Assignment 6 Solution

Digital Communication System-I

May 2023

1. (d) Here M = 4 $\therefore$ Symbol error rate for 4-PAM is derived as,

$$P_e = 2\left(\frac{M-1}{M}\right) Q\left(\sqrt{\frac{6\log_2 M}{M^2-1} \times \frac{\varepsilon_b}{N_0}}\right)$$
$$\text{or, } P_e = 1.5 \times Q\left(\sqrt{0.8\varepsilon_b/N_0}\right).$$

2. (a) 7 dB $= 10^{0.7} \approx 5$

$$\therefore \frac{\varepsilon_b}{N_0} = 5$$

For QPSK probability of symbol error $P_e = 2Q\left(\sqrt{\frac{2\varepsilon_b}{N_0}}\right) - Q^2\left(\sqrt{\frac{2\varepsilon_b}{N_0}}\right)$

$$\therefore P_e = 1.6 \times 10^{-3}.$$

3. (b) In case of an M-ary PAM modulation, for increasing the transmission rate by 1 bit, one would need 6 dB more power.

4. (d) Approximate probability of symbol error for $M-$ary PSK is calculated as

$$P_e = 2Q\left[\sin\left(\frac{\pi}{\mathrm{M}}\right)\sqrt{\left(2\log_2\mathrm{M}\right)\left(\frac{\epsilon_\mathrm{b}}{\mathrm{N}_0}\right)}\right]$$
$$\implies \sin\left(\frac{\pi}{M}\right)\sqrt{2\log_2 M} = 1.3615$$
$$\implies M \approx 4.$$

5. (c) The correlation factor between two signals in a binary FSK is

$$\rho = \frac{\sin(2\pi\Delta fT)}{2\pi\Delta fT} = -0.1892 \text{ for } \Delta fT = 0.8.$$

6. (a) QAM does not have constant energy signal because the QAM signal does not have constant envelop. If M = 4, both QPSK and 4-QAM gives the same performance, but as we go to higher constellation order, QAM gives better performance than PSK.

The signal constellation of QAM can be of many types like rectangular QAM, hexagonal QAM, cross QAM etc.

Hence, the correct option is "For large M, it gives better performance than PSK".

7. (a) Since the rate of transmission is $R = 10^4$bits/sec, the bit interval T_b is 10^{-4}sec. The probability of error in a binary PAM system is

$$P_e = Q\left[\sqrt{\frac{2\mathcal{E}_b}{N_0}}\right]$$

where the bit energy is $\mathcal{E}_b = A^2T_b$. With $P_e = P_2 = 10^{-4}$, we obtain

$$\sqrt{\frac{2\mathcal{E}_b}{N_0}} = 4.75 \Longrightarrow \mathcal{E}_b = \frac{3.72^2 N_0}{2} = 0.0692$$

Thus

$$A^2T_b = 0.0692 \Longrightarrow A = \sqrt{0.0692 \times 10^4} = 26.31$$

8. (c) Since the signals are orthogonal to each other, the distance between any two pair of signaling points in signal space diagram will be the length of hypotenuse.) From Pythagoras theorem the distance will be $\sqrt{4E}$.

9. (c) Both FSK and PPM are examples of orthogonal signaling modulation scheme.

10. (c) There is a factor $\left(\frac{M}{M-1}\right)$ in the expression of error probability of simplex signaling which gives SNR boost over orthogonal signaling.