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Performance comparison of different modulation formats for a 40 GHZ DWDM optical fiber communication system

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مقارنة أداء تنسيقات التعديل المختلفة لنظام اتصالات الألياف الضوئية *DWDM* بتردد 40 جيجا هرتز

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Abstract:
One essential optical technology for multiplexing numerous different wavelengths toward a single optical cable is dense wavelength division multiplexing or DWDM. This article describes a dispersion compensating mechanism for a 32-channel DWDM system model. The optical link's pulse broadening effect is limited using the dispersion compensation approach. The 32-channel DWDM system employing DCF for NRZ Modulation Scheme at Different Bit Rate with Different Power Levels is investigated, evaluated, and simulated to solve the dispersion issue. Using an NRZ modulation technique and an erbium-doped fiber amplifier (EDFA) over a 40–160 km single-mode fiber transmission distance and an 8–32 km dispersion compensation fiber (DCF), the suggested model operates at 10–40 Gbps.

Keywords: Dense wavelength division multiplexing (DWDM), dispersion effect, erbium-doped fiber amplifier, bit error rate, Q-factor, NRZ Modulation, Optisystem software.

الملخص
تعتبر تقنية تقسيم الطول الموجي الكثيف (DWDM) إحدى التقنيات البصرية الأساسية لإرسال العديد من الأطوال الموجية المختلفة نحو كابل بصري واحد. تصف هذه المقالة آلية تعويض التشتت لنموذج نظام تقسيم الطول الموجي الكثيف (DWDM) ذي 32 قناة. يتم تقييد تأثير توسيع النبضة للرابط البصري باستخدام نهج تعويض التشتت. يتم التحقيق في نظام تقسيم الطول الموجي الكثيف (DWDM)ذي 32 قناة والذي يستخدم DCF لمخطط تعديل NRZ بمعدلات بت مختلفة ومستويات طاقة مختلفة، ويتم تقييمه ومحاكاته من أجل حل مشكلة التشتت. باستخدام تقنية تعديل NRZ ومضخم الألياف المشبع بالإربيوم (EDFA) على مسافة نقل ألياف أحادية الوضع تتراوح بين 40 و160 كم وألياف تعويض التشتت (DCF) تتراوح بين 8 و32 كم، يعمل النموذج المقترح بسرعة تتراوح بين 10 و40 جيجابت في الثانية.

الكلمات المفتاحية: تقسيم الطول الموجي الكثيف(DWDM) ، تأثير التشتت، مكبر الألياف المشبع بالإربيوم، معدل خطأ البت، عامل Q، تعديلNRZ ، برنامج Optisystem

Introduction

A WDM system uses a single fiber to carry several wavelengths. There is a great need for high data transmission capacity these days, so the system's capacity should be examined. We have a new technology called the DWDM system, which allows each channel to send data with a variety of bit formats and bit rates without affecting the others [1]. Additionally, every channel has a dedicated bandwidth, and all of them reach the receiver simultaneously without modifying either the bandwidth or the signal parameters [2]. DWDM offers dynamical outfitting, extendable architecture, and transpiring as a physical layer. Dispersion effects and non-linear effects reduce the performance of optical fiber transmission [3]. Using a dispersion compensation system, the dispersion in the broadening of pulses in the time domain is caused by the difference in group velocity of various modes. Reduce total collected dispersion while extinguishing most non-linear effects [4]. The positive dispersion of a single fiber can be compensated by the large value of the opposite dispersion of DCF. Which is essential, low nonlinear effect and low insertion loss.

In standard single mode fiber, return to zero (NRZ) and return to zero (RZ) modulation formats are most commonly used and RZ performs well as compared to NRZ modulation format because of more adversely affected in terms of signal degradation due to Kerr nonlinear effects and chromatic dispersion effects in DWDM system [5].

In this study, we used NRZ modulation format with varying bit rates and transmission distance to simulate the 32-channel DWDM system center frequency of the first channel at 193.4 THz with channel spacing of 100 GHz. We have examined two distinct DWDM transmitter input power levels: -10 dBm and 0 dBm. DCF aids in compensating for dispersion issues, whereas EDFA serves as an optical amplifier to increase the optical signal to noise ratio (OSNR). Opti system software is used for this system characterization and performance analysis [3].

