Multilevel Modulation Technique Based on Duo-Binary Transmission and Quaternary-Duo-Binary Transmission in Non-linear Regime

Majed Omar Al-Dwairi

Al-Balq'a Applied University/ Faculty of Engineering Technology, Jordan

Abstract: The comparison between the dispersion tolerance of DB and QDB for B2B transmission was done. The dispersion tolerance for DB modulation format gives better performances than the QDB format. Simulation for Duo-binary transmission and Quaternary transmission in nonlinear regime was done, were DB transmission gives the best performance while the better for 100km fiber length.

Key words: Multilevel modulation • Duo-binary transmission (DBT) • Quaternary Duo-binary transmission (QDBT) • Dispersion tolerance • Nonlinear regime

INTRODUCTION

Optical duobinary modulation (DBM) has received considerable attention in many works [1-6]. Due to the narrow spectral bandwidth compared with the typical nonreturn-to-zero (NRZ) format, DBM has higher spectral efficiency, better chromatic dispersion tolerance and less sensitivity to nonlinear effects. These benefits are crucial advantages for dense wavelength-division-multiplexed transmission systems. However, under high input optical power, the spectral width broadens rapidly during transmission due to the self-phase modulation (SPM) effect. Therefore, dispersion tolerance weakened rapidly with increasing input optical power [4,5]. Prechirped DBM was first proposed in 1998 and the theoretical investigation was provided to explain the benefits of phase modulation [6]. Later, the phase-modulation DBM (PMDBM) was proposed to improve SPM tolerance by counterbalancing the effects of phase modulation, chromatic dispersion and SPM [1-3]. However, in the new scheme, an extra modulator is often employed to provide the required phase modulation [2,3]. An extra modulator increases transmitter complexity and cost and hampers the use of this modulation format in cost-sensitive metro area transmission systems. A main drawback of optical duobinary modulation is the need to double the driving voltage which is applied to the MZ modulator as compared to the binary case. Obtaining high driving voltages is especially challenging at high bit rates. DBT was simulated before in chair for communication for B2B transmissions [7]. The improvements of DB are significantly reduced in the nonlinear regime by the self-phase modulation (SPM) limitations[8]. Beyond the limitation an approximately 8dB due to nonlinear duobinary. Quaternary duo-binary QDB is 4-level modulation format based on the well known duo-binary format, so the implementation of this format more attractive due to the narrow bandwidth, as QDB more tolerant to the effect of dispersion but increasing the complexity of implementation.many work was done for transmission systems. However, under high input optical multilevel modulation format for cost effective [9],[10].In our paper we focus on the nonlinear regime for DB transmission and QDB transmission, starting with comparing the dispersion tolerance between DB and QDB for back-to-back (B2B) transmission and make simulation for non-linear transmissions for both types by evaluating the BER vs. OSNR for different input power and fiber length.

Dispersion Tolerance: Dispersion is the effect of degradation in optical fiber which arises due to the group velocity of light where it is wavelength dependent in single mode fibers, the various forms of dispersion can commonly referred to as group velocity dispersion (GVD), which further be classified as operating normal or anomalous dispersion regime. In normal regime, longer wavelength travel faster than shorter and vice versa for anomalous dispersion regime. Dispersion characterization in single mode fibers is usually done with the dispersion coefficient, D, measured in [ps/nm.km]. The dispersion parameter is defined by (1) [7].

Corresponding Author: Majed Omar Al-Dwairi, Al-Balq'a Applied University/ Faculty of Engineering Technology, Jordan.
\[ D = \frac{2\pi c}{\lambda c^2} \beta \]  

(1)

Where: \( c \) = speed of light, \( \lambda c \) = carrier wavelength, \( \beta \) = group velocity dispersion coefficient, dispersion tolerance evaluated for DB and QDB for B2B transmission.

