International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Performance Comparison of Various Compensation Techniques Based on SPM Over Optical Fiber

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A B S T R A C T

In the modern world, telemetry systems play a very important role in monitoring. The purpose of telemetry systems is to acquire, process and transmit information about the monitored process using various available transmission media. The most commonly used transmission medium is single mode optical fiber. Here, at the transmitter side, the signal is masked with the optical chaos by employing masking techniques for the security purpose. The masked signal is sent over the fiber medium and received at the receiver side. In this work, various dispersion compensation techniques are performed in the presence and absence of Self Phase Modulation, a nonlinear effect for the distance of 200 km and comparison is done. From Q-factor, it is observed that symmetric compensation is better than all other compensation schemes.

Keywords:*Telemetry, Masking, Self Phase Modulation*

1.Introduction

In Fiber Optic Communication, information is transmitted using infrared light pulse through an optical fiber. Fiber is favoured over electrical cabling when high transfer speed, significant distance and resistance to electromagnetic interference are required. Generally transmission of medical data requires a high bandwidth with minimum noise interference and capability to transmit a long distance. In such scenario, transmission using Fiber optic cable becomes an optimal chance. Apart from that chaos based fiber optical link can provide outstanding security features. Fiber optic link is yet faster than copper wire, and isn't vulnerable to electromagnetic obstruction. Fiber can achieve speed of several Gigabits for every second or even Terabits when compared to copper wire.The major limiting factor of fiber optic communication link that limits the speed of data transfer and spectrum bandwidth is the chromatic dispersion. This is mainly due to the varying refractive index as a function of wavelength. It causes inter symbol interference (ISI).And signal can not be detected properly. Many ways are available to compensate such dispersion, but one effective technique to compensate it is Dispersion Compensating Fiber (DCF). It also supports secure transmission over long distances. This work gives an emphasis on the study of dispersion in the presence and absence of self phasemodulation , a non linear effect in a single channel with a bit rate of 10 Gbps and analyses the performances based on the quality factor of the received signal at the output.In [1], the authors proposed a chaos based optical communication link for secure transmission of EEG signals for health monitoring. They employed an additive chaos masking scheme for mixing the EEG signals and chaos. To control the dispersion, they used DCF with post order configuration with value of -16.75 ps/nm/km. Their proposed scheme is tested by varying the optical fiber length to determine the quality factor. They achieved the Q factor of about 5.72 withfiber length of 120 km.In [2], the authors experimentally do a comparison of commercial dispersion compensation techniques under real time. They considered a space dense wavelength division multiplexed optical transmission system for the implementation. They introduced dispersion post compensation on Fiber Bragg Grating and DCF for optical fiber operating at a 1550 nm band and compared their performance in terms of bit error rate. The channel bit rate considered for the implementation ranges from 20 Gbps to 40 Gbps.BER achieved for the above said dispersion compensation techniques varied with respect to bit rate from 5×10^{-2} to 1×10^{-10} and 5.8×10^{-2} to 9.73×10^{-12} . Also they observed the degradation in the received signal due to non linear effects like Four Wave Mixing (FWM).In [3], multiple dispersion compensation techniques and their performance measures in terms of BER and Q-Factor are discussed. From the performance analysis, they concluded that transmission of an optical signal for long distance can be supported by using DCF technique rather than FBG technique.In [4], a Carrier suppressed return to zero format system operating at 20 Gbps bit rate with 40 km transmission distance is considered for the simulation. FBG and DCF based dispersion compensation are taken for analyzing the Q factor. In [5], simulation models of pre compensation, post compensation and mix compensation are proposed. They analyzed the said configurations and concluded that post compensation technique performed well compared to the other techniques.Generally, non- linearity is observed at very high light intensities provided by lasers. The behavior of one such non-linearity, Self Phase Modulation (SPM) is investigated in [6]. With the increased power, SPM grows and depletes the signal.

In this work, the analysis of various compensation techniques based on SPM over optical fiber is done for long distance transmission.

