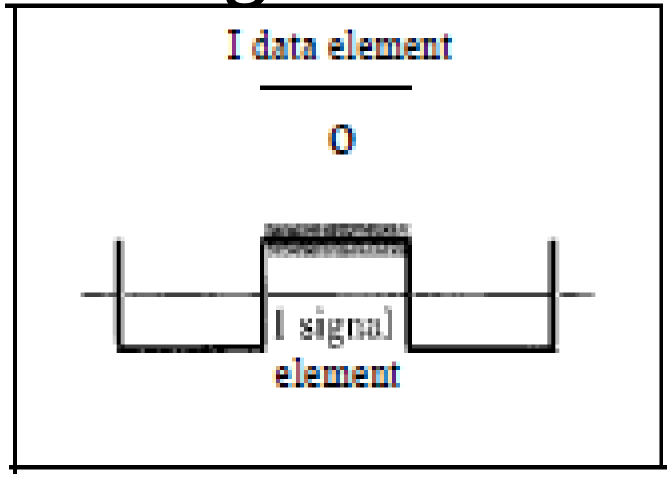
$= 6$ Mbps

b. $SNR_{dB} = 6.02 \text{ X } n_b + 1.76$ dB

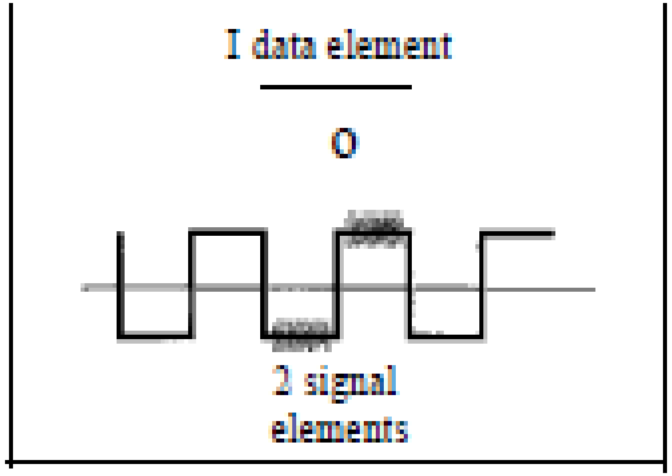
$= 6.02 \text{ X } 10 + 1.76 \text{ dB} = 61.96$ dB

**Q25. Calculate the value of the signal rate for each case in the following figure if the data rate is 1 Mbps and c = 1/2.**

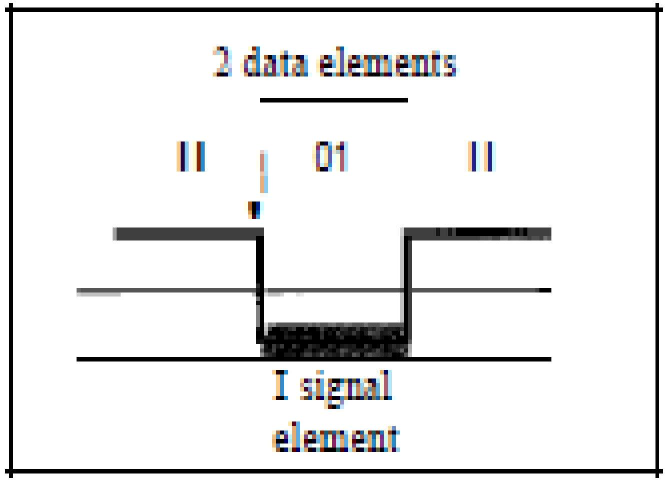
**Formula:**
**$S = c \times N \times 1/r$**



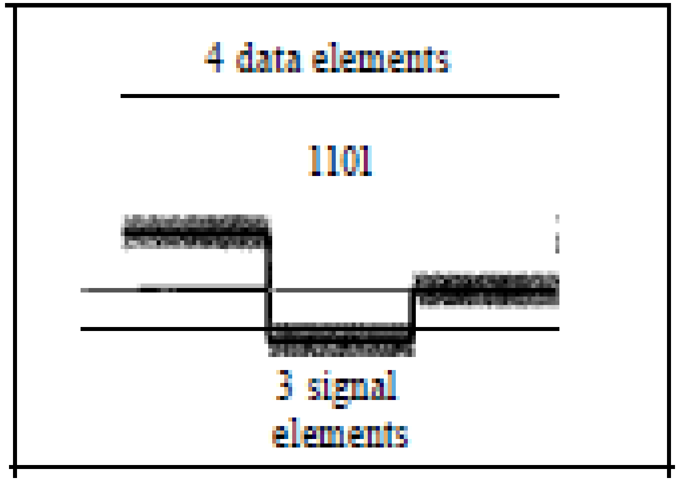

a. One data element per one signal element ($r = 1$)




b. One data element per two signal elements ($r = \frac{1}{2}$)




c. Two data elements per one signal element ($r = 2$)




d. Four data elements per three signal elements ($r = \frac{4}{3}$)

