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Analyzing the Non-Linear Effects in DWDM Optical Network Using MDRZ Modulation Format

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***Abstract* — Major challenge faced by today's telecommunication is the increasing demand of bandwidth and data rates. In order to expand the capacity of the optical system, it has accelerated the development of high capacity DWDM links. There are some barriers in DWDM related to data rate and capacity. These barriers are linear and nonlinear effects. Out of these barriers, linear effects such as attenuation and dispersion can be easily compensated using soliton and dispersion compensating fiber but there is an accumulation of nonlinear effects. The nonlinear effects occur in optical system are Self-Phase Modulation (SPM), Stimulated Brillouin Scattering (SBS), Stimulated Raman Scattering (SRS), Cross Phase Modulation (XPM), And Four-Wave Mixing (FWM). Out of which SBS and SPM is examined in single channel link whereas SRS, XPM and FWM is introduced in multi-channel link**

In this paper optical link of different number of data channels is studied using MDRZ modulation scheme at various input power levels. Paper shows the simulated performance analysis of the impact of Cross Phase Modulation and Four Wave Mixing on DWDM optical network. The analysis is done on the basis of Q-factor, Optical Spectrum and Eye Diagram. Performance of link deteriorates as the input power and the number of data channels increases.

***Keywords*—DWDM, MDRZ, XPM, FWM, SRS, SBS, SPM**

I. Introduction

The continuing demand of more and more bandwidth and data rates is the major challenge faced by today’s communication industry. Wavelength division multiplexed optical network is a fascinating solution to fulfil the worldwide rising requirement for transmission capacity in the next generation fiber optical metro networks. In DWDM systems, the entire optical bandwidth is divided into a number of channels with different wavelengths that allows many light beams of distinct wavelengths to be simultaneously sent into the core of the fiber. It means that by increasing the number of carriers the optical traffic capacity can be increased as required.
While working with WDM it is assumed that different channels propagate along the fiber without affecting one another. If the power level is increased this assumption fails. Because of the high optical input power levels results in to various nonlinear effects and chromatic dispersion. Nonlinear distortion is one of the dominant penalty factors in dense WDM transmission systems and its suppression leads to system performance enhancement such as in the transmission distance and capacity.

There are several nonlinear effects in optical links, such as Stimulated Raman Scattering (SRS), Stimulated Brillouin Scattering (SBS), Self-Phase Modulation (SPM), Cross Phase Modulation (XPM), and Four-Wave Mixing (FWM). Out of which SBS and SPM is examined in single channel link whereas SRS, XPM and FWM is introduced in multi-channel link. The phenomena of XPM, FWM and SRS are described below:

A. Cross Phase Modulation (XPM)

Cross phase Modulation is a nonlinear effect where the optical intensity of one beam influences the phase change of another beam in the presence of Kerr effects. In WDM system multiple pulse travel in a fiber, this multiple pulses will overlap with each other causing cross phase modulation.[4]

The major effects caused by XPM on the performance of the optical link are pulse broadening and distortion.[4]

B. Four Wave Mixing (FWM)

FWM can be compared to the intermodulation distortion in standard electrical systems. When three wavelengths (λ_A, λ_B, and λ_C) interact in a nonlinear medium, they give rise to a fourth wavelength (λ_D), which is formed by the scattering of the three incident photons, producing the fourth photon. This effect is known as Four Wave Mixing (FWM) and is a fiber-optic characteristic that affects WDM systems.

$$\lambda_D = \lambda_A \pm \lambda_B \pm \lambda_C \qquad \text{here, } A \neq B \neq C \quad (1)$$ [4]

C. Stimulated Raman Scattering (SRS)

When light propagates through a medium, the photons interact with silica molecules during propagation. The photons also interact with themselves and cause scattering effects, such as Stimulated Raman Scattering (SRS), in the forward and reverse directions of propagation along the fiber. [4]

This paper describes the analysis of the impact of nonlinear effects on the performance of an optical network using Modified-Duo-binary-Return-to-Zero (MDRZ) modulation format. In the case of MDRZ modulation format, first the NRZ duo binary signal is generated and then this signal is fed to another MZ-Modulator which is driven by the electrical sinusoidal signal -90° phase shift. [3]

