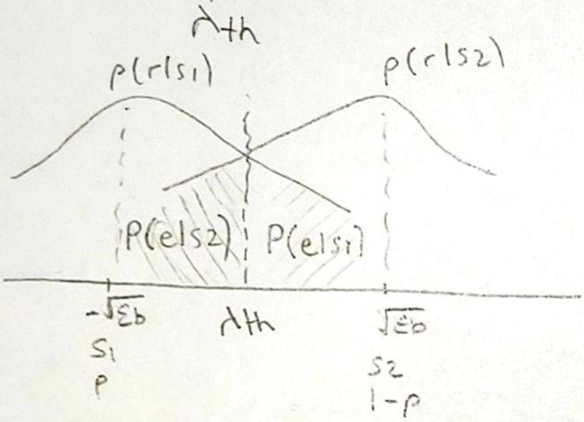
Q1. In a binary PAM system ...
babilities

S1. $r\sqrt{\mathcal{E}_b} \overset{s_1}{\underset{s_2}{\gtrless}} \frac{N_0}{4} \ln\left(\frac{1-p}{p}\right)$

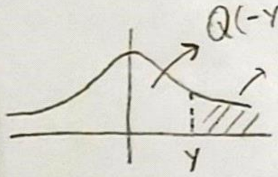
$$r \overset{s_1}{\underset{s_2}{\gtrless}} \underbrace{\frac{N_0}{4\sqrt{\mathcal{E}_b}} \ln\left(\frac{1-p}{p}\right)}_{\lambda_{th}}$$



$$P_e = \underbrace{Pr\{s_1\}}_{p} \cdot P\{e|s_1\} + \underbrace{Pr\{s_2\}}_{1-p} \cdot P\{e|s_2\}$$

$$P(e|s_1) = \int_{\lambda_{th}}^{\infty} \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(r+\sqrt{\mathcal{E}_b})^2}{2\sigma}} dr$$

Q-function



• y represents threshold val.

$$Q(y) = \int_{y}^{\infty} \frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2}} dx$$

$$\int_{\frac{\lambda_{th}+\sqrt{\mathcal{E}_b}}{\sigma_n}}^{\infty} \frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2}} dx \qquad x = \frac{r+\sqrt{\mathcal{E}_b}}{\sigma_n} \qquad dx = \frac{dr}{\sigma_n}$$

$$Q\left(\frac{\lambda_{th}+\sqrt{\mathcal{E}_b}}{\sqrt{N_0/2}}\right)$$

Similarly for $P(e|s_2)$

$$P(e|s_2) = \int_{-\infty}^{\frac{\lambda_{th}-\sqrt{\mathcal{E}_b}}{\sigma_n}} \dots e^{-\frac{(x^2)}{2}} dx$$

looks like $Q(-y)$

$$Q\left(\frac{-\lambda_{th}+\sqrt{\mathcal{E}_b}}{\sigma_n}\right)$$

• Bu soru tipinin uniform distributionlu hali çıkabilir

b) $p = 0.3 \quad 1-p = 0.7$

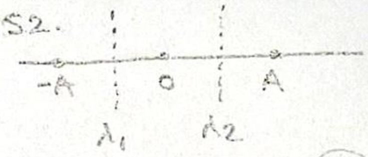
$P_e = 3.339 \times 10^{-6}$

$p = 0.5$

$P_e = 3.88 \times 10^{-6}$

Q2. A three-level PAM

S2.



$r > \lambda_2 \quad A$

$\lambda_2 > r > \lambda_1 \quad 0$

$\lambda_1 > r \quad -A$

$AWGN(0, \sigma_n^2)$

$p(r|s_0) \quad p(r|s_1) \quad p(r|s_2)$

assume they are equal (1/3)

$$P_e = \frac{1}{3}\left[P(r|s_0) + P(r|s_1) + P(r|s_2)\right]$$

$$P_e = \frac{1}{3}\left[Q\left(\frac{\lambda_1 + A}{\sigma_n}\right) + Q\left(-\frac{\lambda_1}{\sigma_n}\right) + Q\left(\frac{\lambda_2}{\sigma_n}\right) + Q\left(\frac{-\lambda_2 - A}{\sigma_n}\right)\right]$$

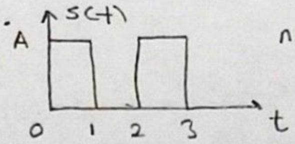
$\lambda_1 = -\frac{A}{2} \quad \lambda_2 = \frac{A}{2}$ (erroru minimize etmek için optimum thresholdu A/2 ve -A/2 seçtik)

$$P_e = \frac{4}{3} Q\left(\frac{A}{2\sigma_n}\right)$$

Q3. The received signal in a binary comm.

