

SOLUCIÓN DEL TEST DEL 16-1-01

1) b)

$$H = \sum_{i=1}^L p_i \cdot \log_2 \left(\frac{1}{p_i} \right) = \sum_{i=1}^{L-1} 0.5^i \cdot \log_2(2^i) + 0.5^{L-1} \cdot \log_2(2^{L-1}) =$$

$$2 \cdot (1 - (L+1) \cdot 0.5^L) + (L-1) \cdot 0.5^{L-1} = 2 - 2 \cdot L \cdot 0.5^L - 2 \cdot 0.5^L + L \cdot 0.5^{L-1} - 0.5^{L-1} =$$

$$2 - 2 \cdot L \cdot 0.5^L - 2 \cdot 0.5^L + L \cdot 0.5^L \cdot 0.5^{-1} - 0.5^L \cdot 0.5^{-1} = 2 - 2 \cdot 0.5^L - 2 \cdot 0.5^L = 2 - 4 \cdot 0.5^L$$

2) a)

$$111 * x(n) = \begin{array}{r} 1 \quad a \\ \quad 1 \quad a \\ \quad \quad 1 \quad a \\ \hline 1 \quad a + 1 \quad a + 1 \quad a \Rightarrow y_k \end{array}$$

$$-1-1-1 * x(n) = \begin{array}{r} -1 \quad -a \\ \quad -1 \quad -a \\ \quad \quad -1 \quad -a \\ \hline -1 \quad -a - 1 \quad -a - 1 \quad -a \Rightarrow y_k \end{array}$$

HLSE $\rightarrow \sum_i (y - y_k)^2 \min$ para que la media = 0

$y - \text{media} = 0.8, -0.7, -0.2, 0.3$

\parallel
0.3

$$(-0.2)^2 + (-1.7 - a)^2 + (-1.2 - a)^2 + (0.3 - a)^2 = 1.8^2 + (0.3 + a)^2 + (0.8 + a)^2 + (0.3 + a)^2 \Rightarrow$$

$$= 0.04 + 2.89 + a^2 + 3.4a + 1.44 + a^2 + 2.4a + 0.09 + a^2 - 0.6a = 3.24 + 0.09 + a^2 + 0.6a + 0.64 +$$

$$a^2 + 1.6a + 0.09 + a^2 + 0.6a \Rightarrow 4.46 + 5.2a = 4.06 + 2.8a \Rightarrow 0.4 = -2.4a \Rightarrow a = -0.16667$$

3) a)

$$\begin{array}{l} \overbrace{111\dots 1}^n \\ \underbrace{000\dots 0}_k \end{array} \rightarrow d_{\min} = n \rightarrow r = n - 1 \rightarrow (*)$$

$$\begin{array}{l} d_{\min} \geq 2e + 1 \\ r \geq 2e \end{array} \rightarrow e \left\lfloor \frac{d_{\min} - 1}{2} \right\rfloor = \begin{array}{l} n \text{ par, } e = \frac{n-2}{2} \\ n \text{ impar, } e = \frac{n-1}{2} \end{array}$$

a) $e = \frac{n-1}{2} \Rightarrow (*) e = \frac{r}{2}$

b) $d = 2e$

c) $d = 2e \rightarrow \begin{array}{l} n - 2, n \text{ par} \\ n - 1, n \text{ impar} \end{array}$

4) c)

$$u_t = 18300 \text{ bps} \quad u_t = u_m \cdot q_1 \quad q_1 = \log_2(A_1) \quad u_t' = 24400 \text{ bps}$$

$$W_{\text{QAM}} = \frac{1+a}{T} \rightarrow 4000 = (1+a) \cdot u_m \rightarrow \begin{matrix} a=0, u_m=4000 \\ a=1, u_m=2000 \end{matrix}$$

$$18300 = u_m \cdot q \quad \text{con } 2000 \leq u_m \leq 4000 \Rightarrow q_1 = 6 \frac{\text{bits}}{\text{símbolo}}$$

