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Research on OSNR and BER of 40G DWDM System on DRZ

FENG Xiancheng*, LI Xiaopeng, SI Qinghua
College of Electrical and Electronic Engineering Wuhan Institute of Technology, Wuhan 430073, China
*Corresponding author, e-mail: xcfeng68@hotmail.com

Abstract

The signal modulation format is a key issue for 40G DWDM fiber optical communication system, which determines transmission quality and spectral efficiency. Firstly, the scheme of key technologies and modulation format (ODB, CSRZ, DRZ, DPSK, DQPSK) of 40G DWDM system is introduced. Through the Q value with OSNR and BER, the theoretical curve between OSNR and BER is given. And then it proposes optical interface parameters requirements of 40G DWDM system. By way of adopting VOA compensation in experimental system, OTU typical spectrum,eye diagram, BER and OSNR performances have been tested and analyzed. Experiment results show that DRZ code have better transmission performance, are suitable for long or middle distance transmission, meet the demand of commercial application.

Keywords: *DWDM, 40G Modulation Format, OSNR，BER，Differential Return Zero Code*

1. Introduction

It is the increasing capacity and rate requirement that improve the development of 40G DWDM Tb/s system, such as Broadband, IPTV, Triple Play, P2P, etc. In recent years, OFC and ECOC have reported a great number of transmission experiments in laboratories or testing grounds of 40Gbps WDM system. Numerous equipment manufacturers have been constantly launching different kinds of modules compatible to 40Gbps to meet the application of 40G interface. Some leading equipment manufacturers have announced to provide high-capacity WDM transmission system with 40G interface. While relevant technologies are well-developed, 40G transmission is in lack of corresponding standards. According to a survey by Heavy Reading, 60% of operators will choose 40G optic-network technology in three years. The market scale of 40G technology will reach 2 billion dollars until 2010[1-4].

2. Key Technologies of 40G System

2.1. The Modulation Code Type Technology of 40G

To implement 40G DWDM system, these key technologies should be taken into consideration: In a 40Gbps system, it is necessary to further increase the emission power of optical signals to meet the demand of OSNR. As a result, the nonlinear effect of optical fiber will lead to the serious distortion of NRZ-code optical signal. The new modulation code type, combining various modulation modes such as ODB, CSRZ, DRZ, DPSK, DQPSK and so on, has become the major code type in 40Gbps WDM system for its excellent properties [5-7]. In addition, the selection of modulation format of 40Gbps high-speed DWDM optical fiber transmission system is relevant to the overall designing of the entire system, which includes aspects like type of optical fiber, interval of transmission system, distance, number of channels, interval of channels. In terms of transmission physical effect, not only dispersion and inter-band nonlinear effect but also PMD and in-band nonlinear effect should be considered [8-10].

2.2. The Relationship between OSNR and BER

Optical signal consists of modulated mark and space. In ASK direct direction system, mark “1” and space “0” is represented by non-optical pulse. If “1” and “0” behave according to Gaussian distribution, then

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$$BER = \frac{1}{Q\sqrt{2\pi}}\exp\left(-\frac{Q^2}{2}\right) \quad (1)$$

Q for Quality factor, eg. $BER = 10^{-9}$ Q=6, Figure 1 is the relation curve between BER and Q.

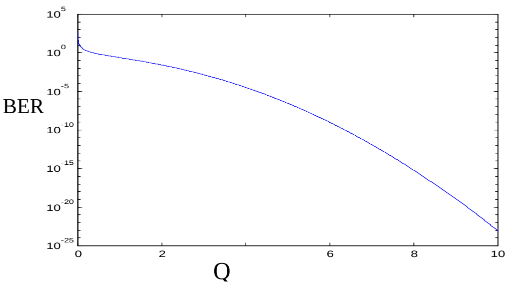


Figure 1. The Relation Curve Between BER and Q

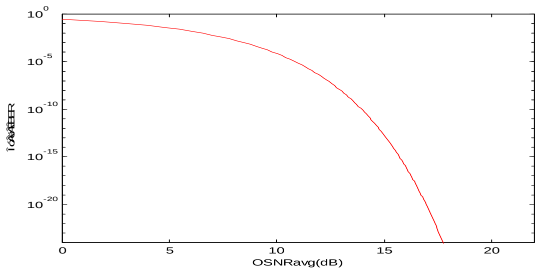


Figure 3. The Relation Curve of BER and $OSNR_{avg}$

2.3. The Relation between Q and SNR

Q represents quality factor, a useful index to describe system noise performance. Even though the value of BER is low, Q can be precisely measured. Q can be represented by the function of OSNR (mainly ASE noise) through transformation.

