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Analysis of Dispersion Compensation System for Optical Fiber Communication in a WDM Network

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Abstract—Fiber-optic dispersion and its effect on optical transmission system are analyzed. In Opti-System simulation environment a dispersion compensation system is built with a simple WDM network. Input optical power is varied from 10-20 dB. To compensate the dispersion of fiber, most commonly used dispersion compensation fiber (DCF) technology is used. Three DCF schemes (pre-compensation, post-compensation, mix-compensation of dispersion compensation) are compared. It was found that the mix- compensation scheme gives best result (Q-Factor and BER performance). Simulation result also showed the effect of Erbium Doped Fiber Amplifier (EDFA) in optical fiber transmission to reduce the losses. Design also includes the optimum power level that can be used for this system in the mentioned power range.

Kewords— dispersion compensation; optical communication DCF; simulation; Q-factor

1 Introduction

In recent years, with the rapid growth internet business needs, people urgently need more capacity and network systems. [1] So the demand for transmission capacity and bandwidth are becoming more and more challenging to the carriers and service suppliers. Under the situation, with its huge bandwidth and excellent transmission performance, optical fiber is becoming the most favorable delivering media and laying more and more important role in information industry [2, 3]. The optimal design and application of optical fiber are very important to the transmission quality of optical fiber transmission system. Therefore, it is very necessary to investigate the transmission characteristics of optical fiber. And the main goal of communication systems is to increase the transmission distance. Loss and dispersion are the major factor that affect fiber-optical communication being the high-capacity develops. The EDFA is the gigantic change happened in the fiber-optical communication system; the loss is no longer the major factor to restrict the fiber-optical transmission. Since EDFA works in 1550 nm wave band, the average Single Mode Fiber (SMF) dispersion value in that wave band is very big, about 15-20 ps / (nm.km-1)[4]. It is easy to see that the dispersion become the major factor that restricts long distance fiber-optical transfers [5].

In this study, we propose three DCF compensation scheme, pre-compensation, under-compensation and mix compensation scheme. Simulation studies show that mix compensation scheme is the best. It can greatly reduce the influences of the fiber nonlinearity and increase the transmission distance greatly.

The rest of paper is organized as followed. In Section II, the cause of fiber dispersion and its effects on optical transmission is introduced. In Section III, present Fiber dispersion compensation technology. In Section IV, present the research of DCF dispersion compensation scheme. Section V present transmission system simulation with software OPTISYSTEM, analyses and compare each kind of compensation scheme, Section VI concludes the paper.

2 The effect of fiber-optic dispersion on optical transmission

Loss and dispersion are the key issues that have an effect on fiber-optical communication being the high-capacity develops. The EDFA is the huge change happened within the fiber-optical communication system; the loss is not any longer the main issue to limit the fiber-optical transmission. Since EDFA works in 1550 nm wave band, the common Single Mode Fiber (SMF) dispersion price in this wave band is extremely massive, concerning 15-20ps / (nm. km-I). It is simple to envision that the dispersion become the key factors that prohibit long

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distance fiber-optical transfers [6]. Dispersion is outlined as owing to totally different | the various frequency or mode of sunshine pulse in fiber transmits at different rates, in order that these frequency elements or models receive the fiber terminals at totally different time. It will cause intolerable amounts of distortions that ultimately result in errors.

In single-mode fiber performance is primarily restricted by chromatic dispersion (also referred to as cluster speed dispersion), that happens as a result of the index of the glass varies slightly reckoning on the wavelength of the light from real optical transmitters essentially has nonzero spectral breadth (due to modulation)[7,8].Polarization mode dispersion , another supply of limitation, happens as a result of though the single-mode fiber will sustain just one crosswise mode, it will carry this mode with two totally different polarizations, and slight imperfections or distortions in an exceedingly fiber will alter the propagation velocities for the two polarizations. This phenomenon is called birefringence. Mode birefringence Bm is defined as the follow Formula:

$$B_m = \frac{|\beta_x - \beta_y|}{k_0} = n_x - n_y \qquad (1)$$

n_x, n_y are the effective refractive of the two orthogonal polarizations. For a given Bm, its fast axis and slow axis components will be formed the phase difference after the light waves transmission L Km.

