Module 11 : Link Design

Lecture : Link Design

Objectives

In this lecture you will learn the following

- Design criteria
- Power Budget Calculations
- Rise Time Budget Calculation

- The optical link design essentially is putting the various optical components which we discussed earlier, so that information can be transmitted satisfactorily. The satisfactoriness of the transmission can be defined in terms of some characteristic parameters.
- The user generally specifies the distance over which the information is to be sent and the data rate to be transmitted. The Designer then has to find the specification of the system components.
- The designer generally has to define some additional criteria either as per the standards or as per the user specifications.
- The Design criteria are given in the following.

(1) **Primary Design Criteria**

- Data Rate
- Link length

(2)

Additional Design Parameters

- Modulation format eg Analog/digital
  - Depends upon the type of signals user want to transmit. For example if it is a TV signal, then may be analog transmission is more suited as it requires less bandwidth and better linearity. On the other hand if data or sampled voice is to be transmitted, digital format may be more appropriate.
  - The digital signals have to be further coded to suite the transmission medium and also for error correction.
- System fidelity: BER, SNR
  - The system fidelity defines the correctness of the data received at the receiver.
  - For digital transmission it is measured by the Bit Error Ratio (BER) . The BER is defined as

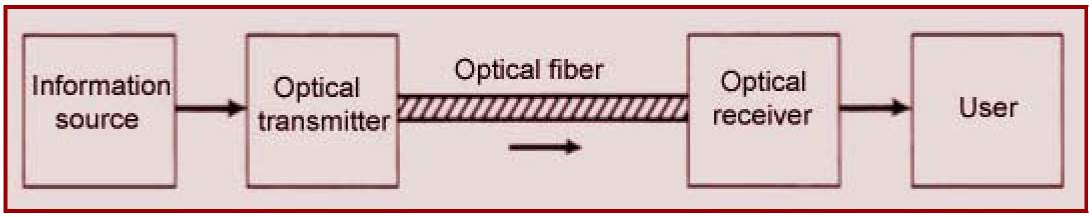
$$\text{BER} = \frac{\text{Number of bits in error}}{\text{Total Number of bits transmitted}}$$

In optical system the BER has to be less than 10^{-9}.

  - For analog system the quality parameter is the Signal-to-noise (SNR) ratio. Also there is a parameter called the inter-modulation distortion which describes the linearity of the system.
- Cost : Components, installation, maintenance
  - Cost is one of the important issues of the link design.
  - The cost has three components, components, installation and maintenance.
  - The component and the installations cost are the initial costs. Generally the installation cost is much higher than the component cost for long links. This is especially true for laying the optical cable. It is therefore appropriate to lay the cables keeping in view the future needs.
  - The optical link is suppose is supposed to work for at least 25years. The maintenance costs are as important as the initial cost. An initial cheaper system might end up into higher expenses in maintenance and therefore turn out to be more expensive as a whole.
- Upgradeability
  - The optical fiber technology is changing very rapidly and the data rates are increasing steadly.
  - The system should be able to adopt new technology as weel should be able to accommodate higher data rates with least possible changes.

- Commercial availability
  - Depending upon which part of the world one is, the availability of the components and the systems may be an issue.

- Here we discuss design of a simple point-to-point optical link.
- A simple point to point link is shown in the following Fig.



