CHAPTER 4

Optical Loss Budgets

The optical loss budget is an important aspect in designing networks with the Cisco ONS 15530. The optical loss budget is the ultimate limiting factor in distances between nodes in a topology. This chapter contains the following major sections:

- About dB and dBm, page 4-1
- Overall Optical Loss Budget, page 4-2
- Optical Loss for Transponder Line Cards, page 4-4
- Optical Loss for 2.5-Gbps ITU Trunk Cards, page 4-5
- Optical Loss for 10-Gbps ITU Tunable and Non tunable Trunk Cards, page 4-6
- Optical Loss for OADM Modules, page 4-6
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Note The optical specifications described in this chapter are only for the individual components and should not be used to characterize the entire network performance.

Note The information in this chapter applies only to nonamplified network design.

About dB and dBm

Signal power loss or gain is never a fixed amount of power, but a portion of power, such as one-half or one-quarter. To calculate lost power along a signal path using fractional values, you cannot add 1/2 and 1/4 to arrive at a total loss. Instead, you must multiply 1/2 by 1/4. This makes calculations for large networks time-consuming and difficult.

For this reason, the amount of signal loss or gain within a system, or the amount of loss or gain caused by some component in a system, is expressed using the *decibel* (dB). Decibels are logarithmic and can easily be used to calculate total loss or gain just by doing addition. Decibels also scale logarithmically. For example, a signal gain of 3 dB means that the signal doubles in power; a signal loss of 3 dB means that the signal halves in power.

Keep in mind that the decibel expresses a ratio of signal powers. This requires a reference point when expressing loss or gain in dB. For example, the statement "there is a 5 dB drop in power over the connection" is meaningful, but the statement "the signal is 5 dB at the connection" is not meaningful. When you use dB you are not expressing a measure of signal strength, but a measure of signal power loss or gain.

It is important not to confuse decibel and *decibel milliwatt* (dBm). The latter is a measure of signal power in relation to 1 mW. Thus a signal power of 0 dBm is 1 mW, a signal power of 3 dBm is 2 mW, 6 dBm is 4 mW, and so on. Conversely, –3 dBm is 0.5 mW, –6 dBm is 0.25 mW, and so on. Thus the more negative the dBm value, the closer the power level approaches zero.

Overall Optical Loss Budget

An optical signal degrades as it propagates through a network. Components such as OADM modules, fiber, fiber connectors, splitters, and switches introduce attenuation. Ultimately, the maximum allowable distance between the transmitting laser and the receiver is based upon the optical loss budget that remains after subtracting the power losses experienced by the channels as they traverse the components at each node.

Table 4-1 lists the laser transmitter power and receiver sensitivity range for the transponder line cards, ITU trunk card, the OSC (Optical Supervisory Channel) module, and the PSM (protection switch module).

Table 4-1   Trunk Side Transmitter Power and Receiver Ranges

Card or Module Type	Transmitter Power (dBm)		Receiver Sensitivity (dBm)	
	Minimum	Maximum	Minimum	Overload
Transponder line card	5	10	–28	–8
8-port multi-service muxponder	5	10	–28	–8
2.5-Gbps ITU trunk card	5	10	–28	–8
10-Gbps ITU trunk card	1	6	–22	–8
OSC module	5	10	–19	–1.5
PSM			–31	17[1]

1. The receiver detector only reports up to 0 dBm in the CLI (command-line interface). To measure the actual input power to the receiver, use an optical power meter on the optical monitoring port.

Note   Add the proper system-level penalty to the receive power based on your actual network topology characteristics, such as dispersion.

The goal in calculating optical loss is to ensure that the total loss does not exceed the overall optical (or span) budget. The optical budget is determined by subtracting the minimum receiver sensitivity from the minimum laser launch power on the cards. The OSC has an optical budget of 24 dB, which is equal to the minimum OSC receiver sensitivity (–19 dBm) subtracted from the minimum OSC laser launch power (5 dBm) on the OSC module.

Calculating Optical Loss Budgets

Using the optical loss characteristics for the Cisco ONS 15530 components, you can calculate the optical loss between the transmitting laser on one node and the receiver on another node. The general rules for calculating the optical loss budget are as follows:

- The maximum power loss between the nodes cannot exceed the minimum transmit power of the laser minus the minimum sensitivity of the receiver and network-level penalty.

> ✎
> **Note**   Determine the proper network-level penalty to the receive power based on your actual network topology characteristics, such as dispersion.

