Unit-5

Lecture -3

Rise Time Budget, Short Wave

Example: Spreadsheet Power Budget

Example 8.2 Consider a 1550-nm laser diode that launches a +3-dBm (2-mW) optical power level into a fiber flylead, an InGaAs APD with a –32-dBm sensitivity at 2.5 Gb/s, and a 60-km long optical cable with a 0.3-dB/km attenuation. Assume that here, because of the way the equipment is arranged, a 5-m optical jumper cable is needed at each end between the end of the transmission cable and the SONET equipment rack as shown in Fig. 8.5. Assume that each jumper cable introduces a loss of 3 dB. In addition, assume a 1-dB connector loss occurs at each fiber joint (two at each end because of the jumper cables).

Table 8.1 lists the components in column 1 and the associated optical output, sensitivity, or loss in column 2. Column 3 gives the power margin available after subtracting the component loss from the total optical power loss that is allowed between the light source and the photodetector, which, in this case, is 35 dB. Adding all the losses results in a final power margin of 7 dB.

Table 8.1 *Example of a spreadsheet for calculating an optical-link power budget*

Component/loss parameter	*Output/sensitivity/loss*	*Power margin (dB)*
Laser output	3 dBm	
APD sensitivity at 2.5 Gb/s	–32 dBm	
Allowed loss [3 – (–32)]		35
Source connector loss	1 dB	34
Jumper + connector loss	3 + 1 dB	30
Cable attenuation (60 km)	18 dB	12
Jumper + connector loss	3 + 1 dB	8
Receiver connector loss	1 dB	7 (final margin)

Rise-Time Budget (1)

- A *rise-time budget analysis* determines the dispersion limitation of an optical fiber link.
- The total rise time t_{sys} is the root sum square of the rise times from each contributor t_i to the pulse rise-time degradation:
  - The transmitter rise time t_{tx}
  - The group-velocity dispersion (GVD) rise time t_{GVD} of the fiber
  - The modal dispersion rise time t_{mod} of the fiber
  - The receiver rise time t_{rx}

$$
\begin{aligned}
t_{sys} &= \left[t_{tx}^2 + t_{mod}^2 + t_{GVD}^2 + t_{rx}^2\right]^{1/2} \\
&= \left[t_{tx}^2 + \left(\frac{440L^q}{B_0}\right)^2 + D^2\sigma_\lambda^2 L^2 + \left(\frac{350}{B_e}\right)^2\right]^{1/2}
\end{aligned}
$$

Here B_e and B_0 are given in MHz, so all times are in ns.

Rise-Time Budget (2)

Example 8.3 As an example of a rise-time budget for a multimode link, let us continue the analysis of the link we started to examine in Sec. 8.1.2. We assume that the LED together with its drive circuit has a rise time of 15 ns. Taking a typical LED spectral width of 40 nm, we have a material-dispersion-related rise-time degradation of 21 ns over the 6-km link. Assuming the receiver has a 25-MHz bandwidth, then from Eq. (8.4) the contribution to the rise-time degradation from the receiver is 14 ns. If the fiber we select has a 400-MHz · km bandwidth-distance product and with $q = 0.7$ in Eq. (8.6), then from Eq. (8.15) the modal-dispersion-induced fiber rise time is 3.9 ns. Substituting all these values back into Eq. (8.17) results in a link rise time of

$$
\begin{aligned}
t_{sys} &= \left(t_{tx}^2 + t_{mat}^2 + t_{mod}^2 + t_{rx}^2\right)^{1/2} \\
&= [(15\text{ ns})^2 + (21\text{ ns})^2 + (3.9\text{ ns})^2 + (14\text{ ns})^2]^{1/2} \\
&= 30\text{ ns}
\end{aligned}
$$

This value falls below the maximum allowable 35-ns rise-time degradation for our 20-Mb/s NRZ data stream (0.70/bit rate). The choice of components was thus adequate to meet our system design criteria.

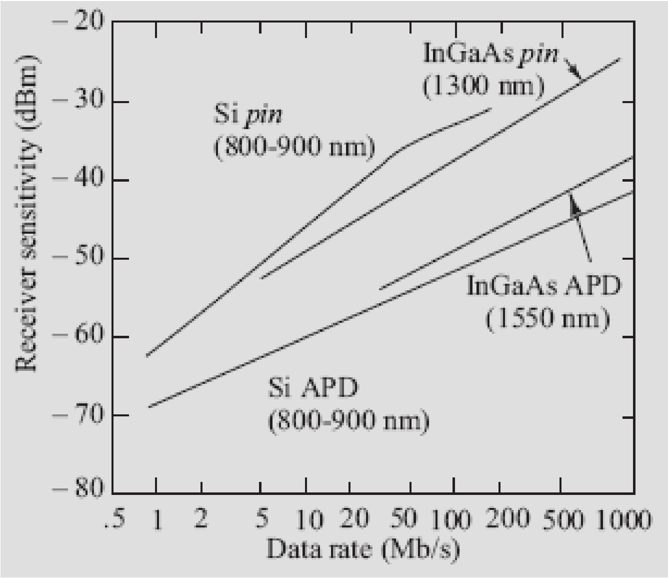
Example 8.4 Assume that the laser diode together with its drive circuit has a rise time of 0.025 ns (25 ps). Taking a 1550-nm laser diode spectral width of 0.1 nm and an average dispersion of 2 ps/(nm · km) for the fiber, we have a GVD-related rise-time degradation of 12 ps (0.012 ns) over a 60-km long optical cable. Assuming the InGaAs-APD-based receiver has a 2.5-GHz bandwidth, then from Eq. (8.4) the receiver rise time is 0.14 ns. Using Eq. (8.17) to add up the various contributions, we have a total rise time of 0.14 ns.

