Performance Analysis of 8-Channel DWDM With 0.4nm Spacing Using Duobinary Modulation Format

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Abstract— The growing data and internet traffic in telecommunication has lead to an increase in demand for high transmission capacity. Although Non Return to Zero (NRZ) modulation is suitable for long haul systems due to its simplicity, one way of achieving a more efficient use of channel bandwidth is to use duobinary coding. It is a three level code of -1, 0 and 1. Data generator and duobinary encoder make up the electrical section of duobinary transmitter. Duobinary encoder at the transmitter section provides three level electrical signal. It can be either a duobinary filter or a delay and add circuit. Optical section of duobinary transmitter includes a laser diode and Mach Zehnder Modulator. Duobinary Modulation is a better choice for uncompensated single mode fiber, since it is more resilient to dispersion. It can be suggested for long distance communication systems at high bit rates. Duobinary signal can offer many advantages to various Wavelength Division Multiplexing techniques (WDM) , since it eliminates the non linear effects due to low channel spacing.

Keywords— Non Return to Zero (NRZ), duobinary, duobinary encoder, delay and add circuit, duobinary filter, Mach Zehnder Modulator, WDM

INTRODUCTION

In recent years, the demand for faster communication due to the explosive growth in internet activities has lead to the better usage of channel bandwidth. Thus, Optical fiber communication technology which has higher bandwidth than copper cable is preferred to transmit higher data rates at longer distances. In optical fiber communication binary NRZ and RZ is widely used due to its simplicity of implementation. At higher data rates, chromatic dispersion in optical fiber causes waveform distortion and becomes a limiting factor in the Standard Single Mode Fiber (SSMF). Correlative coding, also known as Partial Response Signaling (PRS), can enhance the chromatic dispersion tolerance of a SSMF. Duobinary coding, which was first introduced by A Lender in 1960s , is a type of PRS . It is a three level signal with spectral width one half that of the binary.

Duobinary transmitter section has both optical and electrical part. Electrical section of duobinary transmitter consists of data source, electrical generator and duobinary encoder. Duobinary encoder produce three level electrical signal. It can be either a delay and add circuit or a duobinary filter (5 pole Bessel Thomson low pass filter). Duobinary filter is better than delay and add circuit for generating duobinary signal. The optical section of duobinary transmitter consists of a laser diode and Mach Zehnder Modulator (MZM). MZMs can be of two types - dual arm MZM and single arm MZM. A continuous wave or pulsed light wave generated by a laser diode is modulated by an external MZM and is transmitted through fiber. At the receiver, the square law detector neglects the phase of a received pulse. Therefore the received data sequence is absolute value of transmitted sequence [1,10,11].

Duobinary offers several advantages to Wavelength Division Multiplexing (WDM) techniques. In WDM, each communication channel is allocated to a different frequency and multiplexed onto a single fiber. At the destination wavelengths are spatially separated to different receiver locations. In this configuration the high carrier bandwidth is utilized to a greater extent to transmit multiple optical signals through a single optical fiber. WDM systems are divided into different wavelength patterns, Conventional/Coarse (CWDM) and Dense (DWDM). Conventional WDM systems provide up to 8 channels in the 3rd transmission window (C band) of silica fibers around 1,550 nm. Dense wavelength division multiplexing (DWDM) uses the same transmission window but with denser channel spacing. A typical system would use 40 channels at 100 GHz spacing or 80 channels with 50 GHz spacing. The two major non-linear effects such as FWM and Stimulated Raman Scattering (SRS) in transmission fiber limit the performance of DWDM. In order to eliminate these effects , Duobinary modulation can be used [3,6,7,8].

SIMULATION SETUP

Simulation setup for 8-channel DWDM using duobinary modulation format is shown in Fig.1. 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 filters of Bessel type. The Bessel filters have 5 poles. It acts as duobinary encoder that produces a three level signal. Here, dual arm MZM which is driven in push-pull fashion is used as the modulator to avoid chirping of the output signal. Push-pull means that each arm of MZM are driven by opposite voltages to avoid chirping of the output signal [2,9].