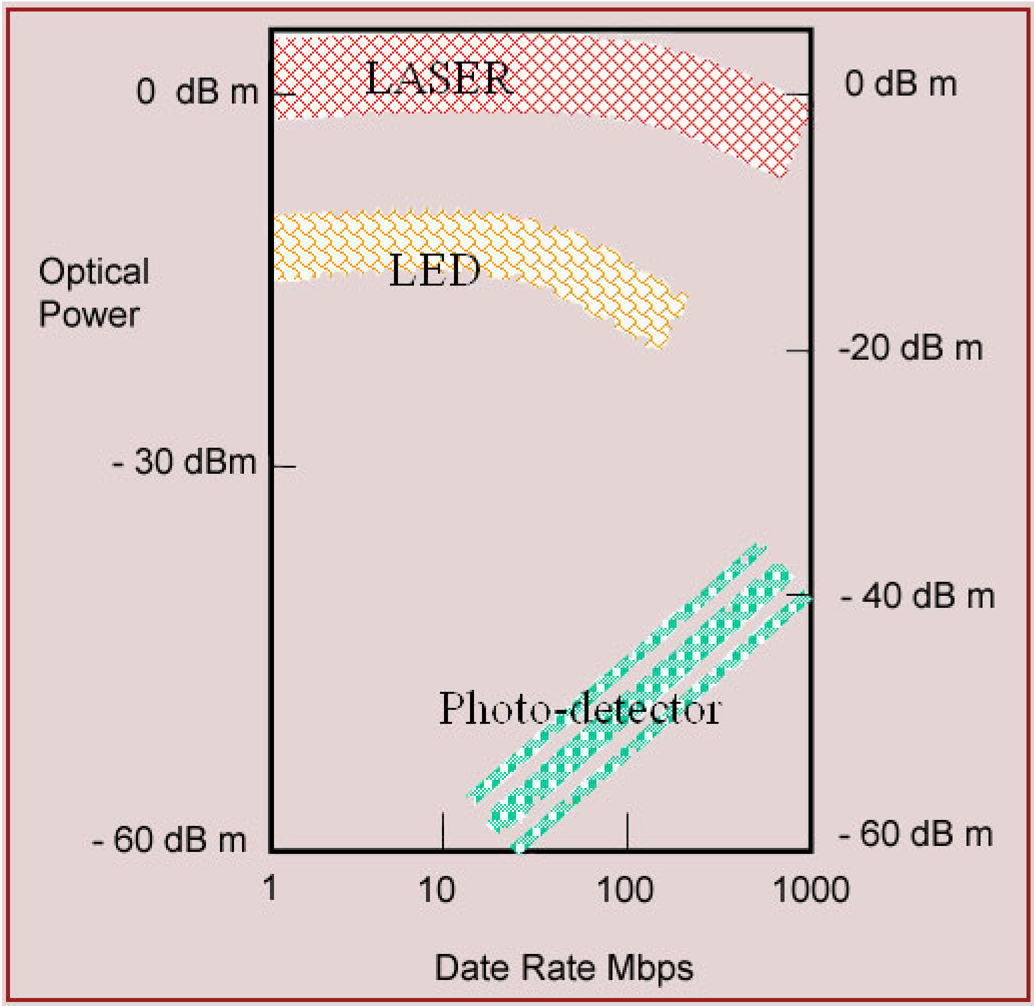
- The link has primarily 3 components to design.

(1) Optical Transmitter.

(2) Optical Fiber

(3) Optical receiver

- The Fig. shows the typical optical power which LEDs and and Lasers can deliver and the photo-detector needs for a BER of 10^{-9}.



- **Note:**

  As the data rate increases the power delivering capacity of the source reduces and at the same time the power requirement of the detector increases.

- The following table gives the combination of the sources and fibers for different link capacity and distance.

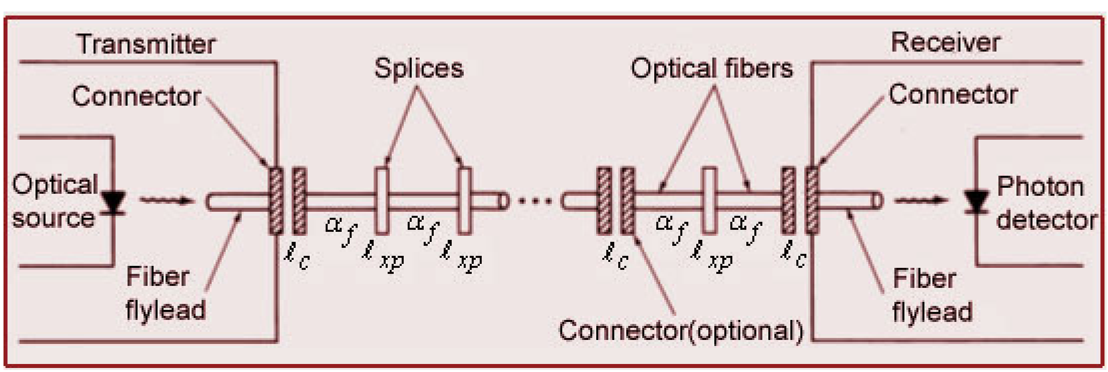
1-10m	10m-.1km	.1-1km	1-3km	3-10km	10-50km	50-100km	>100km	
						LD		10k
	SLED					MM		10-100K
		MM						100K-1M
					LD	GI		1-10M
			LED					10-50M
			GI			LD		50-500M
LD		LD				SM		500M-1G
MM		GI						>1G

