Journal of Computers Vol. 31 No. 6, 2020, pp. 319-325
doi:10.3966/199115992020123106025

An ECDM-PON Uplink Access System Based on Low Coherence Optical DPSK Modulation

Yu-Qi Yuan[1], Wen-Bai Chen[2*]

[1] International School, Beijing University of Posts and Telecommunications, Haidian, Beijing 100876, China
yyqyyl@bupt.edu.cn

[2] School of Automation, Beijing Information Science and Technology University, Chaoyang, Beijing 100101, China
chenwb@bistu.edu.cn

Received 15 August 2020; Revised 25 September 2020; Accepted 24 October 2020

Abstract. In this paper, an ECDM-PON uplink communication scheme based on low coherent optical DPSK modulation is proposed, which combines low coherent optical DPSK modulation and CDMA technology, and uses a passive optical network to transmit the code division multiple access (CDMA) signal encoded in the electrical domain. Simulation tests show that in the case of asynchronous uplink access, this passive optical network system has the same flexibility as the CMDA random access in the electrical domain, low coherence optical fiber communication dispersion problems can also be well resolved.

Keywords: dispersion compensation, ECDM-PON, optical DPSK modulation, uplink random access

1 Introduction

In order to avoid the high cost and implementation complexity of encoding and decoding OCDMA-PON in the optical domain, M. Kashima et al. proposed the ECDM-PON architecture in 2007 to implement the encoding and decoding process in the electrical domain, which uses CDMA as a downlink multiplexing technology with a power budget of 42 Db without amplifiers [1]. In the same year, Yashuiro Kotani et al. introduced an ECDM-PON scheme for electrical domain encoders implemented by large-scale integrated circuits (LSIs) and electrical domain decoders with charge-coupled device matched filters (CCD-MF), which achieves a maximum data rate of 1.25 Gbps, a code length of 8 bits, and a post-encoding code chip rate of 10 Gchip/s [2-3]. Scholars J.B. Rosas-Fernández proposed a code division multiple access ECDM-PON system using a transverse filter as an electrical domain spread spectrum encoder [4-5], Liu B et al. combined ECDM PON technology with OFDM technology [6-7], Han Jilong et al. combined ECDM-PON with wavelet transformation The combination of technology has been studied [8]. The encoding/decoding of ECDM-PON in the electrical domain reduces system cost by avoiding the use of expensive optical components, and the use of existing electrical devices for encoding/decoding reduces implementation complexity and improves system stability. However, the research on ECDM-PON is still in the experimental stage and no mature system is available. In addition, existing research fails to address the effects of multi-address interference when using ECDMA as an access technology for PON uplink. Paper [9] proposes a bipolar optical transmission scheme based on low coherence optical DPSK modulation to solve the problem that only unipolar codes can be transmitted over optical fiber in ECDM-PON, but does not analyze the case of simultaneous multi-user communication and the dispersion problems that may be caused by low coherence light, which is analyzed in this paper.

* Corresponding Author

2 Proposed Bipolar ECDM-PON Scheme

Fig. 1 is a schematic diagram of our proposed ECDM-PON scheme, in which the dashed line is divided into the optical domain part, which is mainly used to realize the uplink communication signal from multiple user devices to the bureau with the help of optical fiber, and the bipolar code division multiple access (CDMA) signal is realized by using a photoelectric balance detector for photoelectric conversion at the bureau. The part outside the dotted line is the electrical domain part: the user device shown on the right of the figure is ONU1, ONU2, ONU3, etc. The baseband signal will be modulated by address code to achieve uplink access code division multiplexing, and the part on the left of the figure is to use the transverse filter to demodulate the received code division multiplexing signal with address code to complete the ECDM-PON uplink communication.

