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Research on the Modulation Performance in GPON System

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Abstract

This paper mainly does research and analysis on anti-dispersive performance and anti-nonlinear performance for intensity modulation formats such as NRZ, RZ, CS-RZ, DRZ, MD-RZ in 40Gbps high-speed single-channel optical transmission system. It compares the five pattern modulation formats in dispersion tolerance, nonlinear tolerance, and advantages and disadvantages in transmission distance. Anti-nonlinear effect ability of CSRZ, RZ are stronger than that of NRZ code; in the single-channel transmission system, DRZ and improved modulation format MDRZ have better resistance foranti-nonlinear performance, so they are suitable for long-distance transmission. RZ has the minimum dispersion tolerance. NRZ than RZ has higher spectrum efficiency than RZ, and thus have a better dispersion tolerance. CSRZ code has higher spectral efficiency, higher dispersion tolerance and nonlinear tolerance than RZ code, making it more suitable for long distance transmission.

Keywords: *GPON, intensity modulation, PMD, EOP*

1. Introduction

With the rapid development of the next generation of optical fiber transmission information system, 40Gbps optical fiber transmission system and its wavelength division multiplexing (WDM) system have been the focus of research. In order to enhance the capacity of the system and diminish the degradation of performance which would be caused by the loss of transmission, systems engineering and optimization would be important. Thereinto, the optical code-pattern would be the important factor which decides the spectrum efficiency, transmission quality and the dispersive tolerance of the system. Thus, the chosen of code-pattern is the first factor in the high speed optical transmission system [1-2].

The application of optical fiber transmission system and dense-wavelength-division-multiplexing (DWDM) system make the dispersive tolerance markedly decrease, and the non-linearity effect has an impact on the system performance. Traditional NRZ code-pattern would not have met the demand, while need other new modulation format. People propose many code-patterns in terms of 40Gb/s optical transmission system [3-11], such as RZ [3], and also propose the RZ of the carrier suppressive (CS-RZ), single sideband-RZ (SSB-RZ), duojdecimal-RZ (D-RZ), mend duojdecimal-RZ (MD-RZ) [4], RZ-DPSK [5-6], full spectrum return-to-zero (FSRZ) and chirp return-to-zero (CRZ).

In the paper, take the 40Gbps for example, the way of modelization of NRZ, RZ, CS-RZ, and DRZ, MD-RZ with computer analyzes the optical spectrum. The 40 Gbps signal transmitted in G.652 fiber by way of single channel with erbium-dope-fiber-amplifier (EDFA) is simulated for these formats. Thus CSRZ, RZ has better anti-linearity ability than the NRZ code; in the single-channel transmission system, DRZand improved modulation format MDRZ has better anti-nonlinearity, and is suitable for long-distance transmission. RZ has the minimum dispersion tolerance. NRZ has higher spectrum efficiencythan RZ, and thus have a better dispersion tolerance. CSRZ code has higher spectral efficiency, higher dispersion tolerance and nonlinear tolerancethan the RZ code,so it's more suitable for long distance transmission.

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2. The Principle and Characteristic

Intensity modulation is the process to transmit information on the amplitude of the optical signal by the modulator, and demodulate the transmitted information at the receiving side by detecting the changes in the amplitude. It includes NRZ, RZ and Duobinary. NRZ also includes carrier-suppressed zero CSRZ, zero chirp CRZ and so on. Besides, there are DRZ and MDRZ generated by combination of Duobinary and RZ.

2.1. The Principle of Chosen Code Pattern [12]

There are three principles for the modulation format that we should follow: firstly, the compact modulation signal spectrum is good at enhancing the operating factor of the spectrum and the dispersive tolerance of group velocity; secondly, a high non-linearity tolerance; thirdly, the structure of the transmitter and receiver are simple as soon as possible.