$$Q = \frac{\langle P_1 - P_0 \rangle}{\sigma_1 + \sigma_0} = \frac{P_S}{\sqrt{\sigma^2_{BEAT}(1)} + \sqrt{\sigma^2_{BEAT}(0)}} = \frac{P_S}{\sqrt{2P_S P_N + mP_N^2} + \sqrt{mP_N^2}}$$
$$= \sqrt{m}\,\frac{P_S}{mP_N}\cdot\frac{1}{\sqrt{2\frac{p_S}{p_N}+1}+1} = \sqrt{2}\,\frac{OSNR}{1+\sqrt{1+2OSNR}} \quad (2)$$

P_S for amplification signal power, P_N for ASE power, m for polarization mode (m=1 or 2), σ^2_{BEAT} for ASE beat noise.

$$\frac{P_S}{mP_N} = \frac{P_S}{P^{total}_{ASE}} \equiv OSNR,\ \text{m=2} \quad (3)$$

Q = 6, then OSNR=44.5 or 16.4dB. Notice that the average OSNR of signal modulated by ASK is lower than this value: $OSNR_{avg}$=13.4dB. Figure 2 is the relation curve between OSNR and Q. Using equation (1) (2) to connect BER and OSNR through Q. Figure 3 is the relation curve of BER and $OSNR_{avg}$

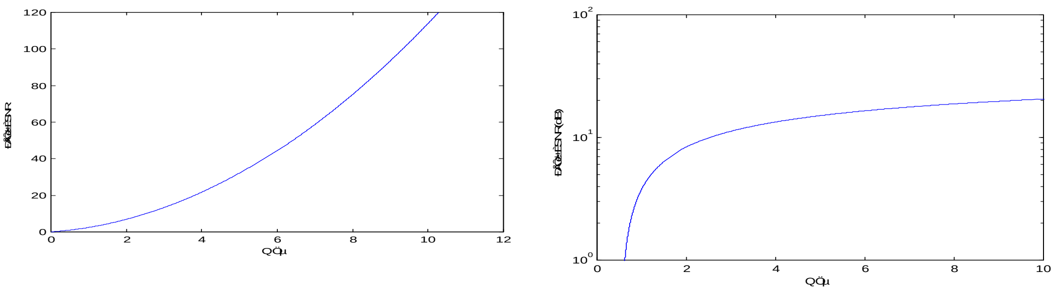


Figure 2. The Relation Curve Between OSNR and Q

2.4. OSNR Budget

In a optical fiber communication system, the signal distortion and OSNR of the receiver's input end is the most important factor to determine the characteristic of BER in system. The following further discusses some important principles of system designing, based on the requirement of OSNR.

Definition of OSNR: $OSNR = P_{sig}/P_{ASE}$

P_{sig} for average optical power of certain channel, P_{sig}=P_{out} -10logM; P_{out} for EDFA total output power; M for channel number; $P_{ASE} = F\ (G\text{-}1)\ hvBo\ (N+1)$ for amplified ASE inside EDFA, noise power in optical filter bandwidth *Bo* cascaded by N+1optical fiber section and EDFA. *Bo* is usually defined to be 12.6 GHz (0.1nm), or 10log(*hvBo*)=-58 dBm in decibels, F for EDFA noise coefficient and G for amplification multiple. If every EDFA has the same gain and exactly counteract sthe loss of optical fiber section, then

$$OSNR_{[dB]} \approx P_{out[dBm]} \text{-}10\log M + 58\text{-}[NF_{[dB]} + G_{[dB]} + 10\log(N+1)] \quad (4)$$

Due to the increase of P_{ASE} and the length of optical fiber section followed by the linear increase of amplifier's progression, low gain with more progression has much higher OSNR than high gain with less progression when the total system length maintains the same.