System Modeling and Simulation Setup

The post dispersion correction technique is used to create a 32-channel DWDM optical fiber communication system with transmission speeds of 10, 20, 30, and 40 Gbps per channel. Opti system software uses NRZ modulation format at various bits to simulate the suggested model. rates at different power levels to examine the effects of dispersion on the optical DWDM transmitter system's performance.

Optisystem Software is a specialized tool for simulating and designing optical communication systems. It is widely used in academic and industrial research to analyze and design optical networks, including **Wavelength Division Multiplexing (WDM)** and **Dense Wavelength Division Multiplexing (DWDM)** systems [1]. The software provides a comprehensive environment for simulating optical systems, ranging from individual optical components to complete systems [6].

Applications of Optisystem:

- Designing and analyzing DWDM and WDM systems.
- Studying dispersion effects and various compensation methods.
- Optimizing the performance of optical amplifiers like EDFA.
- Evaluating the performance of optical communication systems using different modulation techniques.
- Simulating long-haul optical communication systems.

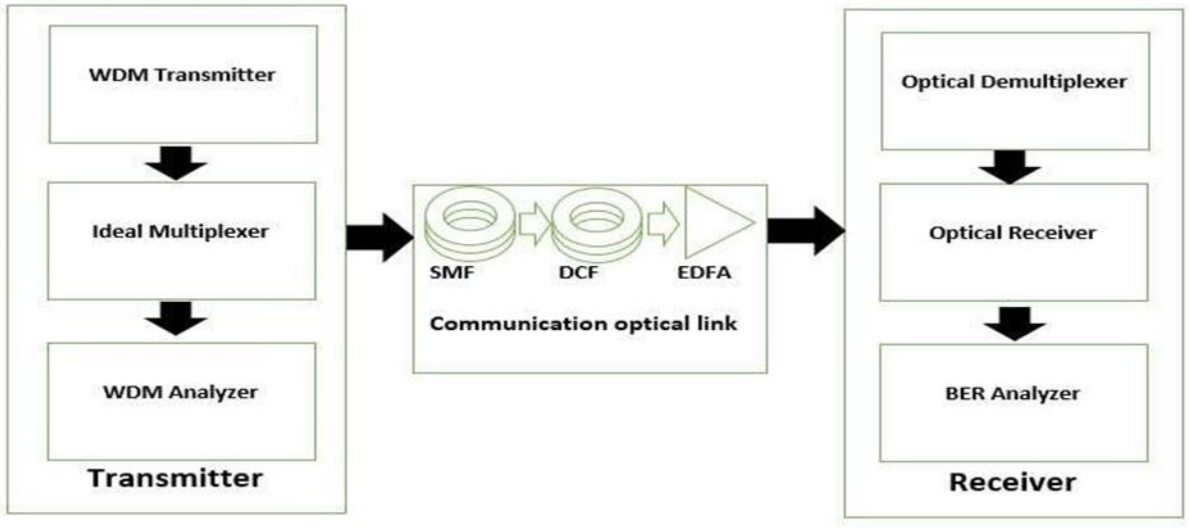


Figure 1: DWDM system modeling.

The system model is divided into basic three-sections shown in Figure 1. The first section consists of a WDM transmitter, ideal multiplexer, and WDM analyzer. 32 CW laser diode as a source are used for generating various wavelength optical signals with 100GHz frequency spacing. These input optical signals are merged through DWDM multiplexer and allow a single optical fiber consisting of SMF, DCF, and EDFA in the second communication optical link section. The 40km of SMF and 8km of DCF with four loops using loop control. Therefore, transmission length is 40km + 8km, 80km + 16km, 120km + 24km, and 160km + 32km using loop control. The EDFA amplifier amplifies the optical signal for batter gain, low insertion loss, and signal capability with an optical link [2].

