Application Note 037 – Fibre Optic Link Budget

This document describes how to calculate the overall link budget for typical installations.

Introduction

Fibre optic networks form the very fabric of our terrestrial broadband transmission platform which delivers multimedia services such as voice, video and data to business and residential users. Originally, optical fibre was installed to carry long-haul services across the planet because its extensive bandwidth offered future-proof expansion opportunities. With the continued demand for emerging services such as VoIP, IPTV and HDTV, network access infrastructure is under extreme pressures to deliver increasing transmission capacity and functionality. Due to its superior transmission capability over copper, optical fibre is migrating into the metropolitan and local area networks (MAN and LAN) and even to the end user.

Convergence between telecoms, datacoms and even satellite delivery platforms underpin the new centralised business models being adopted by Service Providers in reaching a global market. The satellite market is instrumental in delivering new multi-media services across the planet, especially in emerging markets such as Eastern Europe, Middle-East, Africa, Asia and South America. Optical fibre plays a fundamental role in service distribution over so-called passive optical networks (PONs).

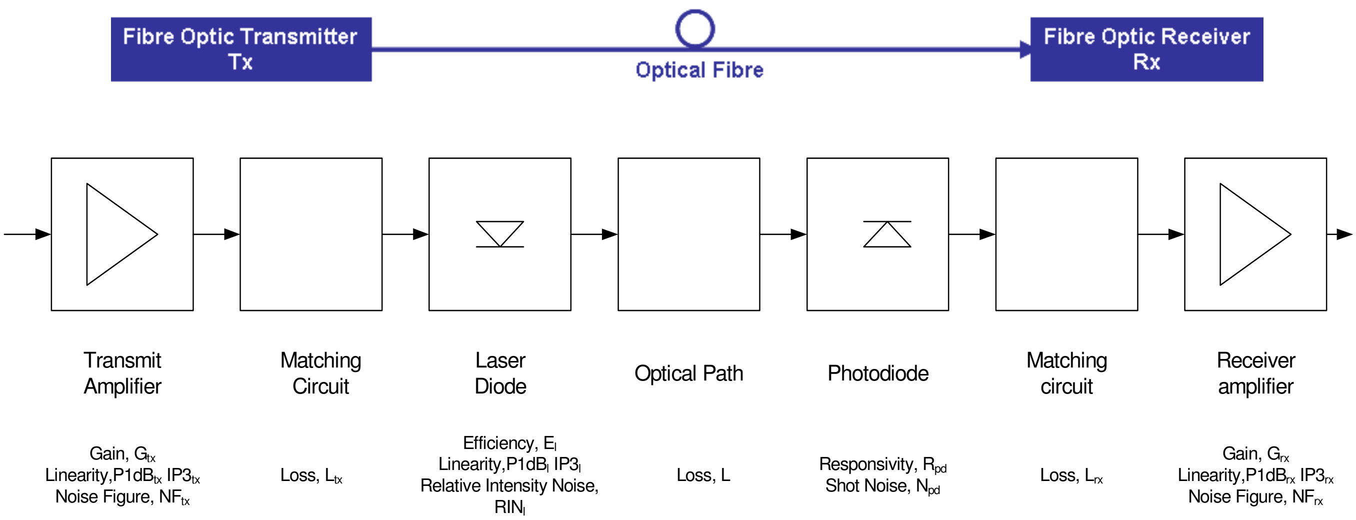
Analogue Fibre Optic Links

In Teleports and Earth Stations, critical satellite transmission infrastructure is supported by off-air up and down links that are increasingly being formed using analogue optical fibre. Fundamentally the end to end design of a fibre optic link (sometimes referred to as a FOL) is quite straight forward (see figure 1), comprising a transmitter, optical fibre (and connectors) and a receiver. These are the elements that enable information to be transported between two points using optical fibre. The electo-optical transmitter (converts electrical information into light) and opto-electrical receiver (reconverts light back into electrical information) performs the necessary conversion processes in order to transport information over optical fibre using light. To understand the contribution the FOL has on the overall service transport performance it is useful to consider the so-called ‘fibre optic link budget’.

Fibre Optic Link Budget

The FOL budget provides the design engineer with quantitative performance information about the FOL. It is determined by computing the FOL power budget and overall link gain.

Figure 1
Fibre Optic Interfacility Link



Fibre Optic Power Budget

The FOL power budget (PB) is simply the difference between the maximum and minimum signals that the FOL can transport.

Fibre Optic Link Gain

FOL link gain is a summation of gains and losses derived from the different elements of the FOL as shown in figure 1. Gains and losses attributed to the Tx, Rx, optical fibre and connectors, as well as any additional in-line components such as splitters, multiplexers, splices etc, must be taken into accounts when computing the link loss budget.

In the case of a simple point-to-point link described in figure 1, and resistively matched (50 ohms) components, the link gain (G) is expressed as:-

$$G = T + R - 2LO \qquad (1)$$

Where T is the gain of the Tx, R is the gain of the Rx, and LO is the insertion loss attributed to the fibre link. Note the factor of two in this last optical term, meaning that for each dB optical loss there is a corresponding 2dB RF loss.

To calculate LO the following information is needed. Standard Corning SMF28 single mode fibre has an insertion loss 0.2dB/km at 1310nm and 0.15dB/km at 1550nm. Optical connectors such as FC/APC typically have an insertion loss of 0.25dB. Optical splices introduce a further 0.25dB loss. Refer to TIA 568 standard for Inter-facility and Premise cable specifications.

Output Noise Power

The output noise power of an analogue FOL must also be considered when quantifying the overall link budget. The measured output noise power is defined as:-

$$\text{Output Noise Power} = ONF + 10\log10\,(BW) \qquad (2)$$

Where ONF (Optical Noise Floor) is the noise output of the link on its own, defined in a bandwidth of 1Hz, and BW is the bandwidth of the service transported over fibre. In a real installation, the NF, or Noise Figure is used to define the noise performance of the fibre optic link and is related to the output noise floor as follows:-

$$ONF = -174dBm + NF + G \qquad (3)$$

-174dBm, is the noise contribution from an ideal 1ohm resistive load at zero degrees Kelvin.

From equation (2), measured output noise power is given as:-

$$= -174dBm + NF + G + 10\log10\,(MBW) \qquad (4)$$

Worked Example

Consider the installation of an L-band SatCom down-link installation used to transport off-air services from the antenna to the control room. The Noise Figure of a typical inter-facility L-band FOL from PPM is 19dB (for 0dB optical loss of the FOL. i.e. a unity gain link). The FOL gain is given in the PPM datasheet as 9dB. Substituting these values into equation (3) gives

$$ONF = -174dBm + 19dB + 9dB$$
$$ONF = -145dB$$

Knowledge of the transmitted service bandwidth enables the Total Output Noise Power of the FOL to be determined from equation (4). For the purposes of this example, we will assume a bandwidth of 25MHz. Therefore the Output Noise Power is:-

$$= -145dBm + 10\log10\,(25000000)$$
$$= -71dBm$$

The maximum power at the input of the FOL (P1dB for the transmitter) is typically -1dBm. So the dynamic range of the FOL is the difference between the maximum and minimum output signal:-

$$DR = Pmax – Pmin$$
$$= (-1dBm) – (-71dBm)$$
$$= 69dBm$$

This is the same as the Carrier-to-Noise Ratio of the link for a -1dBm input signal.

PPM provide a spreadsheet calculator that can be used to easily compute the overall link budget.

Conclusions

This application note has described the factors that determine a fibre optic link budget. It has also shown how a link budget can be calculated.