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# EFFECTIVE FIBER OPTIC COMMUNICATION BY OPTICAL PHASE CONJUGATION FOR A MULTICHANNEL SYSTEM

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***Abstract---*** **Optical communication is a form of telecommunication that uses light as carrier and optical fiber as a transmission medium. Optical communication meant for long haul communication has been intended for an eight channel Wavelength Division Multiplexing (WDM) system. Dispersion is the major effect present in the optical fiber which causes a broadening of pulses and leads to Inter Symbol Interference (ISI). The dispersion effect is compensated by using Optical Phase Conjugation (OPC) technique which utilizes Four Wave Mixing (FWM) as the non-linear degrading effect. It has been found that the apposite modulation format for the transmitter part of the optical system is the Modified Duobinary Return-to-Zero (MDRZ) when compared it with Return-to-Zero (RZ), Non-Return-to-Zero (NRZ), Carrier-Suppressed Return-to-Zero (CSRZ) and Duobinary modulation formats. Dispersion Compensation Fiber (DCF) is used in this case which compensates the dispersion present in the fiber. The feat of the intended system is scrutinized in terms of eye opening, spectrum, bit error rate, Q-value etc.**

***Keywords---*** **Optical fiber, Dispersion, Modulation format, Optical Phase Conjugation, FWM.**

## I. INTRODUCTION

Optical communication is a form of telecommunication that uses light and optical fiber as a carrier. In the last two decades the fiber optic communication saw a unique growth and technological evolution. Being developed in 1970s, the fiber optic communication system has revolutionized the telecommunication industry and has played a major role in the dawn of the Information Age. Due to the proficient consumption of power and low bit error rate, modified duo-binary return-to-zero (MDRZ) is special for the transmitter part of the system [1],[3]. In the direction of exterminating pulse broadening, Optical Phase Conjugation (OPC) is taken into consideration which utilizes Four Wave Mixing (FWM) [6].

Anu Sheetal, Ajay Sharma and R.S Kaler mutually projected that Four Wave Mixing confines the performance of Dense Wavelength Division Multiplexing (DWDM) systems and dogged that MDRZ format is the best one for transmission system afar 1500 km albeit the transmitter and receiver configuration is intricate by using symmetrical dispersion scheme in the year 2008 [3]. K. S. Cheng along with J. Conradi confirmed that for 40 Gb/s system both alternating phase RZ (AP-RZ) format and MDRZ format have less nonlinear pulse interaction by examining the pulse evolution of the optical signals in the first span of Standard Single Mode Fiber (SSMF) in 2002. He also showed that the pulses caused by intrachannel FWM between discrete tones can be repressed by the lack of tones in the signal spectrum [2].

## II.DISPERSION

When the light signal carrying information passes through the optical fiber, due to imperfections in the fiber during manufacture or change in composition of fiber materials affects the optical communication. The effects may be of either linear or nonlinear. It is most often described in light waves, but it may happen to any kind of wave that interacts with a medium or can be confined to a waveguide, such as sound waves. Here the phase velocity of a wave depends on its frequency or alternatively when the group velocity depends on the frequency which leads to Inter- Symbol Interference (ISI) [8].

*A.Dispersion Compensation*

Dispersion Compensating Fiber (DCF) is used to nullify the dispersion caused by the fiber as it is the fiber that has the opposite dispersion of the fiber being used in the transmission system. It controls the chromatic dispersion of an optical fiber system by adding optical elements in the midst of a suitable amount of dispersion. It is done so by increasing the nonlinear properties of the optical fiber. The optical fiber parameters such as Dispersion, Dispersion Slope and Effective Area should be mainly deemed while setting the values. The dispersion value of the compensating fibers utilized should be in the opposite sign to that of the optical fiber used.

*B.Optical Phase Conjugation (OPC)*

The dispersion compensation technique preferred for the system is Optical Phase Conjugation (OPC) technique. It is also referred to as wavefront reversal or time-reversal reflection. When OPC is used to compensate for the chromatic dispersion, the OPC must be placed in the middle of the transmission link, the technique known as "mid-link OPC."

