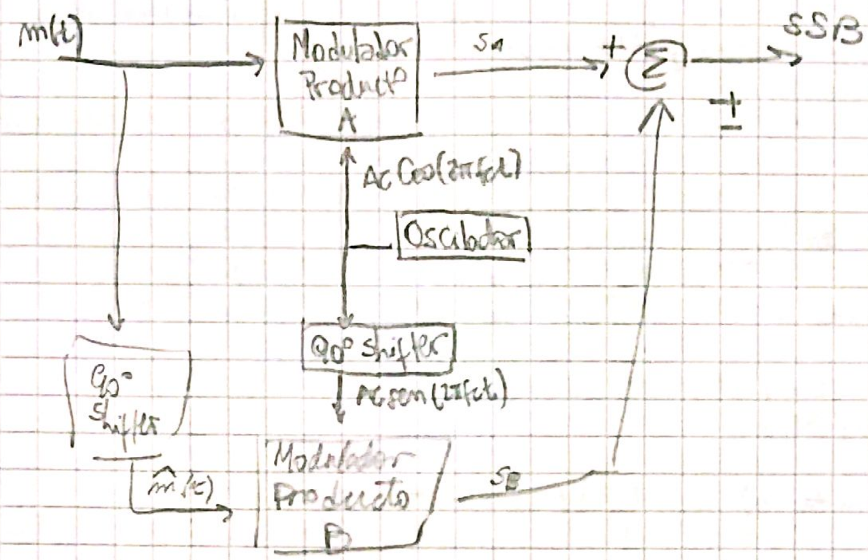
Examen Final



$m_1(t) = \cos(2\pi f_1 t)$, $f_1 = 3kHz$

$\hat{M}_1(f) = -j\, sign(f)\, M_1(f) = -j\, sign\left(\pi\,\delta(f-f_1) + \pi\,\delta(f+f_1)\right)$

$\hat{m}_1(t) = sen(2\pi f_1 t)$

$s_A(t) = A_c \cos(2\pi f_1 t)\cos(2\pi f_c t)$

$= \frac{A_c}{2}\left[\cos(2\pi(f_1+f_c)t) + \cos(2\pi(f_c-f_1)t)\right]$

$s_B(t) = A_c\, sen(2\pi f_1 t)\, sen(2\pi f_c t)$

$= \frac{A_c}{2}\left[\cos((f_c-f_1)t) - \cos((f_c+f_1)t)\right]$

SSB $\quad s_A(t) + s_B(t) = A_c \cos(2\pi(f_c-f_1)t)$ $\quad$ BLI

NOTA

b) $m_2(t) = sen(2\pi f_2 t)$

$M_2(f) = j\pi[-\delta(f-f_2)+\delta(f+f_2)]$

$\hat{M}_2(t) = j\,sign(f)\,M_2(f) = \pi\,sign(f)[-\delta(f-f_2)+\delta(f+f_2)]$

$\hat{m}_2(t) = -\cos(2\pi f_2 t)$

$s_A(t) = A_c \cos(2\pi f_c t)\,sen(2\pi f_2 t)$

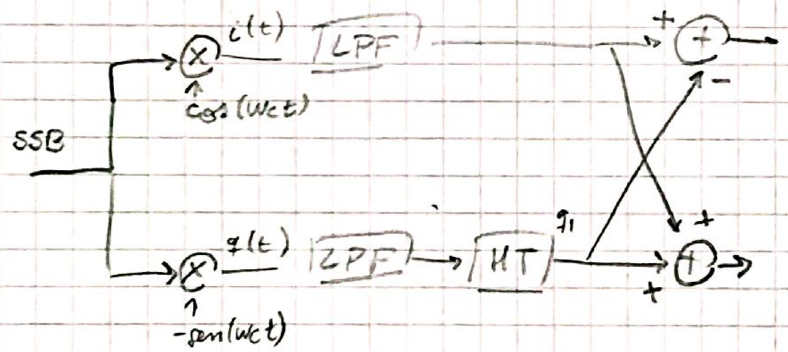
$= \frac{A_c}{2}[sen(2\pi(f_c+f_2)t) - sen(2\pi(f_c-f_2)t)]$

$s_B(t) = -A_c\,sen(2\pi f_c t)\cos(2\pi f_2 t)$

$= -\frac{A_c}{2}[sen(2\pi(f_c+f_2)t) + sen(2\pi(f_c-f_2)t)]$

$s_A(t) - s_B(t) = A_c\,sen(2\pi(f_c+f_2)t)$ BLS

c)