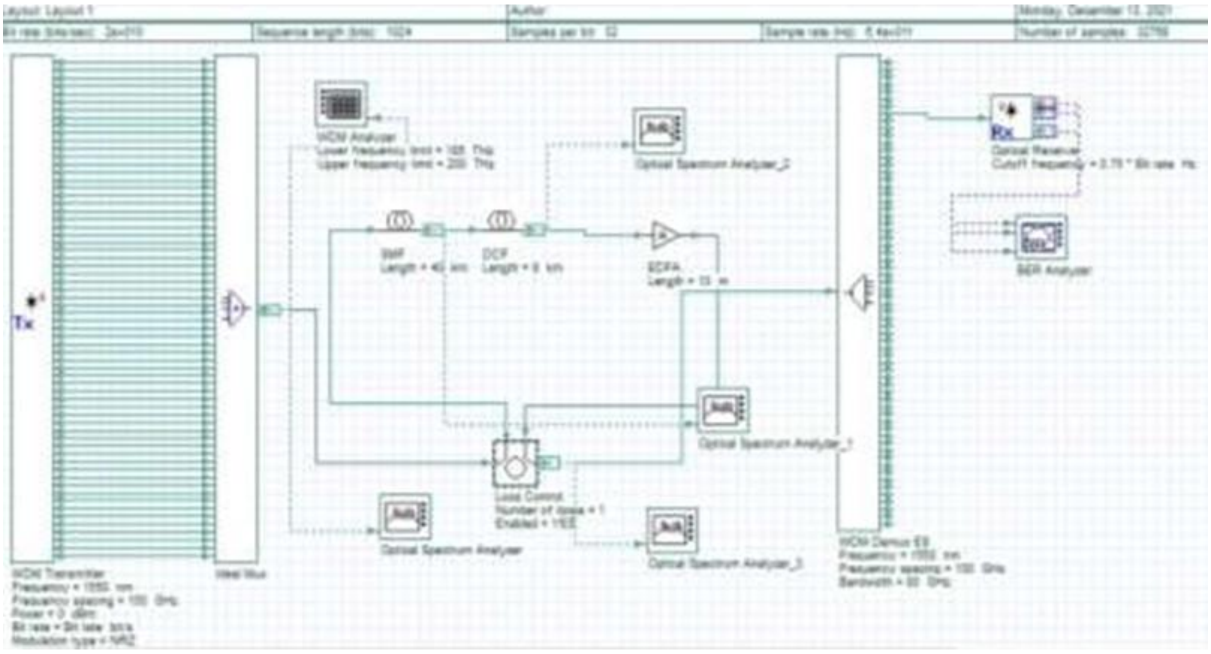


Figure 2: Simulation setup.

The WDM Demultiplexer in the final receiver portion demultiplexes the optical signals into 32 distinct channels. The optical receiver receives the demultiplexing signal outputs, which then go through the BER analyzer. The simulation parameters and fiber parameters are shown in tables 1 and 2, respectively, while the whole simulation model of the 32x10 Gbps, 32x20 Gbps, 32x30 Gbps, and 32x40 Gbps DWDM optical transmission system is shown in Figure 2.

Table 1: Simulation parameters.

Parameters	**Value**
Data Rates	10, 20, 30, 40 Gb/s
Sequence length	128 bits
Sample per bit	32
Transmitter frequency	193.4 THz (1550 nm)
Reference Wavelength	1550 nm
Input transmitter power	10 dBm
Modulation Extinction ratio	30 dBm
frequency spacing	100 GHz
Communication capacity	32x10 Gbps, 32x20 Gbps, 32x30 Gbps, 32x40 Gbps

Table 2: Fiber parameters [7].

Parameters	SMF	DCF
Fiber Length (km)	40, 80, 120, 160	8, 16, 24, 32
Attenuation (db/km)	0.2	0.5
Dispersion (ps/nm/km)	17	-85
Dispersion slop (ps/nm2/km)	0.075	-0.3
Differential group delay (ps/km)	0.2	0.2
PMD coefficient (ps/nm)	0.5	0.5

Results and discussion

The DWDM optical transmission model's performance analysis is simulated using Optisystem software, and a BER analyzer measures the Q-factor and BER. A total of 32 simulations are thus run to examine the performance analysis of the suggested DWDM system model utilizing an NRZ modulation scheme with varying data rates (10, 20, 30, and 40 Gbps) and input transmitter power levels (0 dBm and -10 dBm).

