Receiver Sensitivity Degradation

POWER PENALTY

- **Extinction Ratio**
- **Relative Intensity Noise (RIN)**
- **Timing Jitter**

Power Penalty due Extinction Ratio

$$\text{Extinction Ratio} = P_0 / P_1 = r_{ex}$$

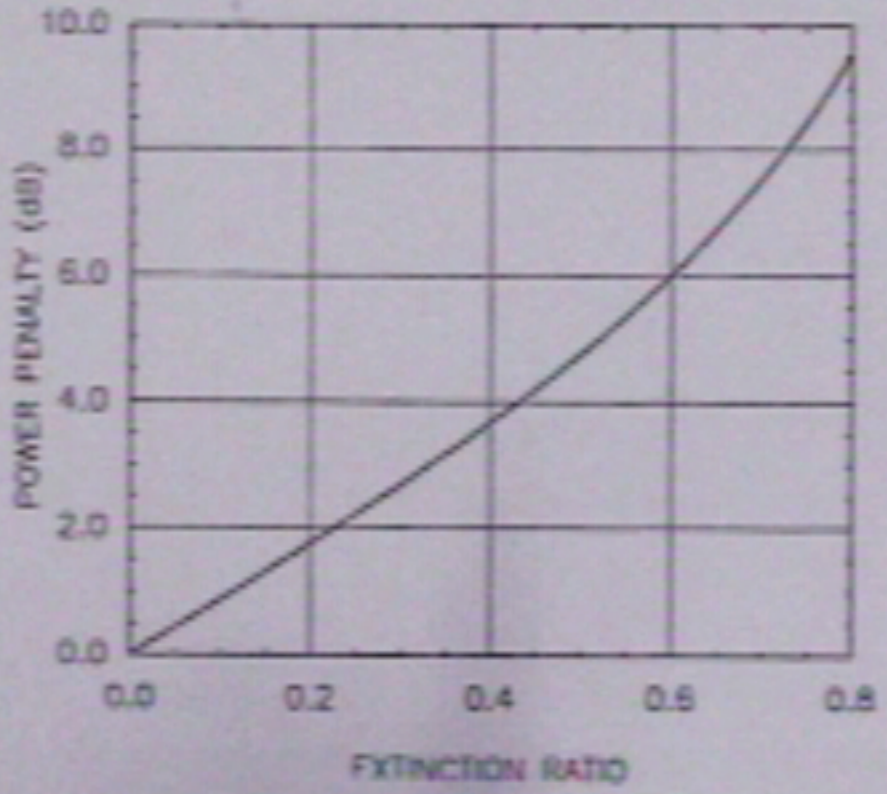
$$\text{Average power } \bar{P}_{rec} = \frac{P_0 + P_1}{2}$$

$$I_0 = R P_0 \quad , \quad I_1 = R P_1$$

$$Q = \frac{I_1 - I_0}{\sigma_1 + \sigma_0} = \frac{R P_1 (1 - r_{ex})}{\sigma_1 + \sigma_0}$$

$$= \frac{1 - r_{ex}}{1 + r_{ex}} \cdot \frac{2 \bar{P}_{rec} R}{\sigma_1 + \sigma_0}$$