II. SIMULATION SETUP

We have carried out the simulation work on OptiSystem Simulation software. OptiSystem is a comprehensive software design suite that enables to plan, test, and simulate optical links in modern optical networks. Proposed algorithm for simulation consists of a transmitter with MDRZ modulation scheme, optical fiber, receiver, and Optical Spectrum Analyzer and BER analyzer to analyze the output result. In order to analyze the impact of nonlinearities on the optical fiber communication system, the number of data channels as well as the input power levels of the optical system is varied. The length of the optical Single Mode Fiber (SMF) is varied and in accordance with it the length of Dispersion Compensating Fiber (DCF) is also varied respectively according to the equation

$$D_{SMF} \text{ X } L_{SMF} = -D_{DCF} \text{ X } L_{DCF} \quad (2)$$

Where, DSMF=Dispersion Coefficient of Single Mode Fiber
L_{SMF}=Length of Single Mode Fiber
D_{DCF}=Dispersion Coefficient of Dispersion Compensating Fiber
L_{DCF}=Length of Dispersion Compensating Fiber

An Erbium Doped Fiber Amplifier (EDFA) is placed after each length of fiber such that the losses are compensated. The compensation is generally offered in following manner

$$\text{Loss of SMF X Length of Fiber} \quad (3)$$

In the simulation setup we have used MDRZ modulation format. There are three different dispersion compensation configuration such as, pre-compensation configuration, post-compensation configuration and symmetric configuration. Out of the three DCF compensation techniques, we have simulated our link using symmetric dispersion compensation configuration. The simulation parameters are given as follows:

Table 1: Simulation Parameters

Parameters	Value
Bit rate	10Gbps
No. of Channels	8, 16, 32
Modulation format	MDRZ
Transmission Length	100
Length of SMF	50 km
Length of DCF	10 km
Dispersion Coefficient of SMF	17 ps/nm/km
Dispersion Coefficient of DCF	-85 ps/nm/km
Gain of EDFA	5 db
DCF Scheme	Symmetric
Input Power	5, 10, 20 dbm

III. RESULTS AND DISCUSSION

We have simulated the optical link operating at 8x10=80 Gbps, 16x10=160 Gbps and 32x10=320 Gbps. For the compensation of dispersion, DCF in symmetrical configuration is used. The non-linear effects with this dispersion compensation configuration using MDRZ modulation have been examined at various input power levels. The nonlinear effects are analyzed in terms of Optical Spectrum and Q Factor with the use of Eye Diagrams.

A. Simulation of Cross Phase Modulation

For analysing the impact of XPM on optical network at various power levels, the number of channels & the input power is varied. Three different number of channels are considered here i.e., Multiplexer with 8 input data channels, 16 channels and 32 channels and accordingly the input power level is varied.

Below are the results obtained through simulation and the results shows the eye diagrams of transmitter with 8 data channels, 16 data channels and 32 data channels using MDRZ modulation formats with symmetrical DCF schemes at the input power level of 5, 10, 20 dBm respectively at the transmission distance of 100 km.

