Application Note:

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

Maxim Integrated Products

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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 = 6kΩ.
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} = -31dBm = 794nW (average power)

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

P_{IN} = 1.3µW(pk-pk)

Table 1. Optical Power Relations*

Parameter	**Symbol**	**Relation**
Average Power	P_{AVG}	$P_{AVG} = (P0 + P1)/2$
Extinction Ratio	r_e	$r_e = P1/P0$
Optical Power of a "1"	P1	$P1 = 2P_{AVG} \frac{r_e}{r_e+1}$
Optical Power of a "0"	P0	$P0 = 2P_{AVG}/(r_e+1)$
Signal Amplitude	P_{IN}	$P_{IN} = P1-P0 = 2P_{AVG} \frac{r_e-1}{r_e+1}$

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

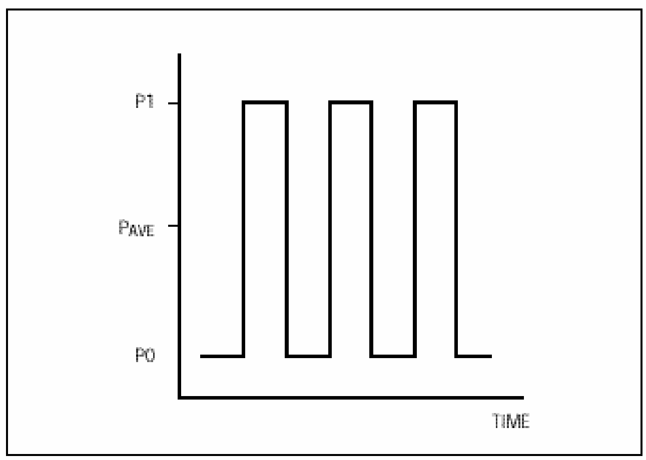

Figure 1. Optical power definitions

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},

$$SNR = 2(SNR_{avg})\,(r_e - 1) / (r_e + 1)$$

$$= 2(7.76)\,(9) / (11)$$

$$= 12.7 \quad \text{(pk-pk signal) / (RMS noise)}$$

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

$$SNR = 6.17$$
(pk-pk signal) / (RMS noise)

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

Preamp equivalent input noise
$$\leq (1.3\mu W)\,(0.85A/W) / 12.7 = 87nA \text{ (RMS)}$$

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 87nA (RMS) is assumed. Therefore, a 10^{-3} BER results in an input voltage of 3.2mV.

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

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

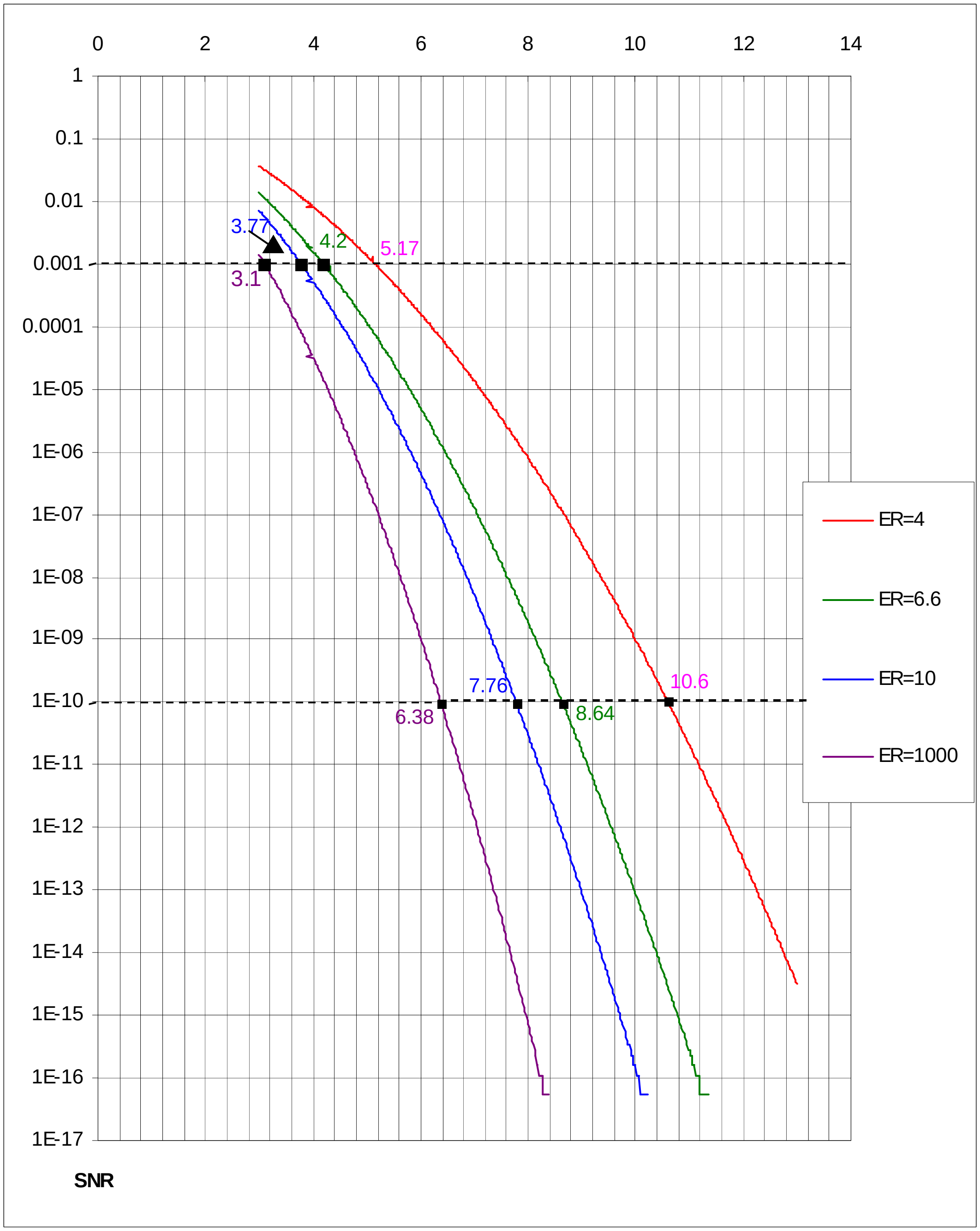

Figure 2. Bit-error rate versus SNR (average signal to RMS noise)