Comparison of Different Dispersion Compensation Techniques in Optical Fiber at High Bit Rate

Mohammad Arshad, Shrish Bajpai, Mohd.Danish

***Abstract*— In this paper, the performance of different dispersion compensation techniques with duobinary modulation format at high bit rates is analyzed. The compensation techniques proposed are dispersion compensation fiber (DCF), reverse dispersion fiber (RDF), negative dispersion fiber (NDF), fiber bragg grating (FBG), optical phase conjugation (OPC). The comparison of different dispersion compensation techniques at different bit rate has been done. The comparison of different techniques has been analyzed from the eye closure, bit error rate and Q- factor characteristics. The different bit rates used are 5, 10, 20, 30 and 40 Gb/s.**

***Index Terms*—Duobinary modulation, Q- factor, fiber bragg grating, eye closure.**

I. INTRODUCTION

The goal of an optical fiber communication system is to transmit the maximum number of bits per second over the maximum possible distance with the fewest errors. It is efficiently used to transmit the data to long distance at high bit rates. Their are many modulation formats used to transmit the data at high rates. Each of these modulation formats has their own advantages and disadvantages. To transmit data at very high bit rate, some special types of modulation formats are used. A very interesting modulation format is optical duobinary, which offers high spectral efficiency and chromatic dispersion tolerance. Duobinary transmission technology was introduced for the first time by A. Lender [1]. Duobinary modulation can be described as a combination of a conventional ASK-based modulation and phase shift keying (PSK). The reduction of the spectral width of the optical duobinary signal is the reason for its better dispersion tolerance compared to NRZ signals and enables an improved spectral efficiency in WDM systems.

A further advantage of duobinary modulation is the suppression of SBS-effect; since in the optical duobinary spectrum the carrier is effectively suppressed. At higher bit rate, the effect of chromatic dispersion is quite high. It limits the overall performance of the optical communication system at high bit rates. There are various types of dispersion compensation techniques used to limit this effect. The fiber based compensation techniques, fiber bragg grating and optical phase conjugator are some of the techniques used for dispersion compensation. In this chapter, performance of various compensation techniques with duobinary modulation format at high bit rate upto 40 GB/s is analyzed. Weinert, Ludwig, Pieper, Weber, Breue, Petermann, and Kuppers [2]. investigated the possibilities of 40 and 4×40 Gb/s time division multiplexing wavelength division multiplexing (TDM/WDM) return-to-zero (RZ) transmission over embedded standard single-mode fibers (SMF) at a transmission wavelength of 1.55μm both experimentally and theoretically. Dispersion of the SMF is compensated by a dispersion compensating fiber (DCF). Transmission over a span of 150 km of SMF in the single channel case and of 100 km SMF in the multichannel case is reported. It is shown numerically that improvement is achieved by employing the newest type DCF which also compensates the dispersion slope of the SMF. Price and Mercier [3] demonstrated a reduced bandwidth optical digital intensity modulation with improved chromatic dispersion tolerance. In this, a simple optical modulation scheme using a lithium niobate Mach-Zehnder modulator driven by a three level drive waveform was proposed. The two-level intensity modulated (IM) optical signal obtained possesses a smaller optical bandwidth and thus greater chromatic dispersion tolerance compared with existing two-level IM methods used for high data rate transmission. Aarrett and Gnauck [4] demonstrated wavelength-division-multiplexed transmission of 16 ×10-Gb/s non return-to-zero channels with 50-GHz spacing over 840 km of conventional single-mode fiber (SMF), or 14 times the 10-Gb/s dispersion limit, using a total of eleven chirped fiber gratings for dispersion compensation Chowdhury [5] proposed recent advances in optical phase conjugation and its application to 40 GB/s transmission**.** Optical phase conjugation is effective in compensating intra-channel nonlinearities in pseudo linear systems. Results of optical phase conjugation in 40 GB/s optical systems with different transmission distances and modulations formats, and varying conjugator locations is presented.

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II. II. SIMULATION SETUP

Figure (1) shows the schematic diagram of dispersion compensation using combination of standard single mode fiber (SSMF) and dispersion compensation fiber (DCF).