- Considering the cost, speed etc, first choose the laser and the detector. Also the type of fiber is chosen from the above table. Generally a multi-core fiber is laid even if the immediate requirement is only one or two fibers.

- The link design then reduces to finding locations of the repeater on a long link.

- Two calculations are carried out in the link design

- The Fig. show the power loss model of an optical fiber link. The power is lost in various components like, fiber, connectors, splicing.



- The fiber loss depends upon the wavelength and also the physical conditions of the fiber. The fiber loss is generally higher than that the specified by the manufacturers. This is primarily due to micro-bending of the fiber. Also the micro-bending loss is higher for 1550nm compared to 1310nm. Therefore the over all loss could be higher at 1550nm than at 1310nm, although intrinsically silica glass has minimum loss at 1550nm. Typical loss ate

1550nm may lie in the range 0.4-0.5 dB/km.

- The splice loss could be between 0.05-0.1 dB per splice.

- The connector loss is higher and could be 0.2-0.3 dB per connector.

Power Budget Calculations

- P_s = Power from the Transmitter in dBm

  P_r = Sensitivity of receiver in dBm for given BER

- Maximum permissible loss $\alpha_{\max} = P_s - P_r$

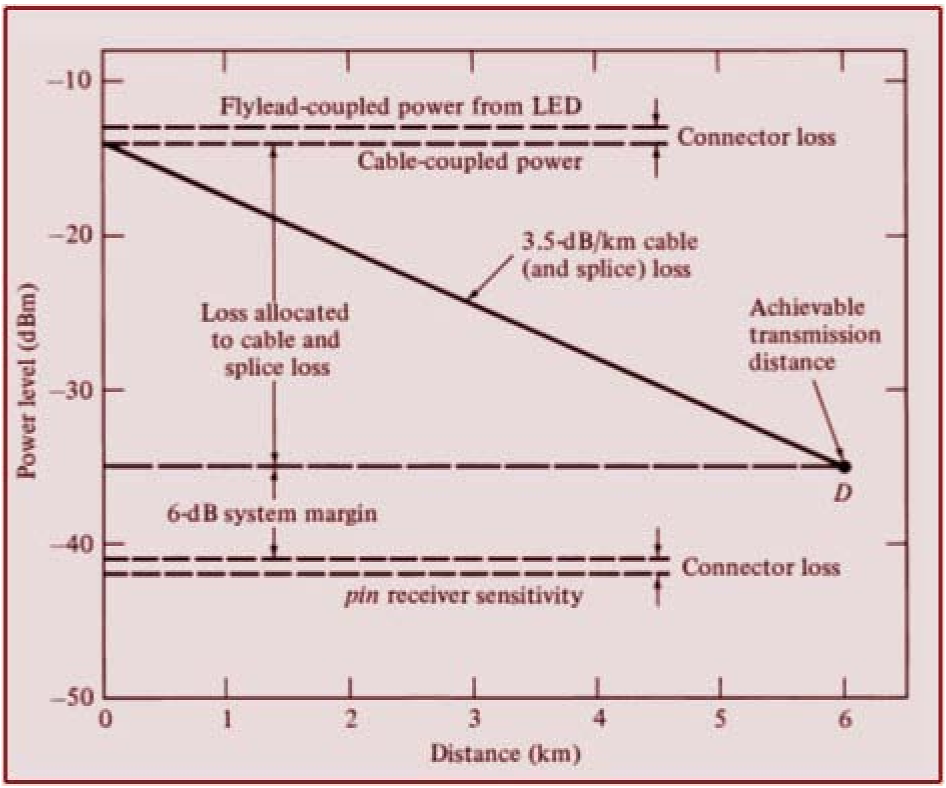
$$\alpha_{\max} = \alpha_{fiber} + \alpha_{conn} + \alpha_{splice} + \alpha_{syst}$$

$$\Rightarrow \alpha_{fiber} = \alpha_{\max} - \left(\alpha_{conn} + \alpha_{splice} + \alpha_{syst}\right)$$