**Sol.** **Given: $c = ½$ , $N = 10^6$ bps**

**To find: S**

**Solution:**

**a. $r = 1$**

**$\Rightarrow S = ½ \times 10^6 \times 1 = ½ \times 10^6 = 500$ kbaud**

**b. $r = ½$**

**$\Rightarrow S = ½ \times 10^6 \times 2 = 10^6$ baud**

**c. $r = 2$**

**$\Rightarrow S = ½ \times 10^6 \times ½ = 250$ kbaud**

**d. $r = 4/3$**

**$\Rightarrow S = ½ \times 10^6 \times 3/4 = 37.5$ kbaud**

**Q26. What is the maximum data rate of a channel with a bandwidth of 300 KHz if we use four levels of digital signaling?**

**Sol. Given: $B = 300 \times 10^3$ Hz, $L = 4$**

**To find: $N_{max}$**

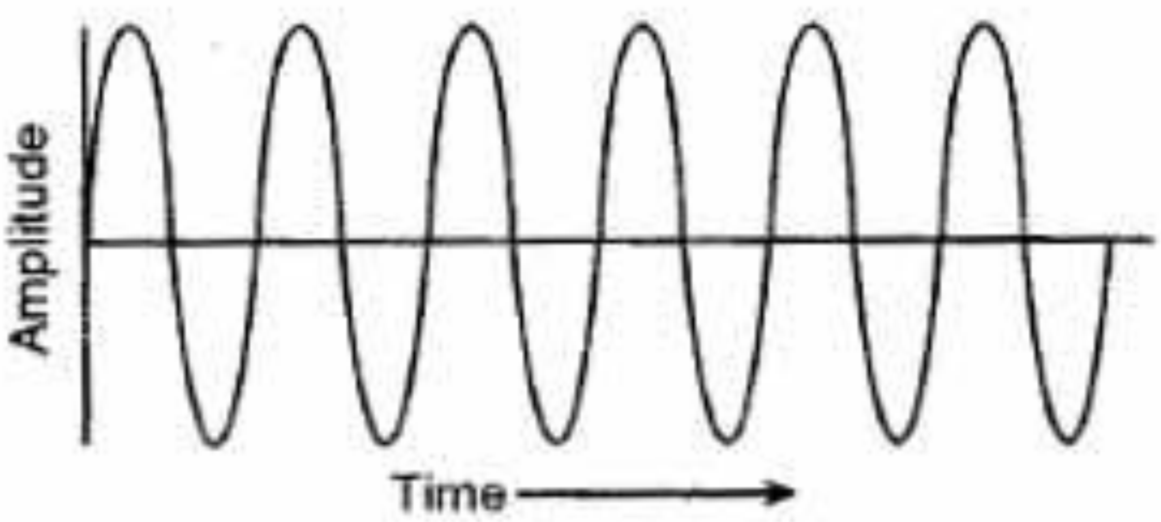
**Solution:** **Formula: $N_{max} = 2 \times B \times \log_2 L$**