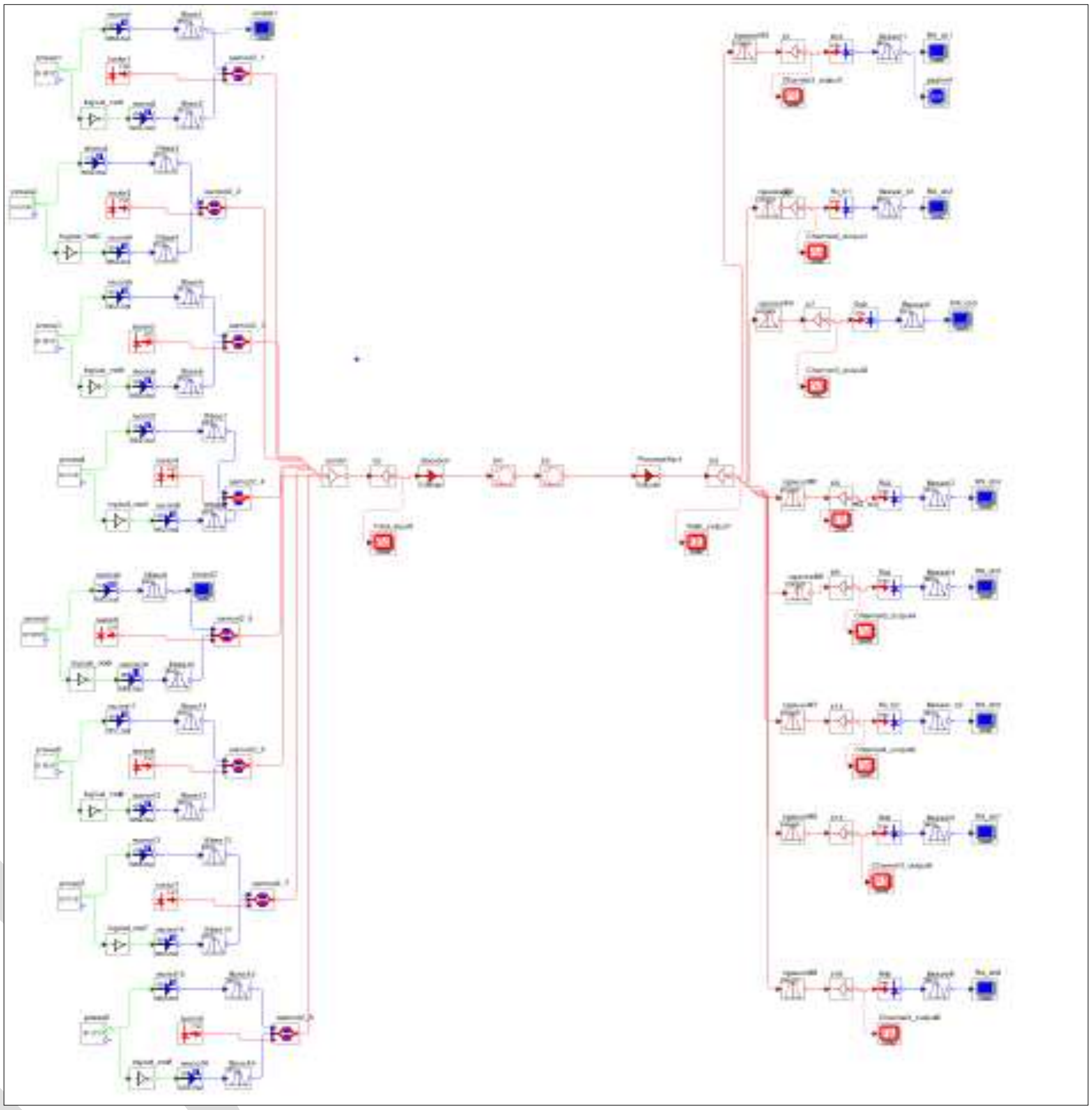


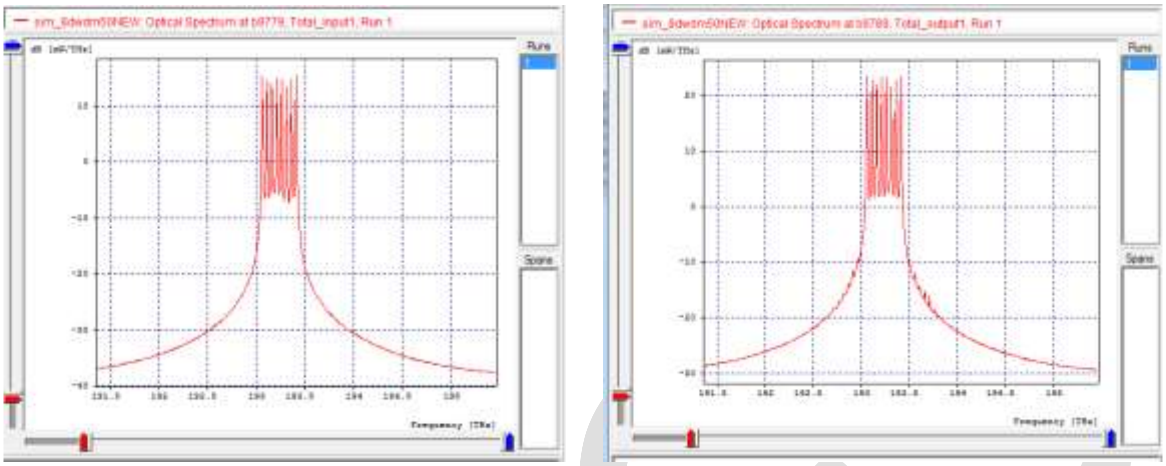
Fig.1. Simulation set up for 8 channel DWDM

As shown in Fig.1, the combiner combines 8 channels, each emitting different wavelengths to a single Standard Single Mode Fiber (SSMF). The channel spacing is chosen as 0.4 nm. In order to provide dispersion compensation , Reverse Dispersion Fiber (RDF) is placed after the SSMF. The RDF simulated had an attenuation of 0.24 dB/km and a negative dispersion of -16 ps/nm/km. Fiber PMD is 0.03ps/km$^{0.5}$. Non linear refractive index is taken as 2.8 E-18 m^2 / W.

At the receiving side, the wavelengths are separated, filtered using an optical filter (Gaussian filter) and detected using a PIN photodiode. Finally this electrical signal is filtered using a Bessel filter whose bandwidth depends on bit rate. SSMF and RDF are simulated at the ratio 1:1 [4,5,12].

RESULTS AND DISCUSSION

The optical spectrum obtained for 10 Gbps DWDM is shown in Fig.2.