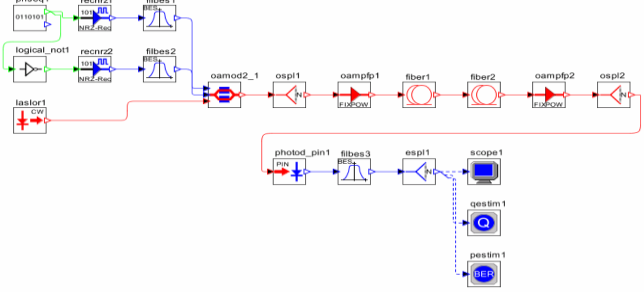

Figure (1) shows the schematic diagram of dispersion compensation using combination of standard single mode fiber (SSMF) and dispersion compensation fiber (DCF).

The general set up for generation of duobinary signal is shown in figure (1). The transmitter section consists of data source (pnseq1), non-return-to-zero (NRZ) modulation driver (recnrz1, recnrz2), electrical filter (filbes1, filbes2), and logical not gate (logical_not1), modulator (oamod2_1) and laser source (laslor1). The data source was simulated to generate pseudo-random sequences with bit rate as variable. The bit rates taken were 5, 10, 20, 30 and 40 Gigabit per second. The data source feeds two drivers one directly and other through NOT gate that generates the NRZ signal. These two signals are passed to electrical filter of Bessel type. The Bessel filters have 5 poles. All the signals i.e. two from the filter and the light of continuous wave (which is generated from the CW laser) are fed to the three arm Mach Zender modulator. The 40 GHz duobinary signal is produced by the transmitter.

The transmission medium consists of standard single mode fiber (SSMF) (fiber1), erbium doped fiber amplifier (EDFA) (oamfp1, oampfp2) as in line amplifiers and dispersion compensation fiber (DCF) (fiber2), and dispersion shifted fiber (DS) (fiber2) as dispersion compensation devices. The length of transmission medium is 100 km. At the receiver side PIN photodiode (photod_pin1) is used as the receiver that converts light energy to electric form.The Bessel electrical filter (filbes3) has 4 poles with -3db bandwidth of 7.5 GHz. The Bessel filter's output is fed to an electrical splitter (espl) that splits the electrical signal to electrical power scope (scope1), Q estimator (qestim1) and BER estimator (pestim1).

Figure (2) shows the schematic diagram of dispersion using a negative dispersion fiber (NDF). The NDF (fiber1) simulated had an attenuation of 0.212 dB/Km and a negative dispersion of -2.5 ps/nm/Km. This setup is simulated using fiber length of 100 km.

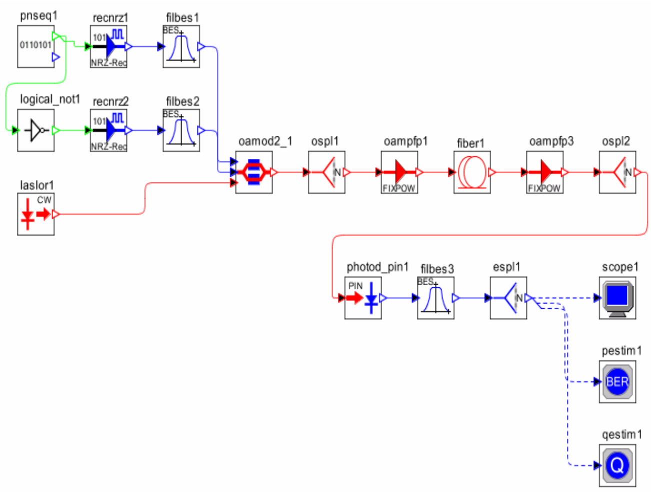

Figure 2: Setup for generation of Duobinary format and its compensation using NDF

Figure (3) shows the schematic diagram of dispersion using a standard single mode fiber (SSMF) and a reverse dispersion fiber (RDF). The RDF (fiber2) simulated had an attenuation of 0.24 dB/Km and a negative dispersion of -16 ps/nm/Km. For dispersion compensation using SSMF and RDF, the ratio of optical fiber lengths must be 1:1. The total simulation length is 100 km.