$$9.15 \geq q \geq 4.57 \quad A_1 = 2^6 = 64 \text{ símbolos}$$

$$q_1 = 5, 6, 7, 8, 9 \quad u_m = 3050 \text{ bauds}$$

$$u_t' = 24400 = 3050 \cdot q'$$

$$q' = 8 \rightarrow A' = 2^8 = 256 \text{ símbolos}$$

$$q = 5 \rightarrow u_m = 3660 \rightarrow q' = 6.66$$

$$q = 6 \rightarrow u_m = 3050 \rightarrow q' = 8 \rightarrow 2^8 = 256$$

$$q = 7 \rightarrow u_m = 2614 \rightarrow q' = 9.33$$

$$q = 8 \rightarrow u_m = 2287.5 \rightarrow q' = 10.66$$

$$q = 9 \rightarrow u_m = 2033.3 \rightarrow q' = 12 \rightarrow 2^{12} = 4096$$

5) a)

$$\text{Hamming} \left(\begin{matrix} n \\ 7, 4 \end{matrix} \right)$$

$$G = (I_k : P)$$

↓

$$I_4$$

$$Y(D) = R(D) + D^r \cdot X(D)$$

$$R(D) = D^r \cdot X(D) \text{ mod } g(D) \Rightarrow D^r \cdot X(D) \Big|_{g(D)}$$

$$R(D) \quad c(D)$$

Nos interesa hallar las Y(D) de las X(D) de la base.

$$n = k + r \rightarrow 7 = 4 + r \rightarrow r = 3$$

$$* X(D) = 1000 = D^3$$

$$D^3 \cdot X(D) = D^6 \quad \Big|_{D^3 + D^2 + 1}$$

$$\underline{D^6 + D^5 + D^3} \quad D^3 + D^2 + D$$

$$D^5 + D^3$$

$$\underline{D^5 + D^4 + D^2}$$

$$D^4 + D^3 + D^2$$

$$\underline{D^4 + D^3 + D}$$

$$D^3 + D = R(D)$$

$$Y(D) = \underbrace{D^2 + D}_{R(D)} + D^3 \cdot \underbrace{D^3}_{X(D)} = D^6 + D^2 + D$$

↓

$$1000:110$$

$$* X(D) = 0100 = D^2$$

$$D^3 \cdot X(D) = D^5 \quad \left| \begin{array}{r} D^3 + D^2 + 1 \\ \hline \end{array} \right.$$

$$\underline{D^5 + D^4 + D^2} \quad D^2 + D + 1$$

$$D^4 + D^2$$

$$\underline{D^4 + D^3 + D}$$

$$D^3 + D^2 + D$$

$$\underline{D^3 + D^2 + 1}$$

$$D^2 + 1 = R(D)$$

$$Y(D) = \underbrace{D+1}_{R(D)} + D^3 \cdot \underbrace{D^2}_{X(D)} = D^5 + D + 1$$

↓

1000:011

$$* X(D) = 0010 = D$$

$$D^3 \cdot X(D) = D^4 \quad \left| \begin{array}{r} D^3 + D^2 + 1 \\ \hline \end{array} \right.$$

$$\underline{D^4 + D^3 + D} \quad D + 1$$

$$D^3 + D$$

$$\underline{D^3 + D^2 + 1}$$

$$D^2 + D + 1 = R(D)$$

$$Y(D) = \underbrace{D^2 + D + 1}_{R(D)} + D^3 \cdot \underbrace{D}_{X(D)} = D^4 + D^2 + D + 1$$

↓

0010:111

$$* X(D) = 0001 = 1$$

$$D^3 \cdot X(D) = D^3 \quad \left| \begin{array}{r} D^3 + D^2 + 1 \\ \hline \end{array} \right.$$

$$\underline{D^3 + D^2 + 1} \quad 1$$

$$D^2 + 1 = R(D)$$

$$Y(D) = \underbrace{D^2 + 1}_{R(D)} + D^3 \cdot \underbrace{1}_{X(D)} = D^3 + D^2 + 1$$

↓

0001:101

$$\Rightarrow G = \begin{pmatrix} 1 & 0 & 0 & 0 & 1 & 1 & 0 \\ 0 & 1 & 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 1 & 0 & 1 & 1 & 1 \\ 0 & 0 & 0 & 1 & 1 & 0 & 1 \end{pmatrix}$$