SENSITIVITY DEGRADATION



Thermal noise dominated

$$\sigma_0 \approx \sigma_1 \approx \sigma_T$$

$$\bar{P}_{rec} = \frac{1 + r_{ex}}{1 - r_{ex}} \frac{\sigma_T Q}{R}$$

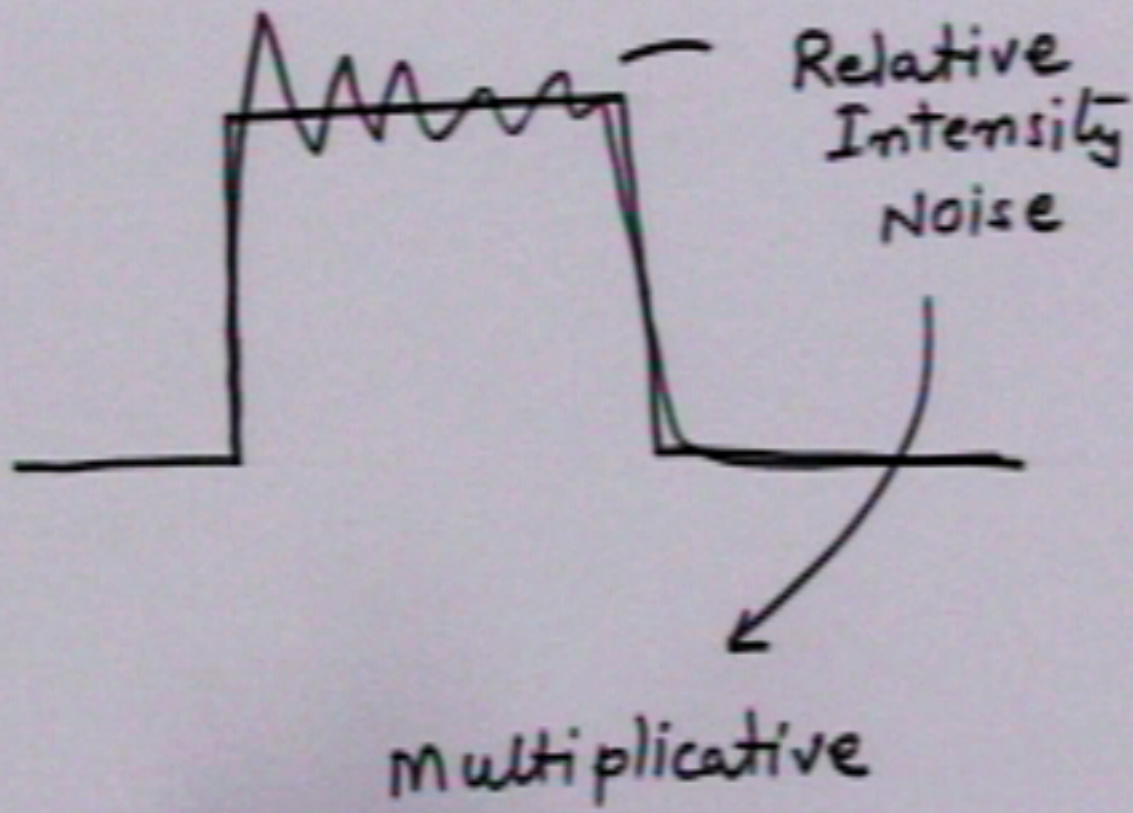
Power Penalty

$$\delta_{ex} = 10 \log \left\{ \frac{\bar{P}_{rec}(r_{ex})}{\bar{P}_{rec}(0)} \right\}$$

$$= 10 \log \left\{ \frac{1 + r_{ex}}{1 - r_{ex}} \right\}$$

δ_{ex} = 1 dB for $r_{ex} = 0.12$

= 4.8 dB for $r_{ex} = 0.5$


Relative
Intensity
Noise
Multiplicative

Power Penalty due to RIN

Var. of total noise

$$\sigma^2 = \sigma_s^2 + \sigma_T^2 + \sigma_I^2$$

$$\sigma_I = R \langle \Delta P_{in}^2 \rangle^{1/2} = R P_{in} r_I$$

$$r_I = \frac{\langle \Delta P_{in}^2 \rangle^{1/2}}{P_{in}}$$

$$I_1 = 2 R \bar{P}_{rec}$$

$$Q = \frac{I_1 - I_0}{\sigma_1 + \sigma_0}$$

$$\sigma_1 = \left(\sigma_S^2 + \sigma_T^2 + \sigma_I^2 \right)^{1/2}$$

$$\sigma_0 = \sigma_T$$

$$I_0 = 0$$

$$Q = \frac{2 R \bar{P}_{rec}}{\left(\sigma_S^2 + \sigma_T^2 + \sigma_I^2 \right)^{1/2} + \sigma_T}$$

