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Investigation of dispersion penalty for optical fiber link at different values of fiber dispersion

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ABSTRACT

Fiber dispersion degrades the performance of optical communication systems by broadening optical pulses as they propagate inside the fiber. This paper demonstrates the effect of dispersion on dispersion penalty at different lengths of fiber for pseudorandom data at the OC-192 rate. This paper shows that the large chirp from directly modulated lasers operating at the OC-192 rate (9.953 Gb/s) has prevented their use in such high data rate systems. Simulation results show power required to achieve the constant bit error rate with the increase in fiber length.

Keywords - Bit Error Rate (BER), Directly Modulated Laser (DML), Single Mode Fiber (SMF).

1. INTRODUCTION

Optical transmission over optical fibers was first proposed in 1966. Since 1980 such systems have been deployed worldwide and indeed revolutionize the technology behind telecommunication [1]. A method to extract the line-width enhancement factor had been used at the wave length for zero dispersion in optical fiber (1310nm) [2]. Directly modulated distributed feedback lasers have attracted much attention recently for application in metropolitan areas systems operating at the OC-48 rate (2.488 GB/s) and below [3]. Because they provide suitable optical output at the lowest cost, footprint and power dissipation [4]. However the frequency chirp characteristics of directly modulated lasers significantly limit the maximum achievable transmission distance over standard single mode fiber [5].

Dispersion is one of the major factors that affect the performance of optical link. As a pulse propagates along the optical fiber it spreads in time resulting in a decrease in peak power and total energy in its own bit period. Spreading of power into adjacent bit periods resulting high bit error rate (BER) and subsequently decrease the transmission distance. In this paper the effect of dispersion on dispersion penalty for different values of fiber length has been demonstrated. The organization of this paper is as follows: introduction in section 1, theory of chromatic dispersion in section 2, experimental setup in section 3, results and discussion in section 4, and a short conclusion has been presented in section 5.

2. CHROMATIC DISPERSION

In optical fiber communications systems, pulses of light representing digital ones are launched into the fiber. Each bit (a digital one or zero) is allocated to its own time slot or bit period (T), which is equal to the reciprocal of the bit rate (BR). Dispersion in optical fibers is due to change in the refractive index of glass as a function of wavelength. This results in the spectral components of a pulse traveling at different group velocities along the optical fiber. Hence, chromatic dispersion broadens optical pulses beyond their allocated time slot, causing intersymbol interference (ISI) as shown in Fig.1.

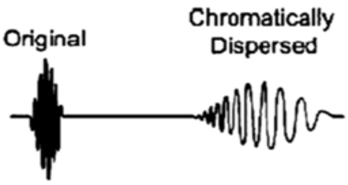

Fig.1 Optical Pulse Broadening caused by dispersion [6]

It had been found that there was increase in linear effects of chromatic dispersion and attenuation with increasing the distance along the optical fiber length [7]. Eventually this will lead to errors at the receiver output with ones being recorded in bit periods into which zeroes were transmitted and zeroes into which ones were transmitted. The type of pulses that used in the simulation is Gaussian pulse [8]. There are two distinct sources of pulse spreading in single mode fiber namely; material dispersion and waveguide dispersion and they are commonly referred to Chromatic dispersion [6]. Chromatic dispersion causes pulse broadening and it limits the transmission distance, bit rate and number of channel on an optical communication [9]. Dispersion becomes more problematic when the optical pulses in transport fiber begin to overlap. Pulse interference depends on dispersion value, and data bit rates, optical source spectral width and fiber length. The dispersion parameter of fiber is given by "equation 1" [10]:

$$D= d\,(1/Vg)/d\lambda \qquad (1)$$

where Vg is group velocity and D is called the dispersion parameter. The typical value of dispersion parameter for single mode fiber (SMF) is 16ps/nm.km at 1550nm. This paper discusses the effect of different values of dispersion parameter on power penalty. The group velocity dispersion limits the bit rate distance product BL which is given by "equation 2" [1]:

$$BL \leq (4|D|\sigma_{\lambda})^{-1} \qquad (2)$$

where σ_{λ} is the root mean square (RMS) source spectral width in wavelength units, B is the bit rate, L is the fiber length. Dispersion induced pulse broadening can also decrease the receiver sensitivity. Here power penalty δ_d is defined as the required increase (in dB) in the received power that would compensate the peak–power reduction, and δ_d is given by "equation 3" [1]:

