CHAPTER 5

System Engineering

This chapter provides the basic planning and engineering information required to configure an ONS 15454 node for DWDM deployment.

The following topics are covered in this chapter:

5.1 Client Interfaces

Table 5-1 lists all DWDM cards and their assigned class.

Table 5-1 Cards, Protection Type, and Class

Product ID	Card Type	Protection Type	Card Name	Card Description	Class
15454-O48E-1-xx.x	2.5 Gbps	Client 1+1	OC-48 (ANSI)	OC48 ELR/STM16EH 100 GHz -15xx.xxnm	G
15454E-EL16HSxx.xx (ETSI)			STM16 (ETSI)		
15454-MRP-L1-xx.x (ANSI Fiber Switched) 15454-MRP-I-xx.x (ETSI Fiber Switched) 15454-MR-L1-xx.x (ANSI) 15454E-MR-1-xx.x (ETSI)	2.5G MR TXP w/FEC[1] (ISC-1 Not Supported)	Client 1+1 Y-Cable Fiber-Switched	TXPP_MR_2.5G TXP_MR_2.5G	2.5-Gbps Multirate Transponder-Protected 100-GHz-Tunable xx.xx-xx.xx 2.5-Gbps Multirate Transponder 100-GHz-Tunable xx.xx-xx.xx	D/E/F
	2.5G MR TXP w/o FEC	Client 1+1 Y-Cable (No ISC-I) Fiber-Switched (No ISC-I)			
	2.5G MR TXP 2R[2] Mode	Client 1+1 Y-Cable (No ETR/CLO) (No ISC-3) Fiber-Switched (No ETR/CLO) (No ISC-I)			

Table 5-1 Cards, Protection Type, and Class (continued)

Product ID	Card Type	Protection Type	Card Name	Card Description	Class
15454-192L-1-xx.x (ANSI) 15454E-64L-1-xx.x (ETSI)	10-Gbps LR[3] ITU-T	Client 1+1	OC-192(ANSI) STM-64 (ETSI)	OC-192 LR/STM64 LH ITU 15xx.xx	C
15454 10T-L1-xx.xx (ANSI) 15454E 10T-xx.xx (ETSI)	10G MR TXP w/FEC 10G MR TXP w/o FEC	Client 1+1 Y-Cable	TXP_MR_10G	10-Gbps Transponder-100-GHz - Tunable xx.xx-xx.xx	A/B/C
15454-10M-L1-xx.xx (ANSI) 15454E-10M-xx.xx (ETSI)	4x2.5-Gbps MXP w/FEC 4x2.5-Gbps MXP w/o FEC	Client 1+1 Y-Cable	MXP_2.5G_10G	2.5-Gbps-10-Gbps Muxponder-100-GHz-Tunable xx.xx-xx.xx	A/B/C
15454-DMP-L1-xx.xx (ANSI Fiber-switched) 15454-DMP-1-xx.x (ETSI Fiber Switched) 15454-DM-L1-xx.x (ANSI) 15454-DM-1-xx.x (ETSI)	2.5G Data MXP w/o FEC	Client 1+1 Y-Cable Fiber-Switched	MXPP_MR_2.5G MXP_MR_2.5G	2.5-Gbps Multirate Muxponder-Protected-100-GHz-Tunable 15xx.xx-15yy.yy 2.5-Gbps Multirate Muxponder - 100-GHz-Tunable 15xx.xx-15yy.yy	E
15454-10E-L1-xx.xx (ANSI) 15454E-10E-1-xx.xx (ETSI)	10G Enh MR TXP w/ FEC 10G Enh MR TXP w/ FEC 10G Enh MR TXP w/o FEC	Client 1+1 Y-Cable	TXP_MR_10E	10-Gbps Transponder 100-GHz-Enhanced-Tunable xx.xx-xx.xx	A/C/I
15454-10ME-xx.x (ANSI) 15454E-10ME-xx.x (ETSI)	4x2.5-Gbps Enh MXP w/ EFEC[4] 4x2.5-Gbps Enh MXP w/ FEC	Client 1+1 Y-Cable	MXP_2.5G_10E	10-Gbps Muxponder - 100-GHz-Enhanced FEC -Tunable xx.x-xx.x	A/C/I

Table 5-1 Cards, Protection Type, and Class (continued)

Product ID	Card Type	Protection Type	Card Name	Card Description	Class
15454-10E-L1-C=	10G Enh MR TXP w/ FEC 10G Enh MR TXP w/ FEC 10G Enh MR TXP w/o FEC	Client 1+1 Y-Cable	TXP_MR_10E	10-Gbps Transponder Full C-Band Tunable	A/C/I
15454-10E-L1-L=				10-Gbps Transponder Full L-Band Tunable	
15454-10ME-L1-C=	10G Enh MR MXP w/ EFEC 10G Enh MR MXP w/ FEC 10G Enh MR MXP w/o FEC		MXP_2.5G_10E	10-Gbps Muxponder Full C-Band Tunable	
15454-10ME-L1-L=				10-Gbps Muxponder Full L-Band Tunable	
15454-10DME-C=	10G Enh DATA MXP w/ EFEC 10G Enh DATA MXP w/ FEC 10G Enh DATA MXP w/o FEC		MXP_MR_10DME	10-Gbps Data Muxponder Full C-Band Tunable	
15454-10DME-L=				10-Gbps Data Muxponder Full L-Band Tunable	
15454-GBIC-xx.x (ANSI) 15454E-GBIC-xx.x (ETSI)	GE WDM[5] GBIC[6]	Client 1+1	WDM GBIC xx.x	GBIC xx.x WDM 100GHz	G
15530-ITU2-xx10 (w/splitter) 15530-ITU2-xx20 (no splitter)	10Gbps Aggregation (w/splitter) 10Gbps Aggregation	Client 1+1 Fiber-switched/ Splitter	ONS 15530 Ch x 10-Gbps ITU Trunk Card MU w/ Splitter ONS 15530 Ch x 10-Gbps ITU Trunk Card MU w/o Splitter	ONS 15530 10-Gbps ITU Trunk Card with splitter ONS 15530 10-Gbps ITU Trunk Card without splitter	C
15530 -ITU3-xx10 (w/splitter) 15530-ITU3-xx20 (no splitter)	2.5 Gbps Aggregation (w/ splitter) 2.5 Gbps Aggregation	Client 1+1 Fiber-switched/ Splitter	15530-ITU3-xx10 15530 ITU3-xx 20	ONS 15530 Ch x/y 2.5-Gbps ITU Trunk Card MU w/ Splitter ONS 15530 Ch x/y 2.5-Gbps ITU Trunk Card MU w/o Splitter	J