$$\varphi = k_o B_m L = \frac{2\pi}{\lambda}(N_X - N_Y)L = (\beta_X - \beta_Y)L \qquad (2)$$

If the Bm is a constant, through the light waves in transmission process the phase difference between its fast axis and slow axis will periodicity repetition. The power exchange also periodically. The length that it leads to a phase difference of 2π or power periodic exchange is called polarization beat length:

$$L_B = \frac{2\pi}{|\beta_X - \beta_Y|} = \frac{\lambda}{B_m} \qquad (3)$$

If the incident light has two polarization components, due to refractive difference between the fast axis and slow axis, the transmit rate of two polarization components will be different. Because the randomness of fiber birefringence changes, the group velocity of different polarization direction is also random, this will result in the output pulse broadening. Degree of pulse broadening can be expressed by different group delay Δτ.

$$\Delta\tau = \mathrm{I}\, \frac{L}{v_{gx}} - \frac{L}{v_{gy}}\, \mathrm{I} = \frac{d}{d\omega}(\beta_X - \beta_Y)L = \left(\frac{n_X - n_Y}{c} + \frac{\omega}{c}\frac{d(n_X - n_Y)}{d\omega}\right) \qquad (4)$$

From the equations gift that the initial pulse is broadened by the transmission. The longer the optical signal transmission distance, the larger the fiber dispersion constant, the lot of pulse broaden. The two adjacent pulse result overhearing, error judgment can generated [9].

The influence of dispersion on system performance is additionally mirrored within the fibre nonlinear effects. Dispersion exaggerated the heartbeat form distortion caused by the self-phase modulation dispersion (SPM); the different hand, dispersion in WDM systems can even increase the cross-phase modulation, four-wave admixture (FWM) and different nonlinear effects[10,11].

3 DCF dispersion compensation technology

In order to enhance overall system performance and reduced the maximum amount as doable the transmission performance influenced by the dispersion, many dispersion compensation technology were proposed [12]. Amongst the assorted technique planned within the literature, those that seem to carry immediate promise for dispersion compensation and management might be broadly speaking classified as: dispersion compensating fiber (DCF), chirped fiber Bragg gratings (FBG), and high-order mode (HOM) fiber [13].

The idea of exploitation dispersion compensation fiber for dispersion compensation was planned as early as in 1980 however, till once the invention of optical amplifier; DCF began to be widespread attention and study. As product of DCF a lot of mature, stable, not simply full of temperature, wide zero information measure, DCF has become a most helpful methodology of dispersion compensation and has been extensively studied.

There is positive second-order and third-order dispersion value in SMF (single mode fiber), while the DCF dispersion value is negative. So by inserting a DCF, the average dispersion is close to zero [14]. As the local dispersion of higher transmission link, FWM and XPM were ignored; only to consider the role of SPM and dispersion, the signal transmission can be simulate by solve the nonlinear Schrodinger equation.

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$$\frac{\partial A_j(z,t)}{\partial z} + \frac{1}{2} i\beta_2(\lambda_i)\frac{\partial^2 A_j(z,t)}{\partial t^2} \; i\gamma|A_j(z,t)|^2 A_j(z,t) + \frac{\alpha}{2}A_j(z,t)=0 \quad (5)$$

$A_j(z,t)$ is complex amplitude of j channel optical pulse, $\beta_2(\lambda_i)$ is the dispersion parameter of j channel, γ is the nonlinear co-efficent, α is the loss co-efficient. After N-section dispersion compensation of DCF, the channel residual dispersion can be expressed as:

$$\Delta D(\gamma_i) = NL_{SMF}\left[(1-\mu_P)D_{SMF}(\lambda_P) + (j-P)\Delta\lambda\left(\frac{dD_{SMF}(\lambda_P)}{d\lambda} - \frac{\mu_P D_{SMF}(\lambda_P)}{D_{DCF}(\lambda_P)}\frac{dD_{DCF}(\lambda_P)}{d\lambda}\right)\right] \quad (6)$$

