Simulative Analysis of the Impact of Non-Linearity in Terms of BER, Q-Factor and Jitter in Optical Soliton Transmission at 40 GB/S.

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ABSTRACT

In this paper we have analyzes the impact of chirp factor in terms of Q-factor, BER and jitter with different dispersion parameters for optical Soliton transmission links at 40 Gb/s. The results show that BER is minimum, Q-factor is maximum and the jitter value is minimum at or near 0.7 values of chirp factor, also, the performance Soliton transmission system has optimum value. Further, it has been indicated that BER is increased, Q-factor is decreased and jitter is increased from third order of PMD to second order of PMD to first order of PMD at chirp factor of 0.7 value at which optimum transmission of soliton is done.

Keywords

Soliton, BER, Chirp-factor, Q-factor, Jitter, NRZ, GVD

1. INTRODUCTION

Due to ever increasing demand for higher information rate and hence the bandwidth, the suitable media for fulfilling such a requirement, optical fiber has proved to be one of best media alternative due to its high information carrying capacity. The optical fiber can offer 100's of THz bandwidth provided it is exploited practically. At present the input bit rates of 10 Gb/s and 20 Gb/s for a single channel are commonly used in optical communication systems and now we are using 40Gb/s for commercial purpose . The dispersion phenomenon is a problem for high bit rate and long haul optical communication systems. An easy solution of this problem is optical soliton's pulses that preserve the shape over long distances [1, 2].

The term soliton (formed from Latin solitarius – solitary) is one of the fundamental unifying ideas in modern theoretical physics and mathematics. Solitons are a special breed of optical pulses that can propagate through an optical fiber undistorted for tens of thousands of kilometers by using optical amplifiers. The key to soliton formation is the careful balance of the opposing forces of group velocity dispersion (GVD) and self-phase modulation (SPM). SPM is the frequency change caused by a phase shift induced by the pulse itself. The group velocity of a signal is function of wavelength, therefore each spectral component can be assumed to travel independently and to undergo a group delay, which ultimately results in pulse broadening. So by carefully balancing the SPM and GVD, a pulse may propagate through a fiber without any broadening in the time or frequency domains [12]

An impressive practical implementation of the soliton concept has been achieved in fiber optics, where soliton pulses are used as the information carriers to transmit digital signals over long-haul. Soliton based optical communication systems can be used over distance of several thousands of kilometers with huge information carrying capacity by using optical amplifiers. But there are number of factors which cause the degradation in the performance of optical soliton system and the one of them is Chirp factor. The chirp factor is the deviation of frequency of light waves from its central frequency and results in the broadening of optical pulses and thereby decreasing the rate of information. The value of chirp is given by:

$$\delta f(t) = \left(\frac{\alpha_e}{4\pi}\right)\left[\frac{d}{dt}\ln(\Delta P) + \chi\Delta P\right] \quad (1)$$

Where αe is line width enhancement factor, ΔP is variation in optical power variation and χ is constant. The above equation can be divided into two parts: One is known as transient chirp and caused by the relaxation oscillator and second one is adiabatic chirp and it is produced by change in carrier densities because of power variation Δp in the present work the effect of chirp factor on bit error rate-value is study at the rate of 40 Gb/s [13].

In this paper, we have analyzed the impact of Chirp factor in terms of BER, Q-factor and jitter on optical soliton transmission system with different dispersion parameters having input bit rate 40 GB/s. The BER can be estimated from equation (2), and requires Q >6 for the BER 10-9. This BER gives the upper limit for the signal because some degradation occurs at the receiver end.