Table 5-1 Cards, Protection Type, and Class (continued)

Product ID	Card Type	Protection Type	Card Name	Card Description	Class
15530-TSP1-xx11 (MM[7] w/splitter) 15530-TSP1-xx12 (SM[8] w/splitter) 15530-TSP1-xx21 (MM, no splitter) 15530-TSP1-xx22 (SM, no splitter)	MR MM Transponder (w/ splitter) MR SM Transponder (w/ splitter) MR MM Transponder MR SM Transponder	Client 1+1 Y-Cable Fiber-switched/ Splitter	15530-TSP1-xx11 15530-TSP1-xx12 15530-TSP1-xx21 15530-TSP1-xx22	ONS 15530 Transponder Ch x/y - 1310 nm MM SC w/splitter ONS 15530 Transponder Ch x/y - 1310 nm SM SC w/splitter ONS 15530 Transponder Ch x/y - 1310 nm MM SC w/o splitter ONS 15530 Transponder Ch x/y - 1310 nm SM SC w/o splitter	J
15530-MSMP-xx12 (w/ splitter) 15530-MSMP-xx22 (no splitter)	Data Muxponder (w/splitter) Data Muxponder	Client 1+1 Fiber-switched/ splitter	15530 MSMP-xx12 15530 MSMP-xx22	MR Data Muxponder (w/ splitter) MR Data Muxponder (w/o splitter)	J

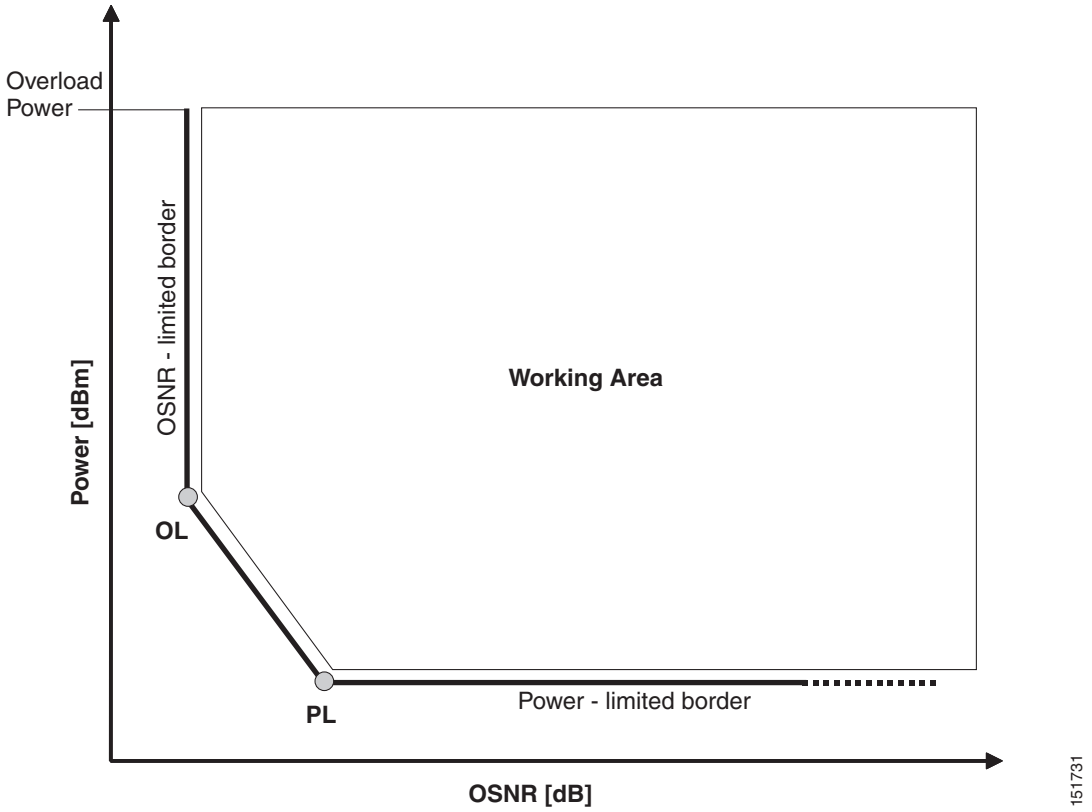
1. FEC: Forward Error Correction
2. 2R: reshape and regenerate
3. LR: Long Range
4. EFEC: Enhanced FEC
5. WDM: Wavelength division multiplexing
6. GBIC: Gigabit Interface Converter
7. MM: Multimode
8. SM: Single mode

Client interfaces (cards) have been grouped in ten classes (Class A through Class J). All client interfaces supported by DWDM can be specified in terms of their ISO-BER curve.

The operative area of an interface is defined on a two-dimensional Cartesian plane where the X axis is the optical signal-to-noise ratio (OSNR) value [in dB] and the Y axis is the power value [in dBm], as shown in Figure 5-1.

The limits to the operative area are three lines that result from a simple approximation of an ISO-BER line. The original ISO-BER line has two points, OSNR Limited (OL) and Power Limited (PL), that define the two main borders of the simplified working area. The two main borders are “OSNR Limited” and “Power Limited.” OL and OP are defined by two sets of coordinates, namely OLOSNR/OLPower and PLOSNR/PLPower, whose initial values are defined in Table 5-2, Table 5-3, and Table 5-4.

Figure 5-1 Client Interface ISO BER Curve and Rectangle Definition for Specifying Performance



The upper limit of the "OSNR limited" border is the interface power overload, which also draws an upper limit to the working area. Theoretically, there is no upper limit to the OSNR value, but physical constraints limit this value to 35 to 40 dB.