- The minimum attenuation between the nodes must be greater than the maximum transmitter power of the laser minus the receiver overload value.

The following example shows how to calculate the optical loss budget for 2.5-Gbps data channels using the values in Table 4-1:

- The power loss between the transmit laser and receiver must not exceed 33 (5 – (–28)) dB or the signal will not be detected accurately.

- At least 18 (10 – (–8)) dB of attenuation between neighboring nodes prevents receiver saturation.

To validate a network design, the optical loss must be calculated for each band of channels. This calculation must be done for both directions if protection is implemented, and for the OSC between each pair of nodes. The optical loss is calculated by summing the losses introduced by each component in the signal path.

At a minimum, any data channel path calculation must include line card transmit loss, channel add loss, fiber loss, channel drop loss, and line card receive loss (see Figure 4-1). In ring topologies, pass-through losses must be considered. Losses due to external devices such as fixed attenuators and monitoring taps also need to be included.

Figure 4-1   Elements of Optical Loss in a Minimal Configuration
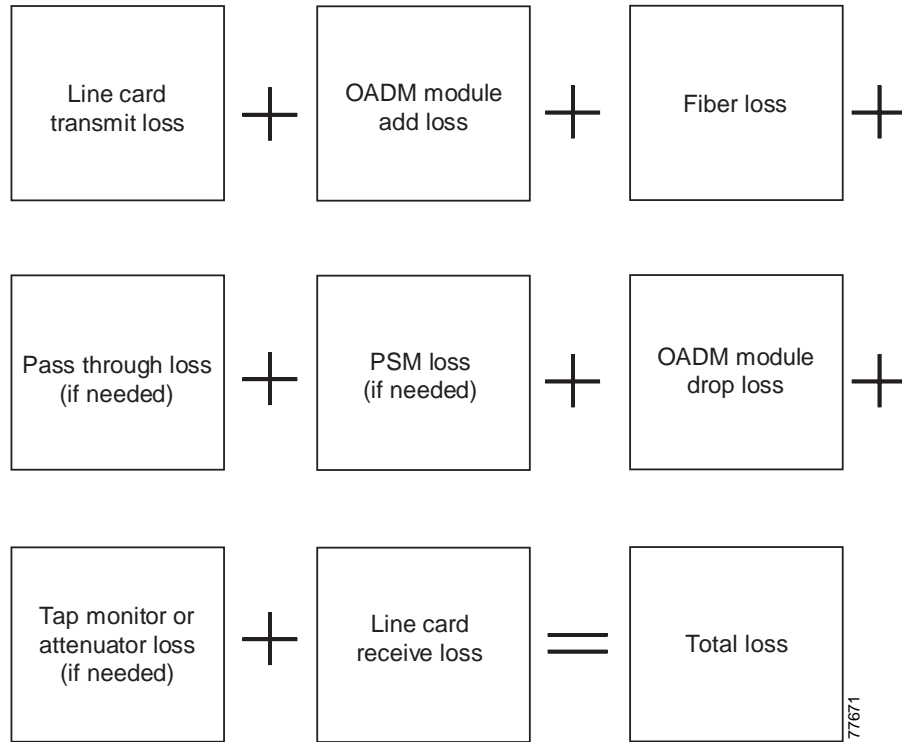
For examples of optical loss budget calculations, see the shelf configurations described in Chapter 6, "Example Shelf Configurations and Topologies."

Optical Loss for Transponder Line Cards

In both the receive and transmit directions, splitter transponder line cards attenuate the ITU signal significantly more than the nonsplitter transponder line cards.

Table 4-2 shows the optical loss for the splitter and nonsplitter transponder line cards supported by the Cisco ONS 15530 in the transmit and receive directions.

Table 4-2   Optical Loss for Transponder Line Cards

Protection Type and Direction	Loss (dB)
Splitter Tx	4.05
Splitter Rx	1.35
Nonsplitter Tx	0.5
Nonsplitter Rx	0.5

Optical Loss for 8-Port Multi-Service Muxponders

In both the receive and transmit directions, splitter 8-port multi-service muxponders attenuate the ITU signal significantly more than the nonsplitter transponder line cards.

Table 4-3 shows the optical loss for the splitter and nonsplitter 8-port multi-service muxponders supported by the Cisco ONS 15530 in the transmit and receive directions.