In the phase conjugation method of Four-Wave Mixing (FWM), three input waves interact in a nonlinear medium to produce a fourth complex conjugate of one of the input fields. The fourth wave can be either forward-going or backward-going,that depends on the geometry of the setup. The OPC technique is implemented using by using the DCF and the nonlinear effect FWM. In FWM, wavelength conversion is performed which is obtained before the Highly Non-Linear Fiber (HNLF). Then it is exactly shifted to another wavelength after it.

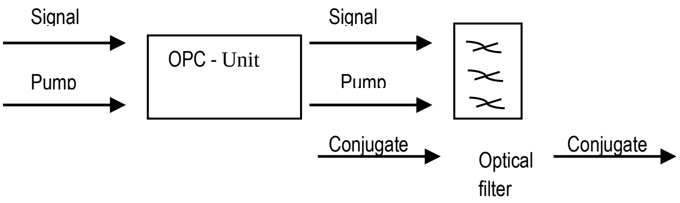


Fig. 1. Mechanism of OPC

Fig. 1. shows the mechanism of OPC in which conjugation takes place in the reverse direction in order to find the path of the incident beam. The reversing operation takes place in order to retrace the incident beam. The special case here is, where the three input beams all are on the same wavelength, the conjugate wave will also be at the equivalent wavelength. This process is known as Degenerate Four-Wave Mixing (DFWM). The two pump waves are preferred to propagate in opposite directions to each other, and as well the conjugate wave will be exactly reversed in direction of propagation from the probe wave, regardless of the angle of the input probe wave.

By applying OPC technique, the robustness of the transmission link can be increased, most of the Self Phase Modulation (SPM) impairments are compensated and its structure can be greatly abridged.

## III. SCRUTINY OF MODULATION FORMAT

A perfect modulation format for long haul, high speed and WDM transmission links must have a narrow spectral width, low susceptibility to fiber nonlinearity, large dispersion tolerance and better transmission performance. In an optical modulation format, it is used to impress data on an optical carrier wave for transmission over optical fiber. To hit upon modified duo-binary return-to-zero (MDRZ) as the finest, it has been investigated along with diverse modulation formats such as Return to Zero (RZ),Non-Return to Zero (NRZ), Carrier-Suppressed Return-to-Zero (CSRZ) and Duobinary modulation formats.

Fig. 2. shows the block diagram for the generation of modulated signal. Here the laser is chosen as the input source added to the Pseudo Random Bit Sequence (PRBS) generator and by this means given to optical modulators such as Mach Zehnder Modulator (MZM) by choosing the appropriate modulation format in prior. Thus the modulated input is passed via the optical fiber to the receiver. The required modulated signal is acquired in consequence.

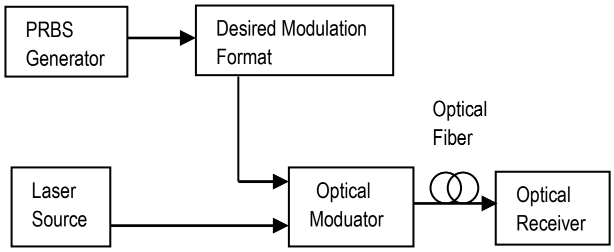


Fig. 2. Block diagram for the generation of modulated signal

The length of the optical fiber and bit rate of are kept constant as km and 40 Gb/s respectively, then the modulated signal is checked for each case. For RZ and NRZ, the modulation format can be selected directly but when it is MDRZ is the case, a separate subsystem is required which is given as input to each port of the eight channel WDM system. From the annotations it is found that, the RZ modulation format has a broader optical spectrum which results in decreased tolerance and spectral efficiency. The pulse shape enables robust to fiber nonlinear effects and also to the polarization mode dispersion. In contrast to RZ modulation format, NRZ , which has been used in the early days since it is insensitive to laser phase noise and also requires low electrical bandwidth for transmitter and receiver has a narrow optical spectrum. Hence it has enhanced dispersion tolerance. But the main hitch in this case is, it has the effect of Inter Symbol Interference (ISI) which is not apposite for high bit rates and long distance.