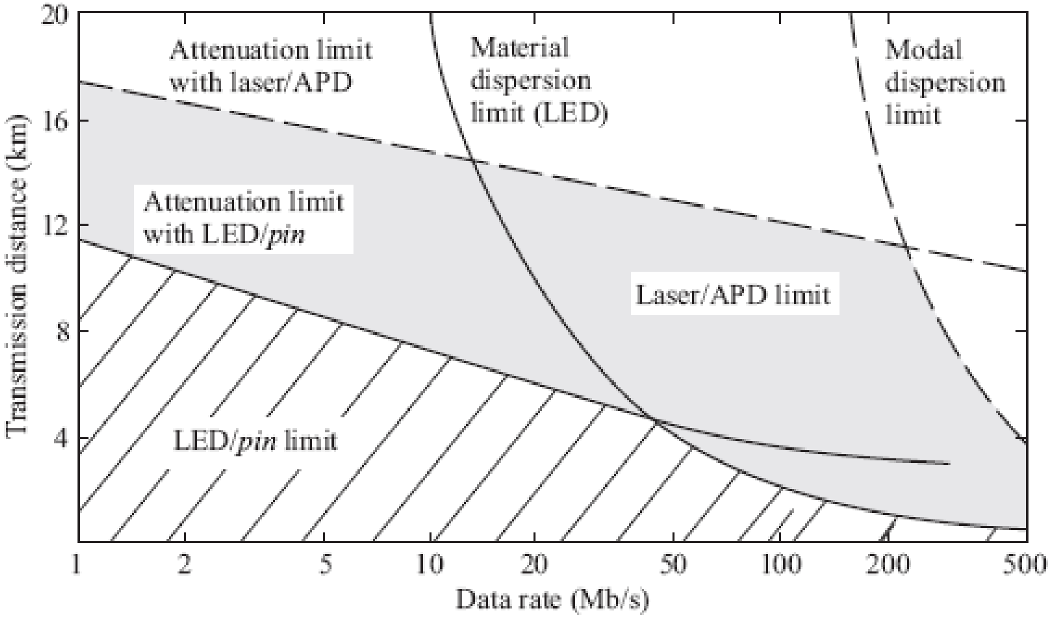
Table 8.2 lists the components in column 1 and the associated rise times in column 2. Column 3 gives the allowed system rise-time budget of 0.28 ns for a 2.5-Gb/s NRZ data stream at the top. This is found from the expression $0.7/B_{NRZ}$ where B_{NRZ} is the bit rate for the NRZ signal. The calculated system rise time of 0.14 ns is shown at the bottom. The system rise time, in this case, is dominated by the receiver and is well within the required limits.

Short-Wavelength Band

Attenuation and dispersion limits on the transmission distance vs. data rate for a 770–910-nm LED/*pin* combination.

- The BER was 10^{-9} ; the fiber-coupled power was –13 dBm up to 200 Mb/s.
- The attenuation limit curve was derived by using a fiber loss of 3.5 dB/km
- The receiver sensitivities shown in the left figure (8.3)





Attenuation-Limited Distances for Two Single-Mode Links

1. A DFB laser that has a fiber-coupled output of 0 dBm at 1550 nm.
2. At 1550 nm the single-mode fiber has a 0.20-dB/km attenuation.
3. The receiver has a load resistor R_L = 200 Ω and T = 300°K.
4. At a 10^{-12} BER a value of Q = 7 is needed.
5. The InGaAs pin and APD photodiodes have a responsivity of 0.95 A/W.
6. The gain of the APD is M = 10 and the noise figure F(M) = 5 dB.

Example 8.5 What are the attenuation-limited repeaterless transmission distances?

(*a*) From the receiver sensitivity curves shown in Fig. 7.11, we can deduce that for an InGaAs *pin* photodiode operating at 1550 nm with a 10^{-12} BER, the receiver sensitivity can be approximated by the straight-line equation $P_R = 8 \log B - 28$ dBm, where B is the data rate in Gb/s. To find the attenuation-limited repeaterless transmission distance L_{pin}, we use Eq. (8.2) with a combined connector loss plus system margin of 3 dB, so that

$$
\begin{aligned}
L_{\text{pin}} &= (P_S - P_R - 3\text{ dB})/\alpha \\
&= (0\text{ dBm} - 8 \log B + 28\text{ dB} - 3\text{ dB})/\alpha \\
&= (-8 \log B + 25)/0.2
\end{aligned}
$$

(*b*) Similarly, from the receiver sensitivity curves shown in Fig. 7.11, for the InGaAs APD the receiver sensitivity can be approximated by the straight-line equation $P_R = 5 \log B - 38$ dBm, where B is the data rate in Gb/s. Again, we use Eq. (8.2) with a combined connector loss plus system margin of 3 dB, so that attenuation-limited repeaterless transmission distance L_{pin} when using an APD is

$$
\begin{aligned}
L_{\text{APD}} &= (P_S - P_R - 3\text{ dB})/\alpha \\
&= (0\text{ dBm} - 5 \log B + 38\text{ dB} - 3\text{ dB})/\alpha \\
&= (-5 \log B + 35)/0.2
\end{aligned}
$$

The results for the attenuation-limited repeaterless transmission distances L_{pin} and L_{APD} are plotted in Fig. 8.7.