Table 5-2 Optical Performance in the 10-Gbps Interface Classes A, B, C, and I

Parameter	Class A		Class B		Class C	Class I		Unit
	Power Limited	OSNR Limited	Power Limited	OSNR Limited	OSNR Limited	Power Limited	OSNR Limited	
Maximum bit rate	10		10		10	10		Gbps
Regeneration	3R		3R		3R	3R		
FEC	Yes		No		No	Yes (E-FEC)		
Threshold	Optimum		Average		Average	Optimum		
Maximum BER	10^{-15}		10^{-12}		10^{-12}	10^{-15}		
OSNR sensitivity	23	9	23	19	19	20	6	dB
Power sensitivity	–24	–18	–21	–20	–22	–26	–18	dBm
15530-ITU2-xx10 power sensitivity	—	—	—	—	–20.5	—	—	dBm
Power overload	–8		–8		–9	–8		dBm

Table 5-2 Optical Performance in the 10-Gbps Interface Classes A, B, C, and I (continued)

Parameter		Class A		Class B		Class C	Class I		Unit
		Power Limited	OSNR Limited	Power Limited	OSNR Limited	OSNR Limited	Power Limited	OSNR Limited	
Transmitted power range	TXP_MR_10G MXP_2.5G_10G	+2.5 / +3.5		+2.5 / +3.5		—	—		dBm
	OC192_LR	—		—		+3 / +6	—		dBm
	TXP_MR_10E MXP_2.5G_10E	+3 / +6		—		+3 / +6	+3 / +6		dBm
	15530-ITU2-xx20	—		—		+3 / +6	—		dBm
	15530-ITU2-xx10	—		—		–1.2 / +1.8	—		dBm
Dispersion compensation tolerance		+/– 800		+/– 1000		+/– 1000	+/– 1000	+/– 800	ps/nm

Table 5-3 Optical Performance in the 2.5-Gbps Interface Classes D, E, F and G

Parameter		Class D		Class E		Class F	Class G		Unit
		Power Limited	OSNR Limited	Power Limited	OSNR Limited	OSNR Limited	Power Limited	OSNR Limited	
Maximum bit rate		2.5		2.5		2.5	2.5		Gbps
Regeneration		3R		3R		2R	3R		
FEC		Yes		No		No	No		
Threshold		Average		Average		Average	Average		
Maximum BER		10^{-15}		10^{-12}		10^{-12}	10^{-12}		
OSNR sensitivity		14	6	14	10	15	14	11	dB
Power sensitivity		–31	–25	–30	–23	–24	–27	–23	dB
Power overload		–9		–9		–9	–9		dBm
Transmitted power range	TXP_MR_2.5G	–1 / +1		–1 / +1		–1 / +1	–2 / 0		dBm
	TXPP_MR_2.5G	–4.5 / –2.5		–4.5 / –2.5		-4.5 / –2.5			dBm
	MXP_MR_2.5G	—		+2 / +4		—			dBm
	MXPP_MR_2.5G	—		–1.5 / +0.5		—			dBm
Dispersion compensation tolerance		–1200 + 5400		–1200 + 5400		–1200 +3300	–1200 +5000		ps/nm

Table 5-4 Optical Performance in the 2.5-Gbps Interface Classes H and J

Parameter	Class H		Class J	Unit
	Power Limited	OSNR Limited	Power Limited	
Maximum bit rate	1.25		2.5	Gbps
Regeneration	3R		3R	
FEC	No		No	

Table 5-4 Optical Performance in the 2.5-Gbps Interface Classes H and J (continued)

Parameter		Class H		Class J	Unit
		Power Limited	OSNR Limited	Power Limited	
Threshold		Average		Average	
Maximum BER		10^{-12}		10^{-12}	
OSNR sensitivity		13	8	12	dB
Power sensitivity		–28	–18	–26	dBm
15530-ITU3-xx10 15530-TSP1-xx11 15530-TSP1-xx12 Power sensitivity		—		–24.5	
Power overload		–7		–17	dBm
Transmitted power range	DWDM-GBIC	0 / +3		—	dBm
	15530-ITU3-xx20 15530-TSP1-xx21 15530-TSP1-xx22 15530-MSMP-xx22	—		+5 / +10	
	15530-ITU3-xx10 15530-TSP1-xx11 15530-TSP1-xx12 15530-MSMP-xx12	—		+0.8 / +5.8	
Dispersion compensation tolerance		–1000 / +3600		–1000 / +3200	ps/nm

5.2 System Optical Performance

This section discusses the optical performance parameters of a Cisco ONS 15454 DWDM system.

5.2.1 Maximum Number of Nodes

The Network Wizard in the Cisco MetroPlanner tool allows you to create a ring or a linear topology with a maximum of 60 locations. Up to 20 of these 60 locations can be equipped with optical amplifier cards (OPT-PRE and/or OPT-BST) and optical service channel cards (OSCM and/or OSC-CSM cards). Up to 16 of those 20 locations can be equipped with optical add/drop multiplexer (OADM) cards.

The entire network cannot include more than 40 amplifiers in each direction [clockwise(CW)/counter clockwise(CCW)], which relates to the 20 locations that can be equipped with optical amplifier cards and optical service channel cards.

Before 3R regeneration occurs, individual optical connections cannot include more than 30 amplifiers per direction (CW/CCW), which relates to the number of OADM nodes you can have in the network, assuming that there are a maximum of two optical amplifiers in the same node.

5.2.2 Optical Performance (OSNR Limited)

A network configuration, whether ring or linear, is created by a general combination of spans and nodes with unequal losses. Cisco MetroPlanner requires that the design of a network (in terms of amplifier and OADM card placement) must satisfy the traffic demand between the nodes. This section contains optical performance information from a limited number of reference cases characterized by configurations with equal span and node losses.

The optical performance examples provided in the "5.2.3 C-Band Optical Performance" section on page 5-8 and the "5.2.4 L-Band Optical Performance" section on page 5-18 are calculated for the worst channel path that can be provisioned with regard to the number of amplified nodes multiplied by the span loss (assuming equal spans and node losses in a link). For example, saying that a referenced optical performance is 5x20 dB means that the longest channel path on a ring can pass through five amplified nodes with a maximum of 20 dB loss for each span.

Note The span losses specified in this section are end-of-life values including margins for cable aging and repairs.

Note The optical performance examples are given for the Metro Core applications only.

5.2.3 C-Band Optical Performance

Table 5-5 details the target system performance of an ONS 15454 DWDM C-band system.

Table 5-5 C-Band Supported Topologies and Node Types

Number of Channels	Fiber Type	Topologies	Node Type
32	SMF-28[1]	Ring	Hub
	E-LEAF[2]	Linear	Active OADM
	TW-RS[3]	Linear without OADM	Passive OADM
			ROADM
			Terminal
			Line
			OSC regeneration
16	SMF-28	Ring	Hub
		Linear	Active OADM
		Linear without OADM	Passive OADM
			ROADM
			Terminal
			Line
			OSC regeneration

Table 5-5 C-Band Supported Topologies and Node Types (continued)

Number of Channels	Fiber Type	Topologies	Node Type
8	SMF-28	Linear without OADM	Terminal Line

1. SMF-28 = single-mode fiber 28
2. E-LEAF = enhanced large effective area fiber
3. TW-RS = TrueWave reduced slope fiber

For a description of rings and linear configurations with fixed OADM nodes and without OADM nodes, refer to the "Network Reference" chapter in the *Cisco ONS 15454 DWDM Reference Manual*. For optical performance information for ROADM rings and single-span networks, also refer to the "Network Reference" chapter in the *Cisco ONS 15454 DWDM Reference Manual*.