### A Dispersion Tolerance of Duo-Binary (DB):

The simulations were carried out for dispersion tolerance for duo-binary was determined for a fixed bit error rate (BER) \( 10^{-4} \) at a given Optical signal to noise ratio (OSNR) using low pass filter method, the modulation data rate was 107 Gb/s. The MOVE IT simulation tool, which is available at the Chair for Communication of Christian-Albrecht’s-University in Kiel, was used for this purpose and all next simulation sections. The Simulation results is shown in Figure 1.

### Dispersion Tolerance of Quaternary Duo-Binary (QDB):

This modulation format based on Duo-binary, the dispersion tolerance of QDB was varied for a fixed BER \( 10^{-4} \) for a given OSNR, where the data rates were 53.5 Gb/s each results in a total transmission capacity of 107 Gb/s. Figure 1 shows the average vale of chromatic dispersion tolerance.

### Duo-Binary Transmission in Non-Linear Regime:

The features of Duo-binary employed to reduce the bandwidth occupancy of the signal, by shaping the spectrum of the signal so it will be more compatible with the systems reaction on a single bit spread over several bit intervals. The implementation of Duo-binary can either be done with a delay-add- filter or low-pass filter. The low-pass filter approach will tend to be more tolerant to the effect of chromatic dispersion [7], so in this paper the simulation for non-linear fiber optics will be done on the base of implementation low pass filter. In Figure 2 shown the block diagram for Duo-binary transmitter, the simulation bit rate 10.7Gb/s, with the given parameters: (Dispersion \( D = 17 \) ps/nm/km, nonlinear coefficient \( \alpha = 1.62(W.km)^{-1} \), \( \alpha = 0.2dB/km \), Duo-Binary filter low-pass filter Bessel filter(0.42*10.7Gb/s). The receiver consists of a pin diode followed by 2nd order Butterworth low-pass filter with 7GHz cut-off frequency.

The simulation was done for different input power (0, 3, 8 and 11dBm) and different fiber length(50, 100, 150 and 200km) the received simulation results for 0dBm and 8dBm shown in Fig. 3 and Fig. 4.

As seen from the Figures 3 and 4, BER becomes worse by increasing the fiber length for fixed input power, were the best BER was received for 100km.

### Quaternary Duo-Binary (QDB) Transmission in Non-Linear Regime:

Quaternary duo-binary is a 4-level modulation format based on the well known duo-binary format, so the implementation of this format more
nonlinear Duobinary pin=8dBm

Fig. 4: Nonlinear DB at input power 8 dBm

nonlinear QDB,150km average

Fig. 7: Nonlinear QDB average value for 150 km

nonlinear DB & QDB 0dBm

Fig. 8: Nonlinear D and QDB for 0 dbm

It is well known that the output of this scheme gives 4 levels, which consists of various combinations of 1, 0 and -1. Were the resulting 2 outputs which we find the average value. The simulation regime for nonlinear was done with bit rate 53.5Gb/s to compare the results with DB 107 Gb/s. For all simulation models given the parameters: Dispersion D=17 ps/nm/km, nonlinear coefficient \(\alpha=1.62(\text{W.km})^{-1}\), and \(\alpha=0.2\text{dB/km}\). The receiver consists of a pin diode followed by 2nd order Butterworth low-pass filter with 7GHz cut-off frequency. The simulation was done for different input power (0, 3, 8 and 11 dBm) and different fiber length (50, 100, 150 and 200 km). The received simulation results is shown only for 100 km and 150 km in Figure 5 and Figure 6.
Fig. 9: Nonlinear DB and QDB for 8 dbm

**DISCUSSION AND CONCLUSIONS**

The comparison between the dispersion tolerance between DB and QDB for B2B transmission was done and the results shown in Figure 1, were the dispersion tolerance for DB modulation format gives better than the QDB format. The final results for the simulation work for 0dBm and 8dBm for Duo-binary and Quaternary Duo-binary shown in figure 8 and figure 9. were the DB transmission for different fiber length gives best results while the best results for DB transmission fiber length 100km, which is expected results

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