In the formula, μ_P is the dispersion compensation rate of p-channel

$$\mu_P = \left|\frac{D_{DCF}(\lambda_P)L_{DCF}}{D_{SMF}(\lambda_P)L_{SMF}}\right| \quad (7)$$

L_{SMF} and L_{DCF} are the conventional single-mode fiber length and dispersion compensation fiber length within the amplifier spacing $\Delta\lambda$ is the channel wavelength spacing $D_{DCF}(\lambda_P)$ and $D_{SMF}(\lambda_P)$ are the dispersion co-efficent of conventional single-mode fiber and dispersion compensation fiber at the λ_P wavelength.

4 Dispersion compensation scheme

The dispersion compensation system within the WDM is studied in this paper. Supported optical transmission equation, considering the varied styles of nonlinear effects and also the impact of EDFA, system simulation model are established. Consistent with relative position of DCF and single-mode fiber, post-compensation, pre-compensation, mix-compensation is planned. DCF Pre-compensation scheme deliver the goods dispersion compensation by place the DCF before a usual single-mode fiber or when the optical transmitter. Post-compensation scheme delive the goods dispersion compensation by place the DCF when a usual single-mode fiber or before the optical transmitter. Mix-compensation scheme is carries with it post-compensation and pre-compensation. Different location on the system can generate totally different nonlinear effects. The simulation of three dispersion compensation system is shown in Figure 1.

Figure 1 (a) shows the post-compensation schemes. The WDM system consists of eight channels, every channel with 40Gb/s. The simulation module includes the transmission module, transmission link and therefore the receive module. Simulation models use Mach-Zehnder external modulator to modulate the CW optical device. Eight completely different centre frequency wavelength of the light carrier were made. The centre frequency vary of optical device is 192.6-194.01THZ. Transmission code is the DPSK modulation code. 8-Channel WDM bandwidth is 80GHZ. Optical fiber transmission link composed of a 160 Km. The sort of fiber is G.655. Dispersion compensation is achieved with DCF. EDFA is employed to compensate the ability loss generating by SMF and therefore the DCF signal. Receiver module includes demultiplexer and receiver filters.

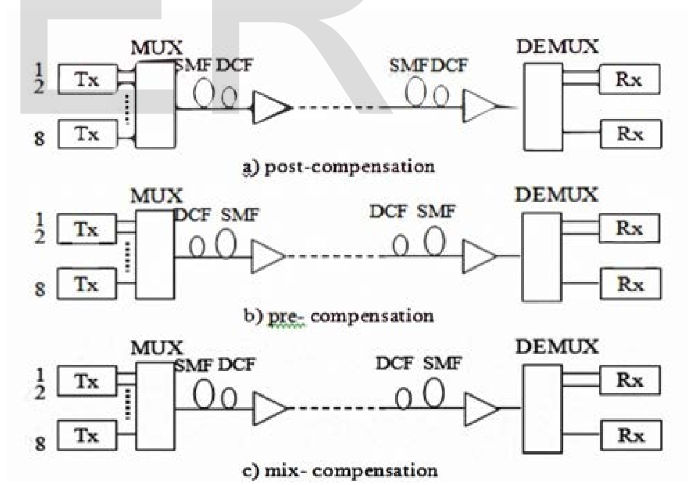

Figure 1 the three dispersion compensation system

Figure 1 (b) and Figure l (c) respectively show the pre- compensation scheme and the mix- compensation scheme. The simulation configuration is as similar as Figure 1 (a). The difference is that at the transmitter DCF compensate 80Km of single-mode fiber dispersion in Figure 1 (b). In Figure l (c), there is a mix- mix- compensation scheme.