5.2.3.1 Optical Performance for Rings and Linear Networks with OADM Nodes

The following tables provide optical performance estimates for open and closed ONS 15454 rings and linear networks with OADM nodes.

Table 5-6 shows the optical performance for 32-channel networks using SMF fiber. Span losses shown in the table assume:

- OADM nodes have a loss of 16 dB and equal span losses.
- The dispersion compensation unit (DCU) loss is 9 dB.
- OPT-PRE and OPT-BST/OPT-BST-E amplifiers are installed in all nodes.
- The OPT-PRE amplifier switches to control power whenever the span loss is higher than 27 dB.

Table 5-6 Span Loss for 32-Channel Ring and Linear Networks with OADM Nodes Using SMF Fiber

Number of Spans	10 Gbps				2.5 Gbps					
	Class A	Class B	Class C	Class I	Class D	Class E	Class F	Class G	Class H	Class J
1	35 dB	25 dB	25 dB	37 dB	37 dB	33 dB	30 dB	32 dB	34 dB	30 dB
2	29 dB	21 dB	20 dB	30 dB	31 dB	27 dB	25 dB	26 dB	28 dB	25 dB
3	26 dB	17 dB	15 dB	28 dB	29 dB	25 dB	23 dB	24 dB	26 dB	23 dB
4	24 dB	—	—	25 dB	26 dB	23 dB	20 dB	22 dB	24 dB	20 dB
5	23 dB	—	—	24 dB	25 dB	22 dB	16 dB	20 dB	23 dB	16 dB
6	21 dB	—	—	23 dB	24 dB	19 dB	—	17 dB	21 dB	—
7	20[1] dB	—	—	22 dB	23 dB	16 dB	—	—	19 dB	—

1. 0.5 dB of OSNR impairment recovered by FEC margin @ BER > 10-6

Table 5-7 shows the optical performance for 16-channel networks using SMF fiber. Span loss values assume the following:

- OADM nodes have a loss of 16 dB and equal span losses.
- The DCU loss is 9 dB.
- All nodes have OPT-PRE and OPT-BST/OPT-BST-E amplifiers installed.

- The OPT-PRE amplifier switches to control power whenever the span loss is higher than 27 dB.

Table 5-7 Span Loss for 16-Channel Ring and Linear Networks with OADM Nodes Using SMF Fiber

Number of Spans	10 Gbps				2.5 Gbps					
	Class A	Class B	Class C	Class I	Class D	Class E	Class F	Class G	Class H	Class J
1	37 dB	29 dB	28 dB	37 dB	37 dB	36 dB	33 dB	35 dB	37 dB	33 dB
2	32 dB	24 dB	24 dB	34 dB	35 dB	31 dB	28 dB	30 dB	32 dB	28 dB
3	29 dB	22 dB	21 dB	31 dB	32 dB	28 dB	25 dB	27 dB	29 dB	25 dB
4	27 dB	19 dB	17 dB	29 dB	30 dB	26 dB	23 dB	25 dB	27 dB	23 dB
5	26 dB	—	—	27 dB	28 dB	24 dB	22 dB	24 dB	25 dB	22 dB
6	25 dB	—	—	26 dB	27 dB	23 dB	21 dB	23 dB	24 dB	21 dB
7	24 dB	—	—	25 dB	256dB	23 dB	19 dB	22 dB	23 dB	19 dB

Table 5-8 shows the optical performance for 32-channel networks using TW-RS fiber. Span loss values assume the following:

- OADM nodes have a loss of 16 dB and equal span losses.
- The DCU is 550 ps with 4 dB loss.
- All nodes have OPT-PRE and OPT-BST/OPT-BST-E amplifiers installed.
- The OPT-PRE amplifier switches to control power whenever the span loss is higher than 27 dB.

Table 5-8 Span Loss for 32-Channel Ring and Linear Networks with OADM Nodes Using TW-RS Fiber

Number of Spans	10 Gbps				2.5 Gbps					
	Class A	Class B	Class C	Class I	Class D	Class E	Class F	Class G	Class H	Class J
1	35 dB	25 dB	25 dB	37 dB	37 dB	33 dB	30 dB	32 dB	34 dB	30 dB
2	29 dB	21 dB	20 dB	31 dB	32 dB	28 dB	26 dB	27 dB	29 dB	26 dB
3	27 dB	17 dB	15 dB	29 dB	30 dB	26 dB	23 dB	25 dB	27 dB	23 dB
4	25 dB	—	—	27 dB	28 dB	23 dB	20 dB	22 dB	24 dB	20 dB
5	23 dB	—	—	26 dB	27 dB	22 dB	16 dB	20 dB	23 dB	16 dB
6	21 dB	—	—	24 dB	25 dB	19 dB	—	17 dB	21 dB	—
7	20 dB	—	—	22 dB	24 dB	16 dB	—	—	19 dB	—

Table 5-9 shows the optical performance for 32-channel networks using E-LEAF fiber. Span loss values assume the following:

- OADM nodes have a loss of 16 dB and equal span losses.
- The DCU is 550 ps with 4 dB loss.
- All nodes have OPT-PRE and OPT-BST/OPT-BST-E amplifiers installed.
- The OPT-PRE amplifier switches to control power whenever the span loss is higher than 27 dB.

Table 5-9 Span Loss for 32-Channel Ring and Linear Networks with OADM Nodes Using E-LEAF Fiber

Number of Spans	10 Gbps				2.5 Gbps					
	Class A	Class B	Class C	Class I	Class D	Class E	Class F	Class G	Class H	Class J
1	35 dB	25 dB	25 dB	37 dB	37 dB	33 dB	30 dB	32 dB	34 dB	30 dB
2	29 dB	21 dB	20 dB	31 dB	32 dB	28 dB	26 dB	27 dB	29 dB	26 dB
3	27 dB	17 dB	15 dB	29 dB	30 dB	26 dB	23 dB	25 dB	27 dB	23 dB
4	24 dB	—	—	26 dB	28 dB	23 dB	20 dB	22 dB	24 dB	20 dB
5	22 dB	—	—	24 dB	27 dB	22 dB	16 dB	20 dB	23 dB	16 dB
6	20 dB	—	—	22 dB	25 dB	19 dB	—	17 dB	21 dB	—
7	17 dB	—	—	20 dB	24 dB	16 dB	—	—	19 dB	—

5.2.3.2 Optical Performance for Linear Networks Without OADM Nodes

The following tables list the reference optical performances for linear networks without OADM nodes.