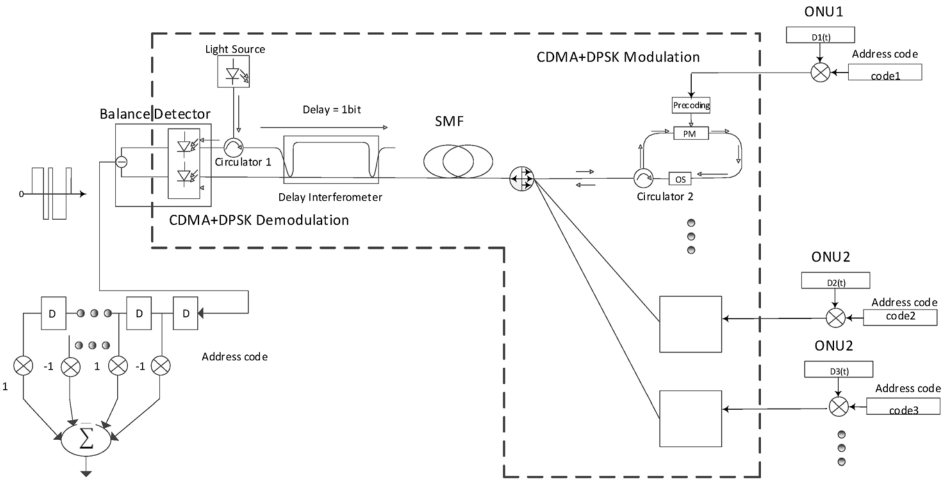


Fig. 1. An Ecdm-pon scheme for optical bipolar transmission proposed in this paper

The above two aspects from the optical and electrical domain for the basic introduction of the proposed program, the following point ONU1 uplink communication access process is described in detail: for the electrical signal, ONU1 point of the baseband digital signal D1 (t) after the address code Cord1 spread spectrum modulation generated ONU1 spread spectrum signal, this spread spectrum signal after pre-coding modulation phase modulator to achieve optical DPSK modulation.

For the optical signal, the low coherent optical signal from the light source is pre-processed by the delay interferometer. The pre-processed light signal enters the phase modulator PM via loop 2, and the modulated light signal is returned to the delay interferometer via loop 2 and the optical switch OS again, which demodulates the coherent DPSK modulated signal. The demodulated signal is converted by the balance detector into a bipolar electrical signal output, which is demodulated using a transverse filter and address code,to enable the transmission of the baseband digital signal from ONU1 to the OLT. The optical switch OS reduces the interference from the ONU to the OLT and is turned on only when there is a message sent from ONU1. The above optical signal passes through the delayed interferometer twice, the main purpose of which is to overcome the unstable stability of the delayed interferometer in conventional optical DPSK modulation by means of low coherence optical interference. The main process of signal transmission and modulation is shown in Fig. 2.

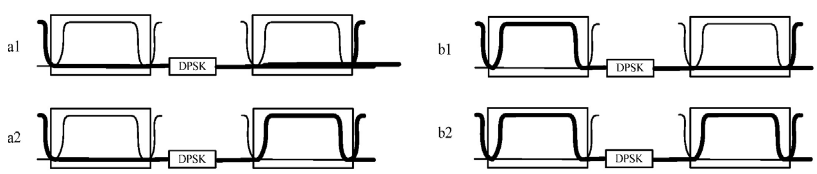
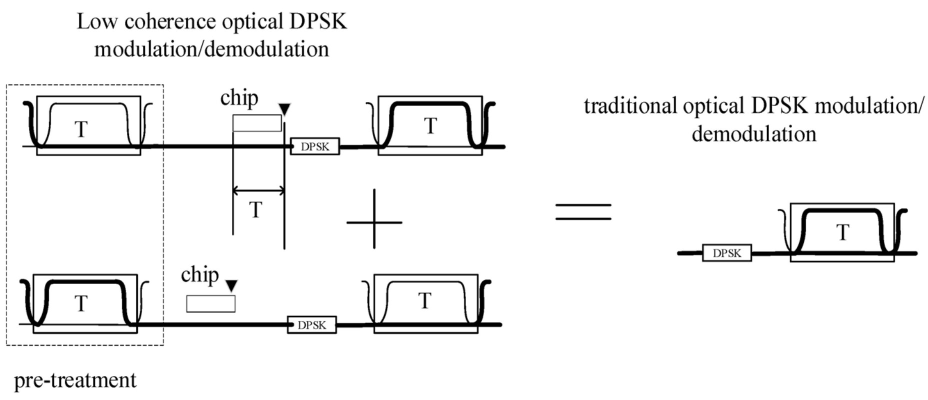


