ENEE3309

Communication Notes

Digital communication systems

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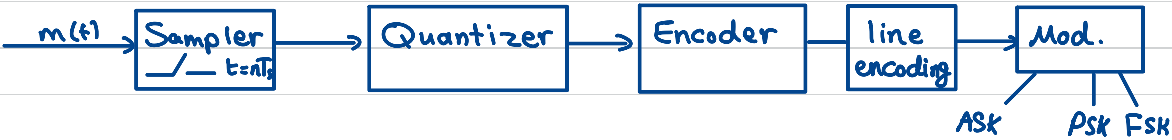
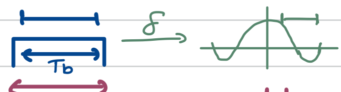
Digital Communication System



Line encoding :

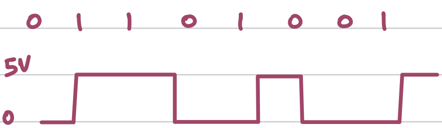
① Unipolar non-return to zero (NRZ)

digit 0 → 0V
digit 1 → 5V



bit duration = T_b → data rate

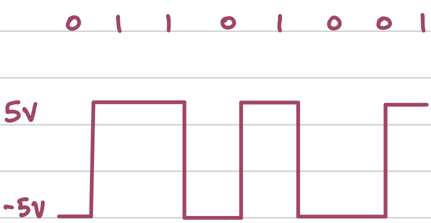
bit rate = $R_b = \left(\frac{1}{T_b}\right)$



DC value ✓

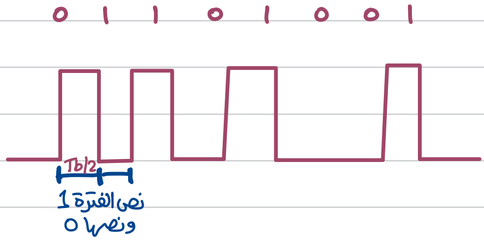
② Polar NRZ

digit 0 → −5V
digit 1 → 5V



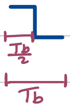
DC value ✗

③ Unipolar Rz

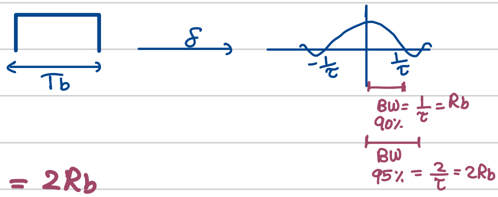


digit 0 ⟶ 0V

digit 1 ⟶



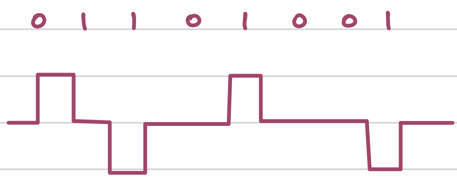
To Evaluate BW



$$BW_{90\%} = \frac{1}{\frac{Tb}{2}} = \frac{2}{Tb} = 2Rb$$

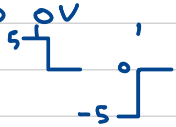
$$BW_{95\%} = \frac{2}{\frac{Tb}{2}} = \frac{4}{Tb} = 4Rb$$

