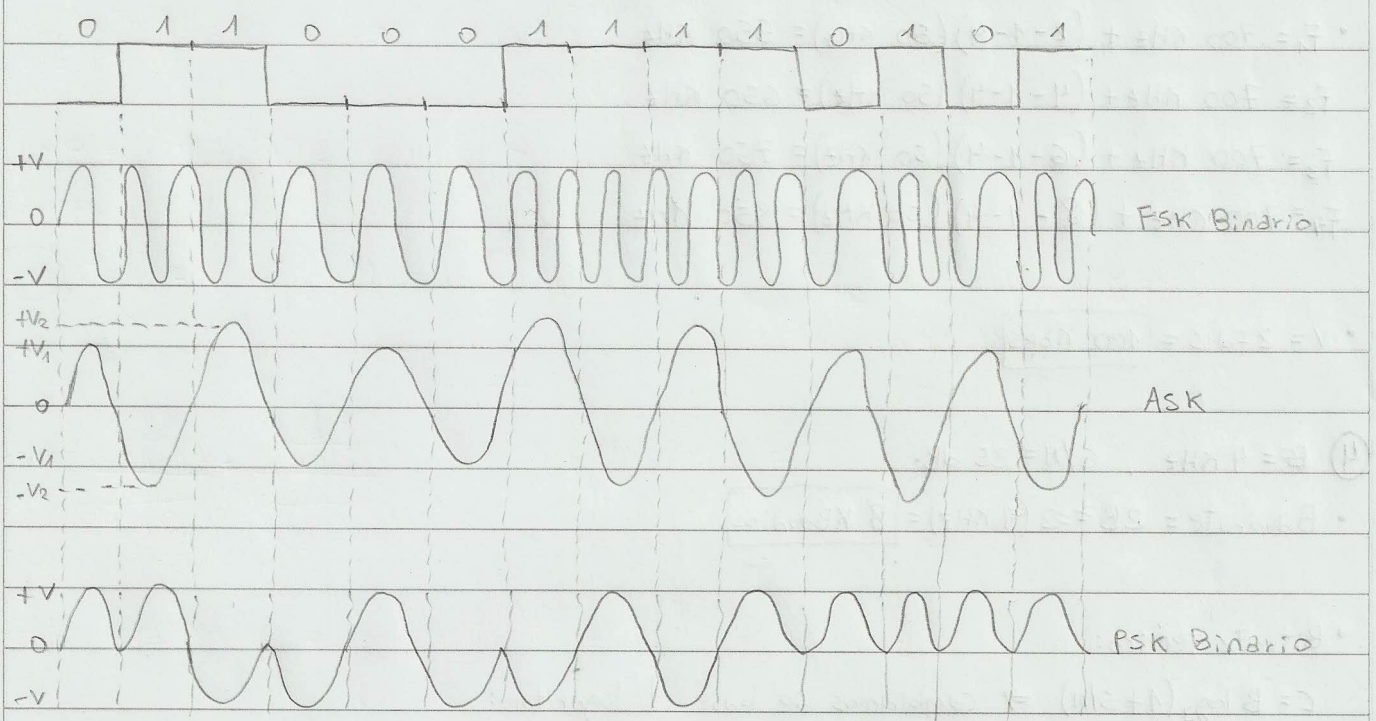
Codificación de señales - Nyquist y Shannon

① Tren de bits: 0110001111 0101



② $F_c = 500$ KHz , $F_d = 30$ KHz , $M = 8$

a) $F_i = F_c + (2i - 1 - M) F_d \Rightarrow$

$F_1 = 500\ KHz + (2 - 1 - 8)(30\ KHz) = 290\ KHz$

$F_2 = 500\ KHz + (4 - 1 - 8)(30\ KHz) = 350\ KHz$

$F_3 = 500\ KHz + (6 - 1 - 8)(30\ KHz) = 410\ KHz$

$F_4 = 500\ KHz + (8 - 1 - 8)(30\ KHz) = 470\ KHz$

$F_5 = 500\ KHz + (10 - 1 - 8)(30\ KHz) = 530\ KHz$

$F_6 = 500\ KHz + (12 - 1 - 8)(30\ KHz) = 590\ KHz$

$F_7 = 500\ KHz + (14 - 1 - 8)(30\ KHz) = 650\ KHz$

$F_8 = 500\ KHz + (16 - 1 - 8)(30\ KHz) = 710\ KHz$

b) Velocidad de transmisión: $2F_d = \frac{1}{T_s} \Rightarrow$ **60 Kbps**

c) $\Delta F = B = (F_8 + F_d) - (F_1 - F_d) = F_8 + F_d - F_1 + F_d = F_8 - F_1 + 2F_d =$ **480 KHz**