6) d)

Hamming $\binom{15}{n} \binom{11}{k}$

$$e = 1, n = 2^r - 1, n = k + r \Rightarrow r = 4 \Rightarrow n = 2^4 - 1 = 15$$

$$d = 2e = 2 \rightarrow \text{Detecta hasta 2 errores}$$

$$d_{\min} = 2e + 1 = 3 \Rightarrow d = d_{\min} - 1 = 2$$

$$\text{Prob(no detección)} = P_{\#e} > 3 \approx P_{\#e=3} = \binom{15}{3} \cdot p^3 \cdot (1-p)^{12} \approx \binom{15}{3} \cdot p^3 = \frac{15!}{3! \cdot 12!} \cdot p^3 = 455 \cdot p^3$$

$$= 455 \cdot (10^{-3})^3 = 455 \cdot 10^{-9} = 4.55 \cdot 10^{-7}$$

7) a)

$$E = \frac{H}{L}$$

$$\left\{ \begin{aligned} H &= 2 - 4 \cdot \left(\frac{1}{2}\right)^L \Big|_{L=5} = 2 - 4 \cdot \frac{1}{32} = 2 - \frac{1}{8} = \frac{15}{8} = 1.875 \\ H &= \sum_{i=1}^5 P_i \cdot \log_2 \left(\frac{1}{P_i}\right) = \frac{1}{2} \cdot \log_2(2) + \left(\frac{1}{2}\right)^2 \cdot \log_2(2)^2 + \left(\frac{1}{2}\right)^3 \cdot \log_2(2)^3 + \left(\frac{1}{2}\right)^4 \cdot \log_2(2)^4 = \\ &= \frac{1}{2} + \frac{1}{4} \cdot 2 + \frac{1}{8} \cdot 3 + \frac{1}{16} \cdot 4 = \frac{1}{2} + \frac{1}{2} + \frac{3}{8} + \frac{8}{16} = \frac{15}{8} = 1.875 \end{aligned} \right.$$

$$A \quad \frac{1}{2}$$

B $\frac{1}{4}$	}	$\frac{1}{2}H$	A	1
C $\frac{1}{8}$			B	0 1
D $\frac{1}{16}$			C	0 0 1
E $\frac{1}{16}$			D	0 0 0 1
			E	0 0 0 0

$$\bar{L} = \frac{1}{2} \cdot 1 + \frac{1}{4} \cdot 2 + \frac{1}{8} \cdot 3 + \frac{1}{16} \cdot 4 = \frac{1}{2} + \frac{1}{2} + \frac{3}{8} + \frac{8}{16} = \frac{15}{8} = 1.875$$

$$E = 1$$

8) b)

a)

$$\begin{aligned} H &= 0.25 \cdot \log_2 \left(\frac{1}{0.25}\right) + 0.5 \cdot \log_2 \left(\frac{1}{0.5}\right) + 0.15 \cdot \log_2 \left(\frac{1}{0.15}\right) + 0.1 \cdot \log_2 \left(\frac{1}{0.1}\right) \\ &= 0.5 + 0.5 + 0.4105 + 0.3322 = 1.7427 \frac{\text{bits}}{\text{simbolo}} \end{aligned}$$

$$\text{donde } \log_2(x) = \frac{\log(x)}{\log 2}$$

b)

$$d_{\min} \geq 2e + 1 \Rightarrow 4 \geq 2e \Rightarrow e = 2 \quad r > 2e \Rightarrow r = 4$$

$$e\text{-perfecto} \Rightarrow (\text{ver debajo}) \Rightarrow n = 5 \rightarrow \text{código } \binom{5,1}{n, k} \quad \begin{array}{l} n = k + r \\ 5 = k + 4 \rightarrow 1 \end{array}$$

$$P_{\text{error}} = P_{\#e \geq 3} \approx P_{\#e=3} = \binom{5}{3} \cdot p^3 \cdot (1-p)^2 \approx \binom{5}{3} \cdot p^3 = 10 \cdot (10^{-2})^3 = 10^{-5}$$

