PROBLEMA 1:

(a) $$f_i(t) = f_c + K_f\, m_1(t) = f_c + K_f \,\mathrm{sinc}(320\cdot 10^3 t)$$

Valor máximo:

$$\boxed{f_i(t)\Big|_{max}} = f_c + K_f\, m_1(t)\Big|_{max} = f_c + K_f \cdot 1 =$$

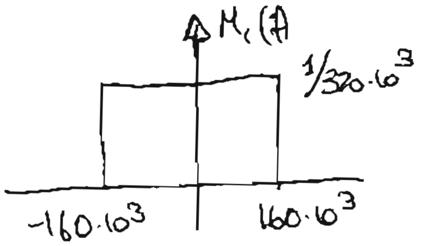
$$= 25\cdot 10^6\ Hz + 240\cdot 10^3\ Hz/V \cdot 1\ V = \boxed{25{,}24\ MHz}$$

$$B_T[\mathrm{CARSON}] = 2\Delta f\left(1+\frac{1}{D}\right)$$

$$\Delta f = K_f \cdot m_1(t)\Big|_{max} = 240\ KHz$$

$$D = \frac{\Delta f}{W}$$

$$m_1(t) = \mathrm{sinc}(320\cdot 10^3 t) \rightleftharpoons \frac{1}{320\cdot 10^3}\,\Pi\left(\frac{f}{320\cdot 10^3}\right)$$



$$W = 160\ KHz$$

$$D = \frac{240\ KHz}{160\ KHz} = 1.5$$

$$\boxed{B_T[\mathrm{CARSON}] = 2\cdot 240\cdot 10^3\left(1+\frac{1}{1.5}\right) = 800\ KHz}$$

$$\frac{B_T}{\Delta f} = \frac{2n_{max}}{D}$$

PARA $D = 1 \Rightarrow n_{max} = 3$ $\quad \frac{2n_{max}}{D} = 6$

$D = 2 \Rightarrow n_{max} = 4$ $\quad \frac{2n_{max}}{D} = 4$

INTERPOLANDO: $D = 1.5$ $\quad \frac{2n_{max}}{D} = 5$

$$B_T[1\%] = \frac{2n_{max}\cdot\Delta f}{D} = 5\cdot 240\ KHz = 1200\ KHz$$

$$\boxed{B_T = \frac{B_T[\text{CARSON}] + B_T[1\%]}{2} = 1\ \text{MHz}}$$

(b) LA CONDICION: $P_C = \frac{A_c^2}{2} \geq 20\, B_T N_0$

$$\frac{A_c^2}{N_0} \geq 40\, B_T \Rightarrow \boxed{A_c \geq \sqrt{40\, B_T N_0} = 6325\sqrt{N_0}}$$

(c)

$$SNR_I \equiv 30\ \text{dB} \equiv 1000 = \frac{A_c^2}{2 N_0 B_T}$$

$$A_c^2 = 2000\, B_T N_0 \Rightarrow \boxed{A_c = 44721\sqrt{N_0}}$$

SI SE CUMPLE CONDICION APARTADO (b). EL SISTEMA FUNCIONA POR ENCIMA DEL UMBRAL.

(d) LA DENSIDAD ESPECTRAL DE RUIDO A LA SALIDA:

$$S_{no}(f) = \frac{N_0 f^2}{A_c^2} K_d^2\, \Pi\left(\frac{f}{2W}\right)$$

SE HA AÑADIDO EL FACTOR K_d^2

W = 160 KHz ES EL ANCHO DE BANDA DE LA SEÑAL FDM.

CUANTO MAS ALEJADOS DEL ORIGEN MÁS RUIDO, EL PRIMER CANAL MENOS RUIDO.