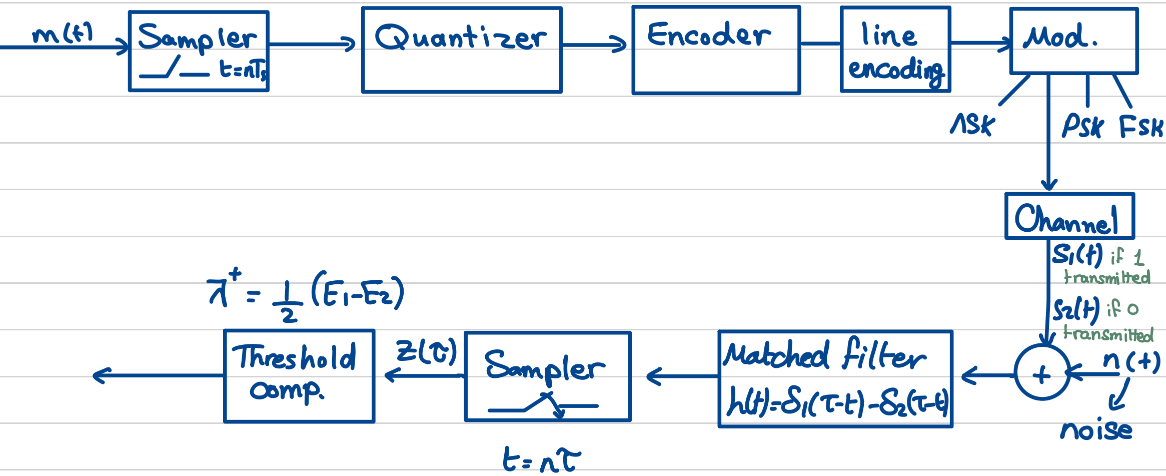
④ Bipolar Rz



digit 0 ⟶ 0V

digit 1 ⟶





AWGN

$z(\tau) > \lambda^* \rightarrow 1$ is transmitted

$z(\tau) < \lambda^* \rightarrow 0$ is transmitted

Note:

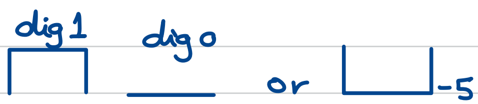
- τ : bit duration $\tau = T_b$
- $R_b : \frac{1}{\tau} = \frac{1}{T_b}$: bit Rate

- $E1 =$ energy for $S_1(t)$

where $E1 = \int_0^{\tau} S_1^2(t)\,dt \quad E2 = \int_0^{\tau} S_2^2(t)\,dt$

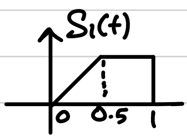
- $E_{avg} = E_b =$ average energy per bit $E_b = \frac{E_1 + E_2}{2}$

Base Band Signal transmission



if $S_1(t) = -S_2(t)$ [antipodal]

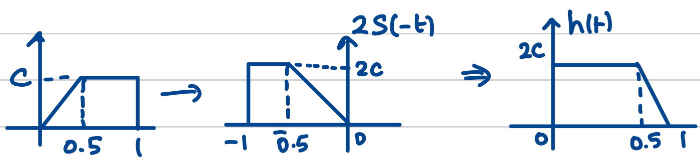
Example : the binary digital communication signaling scheme emplies the following 2 equal probable signals $S_1(t)$ and $S_2(t) = -S_1(t)$ [antipodal] to represent binary logic 1 and 0 respectively over a channel corrupted by AWGN with power spectral density $\frac{N_o}{2}$ w/Hz . Here,



bit rate $= 1 \left(\frac{1}{\tau}\right)$

ⓐ Find and sketch the impulse response $h(t)$, of the matched filter.

$$h(t) = S_1(T-t) - S_2(T-t)$$
$$= 2S_1(T-t)$$
$$= 2S_1(1-t)$$



ⓑ Evaluate average energy per bit

$$E_1 = \int_0^T S_1^2(t)\,dt \;,\; E_2 = \int_0^t S_2^2(t)\,dt \rightarrow E_1 = E_2$$

