

**Application Note:**

# **HFAN-3.0.1**

Rev.1; 04/08

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## **Setting a LOP (Loss of Power) Threshold Level Equivalent to a BER Level of $10^{-3}$**

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# Setting a LOP (Loss of Power) Threshold Level Equivalent to a BER Level of $10^{-3}$

The following example outlines how one might set the LOP threshold in a photodiode receiver such that the assert level is equivalent to a BER (bit-error rate) of  $10^{-3}$ .

The assumptions are as follows:

1. The extinction ratio ( $r_e$ ) = 10.
2. The optical input sensitivity is -31dBm.
3. A typical PIN responsivity ( $p$ ) = 0.85A/W.
4. A typical preamplifier transimpedance gain = 6k $\Omega$ .
5. Noise-limited input sensitivity.

See the equations in Table 1, which show the relationship between the received average power ( $P_{AVG}$ ) and the peak-to-peak signal amplitude ( $P_{IN}$ ). See Figure 1 for definitions of the parameters.

$$P_{AVG} = -31\text{dBm} = 794\text{nW} \quad (\text{average power})$$

$$P_{pk-pk} = P_{IN} = 2P_{AVG}(r_e-1)/(r_e+1) \quad (\text{see Table 1})$$

$$P_{IN} = 1.3\mu\text{W}(\text{pk-pk})$$

**Table 1. Optical Power Relations\***

Parameter	Symbol	Relation
Average Power	$P_{AVG}$	$P_{AVG} = (P_0 + P_1)/2$
Extinction Ratio	$r_e$	$r_e = P_1/P_0$
Optical Power of a "1"	$P_1$	$P_1 = 2P_{AVG} \frac{r_e}{r_e + 1}$
Optical Power of a "0"	$P_0$	$P_0 = 2P_{AVG}/(r_e + 1)$
Signal Amplitude	$P_{IN}$	$P_{IN} = P_1 - P_0$ $= 2P_{AVG} \frac{r_e - 1}{r_e + 1}$

\*Assuming a 50% average input data duty cycle (true for SONET/ATM data).

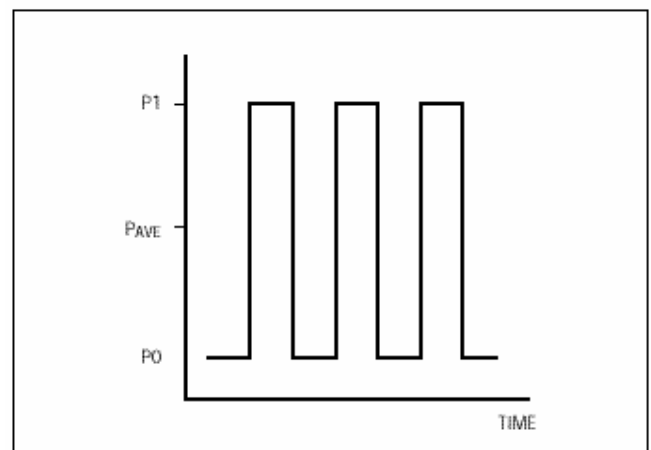


Figure 1. Optical power definitions

The curves in Figure 2 show the relationship between the BER and the signal-to-noise ratio (SNR) as a function of  $r_e$ . To achieve a BER of  $10^{-10}$ , a SNR of 7.76 (average signal/RMS noise) is required. In Figure 2, notice that the SNR has the units of average power. For this example, it is important that the SNR be in terms of the peak-to-peak signal. Therefore, the following conversion is required:

At a BER of  $10^{-10}$ ,

$$\begin{aligned} \text{SNR} &= 2(\text{SNR}_{\text{avg}})(r_e - 1) / (r_e + 1) \\ &= 2(7.76)(9) / (11) \\ &= 12.7 \text{ (pk-pk signal) / (RMS noise)} \end{aligned}$$

At a BER of  $10^{-3}$ , the SNR drops to:

$$\begin{aligned} \text{SNR} &= 6.17 \\ &\text{(pk-pk signal) / (RMS noise)} \end{aligned}$$

In an optical receiver, the input voltage to the limiting amplifier can be found by multiplying the input power ( $P_{\text{IN}}$ ) by the photodiode responsivity and transimpedance gain. Assuming an input sensitivity of  $1.3\mu\text{W}$ , a responsivity of  $0.85\text{A/W}$ , and a transimpedance gain of  $6\text{k}\Omega$ , the input voltage is  $6.6\text{mV}$  (pk-pk). To achieve a BER of  $10^{-10}$ , the equivalent input noise of the preamplifier must be no more than  $87\text{nA}$ .