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5 System and component description

Here from the block diagram we can see the WDM system consists of six channels, each channel with 40 Gb/s. The simulation module includes the transmission module, transmission link and the receiver module. Simulation model use Mach-Zehnder external modulator to modulate the CW Laser. Six different centre frequency wavelength of the light carrier were engendered. The centre frequency range of Laser is 192.6-194.01 THZ. Transmission code is the DPSK modulation code. Six channel WDM bandwidth is 80 GHZ. Optical fiber transmission link composed of a 250 Km.

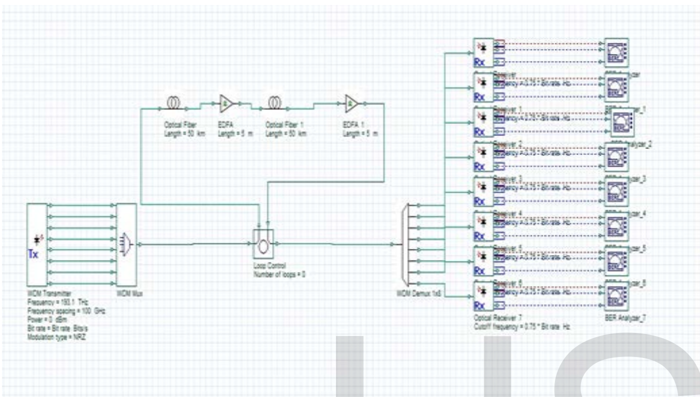

Figure 2 Dispersion compensation system using simple WDM network

The kind of optical fiber is G.655. Dispersion compensation is achieved with DCF. EDFA is utilized to compensate the power loss engendering by SMF and the DCF signal. Receiver module includes multiplexer and receiver filters.

In the pre-compensation scheme, the compensation is done after the fiber, i.e. SMF is placed after DCF here. The other components are quite similar to the post-compensation system.