$r(t) = s(t) + n(t)$ antipodal signal

S3.



$n(t) + s(t) \rightarrow \boxed{\text{MF } h(t)} \rightarrow y(t)$

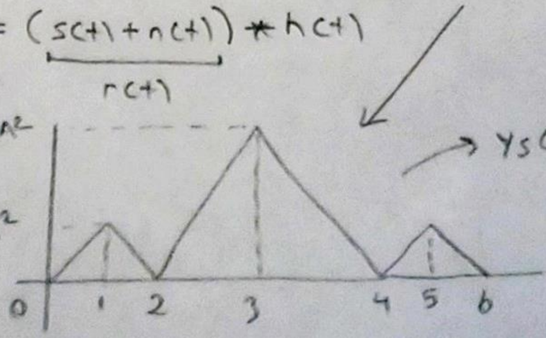
$h(t) = s(T_b - t)$ symbol duration $(T_b) = 3$

kaydırıp baktığımızda

$h(t) = s(t)$ çıkıyor

$h(t) * s(t)$ (contuinous time convolution)

$= \underbrace{(s(t) + n(t))}_{r(t)} * h(t)$



$y(t) = y_s(t) + y_n(t)$

$S_{yn}(f) = S_n(f) \cdot |H(f)|^2$ $\quad t=3$ 'te

$h(t) = s(t)$

$var\{y_n\} = E\{(y_n(t) - \mu_{y_n})^2\}$

$= E\{\int_0^{T_b} n(\tau)s(\tau)d\tau \int_0^{T_b} n(u)s(u)du\}$

$= E\{\int_0^{T_b}\int_0^{T_b} n(\tau)n(u)s(\tau)s(u)\,d\tau\, du\}$

$= \int_0^{T_b}\int_0^{T_b} \underbrace{E\{n(\tau)n(u)\}}_{\frac{N_0}{2}} s(\tau)s(u)\,d\tau\, du$

$var = \frac{N_0}{2}\int_0^{T_b} s^2(\tau)d\tau = N_0 A^2$

$P_e = Q\left(\sqrt{\left(\frac{S}{N}\right)_0}\right)$

$\left(\frac{S}{N}\right)_0 = \frac{(Y_s(T_b))^2}{E\{y_n(t)^2\}} = \frac{(2A^2)^2}{N_0 A^2}$

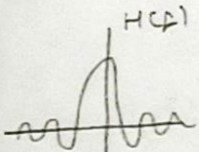
veya

$\left(\frac{S}{N}\right)_0 = \frac{2E_s}{N_0}$

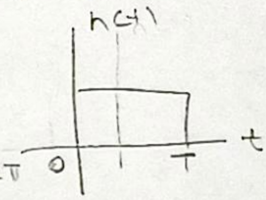
so,

$P_e = Q\left(\frac{2A}{\sqrt{N_0}}\right)$

Q4. $H(f) = (1 - \exp(-j2\pi f T))/j2\pi f$



$\xrightarrow{F^{-1}}$



$H(f) = \frac{1}{j2\pi f} - \frac{e^{-j2\pi f T}}{j2\pi f}$

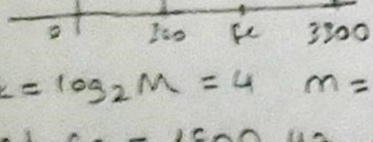
$\Rightarrow u(t) - u(t-T)$

$h(t) = s(T-t)$ ↳ signal ↳ mF

$h(T-t) = s(t)$

Q.5 A voice-band telephone

S.5 (passband assumption)



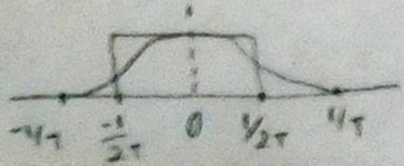
$R_s = 2400 \frac{sym}{s}$

$R_b = 9600 \frac{bits}{s}$

$k = 4$ bits/sym

$k = \log_2 M = 4 \quad m = 16$

let $f_c = 1800$ Hz choosen



raised cosine spectrum

$300 = f_c - \frac{1+\beta}{2T}$, $\quad 3300 = f_c + \frac{1+\beta}{2T}$

$\frac{1-\beta}{2T} \le |f| \le \frac{1+\beta}{2T}$

$\frac{1+\beta}{2T} = 1500$

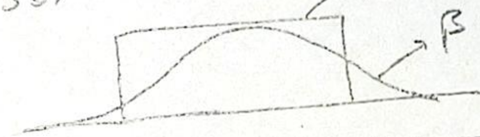
$\frac{1+\beta}{2T}$ raised cosine karakteristiğinden geldi

$1+\beta = 3000\,T$ → symbol duration

$1+\beta = 3000/2400$

$\beta = 0.25$

so,



Q6. A voice-band telephone channel

S6. $300 < f < 3000$

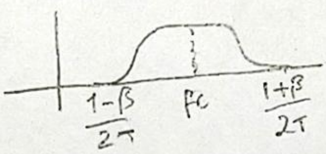
$W = 2700$ ✓ $\quad R_b = 9600$ bit/s

$R_{max} = 2700$

$R_s = 2400$ choosen for tam sayı değerler

$k=4 \quad m=16$

$T_s = 1/R_s = 1/2400$ sym/s.