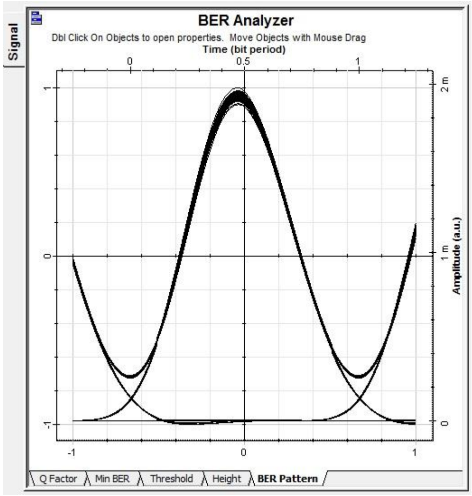

Figure 1: Eye Diagram for 8 Channels & 5dbm Input Power

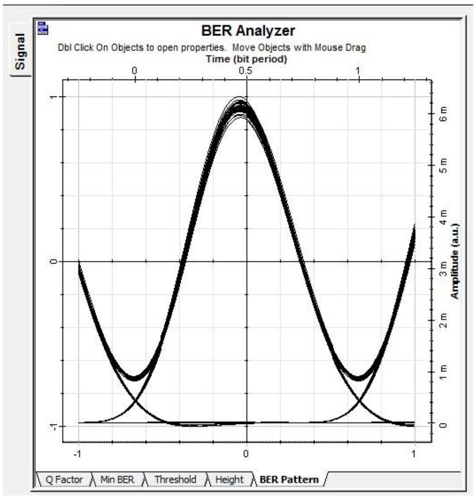

Figure 2: Eye Diagram for 16 Channels & 10dbm Input Power

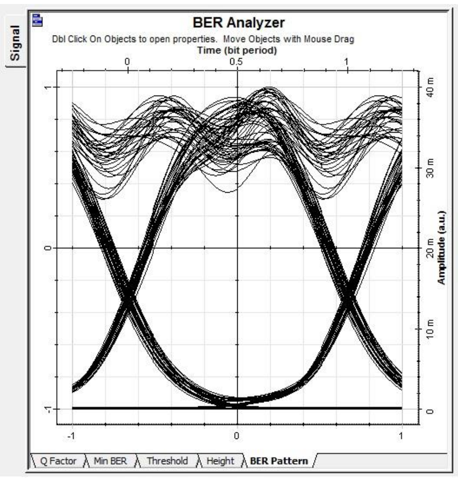

Figure 3: Eye Diagram for 32 Channels & 20dbm Input Power

By analyzing the figure 1, 2, and 3, it can be seen that as the number of channels and the input power levels increases the effect of XPM also increases. Due the effects of XPM, the value of Q-factor decreases and also eye pattern detoriates.

Input Power in dbm	Input Number of Channel	Q-Factor
05 dbm	8	95.42
10 dbm	16	75.86
15 dbm	32	12.08

The effect of cross phase modulation can be decreased by increasing the channel spacing and introducing various dispersion management techniques.

B. Simulation of Four Wave Mixing

For analysing the impact of FWM on optical network at various power levels, the number of channels & the input power is varied. Multiplexer with 8 input data channels, 16 channels and 32 channels are examined at various input power levels.

Below are the results obtained through simulation and the results shows the optical spectrum of transmitter with 8 data channels, 16 data channels and 32 data channels using MDRZ modulation formats with symmetrical DCF schemes at the input power level of 5, 10, 20 dbm respectively at the transmission distance of 100 km.