$$\rightarrow E_{avg} = \frac{E_1 + E_2}{2}$$

ⓒ Evaluate threshold comp. λ^+

$$\lambda^+ = \frac{1}{2}(E_1 - E_2) = 0$$

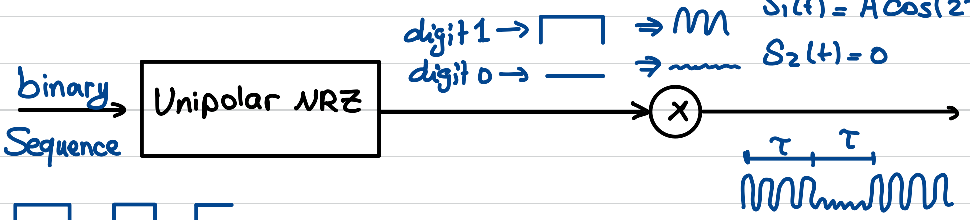
ⓓ Evaluate P_b

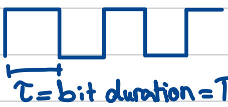
$$P_b = Q\left(\sqrt{\frac{\int_0^T (s_1(t) - s_2(t))^2 \, dt}{2\eta_0}}\right)$$

- Binary Amplitude shift Keying (BASK)

$S_1(t) = A\cos(2\pi f_c t)$

$S_2(t) = 0$





$\frac{1}{\tau} = R_b =$ bit Rate

$$E_1 = \int_0^{\tau} s(t)^2 dt = \int_0^{\tau} A^2 \cos^2(2\pi f_c t)\, dt = \int_0^{\tau} \frac{A^2}{2} dt + \int_0^{\tau} \frac{A^2}{2} \cos(4\pi f_c t)\, dt$$

$$= \frac{A^2}{2}\tau + \frac{A^2}{2} \cdot \frac{1}{4\pi f_c}\left(\sin(4\pi f_c t) - \sin(0)\right) ; \ f_c = \frac{n}{\tau}$$

$$E_2 = \int_0^{\tau} (0)^2 d\tau = 0 \qquad = \frac{A^2}{2}\tau$$

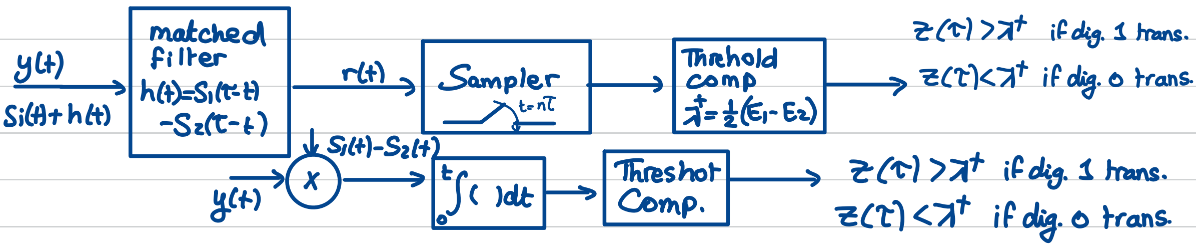
average energy per bit

$$E_{avg} = \frac{E_1 + E_2}{2} = \frac{E_1}{2} = \frac{A^2\tau}{4}$$

$$\lambda^+ = \frac{1}{2}(E_1 - E_2) = \frac{A^2\tau}{4} = E_{avg}$$

To obtain optimum Receiver

- Matched Filter



Note: $r(t) = y(t) * h(t)$

$$= \int_{-\infty}^{\infty} y(\lambda)\, h(t-\lambda)\, d\lambda$$

$$= \int_{-\infty}^{\infty} y(\lambda)\left[S_1(\lambda) - S_2(\lambda)\right] d\lambda$$

Prob. of Error $\Rightarrow P_b = Q\left(\sqrt{\int_0^{\tau} \frac{(S_1(t)-S_2(t))^2}{2N_0} dt}\right)$

