Performance Analysis of 32 × 2.5 Gb/s DWDM Metropolitan Area Network using SMF-28 and MetroCor Optical Fibres

Atul Mahajan [1], Anu Sheetal [2], Jaswinder Singh [3]
[1]ACET, Amritsar, Punjab, India.
[2]GNDU Regional Campus, Gurdaspur, Punjab, India
[3]BCET, Gurdaspur, Punjab, India

Abstract: *In this paper, we present the simulative analysis of 32 × 2.5 Gb/s DWDM metro system with 100GHz channel spacing using SMF-28 and the Negative Dispersion Fibre (NDF) such as MetroCor which enhances the capabilities of the metropolitan area optical systems while at the same time reducing the system cost by eliminating the need of dispersion compensation. It is observed that MetroCor fibre outperforms SMF-28 fibre and the faithful transmission distance achieved is upto 300 km without dispersion compensation.*

***Keywords**: DML, NDF, MetroCor, SMF-28.*

1. Introduction

Dense Wavelength Division Multiplexing (DWDM) technologies are being in practice internationally, since it is recognized that they can satisfy the traffic demands for high-capacity networking. The choice of the optical transmitter and its associated characteristics will determine the maximum distance upto which the signal can be transmitted. Low-cost Directly Modulated Lasers (DML) recently attracted much attention for use as transmitters in 2.5Gb/s metro area applications [1]. However, DMLs have some major drawbacks. The output power waveform is not an exact replica of the modulation current and the instantaneous optical frequency varies

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with time depending on the changes of the optical power (an effect also known as frequency chirp) [2]-[3]. Here, we have used the DML2 which are the transient chirp dominated laser diodes (which exhibit more overshoot and ringing in output power and frequency deviations) and it is seen that these lasers perform better over NDFs than the adiabatic chirp dominated lasers i.e. DML1 (which exhibit damped oscillations and large frequency difference between steady state ones and zeroes) specially for metro applications [1]. The majority of access networks work on Single Mode Fibres (SMFs) which have a positive dispersion component; the compensation used for such positive dispersive fibres is controlling the magnitude of Self Phase Modulation (SPM) effect by changing the optical power in a fibre [4]. The interaction of the positive chirp with the positive dispersion of conventional standard single-mode fibres (like Corning SMF-28 fibre or any other fibre with similar dispersion characteristics) deteriorates the optical signal and sets a limit in the maximum achievable transmission distance [3]. The transmission performance of waveforms produced by DMLs over fibres with different signs of dispersion and also different absolute dispersion values strongly depends on the characteristics of the laser frequency chirp. The chirp of DML is related to the laser output optical power through the expression [5]-[6]:

$$V(t) = \alpha / 4\pi \{d/dt [\ln (P(t))] + k P(t)\} \quad (1)$$

where á is the linewidth enhancement factor and k the adiabatic chirp coefficient. In equation (1), the first term is a structure-independent “transient” chirp and the second term is a structure-dependent “adiabatic”chirp [7].

Tomkos et.al [1] showed the detailed experimental and theoretical study, showing that a novel nonzero dispersion-shifted fibre with negative dispersion enhances the capabilities of metropolitan area optical systems. The performance of these fibres was studied using different types of optical transmitters for both 1310 and 1550nm wavelength and at 2.5 to 10Gb/s bit rates. Horche et.al [4] showed that the effect of directly modulated laser chirp can be compensated by a negative dispersion fibre, but that only occur at specific range of DML output and pulse broadened by the positive dispersion can be equalized using SPM in optical fibre. Chung et.al [8] demonstrated the error free transmission of DMLs at 2.5,10 and 40 Gb/s Coarse Wavelength Division Multiplexing (CWDM) and DWDM systems over negative dispersion fibres. Sheetal et.al [10] presented the simulative analysis of 40Gb/s long haul (500-2000km) DWDM system with a ultra high

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capacity for carrier suppressed return to zero (CSRZ), Duobinary Return-to-zero (DRZ) and Modified DRZ (MDRZ).The DWDM system had been analysed for the symmetrical dispersion compensation schemes for 16 channels with 25 GHZ channel spacing.

However, the feasibility of the DWDM metro systems for 32 channels without dispersion compensation beyond 200km is not available as such in the literature. So, here we compare the performance of 2.5Gb/s DWDM metro system with 100GHz channel spacing using SMF-28 and the Negative Dispersion MetroCor Fibre. In section 2, the system description and simulation parameters have been described. In section 3, comparison of results of the simulated systems has been reported and finally in section 4, conclusions are made.