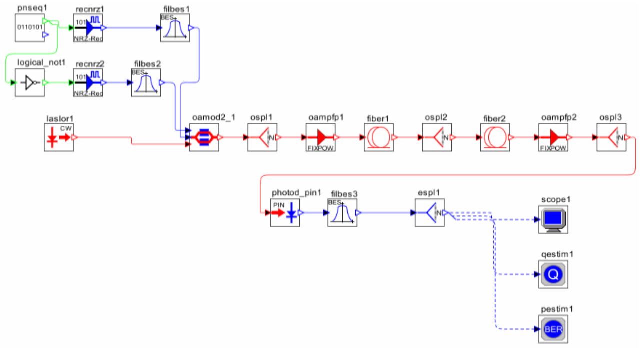

Figure 3: Setup for generation of Duobinary format and its compensation using RDF

Figure (4) shows the schematic diagram of dispersion using a fiber Bragg Grating (grating_ideal1) (FBG). The fiber optic link used in this set was dispersion shifted normal fiber (fiber1). This fiber had an attenuation of 0.2 dB/Km at 1550 nm and a negative dispersion of -2 ps/nm/Km. This setup is simulated using fiber length of 100 km.

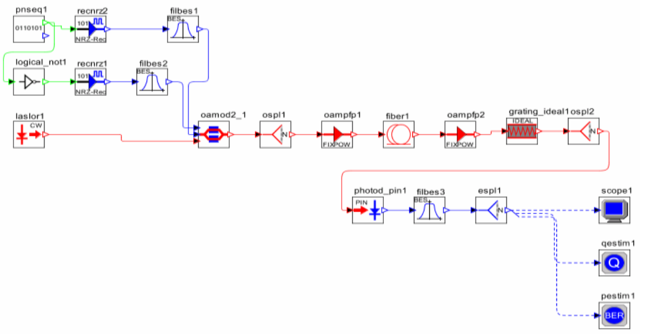

Figure 4: Setup for generation of Duobinary format and its compensation using FBG

Figure (5) shows the schematic diagram of dispersion using an Optical Phase Conjugation (OPC). The optical phase conjugator (phconj1) is simulated to give a phase shift of 2.57070796 at 100% efficiency. The fiber optic link used in this set was dispersion shifted normal fiber. This fiber had an attenuation of 0.2 dB/Km at 1550 nm and a negative dispersion of -2 ps/nm/Km. This setup is simulated using fiber length of 100 km. For OPC, the setup is simulated using two section of fiber of equal length at either side of OPC.

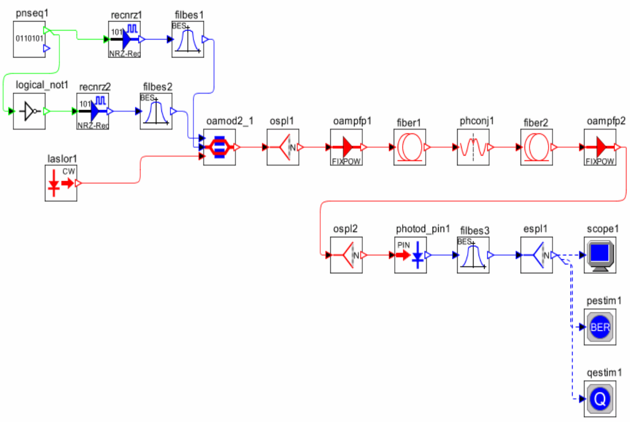

Figure 5: Setup for generation of Duobinary format & its compensation using OPC

III. III. RESULTS

In previous section, various component and parameters used in simulation setup are discussed. Using some of these components, the values of bit error rate (BER), Q-factor, eye closure has been measured. The measurement component used are Q estimator to measure Q-factor, BER estimator to measure to measure bit error rate (BER), electrical scope to measure eye diagrams.

Figure (6) shows the eye closure characteristics of different compensation techniques at different bit rates. As seen from diagram NDF and OPC have low value of eye closure at 5 Gb/s. At 10 Gb/s all the dispersion compensation techniques except from DCF have low values of eye closure. FBG have less eye closure value at 20 Gb/s as compared to the other compensation techniques. The dispersion compensation techniques using SSMF and RDF and DCF shows the minimum value of eye closure at higher bit rates i.e. at 30 and 40 Gb/s. Overall the NDF, OPC and FBG dispersion compensation techniques are more useful at bit rates of 5, 10 and 20 Gb/s whereas DCF and RDF are favorable at 30 and 40 Gb/s.

