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Research on demodulation technology of atmospheric laser communication system base on CPolSK

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Abstract

In order to reduce the impacts of atmospheric turbulence and background light etc. factors to atmospheric laser communication system performance, the atmospheric laser communication system using circular polarization modulation technology is adopted and researched. This system uses polarization shift keying modulation (PloSK), which is a new standard digital modulation technique in optical communication field. In this modulation, two rotation states of the circle polarization light (left handed and right handed) representation logic signal ' 0 ' and ' 1 ', are used to information loaded and data transmission. In the receiver, the modulation optical signal is detected with dual differential probe method. Under the OptiSystem system simulation environment, several direct detection system model based on OOK intensity modulation, single rode circular polarization modulation and circular polarization modulation with balanced detection is constructed, and compares and analysis of the various communication system performance. The results show that: at the same parameter conditions, bit error rate of CPolSK system with balanced detection lower about two orders of magnitude than the OOK system and single rode CPolSK system, the eye diagram and the waveform chart are also significantly better than OOK system's. It can be seen, based on circular polarization shift keying (CPolSK) laser communication system with dual differential detection is superior on anti-interference of atmospheric interference, and reducing error rate, and will be easy to implement.

Key words: Optical communication; Circular polarization shift keying (CPolSK); Differential detection; Error rate;

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1. INTRODUCTION

Space optical communication (FSO) has some advantages such as a high transmission speed, communication capacity, the available bandwidth wide and good security, etc., has become the development trend of future communications. When the FSO optical signals transmitted in the atmosphere channel, affected by atmospheric turbulence and background noise and other factors, and greatly reducing the performance of the communication system, which greatly limits the FSO technology for further development and application.

The current FSO systems are mostly used intensity modulation / direct detection (IM / DD) method, but due to the disturbance and other factors directly affect the reliability of the detection results. Presented in this paper using circular polarization shift keying (CPloSK) [1-3] to modulate optical signal and transmit. The modulation use the polarization vector characteristics of light[4-5], encode to the polarization and modulation. It can be applied both binary and multi-band data transmission, and can also improve effectively the communication system sensitivity and error performance. This paper will also compare and analyze based on a variety of demodulation device base on CPloSK modulation with OOK modulation system.

2. CICULAR POLARIZATION SHIFT KEYING(CPloSK)

Figure 1 is a timing diagram of the circular polarization modulation and OOK modulation. Figure 1 (b) shown, CPloSK is used to characterize the data binary "0" and "1" with two circular polarization states the data, the intensity of pulse in the modulation process does not change, just the polarization state of the pulse changes. Right-handed circularly means logic "0", left-hand circularly indicates "1." With OOK modulation using pulse of the "pass - off" to characterize the "0" and "1" are different, Figure 1 (a) shown.

(a) (b)

Fig.1 Sequence chart of circular polarization modulation

Shown in Figure 2, the laser through the polarization beam splitter (PBS) are divided into orthogonally linearly polarized that is p light and s light, then modulate wherein a light beam. the modulated signals pass through the polarization beam combiner control (PBC) and complex to the same optical path, after a 1/4 wave plate (QWP), adjust the angle between the QWP fast (slow) axis and the propagation direction of the linearly polarized light of a certain value, linearly polarized light the post QWP becomes circular polarization with Sinistral and Dextral alternating; finally through the antenna out.

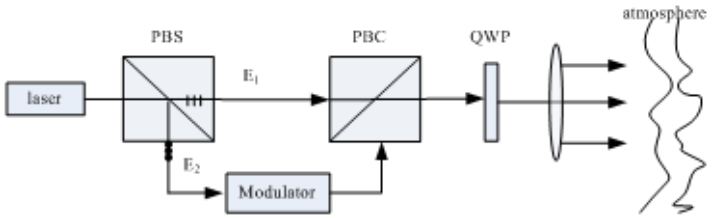


Fig.2 Schematic diagram of CPloSK

Shown in Figure 3, assuming that out of a light beam from the laser is formed by the two orthogonal linear polarized alternating, the two orthogonal linear polarization light, respectively E_1, E_2, the amplitude both are 1, and coincides the Y, X axis of the coordinate system each of. the angle of QWP fast axis and the X axis is θ, the Jones matrix of E_1, E_2 can be expressed as[6]:

$$E_1 = \begin{bmatrix} 0 \\ 1 \end{bmatrix}, \quad E_2 = \begin{bmatrix} 1 \\ 0 \end{bmatrix} \tag{1}$$

the Jones matrix of G can be expressed as:

$$G = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 - i\cos 2\theta & -i\sin 2\theta \\ -i\sin 2\theta & 1 + i\cos 2\theta \end{bmatrix} \tag{2}$$