$\frac{1+\beta}{2T} = 2700$

$\beta = 0.125$

m : (constellation size)

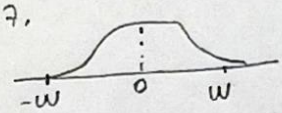
β : (roll-off factor)

Q7. Consider the transmission of data via PAM

S7.

$W = 3000$ Hz

(baseband assumption)



$\frac{1+\beta}{2T} = 3000 \qquad R(1+\beta) = 6000$

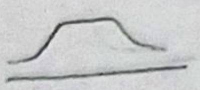
$\beta = 0.25 \qquad R = 4800$

$\vdots \qquad \vdots$

$\beta = 1 \qquad R = 3000$

$\beta = 0 \qquad R = 6000$

double sideband PAM case



$\frac{1+\beta}{2T} = 1500$

Q8. In a binary PAM

$y_m = a_m + n_m + i_m$

S8. $\vdots$ $\quad \downarrow \quad \downarrow$

$+1$ veya -1 $\quad \mathcal{N}(0,\sigma_n^2) \quad$ ISI $\rightarrow -\frac{1}{2}, 0, \frac{1}{2}$

$P = \{1/4, 1/2, 1/4\}$

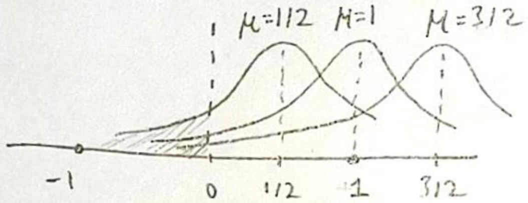
if $a_m = +1$

$y_m = +1 + n_m + i_m$

$y_m = \frac{1}{2} + n_m \qquad P_1 = 1/4$

$y_m = 1 + n_m \qquad P = 1/2$

$y_m = 3/2 + n_m \qquad P = 1/4$



$$P_e = \frac{1}{2} P(e|a_m=+1) + \frac{1}{2} P(e|a_m=-1)$$

$$\int_{-\infty}^{\frac{0-1/2}{\sigma_n}} \underbrace{\qquad}_{1/2} + \int_{-\infty}^{\frac{0-1}{\sigma_n}} \underbrace{\qquad}_{1} + \int_{-\infty}^{\frac{0-3/2}{\sigma_n}} \underbrace{\qquad}_{3/2}$$

$$\frac{1}{4} Q\left(\frac{1}{2\sigma_n}\right) + \frac{1}{2} Q\left(\frac{1}{\sigma_n}\right) + \frac{1}{4} Q\left(\frac{3}{2\sigma_n}\right)$$

similarly for $P(e|a_m=-1)$,

$$P(e|a_m=+1) = P(e|a_m=+1)$$

$$P_e = \frac{1}{2} P(e|a_m=+1) + \frac{1}{2} P(e|a_m=-1)$$

Q9. Binary PAM is used to

$s(t) \rightarrow$ [channel $h(t)$] $\xrightarrow{T}$ $x(t)$ [equaliter $c(t)$] $\rightarrow q_m$

$C(f).H(f) = 1$ olacak şekilde tasarlama

$x(t) = s(t) * h(t) = s(t) + 0.3\,\delta(t+T)$

$= 0.3\, s(t+T) \qquad m=1$

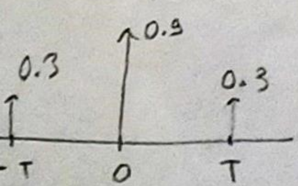
$h(t) = h_{-1}\cdot\delta(t+T) + h_0\,\delta(t) + h_1\,\delta(t-T)$