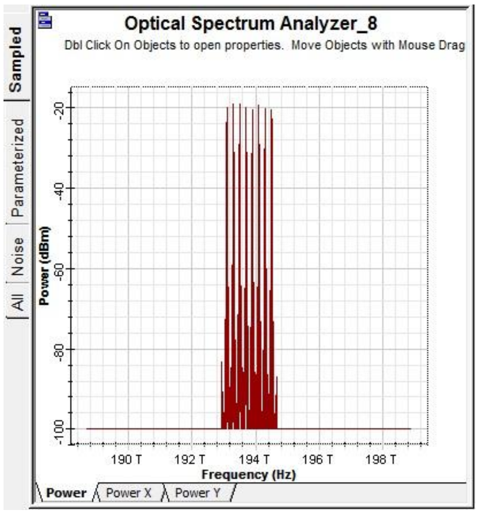

Figure 4: Input Spectrum for 8 Channels & 5 dbm Input Power

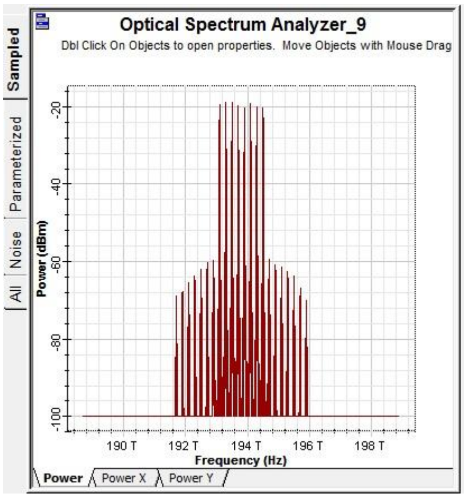

Figure 5: Output Spectrum for 8 Channels & 5 dbm Input Power

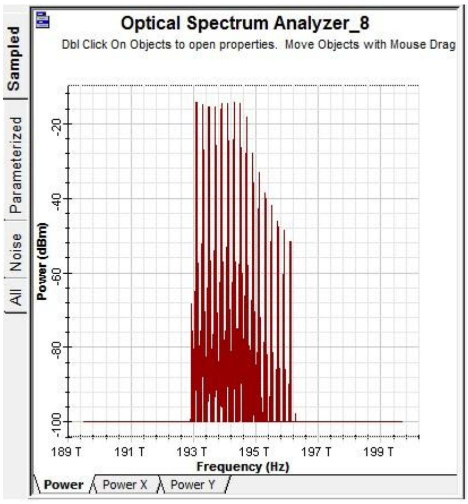

Figure 6: Input Spectrum for 16 Channels & 10 dbm Input Power

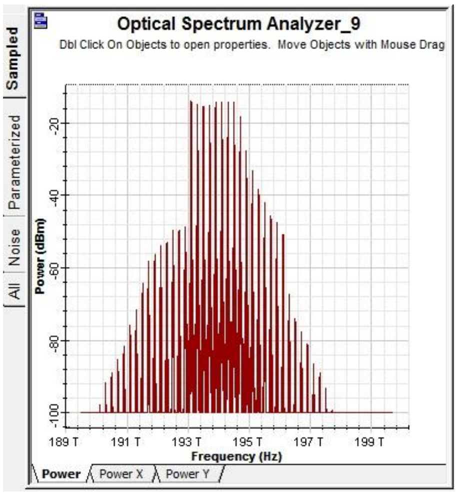

Figure 7: Output Spectrum for 16 Channels & 10 dbm Input Power

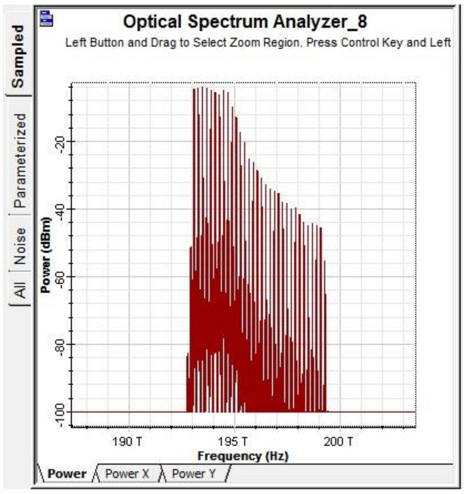

Figure 8: Input Spectrum for 32 Channels & 20 dbm Input Power

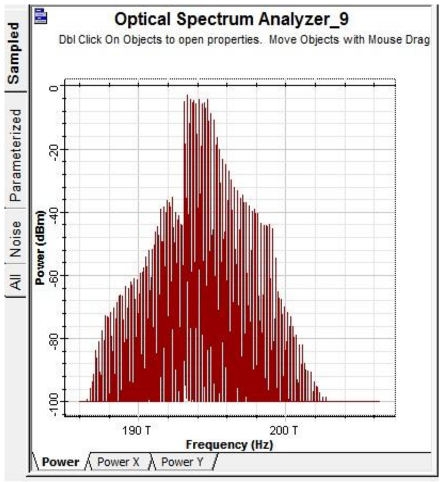

Figure 9: Output Spectrum for 32 Channels & 20 dbm Input Power

It can be seen that from the above Figure 4, 5, 6, 7, 8 and 9 non linear effect four wave mixing are introduced at the output optical spectrum. These nonlinear effects will detoriates the performance of the DWDM optical network. To reduce the effect of FWM, rectangular filter can be used. Also uneven channel spacing at the input side can be used to overcome these effects.

IV. CONCLUSION

In this paper, we have simulated a DWDM optical link operating at 80 Gbps, 160 Gbps and 320 Gbps over a transmission distance of 100 km. For compensation of the chromatic dispersion DCF is employed in symmetrical configurations. Paper briefly analysis the nonlinear effects XPM and FWM in DWDM optical network. From the result we can conclude that the effect of XPM and FWM increases with the increase in input power levels and number of input data channels. The performance is measured in terms of Q-factor, Eye Diagram and Optical Spectrum.

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