In fact, the loss of N optical fiber sections is not the same. But each level of EDFA gain is possible to be considered as line loss ($L_i = G_{i+1}$) to make up for the former optical fiber section, because EDFA mainly works in (deep) saturated conditions. In engineering design, given the fact that each optical amplifier mainly works in saturated conditions, total output power remaining unchanged, the gain of operating point will spontaneously adapt to the same as the former optical fiber section' loss, which is different with rated gain. As a result, OSNR:

$$OSNR_{[dB]} = P_{out[dBm]} \text{-}10\log M + 58\text{-}NF_{[dB]} \text{ - } 10\log[G(1) + \sum^{N-1} L(i)\ ] \quad (5)$$

According to the line loss, the OSNR evolutionary process of DWDM system can be estimated, which is of vital guiding significance in engineering for network planning.
Take equal-loss optical fiber section for example, we can obtain the total output power of EDFA:

$$Pout[dBm] \ = \ G[dB] + F[dB] + OSNR[dB] + 10\log[M\ (N+1)] + \triangle P[dB] - 58 \quad (6)$$

$\triangle P[dB]$ is the channel power difference caused by various factors (such as EDFA and wavelength characteristics of each component's gain or loss, nonlinear effect of optical fiber). It can also be concluded that when EDFA total output power maintains the same, number of channels M and number of optical fiber sections should meet:

$$M\ (N+1) \leqslant 10^{0.1\,(58 + Pout[dBm]\ -\ G[dB] - F[dB] -\ OSNR[dB] - \triangle P[dB])} \quad (7)$$

For example, data rate of channel= 40Gbps(OSNR lower limit =20dB), EDFA total output power= 23dBm, F=8dB, P=3dB, G=22dB(0.275dB/km×80km), and then M(N+1)=631, M=40, thus N=14.

In sum, 40G DWDM system is a sophisticated integrated system which combines latest code-type modulating technology, management technology of strong dispersion, high tolerance of OSNR, high sensitivity of testing and receiving and coding error correcting technology.

3. Optical Interface of 40G WDM System

The reference configuration of 40G DWDM system is shown in Figure 4. In it, OUT for optical wavelength converter to fulfill 3R function (re-amplifying, re-forming, re-timing); OMU for optical multiplexer unit to fulfill multiplexing of various wavelength; OA for optical amplifying unit to fulfill signal optical domain amplification (including dispersion compensation); ODU for photolysis multiplexer unit to fulfill photolysis multiplexing of various wavelength; Tx/Rx for client side-light interface.

Figure 4 defines 6 reference points outside the system and 2 inside, and they are S, MPI-SM, RM, SM, MPI-RM, R and Sn, Rn. Among them, R and S are interface reference points of MS-ULH WDM system and customer system. MPI-SM, RM, SM, MPI-RM are reference points of main optical channel of MS-ULH WDM system; Sn, Rn are reference points respectively between OUT and OMU, ODU in MS-ULH WDM system. And the specific meanings of these reference points are as follows:

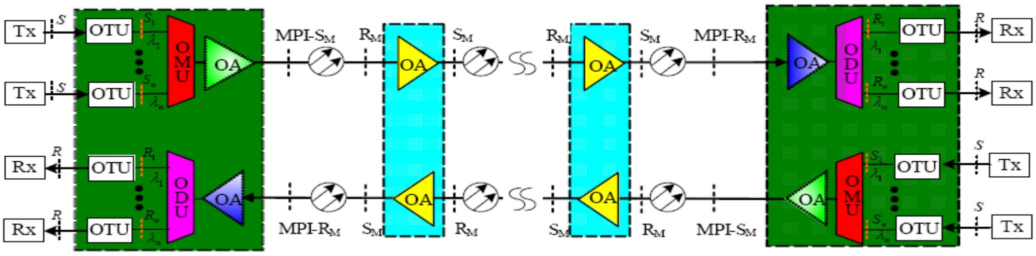


Figure 4. The Reference Configuration of 40G DWDM System

S for reference point at optical fiber joint after the custom signal emitter output interface;
Sn for reference point at optical fiber joint after OUT' connection to OMU output interface;
MPI-SM for reference point at optical fiber joint after OA, after OMU, output interface;
RM for reference point at optical fiber joint before OA input interface;
SM for reference point at optical fiber joint after OA output interface;
MPI-RM for reference point at optical fiber joint before OA, before ODU, input interface;
Rn for reference point at optical fiber joint before input interface connecting OUT, after ODU;
R for reference point at optical fiber joint before customer signal receiver input interface.