$\Rightarrow N = 2 \times 300 \times 10^3 \times \log_2 4$

$\Rightarrow N = 600 \times 10^3 \times \log_2 2^2$

$\Rightarrow N = 12 \times 10^5 = 120$ kbps

# Chapter – 5 : Analog Transmission




Analog Signal Waveform

**Q27. What is the required bandwidth for the following cases if we need to send 6000 bps? Let d = 1.**

**a. ASK**

**b. FSK with $2\Delta f = 4$ KHz**

**c. QPSK**

**d. 16-QAM**

**S = N**
**(r = 1)**

**Sol.** a. $B = (1+d) \times S = (1+1) \times 6000 \text{ bps} = 12$ kHz

b. $B = (1+d) \times S + 2\Delta f = 12 \text{ kHz} + 4 \text{ kHz} = 16$ kHz

**S = N**
**(r = 1)**

c. $B = (1+d) \times S = (1+1) \times 3000$ bps = 6 kHz

$r = 2$

$\Rightarrow S = N \times 1/r$

$= 6000 \times ½$

= 3000 baud

d. $B = (1+d) \times S = (1+1) \times 6000/4$ bps = 3 kHz

$r = \log_2 L = \log_2 16$

$= 4$

$\Rightarrow S = N \times 1/r$

$= 6000 \times 1/4$ baud

**Q28. Calculate the bit rate for the given baud rate and type of modulation.**

**a. 2000 baud, FSK**

**b. 2000 baud, ASK**

**c. 2000 baud, BPSK**

**d. 2000 baud, 16-QAM**

**Sol.** **a. r = 1, S = N => N = 2000 bps**

**b. r= 1, S = N => N = 2000 bps**

**c. r = 1 => S = N => N = 2000 bps**

**d. r = 4 => S = ¼ X N => N = 4 X 2000 = 8000 bps**

**Q29. What is the number of bits per baud for the following techniques?**

**a. FSK with 16 different frequencies**

**b. QAM with a constellation of 256 points.**

**Sol.** **a.** $\log_2 16 = 4$

**b.** $\log_2 256 = 8$

**Q30. A corporation has a medium with a 2-MHz bandwidth (low pass). The corporation needs to create 10 separate independent channels each capable of sending at least 10 Mbps. The company has decided to use QAM technology. What is the minimum number of bits per baud for each channel? What is the number of points in the constellation diagram for each channel? Let d = 0.**

**Sol.** **Bandwidth for each channel = 2 MHz/10 = 0.2 MHz**

**Value of r can be calculated as B = (1+d) X 1/r X N**

$\Rightarrow 0.2 \times 10^6 = 1/r \times 10 \times 10^6$

$\Rightarrow r = 50$

**No. of levels** $\Rightarrow L = 2^r = 2^{50}$

**Therefore, We need a** $2^{50}$ **– QAM technique**

**Q31. Calculate the baud rate for the given bit rate and type of modulation.**

**a. 4000 bps, FSK**

**b. 6000 bps, ASK**

**c. 8000 bps, QPSK**

**d. 72,000 bps, 64-QAM**

**Sol.** a. $S = N \Rightarrow S = 4000$ baud

b. $S = N \Rightarrow S = 6000$ baud

c. $S = N \times 1/r = N \times \frac{1}{2} = 8000 \times \frac{1}{2} = 4000$ baud

d. $r = \log_2 64 = 6 \Rightarrow S = N \times 1/r = 72000 \times 1/6 = 12000$ baud

Q32. Draw the constellation diagram for the following:

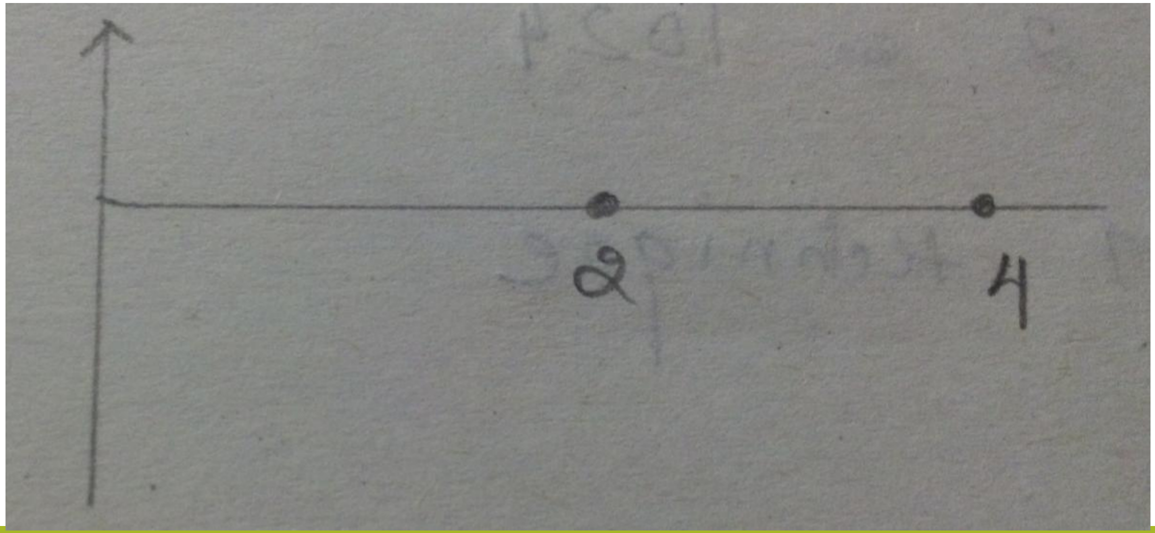
a. ASK, with peak amplitude values of 2 and 4

