1. (a) 18 M symbols/sec. 8 QAM has 3 bits/symbol.

(b) \[ P_A = \frac{1}{8} \left[ 4x E^2 + 4 \cdot (\sqrt{2}E)^2 \right] = \frac{3}{2} E^2 \]

\[ P_B = \frac{1}{8} \left[ 4x E^2 + 2 \cdot (\sqrt{3}E)^2 + 4 \cdot (\sqrt{1}E)^2 \right] = \frac{9}{2} E^2 \]

(c) \[ P_A < P_B \], so constellation A is more power efficient.

(d) To achieve the same error probability, it requires the same SNR for both systems, i.e.

\[ SNR_A = SNR_B \]

2. (a) \[ b_k = 110100010110 \]
\[ d_k = 1011000011011 \]

(b) \[ d_k = b_k \oplus d_{k-1} \]

(c) Please see Fig. 6.43 in Textbook p.416.
3. (a) \[ P_1 + P_2 + P_3 = P \quad - (1) \]
\[ P_1 + \frac{P_1 \sigma_1^2}{q_1} = K \quad - (2) \]
\[ P_2 + \frac{P_2 \sigma_2^2}{q_2} = K \quad - (3) \]
\[ P_3 + \frac{P_3 \sigma_3^2}{q_3} = K \quad - (4) \]
\[ (2)+(3)+(4) : \quad 3K = P + P \sum_{i=1}^{3} \frac{\sigma_i^2}{q_i^2} \quad - (5) \]

\[ \Rightarrow P_i = K - \frac{P \sigma_i^2}{q_i^2} \quad \text{where} \quad K = \frac{1}{3} P + \frac{P}{3} \sum_{i=1}^{3} \frac{\sigma_i^2}{q_i^2} \]

(b) \[ p = 2, \quad K = \frac{2}{3} + \frac{1}{3} (\frac{1}{4} + \frac{1}{5} + \frac{1}{4}) = \frac{9}{4} \]

\[ \Rightarrow \begin{cases} P_1 = \frac{9}{4} - 1 \cdot \frac{1}{1} = \frac{5}{4} \\ P_2 = \frac{9}{4} - 1 \cdot \frac{1}{5} = \frac{3}{4} \\ P_3 = \frac{9}{4} - 1 \cdot \frac{1}{4} = 0 \end{cases} \]
3-(c) \[ P_1 = \frac{5}{4}, \quad P_2 = \frac{3}{4} \]

3-(d) \[ P_1 : P_2 : P_3 = 5 : 3 : 0 \]

So we will allocate the 16 bits as:

- 10 bits to sub-channel 1
- 6 bits to sub-channel 2
- 0 bits to sub-channel 3

to achieve best performance.

4-(a) \[ \frac{(E_b/N_0)_{req}}{(E_b/N_0)_{recv}} = \frac{10}{10^{-2}} = 10^3 \]

\[ \therefore \text{The min processing gain} = 10^3 \text{ in order to meet the required performance.} \]

(b) \[ m - 1 > 10^3 \]

\[ \therefore N = 1023 \text{ and } m = 10 \frac{N}{c}. \]

(c) Anti-jam Margin \[ J = \frac{P_{ch}}{(E_b/N_0)} \]

\[ P_e = \frac{1}{2} \text{erfc} \left( \sqrt{\frac{E_b}{N_0}} \right) = 10^{-6} \]

\[ \left( \frac{E_b}{N_0} \right) = \left[ \text{erfc} \left( 2 \times 10^{-6} \right) \right]^2 \Rightarrow J = 10^3 \left[ \text{erfc} \left( 2 \times 10^{-6} \right) \right]^2 \approx 100 \]
(a) 
\[ P_r = P_t G_t G_r \left( \frac{\Delta}{4\pi d} \right)^2 \]
where 
\[ \lambda = \frac{c}{f} = \frac{3 \times 10^8}{2.3 \times 10^9} = 0.13 \text{ m} \]
\[ G_r = \eta \left( \frac{\pi D^2}{\lambda} \right)^2 = 0.55 \times \left( \frac{\pi \times 0.64}{0.13} \right)^2 = 1.3 \times 10^6 \]
\[ \Rightarrow P_r = 1.7 \times 10^{-27} \times 1.3 \times 10^6 \times \left( \frac{0.13}{4\pi \times 1.6 \times 10^{-8}} \right)^2 \]
\[ = 4.63 \times 10^{-17} \text{ W} \]

Note: Since the Haykin's book does not give the formula for \( G_r = \eta \left( \frac{\pi D}{\lambda} \right)^2 \), so, if you use \( G_r = 0.55 \), we will also give you credits.

Then \( P_r = 1.96 \times 10^{-22} \text{ W} \)

(b) \( N_0 = kT = 1.38 \times 10^{-23} \times 298 = 2.07 \times 10^{-22} \text{ W/Hz} \)

To achieve max data rate, we let link margin \( M = 1 \), i.e. \( \frac{E_b}{N_0} \) \text{recv} = \( \frac{E_b}{N_0} \) \text{req} = 3 \text{dB} = 2

\[ \Rightarrow \left( \frac{E_b}{N_0} \right) \text{recv} \cdot R = \frac{P_r}{kT} \]
\[ \Rightarrow R = \frac{P_r}{kT} \cdot \left( \frac{E_b}{N_0} \right) \text{recv} = \frac{4.63 \times 10^{-17}}{2.07 \times 10^{-22}} \times \frac{1}{2} = 1.12 \times 10^5 \text{ b/s} \]
\[ = 112 \text{ Kbps} \]