2.2. The principle of NRZ

We usually use the Mach-Zehnder modulator (MZM) and the consecutive wave (CW) laser in the modulation system. Except for the NRZ, their appearance would be performed by the two concatenation of MZM. These two concatenations of MZM play a different role. The first MZM is used to bring various pulses by the drive of the clock signal. The second one is used to load the data.

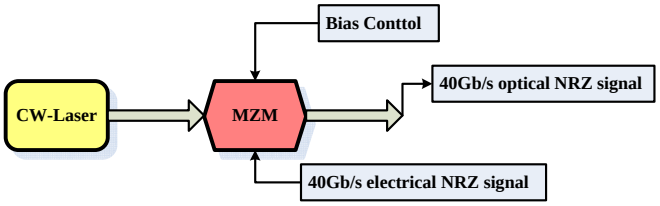


Figure 1. Blocks Diagram of NRZ

Figure 1 is the frame of the NRZ signal of the optics. When transmitted the “1” in the NRZ, optical signal impulse occupies a whole bit-time; when there is no optical pulse, the signal is “0”. The realization of the coding is simple, only needing a high speed exterior modulator that can work effectively at the speed of 10Gbps. The advantage of NRZ is the simplicity of application, low cost and high spectrum efficiency, which can be used widely into the synchronous digital hierarchy (SDH) and wavelength division multiplexing (WDM) system. Under the 10Gbps system and more less, we use the NRZ modulation model. The disadvantage of NRZ is that the transition doesn't return zero between two codes, the sensitivity for transmission loss. So it is not suitable for high speed and the extra long-distance transmission.

2.3. The Principle of RZ and CS-RZ

Figure 2 is the frame about the principle of the generation of RZ and CS-RZ, which is all composed by the two concatenation of MZM. The technology of RZ code prevails recently, which is used in the high speed of 40Gps optical transmission system. In the pulse sequence of RZ code, the transition area which connects “1” amplitude of electric field has the independent time envelope. Because modulation format of RZ has the different transition all the time in the code bits, thus it can bring more “neatness” optical signal in order to unscramble the receiver. The advantage of RZ is the low average of optical power; higher ability on anti-non-linearity effect and anti-polarization mode dispersion (PMD) [12]. RZ code is also more conducive to clock recovery. Because the consecutive “1” of NRZ is a whole, the eye pattern of RZ code stretches bigger, the better ability of anti-error-code performance, and provides the improvement on 3dB of the optical signal noise ratio (OSNR).

The CS-RZ code is based on the traditional RZ code, and join the phase separation of π in each adjacent sign bit (no matter the sign bit is “0” or “1”). The phase separation of the carrier can be regarded as the signal with a minus but the carrier is invariability. The typical

value of this signal with positive and negative ambipolar is '0', so there is no pinnacle in the zero frequency because of without △ function (impulse function), after multiplying the according carrier, and there is also no pinnacle in the carrier. In the CS-RZ, because the sign about consecutive code of amplitude of electric field is reversed, we can get the low width of spectrum. With the high power, it not only increases the dispersive capacity, but also enhances the resist of the non-linearity of self-phase modulation (SPM) and four-wave-mixing (FWM), and so on.

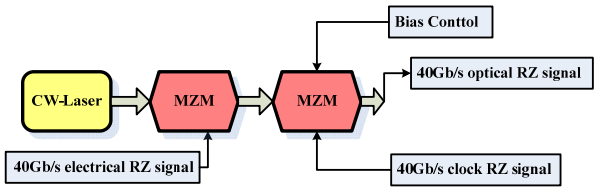


Figure 2. Blocks Diagram of RZ/CS-RZ

2.4. The Principle of DRZ

Optical duobinary NRZ (DRZ) is a combination ofDuobinarycode and RZ code, which canbe generated by two MZ modulators in series production, shown in Figure 3. Pseudo-random binary sequence PRBS source, instead of the actual data information transmitted,get through the binary precoder, NRZ generator and an associated coder to generate NRZ duobinary signal. After it get through the first stage Mach-Zehnder modulator, a second stage Mach-Zehnder modulator will obtain DRZ signalsdriven by a 40GHz frequency sinusoidal signal. Binary precoder achieves the result through difference of time delay, and the relevant encoder achieves the result through sum of the time delay, both will help improve the quality of signal transmission and system receiver sensitivity. When the number of odds between two adjacent 1 in DRZ code equals 0, the phase inversion occurs.

