\[
\text{Electrical SNR} = \frac{\text{Signal Power}}{\text{Noise Power}} = \frac{S}{N}
\]

\[
I = I_s + I_n
\]

\[
I_s = R_s I_s = \text{signal current}
\]

\[
P_s = \text{opt. signal power}
\]

\[
I_n = \text{noise current}
\]

\[
P_n = \text{opt. noise power} = R_n P_n
\]

\[
N = (2 R_n P_n)^2
\]

\[
\text{Electrical SNR} = \frac{P_s}{P_n}
\]

\[
P_n = 2 P_A 0S
\]

\[
P_A = \text{PES of optical noise due to all other amplifiers} = N_0 h v_0 \cdot v_p (\nu - 1)
\]

\[
\text{Electrical SNR} = \frac{P_s}{2 P_n} = \frac{P_s}{2 R_n P_n} = \frac{P_s}{4 N_0 h v_0 v_p (\nu - 1) P_A}
\]

**Scaling Laws:**

As \( N_0 \) increases, SNR \( \phi \) increases almost linearly.

Placeo: Assume event \( P_0 \) km = 100 km.

\( \Rightarrow \) As FO link length \( P \), SNR \( \phi \)

As \( v_p \), SNR \( \phi \)

As \( L \), SNR \( \phi \)

Suppose any gain compensates for fiber loss exactly.
\[ G = e^{\text{La}}, \quad L_a = \text{FOIL (factor, outer, inner, last)} \]

As \( L_a, \) \( G \) changes, \( \text{SNR} \) changes.

As \( L_a \) changes, \( G \) changes, \( \text{SNR} \) changes.

---

**Diagram:**

- Diagram illustration of system output over time, showing input and output signals.

- Block diagram of system components: input signal \( P \), amplifier, filter, and output signal \( Y(t) \).

---

**Diagram:**

- Diagram representing signal paths: \( I_1 \) to \( I_2 \), \( I_0 \) to \( I' \).

- Notation: \( I_1 \) to \( I_2 \) indicates good performance, \( I_0 \) to \( I' \) indicates poor performance.

---

**Text:**

Measure of SNR: \( \sigma = \text{SNR} \), \( \sigma' = \text{SNR}' \)

Best window (AD) is \( 10 \log_{10} (I_1 - I_0) \)

Best window (AD) is a measure of performance, but not the best.

A better measure of the performance is quality factor (Q-factor).

**Q-factor:**

\[ Q = \text{SNR} \]

\[ I_2 = \text{mean of } I_2 \text{, } I = I_2 \]

\[ I_0 = \text{mean of } I_0 \text{, } I = I_0 \]

\[ (I - I_0)^2, \quad Q \uparrow \]
\[
\begin{align*}
S_0 &= \frac{S_1 - S_0}{\sigma_1 + \sigma_0} \\
\alpha &= \frac{S_0 I_0}{\sigma_1 + \sigma_0} \\
\text{LET } \sigma_1, \sigma_0 \text{ BE LARGE, } \sigma_1 = \sigma_0 \\
\alpha &= \mu \\
\text{But we expect } \sigma_1 < \text{ small } \therefore \sigma_1, \sigma_0 \text{ are correlated.} \\
\alpha &= \frac{I_1 - I_0}{\sigma_1 + \sigma_0}
\end{align*}
\]

This definition is not unique.

**Bit Error Rate (BER)**

Let \( N \) be the \( N \) of this transmission.

Let \( N_b \) be the \( N \) of bit error rate.

\[
\text{BER} = \lim_{N \to \infty} \frac{N_b}{N}
\]

Suppose \( N = 10 \)

\( N_b = 2 \)

\( \text{BER} = \frac{2}{10} = 0.2 \)

\( N \) should be very large.

\[
\text{BER} = \frac{1}{2} \text{erfc} \left( \frac{\alpha I_0}{\sigma_1} \right)
\]

\( \alpha = \frac{I_1 - I_0}{\sigma_1 + \sigma_0} \)

\text{erfc} = \text{complementary error function}

For large \( \alpha \)

\[
\text{BER} = \frac{\text{erfc} \left( \frac{\alpha I_0}{\sigma_1} \right)}{\sqrt{2}}
\]

As \( \alpha, I_0 \) \( \text{BER} \phi \)
Numerical Simulations:

TX

20 km

LF

TX

1600 km

OFD Length = 10 km

Num. Exp. 1: Change Freq. by 1800 Hz to Simulate Frequency

TX Distance = 1600 km.

\[
\text{OFD Length} = 10 \text{ km}
\]

Number of TF

\[
\frac{1600 \text{ km}}{50 \text{ km}} = 32
\]

In OFD 1 = 20

Total number of Freq. channels = 80

Num. Exp. 2: Change the Gain C

\[
G = 2 \times C
\]

Length of 1st TF = 80 km → 160 km.

Total link length = 1600 km.

\[
\text{Num. of TFs} = \frac{1600 \text{ km}}{160 \text{ km}} = 10
\]

In OFD 1 = 10

Total number of channels = 20.

Num. Exp. 3: Turn OFF the OFD & see the Impact of Disabling OFD TX.