b. BPSK, with a peak amplitude value of 3

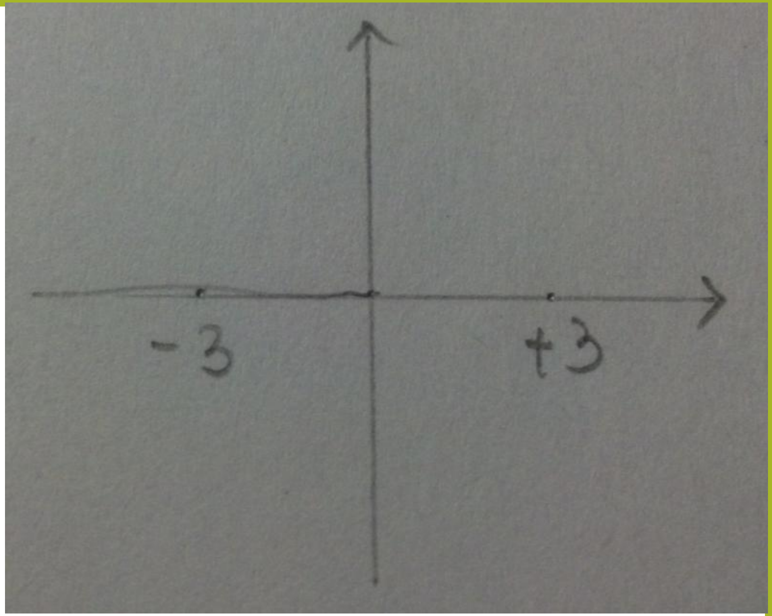
c. QPSK, with a peak amplitude value of 4

d. 8-QAM with two different peak amplitude values, 1 and 3, and four different phases.

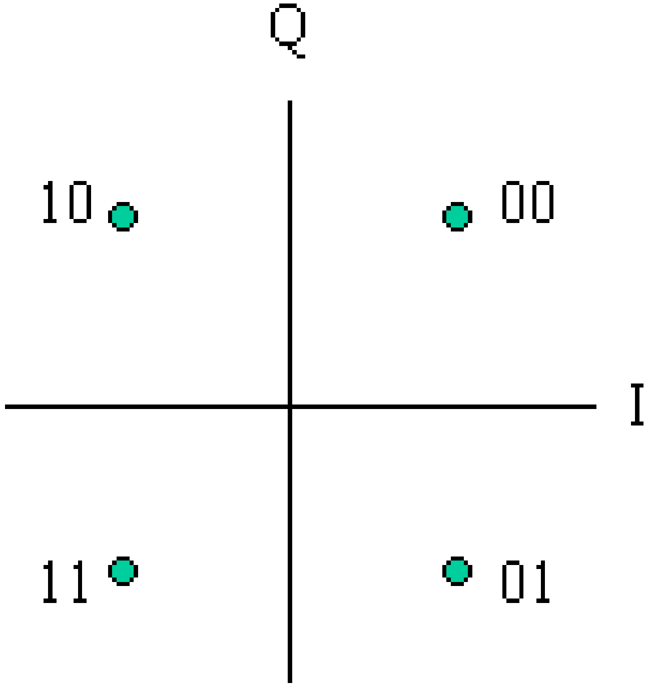
Sol. a. We have two signal elements with peak amplitudes 2 and 4. The phase of both signal elements are the same, which we assume to be 0 degrees.