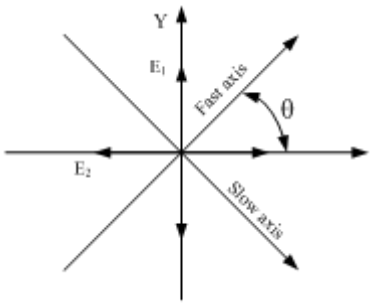


Fig.3 Diagram of coordinate system of E_1, E_2 and QWP

E1, E2 through QWP, converted to a new polarized light, and its Jones matrix Division expressed as:

$$E_1' = GE_1 = \frac{1}{\sqrt{2}} \begin{bmatrix} -i\sin 2\theta \\ 1 + i\cos 2\theta \end{bmatrix}, \tag{3}$$

$$E_2' = GE_2 = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 - i\cos 2\theta \\ -i\sin 2\theta \end{bmatrix} \tag{4}$$

By the Jones matrix of the circularly polarized light shows, when E_1' , E_2' for circularly polarized light, it must meet the following criteria:

$$\sin 2\theta = 1, \cos 2\theta = 0 \tag{5}$$

Only θ is times of $\pi/4$, so that ensure the light is circularly polarized light. when $\theta \neq \pi/4$, E_1', E_2' is ellipse polarized light and not light is circularly polarized light. For handy operation, there $\theta = \pi/4$, the Jones matrix Division of E_1', E_2' and wave plate can be expressed as:

$$E_1' = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 \\ i \end{bmatrix}, \quad E_2' = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 \\ -i \end{bmatrix} \tag{6}$$

$$G = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & -i \\ -i & 1 \end{bmatrix} \tag{7}$$

Linearly polarized light E_1, E_2 through the QWP, respectively to the left、right-handed circularly polarized light E_1' , E_2'.

Receiver receives the circularly polarized light through the atmosphere channel transmission, to demodulate the light single is the most important. In this paper, the receiver using a balanced probe shown in Figure 4. According to the optical path conversion reversible principle, the light through QWP, the circular polarized light into linearly polarized light. Left and right-handed circularly polarized light E_1' , E_2', through QWP, respectively, into linearly polarized light E_1'', E_2'' with orthogonal to both vertical. The same way, it can be deduced Jones

matrix

$$E_1'' = GE_1' = \begin{bmatrix} 1 \\ 0 \end{bmatrix}, \quad E_2'' = GE_2' = \begin{bmatrix} 0 \\ 1 \end{bmatrix} \tag{8}$$

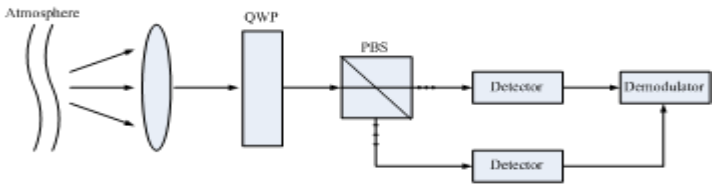


Fig.4 Receiver block diagram

The PBS prism breaks down the optical signals into two orthogonal polarization directions E_1'' , E_2'' , then detecte respectively by the detector two optical signals and achieve a photoelectric conversion. The converted signal to do the difference, then use judgment rules for data determination, you can get transport information.

3. COMPARATIVE ANALYSIS OOK COMMUNICATION PERFOMANCE WITH CPloSK

Sec. 3.1 Communication System Introduction

In OptiSystem simulation environment constructed OOK modulation system, and several circular polarization modulation systems. The receivers simulation model of circular polarization modulation systems are: single-channel receiver, two-way signal is first amplified and then re-differential, and before amplification to difference. By setting appropriate parameters, analysis the effect of different modulation schemes, different receiving programs on communication system performance, compare to the simulation results of OOK with CPolSK systems and difference two different scheme.

