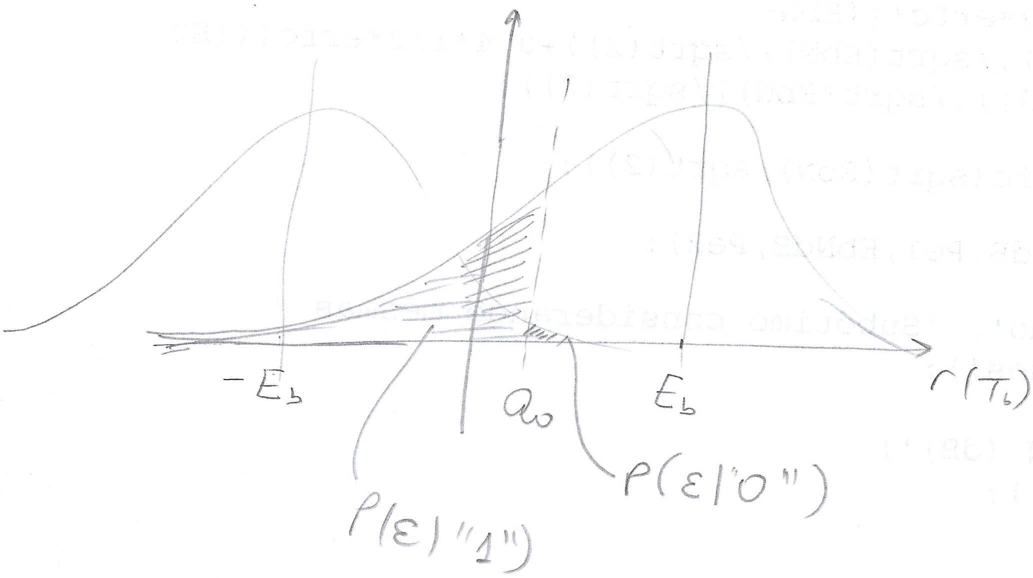
11.2.4 O custo total é

$$C = C_{10} \cdot P(\varepsilon | m = \text{"1"}) + C_{01} \cdot P(\varepsilon | m = \text{"0"})$$



$$C = C_{10} \cdot \left[1 - Q\left(\frac{a_0 - E_b}{\sigma_n}\right)\right] + C_{01}\left[Q\left(\frac{a_0 + E_b}{\sigma_n}\right)\right]$$

$$= C_{10}\, Q\left(\frac{E_b - a_0}{\sigma_n}\right) + C_{01}\, Q\left(\frac{E_b + a_0}{\sigma_n}\right).$$

$$\sigma_n = \frac{N}{2} \cdot E_b \; e^{(Pb/a)}$$

$$\frac{dC}{da_0} = -\frac{C_{10}}{\cancel{\sigma_n}}\, Q'\left(\frac{E_b - a_0}{\sigma_n}\right) + \frac{C_{01}}{\cancel{\sigma_n}}\, Q'\left(\frac{E_b + a_0}{\sigma_n}\right) = 0$$

$$\Rightarrow C_{01}\, e^{-\left(\frac{E_b + a_0}{\sigma_n}\right)^2 / 2} = C_{10}\, e^{-\left(\frac{E_b - a_0}{\sigma_n}\right)^2 / 2} \Rightarrow$$

