Long-Haul DWDM RF Fiber Optic Link System

EMCORE Corporation - Broadband Division, Alhambra, CA, USA

ABSTRACT

EMCORE's vertically integrated ISO-9001 facility, staffed with our optics/RF engineering team, has been successfully designing and manufacturing the necessary system and associated components for the successful deployments of reliable long-haul DWDM RF fiber optic link systems in the satcom, CATV, and telecommunication signal transport infrastructures. This application note provides an overview of a typical long-haul DWDM RF fiber optic link system, its associated components, recommended platform, and application example.

SYSTEM COMPONENTS

A long-haul DWDM RF fiber optic link system, illustrated in Figure 1, consists of the following components:

- **DWDM Tx (RF-to-Optical Transmitter)** – This unit accepts up to 40 GHz wideband modulated RF signals and internally RF amplifies with adjustable gain attenuation (up to 30 dB). RF signals are then directly modulated onto a cooled distributed-feedback laser (DFB) and it outputs modulated optical power onto a specific ITU-DWDM wavelength.
- **DWDM MUX (Optical Multiplexer)** – This unit accepts up to 32 ITU-DWDM wavelengths, filters/combines and projects them into single fiber medium, then outputs to a single optical connector for interface to long-haul fiber cable.
- **OPTICAL AMP (Erbium-Dope Fiber Amplifier)** – This unit provides active amplification of incoming weak optical signal, then outputs fixed-level amplified optical signal (up to 23 dBmo) to extend signal transport distance reach.
- **DISPERSION COMP (Zero-Dispersion Compensation Fiber)** – This unit provides correct amount of dispersion level to eliminate optical signal dispersion when the signal travels through the infrastructure and the compensation fibers.
- **DWDM DEMUX (Optical De-Multiplexer)** – This unit accepts a single optical signal, filters/distributes and outputs each of the up to 32 ITU-DWDM wavelengths to a dedicated output connector.
- **DWDM Rx (Optical-to-RF Receiver)** – This unit accepts modulated optical signals, directly demodulates with a wideband photodiode, internally RF amplifies with adjustable gain attenuation (up to 30 dB), and outputs the modulated RF signal.

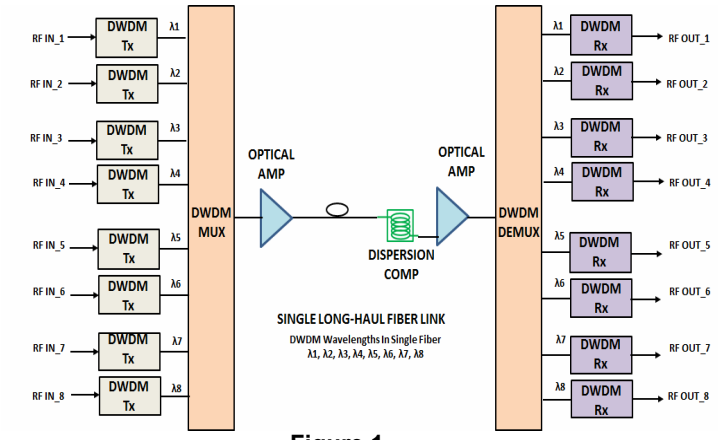


Figure 1

SYSTEM DESIGN

The key to a successful design and implementation of a long-haul DWDM RF fiber optic link system is the availability of pre-design information pertaining to the desired system performances:

- Desired system bandwidth capacity
- Desired system transport distance
- Desired system RF link gain, noise figure
- Site diversity and system time delay requirements
- Optical loss budget of fiber cable infrastructure
- Desired system RF carrier to noise
- Desired system RF input levels

With the pre-design system information provided, EMCORE employs in-house system design tools consisting of RF, optical, and system link budgets, and performs analyses to generate system configurations, block diagrams, and specifies associated components.