Fig.5 is the diagram of laser communication system based on OOK. Intensity modulated uses the presence or absence of optical signal's intensity to characterize and transmission information. By setting the receiver threshold of the appropriate system, then the decision circuit conversion the analog signal into a digital signal. Exceeds the threshold decision level will be sentenced to "1", and below the threshold level will be judged as "0"[7].

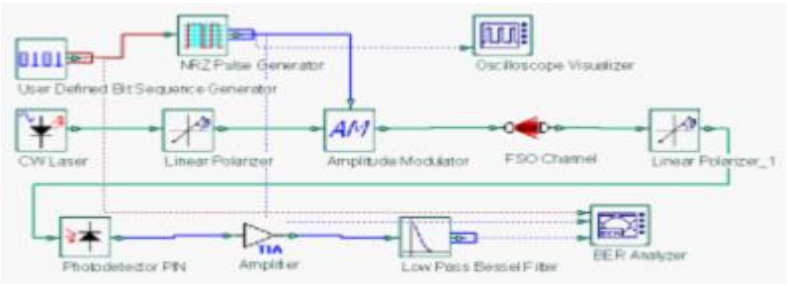


Figure4. The optical communication system based on OOK

Figure 6 is a single received CPolSK laser communication system modulation[8]. Based on CPolSK technique laser communication system with the left/right-handed circularly polarized light indicates transmission information to achieve the communication process. Shown in Figure 6, prior to detection in the PIN, at first pass Waveplate, the circularly polarized light becomes linearly polarized light through, and then through a prism the light beams into two ± 45 ° linearly polarized orthogonal, but only allows the 45 ° line

polarized light into the detector, and is detected demodulated "1" signal; otherwise, can be demodulated a "0" signal. Its demodulation principle is similar to OOK demodulation system.

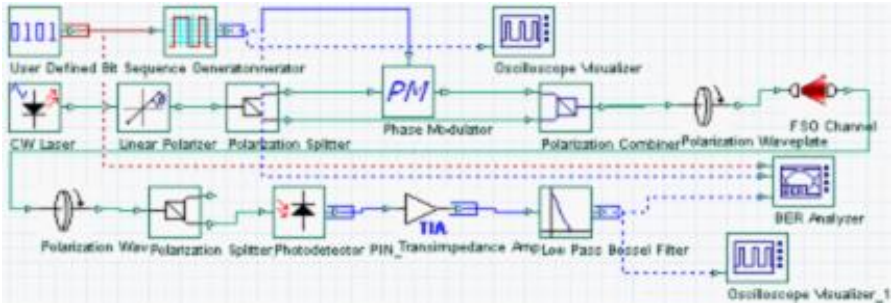


Fig.6 CPloSK system with single detection

CPolSK balance detection system transmits information with different rotation circular polarization[9]. And a single channel receiving CPolSK systems similar, at first Waveplate at the receiving end is used to the left / right-handed circularly polarized light into± 45 ° linearly polarized light and then be detected. Using polarization beam splitter (PBS) before the PIN detector into ± 45 ° linearly polarized light to separate two-way transmission, Fig.7-8 is two kinds of differential demodulation CPolSK systems, and which is respectively, for receiving with first two-way signal amplified and then do the poor, and amplification after do poor.

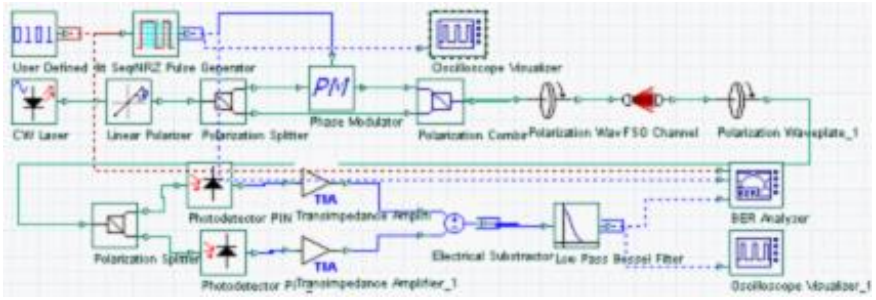


Fig.7 CPloSK system with balance detection (a)