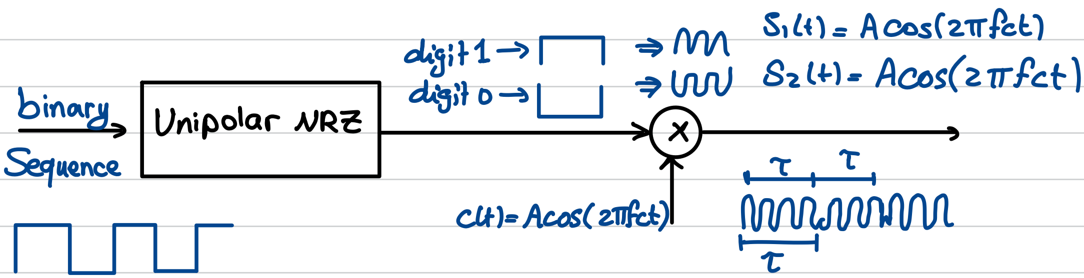
$$P_b = Q\left(\frac{\sqrt{\int_0^{\tau}(S_1(t)-S_2(t))^2 dt}}{2N_0}\right) = Q\left(\sqrt{\frac{\int_0^{\tau}(S_1(t))^2}{2N_0}}\right)$$

$$= Q\left(\sqrt{\frac{E_1}{2N_0}}\right) = Q\left(\sqrt{\frac{A^2\tau}{4N_0}}\right) = Q\left(\sqrt{\frac{E_{avg}-E_b}{N_0}}\right) = Q\left(\sqrt{SNR}\right)$$

↳ Signal noise ratio

Binary phase shift Keying (BPSK)

$$\left.\begin{aligned} S_1(t) &= A\cos(2\pi f_c t) \\ S_2(t) &= -A\cos(2\pi f_c t) \end{aligned}\right\} \text{antipodal}$$



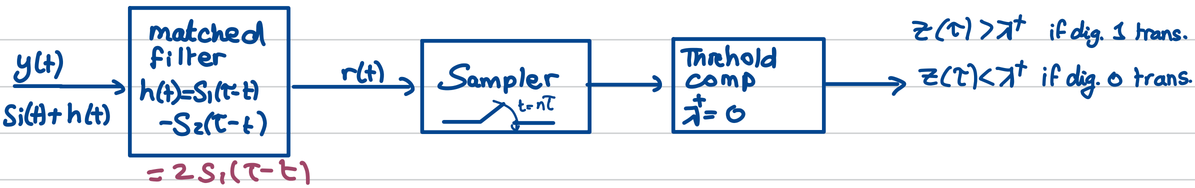
$$E_1 = \int_0^{\tau} A^2\cos^2(2\pi f_c t)\, dt = \frac{A^2\tau}{2} = E_2$$

$$E_{avg} = \frac{E_1+E_2}{2} = E_1 = \frac{A^2\tau}{2}$$

$$\lambda^{+} = \frac{1}{2}(E_1 - E_2) = 0$$

$$P_b = Q\left(\frac{\int_0^T (S_1(t)-S_2(t))^2\,dt}{2N_0}\right) = Q\left(\sqrt{\frac{\int_0 (2S_1(t))^2\,dt}{2N_0}}\right) = Q\left(\sqrt{\frac{4E_1}{2N_0}}\right) = Q\left(\sqrt{\frac{2E_b}{N_0}}\right) = Q\left(\sqrt{2SNR}\right)$$

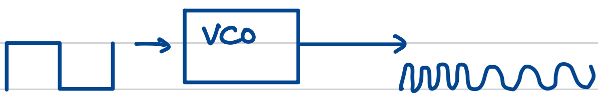
- **Matched Filter**



BFSK : Binary Freq. shift Keying

$S_1(t) = A\cos(2\pi f_1 t)$; $f_1 = f_c + \Delta f$

$S_2(t) = A\cos(2\pi f_2 t)$; $f_2 = f_c - \Delta f$



$$E_1 = \int_0^T A^2\cos^2(2\pi f_1 t)\,dt = \frac{A^2}{2}T$$

$$E_2 = \int_0^T A^2\cos^2(2\pi f_2 t)\,dt = \frac{A^2}{2}T$$

$E_{avg} = ?$

$\lambda^+ = ?$

$P_b = Q(\quad)$