2.Proposed Methodology

A Dispersion Compensation Fiber is used to compensate effect of dispersion and to improve quality of signal at receiver. There are three types of compensation schemes. They are

- pre compensation - DCF is positioned prior to the single mode fiber.
- post compensation -DCF is positioned following the single mode fiber.
- symmetric compensation - DCF is positioned on both sides of the single mode fiber.

Nonlinear effects present in optical fiber are due to optical intensity dependent refractive index and inelastic scattering. When the total input power is above the threshold level, the fiber will behave in a non linear manner. Self Phase Modulation (SPM) is one such non-linearity. It arises when the index of refraction of the fiber has an intensity-dependent component. This nonlinear index of refraction produces induced phase shift and hence chirping of the pulses. This pulse chirping increases effects of chromatic dispersion.The proposed scheme, as shown in Fig.1, consists of the user defined bit sequence generator at 10 Gbps which is modulated with the continuous laser source of 1550 nm in the Mach Zender modulator with an extinction ratio of 50:50. The modulated output is then added in the optical adder where masking is performed with the chaotic signal. The masked signal is then sent through the optical fiber. The dispersion in the fiber is compensated by employing various compensation techniques. This layout is used for comparing various compensation schemes in the presence and absence of Self Phase Modulation (SPM), a non-linear effect. In between transmitter and receiver, Erbium Doped Fiber Amplifier (EDFA) is used to reduce the attenuation in the fiber. At the receiver side, the output after compensation is sent to the optical subtractor where the chaotic signal generated as in the transmitter side is subtracted and the signal is sent to the optical receiver and is filtered with the help of a Bessel filter. From the Q factor value obtained from eye diagram analyser, the performance comparison of various compensation techniques based on SPM is studied upto a fiber length of 200km. The simulation of the proposed methodology is implemented using Optisystem software. In general, for a system with optical window of 1550 nm, the value of dispersion used for the dispersion compensated fiber in order to perform compensation and reduction of broadening of pulses is about -20ps/nm/km to -90ps/nm/km.