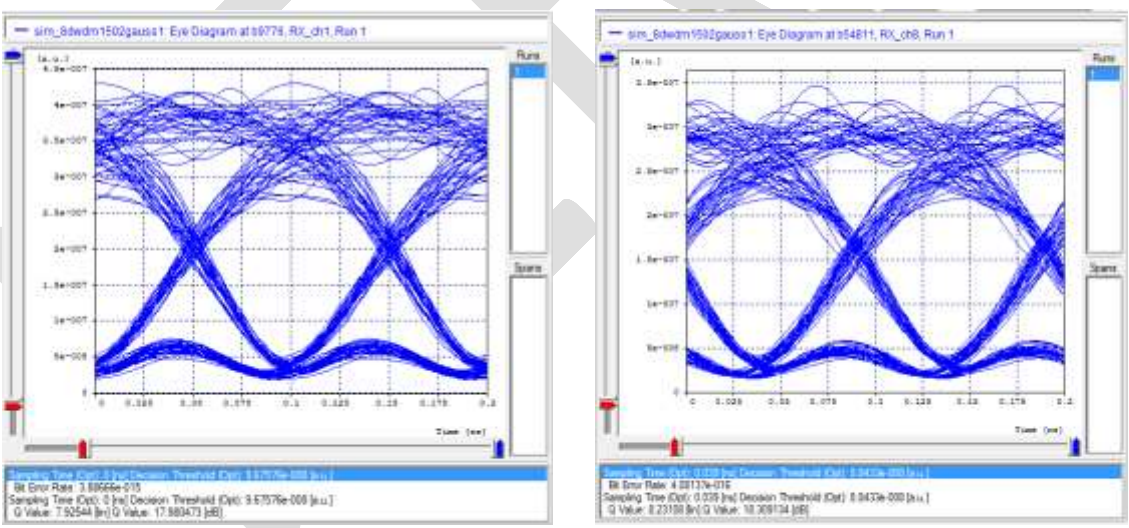


(a) Before transmission (b) After transmission (300 km)

Fig.2.Optical spectrum

From the optical spectrum , it can be seen that duobinary reduces nonlinear effects such as Four Wave Mixing and Stimulated Raman Scattering (power tilt ≈ 0) for longer distances.

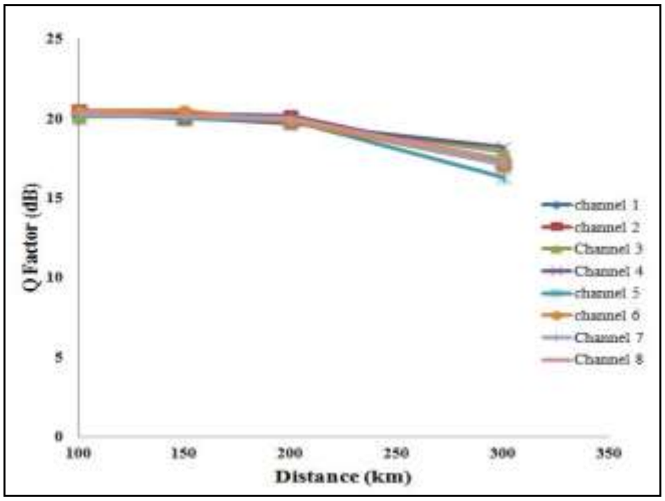
Fig. 3. shows the eye diagram for channel-1 and channel- 8 for 8-channel DWDM system after 300 km. It gives a Q Factor 17.480 for channel-1 and 18.309 for channel- 8. Corresponding BERs are 4.1712e-14 and 4.0813e-16 respectively.



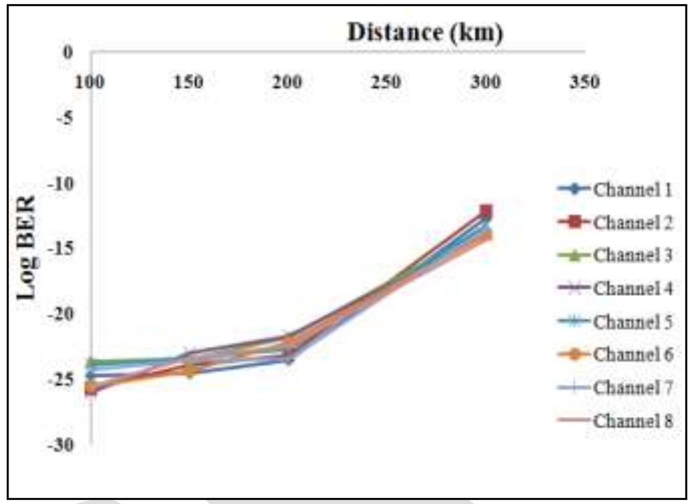
(a) Channel-1 (b) channel- 8

Fig.3.Eye diagram

Variation of Q Factor and BER with distance for 8 channel DWDM at 10 Gbps is shown in Fig.4.



(a) Distance vs Q Factor



(b) Distance vs BER

Fig.4.Variation of Q Factor and BER with distance

From the graphs , it is observed that duobinary modulation based DWDM provides better Q Factor and lower BER for large distances.

CONCLUSION

In this work , analysis of 8-channel DWDM using duobinary modulation format has been done. The channel spacing is chosen as 0.4 nm . From the analysis it is found that duobinary modulation reduces nonlinear effects such as FWM and SRS thereby providing better Q Factor and lower BER for longer distances .

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