2. System Description and Simulation

The schematic of the 32 channel DWDM metro system is shown in Figure 1. Each channel of the transmitter section consists of Pseudo Random Bit Sequence (PRBS) followed by NRZ pulse generator, DML-2 laser source and WDM multiplexer. The logical sequence generated by PRBS at 2.5Gb/s is converted to electrical signal using NRZ electrical pulse generator. The rise and fall time of NRZ is taken to be 0.5 bit with amplitude of 1a.u. Here, 32 DML-2 sources used have frequency range = 192.4 - 195.5THz with channel spacing = 100GHz within the channels and input power = 1mW for each laser source. All the 32 channels are fed to WDM multiplexer operating at 1550nm with a bandwidth of 10GHz and channel spacing of 100GHz.

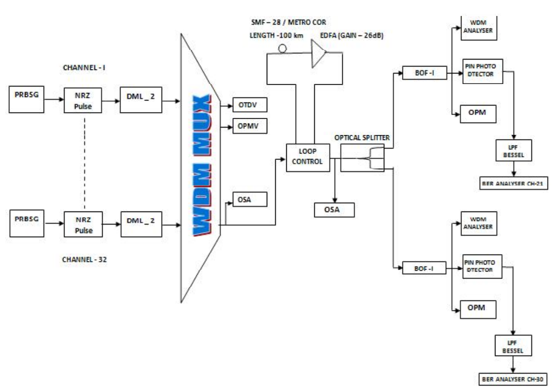

Figure 1. *Schematic of Simulation Setup*

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The optical channel consists of optical fibre and an Erbium Doped Fibre Amplifier (EDFA) with a gain = 26dB and Noise Figure = 4dB. Here, the system is simulated for negative dispersion MetroCor and positive dispersion SMF-28 fibre whose parameters are given in Table 1. Further, loop control is used to vary the length of the fibre and a optical splitter splits the output at two destination channels namely channel 21 and channel 30. The signals are then fed to the first order Bessel optical filters operating at a BW = 10GHz and at frequencies 192.6THz and 193.5THz.

Table 1. *Fibre Parameters*

Fibre	Reference wavelength (nm)	Attenuation (dB/km)	Dispersion (ps/nm/km)	Dispersion Slope (ps/km-nm2)	Effective core area $A_{eff}(\mu m^2)$	Non linear refractive index n_2 (10^{-20} m^2/W)
MetroCor	1550	0.25	-5.6	0.12	50	2.6
SMF-28	1550	0.25	16.75	0.075	80	2.6

At the receiver, the signal is detected by a PIN photodiode with a responsivity = 1A/W, Dark current = 10nA and thermal noise = 1.8×10^{-22} W/Hz. It is then passed through a low pass Bessel filter with 3dB cut off frequency = 0.75 × bit rate, order of filter = 4 and depth = 100dB. Thereafter, signal is fed to the BER analyzer, which is used as a visualizer to generate graphs and results such as eye diagrams, BER, Q value, eye opening etc. WDM Analyzer and the Optical Power Meter is used at the output to obtain noise power, signal power and OSNR values for different channels.

3. Results and Discussion

To estimate the performance, the BER, Q value [dB] and the eye diagrams of the electrical scope have been considered for the middle channel and the end channel. Figure 2(a) & (b) show the graphical representation of

Q factor and BER value as a function of length[km] for SMF-28 and Metrocor fibres respectively. Figure 2(a) depicts the graphical representation of the Q value vs. Length. It clearly shows that the Q value of the Metrocor fibre is much better than that of the SMF-28. Figure 2(b) also shows that BER of MetroCor fibre is much better than the SMF-28. Also, we find that as the fibre length increases the system performance deteriorates. The faithful transmission distance for SMF-28 is 100km and for MetroCor is 300km.

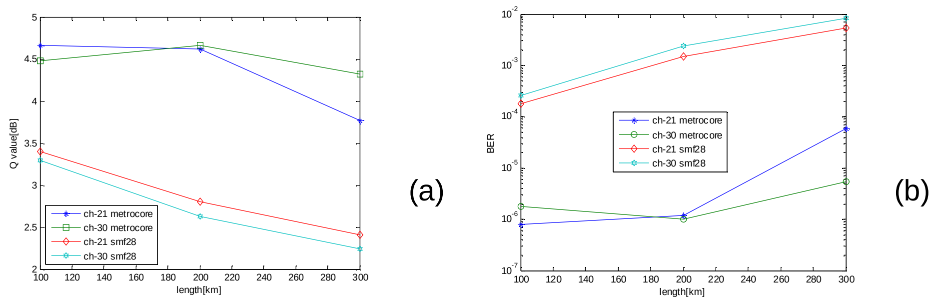
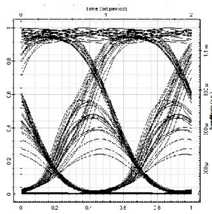
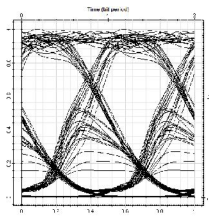