Power Limited Link Length

$$L_{P\max} = \frac{\alpha_{fiber}}{Loss / Km}$$

Beyond this distance the SNR is below the acceptable limit



- System margin is generally taken to be 6 dB to accommodate deterioration of components over time.

Rise Time Budget Calculation

- Rise time analysis gives effective bandwidth of the link

$$t_{sys} = \left\{t_{tx}^2 + D^2\sigma_\lambda^2 L^2 + t_{rx}^2\right\}^{1/2}$$

For satisfactory operation of the link

$$t_{sys} \leq 0.7T_b$$

Rise time limited link length

$$L_{RT\max} = \frac{1}{D\sigma_\lambda}\left\{\left(0.7T_b\right)^2 - \left(t_{tx}^2 + t_{rx}^2\right)\right\}^{1/2}$$

Beyond this distance the signal distortion is unacceptable

- Rise time of a system or component = 1/bandwidth

Here,

t_{sys} = Total system rise time.

t_{tx} = Transmitter rise time

t_{rx} = Receiver rise time. Generally $t_{rx} \gg t_{tx}$.

D = Dispersion of the fiber

σ_λ = Spectral width of the transmitter

L = Length

T_b = Data bit duration $= \dfrac{1}{\text{Data Rate}}$

Note: For RZ data the system rise time t_{sys} should be $\leq 0.35\,T_b$.

- In the link design two lengths, the power budget length $L_{P\max}$ and the rise time budget length $L_{RT\max}$ are calculated.

- The repeater has to be installed at a distance $\min(L_{P\max}, L_{RT\max})$.

Rise Time Budget Calculation (contd)

- Generally, the links are power limited and the repeaters are installed at $L_{P\max}$. Typical repeater length is about 50-60 km in practice. Following example clearly demonstrates this.

EXAMPLE:

Let us take typical parameters for a link.

Data rate = 1 GHz.

DFB Laser spectral width = 0.1nm

SM fiber dispersion at 1550nm = -20 ps/km/nm = -0.02 ns/km/nm
Rise time of the receiver = 0.1 nsec

Rise time of the transmitter = 0.1nsec
Fiber loss = 0.4dB/km

Transmitter power -3 dBm
Min Detectable power -40 dBm
Neglect splice and connector losses.

SOLUTION:

$\Rightarrow \quad T_b = 1/1GHz = 1n\sec$

$$L_{RT\max} = \frac{1}{D\sigma_\lambda}\left\{(0.7T_b)^2 - (t_{tx}^2 + t_{rx}^2)\right\}^{1/2}$$

$$= \frac{1}{0.02\times 0.1}\left\{(0.7\times 1)^2 - ((0.1)^2 + (0.1)^2)\right\}^{1/2} = 178\,\text{km}$$

$$\alpha_{\max} = P_s - P_r = -3-(-40) = 37\,\text{dB}$$

$$\alpha_{fiber} = \alpha_{\max} - (\alpha_{conn} + \alpha_{splice} + \alpha_{syst}) = 37-(0+0+6) = 31\text{dB}$$

$$L_{P\max} = \frac{\alpha_{fiber}}{Loss\,/\,Km} = \frac{31}{0.4} = 77.5\text{km}$$

- Since $L_{P\max} < L_{RT\max}$, the link is power limited and the repeater has to be installed at a distance of less than 77.5Km.

Recap

In this lecture you have learnt the following

- Design criteria
- Power Budget Calculations
- Rise Time Budget Calculation

Congratulations, you have finished Module 11. To view the next lecture select it from the left hand side menu of the page