CANAL 1 0 A 4 KHz

PROBLEMA 1 (CONTINUACIÓN)

$$\boxed{P_{No}^{CANAL\ 1}} = 2\int_0^{4000} S_{No}(f)\,df = 2\frac{No}{A_c^2}K_d^2\left.\frac{f^3}{3}\right]_0^{4000} =$$

$$= \frac{2\cdot(10^{-6}\ V/Hz)^2\cdot(4000)^3}{3\cdot 2000\cdot 10^6} = \boxed{2,13\cdot 10^{-11}\ W}$$

(e) EL CANAL FDM MAS ALEJADO DEL ORIGEN DE FRECUENCIAS TENDRA MAS RUIDO: CANAL 40.

$$\boxed{P_{No}^{CANAL\ 40}} = 2\int_{39\cdot 4000}^{40\cdot 4000} S_{No}(f)\,df = 2\frac{No}{A_c^2}K_d^2\left.\frac{f^3}{3}\right]_{156000}^{160.000}$$

$$= \frac{2\cdot(10^{-6})^2\left[(160\cdot 10^3)^3-(156\cdot 10^3)^3\right]}{3\cdot 2000\cdot 10^6} = \boxed{9,99\cdot 10^{-8}\ W}$$

$$SNR_o = \frac{3A_c^2K_f^2P}{2W^3No} = \frac{3\cdot(240\cdot 10^3)^2\cdot 1}{2\cdot(160\cdot 10^3)^3}2\cdot 10^9 = 42\,187'5 \equiv 46'25\,dB.$$

$$\boxed{P_{No}^{Total}} = 2\int_0^{40\cdot 4000} S_{No}(f)\,df = \frac{2\cdot(10^{-6})^2\cdot(160\cdot 10^3)^3}{3\cdot 2\cdot 10^9} = \boxed{1'37\cdot 10^{-6}\ W}$$

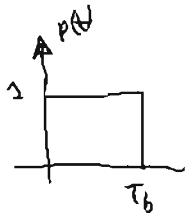
$$\boxed{P_{So}^{Total}} = SNR_o\cdot P_{No}^{total} = \boxed{57'8\ mW}$$

$$\boxed{P_{So}^{CANAL} = P_{So}^{total}/40 = 1'45\ mW}$$

$$\boxed{SNR_o^{CANAL\ 40}} = \frac{1'45\cdot 10^{-3}}{9'99\cdot 10^{-8}} = 14.515 \equiv \boxed{41'62\ dB > 40\ dB}$$

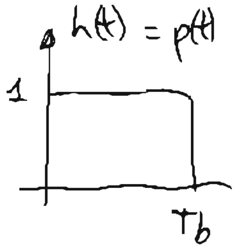
PROBLEMA 2:

Símbolos $g_i(t) = \pm A\, p(t)$ con

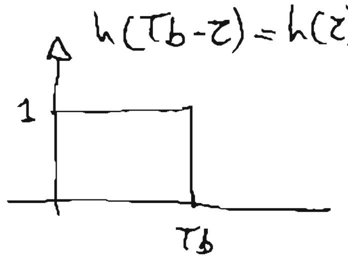


(a) $x(t) = g_i(t) + w(t)$

$$y(t) = \int_{-\infty}^{\infty} x(\tau)\, h(t-\tau)\, d\tau = \int_0^{T_b} x(\tau)\, h(t-\tau)\, d\tau$$



$$y(T_b) = \int_0^{T_b} x(\tau)\, h(T_b-\tau)\, d\tau$$



$$= \int_0^{T_b} x(\tau)\, d\tau = \int_0^{T_b} g(\tau)\, d\tau + \int_0^{T_b} w(\tau)\, d\tau .$$