$$2^r = 1 + \binom{n}{1} + \binom{n}{2} \text{ ya que } e = 2$$

$$2^r = 1 + n + \frac{n!}{2!(n-2)!} = 1 + n + \frac{n \cdot (n-1)}{2}$$

$$2^4 - 1 = n + \frac{n^2 - n}{2} \rightarrow 30 = 2n + n^2 - n \rightarrow n^2 + n - 30 = 0$$

$$n = \frac{-1 \pm \sqrt{1+120}}{2} = \frac{-1 \pm 11}{2} \rightarrow \begin{matrix} 5 \\ -6 \end{matrix} \rightarrow n = 5$$

$$n = k + r$$

$$5 = k + 4 \rightarrow k = 1 \rightarrow \text{código}(5,1)$$

$$P_E = P_{\#e \geq 3} \approx P_{\#e=3}$$

c)

1 A

2 B

3 C

4 D

5 AC

6 CB

7 BC

8 CBA

9) d)

QAM-4

PAM

$$a_1 = 0.3$$

$$¿a_2?, A \uparrow \uparrow$$

$$\left(\frac{S}{N_1}\right)$$

$$\left(\frac{S}{N_2}\right) = 18000 \cdot \frac{S}{N_1}$$

$$P_{E1}$$

$$P_{E2} = P_{E1} = P_{E1}$$

$$P_{E1} = N_v \cdot Q\left[\sqrt{\frac{3(1+a)}{A^2-1} \cdot \left(\frac{S}{N_1}\right)}\right]$$

$$P_{E2} = N_v \cdot Q\left[\sqrt{\frac{3(1+a)}{A^2-1} \cdot \left(\frac{S}{N_2}\right)}\right]$$

$$N_{v1} = 4 \cdot \left(1 - \frac{1}{\sqrt{A}}\right)$$

$$N_{v2} = 2 \cdot \left(1 - \frac{1}{A}\right)$$

$$N_{v2} = 4 \cdot \left(1 - \frac{1}{2}\right) = 2$$

$$N_{v2} \cong 2$$

$$P_E = 2 \cdot Q\left(\sqrt{\frac{3 \cdot 1.3}{3} \cdot \left(\frac{S}{N_1}\right)}\right)$$

$$P_E = 2 \cdot Q\left(\sqrt{\frac{3(1+a)}{A^2-1} \cdot 18000 \cdot \left(\frac{S}{N_2}\right)}\right)$$

$$1.3 \cdot \left(\frac{S}{N_1}\right) = \frac{3 \cdot (1+a)}{A^2-1} \cdot 18000 \cdot \left(\frac{S}{N_1}\right) \rightarrow (A^2-1) = \frac{5400}{1.3} \cdot (1+a) \approx A^2 = 41538.46 \cdot (1+a)$$

siendo $0 < a < 1 \rightarrow \left. \begin{matrix} a = 0 \rightarrow A^2 = 41538.46 \\ a = 1 \rightarrow A^2 = 83076.92 \end{matrix} \right\}$ un cuadrado perfecto entre ambos

$$65536 = 256^2 \rightarrow a = 0.57 \rightarrow A \in \{203.8, 288.23\} \rightarrow A = 2^q = 256 \rightarrow q = 8 \frac{\text{bits}}{\text{símbolo}}$$

10) d)

$$L = 2^5 - 1 = 31, p^0(D) = D^2 + D^4, p^{31}(D) = p^0(D)$$

a)

$$p^n(D) = 1 + D + D^3 + D^4$$

$$D \cdot p^n(D) = D + D^2 + D^4 + D^5 \quad | \underline{D^5 + D^2 + 1}$$

$$\frac{1 + D^2 + D^5}{D^4 + D + 1} \quad 1$$

$$D^4 + D + 1 \equiv 11001 \rightarrow \text{No}$$

b)

$$p^n(D) = 1 + D^4$$

$$D \cdot p^n(D) = D + D^5 \quad | \underline{D^5 + D^2 + 1}$$

$$\frac{D^5 + D^2 + 1}{D^2 + D + 1} \quad 1$$

$$D^2 + D + 1 \equiv 110 \rightarrow \text{No}$$

c)