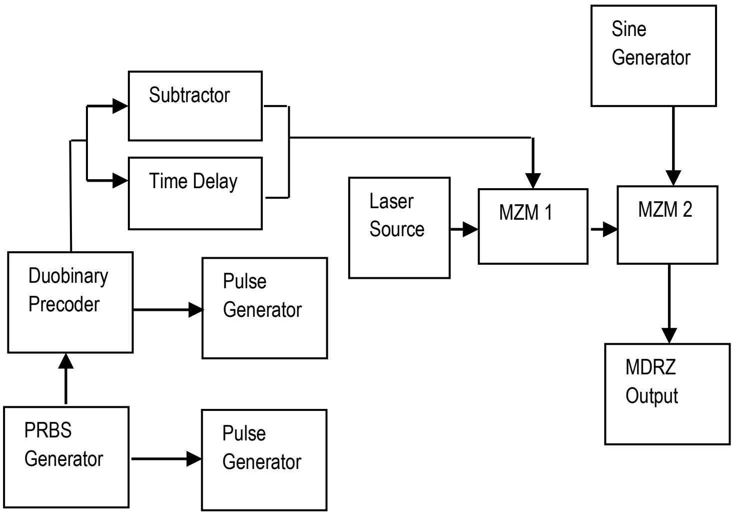


Fig. 3. Subsystem for MDRZ modulation format

At long last, the MDRZ modulation format is observed which is shown in Fig. 3. It provides much narrower bandwidth than the duobinary modulation format facilitating wider dispersion tolerance and high fiber non linearity tolerance. The MDRZ signal is generated by utilizing a delay-and-subtract circuit.

While evaluating MDRZ among the above mentioned modulation formats, MDRZ repress all discrete frequency tones that appear in the conventional RZ signal spectrum. Nevertheless the uniqueness of the MDRZ modulation format is that, it has the slightest timing jitter and amplitude distortion. [4]

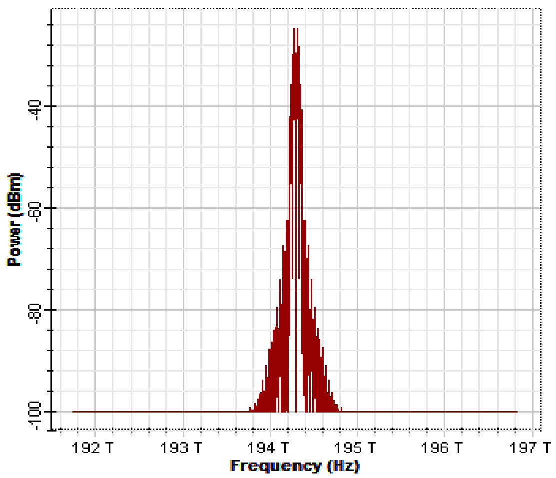


Fig. 4. Optical spectrum of MDRZ format

Fig. 4. illustrates the output spectrum of the MDRZ modulation format for the power level of 1 mW and for a bit rate of 40 Gb/s. The carrier of the signal is suppressed which resulted in a narrow spectrum.

## IV. MULTICHANNEL SYSTEM

The multichannel system considered in our work is an eight channel Wavelength Division Multiplexing (WDM) system. The modulation format which has been chosen is given as the input to the each port of the multiplexer. All the eight inputs get multiplexed and the single input is fed to the Dispersion Compensating Fiber (DCF). Then, the OPC technique is followed by utilizing FWM process. Finally the demultiplexed output is obtained in the optical receiver later than passing it through demultiplexer. Fig. 4. depicts the fiber optic communication which utilizes OPC technique to minimize the dispersion present in the optical fiber.