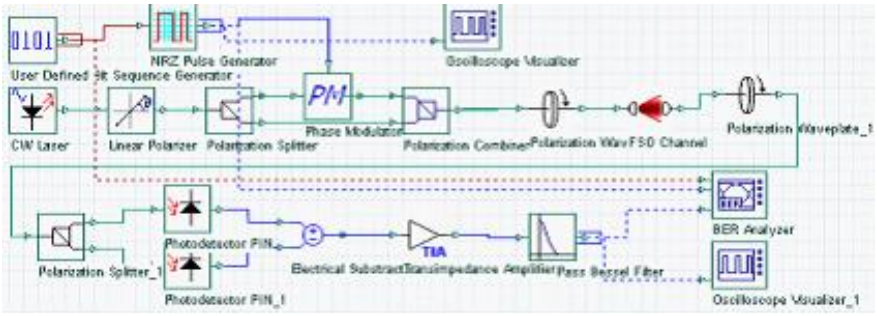
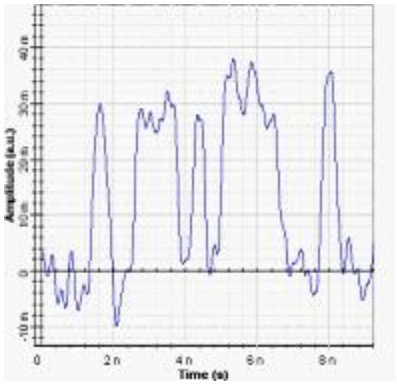


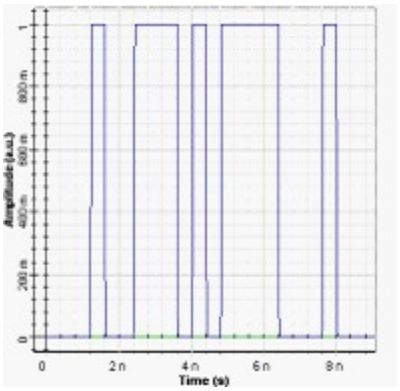
Fig.8 CPloSK system with balance detection (b)

Sec. 3.2 Performance Analysis

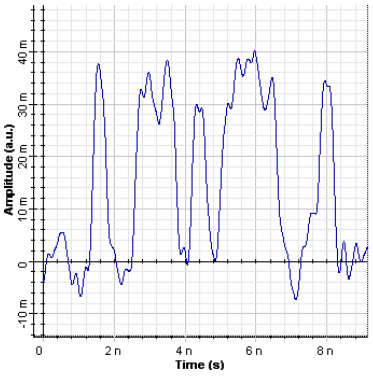
Here we have to analyze and compare the above structure these types of modulation system performance. System performance is expressed in many, here the main evaluation of these types of digital modulation systems the final receiving performance, such as in the same laser power, the same transmission channel environment, signal waveform diagram of the end receiver and system error rate performance. These simulation system parameters are set as follows：【10-13】laser transmitter power is set to 74mw (18.7dBm), communication speed is 2.5Gbit / s, atmospheric channel attenuation is 1.1dB/km (in this case, light haze【13】, visibility is less than 10km) [10], the communication distance is2km, detector sensitivity 1A / W.



(b)



(a)



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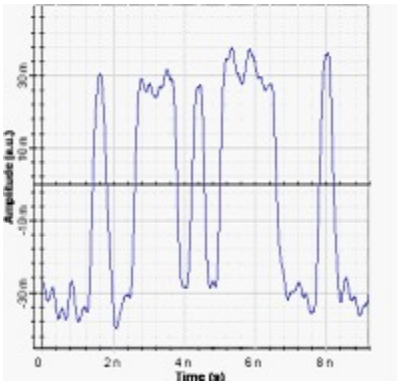
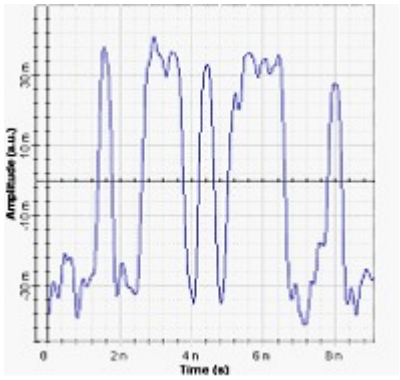