4. Testing and Analysis

4.1 Configuration Testing

OTU performance testing of 40G DWDM system is shown in Figure 5.

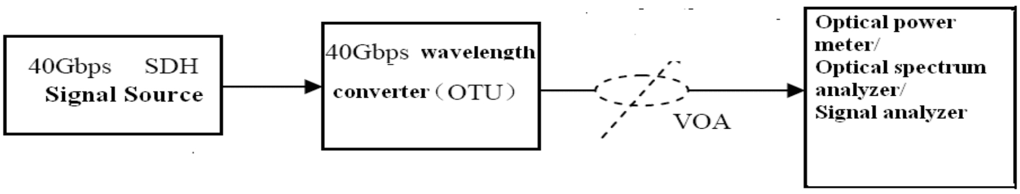


Figure 5. Configuration Diagram of 40 G OTU Performance Test

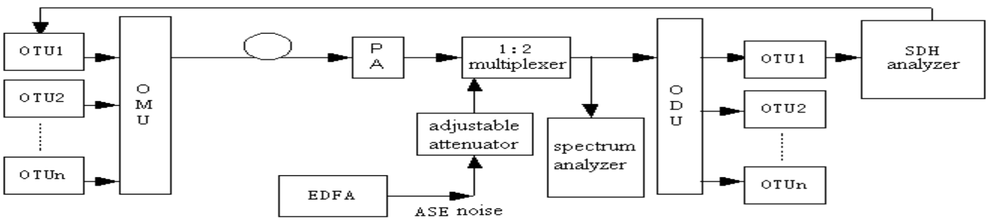


Figure 6. Configuration diagram of 40 G OTU OSNR Performance Test

Among them, VOA represented in dotted line means to add in proper VOA when testing eye pattern performance so as to make it meet the demand of input optical power requirement range of communication signal analyzer. The deployment diagram of BER and OSNR performance testing of 40G DWDM system is shown as Figure 6.

4.2 Wavelength Converter and System Experiment

1) 40G DWWM Wavelength Converter Spectrum and Eye diagram

DRZ 40G DWWM wavelength converter spectrum and eye diagram are shown Figure 7. The typical -3dB spectrum width of DRZ module is 0.6nm.

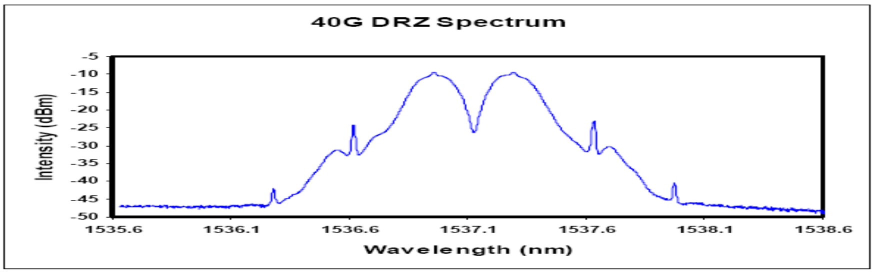


Figure 7. DRZ 40G DWDM OTU Typical Spectrum

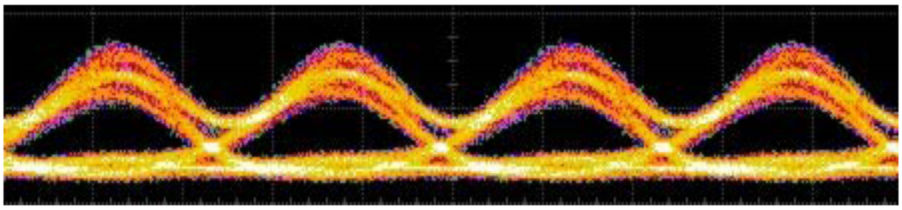
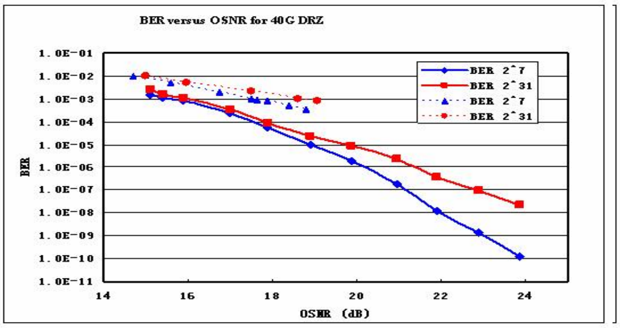