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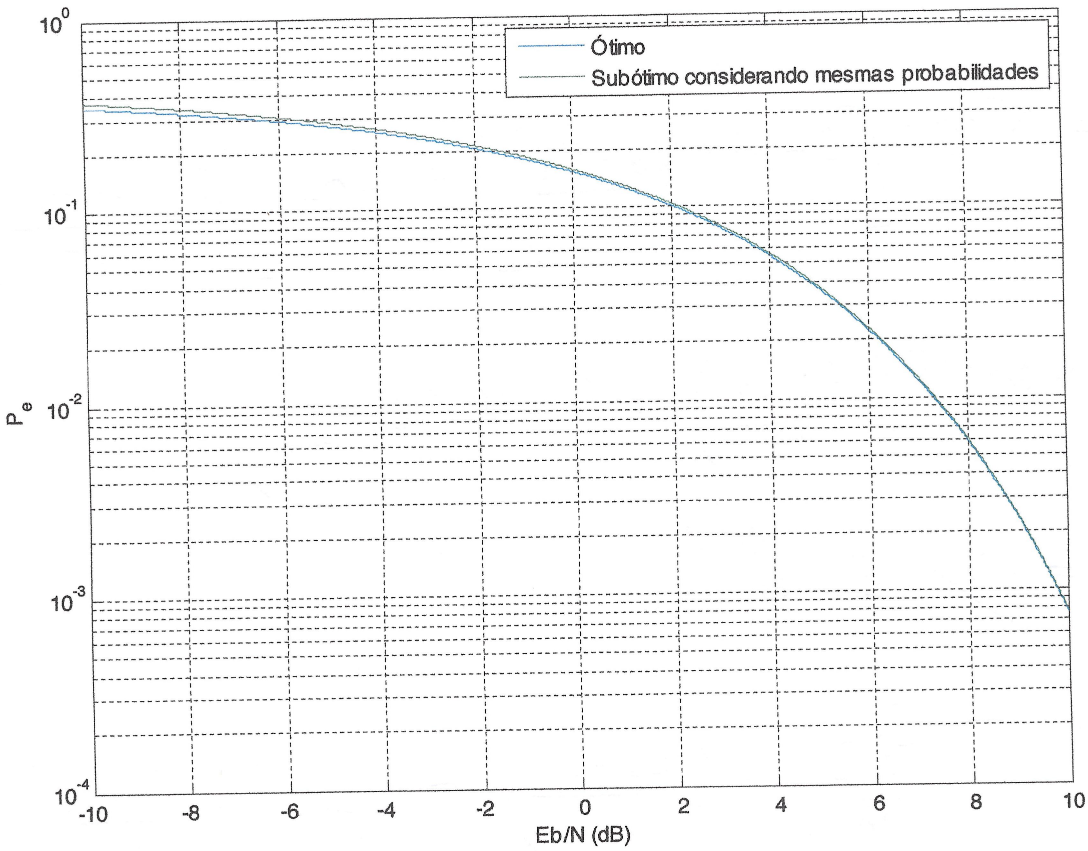
```
EbNdB = linspace(-10,10,1000);
EbN = 10.^(EbNdB/10);
Pe1 = 0.6*1/2*erfc(((EbN-
1/2*log(2/3))./sqrt(EbN))/sqrt(2))+0.4*1/2*erfc(((Eb
N+1/2*log(2/3))./sqrt(EbN))/sqrt(2));

Pe2 = 1/2*erfc(sqrt(EbN)/sqrt(2));

semilogy(EbNdB,Pe1,EbNdB,Pe2);

legend('Ótimo', 'Subótimo considerando mesmas
probabilidades');
grid;
xlabel('Eb/N (dB)')
ylabel('P_e');
```



$$\Rightarrow \frac{C_{10}}{C_{01}} = e^{\frac{-\cancel{E_b^2} - 2a_0 E_b - \cancel{a_0^2}}{2\sigma_n^2} + \frac{\cancel{E_b^2} - 2a_0 E_b + \cancel{a_0^2}}{2\sigma_n^2}}$$

$$\Rightarrow \frac{C_{10}}{C_{01}} = e^{-\frac{2a_0 E_b}{\sigma_n^2}} \Rightarrow \frac{2a_0 E_b}{\sigma_n^2} = \ln \frac{C_{01}}{C_{10}} \Rightarrow$$