Fig. 2. Optical signal transmission in a delayed interferometer

Fig. 2 shows four different paths of the optical signal after round-trip passes in the delayed interferometer, which we have named a1, a2, b1, and b2. Since the optical signals a1 and b2 have unequal optical path lengths, they are incoherent and will be subtracted and canceled out by the photobalance detector. The light signals a2 and b1 pass through equal length light paths, which are coherent light. Since the incoherent light is canceled out, only the coherent light portion is discussed below.When only the cases a2 and b1 are considered, Fig. 3 shows that this case is essentially equivalent to the optical DPSK modulation/demodulation scheme used in the field of optical communications.For Fig. 3(a), since the light source is a low coherence light source, only light chips with the same optical range as indicated by the black triangle at the head of the chip in the figure can eventually interfere with each other in the delayed interferometer. Since the difference in arm length of the delay interferometer corresponds to a delay time of T, the length of time before and after the code piece or optical chip can be interfered with during DPSK modulation is also T.

Therefore, differential phase modulation using a DPSK phase modulator followed by demodulation using a delayed interferometer is consistent with conventional optical DPSK modulation/demodulation as shown in Fig. 3(b).Thus, Fig. 3(a) actually illustrates two optical slices before and after the diagram to achieve optical DPSK phase modulation, with subsequent demodulation using a delayed interferometer. Comparing the modulation/demodulation process in Fig. 3(a) with the conventional optical DPSK modulation/demodulation process shown in Fig. 3(b), we can conclude that they are equivalent.

The difference between Fig. 3(a) and Fig. 3(b): for Fig. 3(b), environmental factors such as temperature, vibration, etc. will change the delayed interferometer arm length difference, which will make the phase of the interferometer very unstable, which will lead to errors in the transmission of information; However, in Fig. 3(a), a2 and b1 are equal optical paths, which ensures the stability of the DPSK signal modulation/demodulation.The two delayed interferometers shown in Fig. 3(a) essentially correspond to the same delayed interferometer, and are represented as two delayed interferometers to facilitate the logical description of the round-trip of the transmitted and received light signals to and from the delayed interferometer, respectively. Due to the fast speed of light, the round-trip time is very short for short-range communications (much smaller than the time period of environmental variables), thus ensuring that the arm lengths of the transmitting and receiving delayed interferometers remain essentially unchanged, which ensures the stability of DPSK signal modulation/demodulation.



(a) (b)

Fig. 3. Coherent signals and equivalent optical paths in a delayed interferometer

The previous analysis of a user unit uplink communication process shows that for spread spectrum baseband signals, this communication process is equivalent to the traditional optical DPSK modulation, which enables the transmission of bipolar codes. The code division multiple access uplink communication is a multi-user simultaneous data transmission. This kind of data transmission is often asynchronous, and it is very difficult to theoretically analyze the asynchronous multi-user simultaneous uplink data transmission, so we verify the performance of the multi-user asynchronous uplink communication shown in Fig. 1 by means of simulation test.