RECOMMENDED PLATFORM

EMCORE recommends its Optiva RF fiber system platform for the deployment of the long-haul DWDM RF fiber link system:

- Proven, widely deployed
- Intuitive SNMP management & control
- Common platform to transport RF, HD video, audio, and data

APPLICATION EXAMPLE

A 35 km SMF-28 RF fiber transport link between antenna site and distribution facility is desired, as illustrated in Figure 2. The pre-design information is listed below:

- Desired system bandwidth capacity: 24 channels
- Desired system transport distance: 35 km
- Site diversity requirements: none
- Desired system RF link gain: -10 dB, each channel
- Desired system noise figure: 40 dB, each channel
- Desired system IIP3: 12 dBm, each channel
- Optical loss budget of fiber cable infrastructure: 10 dBo
- Desired system RF carrier to noise: 40 dB, each channel

A system analysis is performed for the RF and optical link budgets as shown in Figures 3 and 4 on the following page. The following system components are required with Optiva platform implementation:

- Twenty-four DWDM Tx cards, each with 9 dBmo optical power
- One set of 32-channel DWDM MUX and DEMUX
- One 4.6 km dispersion compensation spool
- One 14 dBmo optical pre-amplifier
- Twenty-four Rx cards
- Desired RF input levels: -15 dBm per carrier

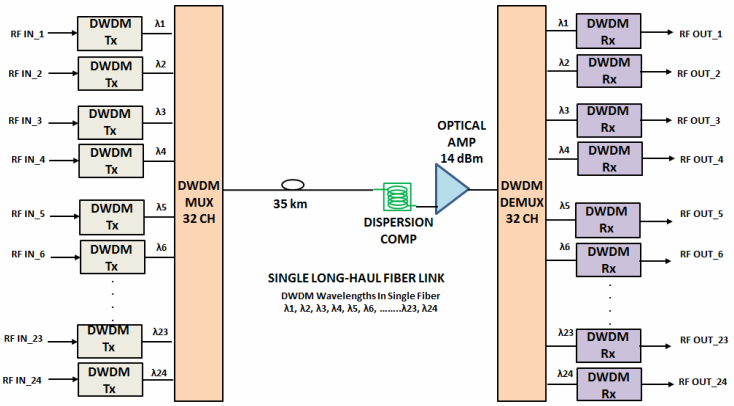


Figure 2

The EMCORE system design tool performed the analyses and yielded the following results:

- System RF link gain: -5.2dB, each channel
- System noise figure: 38.5 dB, each channel
- System IIP3: 11dBm, each channel
- Total optical loss: 12.9 dBo
- System RF carrier to noise: 44.8 dB, each channel

These systems are also easily upgradeable should path lengths requirements change. Figures 5 and 6 on page 4 show the system length changing from 35 km to 95 km. This increase in optical length has minimal effect on the systems overall performance

- System RF link gain: -6.1 dB, each channel
- System noise figure: 40.6 dB, each channel
- System IIP3: 9.1 dBm, each channel
- Total optical loss: 13.4 dBo
- System RF carrier to noise: 42.7 dB, each channel

The system design appeared to meet the desired system requirements with the system components.