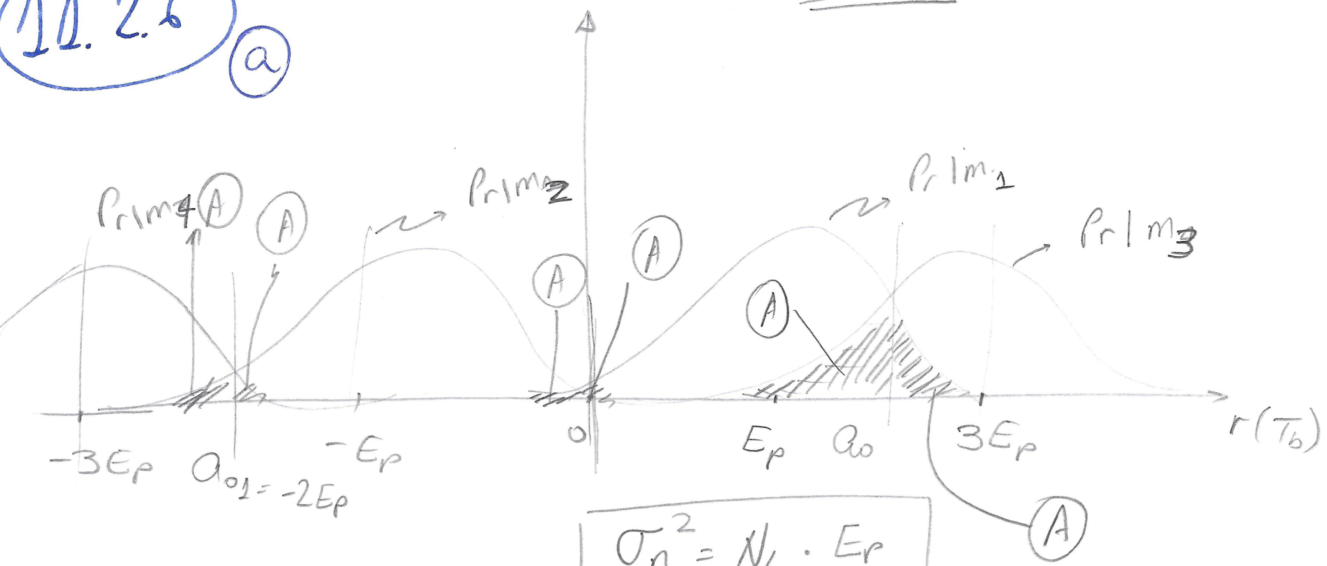
$$\Rightarrow a_0 = \frac{1}{2}\frac{\sigma_n^2}{E_b} \ln \frac{C_{01}}{C_{10}} = \frac{1}{2}\frac{\frac{N}{2}\cdot E_b}{E_b} \ln \frac{C_{01}}{C_{10}}$$

$$\Rightarrow \boxed{a_0 = \frac{N}{4} \ln\left(\frac{C_{01}}{C_{10}}\right)}$$

11.2.6

0 → Fora!

(a)



$$\boxed{\sigma_n^2 = \frac{N}{2}\cdot E_p}$$

(b)

$$\boxed{\begin{array}{ll} a_{01} = -2E_p & \\ a_{02} = 0 & a_{03} = 2E_p \end{array}}$$

$$A = Q\left(\frac{a_{02} - E_p}{\sigma_n}\right) = Q\left(\frac{2E_p - E_p}{\sqrt{\frac{N}{2} E_p}}\right) = Q\left(\frac{E_p}{\sqrt{E_p N/2}}\right) = Q\left(\sqrt{\frac{2E_p}{N}}\right)$$

$$P_{e_M} = \frac{P_{e|m_1} + P_{e|m_2} + P_{e|m_3} + P_{e|m_4}}{4} = \frac{A + 2A + 2A + A}{4} = \frac{6}{4} A$$

$$\boxed{P_{e_M} = \frac{3}{2} Q\left(\sqrt{\frac{2E_p}{N}}\right)}$$

$P_e =$

$$E_{p_M} = \frac{E_p + E_p + 9E_p + 9E_p}{4} = 5E_p$$

$$E_b = \frac{E_{p_M}}{2} = \frac{5}{2} E_p \Rightarrow \boxed{E_p = \frac{2}{5} E_b}$$