Table 5-10 shows the optical performance for 32-channel linear networks using SMF fiber. Span loss values assume the following:

- No OADM nodes are installed and span losses are equal.
- The DCU loss is 9 dB.
- Only OPT-PRE amplifiers are installed.

Table 5-10 Span Loss for 32-Channel Linear Networks without OADM Nodes Using SMF Fiber

Number of Spans	10 Gbps				2.5 Gbps					
	Class A	Class B	Class C	Class I	Class D	Class E	Class F	Class G	Class H	Class J
1	35 dB	25 dB	25 dB	37 dB	37 dB	33 dB	30 dB	32 dB	34 dB	30 dB
2	27 dB	20 dB	19 dB	29 dB	30 dB	26 dB	23 dB	25 dB	26 dB	23 dB
3	24 dB	17 dB	17 dB	25 dB	26 dB	23 dB	20 dB	22 dB	23 dB	20 dB
4	22 dB	15 dB	14 dB	23 dB	24 dB	21 dB	19 dB	20 dB	22 dB	19 dB
5	21 dB	—	—	22 dB	22 dB	20 dB	18 dB	19 dB	20 dB	18 dB
6	20 dB	—	—	21 dB	21 dB	19 dB	17 dB	18 dB	19 dB	17 dB
7	19 dB	—	—	20 dB	20 dB	18 dB	16 dB	18 dB	19 dB	16 dB

Table 5-11 shows the optical performance for 32-channel linear networks using TW-RS fiber. Span loss values assume the following:

- No OADM nodes are installed and span losses are equal.
- The DCU is 550 ps with 4 dB loss.
- Only OPT-PRE amplifiers are installed.

Table 5-11 Span Loss for 32-Channel Linear Networks without OADM Nodes Using TW-RS Fiber

Number of Spans	10 Gbps				2.5 Gbps					
	Class A	Class B	Class C	Class I	Class D	Class E	Class F	Class G	Class H	Class J
1	35 dB	25 dB	25 dB	37 dB	37 dB	33 dB	30 dB	32 dB	34 dB	30 dB
2	28 dB	20 dB	20 dB	30 dB	31 dB	27 dB	24 dB	26 dB	27 dB	24 dB
3	26 dB	18 dB	17 dB	27 dB	28 dB	24 dB	22 dB	23 dB	25 dB	22 dB
4	24 dB	15 dB	14 dB	25 dB	26 dB	23 dB	21 dB	22 dB	24 dB	20 dB
5	23 dB	—	—	24 dB	25 dB	22 dB	19 dB	21 dB	22 dB	19 dB
6	22 dB	—	—	23 dB	24 dB	20 dB	17 dB	19 dB	21 dB	17 dB
7	21 dB	—	—	23 dB	23 dB	19 dB	16 dB	18 dB	20 dB	16 dB

Table 5-12 shows the optical performance for 32-channel linear networks using E-LEAF fiber. Span loss values assume the following:

- No OADM nodes are installed and span losses are equal.
- The DCU is 550 ps with 4 dB loss.
- Only OPT-PRE amplifiers are installed.

Table 5-12 Span Loss for 32-Channel Linear Networks without OADM Nodes Using E-LEAF Fiber

Number of Spans	10 Gbps				2.5 Gbps					
	Class A	Class B	Class C	Class I	Class D	Class E	Class F	Class G	Class H	Class J
1	35 dB	25 dB	25 dB	37 dB	37 dB	33 dB	30 dB	32 dB	34 dB	30 dB
2	28 dB	20 dB	20 dB	30 dB	31 dB	27 dB	24 dB	26 dB	27 dB	24 dB
3	25 dB	18 dB	17 dB	27 dB	28 dB	24 dB	22 dB	23 dB	25 dB	22 dB
4	24 dB	15 dB	14 dB	25 dB	26 dB	23 dB	21 dB	22 dB	24 dB	20 dB
5	23 dB	—	—	24 dB	25 dB	22 dB	19 dB	21 dB	22 dB	19 dB
6	21 dB	—	—	22 dB	24 dB	20 dB	17 dB	19 dB	21 dB	17 dB
7	20 dB	—	—	21 dB	23 dB	19 dB	16 dB	18 dB	20 dB	16 dB

Table 5-13 shows the optical performance for 16-channel linear networks using SMF fiber. Span loss values assume the following:

- No OADM nodes are installed and span losses are equal.
- The DCU loss is 9 dB.
- Only OPT-PRE amplifiers are installed.
- The minimum channel power is 4 dBm.
- Wavelengths are picked up without any restriction from Bands 4 and 5 (1542.14 to 1545.51 nm).

Table 5-13 Span Loss for 16-Channel Linear Networks without OADM Nodes Using SMF Fiber

Number of Spans	10 Gbps				2.5 Gbps					
	Class A	Class B	Class C	Class I	Class D	Class E	Class F	Class G	Class H	Class J
1	37 dB	29 dB	28 dB	37 dB	37 dB	36 dB	33 dB	35 dB	37 dB	33 dB
2	32 dB	23 dB	23 dB	33 dB	34 dB	30 dB	27 dB	29 dB	31 dB	27 dB
3	28 dB	21 dB	20 dB	30 dB	30 dB	26 dB	24 dB	26 dB	27 dB	24 dB
4	26 dB	19 dB	18 dB	27 dB	28 dB	24 dB	22 dB	23 dB	25 dB	22 dB
5	24 dB	18 dB	17 dB	26 dB	26 dB	23 dB	21 dB	22 dB	24 dB	21 dB
6	23 dB	17 dB	17 dB	24 dB	25 dB	22 dB	20 dB	21 dB	22 dB	20 dB
7	22 dB	16 dB	15 dB	23 dB	24 dB	21 dB	19 dB	20 dB	21 dB	19 dB

Table 5-14 shows the optical performance for 8-channel linear networks with 8 dBm per channel using SMF fiber. Span loss values assume the following:

- No OADM nodes are installed and span losses are equal.
- The DCU loss is 9 dB.
- Only OPT-PRE amplifiers are installed.