Table 4-3   Optical Loss for 8-Port Multi-Service Muxponders

Protection Type and Direction	Loss (dB)
Splitter Tx	4.05
Splitter Rx	1.35
Nonsplitter Tx	0.5
Nonsplitter Rx	0.5

Optical Loss for 2.5-Gbps ITU Trunk Cards

In both the transmit and receive directions, splitter 2.5-Gbps ITU trunk cards attenuate the ITU signal significantly more than the nonsplitter 2.5-Gbps ITU trunk cards.

Table 4-4 shows the optical loss for the splitter and nonsplitter 2.5-Gbps ITU trunk cards supported by the Cisco ONS 15530 in the transmit and receive directions.

Table 4-4   Optical Loss for 2.5-Gbps ITU Trunk Cards

Protection Type and Direction	Loss (dB)
Splitter Tx	4.05
Splitter Rx	1.35
Nonsplitter Tx	0.5
Nonsplitter Rx	0.5

Optical Loss for 10-Gbps ITU Tunable and Non tunable Trunk Cards

In both the receive and transmit directions, splitter 10-Gbps ITU tunable and non tunable trunk cards attenuate the ITU signal significantly more than the nonsplitter 10-Gbps ITU tunable and non tunable trunk cards.

Table 4-5 shows the optical loss for the splitter and nonsplitter 10-Gbps ITU tunable and non tunable trunk cards supported by the Cisco ONS 15530 in the transmit and receive directions.

Table 4-5   Optical Loss for 10-Gbps ITU Tunable and Non tunable Trunk Cards

Protection Type and Direction	Loss (dB)
Splitter Tx	4.05
Splitter Rx	1.35
Nonsplitter Tx	0.5
Nonsplitter Rx	0.5

Optical Loss for OADM Modules

OADM (optical add/drop multiplexer) modules attenuate the signals as they are multiplexed, demultiplexed, and passed through. The amount of attenuation depends upon the path the optical signal takes through the modules.

Loss for Data Channels

Table 4-6 shows the optical loss for the data channels between the 4-channel OADM modules and the line cards, and between the pass-through add and drop connectors on the OADM modules.

Table 4-6   Optical Loss for Data Channels Through the OADM Modules

Type of OADM Module	Trunk IN to Line Card (Data Drop) in dB[1]	Line Card to Trunk OUT (Data Add) in dB	Trunk IN to Thru OUT (Pass Through) in dB	Thru IN to Trunk OUT (Pass Through) in dB
4-channel with OSC	4.1	4.1	1.5	1.5
4-channel without OSC	4.1	4.1	1	1

1. The insertion loss is the worst case value so care should be taken when calculating minimum loss budget.

Note   The insertion losses listed in Table 4-6 are worst case values. Take this into consideration when calculating the minimum loss budget.

Loss for the OSC

Table 4-7 shows the optical loss for the OSC between the OSC module and the OADM modules.

Table 4-7   Optical Loss for the OSC Through the OADM Modules

Type of OADM Module	Trunk IN to OSC Transceiver (dB)	OSC Transceiver to Trunk OUT (dB)
4-channel OADM with OSC	2.8	2.8

Optical Loss for PSMs

The PSM attenuates the trunk signal as it passes between the trunk fiber and the OADM module, ITU trunk card, or transponder line card. Table 4-8 shows the optical loss for the channels passing through a PSM.

Table 4-8   Optical Loss for Channels Passing Through PSMs

Direction	Minimum Loss (dB)	Maximum Loss (dB)
Transmit	2.7	3.7
Receive		1.7

Client Signal Latency on Aggregation Card

The process of aggregating client signals on the ESCON aggregation card and the 8-port FC/GE aggregation card adds latency between the client equipment in the network.

ESCON Aggregation Cards

The ESCON aggregation card adds latency to ESCON traffic. The amount of latency depends on how traffic is configured on the node. Table 4-9 shows the ESCON latency values for different configurations of the ESCON aggregation card.

Table 4-9   Latency for ESCON Aggregation Cards

Traffic Mix in the ITU Wavelength	Latency (in microseconds)
ESCON only	8.5
ESCON and FC	8.5
ESCON and GE	17

4-Port 1-Gbps/2-Gbps FC Aggregation Cards

The 4-port 1-Gbps/2-Gbps FC aggregation card adds latency to FC traffic. The amount of latency depends on how traffic is configured on the node. Table 4-12 shows the FC latency values for different configurations of the 4-port 1-Gbps/2-Gbps FC aggregation card.