$$BER = \frac{1}{2}\, \mathrm{erfc}\,(Q/\sqrt{2}) \quad (2)$$

2. SYSTEM DESCRIPTION

Typical optical soliton transmission system consists of a transmitter, optical fiber as a channel, and receiver. The soliton communication system requires an optical source capable of producing pulses at a high repetition rate with a shape closest to the "sech" shape. The source should operate in the wavelength region near 1.55µm. Receivers can feature detectors based on either PIN or APD with aperture and optional error-correction. The soliton transmission system is shown in figure 1 Is to calculate the impact of chirp factor on performance characteristics of optical communication system using optical solitons. This model is a subsystem of transmitter telescope, optical fiber and receiver telescope. The first stage in transmitter section consists of PRBS (pseudo-random bit sequence) generator. Parameter bit rate, order number of leading and trailing zeros are used in the internal PRBS generator. A different seed will be used for each bit sequence for each WDM channel. The second stage is coding/ modulation. NRZ coding is generated by the engines of NRZ pulse generator. In this set up we are taking NRZ format. The transmitter section consists of data source having a bit rate of 40 Gb/s, linear modulator and soliton pulse generator operating at a wavelength range of 1550nm, transmitted power is 70mw and frequency spacing 100GHz. In this set up the length of the fiber is 70 Spans of 50 KM each D17 type + 10,625 DCF type. We are using the in-line-erbium-doped fiber amplifier (EDFA), which amplifies the pulse through a process of stimulated emission similar to what occur in a laser [13].

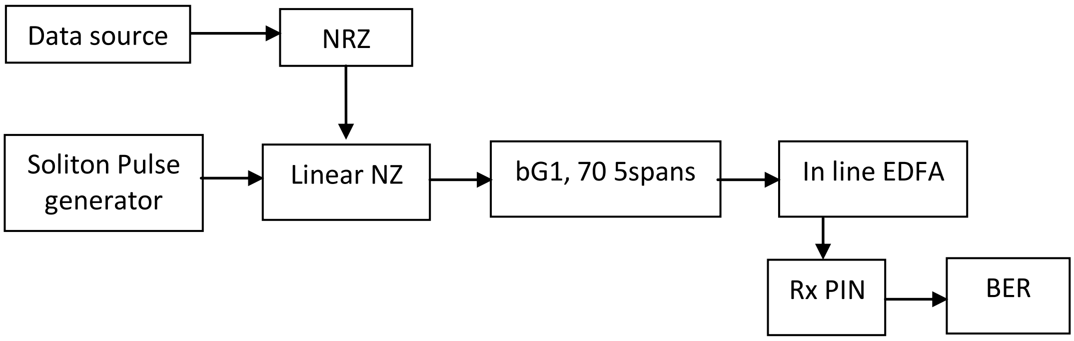

Fig.1. Design layout of soliton communication system

The receiver is a PIN type and is followed by an electrical splitter, BER detector and electrical oscilloscope. Soliton transmission system has been numerically simulated for examine the effect of chirp factor in terms of BER, Q-factor and jitter are shown in Fig.1. The simulation is carried out for three different GVD parameters as shown in table 1.

Table 1. GVD parameters

Case	Order of dispersion	Value
Case I	Fourth	β_2=-21.682 ps^2/km, β_3=0.0141 ps^3/km, β_4=-0.0068 ps^4/km
Case II	Third	β_2=-21.682 ps^2/km, β_3=0.0141 ps^3/km, β_4=-0 ps^4/km
Case III	Second	β_2=-21.682 ps^2/km, β_3=0 ps^3/km, β_4=-0 ps^4/km

3. RESULTS AND DISCUSSION

The right choice of the performance evaluation criteria for the characterization of optical transmission links represent one of the key issuses for an effective design of future long-haul optical systems. The evaluation criteria should provide a precise determination and separation of dominant system limitations, making them crucial for the suppression of propagation disturbances and a performance improvement. The most widely used performance evaluation are the Q-factor, BER and jitter. The chirp factor is the deviation of frequency of light waves from its central frequency and results in the broadening of optical pulses and thereby decreasing the rate of information. Optical Soliton transmission system has been numerically simulated for examine the impact of chirp factor in terms of BER, Q-factor and jitter with different order of GVD parameters is shown in Fig.1. For simulation following parameters are used: frequency of the transmitter is 1550nm, transmitted power is 70mw and frequency spacing 100GHz. BER versus chirp, Q-factor verses chirp and jitter verses chirp plots are shown in Fig.2-4. For every simulation, the simulation parameters are same.