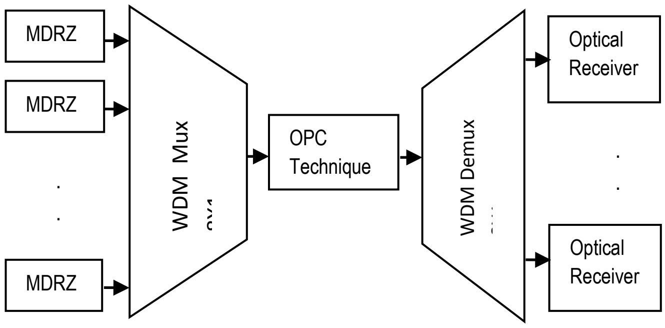


Fig. 5. Fiber optic link set up

Bandwidth, ripple and depth are the three important factors which determine how much power from neighboring channels will act as crosstalk while calculating the feat of a specific channel [7], [9]. The design rule of the WDM system is equivalent to that of the single channel system, but the main aspect is the channel spacing. Here none of the channels should experience sideband instability or else the FWM crosstalk will be enhanced [6].

## V. DCF WITH NON-LINEAR EFFECTS

Nonlinear fiber optics concerns with the nonlinear optical phenomena occurring inside optical fibers. It has continued to raise during the decade of 1990s, perhaps even more dramatically than anticipated. Fiber non linearities, which characterize the fundamental limiting mechanisms to the amount of data that can be transmitted on a single fiber arises due to two basic mechanisms. The most detrimental mechanism arises from the refractive index of glass being dependent on the optical power going through the material. The second mechanism that cause fiber non linearities is the scattering phenomena which products Stimulated Brillouin Scattering (SBS) and Stimulated Raman Scattering (SRS). The nonlinear effects accumulate over long distances. In general, by FWM and SBS, OPC can take place with the help of DCF.

## VI. RESULTS AND DISCUSSIONS

For each modulation format, the maximum Q-factor, minimum BER and eye height have been tabulated.

TABLE I
Performance Analysis of the Optical System

| Modulation Format | Max Q-factor | Min BER | Eye Height |
|---|---|---|---|

| | | | |
|---|---|---|---|
| RZ | 9.77 | 6.47e-023 | 1.69e-004 |
| NRZ | 10.92 | 3.80e-028 | 1.29e-004 |
| CSRZ | 9.88 | 2.06e-023 | 1.38e-004 |
| Duobinary Signal | 8.48 | 9.84e-018 | 7.85e-005 |
| MDRZ | 10.61 | 1.07e-026 | 7.38e-005 |

From the tabulation, it is found that MDRZ is better for an effective optical communication when compared to RZ, NRZ, CSRZ and Duobinary modulation format.

The Eye diagram obtained for RZ and NRZ modulation formats depicts much dispersion. Fig. 6. and Fig. 7. shows the Eye pattern of RZ and NRZ modulation formats respectively.