SSB $A_c\cos(2\pi(f_c-f_2)t)$

$i(t) = A_c\cos(2\pi(f_c-f_1)t)\cdot\cos(2\pi f_c t)$

$= \frac{A_c}{2}\left(\cos(2\pi(f_c-f_1+f_c)t) + \cos(2\pi(f_c-f_1-f_c)t)\right)$

LPF

$= \frac{A_c}{2}\left(\cancel{\cos(2\pi(2f_c-f_1)t)} + \cos(2\pi f_1 t)\right)$

$q(t) = -A_c\cos(2\pi(f_c-f_1)t)\cdot sen(2\pi f_c t)$

$= -\frac{A_c}{2}\left(sen(2\pi(f_c-f_1+f_c)t) - sen(2\pi(f_c-f_1-f_c)t)\right)$

LPF

$= \frac{A_c}{2}\left(\cancel{-sen(2\pi(2f_c-f_1)t)} - sen(2\pi f_1 t)\right)$

$q_1(t) = \frac{A}{2}\cos(2\pi f_1 t)$

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Por la rama inferior sale $A_c \cos(2\pi f_1 t)$

d) $SSB = A_c \operatorname{sen}(2\pi(f_c + f_2)t)$

$i(t) = A_c \operatorname{sen}(2\pi(f_c + f_2)t) \cdot \cos(2\pi f_c t)$

$$= \frac{A_c}{2}\left(\operatorname{sen}(2\pi(f_c + f_2 + f_c)t) + \operatorname{sen}(2\pi(f_c + f_2 - f_c)t)\right)$$

$$= \frac{A_c}{2}\left(\cancel{\operatorname{sen}(2\pi(2f_c + f_2)t}^{\circ\, LPF} + \operatorname{sen}(2\pi f_2 t)\right)$$

$q(t) = -A_c \operatorname{sen}(2\pi(f_c + f_2)t) \cdot \operatorname{sen}(2\pi f_c t)$

$$= -\frac{A_c}{2}\left(\cos(2\pi(f_c + f_2 - f_c)t) - \cos(2\pi(f_c + f_2 + f_c)t)\right)$$

$$= \frac{A_c}{2}\left(\cancel{\cos(2\pi(2f_c + f_2)t)}^{\circ\, LPF} - \cos(2\pi f_2 t)\right)$$

$q_1(t) = -\frac{A_c}{2} \operatorname{sen}(2\pi f_2 t)$

Por la rama superior sale $A_c \cdot \operatorname{sen}(2\pi f_2 t)$

1 (otro). Si BLU $s_1(t) = A_c \cos(2\pi(f_c - f_m)t)$ y $s_2(t) = A_c \cos(2\pi(f_c + f_m)t)$