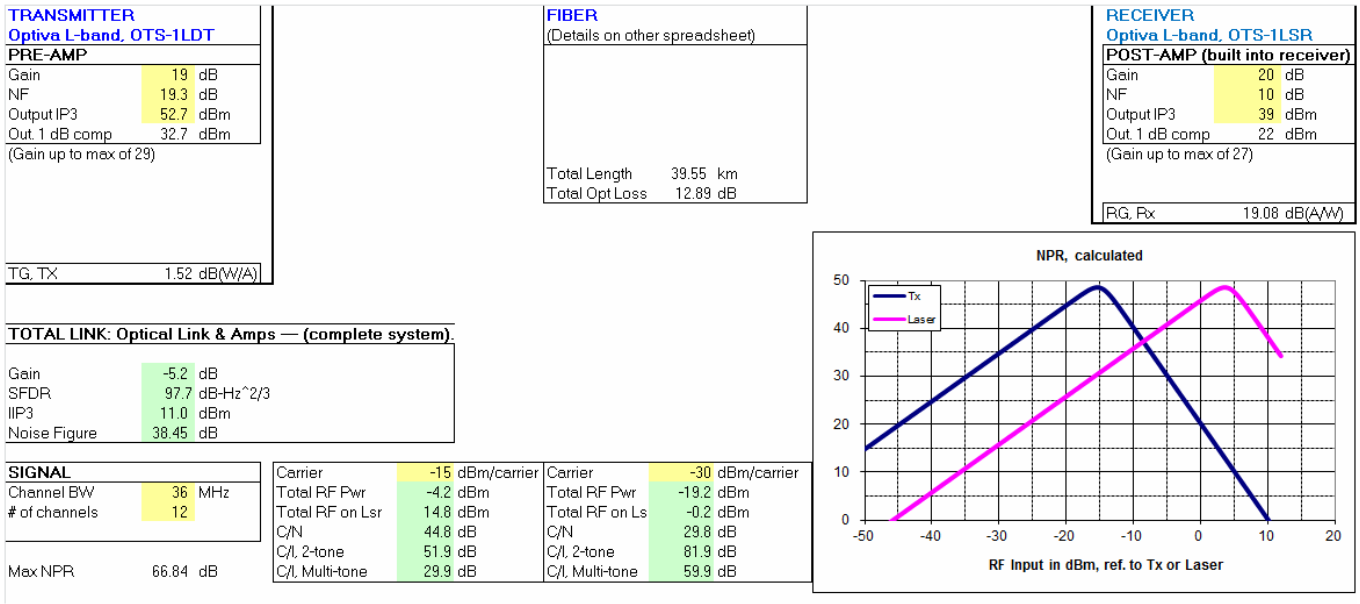


Figure 3

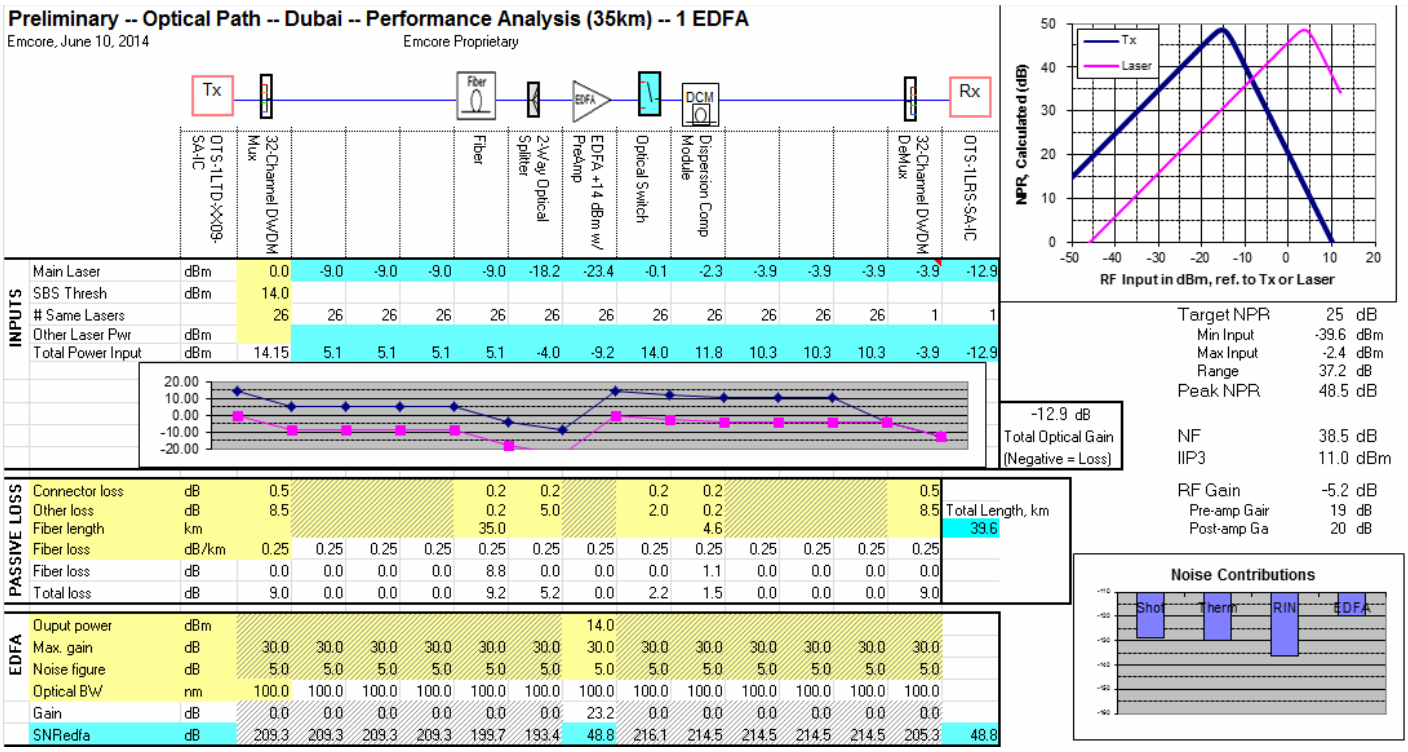
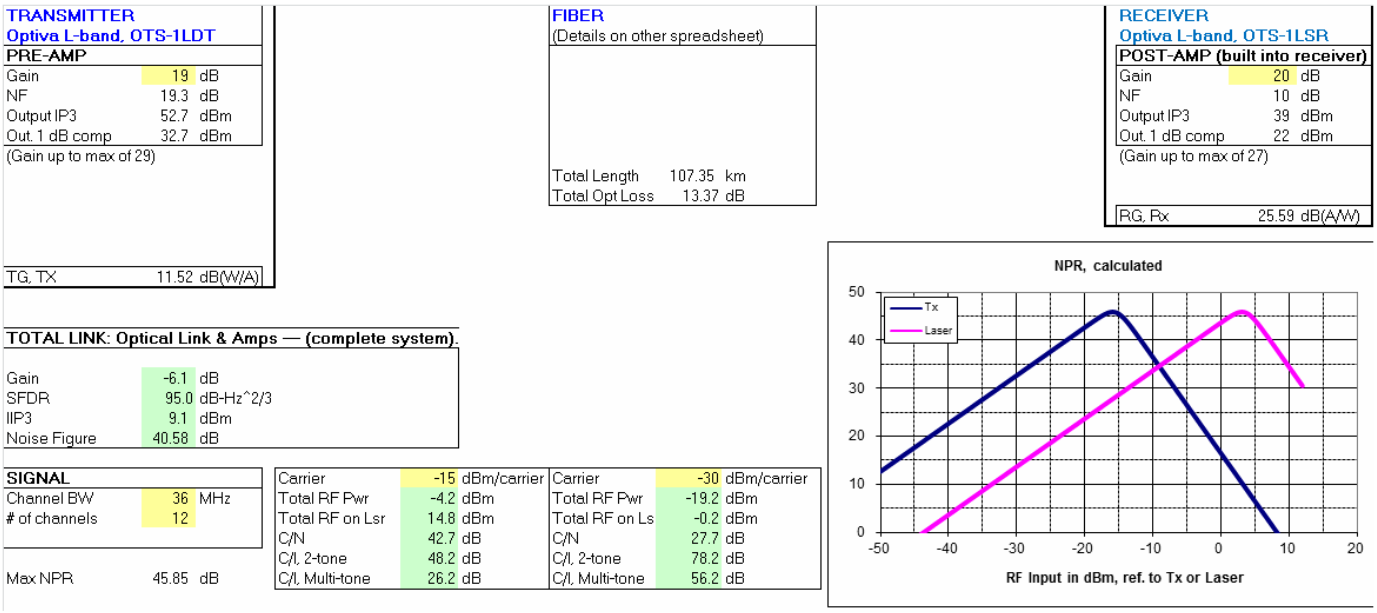


Figure 4



TRANSMITTER		
Optiva L-band, OTS-1LDT		
PRE-AMP		
Gain	19	dB
NF	19.3	dB
Output IP3	52.7	dBm
Out. 1 dB comp	32.7	dBm
(Gain up to max of 29)		
TG, TX	11.52	dB(W/A)