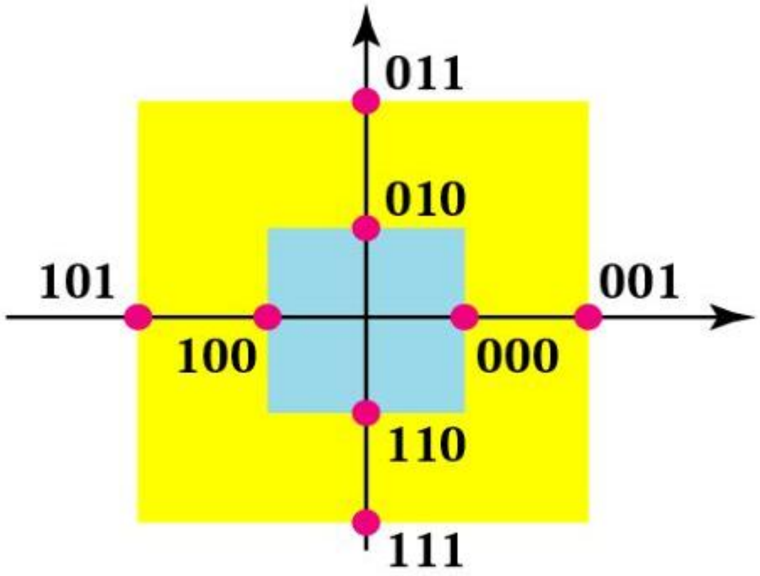
**b. We have two signal elements with the same peak amplitude of 3. However, there must be 180 degrees difference between the two phases. We assume one phase to be 0 and the other 180 degrees.**




**c. We have four signal elements with the same peak amplitude of 4. However, there must be 90 degrees difference between each phase. We assume the first phase to be at 45, the second at 135, the third at 225, and the fourth at 315 degrees. Note that this is one out of many configurations. The phases can be at 0, 90, 180, and 270. As long as the differences are 90 degrees, the solution is satisfactory.**



d. We have four phases. For each phase, however, we have two amplitudes, 1 and 3 as shown in the figure. Note that this is one out of many configurations. The phases can be at 45, 135, 225, and 315. As long as the differences are 90 degrees, the solution is satisfactory.



**Q33. How many bits per baud can we send in each of the following cases if the signal constellation has one of the following number of points?**

**a. 4**

**b. 8**

**c. 32**

**d. 2048**

**Sol.** a. $r = 2$

b. $r = 3$

c. $r = 5$

d. $r = 11$

**Formula:**
$r = \log_2 L$

**Q34. The telephone line has 4 KHz bandwidth. What is the maximum number of bits we can send using each of the following techniques? Let d = 0.**