Figure 8. DRZ 40G DWDM OTU Typical Eye Diagram

According to the test results, 40G wavelength converter of DRZ can continue to use the current WDM system frequency, but it has wider spectrum width and lower duty ratio than normal NRZ.

2) OSNR and BER Performance of 40G DWDM Wavelength Converter

According to test results from Figure 9, the lowest tolerated OSNR of DRZ 40G DWDM wavelength converter at E-03 error rate is approximately 14dB.



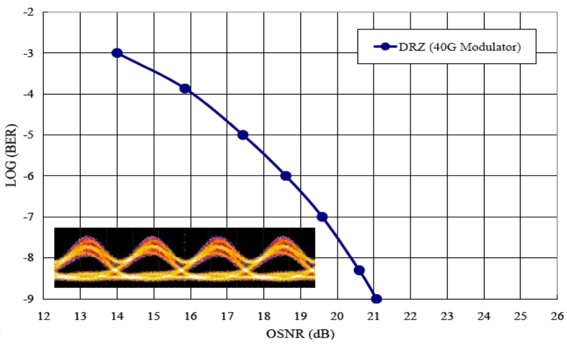


Figure 9. 40G DWDM System back-to-back Testing of BER and OSNR Based on DRZ

Figure 10. 40G DWDM 1600km long-fiber Transmission BER and OSNR Curve

In Figure 10, 1660km long-fiber transmission system has implemented pre-compensation of dispersion. The single channel transmission optical power is 4dBm/ch, so the lowest OSNR of 1600km long-fiber transmission is approximately 18.6dB.

3) The Transmission Performance of 40G DWDM Wavelength Converter

1. DRZ 40G DWDM Wavelength Converter System Transmission OSNR Performance
2. The Dispersion Tolerance of DRZ 40G DWDM Wavelength Converter through System Transmission Figure 11 is the dispersion window after DRZ transmitting 1600 km; we can see that the dispersion window is very small of 40 ps/nm with adding the window by configuring TDC.

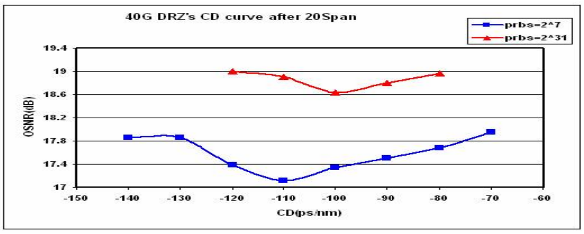


Figure 11. 40G DWDM Transmission 1600km System Dispersion Curve

5. Conclusion

Different modulation codes have different characteristics of optical signal channel transmission. To choose which modulation code to be adopted in a specific high speed optical transmission system, we should take the actual demand into account and conduct some complex system simulations or experiments. To judge a modulation code, we should regard of not only its capability of dispersion resistance,polarization mode dispersion resistance, and the negative effects of non-linear resistance, but also its bandwidth efficiency and noise immunity. Nowadays, optical transmission system based on NRZ code has been used in China's Communication Network in vast scale. However, from 2006, some telecommunication companies in China have begun using optical transmission system with a speed of 40 Gb/s for field trial and test, to meet the requirement of system upgrade. From the results of practical applications, we've found that the system with a speed of 40 G must use modulation code from NRZ code which has been used for long time into RZ or other more efficient codes [11-12].

Long distance transmission experiment results has shown that, including data like the lowest tolerated OSNR and tolerance of dispersion, N×40G DWDM system that is based on modulating and coding technology such as DRZ is mature and able to meet the demand of business requirements.

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