$$\sigma_S = 2 \left\{ q R \bar{P}_{rec} B \right\}^{1/2}$$

$$\sigma_I = 2 r_I R \bar{P}_{rec}$$

$$\bar{P}_{rec}(r_I) = \frac{Q\sigma_T + qBQ^2}{R(1 - r_I^2 Q^2)}$$

Power Penalty

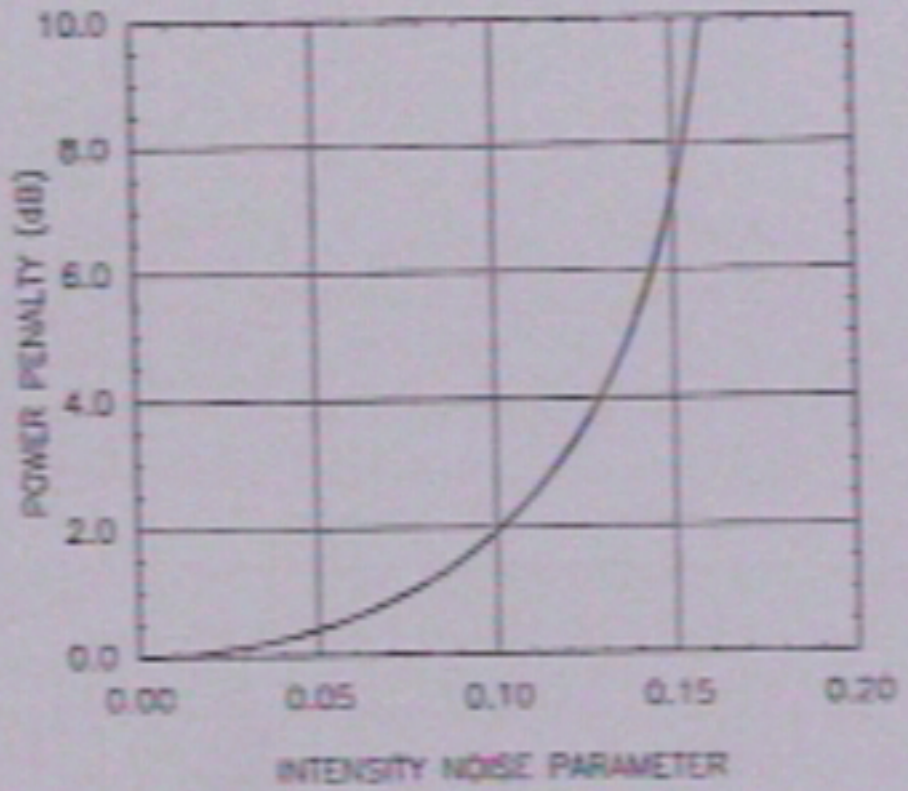
$$\delta_I = 10 \log \left\{ \frac{\bar{P}_{rec}(r_I)}{\bar{P}_{rec}(0)} \right\}$$

$$= 10 \log \left\{ 1 - r_I^2 Q^2 \right\}$$

For BER $= 10^{-9}$, $Q \approx 6$

$$\delta_I = 10 \log \left\{ 1 - 36\, r_I^2 \right\}$$

SENSITIVITY DEGRADATION



$\delta_I = 0.02$ dB for $r_I = 0.01$

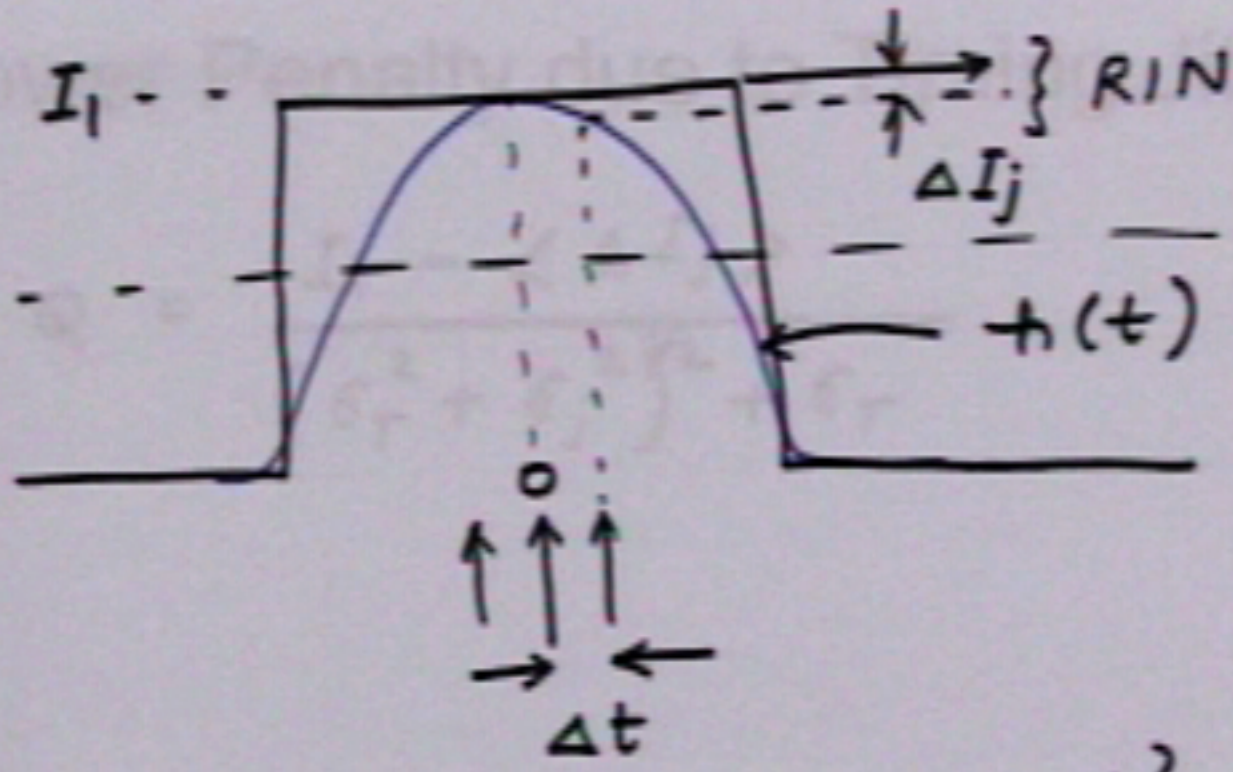
$= 2$ dB " $r_I \sim 0.1$

∞ " $r_I = Q^{-1}$

Receiver will never acheive the BER (required)