**a. ASK**

**b. QPSK**

**c. 64 - QAM**

**d. 128 – QAM**

**Sol.** B = (1+d) X S => 4 X $10^3$ = S => S = N X 1/r = 4 X $10^3$ => N = 4 X $10^3$ X r

a. N = 4 X $10^3$ X 1 = 4 kbps

b. N = 4 X $10^3$ X 2 = 8 kbps

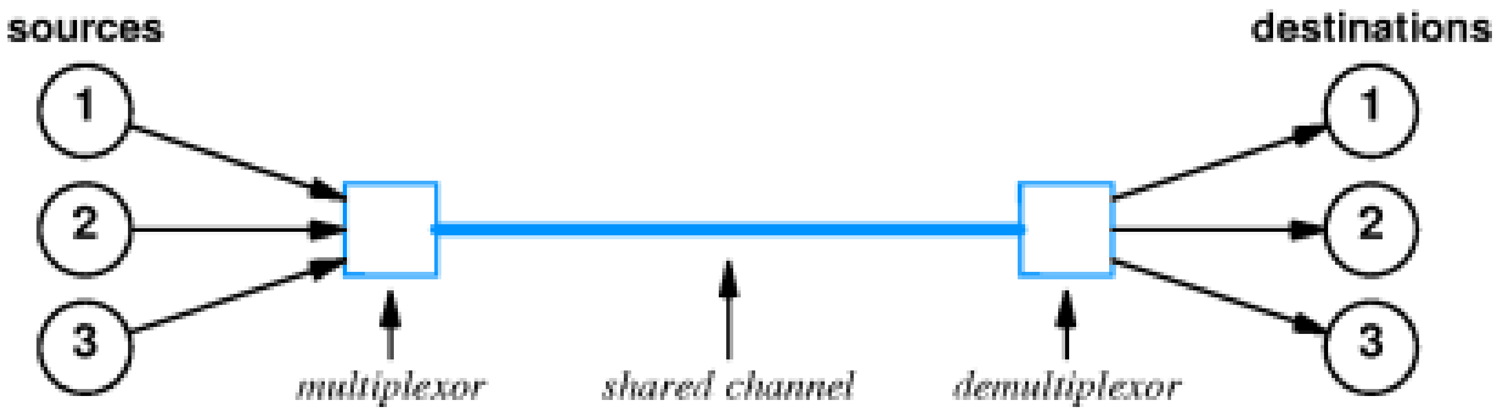
c. N = 4 X $10^3$ X 6 = 24 kbps

d. N = 4 X $10^3$ X 7 = 28 kbps

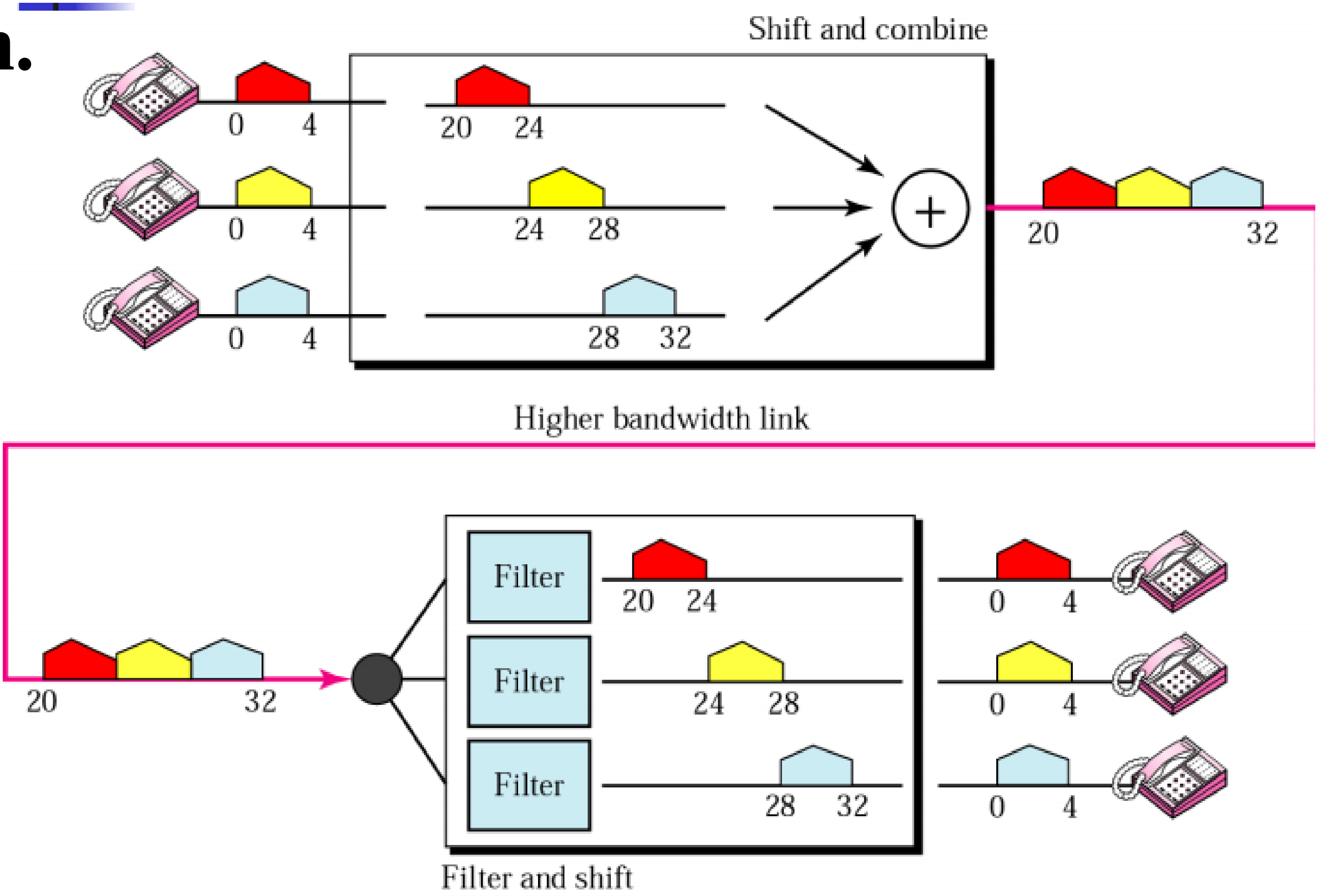
$r = \log_2 L = \log_2 128 = \log_2 2^7 = 7$

