Power & dBm Unit

\[ P_{\text{dBm}} = 10 \log_{10} \left( \frac{P_{\text{Watt}}}{1 \text{Watt}} \right) \]

\[ P_{\text{W}} = 10^{\frac{P_{\text{dBm}}}{10}} \]

\[ P = K |E|^2 \]

For communication, set \( K = 1 \)

\[ P = |E|^2 \]

\( \text{dBm Unit:} \)

\[ P_{\text{dBm}} = 10 \log_{10} \left( \frac{P_{\text{Watt}}}{1 \text{Watt}} \right) \]

\[ P_{\text{W}} = 10^{\frac{P_{\text{dBm}}}{10}} \]

\[ P_{\text{Watt}} = \frac{10}{10^{P_{\text{dBm}}}} \]

\[ \text{Inverse:} \]

\[ P_{\text{Watt}} = \frac{10}{10^{P_{\text{dBm}}}} \]

\[ P_{\text{dBm}} = 10 \log_{10} \left( \frac{P_{\text{Watt}}}{1 \text{Watt}} \right) \]

\( \text{Fiber Loss:} \)

\[ P_{\text{in}} = 0 \text{ dBm} \]

\[ P_{\text{out}} = 10 \text{ km} \]

\[ P_{\text{loss}} = 0.25 \text{ dBm} \]

\[ \frac{P_{\text{out}}}{P_{\text{in}}} = F \]

\[ \frac{P_{\text{in}}}{P_{\text{out}}} = F = 0.5 \]

\[ F = 0.5 \]

\[ F = \left( \frac{P_{\text{in}}}{P_{\text{out}}} \right) \]

\[ P_{\text{out}} = F P_{\text{in}} \]
Optical fiber loss

\[ P_{in} = ? \]

\[ P_{out} = \frac{P_{in}}{L} \]

\[ P_{out} = P_{in} \cdot e^{-\alpha L} \]

**Hint:** Show that

\[ \lim_{N \to \infty} e^{-N} = 0 \]

\[ \alpha = \text{Fiber loss coefficient} \]

\[ \text{(\( \delta \)) can be written as} \]

\[ \text{Loss (dB)} = -10 \log_{10} \frac{P_{out}}{P_{in}} = -10 \log_{10} \frac{P_{in} \cdot e^{-\alpha L}}{P_{in}} \]

\[ = (-2 \alpha L) (-10 \log_{10} 10) \]

\[ = 2 \alpha L + 39.2 \]

\[ L \to \text{km} \]

\[ \alpha \to \text{km}^{-1} \]

\[ 2 \alpha \to \text{dimensionless} \]

**Loss per unit length (dB/km):**

\[ \frac{\text{loss (dB)}}{L} = 2 \alpha \text{dB/km} \]

**Example:** Fiber loss per unit length is 0.2 dB/km. Find \( \alpha \) in dB.

\[ \frac{\text{loss (dB)}}{L} = 0.2 \text{ dB/km} \]

\[ \alpha (\text{dB/km}) = \frac{0.2}{2} \text{ dB/km} = 0.1 \text{ dB/km} \]

**Power flow:**

\[ P_{TX} \]

\[ F \]

\[ F = \frac{P_{RX}}{P_{TX}} \]

\[ F(\text{dB}) = -10 \log_{10} \frac{P_{RX}}{P_{TX}} \to (1) \]
\[
F(\Delta \theta) = -10 \log_{10} \frac{P_{in}}{P_{eff}} \Rightarrow G = \frac{P_{in}}{P_{eff}}
\]

\[
G(\Delta \theta) = 10 \log_{10} \frac{P_{in}}{P_{eff}} \Rightarrow G = G(\Delta \theta)
\]

\[
\frac{P_{in}}{P_{eff}} = \frac{P_{in}}{P_{in}} \cdot \frac{P_{in}}{P_{eff}} = GF
\]

\[
P_{in} = GF P_{eff}
\]

Suppose \( P_{in} \) & \( P_{eff} \) are given. In this we write:

\[
\frac{P_{in}(\Delta \theta)}{P_{eff}} = GF
\]

\[
10 \log_{10} \frac{P_{in}(\Delta \theta)}{P_{eff}} = 10 \log_{10} \left( \frac{GF}{1} \right)
\]

\[
P_{in}(\Delta \theta) = 10 \log_{10} \frac{P_{in}(\Delta \theta)}{P_{eff}}
\]

\[
P_{in}(\Delta \theta) = 10 \log_{10} \frac{P_{in}(\Delta \theta)}{P_{eff}} + 10 \log_{10} G + 10 \log_{10} F
\]

\[
P_{in}(\Delta \theta) = P_{in}(\Delta \theta) + G(\Delta \theta) - F(\Delta \theta)
\]

**Example:** Consider a fiber optic link shown below.

![Diagram](image)

**Fiber Loss:** 0.2 dB/km, **Leaky:** 1 dB, **Amplifier gain:** 17.5 dB.

**Number of fiber gain:** 8. So the minimum fiber required.

At the receiver to have a good S/N ratio, it \(-35\) dB. Calculate the linear limit on the transmitter level in dB.

**Peak power calculation:**

\[
F_{peak} = 0.2 \text{ dB/km}
\]

\[
F_{peak} = 0.2 \text{ dB/km}
\]

\[
F(\Delta \theta) = 0.2 \text{ dB/km} \times 100 \text{ km} = 20 \text{ dB}
\]

\[
G(\Delta \theta) = 17.5 \text{ dB}
\]

**Net loss per km** = \( F(\Delta \theta) - G(\Delta \theta) \)

\[
= 20 \text{ dB} - 17.5 \text{ dB}
\]

\[
= 2.5 \text{ dB/km}
\]

**Net loss** = \( 0.2 \text{ dB/km} \times 100 \text{ km} = 20 \text{ dB} \)

\[
= F_{peak}(\Delta \theta)
\]
\( P_{\text{in}} (\Delta n) = P_{\text{in}} (\Delta n) - P_{\text{eff}} (\Delta n) \)

\( P_{\text{in}} (\Delta n) = P_{\text{in}} (\Delta n) + P_{\text{eff}} (\Delta n) \)

\( P_{\text{in}} (\Delta n) \geq -3 \Delta n \)

\( P_{\text{eff}} (\Delta n) = 4 \Delta n \)

\( P_{\text{in}} (\Delta n) \geq -3 \Delta n + 4 \Delta n = 1 \Delta n \)

Can we add something to \( \Delta n \) to make it zero? Yes.

Requires that

\( \frac{P(\Delta n)}{P(\Delta n)} = 10 \log \left( \frac{P(\Delta n)}{P(\Delta n)} \right) \)

\( \text{loss}(\Delta n) = -10 \log \left( \frac{P(\Delta n)}{P(\Delta n)} \right) \)