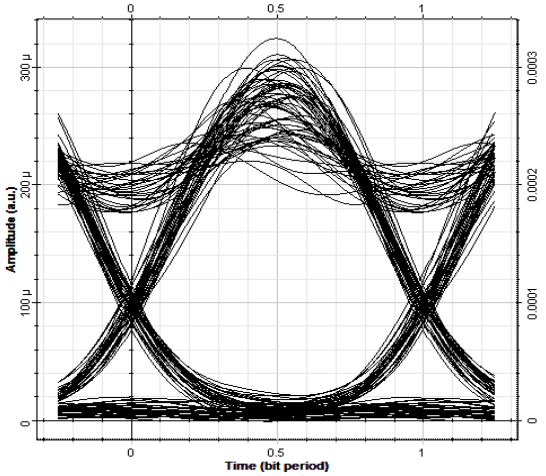

Fig. 6. Eye pattern of the fiber optic link using RZ

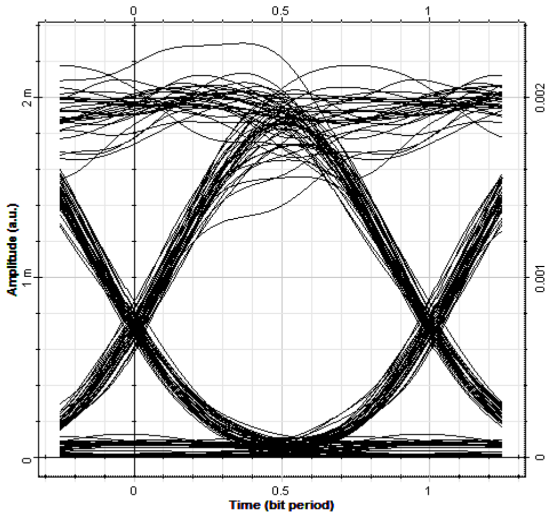

Fig. 7. Eye pattern of the fiber optic link using NRZ

Fig. 8. and Fig. 9. shows the Eye pattern of CSRZ and Duobinary modulation formats respectively.

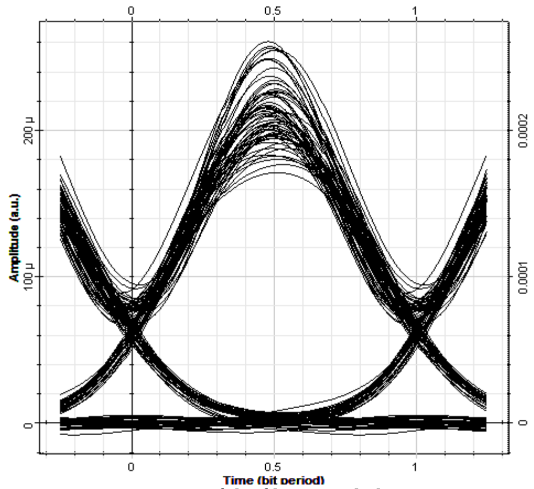

Fig. 8. Eye pattern of the fiber optic link using CSRZ

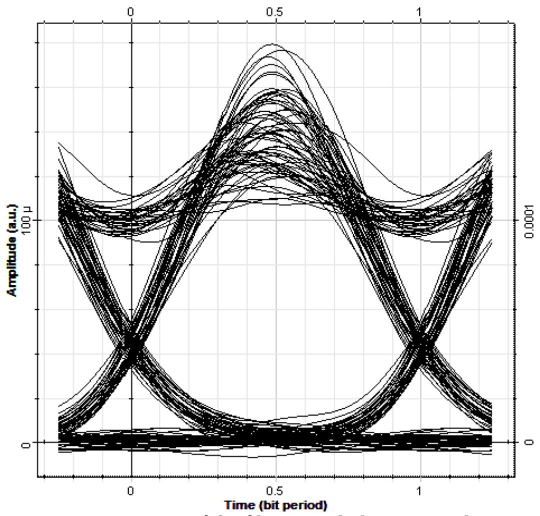

Fig. 9. Eye pattern of the fiber optic link using Duobinary

By combining the multiplexed signal which has then been passed through the DCF having zero dispersion and dispersion slope of 0.075 ps/nm$^2$/k along with the pump signal, the spectrum obtained is revealed in Fig. 10.