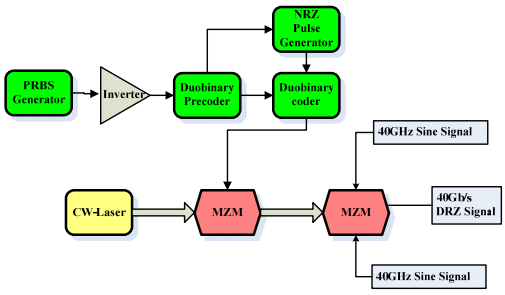


Figure 3. Generation Diagram of DRZ

2.5. The Principle of MD-RZ

Improved duobinary NRZ (MD-RZ) is the optical duobinary NRZ code form, also known as carrier-suppressed duobinary RZ. Improved double binary zero code generation can be achieved employing two cascaded Mach-Zehnder modulators, i.e. obtained through modulating the clock portion of CSRZ by duobinary signal. Figure 4. Duobinary NRZ signal of the first stage Mach Zehnder modulator is generated by the subtracting circuit delay. The second stage Mach Zehnder modulator obtains MD-RZ signal via a sinusoidal signal with a frequency of 20GHz. The way MD-RZ signal is generated and the way DRZ signal is generated are different in delay sum and delay subtraction. The characteristic of MD-RZ code is that the code phase inverseswhen it encounters 1, and code phase remains unchanged when encounters 0.

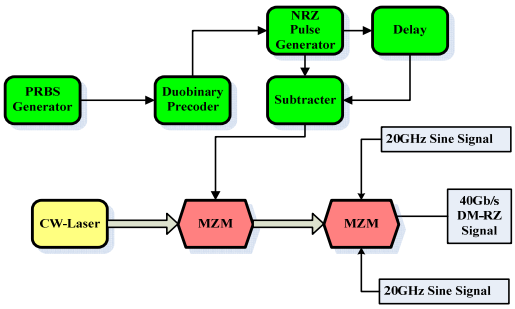
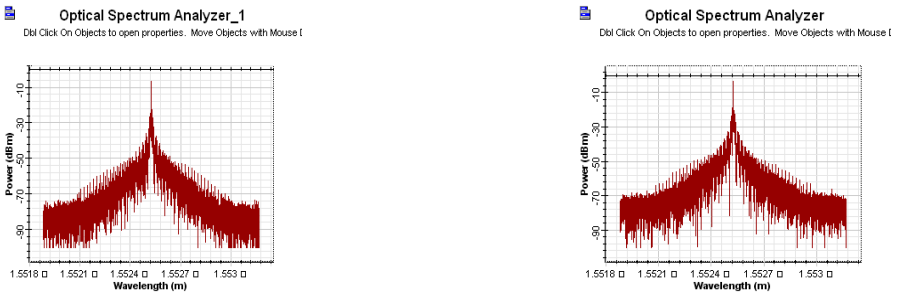


Figure 4. Generation Diagram of MD-RZ

3. The Analysis of Spectrum by kinds of Modulation Formats

The figure below is the spectrum of modulation format; figure5 is the wave and the spectrum of NRZ; the spectrum width of NRZ is about 80GHz (the distance between secondary line spectrum); figure6 is the wave and the spectrum of RZ code, and spectrum width is 160GHz; Figure 7 is the wave and the spectrum of CS-RZ code, and spectrum width is 120GHz with no carrier wave. DRZ signal spectrums are shown in Figure 8. DRZ has a narrower spectrum than ordinary binary code pattern, and the carrier is suppressed at the same time. MD-RZ signal spectrum is shown in Figure 9. MD-RZ signal is return-zero signals, so the spectral width should be wider than that of non-return to zero Duobinarybut narrower than that of RZ code like CSRZ. It has the narrowest bandwidth is the bandwidth of the narrowest NRZ pattern. MD-RZ codes overcome the single-channel transmission system self-phase modulation (SPM) effect more effectively when compared with the RZ and duobinary RZ, and is more conducive to avoid dense wavelength division multiplexing transmission system cross-phase modulation (XPM) and four-wave mixing (FWM) and other nonlinear effects. However, generation of MD-RZ is the most complex compared with that of other modulation formats.