$\downarrow \qquad \downarrow \qquad \downarrow$

$x_{-1} \qquad x_0 \qquad x_1$

$0.3 \qquad 0.9 \qquad 0.3$

channel $h(t)$



$$q_m = \sum_{n=-1}^{1} c_n h_{m-n}$$

$q_{-1} = c_{-1}h_0 + c_0 h_{-1} + c_1 h_{-2}$

$q_0 = c_{-1}h_1 + c_0 h_0 + c_1 h_{-1}$

$q_1 = c_{-1}h_2 + c_0 h_1 + c_1 h_0$

$C(f).H(f) = 1$ olmalı o yüzden

$c(t) * h(t) = \delta(t)$ olmalı

$$q_m = \begin{cases} 1, & m=0 \\ 0, & m=\pm 1 \end{cases}$$

$$\begin{bmatrix} h_0 & h_{-1} & h_{-2} \\ h_1 & h_0 & h_{-1} \\ h_2 & h_1 & h_0 \end{bmatrix} \begin{bmatrix} c_{-1} \\ c_0 \\ c_1 \end{bmatrix} = \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} 0.9 & 0.3 & 0 \\ 0.3 & 0.9 & 0.3 \\ 0 & 0.3 & 0.9 \end{bmatrix}^{-1} \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix} = \begin{bmatrix} c_{-1} \\ c_0 \\ c_1 \end{bmatrix}$$

$q_{-2} = c_{-1}h_{-1} = -0.1429$

$q_2 = c_1 h_1 = -0.1429$

$q_3 = 0$

$q_{-3} = 0$

$$q_m = \begin{cases} 0 & , m=-3 \\ -0.1429 & , m=-2 \\ 0 & , m=-1 \\ 1 & , m=0 \\ 0 & , m=1 \\ -0.1429 & , m=2 \\ 0 & , m=3 \end{cases}$$

Q10. Determine the tapweight coefficients

S10. $x(0) = 1,\ x(-1) = 0.3,\ x(1) = 0.2$

$h(t) = h_{-1}\delta(t+T) + h_0\delta(t) + h_1\delta(t-T)$

$= 0.3\,\delta(t+T) + \delta(t) + 0.2\,\delta(t-T)$

$$q_m = \sum_{n=-1}^{1} c_n h_{m-n}$$

$$\begin{bmatrix} c_{-1} \\ c_0 \\ c_1 \end{bmatrix} = \begin{bmatrix} 1 & 0.3 & 0 \\ 0.2 & 1 & 0.3 \\ 0 & 0.2 & 1 \end{bmatrix}^{-1} \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}$$

$q_{-3} = c_{-1}h_{-2} + c_0 h_{-3} + c_1 h_{-4} = 0$

$q_{-2} = c_{-1}h_{-1} + c_0 \cancel{h_{-2}} + c_1 \cancel{h_{-3}} = -0.102$

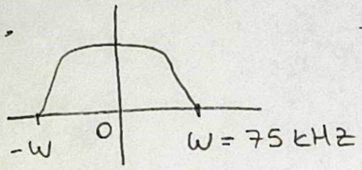
$q_{-1} = \underbrace{c_{-1}h_0} + \underbrace{c_0 h_{-1}} + c_1 h_{-2} = 0$

birbirlerini götürecek şekilde ayarlandı

$q_2 = c_1 h_1 = -0.045$

Q11. A binary PAM wave

S11.



$T_b = 10 \times 10^{-6}$ s

$R_b = 1/T_b = R_s$

$R_s = 10^5 \ \frac{\text{sym}}{\text{sec}}$

(binary PAM = bir sembol bir bit)

$\frac{1+\beta}{2T} = W$ $\quad \beta = 0.5$
(roll-of factor)

Q12. The sampled impulse response

S12.

TX filter → channel $h(t)$ → equalizer $w(t)$ → Rx filter

$$\begin{array}{ccccc} w_m = \{0, & 0.13, & 0.68, & -0.22, & 0.08\} \\ c_{-2} & c_{-1} & c_0 & c_1 & c_2 \end{array}$$

$h(t) = h_{-1}\delta(t+T) + h_0\delta(t) + h_1\delta(t-T) + h_2\delta(t-2T)$

$$\begin{bmatrix} 0.68 & 0.15 & 0 \\ -0.22 & 0.68 & 0.15 \\ 0.08 & -0.22 & 0.68 \end{bmatrix}^{-1} \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix} = \begin{bmatrix} w_{-1} \\ w_0 \\ w_1 \end{bmatrix}$$

$$\begin{bmatrix} w_{-1} \\ w_0 \\ w_1 \end{bmatrix} = \begin{bmatrix} -0.2825 \\ 1.2805 \\ 0.4475 \end{bmatrix}$$

$q_{-2} = w_{-1}h_{-1} + w_0\cancel{h_{-2}} + w_1\cancel{h_{-3}} = -0.$

$q_{-2} = -0.0424$

$q_2 = w_{-1}h_3 + w_0h_2 + w_1h_1 = 0.004$

$q_3 = 0$

$q_{-3} = 0$

largest contribution to the residual ISI from $q_{-2} = -0.0424$