1) $m_e = 0$

$$\sigma_e^2 = M_e = \frac{9}{4} + \frac{9}{4} + \frac{1}{4} + \frac{1}{4} = 5 \qquad R_e(f) = 5T$$

$$\bar{R}_v(f) = R_e(f) \cdot \frac{1}{T^2} |G(f)|^2$$

$$\bar{M}_v = \frac{5T}{T^2} \cdot E_g = \frac{5T}{T^2} \cdot \int_{-\infty}^{+\infty} V_0^2 T^2 \, \mathrm{rect}(fT)\, df$$

$$= \frac{5T^2}{T^2} \cdot V_0^2 = 5V_0^2$$

2) $h(kT) = (0.9)^k 1_0(kT) + (0.1)^k 1_0(kT)$

$$R_x(f) = \sigma_x^2 \cdot T$$

$$R_y(f) = R_x(f) |H(f)|^2$$

$$= \sigma_x^2 \cdot T \cdot |H(f)|^2$$

$$M_y = \int_{\hat{I}} df\, R_y(f) = \int_{\hat{I}} df\, \sigma_x^2 T |H(f)|^2 = \sigma_x^2 \cdot T \cdot E_h$$

$$= \sigma_x^2 \cdot T^2 \cdot \sum_{k=-\infty}^{+\infty} |h(kT)|^2 = \sigma_x^2 \cdot T^2 \cdot \sum_{k=0}^{+\infty} \left(0.9^k + 0.1^k\right)^2$$

$$= \sigma_x^2 T \sum_{k=0}^{+\infty} 0.81^k + 0.01^k + 2 \cdot 0.09^k$$

$$= \sigma_x^2 T \left[\frac{1}{1-0.81} + \frac{1}{1-0.01} + \frac{2}{1-0.09} \right]$$

3) $g(t)$ ha estensione spettrale $\left(-\frac{2}{T}, \frac{2}{T}\right)$ (conv. di 4 rect $(\cdot)$ con estensione $\left(-\frac{1}{2T}, \frac{1}{2T}\right)$) uguale a quella di $H(f) = h_0 \frac{T}{4} \operatorname{rect}\left(f/(4T)\right)$

Dunque

$$C(f) = h_0 \frac{T}{4} G_T(f)$$

$$c(t) = h_0 \frac{T}{4} \cdot V_0 \operatorname{sinc}^4\left(\frac{t}{T}\right)$$ è di Nyquist, con

$$V_0' = h_0 \frac{T}{4} V_0$$

$$\sigma_n^2 = R_0 \int_{-\infty}^{+\infty} h_0^2 \frac{T^2}{16} \operatorname{rect}\left(\frac{fT}{4}\right) df$$

$$= R_0 h_0^2 \frac{T^2}{16} \cdot \frac{4}{T} = R_0 h_0^2 \frac{T}{4}$$

$$P_e = \frac{4}{3} \cdot Q\left(\frac{V_0'}{2\sigma_n}\right)$$

4) $m_x = E[2\cos(5t+\varphi)] =$

$$= \frac{1}{2\pi} \int_{-\frac{\pi}{4}}^{\frac{7\pi}{4}} 2\cos(5t+\varphi)\, d\varphi = 0$$

$$\sigma_x^2 = E[4\cos^2(5t+\varphi)] = 4E\left[\frac{1}{2} + \frac{1}{2}\cos(10t+2\varphi)\right]$$

$$= 2$$

$$\sigma_e^2 = \frac{\Delta^2}{12} = \left(\frac{4}{L}\right)^2 \cdot \frac{1}{12}$$

$$SNR = 2 \cdot \frac{12^3}{16\,4} \cdot L^2 = \frac{3}{2} \cdot L^2 \qquad L = 128$$

5) Nella banda $[300, 3200]$ Hz si possono trasmettere

$\frac{1}{T} = 2900$ simboli/s.

Per trasmettere almeno 19 kbit/s, ogni simbolo deve trasmettere almeno 7 bit. La costellazione ha dim. $2^7 = 128$.