$r = \log_2 L = \log_2 64 = \log_2 2^6 = 6$

# Chapter – 6 : Multiplexing



**Q35. Assume that a voice channel occupies a bandwidth of 4 kHz. We need to combine three voice channels into a link with a bandwidth of 12 kHz, from 20 to 32 kHz. Show the configuration, using the frequency domain. Assume there are no guard bands.**



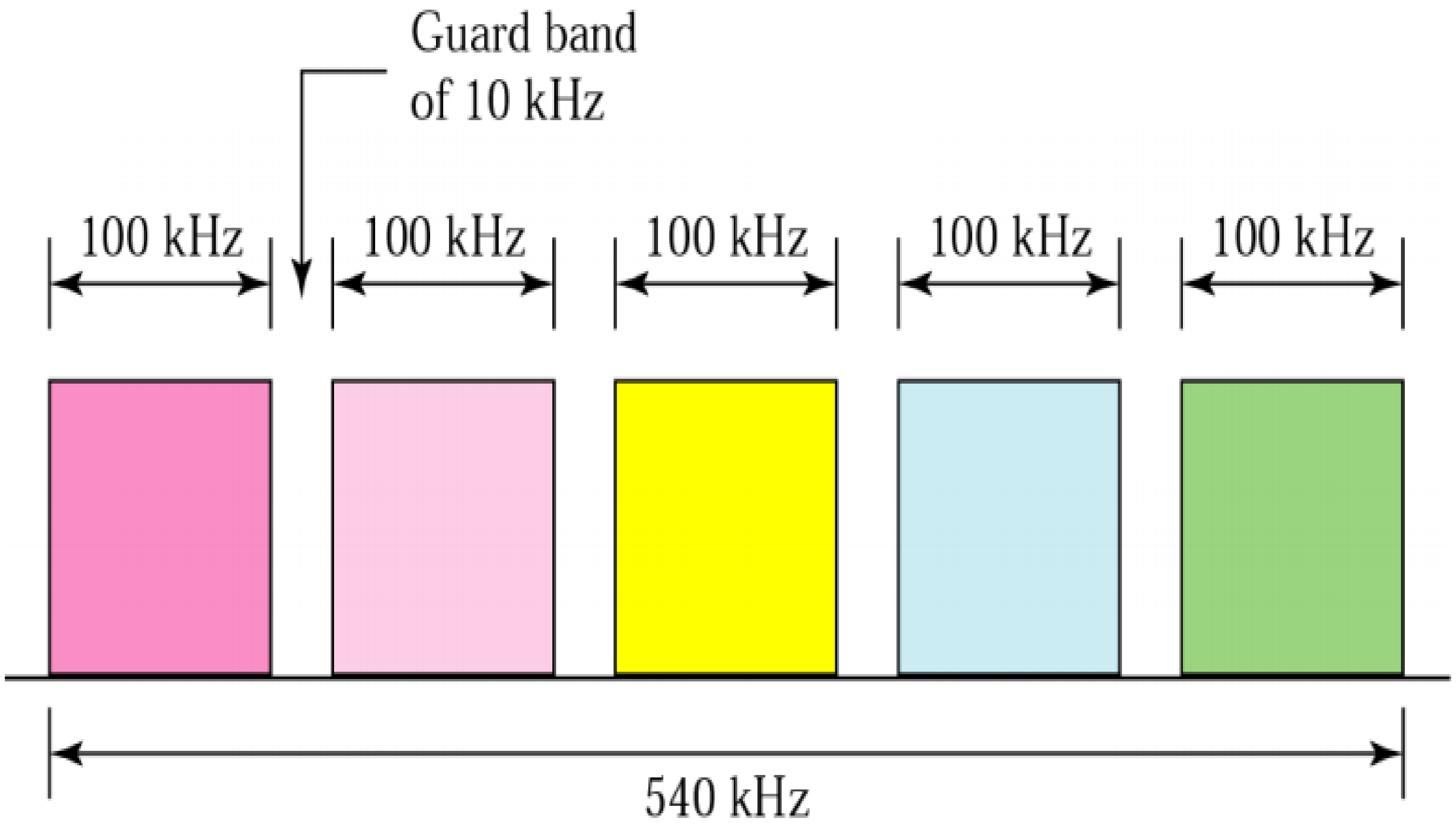

**Sol. Shift (modulate) each of the three voice channels to a different bandwidth, as shown in following figure.**

**Q36. Five channels, each with a 100KHz bandwidth, are to be multiplexed together. What is the minimum bandwidth of the link if there is a need for a guard band of 10 KHz between the channels to prevent interference?**