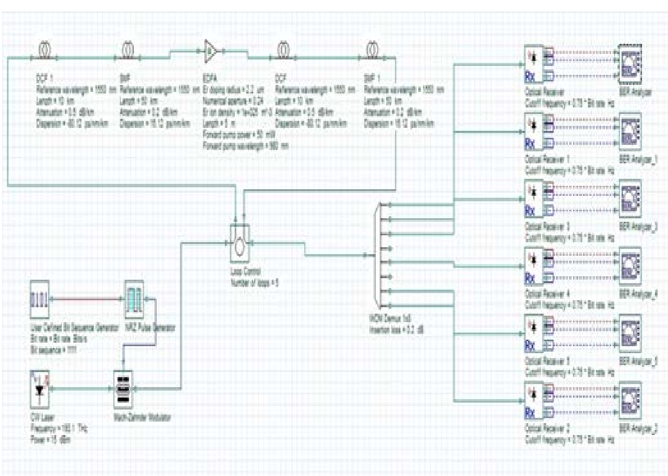

Figure 3 Post-compensation system

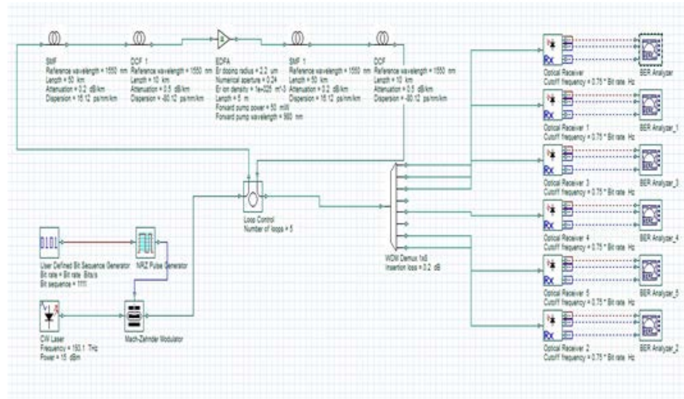

Figure 4 Pre-compensation system

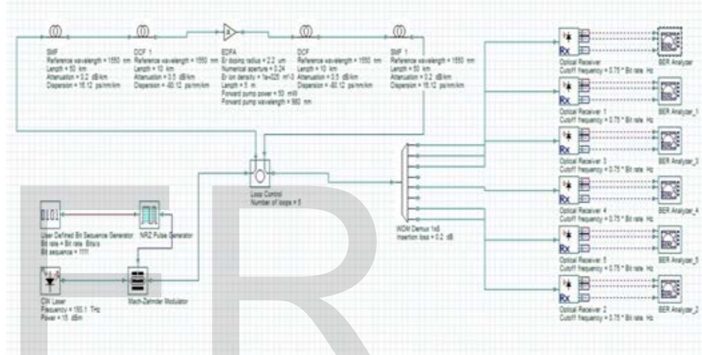

Figure 5 Mix-compensation system

In the mix-compensation system, one stage is similar to the pre-compensation scheme and the other stage is akin to the post-compensation scheme. It is authentically accumulation of both pre and post compensation scheme and that is why it is called a mix-compensation system.

6 Result and analysis

In optical communication systems, only optical signal to noise ratio (OSNR) could not accurately measure the system performance, especially in WDM systems. Typically, as a quality factor, Q is a one of the important indicators to measure the optical performance by which to characterize the BER. Figure

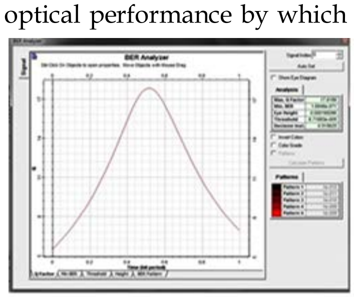

Fig: BER analyzer graph for post-compensation system

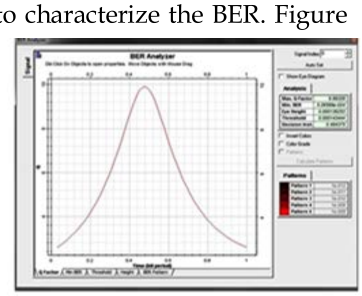

Fig: BER analyzer graph for pre-compensation system

6 display the influence of input optical power on the performance of transmission system.

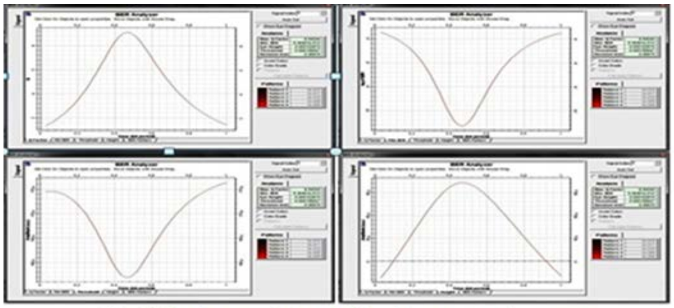

Fig: BER analyzer graph for mix-dispersion compensation system
Parameters- Input bits: 1111, Signal generator: NRZ, Modulation technique: Mach-Zehnder, optical power: 15dB.

Figure 6 BER analyzer graph for mix-dispersion compensation system

Figure 6 appear that the effect of laser average power is just contrary to the previous situations. A moderate bigger value of laser average power is favorable to the performance of the transmission system. And from the figure we can find that with the input optical power increased to about 9 dB, the Q factor increases.

