A full duplex FSO transmission system using RZ-4PAM downlink signals with 67% duty cycle and AMI uplink signals

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Abstract. To improve the transceiver quality of Free Space Optical (FSO) system and ensure that user access is feasible the network, a high-speed full-duplex 100 meters FSO transmission scheme using 67% duty cycle RZ-4PAM downlink and alternative mark inversion (AMI) uplink signals is designed system. In the downlink, one PAM sequence generator and one M-ary pulse generator (MPG) module are used to generate 67% RZ-4PAM optical signals at 10Gbit/s through a Mach-Zehnder intensity modulator (MZM). The upstream AMI signals generator by the pseudo-random binary sequence (PRBS) generator and the precoding process. We have measured optical spectrums, time-domain waveforms and eye diagrams before and after signals transmission by system simulation. The transceiver performance of the downstream RZ-4PAM with 67% duty cycle and upstream AMI optical signals the in the 100m FSO transmission system is analyzed.

Keywords: FSO, Full duplex, AMI, 67% RZ-4PAM, Eye diagram.

1 Introduction

FSO is a broadband effective access mode using laser beam as carrier to transmit and receive optical wireless signals and it supports high speed signals transmission by point-to-point or point-to-multipoint connect [1]. It is the combination of optical fiber communication and wireless communication, which is the popular technology. Compared with other traditional methods, such as microwave or optical fiber communication, FSO has the advantages of higher transmission rate, higher capacity, high confidentiality, low power consumption, no spectrum license, and easy installation [2]. However, the optical signal transmission in the atmosphere is easily affected by the atmospheric turbulence effect. To further improve the communication capacity and transceiver quality of the FSO system, and meet the growing demand for telecommunications services, a few advanced modulation technologies with high spectral efficiency have been introduced. Recently, OFDM

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(Orthogonal Frequency Division Multiplexing)[3], PAM (Pulse Amplitude Modulation)[4], AMI (Alternate Mark Inversion)[5], LDPC (Low-Density Parity-Check)[6] are main modulation formats in the application of broadband communication. PAM is a high-order modulation method, that can effectively improve the transmission rate. It can also be used in simple and low-cost Intensity Modulation Direct Detection (IM/DD) systems. Compared with binary formats such as Non-return to Zero (NRZ), PAM4 signals have higher spectrum efficiency and larger dispersion tolerance, and can achieve high data rate transmission in limited bandwidth[7]. Compared with 33% and 50% RZ-4PAM signals, the spectrum utilization of 67% RZ-4PAM signal is significantly improved[8]. AMI signals have the characteristics of no DC component and small low-frequency component, which is not easy to cause signal distortion in channel transmission[9]. The introduction of AMI and 67% RZ-4PAM signals in full duplex FSO system can improve the frequency band and transmission efficiency, so the communication bandwidth can be enlarged and the system has good transceiver and transmission performance.

We design a 10Gbit/s full-duplex FSO transmission system with downlink 67% duty cycle RZ-4PAM and uplink AMI modulation signals, and the bidirectional transmission distance is 100m. We have measured optical spectrums, time-domain waveforms and eye diagrams before and after signals transmission in the downlink and uplink of the system simulation. The receiver sensitivity before and after 10Gbit/s downlink and uplink using 67% duty cycle RZ-4PAM and AMI signals transmission is simulated and analyzed.

2 Full-duplex FSO system

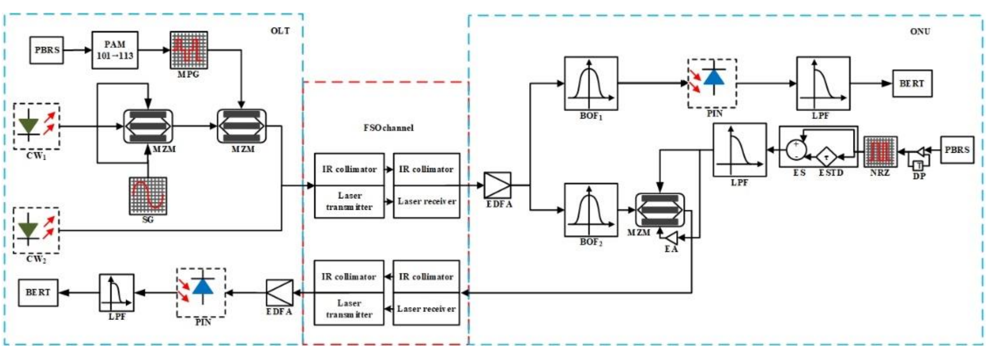

Fig. 1. High speed full duplex FSO transmission system using the downlink 67% duty cycle RZ-4PAM and AMI uplink signals.