In case I i.e. when the order of dispersion is higher or fourth the GVD parameters are β2=-21.682 ps2/km, β3=0.0141 ps3/km, β4=-0.0068ps4/km .It is quite evident from the above table that as the chirp factor varies the bit error and Q-factor also fluctuates and in general deteriorates as the chirp factor varies from 0 (BER=2.367*1014) to 0.6 (BER=1.736*10-11). This is due to the fact that chirp factor (which indicates the change in frequency) in this range is not compatible with the system design as the systems normally operates optimally with chirp factor of 0.7. The above table clearly shows the improvement in bit error rate with the chirp factor in the range of 0.7 (BER=4.398*10-15) to 1(BER=2.858*10-18). Further the values of Q-value at chirp factor 0.7 is 18.2716 and at chirp factor 0.8 is 19.046. Hence quality factor is improved at the value of 0.7 and jitter has minimum value at chirp factor 0.7 it is .001253. The jitter is alter from 0.002255 at 0 chirp factor to 0.003301 at 0.6 chirp factor so minimum value of jitter is at 0.7

In case II the fourth order dispersion is compensated in that case we have taken the parameters of GVD up to third order i.e.β2=-21.682 ps2/km, β3=0.0141 ps3/km, β4=-0 ps4/km . It has been observed that the BER is minimum at or near 0.7 value of chirp factor. It is deteriorates as the chirp factor varies from 0 (BER=9.348*10-14) to 0.6 (BER=2.041*10-23). The table 2 clearly shows the improvement in bit error rate with the chirp factor in the range of 0.7 (BER=3.642*10-14)to 1(BER=1.934*10-17). Further the values of Q-value at chirp factor 0.7 is 18.1968 and at chirp factor 0.8 is 19.2137. Hence quality factor is improved at the value of 0.7 and jitter has minimum value at chirp factor 0.7 it is 0.001384. The jitter is fluctuate from 0.002490 at 0 chirp factor to 0.001384 at 0.6 chirp factor so minimum value of jitter is at 0.7

In case III the fourth order and third order dispersion is compensated in that case we have taken the parameters of GVD up to second order i.e.β2=-21.682 ps2/km, β3=0 ps3/km, β4=-0 ps4/km . It has been observed that the BER is minimum at or near 0.7(BER=1.467*10-12) value of chirp.

The results show that at or near chirp factor 0.7 the optimal results are obtained and quality factor is improved. The value of Q factor varies from 19.4814 to 18.8351 to 19.7745 to 18.4776. It has been also observed that at and near chirp factor 0.7 the optimal results are obtained the values of Q-value at chirp factor 0.7 is 18.0144 and at chirp factor 0.8 is 18.7955. Further the observations also show that minimum value of jitter is at 0.7. The jitter is fluctuate from 0.003498 at 0 chirp factor to 0.003392 at 0.6 chirp factor so all of this alteration is due to the imperfection of fiber. So the fiber behavior is improved at or above the value of chirp factor value of 0.7. Figure 2-4, shows the comparative analysis of BER, Q-factor and jitter at 40Gb/s with variable chirp factor with 4th, 3rd and 2nd order of dispersion.

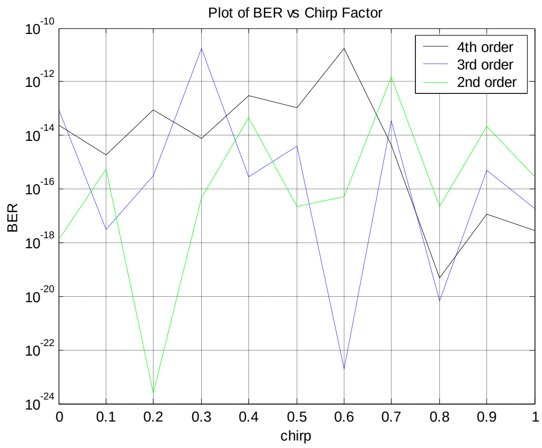

Figure 2. Plot of BER with variable chirp factor with different order of dispersion.