In theory, for the best optical communication system, the bit error rate should be less than or equal to 10-9 and the Q-factor should be larger than 6. After reviewing the performance analysis of a 32-channel DWDM system with 10, 20, 30, and 40 Gbps speeds per channel for optical fiber connection distances of 48, 96, 144, and 192 kilometers, the bit rate and quality factor were found to be adequate. For two different input transmitter power levels (zero dBm and -10 dBm), the varied bit rates translate into different transmission distances. Tables 3 and 4 show eye parameters (such as BER, Q-factor, eye height, and threshold).

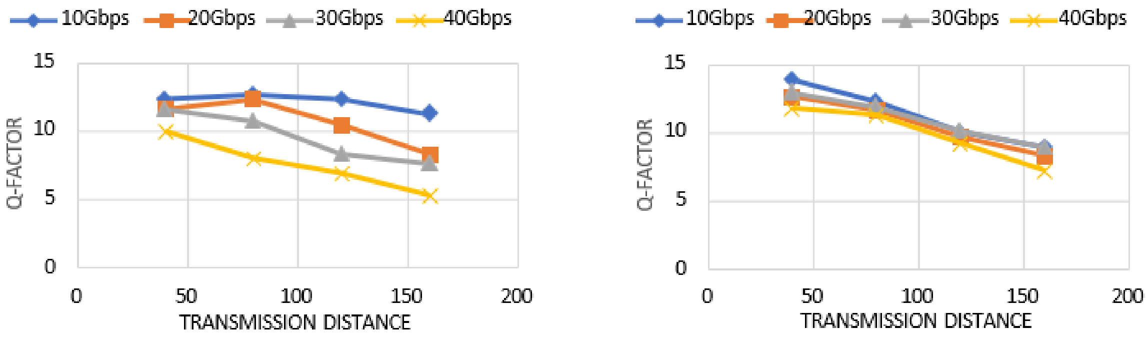
Table 3 For Input Transmitter Power Level -10 dbm.

Bit Rate	**Transmission Distance**		**Eye Parameter**			
	SMF	**DCF**	**BER**	**Q-Factor**	**Eye Height**	**Threshold**
10	40	8	3.04E-35	12.3315	0.00328327	0.0021742
	80	16	8.94E-37	12.6122	0.00329951	0.0021573
	120	24	4.41E-35	12.3013	0.00163991	0.0010948
	160	32	9.59E-30	11.2654	0.00062587	0.0004366
20	40	8	1.32E-31	11.6168	0.00319499	0.0019423
	80	16	3.36E-35	12.3211	0.00322503	0.0018930
	120	24	6.37E-26	10.4617	0.00149506	0.0010598
	160	32	6.00E-17	8.28175	0.00053519	0.0004514
30	40	8	3.90E-31	11.5418	0.00318127	0.0018737
	80	16	5.30E-27	10.6944	0.00291276	0.0019881
	120	24	5.20E-17	8.29905	0.00107751	0.0009229
	160	32	1.62E-14	7.58738	0.00024729	0.0002366
40	40	8	7.75E-24	9.99319	0.00295007	0.0018008
	80	16	6.08E-16	8.00043	0.00260302	0.0021300
	120	24	2.72E-12	6.89224	0.00115151	0.0011651
	160	32	6.91E-08	5.26768	0.00034006	0.0005351

Table 4: Input Transmitter Power Level 0 dBm.

Bit Rate	**Transmission Distance**		**Eye Parameter**			
	SMF	**DCF**	**BER**	**Q-Factor**	**Eye Height**	**Threshold**
10	40	8	8.46E-44	13.8295	0.00438028	0.0031218
	80	16	8.58E-35	12.2479	0.00408483	0.0028446
	120	24	4.17E-24	10.0579	0.00249831	0.0017272
	160	32	2.13E-19	8.92828	0.00139714	0.0010209
20	40	8	5.12E-37	12.6552	0.00423865	0.0028472
	80	16	1.24E-31	11.3222	0.00393454	0.0026345
	120	24	1.94E-22	9.67151	0.00242651	0.0013269
	160	32	4.84E-17	8.30512	0.00127336	0.0009358
	40	8	1.10E-38	12.9547	0.00421977	0.0029296