Si se transmitió 1, $y(T_b)$ es una variable aleatoria Gaussiana con media y varianza:

$$y(T_b)/\text{"1"} = A\int_0^{T_b} d\tau + \int_0^{T_b} w(\tau)\, d\tau = AT_b + \int_0^{T_b} w(t)\, dt$$

$$E[y(T_b)/\text{"1"}] = AT_b + E\left[\int_0^{T_b} w(t)\, dt\right] = AT_b + \int_0^{T_b} E[w(t)]\, dt = AT_b$$

$$\sigma^2_{y(T_b)}/\text{"1"} = E\left[\left(\int_0^{T_b} w(t)\, dt\right)^2\right] = E\left[\int_0^{T_b}\int_0^{T_b} w(t)\, w(\tau)\, dt\, d\tau\right] =$$

$$= \int_0^{T_b}\int_0^{T_b} \underbrace{E[w(t)\, w(\tau)]}_{R_W(t-\tau)}\, dt\, d\tau = \int_0^{T_b}\int_0^{T_b} R_W(t-\tau)\, dt\, d\tau$$

Por ser ruido blanco:

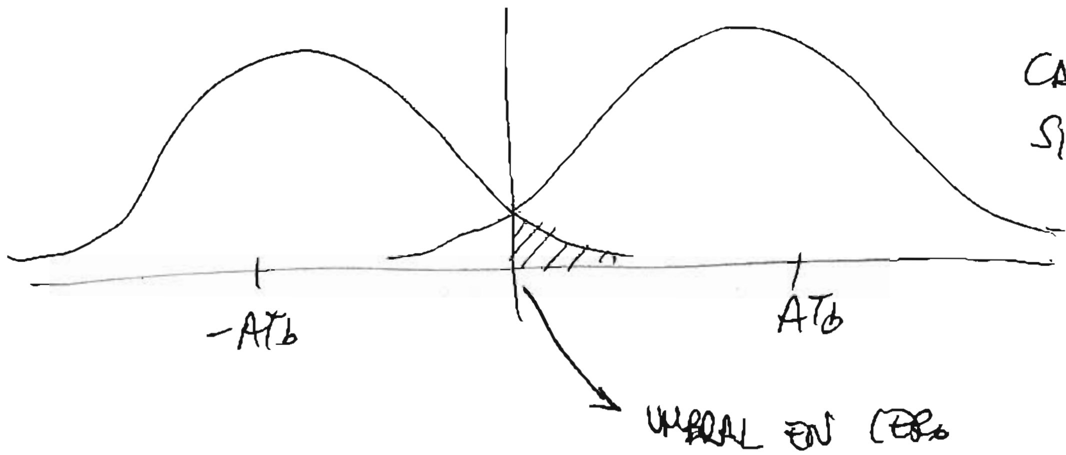
$$S_W(f) = \frac{N_0}{2} \rightleftharpoons R_W(\tau) = \frac{N_0}{2}\delta(\tau)$$

$$S_W(t-\tau) = \frac{N_0}{2}\delta(t-\tau)$$

$$\boxed{\sigma^2_{y(T_b)/\text{"1"}} = \frac{N_0}{2}\int_0^{T_b}\int_0^{T_b}\delta(t-\tau)\,d\tau\,dt = \frac{N_0}{2}\int_0^{T_b}dt = \frac{N_0 T_b}{2}}$$

Si se transmitió cero, se puede comprobar que

$$\boxed{E[y(T_b)/\text{"}\varnothing\text{"}] = -AT_b} \quad y \quad \boxed{\sigma^2_{y(T_b)/\text{"}\varnothing\text{"}} = \frac{N_0 T_b}{2}}$$



CANAL SIMETRICO.

$$\boxed{P_e = P_{e\varnothing} = P_{e1} = \int_0^\infty f(y(T_b)/\text{"}\varnothing\text{"})\,dy = \frac{1}{\sqrt{2\pi\frac{N_0T_b}{2}}}\int_0^\infty \exp\left(-\frac{(y+AT_b)^2}{2\frac{N_0T_b}{2}}\right)dy}$$

$$= \frac{1}{\sqrt{\pi N_0 T_b}}\int_0^\infty \exp\left(-\frac{(y+AT_b)^2}{N_0T_b}\right)dy \quad \left|\begin{array}{l} z = \frac{y+AT_b}{\sqrt{N_0T_b}} \\ dz = \frac{dy}{\sqrt{N_0T_b}}\end{array}\right|$$

$$= \frac{1}{\sqrt{\pi}}\int_{\frac{AT_b}{\sqrt{N_0T_b}}}^\infty \exp(-z^2)\,dz = \frac{1}{2}\operatorname{erfc}\left(\frac{AT_b}{\sqrt{N_0T_b}}\right) = \boxed{\frac{1}{2}\operatorname{erfc}\left(A\sqrt{\frac{T_b}{N_0}}\right)}$$