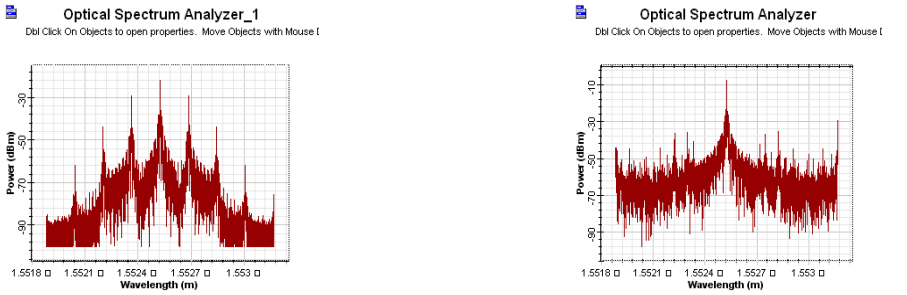


(a) Spectrum of NRZ (b) Spectrum of NRZ-DPSK

Figure 5. Wave and Spectrum of NRZ

(a) Spectrum of RZ (b) Spectrum of RZ-DPSK

Figure 6. Wave and Spectrum of RZ



(a) Spectrum of CS-RZ (b) Spectrum of CS-RZ-DPSK

Figure 7. Wave and Spectrum of CS-RZ

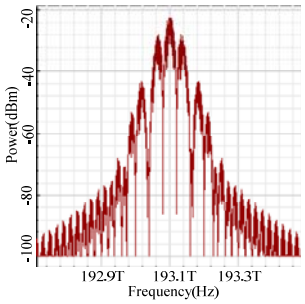


Figure 8. Spectrum of DRZ

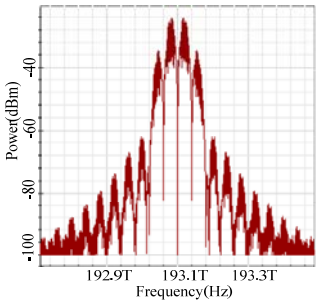


Figure 9. Spectrum of MD-RZ

4. Anti-Nonlinearity Capabilities for Different Intensity Modulation Formats

Nonlinear effects have a serious influence on signal transmission in high-speed optical fiber communication transmission system. Optical signal in the optical fiber nonlinear effects will be more significant as the transmission rate is increased, and the transmission distance is longer. Nonlinearity tolerance largely determines the transmission performance of various modulation formats, and research on the anti-nonlinearity for modulation format of different phases in the high-speed transmission system is very important.

Due to the close relationship between fiber nonlinearity and dispersion closely, the signal has different non-linear effects usingdifferent dispersion compensation ways, the introduction of better dispersion compensating nonlinear effects can be minimized impact on the signal. We ignore the effects polarization mode dispersion and fiber optical amplifier spontaneous emission have on signals, retain dispersion, and compare nonlinear capabilities of a variety of anti-phase modulation formats with symmetrical dispersion compensation when the dispersion is fully compensated.

Several kinds of curves about the eye diagram opening price EOP of the intensity modulation formats changing with SMF into the fiber optical power as shown in Figure 10.