Power Penalty due to Timing Jitter

$$Q = \frac{I_1 - \langle \Delta I_j \rangle}{\left(\sigma_T^2 + \sigma_j^2\right)^{1/2} + \sigma_T}$$



$$\Delta I_j = I_1 \{ h(0) - h(\Delta t) \}$$

$$h(t) = \cos^2(\pi B t/2)$$

B ← Bit rate

Raised cosine filter for minimum ISI

$$H(f) = \begin{cases} [1 + \cos(\pi f/B)]/2 & f < B \\ 0 & f \geq B \end{cases}$$

$$h(t) = \frac{\sin(2\pi Bt)}{2\pi Bt} \cdot \frac{1}{1-(2Bt)^2}$$

$B\Delta t << 1$

$$\Delta I_j = \frac{2}{3}(\pi^2 - 6)(B\Delta t)^2 I_1$$

$$P(\Delta t) = \frac{1}{\sqrt{2\pi}\,\tau_j} e^{-(\Delta t)^2/2\tau_j^2}$$

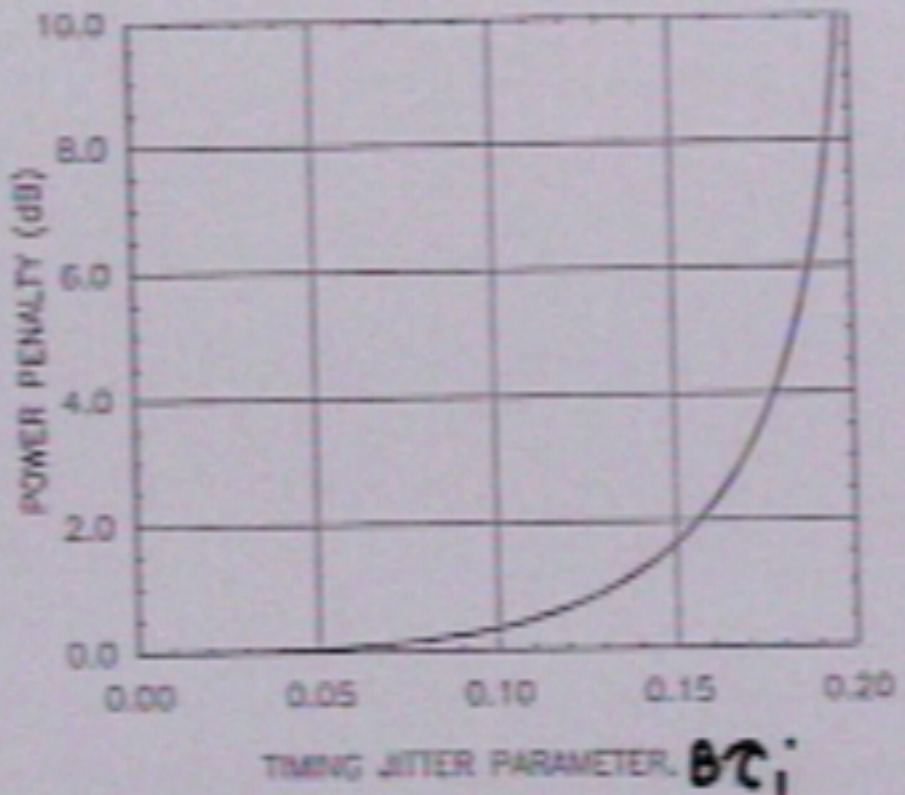
$$P(\Delta I_j) = (\pi b \Delta I_j I_1)^{-1/2} e^{-\frac{\Delta I_j}{b I_1}}$$

$$b = \frac{4}{3}(\pi^2 - 6)(B\tau_j)^2$$

$$\bar{P}_{rec}(b) = \frac{6_T Q}{R}\left\{\frac{1 - b/2}{(1-b/2)^2 - b^2Q^2/2}\right\}$$

Power Penalty

$$\delta_j = 10 \log\left\{\frac{\bar{P}_{rec}(b)}{\bar{P}_{rec}(0)}\right\}$$



$\delta_j = 2\,dB \quad B\tau_j \approx 0.16$

$= \infty \quad \ldots \quad > 0.2$