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**EE422 Communications 2 exam 1. Winter 2006. Each question has 2 points weight**

1) Derive the upper error bound for equation 4.41 (2 pts). Given eq. 4.40, list the following results for Pe for Eb = 3, 4, 5, 6 and No = 0.5 (J). (2 pts)

$$P_e = \frac{1}{2}\,\mathrm{erfc}\left(\sqrt{\frac{E_b}{N_0}}\right)$$

1

upper

$$\mathrm{erfc}(u) < \frac{\exp(-u^2)}{\sqrt{\pi}\,u}$$

we may bound the given $P_e$ as follows

$$P_e = \frac{1}{2}\,\mathrm{erfc}\sqrt{\left(\frac{E_b}{N_0}\right)} < \frac{\exp\left(\frac{-E_b}{N_0}\right)}{2\sqrt{\pi E_b N_0}} = \frac{1}{2}\exp\left(\frac{-E_b}{N_0}\right) * \sqrt{\frac{N_0}{\pi E_b}}$$

4.(4.0)

$E_b = 3$, $N_0 = 0.5$ = $\frac{1}{2}\,\mathrm{erfc}(\sqrt{6}) = ,99959 = 0.499$

$E_b = 4$, $N_0 = 0.5$ : $\frac{1}{2}\,\mathrm{erfc}(\sqrt{8}) = \cancel{\;}$ $6.6447 \times 10^{-6}$

$E_b = 5$, $N_0 = 0.5$ $\frac{1}{2}\,\mathrm{erfc}(\sqrt{10}) = 6.644 \times 10^{-6}$

$E_b = 6$, $N_0 = 0.5$ = $\frac{1}{2}\,\mathrm{erfc}(\sqrt{12}) = 8.143 \times 10^{-8}$

2) What is the relation between Gaussian and Q functions? What does the Q function represent?(2 pt)

0

the Linear combination of Gaussian random variables is also Gaussian, since the ~~the~~ noise vector is W is Gaussian it follows that the rotated noise vector w/state is also Gaussian so Q is Gaussian

it represents the orthonormal matrix for all i

That satisfies the condition $\boxed{QQ^T = I}$

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3) Solve problem 5.10. (3 pts)

3

$$E\{X_j w'(t_k)\} = E\{(s_{ij} + w_j)\, w'(t_k)\}$$

$$E\{s_{ij}\, w'(t_k)\} = s_{ij}\, E[w'(t_k)] = 0$$

$$w'(t_k) = w(t_k) - \sum_{i=1}^{N} w_i\, \phi_i(t_k)$$

~~so~~ we have

$$E\{X_j w'(t_k)\} = E[w_j\, w'(t_k)]$$

$$= E\{w_j\, w(t_k)\} - \sum_{i=1}^{N} \phi_i(t)\, E\{w_j w_i\}$$

But $E\{w_j w(t_k)\} = E\{w(t_k) \int_0^T w(t)\, \phi_j(t)\, dt\} = \int_0^T \phi_j(t)\, E\{w(t_k)\, w(t)\}\, dt$

$$= \int_0^T \phi_j(t) \cdot \frac{N_0}{2}\, \delta(t - t_k)\, dt = \frac{N_0}{2}\, \phi_j(t_k)$$

$$E\{w_j w_i\} = \begin{cases} \frac{N_0}{2} & i = j \\ 0 & i \neq j \end{cases}$$

$\Rightarrow$ Hence we get the final result

$$E\{X_j\, w'(t_k)\} = \frac{N_0}{2}\phi_j(t_k) - \frac{N_0}{2}\phi_j(t_k) \; \boxed{= 0}$$

4) Compare coherent BFSK and QPSK – BW efficiency, BER, and HW complexity. (5 pts)

2

~~BFSK~~

~~band~~ channel bandwidth is the same and BER is the ~~QPSK~~ BFSK is more than QPSK