$$p^n(D) = D^3 + D^4$$

$$D \cdot p^n(D) = D^4 + D^5 \quad | \underline{D^5 + D^2 + 1}$$

$$\frac{D^5 + D^2 + 1}{D^4 + D^2 + 1} \quad 1$$

$$D^4 + D^2 + 1 \neq p^0(D) \rightarrow \text{No}$$

11) a)

$$y(n) = \{1.5, 0.6, -0.7\}$$

		y_k			$\eta = y - y_k$			$\sigma_\eta^2 = \frac{\sum \eta^2}{3}$
1	1	1	1.5	0.5	0.5	-0.9	-1.2	0.83
1	-1	1	-0.5	-0.5	0.5	1.1	-0.2	0.5
-1	1	1	0.5	0.5	0.5	0.1	-1.2	0.56
-1	-1	-1	-1.5	-0.5	2.5	2.1	-0.2	3.56

$$1 \quad 1 \quad \quad \quad 1 \quad -1 \quad \quad \quad -1 \quad 1 \quad \quad \quad -1 \quad -1$$

$$\underline{\quad 0.5 \quad 0.5 \quad \quad \quad 0.5 \quad -0.5 \quad \quad \quad -0.5 \quad 0.5 \quad \quad \quad -0.5 \quad -0.5}$$

$$1 \quad 1.5 \quad 0.5 \quad \quad 1 \quad -0.5 \quad -0.5 \quad \quad -1 \quad 0.5 \quad 0.5 \quad \quad -1 \quad -1.5 \quad -0.5$$

12) b)

$$ECM = E\{a^2\} \cdot DCM + \underbrace{\frac{s_h^2}{h^2(0)}}_0 \approx E\{a^2\} \cdot DCM$$

$$DCM = \frac{\sum_{n \neq 0} h^2(n)}{h^2(0)} \rightarrow \text{será el que tenga } P_E \text{ menor} \Rightarrow ECM \text{ menor} \Rightarrow DCM \text{ menor, ya que}$$

no hay ruido

$$\left(\frac{s}{N_2} \right)$$

GRUPO A :

a)

$$\begin{array}{r} 0.0165 \quad 0.168 \quad 0.0255 \\ \quad \quad 0.11 \quad 1.12 \quad 0.17 \\ \quad \quad \quad 0.022 \quad 0.224 \quad 0.034 \\ \hline \end{array}$$

$$h(n) = 0.0165 \quad 0.278 \quad 1.1675 \quad 0.394 \quad 0.034 \rightarrow \text{DCM} = 0.1716$$

b)

$$\begin{array}{r} -0.03 \quad 0.159 \quad -0.02505 \\ \quad \quad -0.2 \quad 1.06 \quad -0.167 \\ \quad \quad \quad -0.04 \quad -0.212 \quad -0.0334 \\ \hline \end{array}$$

$$h(n) = -0.03 \quad -0.041 \quad 0.9949 \quad -0.379 \quad -0.0334 \rightarrow \text{DCM} = 0.1488$$

c)

$$\begin{array}{r} -0.0465 \quad 0.1755 \quad 0.0165 \\ \quad \quad -0.31 \quad 1.17 \quad 0.11 \\ \quad \quad \quad -0.062 \quad 0.234 \quad 0.022 \\ \hline \end{array}$$

$$h(n) = 0.0465 \quad -0.1345 \quad 1.1245 \quad 0.344 \quad 0.022 \rightarrow \text{DCM} = 0.1099$$

d)

$$\begin{array}{r} -0.0165 \quad 0.1425 \quad 0.045 \\ \quad \quad -0.11 \quad 0.95 \quad 0.3 \\ \quad \quad \quad -0.022 \quad 0.19 \quad 0.06 \\ \hline \end{array}$$

$$h(n) = -0.0165 \quad 0.325 \quad 0.973 \quad 0.49 \quad 0.06 \rightarrow \text{DCM} = 0.2588$$