(d)



(e)

(a) Fig.9 The modulation signal

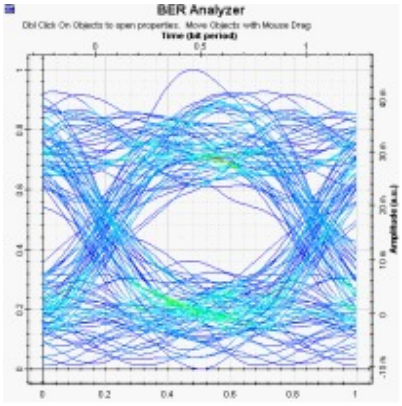
(b)Fig.10 The demodulation signal of OOK system

(c)Fig.11 The demodulation signal of CPolSK system single receiver

(d)Fig.12 The demodulation signal of CpolSK system first amplification

(e)Fig.13 The demodulation signal of CpolSK system first do difference

Fig.9-13 show the demodulated signal waveform of a few communication system with different modulation methods or different receiving. The figures show, OOK systems and single-channel receiving CPolSK system has been demodulated and the signal waveform is similar, both about the same performance. CPolSK communication system with balance detection, the demodulation signal waveform amplitude is the two times than above. In this test condition, from the received waveform, we can't compare well the properties of good or modulation system performance of these types, you can compare their error rate.



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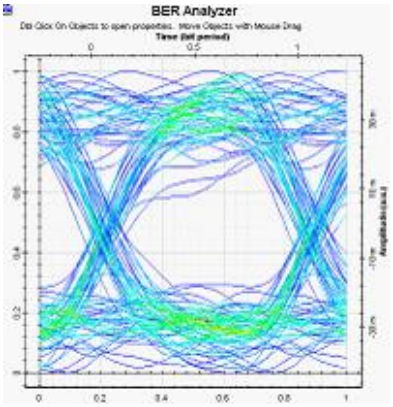
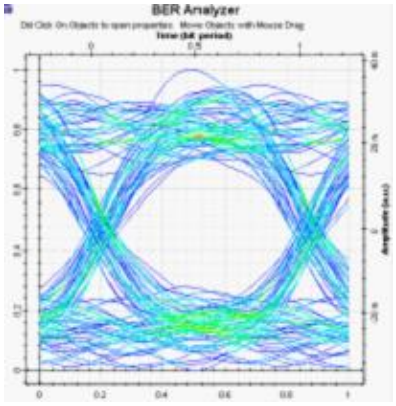


CPloSK first amplification



CPloSK first do difference

Fig.14 eye diagrams of OOK system and two CPloSK system

Figure 14 shows the eye diagrams can be seen, the eye diagram quality of the CPloSK system has been

balanced detection better than OOK system, and eye diagram is relatively clear, the "eyes" opening relatively large. The bit error rate of polarization modulation system with differential receiver is lower at least two orders of magnitude than OOK system. In the circular polarization modulation Dual differential reception system, the signal bit error rate of the dual signal at first subtraction replay amplification than subtracting after amplified is smaller. [14]

4. CONCLUSION

This paper describes the polarization shift keying modulation principle and designs several different receiver Scheme atmospheric laser communication system based on circular polarization shift keying. Based on this, a communication procedure of a laser OOK communication system, a single channel receiver CPolSK system and two balance detection CPolSK communication system are carried on computer simulation, compare and analysis of the performance of their communication system. The results show that: due to the laser beam polarization characteristics of stability in the atmosphere transmission process, based on the parameters of laser polarization modulation / demodulation techniques in anti-interference, improve the transmission rate and lower bit error rate, and so has a unique advantage. The receiving signal amplitude of balanced detection CPolSK atmospheric laser communication system is OOK systems and single-channel receiver CPolSK system twice. Under the same conditions and parameters, the error rate of CPolSK communication system with balance detection lower about 2 orders of magnitude than OOK system. Differential probe circularly polarized Shift Keying atmospheric laser communication technology effectively to improve the performance of the communication system in the future free-space optical communication field has a broad space for development and application prospects.

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