3 System Performance Simulation Studies

3.1 Multi-user Random Access Simulation

Fig. 4 shows a simulation system for multi-user uplink communication. The system simulates the uplink communication of three user segments. The three users transmit address code data, assuming 1010, 1100, 1001 respectively, and the data transmission rate is 100MHz, the corresponding data code period is 10ns, assuming asynchronous transmission of three data, the time delay is 37ns, 13ns and 0ns respectively. The system is simulated by optisystem software, and the uplink transmission data is transformed into electrical signal after differential pre-coding and pulse molding, and then driven into phase modulator PM for optical DPSK modulation; the light source is LED with broadband low coherence light source, and the light source enters the beam splitter after the delay interferometer with a delay length of 10ns, and then enters the phase modulator respectively, and the phase modulator is then connected to the optical DPSK modulator. A delay timer is used to specify the delay time for the asynchronous transmission of each signal, and then the three optical signals are merged by a combiner; the merged signals are passed to the local office, demodulated by delay interferometer, and then fed to a balanced photodetector for conversion into a bipolar electrical signal that is filtered and displayed on an oscilloscope.

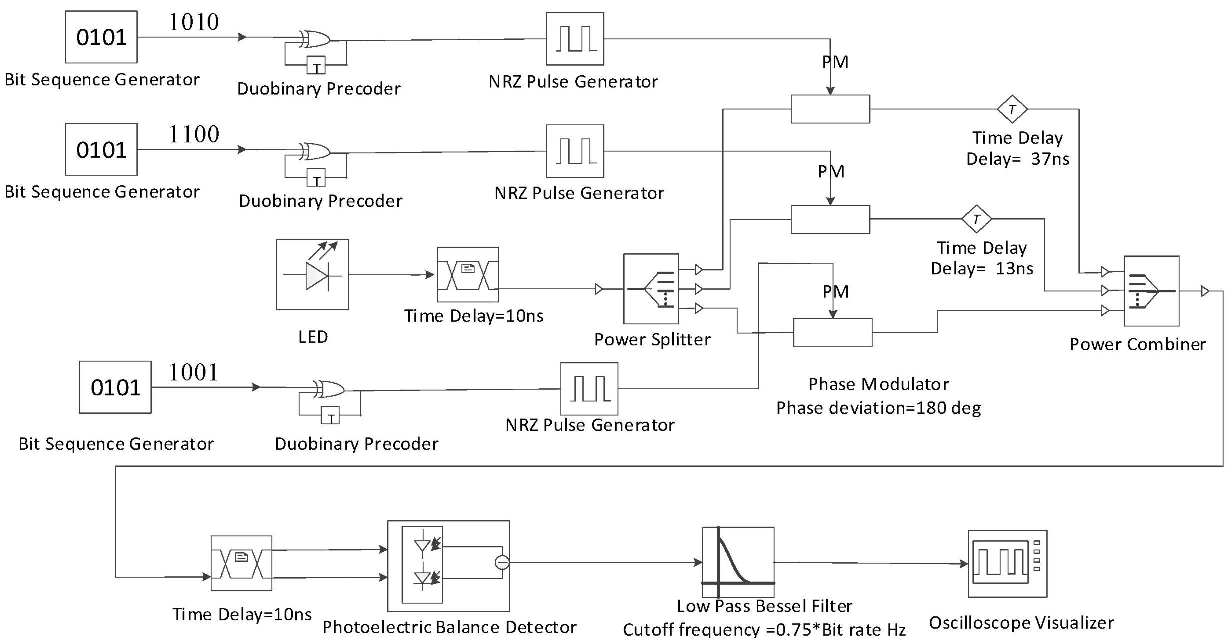
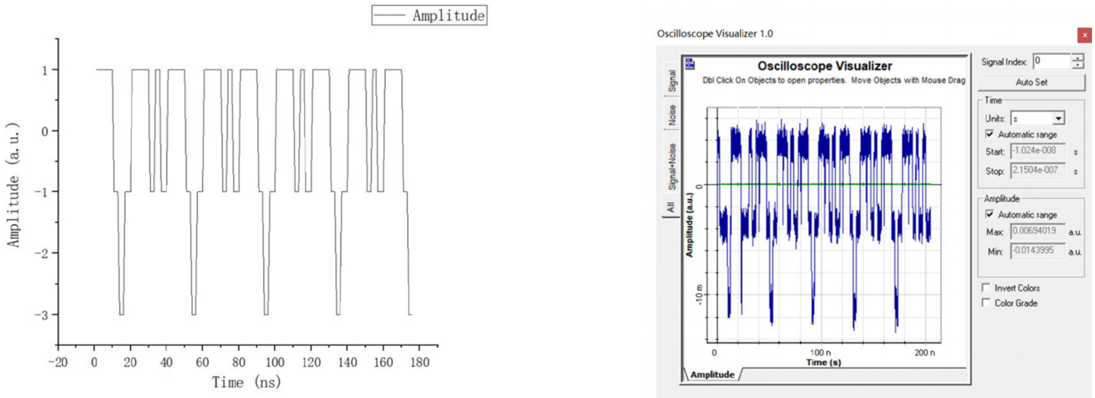


