Comunicaciones Ópticas

Detectores y sistemas de comunicación

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Detectores

$$h = \frac{< electrones >}{< fotones >} = \frac{I_{ph} / q}{P_{in} / hf}$$

$$I_{ph} = h \frac{q}{hf} P_{in}$$

$$h = x(1-R)\left(1-e^{-ad}\right)$$

R: reflectividad d: espesor del diodo

a : coef. absorción del diodo.

x :coef. de no recombinación

*** PIN**

$$S = \frac{I_{ph}}{P_{in}} = h\frac{q}{hf} \Rightarrow I_{PD} = SP_{in} + I_D$$

$$< i_{pd} > = < i_{ph} > + < i_d >$$

$$< i_{ph} > = SP_{in} = h\frac{q}{hf}P_{in} \quad s^2_{i_{ph}} = 2Bq < i_{ph} >$$

$$SNR^{PIN} = \frac{< i_{ph} >^2}{2qB\{< i_{ph} > + < i_d >\} + \frac{4KT^o B}{R_E}}$$

$$SNR^{QL} = \frac{P_{in}T_{bit}}{hf} = \frac{P_{in}T_{bit}}{hc} l = < \text{fotones/bit} >$$

*** APD**

$$< i_{APD} > = M < i_{PD} > + M < i_D > = Mh\frac{q}{hf}P_{in} + M < i_D >$$

$$s^2_{i_{APD}} = 2Bq < i_{APD} > F + \frac{4KT^o B}{R_E} F =$$

$$= 2BqM^2F\left(< i_{PD} > + < i_D >\right) + \frac{4KT^o B}{R_E} F$$

$$PIN = APD \,|\, \begin{cases} M = 1 \\ F = 1 \end{cases} \qquad < i_D > |_{InGaAs} \cong 0$$

$$F(M) = kM + (1-k)\left(2 - \frac{1}{M}\right) \cong kM$$

*** Ancho de banda**

$$I_n \xrightarrow{Tx(E/O)} P_{in} \xrightarrow{fibra} P_{out} \xrightarrow{Rx(O/E)} I_{out}$$

$$\frac{I_{out}}{I_{in}} = h_d h_f \frac{P_{out}}{P_{in}} \qquad h_f = \frac{P_{in}}{I_{in}} \qquad h_d = \frac{I_{out}}{P_{out}}$$

$$f_e = \frac{f_0}{\sqrt{2}} \Rightarrow BW_e = 0.707 BW_{opt}$$

Sistemas de transmisión por fibra óptica

*** idealización**

$$I_D = 0 \quad h = 1 \qquad P\{n\} = \frac{< n >^n e^{-<n>}}{n!}$$

ni atenuación, ni ruido térmico ni de background.

$$P(E) = \frac{1}{2} e^{-<n>} = BER$$

$$< n_a > = \frac{< n >}{2} \qquad < n_a >: \text{sensibilidad}$$

$$\log BER = -0.43 < n > -0.3$$

***** $h < 1 \Rightarrow < n_a > \geq \frac{10}{h} \; : \; BER \leq 10^{-9}$

*** teoría de decisión**

$$< n >_{fotones/bit} \longrightarrow < m >_{electrones/bit} \qquad < m > = \frac{< i_{ph} > T_{bit}}{q}$$

$$< p > = \frac{< i_{th} > T_{bit}}{q} \qquad s^2_p = \left(\frac{T_{bit}}{q}\right)^2 \frac{4KT^o B}{R_E}$$

$$m_{opt} = \frac{m_0 s^2_1 + m_1 s^2_0}{s^2_0 + s^2_1} \text{ : punto decisión óptimo.}$$

$$P(E) = \frac{1}{2} erfc\left(Q / \sqrt{2}\right) \qquad P(E) \leq 10^{-9} \Rightarrow Q \geq 6$$

$$Q = \frac{m_0 + m_1}{s^2_0 + s^2_1} = \frac{< x >^2}{\sum s^2_i}$$

$$Q_{shot} = \sqrt{SNR} \qquad Q_{tèrmic} = \frac{1}{2}\sqrt{SNR}$$

*** PIN**

$$Q = \frac{h < n >}{\sqrt{h < n > + s^2_p} + s_p}$$

$$shot \Rightarrow Q = \sqrt{h < n >} \Rightarrow < n_a > \geq \frac{18}{h}$$

$$tèrmic \Rightarrow < n_a > \geq \frac{6 s_p}{h}$$

*** APD**

$$shot \Rightarrow Q = \sqrt{h < n > / F} \rightarrow < n_a > \geq \frac{18F}{h}$$

$$tèrmic \Rightarrow < n_a > \geq \frac{3 s_p}{M}$$