$i_1(t) = A_c \cos(2\pi(f_c - f_m)t) \cdot \cos(2\pi f_c t)$

$$= \frac{A_c}{2} \cos(2\pi f_m t)$$

Demodula en la rama superior

$q_1(t) = A_c \cos(2\pi(f_c - f_m)t) \operatorname{sen}(2\pi f_c t)$

$$= \frac{A}{2} \operatorname{sen}(2\pi f_m t)$$

$\hat{q}_1(t) = -\frac{A_c}{2} \cos(2\pi f_m t)$

$i_2(t) = \frac{A_c}{2} \cos(2\pi f_m t)$

Demodula en la rama inferior

$q_2(t) = A_c \cdot \cos(2\pi(f_c + f_m)t) \operatorname{sen}(2\pi f_c t)$

$$= -\frac{A_c}{2} \operatorname{sen}(2\pi f_m t)$$

$\hat{q}_2(t) = \frac{A_c}{2} \cos(2\pi f_m t)$

NOTA

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Ejercicio 2

FM banda ancha

$\Delta f = 6,25$ kHz

$10\,Hz < f_m < 3000\,Hz$

$A_c = 5\,V$

$s(t) = A_c \cos(2\pi f_c t + \beta \operatorname{sen}(2\pi f_m t))$

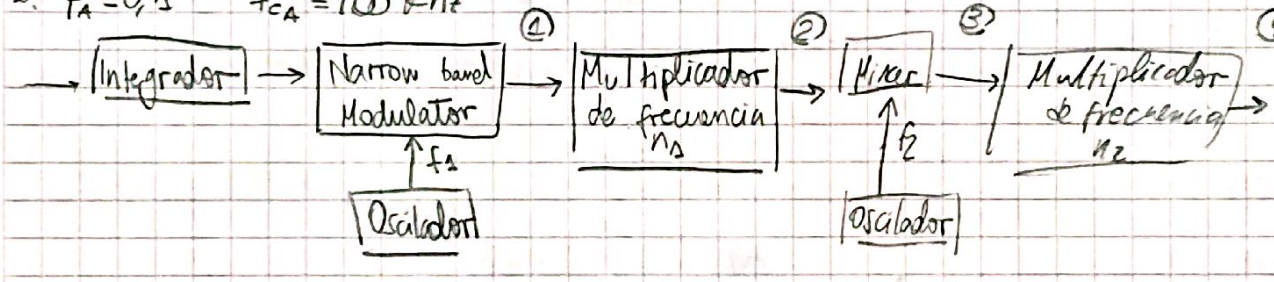
$f_{c,\text{ancha}} = 105\,MHz$

1. β, con $f_m = 10\,Hz$, $A_m = 1$

$\boxed{\Delta f = f_m \beta_{FM}}$ $\boxed{K_f = \frac{\Delta f}{A_m}}$

$\beta_{FM} = \frac{\Delta f}{f_m} = \frac{6,25\,kHz}{10\,Hz} = 625$

2. $\beta_A = 0,1$ $f_{cA} = 100\,kHz$



En ① $u(t) = A_c \cos(2\pi f_c t + \phi(t))$ con $\beta = \beta_A$

En ② $u(t) = A_c \cos(2\pi n f_c t + n\phi(t))$ con $\beta = n\beta_A$

En ③ $u(t) = A_c \cos(2\pi (n f_c + f_2) t + n\phi(t))$ con $\beta = n\beta_A$

En ④ $u(t) = A_c \cos(2\pi n (n f_c + f_2) t + n^2\phi(t))$ con $\beta = n^2\beta_A$

Como queremos FM banda ancha, recalculo el β_{ancha} para la mayor frecuencia $\beta_{\text{ancha}} = \frac{\Delta f}{3000\,Hz} = 2,083$

$\sqrt{\frac{\beta_{\text{ancha}}}{\beta_A}} < n < \sqrt{\frac{\beta_{FM}}{\beta_A}}$

$4,56 < n < 79,05$

La frecuencia de portadora es: $f_{c\,\text{Ancha}} = n^2 f_{c\,\text{ang}} + n f_2$