Table 4-10   1-Gbps FC and FICON Latency Values for 4-port 1-Gbps/2-Gbps FC Aggregation Cards

Traffic Mix on Transmitting Node	Maximum Added End-to-End Latency[1] (Time and Distance)			
	No GE	1518-Byte GE Packets	4470-Byte GE Packets	10,232-Byte GE Packets
One FC/FICON signal only on the 2.5-Gbps aggregated signal carried over a 2.5-Gbps ITU trunk card	12.2 microseconds			
Two FC/FICON signals only on the 2.5-Gbps aggregated signal carried over a 2.5-Gbps ITU trunk card	12.7 microseconds			
One FC/FICON signal only on the 2.5-Gbps aggregated signal carried over a10-Gbps ITU trunk card	11.6 microseconds			
One FC/FICON signal only on the 2.5-Gbps aggregated signal carried over a10-Gbps ITU trunk card		12.8 microseconds	15.2 microseconds	23.9 microseconds
Two FC/FICON signals and GE on the same 2.5-Gbps aggregated signal carried over a 10-Gbps ITU trunk card		13.5 microseconds	16.8 microseconds	26.2 microseconds

1. The latency values are based on configuration of correct transmit buffer sizes as described in the *Cisco ONS 15530 Configuration Guide*.

Table 4-11   2-Gbps FC and FICON Latency Values for 4-port 1-Gbps/2-Gbps FC Aggregation Cards

Traffic Mix on Transmitting Node	Maximum Added End-to-End Latency[1] (Time and Distance)			
	No GE	1518-Byte GE Packets	4470-Byte GE Packets	10,232-Byte GE Packets
One FC/FICON signal only on the 2.5-Gbps aggregated signal carried over a 2.5-Gbps ITU trunk card	10.6 microseconds			
One FC/FICON signal only on the 2.5-Gbps aggregated signal carried over a10-Gbps ITU trunk card	9.9 microseconds			
One FC/FICON signal only on the 2.5-Gbps aggregated signal carried over a10-Gbps ITU trunk card		12.1 microseconds	15.4 microseconds	25.1 microseconds

1. The latency values are based on configuration of correct transmit buffer sizes as described in the *Cisco ONS 15530 Configuration Guide*.

8-Port FC/GE Aggregation Cards

The 8-port FC/GE aggregation card adds latency to FC traffic. The amount of latency depends on how traffic is configured on the node. Table 4-12 shows the FC latency values for different configurations of the 8-port FC/GE aggregation card.

Table 4-12   FC and FICON Latency Values for 8-Port FC/GE Aggregation Cards

Traffic Mix on Transmitting Node	Maximum Added End-to-End Latency[1] (Time and Distance)			
	No GE	1518-Byte GE Packets	4470-Byte GE Packets	10,232-Byte GE Packets
FC/FICON only on the 2.5-Gbps aggregated signal carried over a 2.5-Gbps ITU trunk card	18.8 microseconds (3.8 km)			
FC/FICON only on a 2.5-Gbps aggregated signal carried over a 10-Gbps ITU trunk card	19.9 microseconds (4.0 km)			
FC/FICON only on a 2.5-Gbps aggregated signal mixed with GE on the same 10-Gbps ITU trunk card		22.2 microseconds (4.4 km)	24.8 microseconds (5.0 km)	36.3 microseconds (7.3 km)
FC/FICON and GE on the same 2.5-Gbps aggregated signal carried over a 2.5-Gbps ITU trunk card		27.9 microseconds (5.6 km)	47.1 microseconds (9.4 km)	83.6 microseconds (16.7 km)
FC/FICON and GE on the same 2.5-Gbps aggregated signal carried over a 10-Gbps ITU trunk card		39.2 microseconds (7.8 km)	77.1 microseconds (15.4 km)	151.1 microseconds (30.2 km)

1. The latency values are based on configuration of correct transmit buffer sizes as described in the *Cisco ONS 15530 Configuration Guide*.

8-Port Multi-Service Muxponders

The 8-port multi-service muxponder adds latency to client traffic. Table 4-13 shows the client traffic latency values for the 8-port multi-service muxponder.