30	80	16	5.80E-33	11.9005	0.00393273	0.0026858
	120	24	1.46E-24	10.161	0.00244071	0.0017294
	160	32	1.33E-19	8.98169	0.00128613	0.0010994
40	40	8	2.54E-32	11.7768	0.00406609	0.0026979
	80	16	8.87E-30	11.2729	0.00389816	0.0028487
	120	24	1.45E-20	9.2216	0.00238544	0.0018721
	160	32	2.54E-13	7.22165	0.00115014	0.0010913

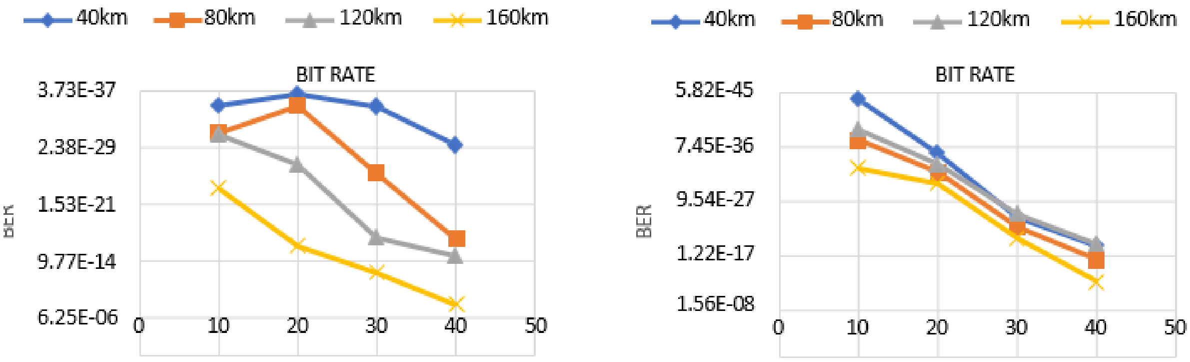


Graph-1 Graph-2

Figure 3: Graph -1 and 2 Q-factor Vs transmission distance with various bit rates for input transmitter power -10 dBm and 0 dBm respectively.

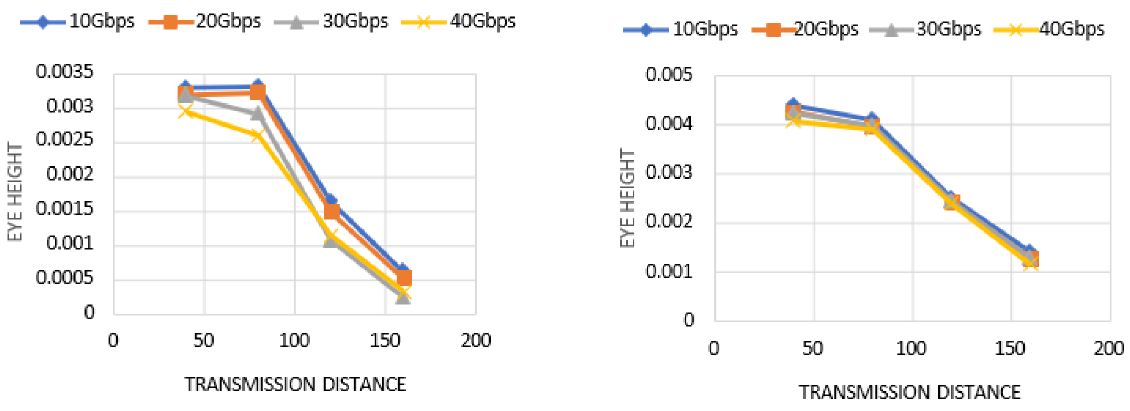
As we increase the transmission distance from 40 km to 160 km, the Q-factor decreases; in other words, when we increase the bit rate from 10Gbps to 40Gbps, the Q-factor also decreases linearly. Fig. 3 displays the graph Q-factor vs. transmission distance with different bit rates for input transmitter power of -10 dBm and 0 dBm.

For input transmitter power of -10 dBm and 0 dBm, Fig. 4 displays both BER vs. data Rate with different Transmission Distances. The tables above demonstrate that the BER increases as the data rate grows from 10 to 40 Gbps. In other words, the bit error rate likewise drops as the transmission distance increases from 40 to 160 kilometers.