Table 5-14 Span Loss for Eight-Channel Linear Networks without OADM Nodes Using SMF Fiber

Number of Spans	10 Gbps				2.5 Gbps					
	Class A	Class B	Class C	Class I	Class D	Class E	Class F	Class G	Class H	Class J
1	37 dB	31 dB	30 dB	37 dB	37 dB	37 dB	35 dB	37 dB	37 dB	35 dB
2	34 dB	26 dB	25 dB	34 dB	34 dB	32 dB	30 dB	31 dB	33 dB	30 dB
3	31 dB	23 dB	22 dB	33 dB	34 dB	29 dB	26 dB	28 dB	30 dB	26 dB
4	29 dB	—	—	30 dB	31 dB	27 dB	24 dB	26 dB	28 dB	24 dB
5	27 dB	—	—	29 dB	30 dB	26 dB	23 dB	25 dB	26 dB	23 dB
6	—	—	—	27 dB	—	—	—	—	—	—

5.2.3.3 Optical Performance for ROADM Rings and Linear Networks

The following tables list the reference optical performances for ROADM rings and linear networks.

Table 5-15 shows the optical performance for 32-channel linear or ring networks using SMF fiber with only ROADM nodes installed. Span loss values assume the following:

- All nodes in the ring or linear network are ROADM with equal span losses.
- The DCU loss is 9 dB.
- OPT-PRE and OPT-BST/OPT-BST-E amplifiers are installed.

Table 5-15 Span Loss for 32-Channel Linear or Ring Networks with all ROADM Nodes Using SMF Fiber

Number of Spans	10 Gbps				2.5 Gbps					
	Class A	Class B	Class C	Class I	Class D	Class E	Class F	Class G	Class H	Class J
1	35 dB	25 dB	25 dB	36 dB	37 dB	33 dB	30 dB	32 dB	34 dB	—
2	30 dB	21 dB	20 dB	32 dB	34 dB	28 dB	25 dB	26 dB	29 dB	—
3	28 dB	18 dB	17 dB	30 dB	32 dB	26 dB	23 dB	24 dB	27 dB	—
4	26 dB	—	—	28 dB	30 dB	24 dB	21 dB	22 dB	25 dB	—
5	25 dB	—	—	27 dB	29 dB	23 dB	20 dB	20 dB	23 dB	—
6	24 dB	—	—	26 dB	28 dB	22 dB	18 dB	19 dB	22 dB	—
7	23 dB	—	—	25 dB	27 dB	21 dB	14 dB	17 dB	20 dB	—
8	22 dB	—	—	24 dB	26 dB	20 dB	—	—	18 dB	—
9	21 dB	—	—	23 dB	25 dB	19 dB	—	—	—	—
10	21 dB	—	—	23 dB	25 dB	18 dB	—	—	—	—
11	18[1] dB	—	—	22 dB	24 dB	17 dB	—	—	—	—
12	17[1] dB	—	—	21 dB	24 dB	15 dB	—	—	—	—
13	15[1] dB	—	—	21 dB	23 dB	—	—	—	—	—
14	—	—	—	20 dB	23 dB	—	—	—	—	—
15	—	—	—	20 dB	22 dB	—	—	—	—	—

1. If the number of boosters is greater than 10 and power per channel is = to +1 dBm.

Table 5-16 shows the optical performance for 32-channel linear or ring network with ROADM and OADM nodes using SMF fiber. Span loss values assume the following:

- All nodes in the ring or linear network are ROADM or OADM.
- OPT-PRE and OPT-BST/OPT-BST-E amplifiers are installed.
- Span losses are equal.

Table 5-16 Span Loss for 32-Channel Ring and Linear Networks with ROADM and OADM Nodes Using SMF Fiber

Number of Spans	10 Gbps				2.5 Gbps					
	Class A	Class B	Class C	Class I	Class D	Class E	Class F	Class G	Class H	Class J
1	30 dB	23 dB	24 dB	31 dB	34 dB	31 dB	28 dB	29 dB	30 dB	28 dB
2	26 dB	19 dB	19 dB	27 dB	27 dB	26 dB	23 dB	26 dB	27 dB	23 dB
3	23 dB	—	—	25 dB	26 dB	23 dB	21 dB	23 dB	24 dB	21 dB
4	21 dB	—	—	23 dB	24 dB	22 dB	18 dB	21 dB	22 dB	18 dB
5	20 dB	—	—	22 dB	23 dB	20 dB	13 dB	20 dB	21 dB	13 dB
6	17 dB	—	—	19 dB	22 dB	18 dB	—	17 dB	18 dB	—
7	15[1] dB	—	—	17 dB	21 dB	16 dB	—	15[1]	16 dB	—

1. 0.5 dB of OSNR impairment recovered by FEC margin @ BER>10-6

The following tables show the pass/fail criteria for eight and sixteen ROADM nodes.

Table 5-17 shows the pass/fail criteria for eight ROADM nodes (seven spans) required for any-to-any node circuit reconfigurations:

- All nodes in the ring are ROADM.
- Span losses are equal.

Table 5-17 Pass/Fail Criteria for 32-Channel, Eight-Node ROADM Rings Using SMF Fiber

Span Loss (dB)	Amplifiers Installed	10 Gbps				2.5 Gbps					
		Class A	Class B	Class C	Class I	Class D	Class E	Class F	Class G	Class H	Class J
1	OPT-PRE only	Yes	<7	<7	Yes	Yes	Yes	Yes	Yes	Yes	—
2	OPT-PRE only	Yes	<7	<7	Yes	Yes	Yes	Yes	Yes	Yes	—
3	OPT-PRE only	Yes	<7	<7	Yes	Yes	Yes	<7	Yes	Yes	—
4	OPT-PRE only	Yes	<7	<7	Yes	Yes	Yes	<7	Yes	Yes	—
5	OPT-PRE only	Yes	<7	<7	Yes	Yes	Yes	<7	Yes	Yes	—
6	OPT-PRE only	Yes	<7	<7	Yes	Yes	Yes	<7	Yes	Yes	—
7	OPT-PRE and OPT-BST/ OPT-BST-E	Yes	<7	<7	Yes	Yes	Yes	<7	Yes	Yes	—
8	OPT-PRE and OPT-BST/ OPT-BST-E	Yes	<7	<7	Yes	Yes	Yes	<7	Yes	Yes	—
9	OPT-PRE and OPT-BST/ OPT-BST-E	Yes	<7	<7	Yes	Yes	Yes	Yes	Yes	Yes	—
10	OPT-PRE and OPT-BST/ OPT-BST-E	Yes	<7	<7	Yes	Yes	Yes	Yes	Yes	Yes	—
11	OPT-PRE and OPT-BST/ OPT-BST-E	Yes	<7	<7	Yes	Yes	Yes	Yes	Yes	Yes	—
12	OPT-PRE and OPT-BST/ OPT-BST-E	Yes	<7	<7	Yes	Yes	Yes	Yes	Yes	Yes	—
13	OPT-PRE and OPT-BST/ OPT-BST-E	Yes	<7	<7	Yes	Yes	Yes	Yes	Yes	Yes	—
14	OPT-PRE and OPT-BST/ OPT-BST-E	Yes	<7	<7	Yes	Yes	Yes	Yes	Yes	Yes	—
15	OPT-PRE and OPT-BST/ OPT-BST-E	Yes	<7	<7	Yes	Yes	Yes	Yes	Yes	Yes	—

Table 5-18 shows the pass/fail criteria for 16 ROADM nodes (15 spans) required for any-to-any node circuit reconfigurations.

