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1 (a) $P_M = 4\left(1-\frac{1}{\sqrt{M}}\right)Q\left(\sqrt{\frac{3}{M-1}\frac{E_s}{N_0}}\right)$

$= 4\left(1-\frac{1}{8}\right)Q\left(\sqrt{\frac{E_s}{21N_0}}\right)$

$= \frac{7}{2}Q\left(\sqrt{\frac{2\times10^{-4}}{21\times10^{-7}}}\right)$

$\approx 3.5Q(9.75900073)$

$\approx 3.5 \times 8.44052\times10^{-23}$

$\approx 2.954182\times10^{-22}$

(b) SNR is high, when symbol ~~2 bit error~~ error occurs, ~~the~~ almost always have 1 bit error. So

$P_e = \frac{P_M}{\log_2 M}$

$= \frac{2.954182\times10^{-22}}{6}$

$\approx 4.92363\times10^{-23}$

2 (a) $\lambda = \frac{3\times10^8}{1.8\times10^9} = \frac{1}{6}$ m

$\Delta f = \frac{100/3.6}{1/6} \approx 166.667$ Hz ← Doppler frequency

~~Coher~~ $T_c \approx \frac{9}{16\pi \Delta f} = \frac{9}{16\pi(166.667\text{Hz})} \approx 1.07429$ ms ← coherence time

$B_c \approx 1/(8\mu s) = 125000$ Hz ← coherence bandwidth

(b) ~~T~~ $T_s = 40\mu s \ll T_c = 1.07429$ ms

So ~~the~~ fading is slow relative to the symbol duration

$B_W = 1/(40\mu s) = 25000$ Hz $\ll B_c = 125000$ Hz

so ~~frequency flat~~ the fading ~~is~~ is flat

(c) ~~re~~ required $SNR_{lin} = \frac{1}{4(10^{-4})} = 2500$

$P_r(\text{dBm}) = -174 + 10\log_{10}(W) + NF(\text{dB}) + SNR(\text{dB})$

$= -174 + 10\log_{10}(25000) + 8 + 10\log_{10}(2500)$

$\approx -174 + 43.9794 + 8 + 33.9794$

≈ -88.0412 dBm

path FSPL (dB) $= 20\log_{10}\left(\frac{4\pi d}{\lambda}\right) = 20\log_{10}\left(\frac{4\pi(3\times10^3)}{1/6}\right) \approx 107.090$ dB

req. transmit power (dBm) $= -88.0412 + 107.090 = 19.0488$ dBm

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2.(d) $\gamma_0 = SNR_{lin} = 10^{20/10} = 100$ For BPSK using gray coding, and SNR is high so $P_e \approx P_M$

$L=1 \Rightarrow P_e \approx \binom{2-1}{1}\left(\frac{1}{400}\right)^1 = \frac{1}{400} = 2.5\times10^{-3} > 10^{-8}$

$L=2 \Rightarrow P_e \approx \binom{4-1}{2}\left(\frac{1}{400}\right)^2 = 1.875\times10^{-5} > 10^{-8}$

$L=3 \Rightarrow P_e \approx \binom{6-1}{3}\left(\frac{1}{400}\right)^3 = 6.25\times10^{-7} > 10^{-8}$

$L=4 \Rightarrow P_e \approx \binom{8-1}{4}\left(\frac{1}{400}\right)^4 = 1.3671875\times10^{-9} \le 10^{-8}$

So $L \ge 4$

3.(a) $\tau_{RMS}^2 = E[\tau^2] - (E[\tau])^2$

$\tau_{RMS} = \sqrt{E[\tau^2] - (E[\tau])^2}$

$E[\tau^2] = \dfrac{(1)^2(0)^2 + (0.6)^2(3)^2 + (0.4)^2(8)^2}{1^2 + 0.6^2 + 0.4^2} = 8.86842\ \mu s^2$

$E[\tau] = \dfrac{(1)^2(0) + (0.6)^2(3) + (0.4)^2(8)}{1^2 + 0.6^2 + 0.4^2} = 1.55263\ \mu s$

$\tau_{RMS} \approx \sqrt{8.86842 - 1.55263^2} \approx 2.54121\ \mu s$

$T_{RMS} \approx 2.54121\ \mu s \ge 15 \times 10\% = 1.5\ \mu s$

Yes, T_{RMS} is larger than 10% of symbol time

So ISI is significant for this channel

(b) Using DSSS, effective SINR $= 15 + 50 = 65$ dB

For BPSK using Gray coding, $P_b \approx P_M = Q(\sqrt{SINR_{lin}}) = Q(\sqrt{10^{65/10}})$

$\approx Q(\sqrt{3162277.66})$

$\approx Q(1778.28)$

≈ 0

$\boxed{\text{assuming } SINR_{lin} \text{ is the ratio } \left(\frac{E_s}{N_0/2}\right)}$

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4.(a) For ~~BPSK~~,

$$G_p = \frac{5\times10^6}{20\times10^3} = 250$$

~~G_p (dB)~~ =

For BPSK using Gray coding

$$P_b = P_M = Q\left(\sqrt{\frac{2E_s}{N_0}}\right) = Q\left(\sqrt{\frac{2E_b}{N_0}}\right)$$

$$Q\left(\sqrt{\frac{2E_b}{N_0}}\right) \geq 10^{-6}$$

$$\sqrt{\frac{2E_b}{N_0}} \geq 4.75342$$

$$\frac{E_b}{N_0} \geq 11.2975$$

$$M_j(\text{dB}) \approx 10\log_{10}250 - 10\log_{10}11.2975 \approx 13.4496 \text{ dB}$$

(b)

$$SIR = \frac{250}{24} = \frac{250}{25-1} = \frac{250}{24} \approx 10.4167$$

$$SIR(\text{dB}) = 10\log_{10}10.4167 \approx 10.1773$$

$$\frac{E_b}{N_0}(\text{dB}) = 10\log_{10}11.2975 \approx 10.5295 \text{ dB}$$

$$\therefore SIR_{\text{dB}} \leq \frac{E_b}{N_0}(\text{dB})$$

$\therefore$ No, it does not meet system requirement.