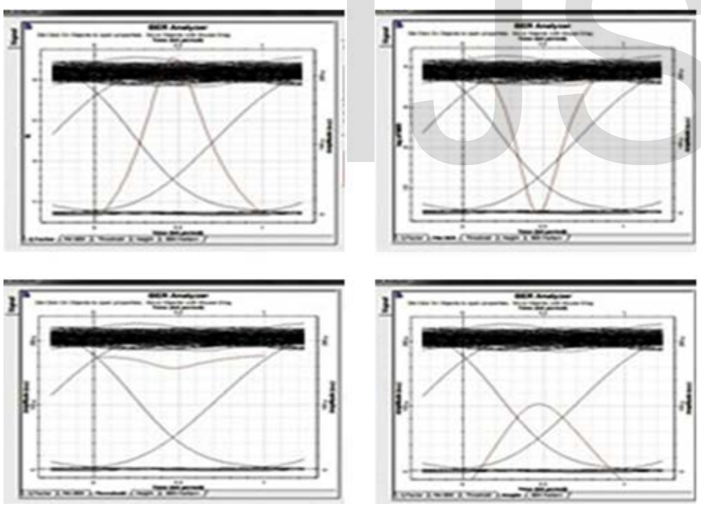

Figure 7 above diagram shows the eye diagram for mix-compensation system

When the input optical power approaches 9 dB, the Q factor becomes the maximum. When the input optical power is greater than 9 dB the quality factor decreased gradually and the error performance is gradually degraded. This is because as the optical power increases, nonlinear effects increase, but the optical signal noise ratio increased. When the input optical power is greater than 9 dB, the nonlinear effects increases rapidly, making the system performance worst. It can be seen from the graph that in terms for BER and Q factor mix-compensation gives better performance.

7 Conclusion

This system work well only for an input power of 9 dB. So there are issues of non-linearity with the increasing power. Also the BER performance is not fully optimized. Many other techniques may be investigated to optimize the BER performance and also to reduce the losses occurred because of the non-linearity effect.

References

[1] Mochida Y, Yamaguchi N, Ishikawa G, "Technology-oriented review and vision of 40Gb/s-based optical transport Networks", Journal of light-wave technology.PP. 2272-228,12002,20(12)

[2] Zhang Hongb in,Q iu Kun, "Emulation of charactrristics of optical fiber transmission for a 10Gb/s single channel situation," acta photonica sinica 2001 vol.30 No.6 715-720

[3] Omae T, "Universal conditions for estimating the nonlinear refractive index n2 of dispersion com- pensating fibers by the CW-SPM method", IEEE Photon Technol. Lett, Vol 13. No.6, pp. 571-573, Nov, 2001

[4] Mohammad. Amin. Dallaali, "Malin Premaratne Power and dispersion constrained optimization of optical links with unequally- spaced repeater modules", Optical Fiber Technology, Vol 13, No 4, pp.309-317, October. 2007.

[5] Zou X Y, Hayee M I, H wang S M, et al. Limitations in 10Gb/s WDM optical-fiber transmission when using a variety of fiber types to manage dispersion and nonlinearities[J]. Lightwave Technol., PP: 1144-1152,June,1996

[6] WuQiang,Yu Chong Xiu, "Analysis on dispersion compensation with DCF", semiconductor optoelectronics,Vol.24 No.3 pp.186- 196.June 2003

[7] Zhaohuaigang, "study on dispersion compensation in optical transmission system", study pn optical communications,Vol.3 ,No.141, 2007

[8] Wangchen,Raomin, "the performance of the DCFTransmissionn system", Journal of applied sciences,Vol.21, No.2,pp.177-181,June 2003

[9] BU CHAL IF, LANNES. Fast eye monitor for 10G/bs and its applicationg for optical PMD compensation [Z]. Optical Society of America,2000.

[10] Killy R I, Thiele H J, Mikhailov v, ea al. Reduction of intrachannel nonlinear distortion in 40-Gb/s based WDM transmission over standard

ISSN 2229-5518
fiber [J]. IEEE Photonics Technology Letters, 2000, 12(12): 1642-1626

[11] Eggleton B 1. Dynamic dispersion, compensation devices for high speed transmission systems. Optical Fiber communication conference and exhibit, 2001(3): WHlII-WH1I3

[12] Djafar K. Mynbaev Lowell L. Scheiner, Fiber-optic communications technology. Beijing: Science publishing company, 2002

[13] Jianjun Yu, Bojun Yang,"Dispersion-allacated soliton technology with long amplifier spacing and long distance," IEEEphoton technol lett, vol 9, pp. 952-954,No.7, 1997:

[14] ZhouZhiQiang, TangYuLiang, "Optimmum schemes of dispersion compensation transmission systems using dispersion compensation fibers",laser technology, VoI.24,No.5,pp.265-269 Oct.2000

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