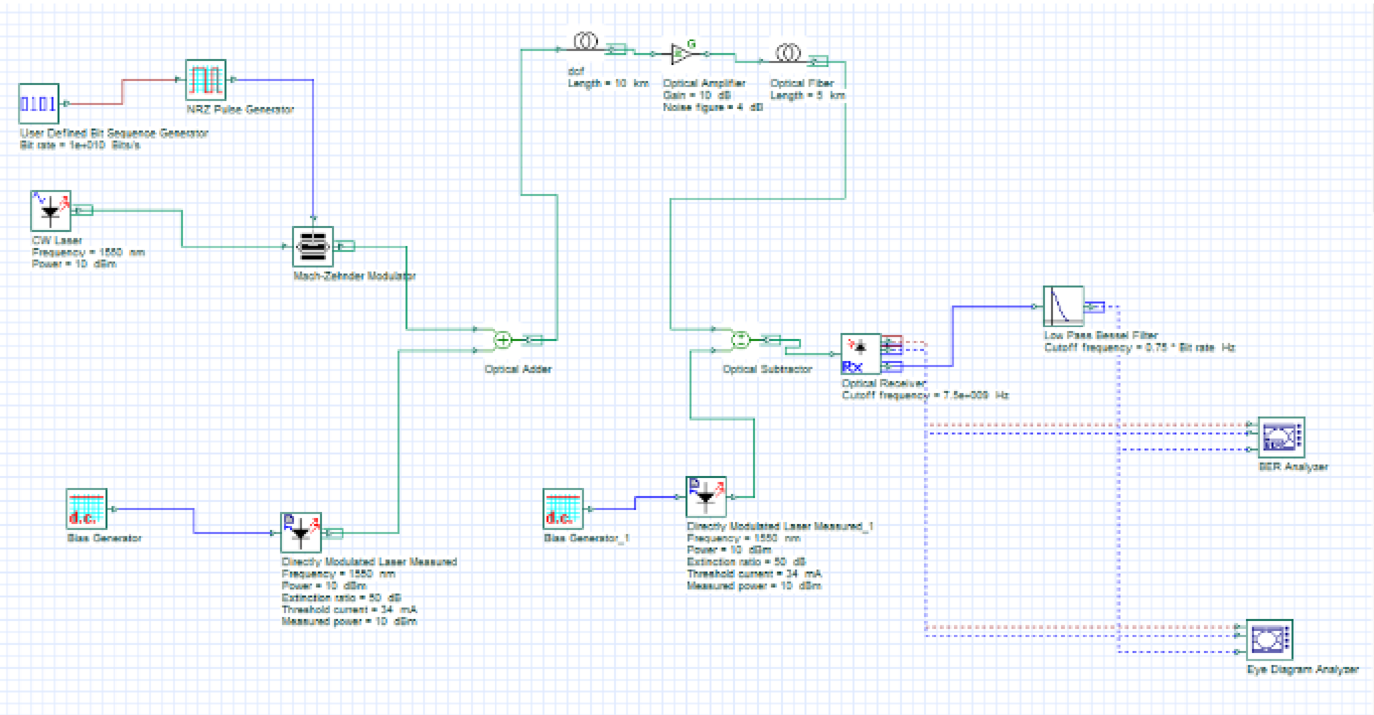

Figure 1 Layout for comparing various compensation techniques in the presence and absence of SPM

In the absence of SPM:

The performance of various compensation techniques in the absence of SPM is analysed at - 20.75 ps/nm/km, - 30.75 ps/nm/km and - 40.75 ps/nm/km and the corresponding Q factor values are tabulated as in Table 1.

In the presence of SPM:

When the Self Phase Modulation (a non-linear effect) is introduced, the phase of the signal is changed and it in turn increases the chromatic dispersion of the fiber already present and degrades the quality of the signal received at the output of the receiver. It depends on the power level, transmission length and effective area of fiber. The performance of various compensation techniques is analysed at - 20.75 ps/nm/km, - 30.75 ps/nm/km and - 40.75 ps/nm/km and the corresponding Q factor values are tabulated as in Table 2.

Distance (in km)	Q Factor at								
	- 20.75 ps/nm/km			- 30.75 ps/nm/km			- 40.75 ps/nm/km		
	Pre Compensation Q-factor	Post Compensation Q-factor	Symmetric Compensation Q-factor	Pre Compensation Q-factor	Post Compensation Q-factor	Symmetric Compensation Q-factor	Pre Compensation Q-factor	Post Compensation Q-factor	Symmetric Compensation Q-factor
5	34.1492	46.5658	24.5933	32.8148	33.5058	19.0879	30.7364	25.7432	16.6489
20	35.2966	42.8464	46.0505	35.2349	48.2958	27.5874	34.6417	49.2157	20.0559
80	4.7212	8.1246	11.6736	4.66643	9.4077	16.2665	14.1919	11.1603	19.7369
100	4.82813	4.511464	4.20094	4.80958	4.364	9.3509	4.78566	4.31174	13.0733
120	4.81359	4.77845	4.59151	4.8504	4.74864	4.28553	4.8661	4.67753	4.18264
150	4.54325	4.45738	4.60189	4.56013	4.5471	4.6792	4.59429	4.68282	4.62994
170	3.84446	3.6127	4.21621	3.9415	3.73031	4.36425	4.00513	3.8546	4.66129
180	3.11826	2.98508	3.93378	3.20673	3.1201	4.19646	3.27501	3.23827	4.35646
200	0	0	**3.27334**	0	0	**3.51192**	0	0	**3.80482**

Table 1. Performance Comparison of various compensation techniques at -20.75 ps/nm/km , - 30.75 ps/nm/km and - 40.75 ps/nm/km in the absence of SPM