$\frac{12}{15}$ $\frac{3}{4}$ $\frac{4}{5}$

$$\boxed{P_{e_M} = \frac{3}{2} Q\left(\sqrt{\frac{4}{5} \frac{E_b}{N}}\right)}$$

Usando código de Gray, $P_e = \frac{1}{2} P_{e_M}$

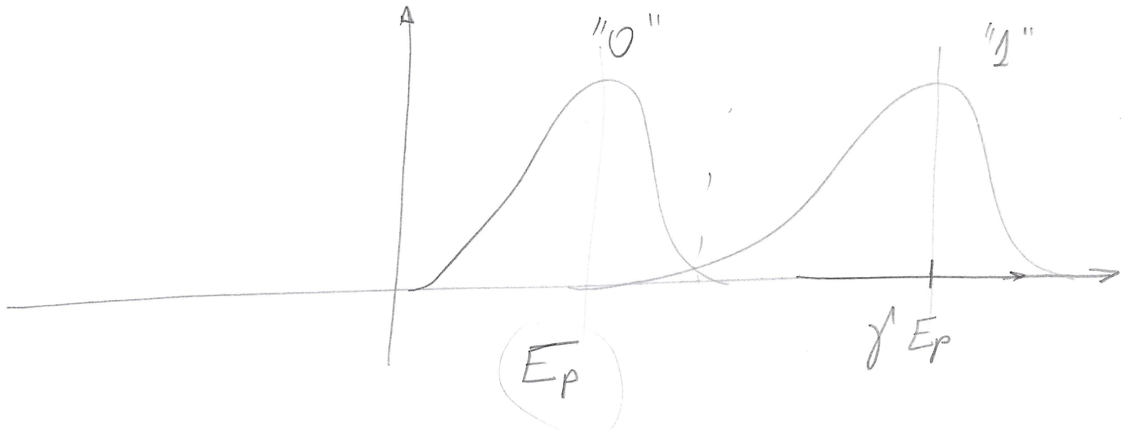
$$\boxed{P_e = \frac{3}{4} Q\left(\sqrt{\frac{4}{5} \frac{E_b}{N}}\right)}$$

11. 2.7

$$\boxed{\begin{aligned} &"0" \rightarrow p(t) \\ &"1" \rightarrow q(t) = \gamma\, p(t) \end{aligned}} \quad \begin{aligned} &\rightarrow E_p \\ &\rightarrow \gamma^2 E_p \end{aligned}$$

$$h(t) = p(T_b - t) - q(T_b - t) = (1-\gamma)\, p(T_b - t)$$

Adoptamos $\boxed{h(t) = p(T_b - t)}$



$$a_0 = \frac{\gamma E_p + E_p}{2} = \frac{(\gamma+1)}{2} E_p \qquad \boxed{a_0 = \frac{\gamma+1}{2} E_p}$$

$$P_e = Q\left(\frac{a_0 - E_p}{\sigma_n}\right) = Q\left(\frac{\frac{\gamma+1}{2}E_p - E_p}{\sqrt{N/2 \cdot E_p}}\right) = Q\left(\frac{\frac{(\gamma+1-2)E_p}{2}}{\sqrt{E_p N/2}}\right)$$

$$= Q\left(\frac{\frac{\gamma-1}{2}\,\frac{E_p}{N}}{\sqrt{\frac{E_p}{N}\,\frac{1}{2}}}\right) = Q\left(\sqrt{\frac{\frac{(\gamma-1)^2}{4^2}\left(\frac{E_p}{N}\right)^2}{\frac{E_p}{N}\cdot\frac{1}{2}}}\right)$$

$$= Q\left(|\gamma-1|\sqrt{\frac{E_p}{2N}}\right)$$

$$E_b = \frac{E_p + \gamma^2 E_p}{2} = (1+\gamma^2)\, E_p/2$$

$$\boxed{\bar{E}_p = \frac{2\,E_b}{(1+\gamma^2)}}$$

$$P_e = Q\left(\sqrt{(\gamma-1)^2 \cdot \frac{\cancel{2}\,E_b}{\cancel{2}N\,(1+\gamma^2)}}\right) = Q\left(\sqrt{\frac{(\gamma-1)^2}{1+\gamma^2}\;\frac{E_b}{N}}\right)$$