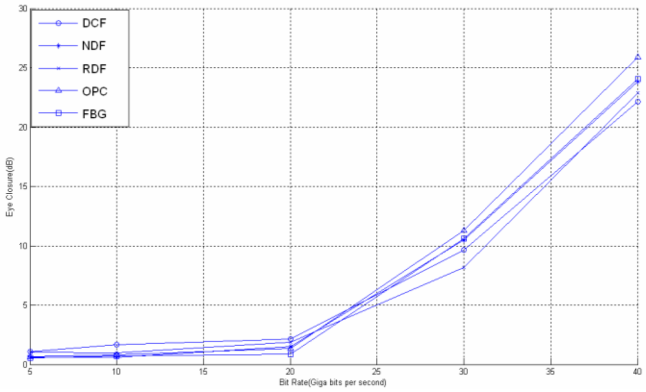

Figure 6: Comparison of eye closure at different bit rates for different dispersion compensation techniques

Figure (7) shows the Q-factor of different compensation techniques at different bit rates. NDF dispersion compensation technique gives a better Q-factor as compared to the other compensation techniques at bit rate values of 5 and 10 Gb/s. FBG has better Q-factor at 20 Gb/s. OPC dispersion compensation techniques shows the better Q-factor when compared to the DCF and RDF at bit rate value of 5, 10 and 20 Gb/s. At the higher bit rate of 30 and 40 Gb/s the dispersion compensation techniques employed using DCF and RDF shows better Q-factor. Hence RDF and DCF can be used for longer distance optical communication system at high bit rates.

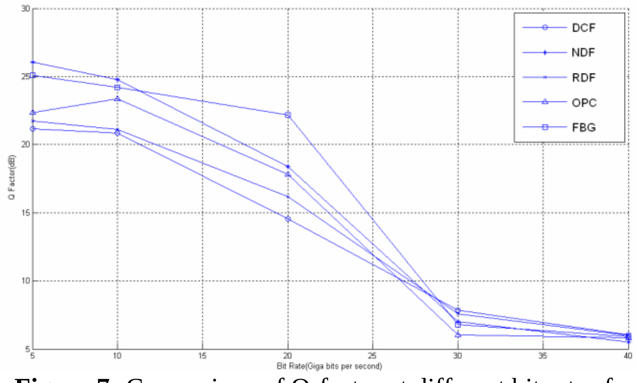

Figure 7: Comparison of Q-factor at different bit rates for different dispersion compensation techniques

Figure (8) shows the bit error rate (BER) of different compensation techniques at different bit rates. NDF has the minimum bit error rate at 5 Gb/s .At 10 Gb/s the value of BER for all the compensation techniques are almost same except from DCF. At the 20 Gb/s, all the dispersion compensation techniques show their minimum bit error rate. OPC and FBG are the best compensation techniques at bit rate value of 30 Gb/s. RDF is the most suitable technique at bit rate of 40 Gb/s. NDF has the highest bit error rate at 40 Gb/s, hence it is not recommended at higher bit rates.

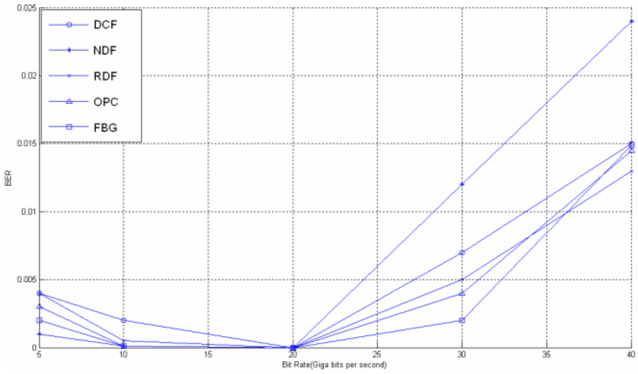

Figure 8 : Comparison of BER at different bit rates for different dispersion compensation techniques

IV. IV. CONCLOUSION

In this chapter, the comparison of different dispersion compensation techniques with duobinary modulation format at different bit rates has been reported. It has been concluded that various dispersion techniques can be recommended at different bit rates. From the eye closure, bit error rate (BER) and the Q-factor characteristics, it is clear that the dispersion compensation technique using negative dispersion compensation (NDF) is suitable at 5 Gb/s. The dispersion compensation techniques using fiber bragg grating (FBG) and optical phase conjugator (OPC) as dispersion compensation devices can be used at bit rate values of 10 Gb/s and 20 Gb/s. At high bit rate values of 30 Gb/s and 40 Gb/s, the dispersion compensation techniques using combination of standard single mode fiber (SSMF) with dispersion compensation fiber (DCF) and reverse dispersion fiber (RDF) can be used for long haul optical communication systems.

V. REFERENCES

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