$$\delta_d = 10 \log_{10} (f_b) \qquad (3)$$

where f_b is the pulse broadening factor and this is the ratio of RMS width of broadened optical pulse and RMS width of the optical pulse at the fiber input. Another relation also exists for dispersion penalty to examine the performance of optical link. An approximate relation to calculate the dispersion penalty as a function of fiber length L is given by "equation 4" [11]:

$$\delta_d = 5*(\log (1+2\pi (B\, D\, \Delta\lambda)^2 L^2)) \qquad (4)$$

The tolerable range of this penalty is 0.5 to 1.0 dB. The system sensitivity degrades rapidly with the dispersion. It is possible to design a system such that the pulse spreads outside the bit slot but ISI is reduced through pulse shaping at the receiver.

3. OPTICAL FIBER RECEIVER

The transmitter comprised a directly modulated laser (DML) operating at 193.6 THz (1548.51 nm) and an extinction ratio of 6.6 dB. The modulation format is non return to-zero, the data load is a pseudo random bit sequence (PRBS) of 2^{23} -1 length. The data rate is 9.953 Gb/s and 100nA value of thermal noise is fixed. As shown in Fig.2 the first stage of optical fiber receiver is detector, which converts the received signal into an electrical form.

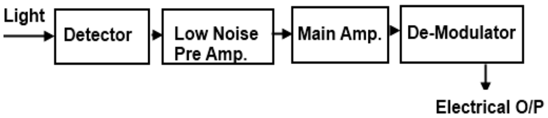

Fig.2 Receiver setup with two stage amplification [12]

In the amplification stages there are two stages of amplifier are used i.e.; pre amplifier and main amplifier. These amplification stages amplify the converted signal, for further processing. Demodulator or decision circuit reproduces the original electrical signal from modulated incoming signals. All spans are standard dispersion fiber with different values of dispersion such as 11ps/nm.km to 19ps/nm.km, and no optical dispersion compensation is used.

4. RESULTS AND DISCUSSION

Results of the work done have been summarized in Fig.3 to Fig.7.

Fig.3 shows the bit error rates (BERs) obtained with uncompensated receiver at different values of fiber dispersion at length 5km. The maximum value of dispersion penalty is 3.8887 dB at 19ps/nm.km. At BER of 2.78×10^{-3}, the percentage increase in received power is 2.80, 4.51, 6.55, 8.71, and 10.95 for dispersion value of 11ps/nm.km, 13ps/nm.km, 15ps/nm.km, 17ps/nm.km and 19ps/nm.km respectively. And at BER of 2.51×10^{-11}, the percentage increase in received power is 7.27, 9.75, 12.43, 15.21, and 18.18 for dispersion value of 11ps/nm.km, 13ps/nm.km, 15ps/nm.km, 17ps/nm.km and 19ps/nm.km respectively.

Fig.4 shows the bit error rates (BERs) obtained with different values of fiber dispersion at fiber length of 10km. The maximum value of dispersion penalty is 8.3208dB at 19ps/nm.km. At BER of 2.78×10^{-3}, the percentage increase in received power is 14.46, 19.22, 24.02, 28.81, and 33.62 for dispersion value of 11ps/nm.km, 13ps/nm.km, 15ps/nm.km, 17ps/nm.km and 19ps/nm.km respectively. And at BER of 2.51×10^{-11}, the percentage increase in received power is 22.72, 29, 35.44, 42, and 48.62 for dispersion value varies from 11ps/nm.km, 13ps/nm.km, 15ps/nm.km, 17ps/nm.km and 19ps/nm.km respectively.