Distance (in km)	Q Factor at								
	- 20.75 ps/nm/km			- 30.75 ps/nm/km			- 40.75 ps/nm/km		
	Pre Compensation Q-factor	Post Compensation Q-factor	Symmetric Compensation Q-factor	Pre Compensation Q-factor	Post Compensation Q-factor	Symmetric Compensation Q-factor	Pre Compensation Q-factor	Post Compensation Q-factor	Symmetric Compensation Q-factor
5	35.3829	26.8858	5.3469	33.5917	22.7744	3.39353	31.1351	19.8094	3.44908
20	77.6138	31.2938	11.4017	85.9	26.7016	7.20139	85.5721	22.39	3.5763
80	17.4831	9.61283	20.2825	15.9636	11.0961	23.0614	15.1078	13.0096	13.2688
100	5.12203	4.49315	11.2543	5.18643	4.36715	12.6702	5.2676	4.32032	22.0026
120	5.5095	4.61135	4.7072	5.66614	4.57104	4.65908	5.79636	4.52084	4.37783
150	3.88526	3.57452	4.5900	4.02156	3.67273	5.00493	4.17241	2.80732	5.32547
170	0	2.0505	3.94502	0	2.08446	4.51989	0	2.12202	5.21252
180	0	0	3.02638	0	0	4.22923	0	0	4.60095
200	0	0	**2.75163**	0	0	**2.90251**	0	0	**3.15309**

Table 2. Performance Comparison of various compensation techniques at -20.75 ps/nm/km , - 30.75 ps/nm/km and - 40.75 ps/nm/km in the presence of SPM

From the results, it is analyzed that the symmetric compensation performs better even in the presence of SPM at the dispersion value of -40.75 ps/nm/km. In Symmetric Compensation, on further increase of dispersion on the negative side in the presence of SPM, it is found that at 200 km Q factor at -40.75 ps/nm/km is increased and a peak value in Q factor of about 3.64691 is achieved at a dispersion value of -70.75 ps/nm/km.

Similarly, for various dispersions Q factor is observed and tabulated in Table.3. The same result is projected in the form of graph as shown in

Fig.2. It confirms that symmetric compensation in the presence of SPM performs well even on further values of dispersion for longer distances.

Dispersion (in ps/nm/km)	**Q factor**
-40.75	3.15309
-50.75	3.33694
-60.75	3.50708
-70.75	3.64691
-80.75	3.50903
-90.75	3.26118
-100.75	3.2711
-110.75	3.29354

Table 3.Q factor variation for different dispersions

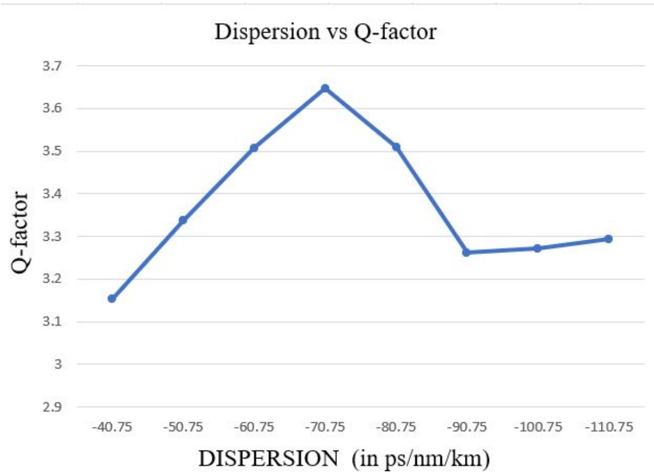

Figure2.Q factor Vs Dispersion

3.Conclusion and Future Work

This work compares the performance of various compensation techniques for the secure optical fiber communication system at different distances over optical fiber in the presence and absence of SPM. For 10Gbps chaos based security system, at the input power of 10dBm, in the absence of SPM, on comparing the various compensation techniques, better Q factor is obtained at about 200 km for the symmetric compensation than all other compensations. In the presence of SPM, on comparing the various compensation techniques, it is observed that the symmetric compensation performs better even at this condition. On further increase of dispersion in negative side in the symmetric compensation technique, it is observed that the better quality factor is achieved nearer to that in the absence of SPM. From the results it is concluded that symmetric compensation performs better than pre and post compensations. The future work involves the addition of Stimulated Brillouin Scattering (SBS), an additional nonlinear effect for single channel and performance comparison of various compensation techniques for longer distances with various dispersion values.

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