FIBER		
(Details on other spreadsheet)		
Total Length	107.35	km
Total Opt Loss	13.37	dB

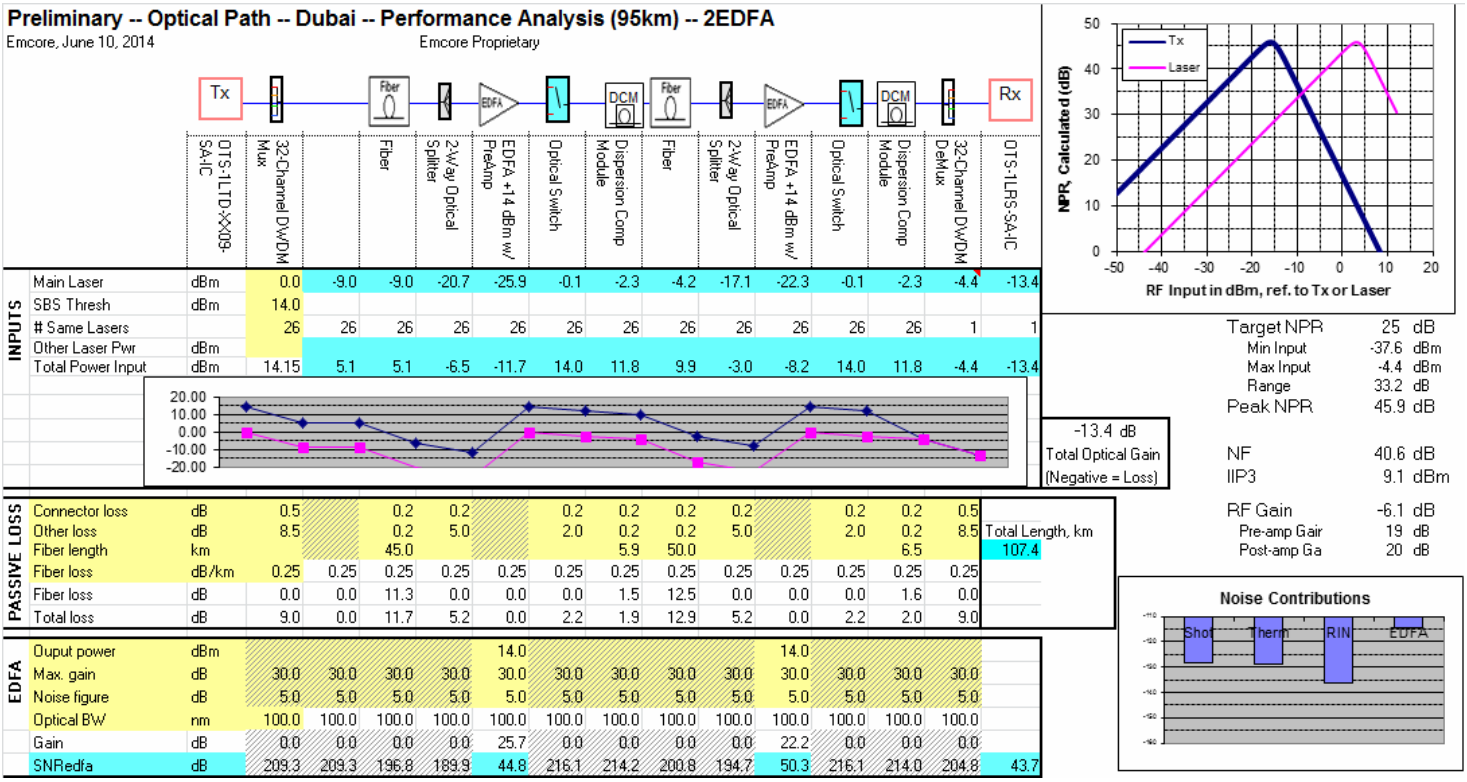
RECEIVER		
Optiva L-band, OTS-1LSR		
POST-AMP (built into receiver)		
Gain	20	dB
NF	10	dB
Output IP3	39	dBm
Out. 1 dB comp	22	dBm
(Gain up to max of 27)		
RG, Rx	25.59	dB(A/W)