Fig. 4. Multi-user uplink communication simulation system diagram

Before analyzing the simulation results, theoretical calculations and analysis are performed: the three uplink signals 1010, 1100, and 1001 correspond to bipolar codes 1-11-1, 11-1-1, and 1-1-11, respectively, and are then transmitted according to the above delay times. The bipolar signal obtained from the oscilloscope when the uplink transmission of the three signals is performed according to the simulation method in Fig. 4 is shown in Fig. 5(b). From the comparison of the simulation results with the theoretical calculation results, it can be seen that the simulation results are in good agreement with the theoretical calculation results, except for the addition of necessary system noise. From the simulation results, it can be seen that in the case of asynchronous uplink access, the proposed passive optical network system has the same characteristics as CMDA random access, which can realize CDMA bipolar code transmission in the optical domain, which will enable PON technology to take full advantage of CDMA random access.



(a) (b)

Fig. 5. Signal Simulation Analysis for Multi-Lane Communication Receivers

3.2 Dispersion Simulation

The broad-spectrum light source transmits in the optical fiber, which causes dispersion and requires dispersion compensation in order to transmit over long distances. In the following simulation, a 20km single-mode fiber is used for transmission, and a fiber grating is used at the receiving end to compensate for the dispersion. Other simulation conditions are: LED light source, spectral width 6THz, optical power 130mw; single-mode fiber dispersion coefficient of 16.75ps/nm/km; in the terminal plus the ideal fiber grating compensation, through experimental methods to obtain: when the fiber grating compensation coefficient of 351ps/nm, can get the best dispersion compensation effect. The dispersion compensation experiment is shown in Fig. 7, the BER of the eye diagram: 1.96e-6 Q-factor greater than 4.6, the performance of the eye diagram is good, considering the need to add the CDMA spread spectrum gain, the system BER will be greatly reduced.