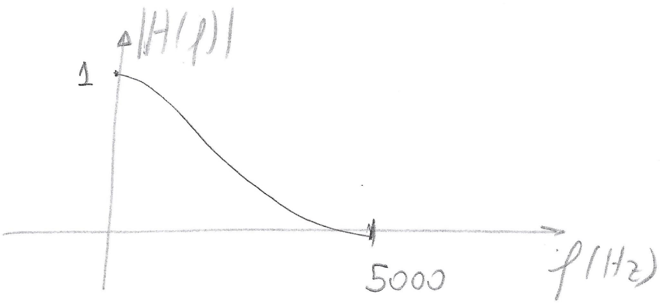
112-8

a) $h(t) = p(T_b - t)$ sendo $p(t)$ pulso do critério de Nyquist com $\rho = 0{,}2$

$$H(f) = P^*(f)\, e^{-j\omega T_b}$$

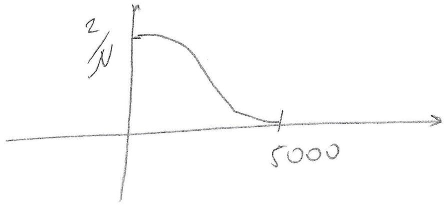
$$r = \frac{2\omega_x}{\omega_b} \Rightarrow \omega_x = \frac{r\,\omega_b}{2}$$

$$|H(f)| = |P(f)|$$



b) $$H(\omega) = \frac{P(-\omega)\, e^{-j\omega T_b}}{S_n(\omega)} = P(-\omega)\, e^{-j\omega T_b} \cdot \frac{1+(f/f_0)^2}{0{,}5N}$$

$$|H(\omega)| = |P(\omega)| \cdot \frac{1+(f/f_0)^2}{0{,}5N}$$



11.3.2

a

$$h(t) = p(T_b - t) - q(T_b - t)^{-\pi t/T_b}$$

$$h(t) = \sqrt{2}\,\text{sen}\left(\pi (T_b - t)/T_b\right)\left\{\cos\left[\omega_c - (\Delta\omega/2)(T_b - t)\right] - \cos\left[\omega_c + (\Delta\omega/2)(T_b - t)\right]\right\}$$

$$= \sqrt{2}\,\text{sen}(\pi t/T_b)\left(-2\,\text{sen}\left(\omega_c^{(T_b-t)} - \cancel{\frac{\Delta\omega}{2}(T_b - t)} + \omega_c + \cancel{\frac{\Delta\omega}{2}(T_b - t)}\right)\right.$$

$$\left.\text{sen}\left(\cancel{\omega_c}^{(T_b-t)} - \frac{\Delta\omega}{2}(T_b - t) - \cancel{\omega_c}^{(T_b-t)} - \frac{\Delta\omega}{2}(T_b - t)\right)\right)$$

$$= \sqrt{2}\,\text{sen}(\pi t/T_b)\cdot(+2)\cdot\text{sen}\left(2\omega_c(T_b - t)\right)\text{sen}\left(\Delta\omega(T_b - t)\right)$$

$$\boxed{h(t) = 2\sqrt{2}\,\text{sen}(\pi t/T_b)\;\text{sen}\left(2\omega_c t - 2\omega_c T_b\right)\text{sen}\left(\Delta\omega t - \Delta\omega T_b\right)}$$

$$E_p = \frac{8\sqrt{2}\,T_b \cos^2\left(\frac{T_b(\Delta\omega/2 - \omega_c)}{2}\right)}{-\Delta\omega^2 T_b^2 + 4\Delta\omega T_b^2 \omega_c - 4T_b^2\omega_c^2 + 4\pi^2}$$

E_q = Resolve numericamente