- All nodes in the ring are ROADM.
- Span losses are equal.

Table 5-18 Pass/Fail Criteria for 32-Channel, 16-Node ROADM Rings Using SMF Fiber

Span Loss (dB)	Amplifiers Installed	10 Gbps				2.5 Gbps					
		Class A	Class B	Class C	Class I	Class D	Class E	Class F	Class G	Class H	Class J
1	OPT-PRE only	<15[1]	<15[1]	<15[1]	Yes	Yes	<15[1]	<15[1]	<15[1]	<15[1]	—
2	OPT-PRE only	<15[1]	<15[1]	<15[1]	Yes	Yes	<15[1]	<15[1]	<15[1]	<15[1]	—
3	OPT-PRE only	<15[1]	<15[1]	<15[1]	Yes	Yes	<15[1]	<15[1]	<15[1]	<15[1]	—
4	OPT-PRE only	<15[1]	<15[1]	<15[1]	Yes	Yes	<15[1]	<15[1]	<15[1]	<15[1]	—
5	OPT-PRE only	<15[1]	<15[1]	<15[1]	Yes	Yes	<15[1]	<15[1]	<15[1]	<15[1]	—
6	OPT-PRE only	<15[1]	<15[1]	<15[1]	Yes	Yes	<15[1]	<15[1]	<15[1]	<15[1]	—
7	OPT-PRE and OPT-BST/ OPT-BST-E	<15[1]	<15[1]	<15[1]	Yes	Yes	<15[1]	<15[1]	<15[1]	<15[1]	—
8	OPT-PRE and OPT-BST/ OPT-BST-E	<15[1]	<15[1]	<15[1]	Yes	Yes	<15[1]	<15[1]	<15[1]	<15[1]	—
9	OPT-PRE and OPT-BST/ OPT-BST-E	<15[1]	<15[1]	<15[1]	Yes	Yes	<15[1]	<15[1]	<15[1]	<15[1]	—
10	OPT-PRE and OPT-BST/ OPT-BST-E	<15[1]	<15[1]	<15[1]	Yes	Yes	<15[1]	<15[1]	<15[1]	<15[1]	—
11	OPT-PRE and OPT-BST/ OPT-BST-E	<15[1]	<15[1]	<15[1]	Yes	Yes	<15[1]	<15[1]	<15[1]	<15[1]	—
12	OPT-PRE and OPT-BST/ OPT-BST-E	<15[1]	<15[1]	<15[1]	Yes	Yes	<15[1]	<15[1]	<15[1]	<15[1]	—
13	OPT-PRE and OPT-BST/ OPT-BST-E	<15[1]	<15[1]	<15[1]	Yes	Yes	<15[1]	<15[1]	<15[1]	<15[1]	—
14	OPT-PRE and OPT-BST/ OPT-BST-E	<15[1]	<15[1]	<15[1]	Yes	Yes	<15[1]	<15[1]	<15[1]	<15[1]	—
15	OPT-PRE and OPT-BST/ OPT-BST-E	<15[1]	<15[1]	<15[1]	Yes	Yes	<15[1]	<15[1]	<15[1]	<15[1]	—

1. Cisco MetroPlanner calculates the maximum ring circumference and number of nodes that can be supported.

5.2.3.4 Optical Performance for Single-Span Networks

Table 5-19 lists the span loss for a single-span link configuration with eight channels. The optical performance for this special configuration is given only for Classes A and C. This configuration assumes a maximum channel capacity of eight channels (8-dBm nominal channel power) used without any restrictions on the 32 available channels.

Table 5-19 Span Loss for Single-Span Link with Eight Channels

Node Configuration	Number of Spans	10 Gbps			2.5 Gbps			
		Class A	Class B	Class C	Class D	Class E	Class F	Class G
With OSCM card	1	37 dB	—	37 dB	—	—	—	—
With OSC-CSM card	1	35 dB	—	35 dB	—	—	—	—

Table 5-20 lists the span loss for a single-span link configuration with 16 channels. The optical performance for this special configuration is given only for Class A and Class C. This configuration assumes a maximum channel capacity of 16 channels (5-dBm nominal channel power) used without any restrictions on the 32 available channels.

Table 5-20 Span Loss for Single-Span Link with 16 Channels

Node Configuration	Number of Spans	10 Gbps			2.5 Gbps			
		Class A	Class B	Class C	Class D	Class E	Class F	Class G
With OSCM or OSC-SCM cards	1	35 dB	—	35 dB	—	—	—	—

Table 5-21 lists the span loss for a single-span link configuration with AD-1C-x.xx cards, OPT-PRE amplifiers, and OPT-BST/OPT-BST-E amplifiers. The single-span link with a flexible channel count is used both for transmitting and receiving. If dispersion compensation is required, a DCU can be used with an OPT-PRE amplifier. The optical performance for this special configuration is given for Classes A through G (8-dBm nominal channel power) used without any restrictions on the 32 available channels.

Table 5-21 Span Loss for Single-Span Link with AD-1C-xx.x Cards, OPT-PRE Amplifiers, and OPT-BST/OPT-BST-E Amplifiers

Node Configuration	Number of Spans	10 Gbps			2.5 Gbps			
		Class A	Class B	Class C	Class D	Class E	Class F	Class G
With OSCM cards[1]	1	37 dB	31 dB	31 dB	37 dB	37 dB	37 dB	37 dB
Hybrid with OSC-CSM cards[2]	1	35 dB	31 dB	31 dB	35 dB	35 dB	35 dB	35 dB

1. OSCM sensitivity limits the performance to 37 dB.
2. OSC-CSM sensitivity limits the performance to 35 dB when it replaces the OSCM.