TOTAL LINK: Optical Link & Amps — (complete system).		
Gain	-6.1	dB
SFDR	95.0	dB-Hz^2/3
IIP3	9.1	dBm
Noise Figure	40.58	dB

SIGNAL		
Channel BW	36	MHz
# of channels	12	
Max NPR	45.85	dB

Carrier	-15	dBm/carrier	Carrier	-30	dBm/carrier
Total RF Pwr	-4.2	dBm	Total RF Pwr	-19.2	dBm
Total RF on Lsr	14.8	dBm	Total RF on Ls	-0.2	dBm
C/N	42.7	dB	C/N	27.7	dB
C/I, 2-tone	48.2	dB	C/I, 2-tone	78.2	dB
C/I, Multi-tone	26.2	dB	C/I, Multi-tone	56.2	dB

Figure 5



Preliminary -- Optical Path -- Dubai -- Performance Analysis (95km) -- 2EDFA

Emcore, June 10, 2014 Emcore Proprietary

		OTS-1LTD-XX09-SA-IC	32-Channel DWDM Mux		Fiber	2-Way Optical Splitter	EDFA +14 dBm w/ PreAmp	Optical Switch	Dispersion Comp Module	Fiber	2-Way Optical Splitter	EDFA +14 dBm w/ PreAmp	Optical Switch	Dispersion Comp Module	32-Channel DWDM DeMux	OTS-1LRS-SA-IC
INPUTS	Main Laser	dBm	0.0	-9.0	-9.0	-20.7	-25.9	-0.1	-2.3	-4.2	-17.1	-22.3	-0.1	-2.3	-4.4	-13.4
	SBS Thresh	dBm	14.0													
	# Same Lasers		26	26	26	26	26	26	26	26	26	26	26	26	1	1
	Other Laser Pwr	dBm														
	Total Power Input	dBm	14.15	5.1	5.1	-6.5	-11.7	14.0	11.8	9.9	-3.0	-8.2	14.0	11.8	-4.4	-13.4
PASSIVE LOSS	Connector loss	dB	0.5		0.2	0.2		0.2	0.2	0.2	0.2		0.2	0.2	0.5	Total Length, km
	Other loss	dB	8.5		0.2	5.0		2.0	0.2	0.2	5.0		2.0	0.2	8.5	
	Fiber length	km			45.0				5.9	50.0				6.5		107.4
	Fiber loss	dB/km	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	
	Fiber loss	dB	0.0	0.0	11.3	0.0	0.0	0.0	1.5	12.5	0.0	0.0	0.0	1.6	0.0	
	Total loss	dB	9.0	0.0	11.7	5.2	0.0	2.2	1.9	12.9	5.2	0.0	2.2	2.0	9.0	
EDFA	Ouput power	dBm					14.0					14.0				
	Max. gain	dB	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	
	Noise figure	dB	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	
	Optical BW	nm	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	
	Gain	dB	0.0	0.0	0.0	0.0	25.7	0.0	0.0	0.0	0.0	22.2	0.0	0.0	0.0	
	SNRedfa	dB	209.3	209.3	196.8	189.9	44.8	216.1	214.2	200.8	194.7	50.3	216.1	214.0	204.8	43.7

-13.4 dB
Total Optical Gain
(Negative = Loss)

Target NPR	25	dB
Min Input	-37.6	dBm
Max Input	-4.4	dBm
Range	33.2	dB
Peak NPR	45.9	dB
NF	40.6	dB
IIP3	9.1	dBm
RF Gain	-6.1	dB
Pre-amp Gair	19	dB
Post-amp Ga	20	dB

Figure 6

CONCLUSION

EMCORE's optics, RF design and manufacturing expertise, backed by proven deployments, is well positioned to design and deliver reliable long-haul RF fiber optic link systems for signal transport applications in the satcom, CATV, and telecommunication infrastructures.