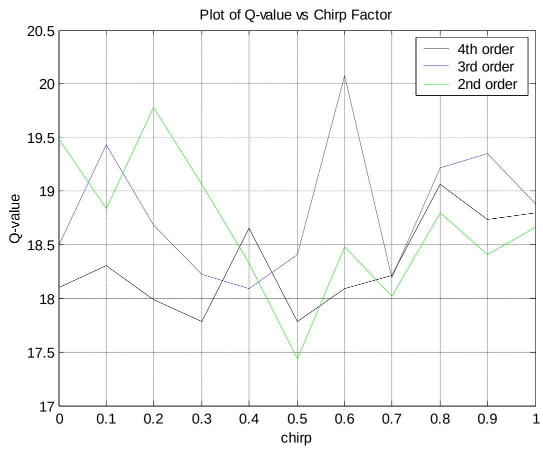

Figure 3. Plot for Q-values with variable chirp factor with different order of dispersion

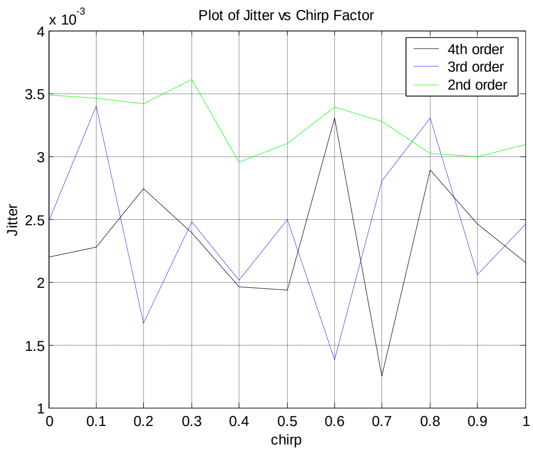

Figure 4. Plot for Jitter with variable chirp factor with different order of dispersion.

4. CONCLUSION

It is concluded from the all above observation that the bit error rate is minimum at or near 0.7 value of chirp factor and the performance soliton transmission system have optimum value, with (β2=-21.682 ps2/km, β3=0.014 ps3/km, β4=-0.006 ps4/km),(β2=-21.682 ps2/km, β3=0.014 ps3/km, β4=0 ps4/km), (β2=-21.682 ps2/km, β3=0 ps3/km, β4=0 ps4/km) respectively. From the above result it can also be concluded that in soliton transmission system the bit error rate is improved as bit error rate is increased from third order of PMD (with β2=-21.682 ps2/km, β3=0.014 ps3/km, β4=-0.006 ps4/km) to second order of PMD (with β2=-21.682 ps2/km, β3=0.014 ps3/km, β4=0 ps4/km) to first order of PMD (with (β2=-21.682 ps2/km, β3=0 ps3/km, β4=0 ps4/km) at chirp factor of value 0.7 at which optimum transmission of solution is done. Similarly the value of quality factor is decreased from third order of PMD (with β2=-21.682 ps2/km, β3=0.014 ps3/km, β4=-0.006 ps4/km) to second order of PMD (with β2=-21.682 ps2/km, β3=0.014 ps3/km, β4=0 ps4/km) to first order of PMD (with (β2=-21.682 ps2/km, β3=0 ps3/km, β4=0 ps4/km) at chirp factor of value 0.7 at which optimum transmission of soliton is done . And the value of jitter is increased from third order of PMD (with β2=-21.682 ps2/km, β3=0.014 ps3/km, β4=-0.006 ps4/km) to second order of PMD (with β2=-21.682 ps2/km, β3=0.014 ps3/km, β4=0 ps4/km) to first order of PMD (with (β2=-21.682 ps2/km, β3=0 ps3/km, β4=0 ps4/km) at chirp factor of value 0.7 at which optimum transmission of soliton is done .

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