GRUPO B :

a)

$$\begin{array}{r} 0.033 \quad 0.336 \quad 0.051 \\ \quad \quad 0.11 \quad 1.12 \quad 0.17 \\ \quad \quad \quad 0.011 \quad 0.112 \quad 0.017 \\ \hline \end{array}$$

$$h(n) = 0.033 \quad 0.446 \quad 1.182 \quad 0.282 \quad 0.017 \rightarrow \text{DCM} = 0.2$$

b)

$$\begin{array}{r} -0.06 \quad 0.318 \quad -0.0501 \\ \quad \quad -0.2 \quad 1.06 \quad -0.167 \\ \quad \quad \quad -0.02 \quad -0.106 \quad -0.0167 \\ \hline \end{array}$$

$$h(n) = -0.06 \quad 0.118 \quad 0.9898 \quad -0.061 \quad -0.0167 \rightarrow \text{DCM} = 0.0219$$

c)

$$\begin{array}{r} -0.093 \quad 0.351 \quad 0.033 \\ \quad \quad -0.31 \quad 1.17 \quad 0.11 \\ \quad \quad \quad -0.031 \quad 0.117 \quad 0.011 \\ \hline \end{array}$$

$$h(n) = -0.093 \quad 0.041 \quad 1.172 \quad 0.227 \quad 0.011 \rightarrow \text{DCM} = 0.045$$

c)

$$\begin{array}{cccc} -0.033 & 0.285 & 0.09 & \\ & -0.11 & 0.95 & 0.3 \\ & & -0.011 & 0.095 & 0.03 \\ \hline \end{array}$$

$$h(n) = -0.033 \quad 0.175 \quad 1.029 \quad 0.395 \quad 0.03 \rightarrow \text{DCM} = 0.1781$$

a) $\text{DCM} = 0.18 = 0.65 \cdot 0.1716 + 0.35 \cdot 0.2$

b) $\text{DCM} = 0.1043 = 0.65 \cdot 0.1488 + 0.35 \cdot 0.0219$

c) $\text{DCM} = 0.087 = 0.65 \cdot 0.1099 + 0.35 \cdot 0.045$

d) $\text{DCM} = 0.1337 = 0.65 \cdot 0.2588 + 0.35 \cdot 0.1781$

13) d)

$$\left. \begin{aligned} \Delta_u(n+1) &= \mathbf{a} \cdot \Delta_u(n) + \frac{\mathbf{b}}{y^2(n)} \\ E\{\Delta_u(n+1)\} &= \frac{1}{L_e \cdot R_y(0)} \\ E\{\Delta_u(n+1)\} &\approx E\{\Delta_u(n)\} \end{aligned} \right\}$$

$$E\left\{ \mathbf{a} \cdot \Delta_u(n) + \frac{\mathbf{b}}{y^2(n)} \right\} = \mathbf{a} \cdot E\{\Delta_u(n)\} + \mathbf{b} \cdot \underbrace{\frac{1}{E\{y^2(n)\}}}_{R_y(0)}$$

$$(1-\mathbf{a}) \cdot E\{\Delta_u(n)\} = \frac{\mathbf{b}}{R_y(0)}$$

$$E\{\Delta_u(n)\} = \frac{\mathbf{b}}{(1-\mathbf{a}) \cdot R_y(0)} = \frac{1}{L_e \cdot R_y(0)} \Rightarrow L_e = \frac{1-\mathbf{a}}{\mathbf{b}}$$

a)

$$\frac{1 - \frac{1}{2}}{\frac{1}{2}} = 1 = L_e \rightarrow \text{No}$$

b)

$$\frac{1 - \frac{2}{3}}{\frac{3}{2}} = \frac{\frac{1}{3}}{\frac{3}{2}} = 0.22 = L_e \rightarrow \text{No}$$

c)

$$\frac{1 - \frac{1}{3}}{\frac{1}{2}} = \frac{\frac{2}{3}}{\frac{1}{2}} = 1.33 = L_e \rightarrow \text{No}$$

14) c)