Table 4-13   Latency Values for 8-Port Multi-Service Muxponders

Protocol	Unidirectional End-to-End Latency for 0 km Fiber	
	Typical Latency (microseconds)	Maximum Latency (microseconds)
ESCON	10	13
Fibre Channel	4	6
GE (optical)	8	10
FE (optical)	16	18
GE (copper)	9	11
FE (copper)	18	20

Table 4-13   Latency Values for 8-Port Multi-Service Muxponders (continued)

Protocol	Unidirectional End-to-End Latency for 0 km Fiber	
	Typical Latency (microseconds)	Maximum Latency (microseconds)
SDI	17	20
DVB-ASI	9	11

Fiber Plant Testing

Verifying fiber characteristics to qualify the fiber in the network requires proper testing. This document describes the test requirements but not the actual procedures. After finishing the test measurements, compare the measurements with the specifications from the manufacturer, and determine whether the fiber supports your system requirements or whether changes to the network are necessary.

This test measurement data can also be used to determine whether your network can support higher bandwidth services such as 10 Gigabit Ethernet, and can help determine network requirements for dispersion compensator modules or amplifiers.

The test measurement results must be documented and referred to during acceptance testing of a network.

Fiber optic testing procedures must be performed to measure the following parameters:

- Link loss (attenuation)
- ORL (optical return loss)
- PMD (polarization mode dispersion)
- Chromatic dispersion

Link Loss (Attenuation)

Testing for link loss, or attenuation, verifies whether fiber spans meet loss budget requirements.

Attenuation includes intrinsic fiber loss, losses associated with connectors and splices, and bending losses due to cabling and installation. An OTDR (optical time domain reflector/reflectometer) is used when a comprehensive accounting of these losses is required. The OTDR sends a laser pulse through each fiber; both directions of the fiber are tested at 1310 nm and 1550 nm wavelengths.

OTDRs also provide information about fiber uniformity, splice characteristics, and total link distance. For the most accurate loss test measurements, an LTS (loss test set) that consists of a calibrated optical source and detector is used. However, the LTS does not provide information about the various contributions (including contributions related to splice and fiber) to the total link loss calculation.

A combination of OTDR and LTS tests is needed for accurate documentation of the fiber facilities being tested. In cases where the fiber is very old, testing loss as a function of wavelength (also called spectral attenuation) might be necessary. This is particularly important for qualifying the fiber for multiwavelength operation. Portable chromatic dispersion measurement systems often include an optional spectral attenuation measurement.

ORL

ORL is a measure of the total fraction of light reflected by the system. Splices, reflections created at optical connectors, and components can adversely affect the behavior of laser transmitters, and they all must be kept to a minimum of 24 dB or less. You can use either an OTDR or an LTS equipped with an ORL meter for ORL measurements. However, an ORL meter yields more accurate results.

PMD

PMD has essentially the same effect on the system performance as chromatic dispersion, which causes errors due to the "smearing" of the optical signal. However, PMD has a different origin from chromatic dispersion. PMD occurs when different polarization states propagate through the fiber at slightly different velocities.

PMD is defined as the time-averaged DGD (differential group delay) at the optical signal wavelength. The causes are fiber core eccentricity, ellipticity, and stresses introduced during the manufacturing process. PMD is a problem for higher bit rates (10 GE and above) and can become a limiting factor when designing optical links.

The time-variant nature of dispersion makes it more difficult to compensate for PMD effects than for chromatic dispersion. "Older" (deployed) fiber may have significant PMD—many times higher than the 0.5 ps/ km specification seen on most new fiber. Accurate measurements of PMD are very important to guarantee operation at 10 Gbps. Portable PMD measuring instruments have recently become an essential part of a comprehensive suite of tests for new and installed fiber. Because many fibers in a cable are typically measured for PMD, instruments with fast measurement times are highly desirable.

Chromatic Dispersion

Chromatic dispersion testing is performed to verify that measurements meet your dispersion budget.

Chromatic dispersion is the most common form of dispersion found in single-mode fiber. Temporal in nature, chromatic dispersion is related only to the wavelength of the optical signal. For a given fiber type and wavelength, the spectral line width of the transmitter and its bit rate determine the chromatic dispersion tolerance of a system. Dispersion management is of particular concern for high bit rates (10 Gbps) using conventional single-mode fiber. Depending on the design of the 10-Gbps transceiver module, dispersion compensation might be needed to accommodate an upgrade from GE to 10 GE in order to keep the same targeted distances.

Portable chromatic dispersion measurement instruments are essential for testing the chromatic dispersion characteristics of installed fiber.

Fiber Requirements for 10-Gbps Transmission

Do not deploy 10-Gbps wavelengths, or even 2.5-Gbps wavelengths, over G.653 fiber. This type of fiber causes enormous amounts of nonlinear effects.