Optical Power Budgets

The key to network distance is Optical Power Budget: the amount of light available to make a fiber optic connection. This paper will explain how to determine the maximum fiber optic distances attainable using media converters in various network environments. A simple calculation is used to determine how much fiber optic light, measured in “dBms”, is available.

The first step in calculating the Optical Power Budget is determining how much light is available for the electronic devices themselves. Two measurements are needed from the manufacturer of the equipment. *Minimum transmit power* represents the worst case transmit power for a device - the device is guaranteed to provide at least that much power. Please note that some vendors will list an “average minimum transmit power”. Average minimum transmit power does not guarantee that a product will perform at that products’ minimum transmit power. Use caution when purchasing products based on averages.

The second piece of information required is the *minimum receive sensitivity*. This figure represents the minimum amount of light required by the receiver to operate correctly. Again, the actual minimum should be used, not an average of minimums.

With minimum transmit power and minimum receive sensitivity data, we can now calculate the available light. To accomplish this, simply subtract the minimum receive sensitivity from the minimum transmit power (available light = minimum transmit power – minimum receive sensitivity). Note that the minimum receive sensitivity is usually a negative number, such as –33dBm. Subtracting a negative number is the same as adding its absolute value. For example, if a device has a minimum transmit power of –10dBm and a minimum receive sensitivity of –33dBm, the available power will be -10dB - (-)33dB = 23dB or -10B + 33dB = 23db.

Also, when connecting devices from different vendors, or different models of products from the same vendor, the available power calculation needs to be computed in both directions with the smaller of the two used for the rest of the calculations. For example, assume you are connecting two devices labeled “Device” 1 and Device 2. Device 1 has a minimum transmit power of –3dBm and a minimum receive sensitivity of –32dBm and Device 2 has a minimum transmit power of –1dBm and a receive sensitivity of –31dBm. The available power going from Device 1 to Device 2 would be calculated by –3dBm - (-)31dBm or 28dB. The available power going from Device 2 to Device 1 would be calculated by –1dBm - (-)32dBm or 29dB. There is less light available in the Device 1 to Device 2 direction so we will use that figure for our calculations, if that half of the link works then so will the other.

Device 1		**Device 2**	
Min Tx Power	-3dBm	Min Tx Power	-1dBm
Min Rx Sens.	-32dBm	Min Rx Sens.	-31dBm

Budget 1		**Budget 2**	
Device 1 Tx	-3dBm	Device 2 Tx	-1dBm
Device 2 Rx.	-31dBm	Device 1 Rx.	-32dBm
Available Power	**28 dB**	Available Power	29 dB

From available power we must subtract out all of the losses. These losses include cable attenuation, connector loss, and splice loss. Cable attenuation is often the most significant loss factor. Cable attenuation is determined by getting the exact number off of the cable you are installing, or using the manufactures worst case number of the type of fiber you planned to install. This number will range from .22dB to .5dB per kilometer. Multiply this factor by the number of kilometers in the installation. A fiber with .4db per kilometer of loss will loose 16db over a 40km distance.

Also remember that fiber does not come in 40km spools, therefore a 40km installation will have several splices. Each splice will typically introduce .1db of additional loss. The fiber installers should be able to provide a guaranteed worst case number. Multiply this number by the number of splices.

Connectors are another source of light loss. A typical long haul installation will have six connectors in the installation. The first connects the fiber to electronics. This connector is usually on indoor, plenum rated fiber. This fiber connects the equipment room to the building entrance for the outdoor (buried or aerial) fiber. There is another connector on this end of the indoor cable and one on the outdoor cable. This is repeated at the other end of the network for a total of six connectors. Individual networks can vary however, and the exact number must be determined. Connector loss is provided by the connector manufacturer and the installer. Multiply the number of connectors by the loss for each connector to get total connector loss.

Each of these losses, cable attenuation, connector loss, and splice loss is then subtracted from the available power. If this number is negative, there is no need to continue, as there is not enough power to drive the network. If this number is positive, there are two more things to consider before pronouncing the network fit. The first is what happens if the fiber gets cut and I have to splice it back together? A proper installation will count on this happening and account for it in the power budget. An estimation of the number of anticipated repairs over the life of the fiber needs to be made. These repairs will add splice loss, so we must multiply the number of anticipated splices by the loss of each splice (same number we used above), and subtract this from the remaining power. The number should still be positive.

Finally, you must account for temperature extremes, as well as any other unforeseen factors. This is typically done by determining a “safety factor”. This number will be different for every organization depending on how much risk they want to assume in their network. Typically a value around 3dB is used. To guarantee error free operation, a value no less then 1.7dB should be used. This safety factor is subtracted from the remaining power from above. If the number is still positive after all of this, you can be assured that your fiber network will deliver the required performance over the life of the installation.

The table to the right contains some typical numbers, which can be used to approximate optical link budget calculations. If at all possible, real numbers from the network in question should be used.

TIA standard for connector loss	.75 dB
Typical cable attenuation at 1310nm	.4 dB
Typical cable attenuation at 1550nm	.3 dB
Typical splice attenuation	.1 dB
Typical distance between splices	6km
Typical safety margin	3 dB

The simple worksheet below will help you in these calculations.

Optical Budget Calculator

Minimum Transmit Power ____________

Minimum Receive Sensitivity – ____________

Available Power = ____________

________ Km of cable X ____________ dB/km = ____________

________ Connectors X ____________ dB/Con. = ____________

________ Splices X ____________ dB/splice = ____________

Link Margin = ____________

________ Repair Splices X ____________ dB/Splice = ____________

Safety Margin – ____________

Excess Power ____________

Here is an example using the numbers from the white paper

Optical Budget Calculator

				Minimum Transmit Power		-10 dBm
				Minimum Receive Sensitivity	–	-33 dBm
				Available Power	=	23 dB
20	Km of cable	X	.5 dB	dB/km	=	10 dB
6	Connectors	X	.75 dB	dB/Con.	=	4.5 dB
4	Splices	X	.1 dB	dB/splice	=	.4 dB
				Link Margin	=	8.1 dB
5	Repair Splices	X	.1dB	dB/Splice	=	.5 dB
				Safety Margin	–	3 dB
				Excess Power		4.6 dB

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