Table 5-22 lists the span loss for a single-span link configuration with one channel and OPT-BST/OPT-BST-E amplifiers. The optical performance for this special configuration is given for Classes A through G. Classes A, B, and C use 8-dBm nominal channel power. Classes D, E, F, and G use

12-dBm nominal channel power. There are no restriction on the 32 available channels. That is, a line card, transponder, or muxponder wavelength can be extracted from the 32 available wavelengths. Also, the optical service channel is not required.

Table 5-22 Span Loss for Single-Span Link with One Channel and OPT-BST Amplifiers

Number of Spans	10 Gbps			2.5 Gbps			
	Class A	Class B	Class C	Class D	Class E	Class F	Class G
1	20 to 30 dB	17 to 26 dB	17 to 28 dB	Unprotected from 29 to 41 dB Protected from 25 to 41 dB	Unprotected from 28 to 37 dB Protected from 24 to 40 dB	Unprotected from 21 to 34 dB Protected from 18 to 34 dB	From 23 to 36 dB

Table 5-23 lists the span loss for a single-span link configuration with one channel, OPT-BST/OPT-BST-E amplifiers, OPT-PRE amplifiers, and ONS 15216 FlexLayer filters. ONS 15216 FlexLayer filters are used instead of the AD-1C-xx.x cards to reduce equipment costs and increase the span length, since the optical service channel is not necessary. The optical performance for this special configuration is given for Classes A through G. Classes A, B, and C use 8-dBm nominal channel power. Classes D, E, F, and G use 12-dBm nominal channel power. There are no restriction on the first 16 available wavelengths (from 1530.33 to 1544.53 nm).

Table 5-23 Span Loss for Single-Span Link with One Channel, OPT-BST/OPT-BST-E Amplifiers, OPT-PRE Amplifiers, and ONS 15216 FlexLayer Filters

Number of Spans	10 Gbps			2.5 Gbps			
	Class A	Class B	Class C	Class D	Class E	Class F	Class G
1	38 dB	30 dB	30 dB	44 dB	40 dB	38 dB	40 dB

5.2.4 L-Band Optical Performance

Table 5-24 details the target system performance for an ONS 15454 DWDM L-band system.

Table 5-24 L-Band Supported Topologies and Node Types

Number of Channels	Fiber Type	Topologies	Node Type
32	SMF-28	Ring	Hub
	DS[1]	Linear	Terminal
		Linear without ROADM	ROADM
			Line
			OSC regeneration

1. DS = Dispersion Shifted fiber

5.2.4.1 Optical Performance for Linear Networks Without ROADM Nodes

Table 5-25 shows the optical performance for 32-channel linear networks using SMF fiber. Span loss values assume the following:

- No ROADM nodes are installed
- Only OPT-AMP-L amplifiers are installed
- Span losses are equal

Table 5-25 Span Loss for 32-Channel Ring and Linear Networks Using SMF Fiber (no ROADM Nodes)

	10 Gbps		
Number of Spans	**Class A**	**Class C**	**Class I**
1	37 dB	27 dB	37 dB
2	32 dB	23 dB	34 dB
3	29 dB	20 dB	30 dB
4	27 dB	16 dB	28 dB
5	26 dB	—	27 dB
6	25 dB	—	26 dB
7	24 dB	—	25 dB

Table 5-26 shows the optical performance for 32-channel linear networks using DS fiber. Span loss values assume the following:

- No ROADM nodes are installed
- Only OPT-AMP-L amplifiers are installed
- Span losses are equal

Table 5-26 Span Loss for 32-Channel Ring and Linear Networks Using DS Fiber (no ROADM Nodes)

	10 Gbps		
Number of Spans	**Class A**	**Class C**	**Class I**
1	37 dB	27 dB	37 dB
2	32 dB	23 dB	34 dB
3	29 dB	20 dB	30 dB
4	26 dB	16 dB	28 dB
5	25 dB	—	27 dB
6	24 dB	—	26 dB
7	23 dB	—	24 dB
8	23 dB	—	24 dB
9	23 dB	—	24 dB
10	22 dB	—	23 dB

Table 5-26 Span Loss for 32-Channel Ring and Linear Networks Using DS Fiber (no ROADM Nodes) (continued)

	10 Gbps		
Number of Spans	Class A	Class C	Class I
11	20 dB	—	23 dB
12	19 dB	—	23 dB
13	18 dB	—	22 dB
14	17 dB	—	22 dB
15	15 dB	—	22 dB

5.2.4.2 Optical Performance for ROADM Rings and Linear Networks

Table 5-27 shows the optical performance for a 32-channel linear or ring network using SMF fiber with only ROADM nodes installed. Span loss values assume the following:

- All nodes in the ring or linear network are ROADM
- OPT-AMP-L and OPT-BST-L amplifiers are installed
- Span losses are equal

Table 5-27 Span Loss for 32-Channel Ring or Linear Networks with all ROADM Nodes Using SMF Fiber

	10 Gbps		
Number of Spans	Class A	Class C	Class I
1	37 dB	27 dB	37 dB
2	33 dB	21 dB	36 dB
3	32 dB	—	34 dB
4	29 dB	—	32 dB
5	28 dB	—	31 dB
6	27 dB	—	30 dB
7	26 dB	—	29 dB
8	25 dB	—	28 dB
9	24 dB	—	27 dB
10	23 dB	—	27 dB
11	22 dB	—	26 dB
12	20 dB	—	25 dB
13	19 dB	—	25 dB
14	16 dB	—	24 dB
15	—	—	23 dB

Table 5-28 shows the optical performance for a 32-channel linear or ring network with ROADM nodes using DS fiber. Span loss values assume the following:

- All nodes in the ring or linear network are ROADM
- OPT-AMP-L and OPT-BST-L amplifiers are installed
- Span losses are equal

Table 5-28 Span Loss for 32-Channel Ring and Linear Networks with ROADM and OADM Nodes Using DS Fiber

	10 Gbps		
Number of Spans	**Class A**	**Class C**	**Class I**
1	37 dB	27 dB	37 dB
2	33 dB	21 dB	36 dB
3	32 dB	—	34 dB
4	29 dB	—	32 dB
5	28 dB	—	31 dB
6	27 dB	—	30 dB
7	26 dB	—	29 dB
8	25 dB	—	28 dB
9	24 dB	—	27 dB
10	23 dB	—	27 dB
11	22 dB	—	26 dB
12	20 dB	—	25 dB
13	19 dB	—	25 dB
14	16 dB	—	24 dB
15	—	—	23 dB
—	—	—	37 dB