Preamp equivalent input noise

$$\leq (1.3\mu\text{W})(0.85\text{A/W}) / 12.7 = 87\text{nA (RMS)}$$

Typically, the input noise associated with a PIN photodiode receiver is dominated by the noise associated with the transimpedance preamp. Therefore, once the preamp input noise is known, the input signal level that generates a BER of  $10^{-3}$  can be calculated easily.

For this example, a preamp input noise level of  $87\text{nA}$  (RMS) is assumed. Therefore, a  $10^{-3}$  BER results in an input voltage of  $3.2\text{mV}$ .

$$\begin{aligned} \text{SNR} \times (\text{transimpedance gain}) \times (\text{input noise level}) \\ = 6.17 \times 6\text{k}\Omega \times 87\text{nA} = 3.2\text{mV(pk-pk)} \end{aligned}$$

Thus, for this example, a LOP assert level of  $3.2\text{mV}$  is equivalent to a BER of  $10^{-3}$ .

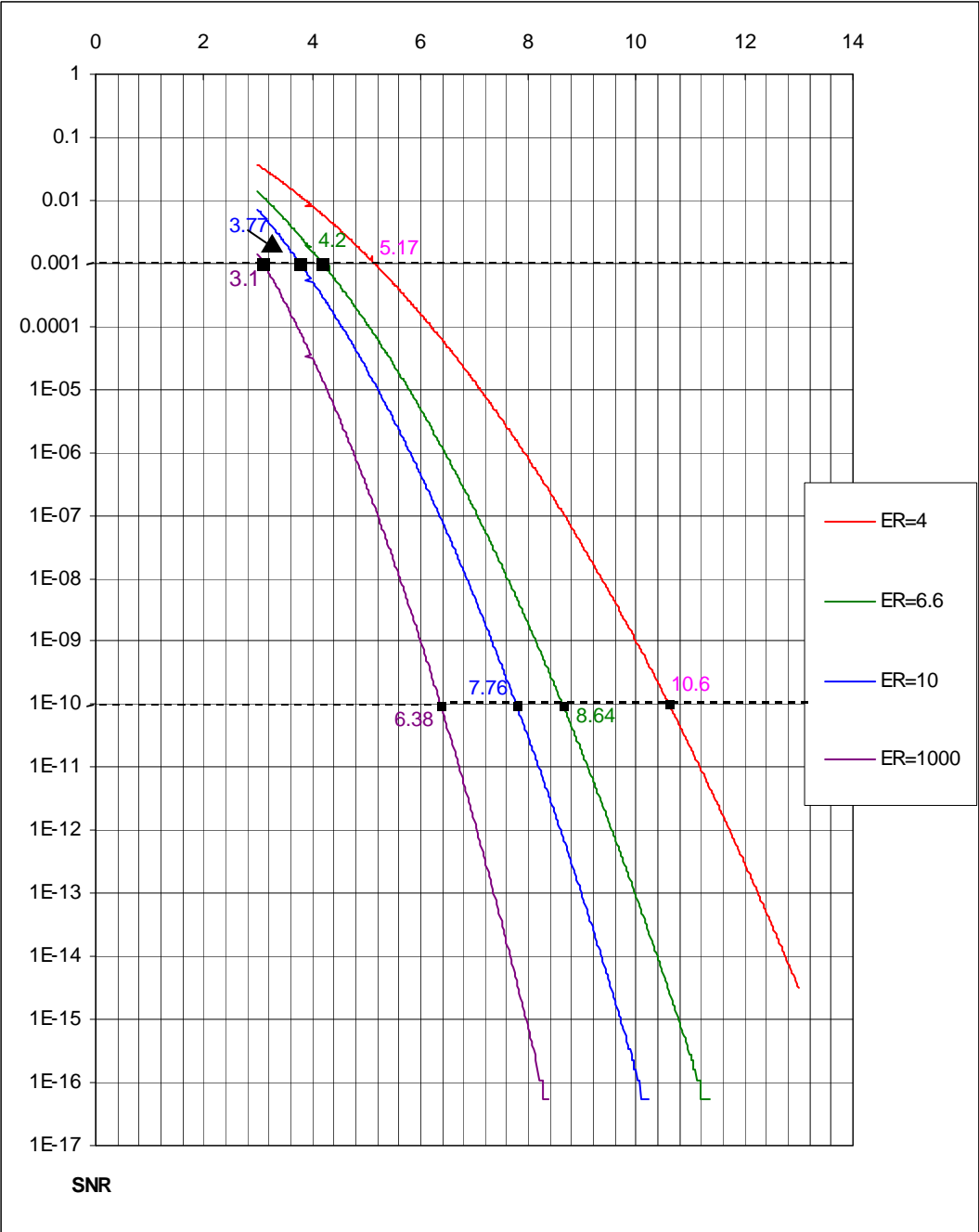


Figure 2. Bit-error rate versus SNR (average signal to RMS noise)