Graph-3 Graph-4

Figure 4: Graph -3 and 4 BER Vs Bit Rate with various Transmission Distance for Input Transmitter Power -10 dBm and 0 dBm respectively.



Graph-5

Graph-6

Figure 5: Graph -5 and 6 Eye Height Vs Transmission Distance with various Bit Rate for Input Transmitter Power -10 dBm and 0 dBm respectively.

For input transmitter power levels of -10 dBm and 0 dBm, as well as the tables above, Figure 5 displays the Eye Height vs. Transmission Distance graph with different bit rates. In terms of eye height, the 0 dBm power level performs better than the -10 dBm power level in both cases. The eye height drops as the transmission distance increases from 40 km to 160 km. In other words, the eye height rapidly.

Conclusion

This study presents a performance analysis of a 32-channel DWDM system utilizing DCF with the NRZ modulation scheme, evaluated at various bit rates and input transmitter power levels. The proposed model is designed and simulated with DCF and an EDFA amplifier to mitigate dispersion effects and attenuation. The performance of the NRZ modulation format is analyzed for two input power levels across different bit rates and transmission link lengths, focusing on metrics such as Q-factor, bit error rate (BER), eye height, and threshold.

The results demonstrate that both input transmitter power levels provide reliable performance for NRZ modulation at bit rates of 10, 20, 30, and 40 Gbps per channel, achieving error-free transmission over varying distances while effectively minimizing dispersion. Notably, an input power level of 0 dBm achieved superior performance, with a Q-factor of 13.8295 and a BER of 8.46E-44 for a 10 Gbps bit rate over a 40 km transmission link.

As bit rates and transmission distances increase, a linear decrease in eye parameters is observed. However, improved values of eye height and threshold highlight reduced dispersion minimized jitter, and enhanced synchronization, confirming the effectiveness of the system in fibre-optic communication.

References

[1] R. Thummar, D. Dhadhal, and (Sr. Member IEEE) Vivekanand Mishra, “Performance Analysis of 64 Channel DWDM System Using Single Mode Fiber at Different Power Levels and Frequency Spacing,” *J. Phys. Conf. Ser.*, vol. 1804, no. 1, p. 012153, Feb. 2021, doi: 10.1088/1742-6596/1804/1/012153.

[2] S. Jain and C. Kumar, “Performance Analysis of FBG WDM System using Different Optical Amplifiers,” *J. Opt. Commun.*, vol. 42, no. 3, pp. 387–395, Jul. 2021, doi: 10.1515/joc-2018-0113.

[3] D. Dhadhal, V. Mishra, and R. Thummar, “Implementation and analysis of 32 channel MDRZ DWDM system at narrow channel spacing,” *J. Phys. Commun.*, vol. 6, no. 9, p. 095003, Sep. 2022, doi: 10.1088/2399-6528/ac8d4b.

[4] Anuranjana, S. Kaur, R. Goyal, and S. Chaudhary, “1000 Gbps MDM-WDM FSO link employing DP-QPSK modulation scheme under the effect of fog,” *Optik (Stuttg).*, vol. 257, p. 168809, May 2022, doi: 10.1016/j.ijleo.2022.168809.

[5] M. A. Shah, B. M. Pirzada, G. Price, A. L. Shibiru, and A. Qurashi, “Applications of nanotechnology in smart textile industry: A critical review,” *J. Adv. Res.*, vol. 38, pp. 55–75, May 2022, doi: 10.1016/j.jare.2022.01.008.

[6] F. Kaeib, O. A. Alshawish, S. Ali Altayf, and M. A. Gamoudi, “Designing and Analysis of Underwater

Optical Wireless communication system," in *2022 IEEE 2nd International Maghreb Meeting of the Conference on Sciences and Techniques of Automatic Control and Computer Engineering, MI-STA 2022 - Proceeding*, 2022, pp. 441–446. doi: 10.1109/MI-STA54861.2022.9837554.

[7] G. S. Daehn, "Sustainable design and manufacture of lightweight vehicle structures," *Altern. Fuels Adv. Veh. Technol. Improv. Environ. Perform. Towar. Zero Carbon Transp.*, pp. 433–461, 2014, doi: 10.1533/9780857097422.2.433.