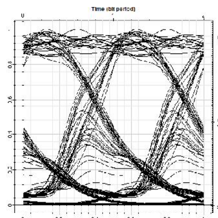
Figure 2. *(a) Q Value vs. fibre length (b) BER vs. fibre length*

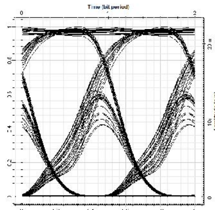
Eye diagrams for the SMF-28 and MetroCor fibres for the transmission distances after 100, 200 & 300 km are shown in Figure 3 & Figure 4 for the middle channel. The eye diagrams clearly show the better eye opening for MetroCor than SMF-28.

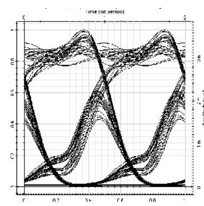
Further, input and the output optical spectrums for both the SMF-28 and MetroCor are shown in Figure 4. The output optical spectrums for both the fibres show large number of spurious signals. Also, due to the Interchannel Four Wave Mixing(IFWM) the initial signal bandwidth has been expanded after the transmission through a nonlinear optical fibre. The wave frequencies interacting through the FWM leads to the generation of frequencies known as spurious waves[10]. The Optical Signal to Noise Ratio (OSNR) values for both the fibres is shown in Table-2.


3(a)


3(b)


3(c)


4(c)


4(b)

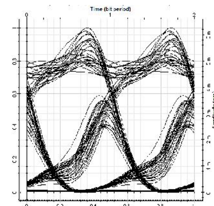
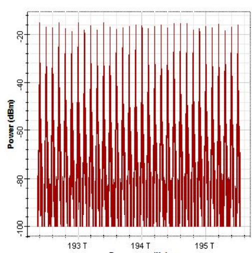
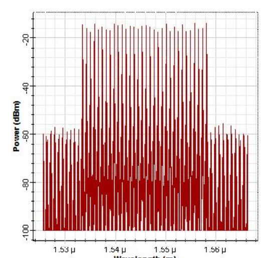

4(c)

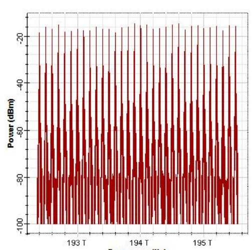
Figure 3 *Eye diagrams of SMF-28 and* ***Figure 4.*** *Eye diagrams of MetroCor fibres at middle channel over transmission distance (a)100km (b)200km (c)300km*



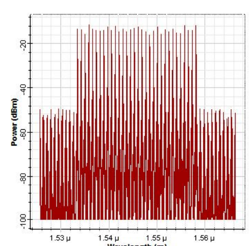
5(a)



5(b)



6(a)



6(b)

Figure 5. *Optical spectrum of 32channel DWDM system for SMF-28*
Figure 6. *Optical spectrum of 32channel DWDM system for MetroCor*
(a) Input Spectrum (b) Output Spectrum

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Table 2. shows the values for the SMF-28 and MetroCor fibre for channel 21 & 30 after 100, 200 & 300km. The OSNR values evidently indicate that MetroCor outperforms SMF-28

Table-2 *OSNR values for MetroCor and SMF-28 Fibres*

Length [km]	OSNR			
	MetroCor		SMF-28	
	Channel 21	Channel 30	Channel 21	Channel 30
100	25.03	24.38	24.94	24.22
200	22.49	21.84	22.4	21.68
300	21.17	20.54	21.09	20.37

4. Conclusions

We have simulated 32 channel DWDM metro systems with 100 GHz channel spacing over a transmission distance upto 300 km using SMF-28 and MetroCor fibres. The system has been compared for negative dispersion fibre (MetroCor) and SMF-28. We found that the performance of MetroCor fibre is superior as compared to SMF-28 fibre. Due to the lower absolute value of dispersion, effective transmission distance for SMF-28 is 100km and for MetroCor is 300km.. For practical transmitters, where both transient and adiabatic chirp exist, the performance of negative dispersion fibres (MetroCor fibre) in comparison with positive dispersion fibres, will always be superior.

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