We can see from the diagram that, the eye open costs of these kinds of intensity modulation format increases slowly with the increases of the fiber optical power,during which MDRZ and DRZ both have good abilities to resist nonlinear effects.When the eye figure opening price reaches 1 db, the fiber optical power is 5.6 dBm and 5 dBm respectively. In these kinds of intensity modulation formats, the nonlinear tolerance of MD – RZ is largest, and the nonlinear resistance of it is best; DRZ follows;the nonlinear tolerance of RZ and CSRZ are similar; the nonlinear tolerance of NRZ is minimal. In general, the non-linear resistance in the zero modulation format is better than that in non-zero modulation format. RZ and CSRZ modulation formats can lead to the broadening of optical pulse and the decreases of pulse peak power when affected by the dispersion, and the influence of nonlinear is relative minor than NRZ code.

5. Dispersion Ability of Different Intensity Modulation Formats

Due to the nonlinear effect and dispersion of the fiber are closely related, the signal transmission in the transmission line will not only affected by fiber nonlinear, also will be affected by severe dispersion, and due to environment temperature, pressure, etc. Will change the dispersion value of transmission lines, so even if using the dispersion compensation fiber or other dispersion compensation device to compensate, but the dispersion are still hard to be compensated completely. The accumulation of residual dispersion can limit the increase of transmission distance, and affect the performance of the system. Dispersion tolerance, therefore, are also an important indicator of measure the different modulation format of dispersion system of robustiousness.

In order to measure the dispersion tolerance of the intensity modulation format, ignore the polarization mode dispersion, nonlinear effect and optical amplifier spontaneous radiation influence on signal transmission, leaving it out of consideration, only keep the dispersion effect of the system.

Here, the method we adopt is to change the dispersion value, measured NRZ, RZ and CSRZ, DRZ, MD - RZ dispersion resistance modulation format is shown in Figure 11.

What can be seen from the Figure 11 is that NRZ signals can tolerate 55 ps/nm that is probably twice as DRZ with stronger ability to resist dispersion, when the opening price dispersion value reaching to ldB eye diagram. Followed by CSRZ, tolerate dispersion value is about 35 ps/nm, MD - RZ can tolerate dispersion value of 12.5 ps/nm. RZ signal can tolerate the minimum value of the dispersion, about 12 ps/nm.

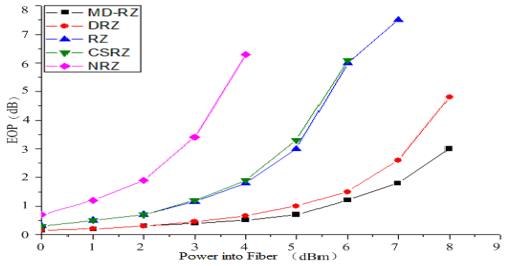


Figure 10. EOP Changes with Optical Power into the Fiber Curve

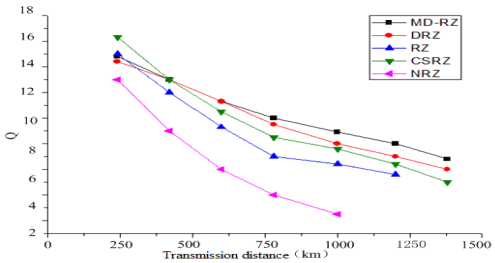


Figure 11. Comparison Chart of Anti-dispersion Capacity

6. Concluding remarks

This chapter mainly studied dispersion properties and anti-nonlinear performance in high speed optical transmission system channel of intensity modulation formats NRZ, RZ, CSRZ, DRZ, MD-RZ, and compared five modulation formats in the dispersion tolerance, nonlinear tolerance and the advantages and disadvantages on transmission distance. CSRZ, RZ has better anti-linearity ability than the NRZ code; in the single-channel transmission system, DRZ and improved modulation format MDRZ has better anti-nonlinearity, and is suitable for long-distance transmission. RZ has the minimum dispersion tolerance. NRZ has higher spectrum efficiency than RZ, and thus have a better dispersion tolerance. CSRZ code has higher spectral efficiency, higher dispersion tolerance and nonlinear tolerance than the RZ code, so it's more suitable for long distance transmission.

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