

Problem 4.1

$$s_1(t) = A \cos \omega_c t$$

$$s_2(t) = -A \cos \omega_c t$$

$$A = 1 \text{ mV}$$

$$N_0 = 10^{-10} \text{ W/Hz}$$

$$P_B = Q\left(\sqrt{\frac{2E_b}{N_0}}\right) = Q\left(\sqrt{\frac{A^2 T}{N_0}}\right) \approx Q(4.47)$$

$$\approx \frac{1}{\sqrt{40\pi}} e^{-10} = 4.05 \times 10^{-6}$$

$$\begin{aligned} \text{Avg. \# of errors in one day} &= P_B \cdot 5000 \text{ bits/sec} \cdot 86,400 \text{ s/day} \\ &= 1750 \text{ bits} \end{aligned}$$

Problem 4.3

$$\begin{aligned} \text{Binary non coherent orthogonal FSK: } E_b/N_0 &= 13 \text{ dB} \\ &= 19.95 \end{aligned}$$

$$\text{coherent BPSK: } E_b/N_0 = 8 \text{ dB} = 6.31$$

$$\text{for non coherent FSK: } P_B = \frac{1}{2} e^{-E_b/2N_0} = 2.32 \times 10^{-5}$$

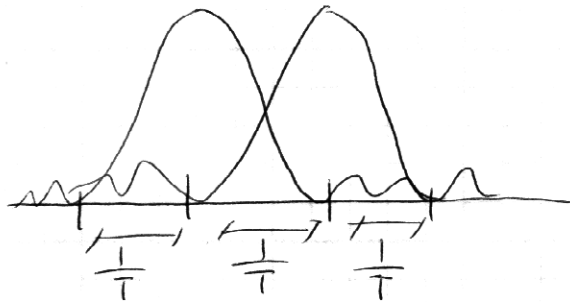
$$\text{for BPSK } P_B = Q\left(\sqrt{\frac{2E_b}{N_0}}\right) \approx 2.07 \times 10^{-4}$$

Problem 4.5

(a) min tone spacing for non-coherent FSK = $\frac{1}{T}$

$$\Delta f = \frac{1}{T} = 1000 \text{ Hz}$$

signals at 1 MHz & 999 kHz



$$\therefore \text{BW} = \frac{3}{T} = 3 \text{ kHz}$$

(b) for non-coherent MFSK = $\frac{M-1}{T} + \frac{2}{T}$
 $= (M+1) \frac{1}{T} = (M+1) \text{ kHz}$

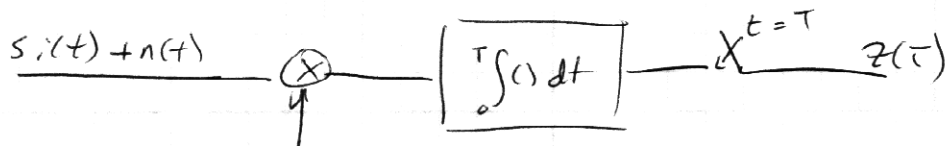
Problem 4.6

$$s_1(t) = \cos \omega_c t$$

$$s_2(t) = -\cos \omega_c t$$

$$E_b/N_0 = 9.6 \text{ dB} \Rightarrow P_E = 10^{-5}$$

with imperfect sync.



$$\sqrt{\frac{2}{T}} \cos(\omega_c t + \phi)$$

$$z(T) = a_1(T) + n_o(T)$$

$$a_1(T) = \frac{2}{T} \sqrt{E_b} \int_0^T \cos \omega_c t \cos(\omega_c t + \phi) dt$$

$$= \sqrt{E_b} \cos \phi$$

$$a_2(T) = -\sqrt{E_b} \cos \phi$$

$$P_B = Q\left(\frac{a_1 - a_2}{2\sigma_o}\right) = Q\left(\sqrt{\frac{2E_b \cos \phi}{N_0}}\right) Q\left(\sqrt{\frac{2E_b \cos \phi}{N_0}}\right)$$

for $E_b/N_0 = 9.6 \text{ dB}$ and $\phi = \pi/4$

$$(a) \quad P_E = Q(3.87) \approx 5.8 \times 10^{-5}$$

$$(b) \quad P_E = 10^{-3} = Q(x) \approx \frac{1}{x\sqrt{2\pi}} e^{-x^2/2} \Rightarrow x = 3.115$$

$$x = \sqrt{\frac{2E_b}{N_0}} \cos \phi \Rightarrow \phi = 43^\circ$$

Problem 4.7

$$s_1(t) = 0.5 \cos 2000\pi t$$

$$s_2(t) = 0.5 \cos 2020\pi t$$

$$\Delta f = 10 \text{ Hz} \Rightarrow \text{tone spacing} \neq \frac{1}{2T} \text{ for } T = 0.01$$

\therefore not orthogonal

$$P_B = Q\left(\sqrt{\frac{E_b(1-\rho)}{N_0}}\right)$$

$$\rho = \frac{1}{E_b} \int_0^T s_1(t) s_2(t) dt$$

$$E_b = \left(\frac{0.5}{2}\right)^2 \cdot T = 0.00125 \text{ J}$$

$$\therefore \rho = 0.94$$

$$P_B = Q(0.612) = 0.27$$