Otra forma:

$\Delta F = 2MF_d = 2 \cdot 8 (30\ KHz) =$ **480 KHz**

③ $f_c = 700$ KHz, $\Delta F = 400$ KHz, $L = 2 \rightarrow M = 2^L = 2^2 = 4$

- $\Delta F = 2M f_d \Rightarrow f_d = \frac{\Delta F}{2M} = \frac{400 \text{ KHz}}{2 \cdot 4} = 50$ KHz

- $F_1 = 700 \text{ KHz} + (2-1-4)(50 \text{ KHz}) = 550$ KHz
  $F_2 = 700 \text{ KHz} + (4-1-4)(50 \text{ KHz}) = 650$ KHz
  $F_3 = 700 \text{ KHz} + (6-1-4)(50 \text{ KHz}) = 750$ KHz
  $F_4 = 700 \text{ KHz} + (8-1-4)(50 \text{ KHz}) = 850$ KHz

- $V = 2 f_d s =$ **100 Kbps**

④ $B = 4$ KHz, $S/N = 35$ dB

- Baudrate $= 2B = 2(4 \text{ KHz}) =$ **8 KBaudios**

- Bitrate teórico:

  $C = B \log_2(1 + S/N) \Rightarrow$ cambiamos de base el logaritmo:

  $\log_a X = \frac{\log_b X}{\log_b a} \Rightarrow \log_2(1+S/N) = \frac{\log_{10}(1+S/N)}{\log_{10} 2}$

  $S/N(dB) = 10 \log(S/N) \Rightarrow S/N = 10^{S/N(dB)/10} = 10^{35 dB/10} = 3162{,}28$

  $C = B \frac{\log(1+S/N)}{\log 2} = (4 \text{ KHz}) \frac{\log(1+3162{,}28)}{\log 2} =$ **46,5 Kbps**

⑤ Módem 32-PSK, $B = 4$ KHz,

$M = 32$

- Bitrate real $= 2B \log_2 M = 2(4 \text{ KHz}) \log_2 32 =$ **40 Kbps**

Práctica N° 4

⑥ Módem 4-PSK ⇒ $M=4$, $C_{real}=64$ Kbps

$$C = 2B\log_2 M \Rightarrow B = \frac{C}{2\log_2 M} = \frac{64\ Kbps}{2\log_2 4} = \boxed{16\ KHz}$$

⑦ Módem 64-QAM ⇒ $M=64$, $B=50$ KHz, $S/N = 5{,}2\times10^4$

- Bitrate teórico $= B\log_2(1+S/N) = (50\ KHz)\log_2(1+5{,}2\times10^4) = 783{,}3$ Kbps
- Bitrate real $= 2B\log_2 M = 2(50\ KHz)\log_2 64 = \boxed{600\ Kbps}$ → máxima velocidad binaria

Bitrate real < Bitrate teórico

⑧ $M_{máx} = \sqrt{1+S/N} \Rightarrow S/N = M_{max}^2 - 1 = 64^2 - 1 = 4095$

$S/N\ (dB) = 10\log(S/N) = 10\log 4095 = \boxed{36\ dB}$

⑨ $B=4$ KHz, $S/N = 37$ dB

- $S/N\ (dB) = 10\log(S/N) \Rightarrow S/N = 10^{S/N(dB)/10} = 10^{37dB/10} = 5011{,}87$
- Si el ruido se duplica ⇒ $S/N = (S/N)/2 = 2505{,}93$
- $M_{máx} = \sqrt{1+S/N} = \sqrt{1+2505{,}93} = 50 \Rightarrow M=32 \Rightarrow \boxed{32\text{-QAM}}$

⑩ $B=8$ MHz, $L=4 \Rightarrow M = 2^L = 2^4 = 16$

Bitrate real $= 2B\log_2 M = 2(8\ MHz)\log_2 16 = \boxed{64\ Mbps}$