PROBLEMA 2 (CONTINUACION)

Conocemos todos los datos excepto Tb.

$$10^{-5} = P_e = \frac{1}{2}\,\mathrm{erfc}(u) \simeq \frac{1}{2}\,\frac{\exp(-u^2)}{u\sqrt{\pi}}$$

$$\frac{\exp(-u^2)}{u} = 2\sqrt{\pi}\cdot 10^{-5} = 3'545\cdot 10^{-5}$$

u	$\exp(-u^2)/u$
2	$9,15\cdot 10^{-3}$
3	$4,11\cdot 10^{-5}$
3,5	$1,367\cdot 10^{-6}$
3,25	$7,96\cdot 10^{-6}$
3,12	$1,898\cdot 10^{-5}$
3,05	$2,99\cdot 10^{-5}$
3,03	$3,399\cdot 10^{-5}$
3,02	$3,62\cdot 10^{-5}$
3,025	$3,51\cdot 10^{-5}$
3,022	**$3,577\cdot 10^{-5}$**

$$u = A\cdot\sqrt{\frac{T_b}{N_0}}$$

$$\frac{u^2}{A^2} = \frac{T_b}{N_0} \Rightarrow T_b = \frac{N_0\cdot u^2}{A^2}$$

$$\frac{1}{T_b} = R_b = \frac{A^2}{N_0\cdot u^2} = \frac{(10\cdot 10^{-3})^2}{5\cdot 10^{-12}\cdot(3'022)^2}$$

$$\boxed{R_b = 2,19\ \text{Mbps}}$$

(b)

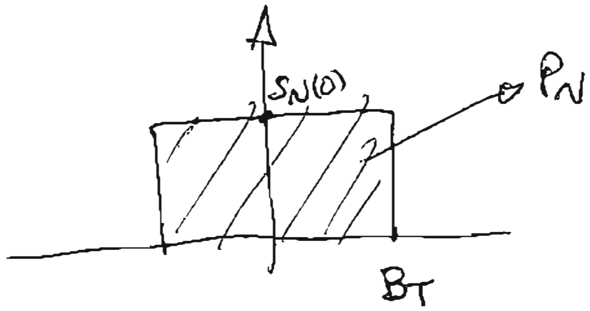
$$w(t) \longrightarrow \boxed{h(t)} \longrightarrow n(t)$$

$$S_n(f) = S_w(f)\cdot|H(f)|^2 = \frac{N_0}{2}|H(f)|^2$$

$$h(t) = \Pi\left(\frac{t - T_b/2}{T_b}\right) \rightleftharpoons T_b\,\mathrm{sinc}(f T_b)\cdot\exp\left(-j2\pi f\frac{T_b}{2}\right)$$

$$\boxed{S_N(f) = \frac{N_0}{2} T_b^2 \, \mathrm{sinc}^2(f T_b)}$$

$$P_N = \sigma^2_{y(T_b)} = \frac{N_0 T_b}{2} \qquad S_N(0) = \frac{N_0 T_b^2}{2}$$



$$S_N(0) \cdot 2 B_T = P_N$$

$$\boxed{B_T = \frac{P_N}{2 S_N(0)} = \frac{N_0 T_b / 2}{2 \cdot \frac{N_0 T_b^2}{2}} = \frac{1}{2 T_b} = \frac{R_b}{2}}$$

$$\boxed{B_T = 1'095 \text{ MHz}}$$