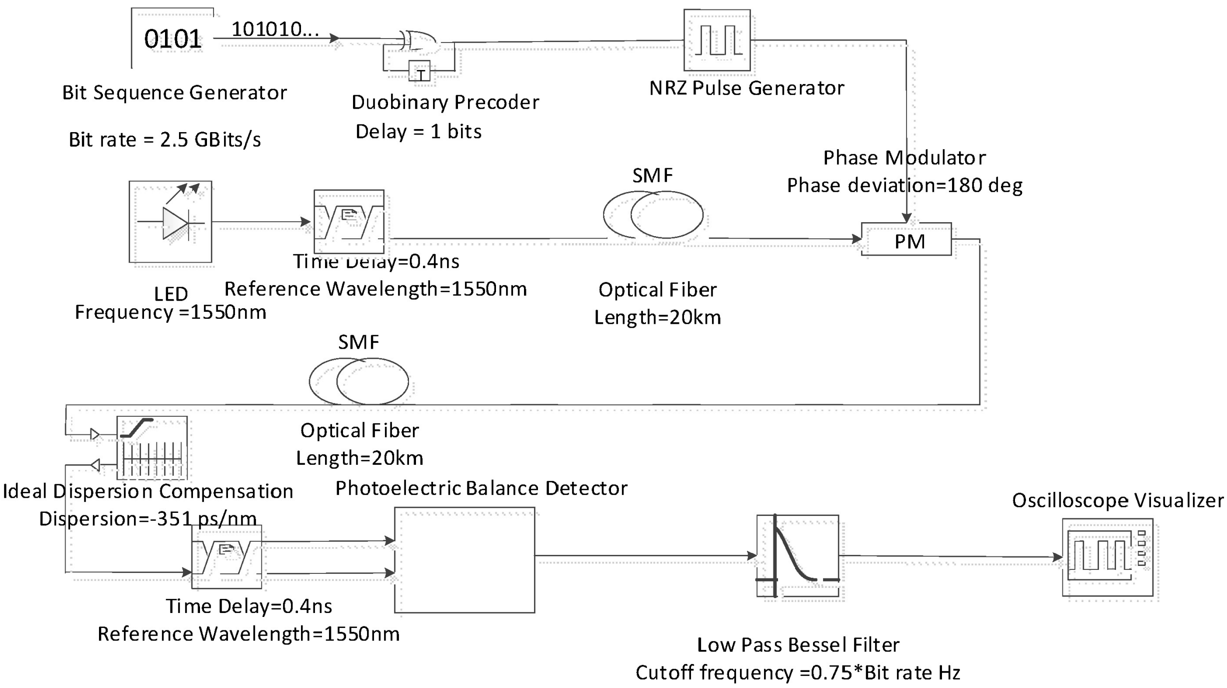


Fig. 6. Dispersion compensation simulation test

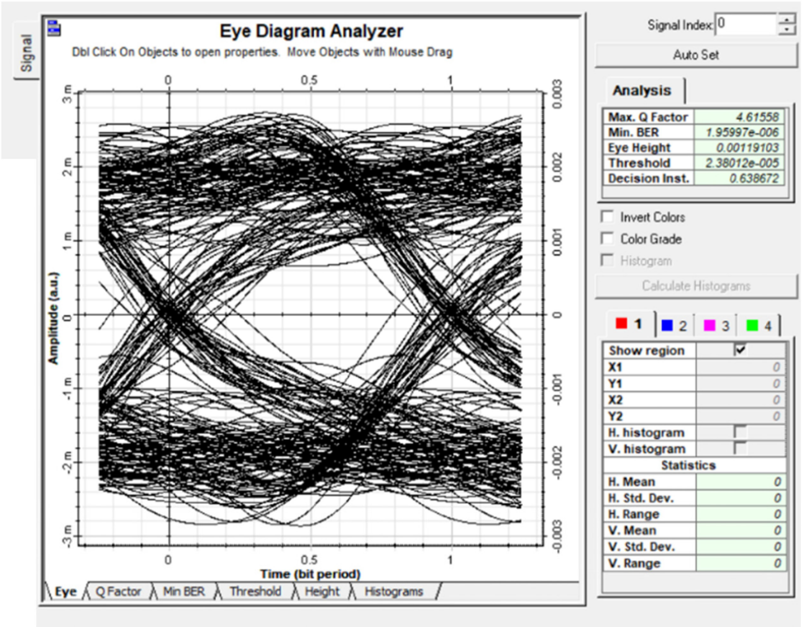


Fig. 7. Eye diagram after dispersion compensation

4 Conclusion

In this paper, an ECDM-PON uplink communication scheme based on low-coherent optical DPSK modulation is proposed and verified. The scheme combines low-coherent optical DPSK modulation with CDMA technology and uses a passive optical network to transmit the domain-coded code division multiple access (CDMA) signals. Simulation tests show that in the case of asynchronous uplink access, this passive optical network system has the same flexibility as the random access CMDA in the electrical domain, but also can solve the problem of dispersion in low coherent fiber optic communication, which has a good application prospect.

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