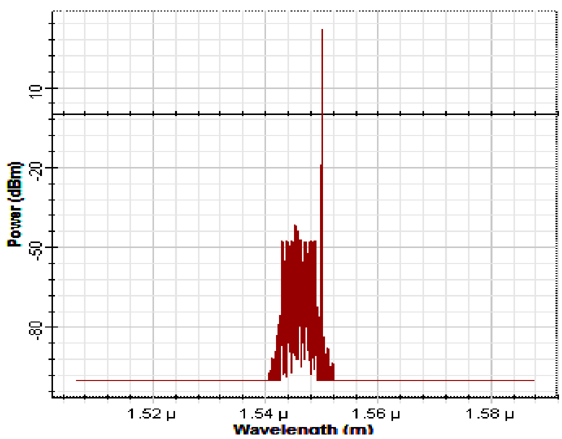

Fig. 10. Optical spectrum of combined inputs

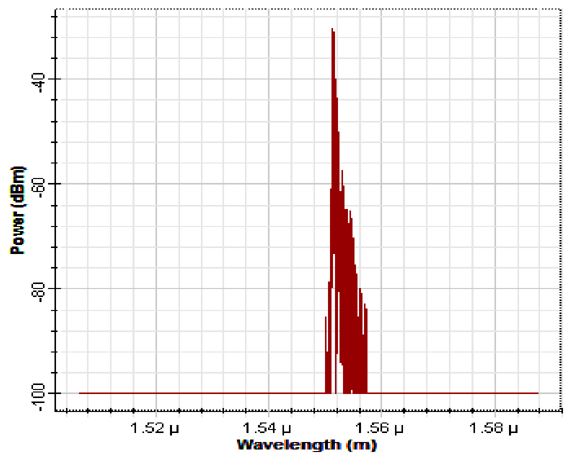


Fig. 11. Optical spectrum of the demultiplexed output

Fig. 11. shows the demultiplexed output achieved at the optical receiver.

Fig.12. depicts the eye pattern of the fiber optic link using the MDRZ modulation format with a distance coverage of 200.1 km. The achieved Q-factor is 10.61 and the BER of 1.078 * $10^{-26}$. Thus the Q-factor is maximized with respect to the DCF length [10].

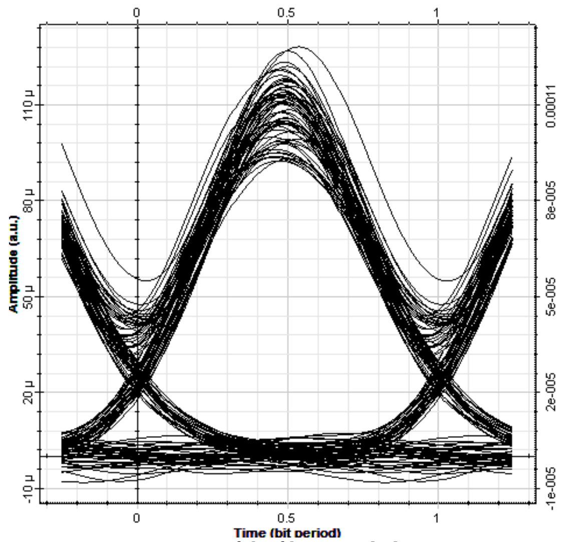


Fig. 12. Eye pattern of the fiber optic link using MDRZ

Thus while comparing the Fig.6,7,8,9 and 12, it confirms that the fiber optic communication by utilizing MDRZ as the modulation format for the system.

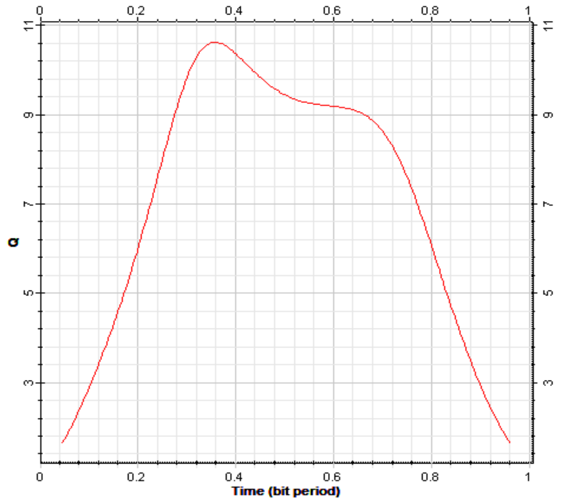


Fig. 13. BER Analyzer of the fiber optic link

Fig. 13. shows the BER Analyzer of the optical link whose Eye height stood at 7.388 * $10^{-5}$ which means the amount of data that can be sent without dispersion.

## VII. CONCLUSION

Thus a fiber optic communication has been intended for an eight channel WDM system. It has been proven through the simulations obtained as a single OPC is enough for effectual dispersion compensation over optical fiber. Also found that the fiber optic link set up performed using the MDRZ modulation format has given a better feat than that of RZ, NRZ, CSRZ and Duobinary modulation formats.

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