$\mathbf{s}_h = 0 \rightarrow \text{óptimo} = \text{inversor canal}$

$$\mathbf{r}_x(0) = 0.86$$

$$\mathbf{r}_x(1) = 0.09$$

$$\mathbf{r}_x(2) = -0.02$$

$$\begin{pmatrix} 0.86 & 0.09 & -0.02 \\ 0.09 & 0.86 & 0.09 \\ -0.02 & 0.09 & 0.86 \end{pmatrix} \cdot \begin{pmatrix} c_{-1} \\ c_0 \\ c_{-1} \end{pmatrix} = \begin{pmatrix} 0.2 \\ 0.9 \\ -0.1 \end{pmatrix} \rightarrow \begin{pmatrix} c_{-1} \\ c_0 \\ c_{-1} \end{pmatrix} = \begin{pmatrix} 0.1166 \\ 1.05777 \\ -0.2242 \end{pmatrix}$$

$$h(0) = c_{-1} \cdot x_1 + c_0 \cdot x_0 + c_{-1} \cdot x_{-1} = 0.989$$

$$\bar{c}_0 = \frac{c_0}{h(0)} = 1.060157$$

15) a)

$$\mathbf{a} = \arctg\left(\frac{0.76+0.05}{1.11+0.05}\right) = \arctg\left(\frac{0.81}{1.16}\right) = 0.609 \text{ rad} = 34.925^\circ$$

↓

$$\text{đ rad} \rightarrow 180^\circ$$

$$0.609 \text{ rad} \rightarrow \mathbf{a}$$

$$45 - \mathbf{a} = 10.07^\circ$$

16) c)

$$v_t = C = W \cdot \log_2\left(1 + \frac{S}{N}\right) \rightarrow N = 10^{-3}$$

$$S = 124 \cdot 10^{-3} \cdot K^2$$

$$W = 3000$$

$$5 = \log_2(1 + 124 \cdot K^2) \quad C = 15000$$

$$32 = 1 + 124 \cdot K^2$$

$$K = 0.5$$

17) a)

$p = 10^{-3}$, $D = 4$ con $\frac{6 > 4}{L \geq D} \rightarrow$ Se puede suponer canal sin memoria (entrelazado)

$$P_e(\text{bloque}) = P_{\#e \geq 2} \approx P_{\#e=2} = \binom{7}{2} \cdot p^2 \cdot (1-p)^5 \approx \binom{7}{2} \cdot p^2 = 21 \cdot (10^{-3})^2 = 21 \cdot 10^{-6} = 2.1 \cdot 10^{-5}$$

18) a)

$$R_y(0) = \frac{\sum y^2(i)}{7} = 79.23$$

$$\Delta_v \approx \frac{1}{L_e \cdot R_y(0)} = \frac{1}{3 \cdot 79.23} = 0.02945$$

19) c)

$$P_E = N_v \cdot Q\left[\sqrt{\frac{3(1+a)}{A-1} \cdot \frac{S}{N}}\right], N_v = 4 \cdot \left(1 - \frac{1}{\sqrt{A}}\right)$$

$$v_t = v_m \cdot \log_2(A)$$

$$W_{QAM} = (1+a) \cdot v_m \rightarrow 21600 = 1.5 \cdot v_m \rightarrow v_m = 14400 \text{ baudios}$$

$$28800 = 14400 \cdot \log_2(A) \rightarrow A = 4$$

$$N_v = 4 \cdot \left(1 - \frac{1}{2}\right) = 2 \rightarrow P_E = 2 \cdot Q\left[\sqrt{\frac{3 \cdot 1.5}{3} \cdot \frac{S}{N}}\right] \leq 10^{-7}$$

$$Q(x) = 5 \cdot 10^{-8} = 0.5 \cdot e^{-\frac{x^2}{2}} \rightarrow x = 5.6777$$

$$\sqrt{1.5 \cdot \frac{S}{N}} = 5.6777 \rightarrow \frac{S}{N} = 21.49 \equiv 13.32 \text{ dB}$$

20) d)

a)

No, al propagar errores, es la otra configuración, la autosincronizante

c)

.....00011000....

.....01001000....

↓ ↓

1 D²

$$c(D) = 1 + D^2$$