Power Budget Example:

Reference: Senior Optical Fiber Communications

Example 11.8

The following parameters are established for a long-haul single-mode optical fiber system operating at a wavelength of 1.3 μm.

Mean power launched from the laser transmitter	−3 dBm	~ .5 mW
Cabled fiber loss	0.4 dB km	— α_{fc}
Splice loss	0.1 dB km	— α_j
Connector losses at the transmitter and receiver	1 dB each	
Mean power required at the APD receiver:		
when operating at 35 Mbit s^{-1} (BER 10^{-9})	−55 dBm	— 3 nwatts
when operating at 400 Mbit s^{-1} (BER 10^{-9})	−44 dBm	(~ 10 higher)
Required safety margin	7 dB	

Shot Noise Limit ← (when operating at 35 Mbit/s)

$\frac{(2\ K^2\ F)\,hf\,\Delta t}{\eta}$

≈ 1 nW (for F = 6, K = 12, η = .8)

↑ Minimum Power Required for BER > 10^{-9}

Estimate:

(a) the maximum possible link length without repeaters when operating at 35 Mbit s^{-1} (BER 10^{-9}). It may be assumed that there is no dispersion equalization penalty at this bit rate.

(b) the maximum possible link length without repeaters when operating at 400 Mbit s^{-1} (BER 10^{-9}) and assuming no dispersion–equalization penalty

(c) the reduction in the maximum possible link length without repeaters of (b) when there is a dispersion–equalization penalty of 1.5 dB. It may be assumed for the purposes of this estimate that the reduced link length has the 1.5 dB penalty

Solution: (a) When the system is operating at 35 Mbit s^{-1} an optical power budget may be performed using Eq. (11.53), where

$$P_i - P_o = (\alpha_{fc} + \alpha_j)L + \alpha_{cr} + M_a \text{ dB}$$

$$3 \text{ dBm} - (-55 \text{ dBm}) = (\alpha_{fc} + \alpha_j)L + \alpha_{cr} + M_a$$

Hence,

$$(\alpha_{fc} + \alpha_j)L = 52 - \alpha_{cr} - M_a$$

$$0.5L = 52 - 2 - 7$$

$$L = \frac{43}{0.5} = 86 \text{ km}$$

(b) Again using Eq. (11.53) when the system is operating at 400 Mbit s^{-1}:

$$-3 \text{ dBm} - (-44 \text{ dBm}) = (\alpha_{fc} + \alpha_j)L + \alpha_{cr} + M_a$$

$$(\alpha_{fc} + \alpha_j)L = 41 - 2 - 7$$

$$L = \frac{32}{0.5} = 64 \text{ km}$$

← Min Power Required ∝ (Δt)

(c) Performing the optical power budget using gives:

$$P_i - P_o = (\alpha_{fc} + \alpha_j)L + \alpha_{cr} + D_L + M_a$$

Hence,

$$0.5L = 41 - 2 - 1.5 - 7$$

and

$$L = \frac{30.5}{0.5} = 61 \text{ km}$$

Rise - Time Budget Example

System $\lambda = 830$ nm

$B = 100$ Mb/sec

$BER = 10^{-9}$

Utilize an LED with a rise-time of 8 ns and a spectral width of 40 nm (Is it band-width limited?)

Silica fiber has $\lambda^2 \frac{d^2 n}{d\lambda^2} \approx .024$ (unit-less)

Use a graded index fiber with a 50 μm core diameter, numerical aperture of 0.25 and an intermodal dispersion of 3.5 ns/km

length = 2.5 km = L

PIN diode detector with rise-time = 10 ns

a) Calculate the system rise-time Δt_{sys}

$$\Delta t_{sys} = \left((\Delta t_s)^2 + (\Delta t_R)^2 + (\Delta t_{mat})^2 + (\Delta t_{modal})^2 \right)^{1/2}$$