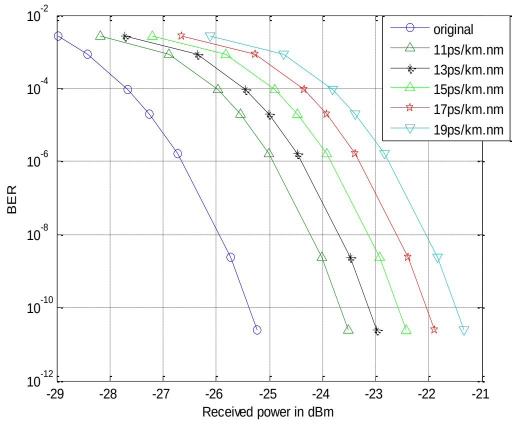

Fig.3 BERs for different values of dispersion at fiber length of 5km

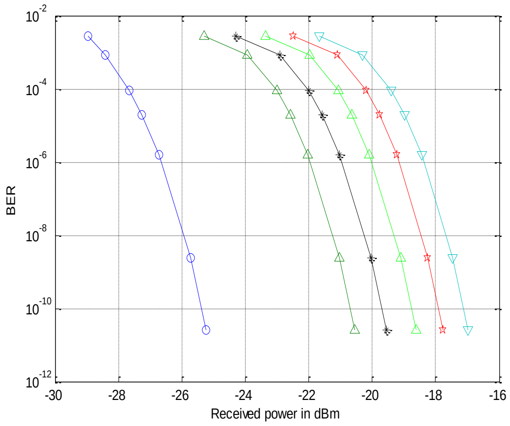

Fig.4 BERs for different values of dispersion at fiber length of 10km

Fig.5 shows the bit error rates (BERs) at different values of fiber dispersion at length 15km; here the maximum dispersion penalty is 11.4721dB. At BER of $2.78x10^{-3}$, the percentage increase in received power is 27.62, 34.81, 41.94, 49.1, and 56.1 for dispersion value of 11ps/nm.km, 13ps/nm.km, 15ps/nm.km, 17ps/nm.km and 19ps/nm.km respectively. At BER of $2.51x10^{-11}$, the percentage increase in received power is 40.34, 50.21, 60.12, 69.94, and 79.62 for dispersion value of 11ps/nm.km, 13ps/nm.km, 15ps/nm.km, 17ps/nm.km and 19ps/nm.km respectively.

Fig. 6 shows the bit error rates (BERs) versus received power at length of 15km, here the maximum dispersion penalty are 13.8334 dB. At BER of $2.78x10^{-3}$, the percentage increase in received power is 40.76, 50.26, 59.61, 68.92, and 78.16 for dispersion value of 11ps/nm.km, 13ps/nm.km, 15ps/nm.km, 17ps/nm.km and 19ps/nm.km respectively. And at BER of $2.51x10^{-11}$, the percentage increase in received power is 58.51, 71.56, 84.22, 96.11, and 106.72 for dispersion value of 11ps/nm.km, 13ps/nm.km, 15ps/nm.km, 17ps/nm.km and 19ps/nm.km respectively.