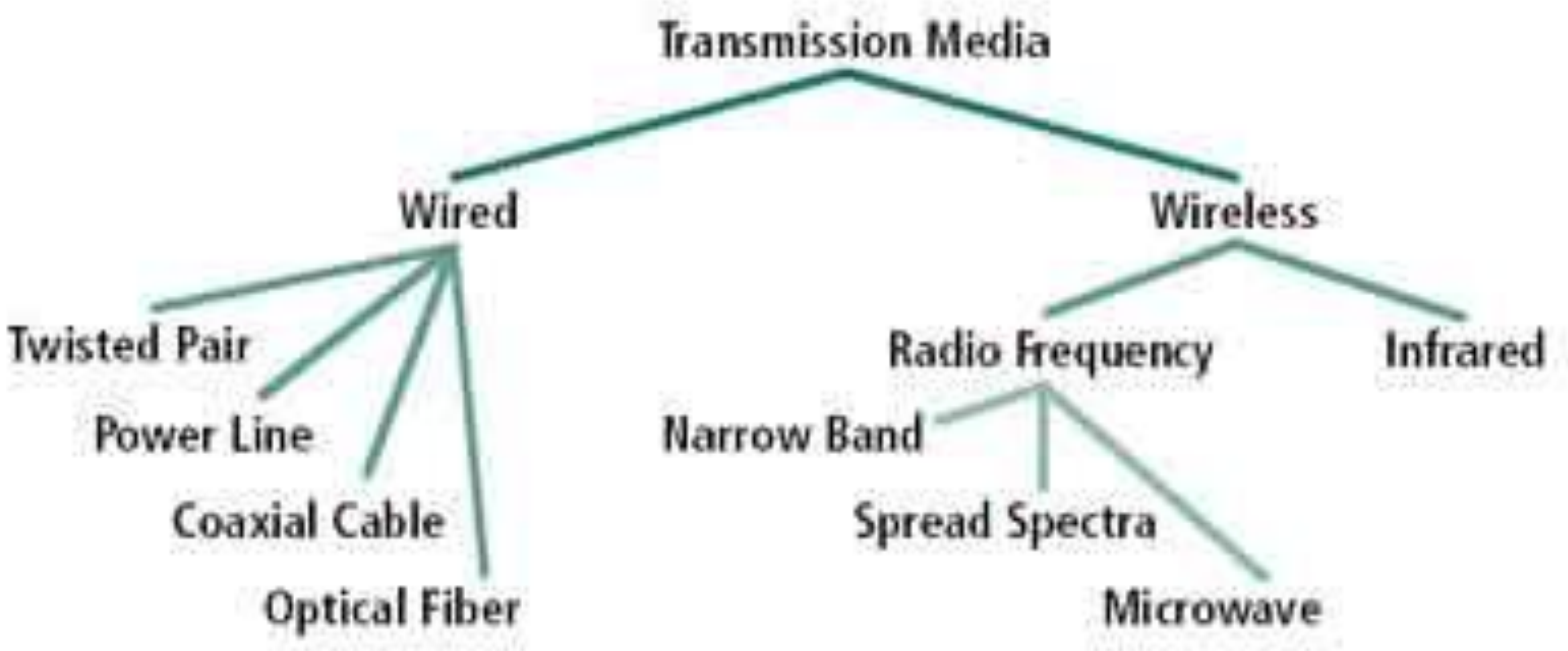
**Sol. For five channels, we need at least four guard bands. This means that the required bandwidth is at least :**

**= 5 x 100 + 4 x 10**

**= 540 KHz**



# Chapter – 7 : Transmission Media



**Q37. A light signal is travelling through a fiber. What is the delay in the signal if the length of the fiber-optic cable is 50 m, 100 m, and 2 Km (assume a propagation speed of 2 x $10^8$ m/s)?**

**Sol.** Length = 50m, 100m, 2 km = 2000m

Propagation Speed = 2 x $10^8$ m/s

Delay = Time = Length ÷ Propagation Speed

a. delay = 50m ÷ 2 x $10^8$ m/s = 25 x $10^{-8}$ s

b. delay = 100m ÷ 2 x $10^8$ m/s = 0.5 x $10^{-6}$ s = 0.5 ms

c. delay = 2000m ÷ 2 x $10^8$ m/s = $10^{-5}$ s