- source: 8 nsec
- detector: 10 nsec
- material dispersion: $\frac{L}{c} \frac{\Delta\lambda}{\lambda} \left(\lambda^2 \frac{d^2 n}{d\lambda^2} \right)$
$$= \frac{2.5\times10^3}{3\times10^8} \times \frac{40}{830} \times .024$$
$$= 9.64 \text{ nsec}$$
- modal dispersion: $3.5\times2.5 = 8.75$ nsec

$$= 18.3 \text{ nsec}$$

To estimate the bit rate, B

bit period is $1/B = T_B$

Generally require system rise-time to be less than 70% of the bit-period for NRZ and half of this for an RZ code

Thus for NRZ

$$B_R \leq \frac{.7}{\Delta t_{sys}} \leq 38 \text{ Mb s}^{-1}$$

and for RZ

$$B_R \leq 19 \text{ Mb s}^{-1}$$

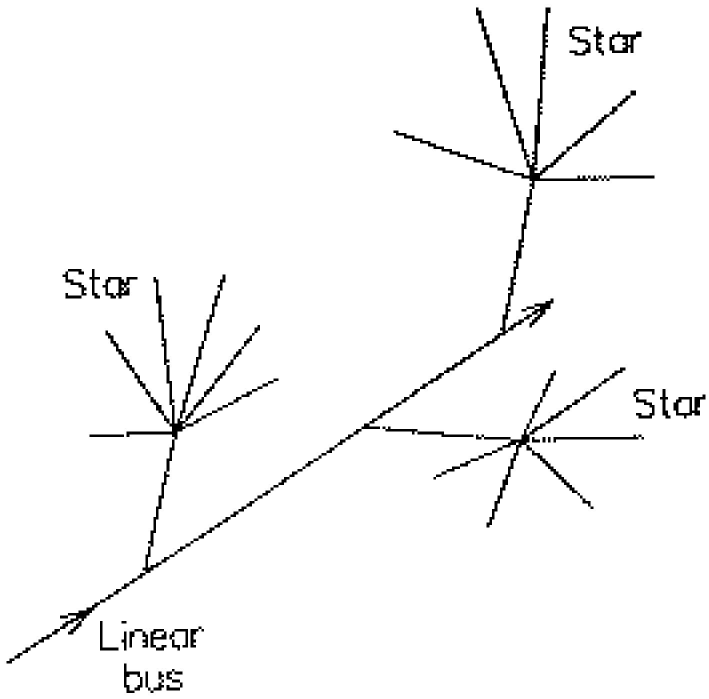

Figure 8.2 A combination of a linear bus network and star networks into a "leaf" topology.

Star Network Power Budget

We begin by calculating the power budget for a star network. Consider the power entering a fiber at the input to a coupler, P_F, and the power required by the receiver, P_R. We will assume an insertion loss, L_{insert}, a power splitting loss, $L_{\text{pwr split}}$, a connector loss, L_C, a system margin, L_M, and a fiber loss, α (dB/km). If L is the distance from the star coupler to each station, the path of the power from the transmitter to the receiver would be as follows:

- P_F in the fiber at the transmitter,
- a fiber loss of αL in going from the transmitter to the star,
- a loss of L_C as the light passes through the fiber/coupler connector pair to enter the star coupler,
- a loss of $L_{\text{pwr split}}$ as the power is divided among the output fibers of the star,
- a loss of L_C as the power passes through coupler/fiber connector pair leaving the star coupler,
- an additional loss of L_{insert} due to the insertion loss of the star coupler, and
- a fiber loss of αL in going to the receiver. (We assume ideal coupling into the receiver.)

Adding up all of these dB losses, the link power budget would be

$$\begin{aligned} 10\log(P_F/P_R) &= L_{\text{pwr split}} + \alpha(2L) + 2L_C + L_{\text{insert}} + L_M \\ &= 10\log N + \alpha(2L) + 2L_C + L_{\text{insert}} + L_M\,. \end{aligned} \tag{8.1}$$