NOTA

3) Condición de umbral

$$\frac{A_c^2}{2} \geq 10 B_T N_0$$

$$B_T = 2\Delta f \left(1 + \frac{1}{\beta}\right)$$ por regla de Carson

$$B_T = 12{,}5\ KHz$$

$$A_c \geq \sqrt{10 \cdot 12{,}5 KHz \cdot 10^{-8} \cdot 2}$$

4) Potencia de ruido

$$P_{N_C} = W N_0 \qquad P_{N_O} = \frac{2 W^3 N_0}{3 A_c^2}$$

$$= 3\ 10^{-6}\ W \qquad = 72 W$$

5) FOM

FM

$$3\beta^2 P_n = \frac{3}{2}\beta^2$$

AM

$$\frac{\mu^2}{P + \mu^2} = \frac{\mu^2}{2 + \mu^2}$$

$$\frac{3}{2}\beta^2 = \frac{\mu^2}{2 + \mu^2}$$

$$\beta = \sqrt{\frac{1}{2+1} \cdot \frac{2}{3}} \sim 0{,}47$$

NOTA

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Ejercicio 3

$R_b = 1\,Mbit/s$ AWGN $\frac{N_0}{2} = 1 \cdot 10^{-8}$

Para banda base $B = R_S = \frac{R_b}{k}$

Para pasabanda $B = 2R_S = \frac{2R_b}{k}$

Para MSK $B = R_b \cdot \frac{3}{2}$

→ BPSK = 2PSK $M=2$, $k = 1\,bit$

$B = 2R_b = 2\,Mbit/s$

→ QPSK = 4PSK $M=4$, $k = 2\,bit$

$B = 2R_b/2 = 1\,Mbit/s$

→ 8PSK $M=8$ $k = 3\,bit$

$B = 2 \cdot R_b/3 = 0{,}67\,Mbit/s$

→ PAM $M=2$, $k = 1\,bit$

$B = R_b = 1\,Mbit/s$

→ FSK $M=2$, $k = 1\,bit$

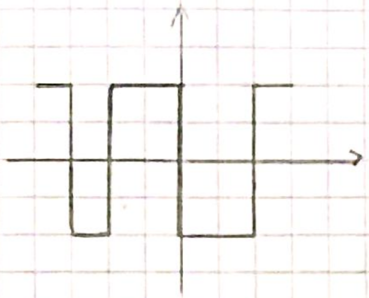
$B = 2R_b = 2\,Mbit/s$

→ 128 QAM $M = 128$ $k=7$

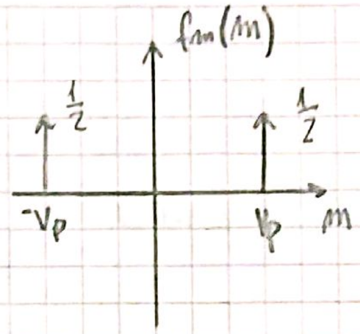
$B = \frac{2R_b}{7}$

SNR_c y P_c

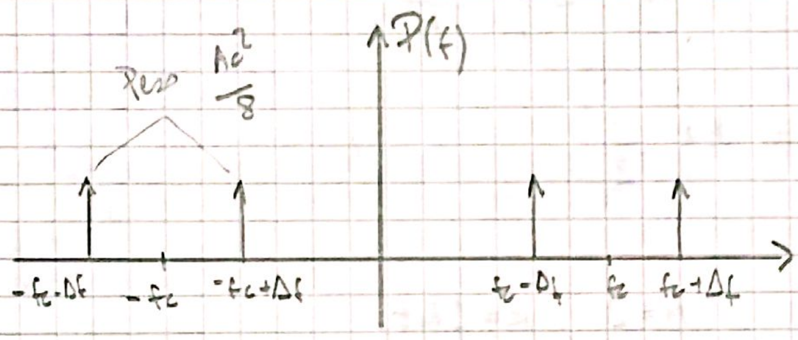
NOTA



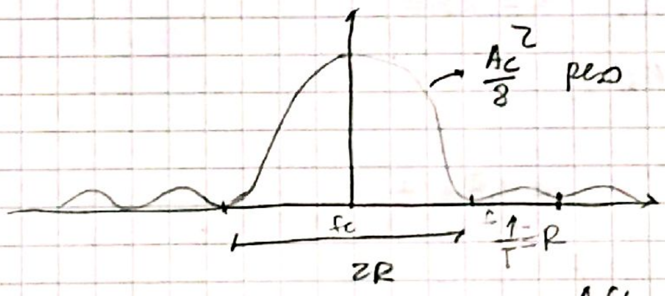
Forma de onda moduladora



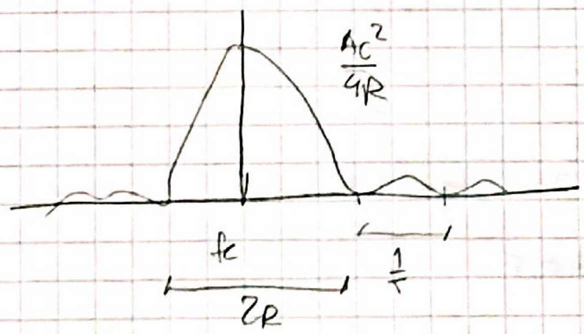
Densidad espectral de potencia de modulación digital



PSD de 2FSK



ASK



BPSK

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Ejercicio 4

$f_s = 1kHz$ → PCM PAM on-off

$SNR_Q = 52,8dB$ ± 4 σ

ancho de banda → pasabajos

$B_T = (1+\alpha)\frac{R_s}{2}$

suponiendo canal ideal, $\alpha = 0$

Si muestreo a $1kHz \to R_s = 1kHz$

$B_T = 500\ Hz$

1) $SNR_Q = 6n - 7,2 = 52,8$

$n = 10 \to M = 2^n = 1024$

$B_T = \frac{R_b}{10} \to R_b = 5kHz$

2) $SNR_{Q\mu} = SNR_{Qu} + 20\log_{10}\left(\frac{\overset{\nearrow 161}{\mu}}{\ln(1+\mu)}\right)$

$52,8dB = 6n - 7,2 + 30 \to n = 5 \to M = 2^n = 32$

3) R_b $\alpha = 0$ $B_T = (1+0)\cdot\frac{R_b}{10} \to R_b = 5kHz$

4) $B_T = (1+0,33)\frac{R_s}{2} \to B_T = 1330\ Hz$

5) $B_T = (1+\alpha)\frac{R_s}{2} \to R_s = \frac{2B_T}{1+\alpha}$ La máxima velocidad es con $\alpha = 0$

NOTA