~~and HW in the QPSK is more than BFSK~~

~~QPSK~~

e

$\frac{1}{2}\,\mathrm{erfc}\left(\sqrt{\frac{E_b}{2N_0}}\right)$

$\frac{1}{2}\,\mathrm{erfc}\left(\sqrt{\frac{E_b}{N_0}}\right)$

HW in the ~~QPSK~~ is more than BFSK

BW efficiency is

$\boxed{\text{of QPSK} = \frac{\log_2 M}{2}}$

$\boxed{\text{of BFSK} = \frac{2\log_2 M}{M}}$

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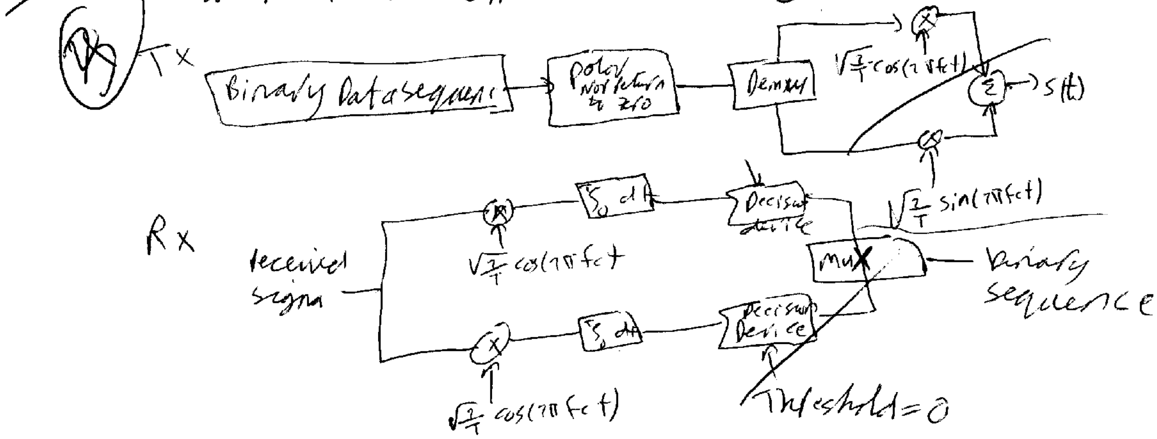
5) How many correlators are required for 16 QAM (minimum hardware)? Draw the block diagram for TX and RX and state the ML detector operation (4 pts)

we need two collelators for 16 QAM




6) Show that the raised cosine filter satisfies the ISI free condition. Specifically, obtain equation 4.53 from 4.60. (2 pts)

6

$$p(f) = \begin{cases} \frac{1}{2W} & 0 \le |f| \le f_1 \\ \frac{1}{4W}\left\{1 - \sin\left[\frac{\pi(|f| - W)}{2W - 2f_1}\right]\right\} & f_1 \le |f| \le 2W - f_1 \\ 0 & |f| \geq 2W - f_1 \end{cases}$$

$\Downarrow \mathcal{F}$

fourier analysis $\mathcal{F}^{-1}$

$$p(t) = (\mathrm{sinc}(2Wt))\left(\frac{\cos(2\pi\alpha W t)}{1 - 16\alpha^2 W^2 t^2}\right)$$

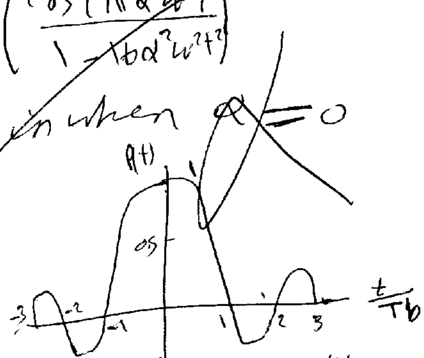
the ISI is ~~in when~~ $\alpha = 0$

$p(t) = \mathrm{sinc}(2Wt)$

$\Downarrow$

we take fourier transformer

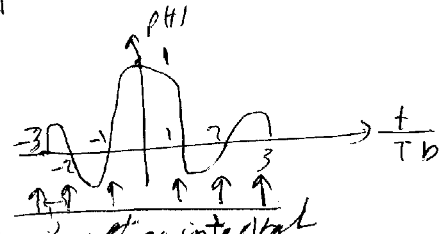
$$p(f) = \frac{1}{2W}\,\mathrm{rect}\left(\frac{f}{2W}\right)$$




$W = \frac{R_b}{2} = \frac{1}{2T_b}$

$\Downarrow$

$\sum_{n=-\infty}^{\infty} p(f - nR_b) = T_b$ ⟸



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7) Given a symbol period of 10 times carrier period. You are asked to implement a carrierless FIR with 4 times oversampling of the carrier. Draw the FIR, and list its coefficients (3 pts)

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$f_s = 10 f_c$

FIR = 4 oversampling