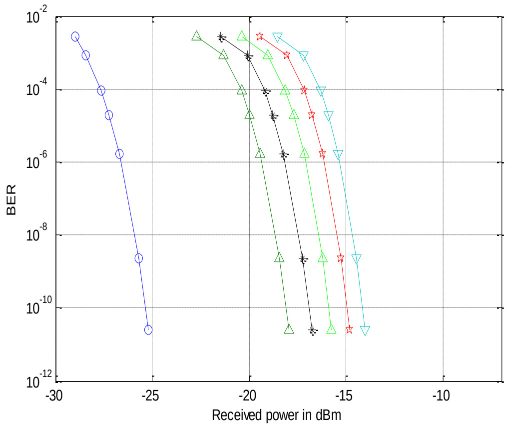

Fig.5 BERs for different values of dispersion at fiber length of 15km

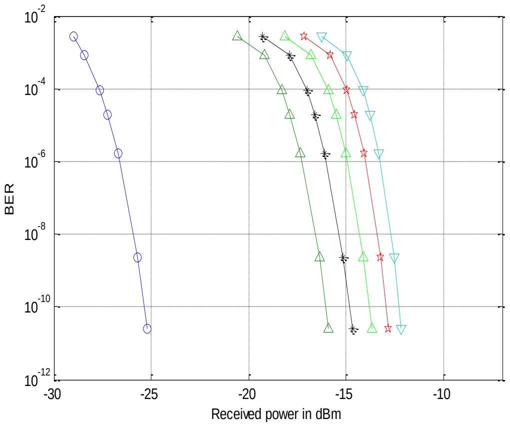

Fig.6 BERs for different values of dispersion at fiber length of 20km

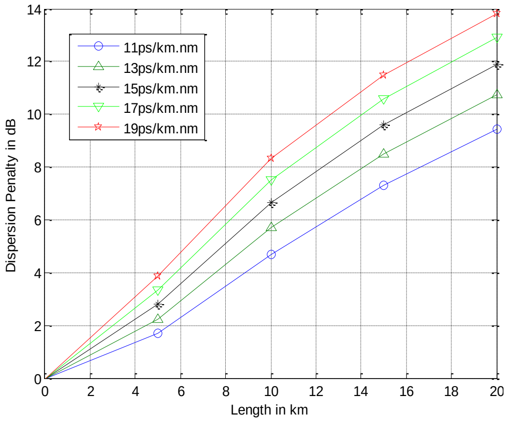

Fig.7 Measured dispersion penalty, at BER= 10^{-9}, with different values of fiber dispersion

Fig.7 plots the dispersion penalty for different values of fiber dispersion as a function of length. With the percentage increase in dispersion of 72, the dispersion penalty has increased by 126.23%, 77.57%, 57.14%, and 46.67% at fiber length of 5km, 10km, 15km and 20km respectively. And with 300% increase in fiber length, the dispersion penalty has increased by 448.5%, 377.2%, 325.5%, 286.18% and 255.62% for dispersion value of 11ps/nm.km, 13ps/nm.km, 15ps/nm.km, 17ps/nm.km and 19ps/nm.km respectively.

5. CONCLUSION

In carrying out an optical fiber link analysis, different device characteristics are required. Dispersion is one of the major factors that affect the performance of an optical fiber link. In this paper, affect of dispersion on dispersion penalty with the change in fiber length has been studied. It has been concluded from this study that with the increase in fiber length dispersion penalty has also increased. With the percentage increase in dispersion of 72.72, the dispersion penalty has increased by 46.67% at fiber length of 20km. With 300% increase in fiber length, the dispersion penalty has increased by 286.18% for typical value of dispersion 17ps/nm.km. Moreover, It has been concluded from the results obtained at different fiber distances that the effect of chromatic dispersion increases linearly with the increase in the optical fiber length.

REFERENCE

[1] G. P. Agrawal, *Fiber Optics Communication Systems*, (John Wiley and Sons, Inc, Third Edition, (2002).

[2] J. C. Cartledge, et al., Extraction of DFB laser rate equation parameters for system simulation purposes, *Journal of Lightwave Technology*, 15, 1997, 852–860.

[3] N. Antoniades, et al., Measurements of laser rate equation parameters for simulating the performance of directly modulated 2.5 Gb/s Metro area transmission systems and networks, *Proc. LEOS*, 2, 2000, 692–693.

[4] I. Papagiannakis, et al., Transmission Performance Improvement Studies for Low-Cost 2.5 Gb/s Rated DML Sources Operated at 10 Gb/s, *Proc. ECOC*, Brussels, Belgium, 2008.

[5] K. Hinton, et al., Modeling high-speed optical transmission systems, *IEEE Journal of Selected Areas Communication,* 11, 1993, 380–392.

[6] Y. Danziger, et al., High-order Mode Fiber: An Innovative approach to chromatic dispersion management that enables optical networking in long-haul high-speed transmission systems, *Optical Networks Magazine*, 2(1), 2001.

[7] S. H. Saeid, Limitations on Light-Wave Communications Imposed by Attenuation and Dispersion in Optical Fibers, *International Journal of Modern Communication Technologies & Research*, 2(3), 2014.

[8] M. B. Pearce, et al., Optimal input Gaussian pulse width for transmission in dispersive nonlinear fibers, *JOSA B, Optical Society of America*, 16(8), 1999, 1189-1196.

[9] P. Ball, Optical and broadband Networks, *Lecture Note*, Oxford Brookes University, Oxford, UK, 2009.

[10] R. Papannareddy, Introduction to Light wave Communication Systems, *Artec House*, Norwood, MA, 1997.

[11] M. D. Casimer, et al., Fiber optics Essential, *Journal of Fiber Optic Technology*, Elsevier, ISBN: 13: 978-0 12-208431-7.

[12] http://www.daenotes.com/electronics/communication-system /optical-fiber.