A high-speed full-duplex FSO transmission system using the downlink 67% duty cycle RZ-4PAM and AMI uplink signals is shown in Figure 1. At the optical line terminal (OLT), One continuous wave$_1$ (CW_1) laser sends a continuous wave signal to the MZM at a frequency of 193.1 THz, and the signal generated by the sine wave is sent to the MZM to generate optical signals with 67% duty cycle. A PBRS produces a random binary sequence, which is transfer to the 10Gbit/s 4PAM electrical signal by a PAM generator and an MPG module. The 4PAM electrical signal is input into another MZM to generate the RZ-4PAM optical signal with 67% duty cycle. Then the modulated optical signal and another optical carrier signal from CW_2 laser at 193.16THz passes through 100m long free space channel. The RZ-4PAM optical signal is amplified through an erbium-doped fiber amplifier (EDFA) to achieve out of band noise filtering and attenuation per-compensation for 100m free space channel transmission. The received optical signal is divided into two parts. One optical signal is first launched into a third-order Bessel filter$_1$ (BOF_1) with center frequency 193.1THz, 3dB bandwidth of 10GHz and modulation order of 4 level, and then the output optical signal is directly detected by one photoelectric detector (PIN) to achieve photoelectric conversion. One low-pass filter (LPF) with 7.5GHz bandwidth is used for achieving electrical noise filtering. The other optical signal passes through BOF_2 with center frequency 193.16THz for generating the uplink carrier. At the ONU, one PBRS generates a random binary sequence, and the double binary precoder is used for pre-coding, which is then transfer to the 10Gbit/s AMI electrical signal by an NRZ pulse generator module. The AMI electrical signal is processed by an electronic subtractor and an electrical signal time delayer to generate the AMI optical signal. The optical AMI signal is generated by one MZM cascaded the electrical low-pass filter. The generated AMI optical signal is transmitted in 100m free space channel, and then is directly detected by one PIN at the OLT receiver.

3 Results

Figure 2 shows that the optical spectrum diagrams before and after 100m free space transmission using the downlink 67% duty cycle RZ-4PAM and AMI uplink signals. Figure 2(a) describes the optical spectrum before the downlink transmission of 67% duty cycle RZ-4PAM signal. The optical spectrum diagram of the downlink receiver is given in Figure 2(b), including one modulated carrier and one unmodulated carrier. The frequency of the unmodulated carrier is 193.16THz, while is used as the uplink carrier remodulation. Figure 2(c) illustrates the optical spectrum diagram before the uplink transmission of AMI signal combines two optical carriers. The downlink carrier is suppressed obviously and the uplink carrier is modulated. The optical spectrum after uplink transmission is presented in Figure 2(d). The peak of spectrums before and after AMI signal transmission are suppressed, which can improve the spectrum efficiency. Since the EDFA is used to compensate for the transmission attenuation caused by miscellaneous molecules and microparticles in the atmosphere. The peak power of the optical power of this transmission system keeps constant before and after transmission.

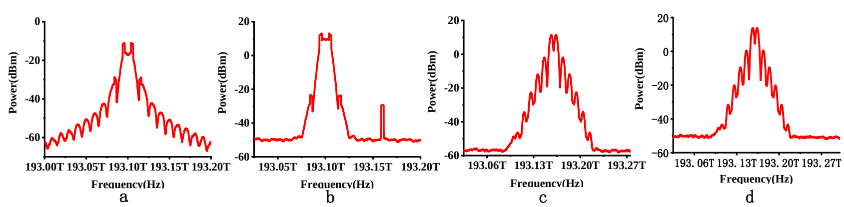

Fig. 2. Optical spectrums of the downlink 67% duty cycle RZ-4PAM and AMI uplink signals before and after transmission.

The time-domain sequential waveform diagrams and the eye diagrams of the downlink 67% duty cycle RZ-4PAM and AMI uplink signals before and after transmission over 100m free space link are extracted to evaluate the system performance, as show in Figure 3 and Figure 4. The downlink 67% duty cycle RZ-4PAM and AMI uplink signals time-domain waveforms of the transmission and received can be seen clearly that has the same change curves, but simply part of the waveform has a slight change are illustrated in Figure 3. The eyes opening is obvious are show in Figure 4, and it is found that the downlink 67% duty cycle RZ-4PAM and AMI uplink signals respectively passes through 100m free space transmission, while slight transmission impairments are introduced to make the eyelids become thickened slightly.

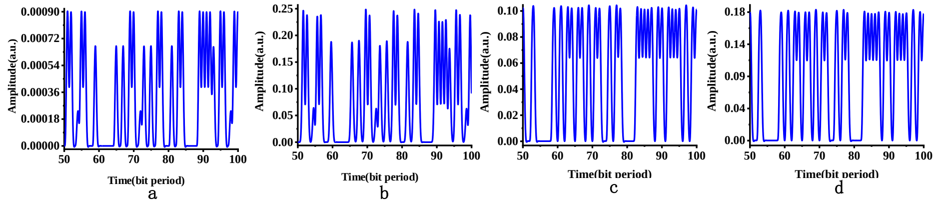

Fig. 3. Time-domain waveforms of the downlink 67% duty cycle RZ-4PAM and AMI uplink signals before and after transmission.

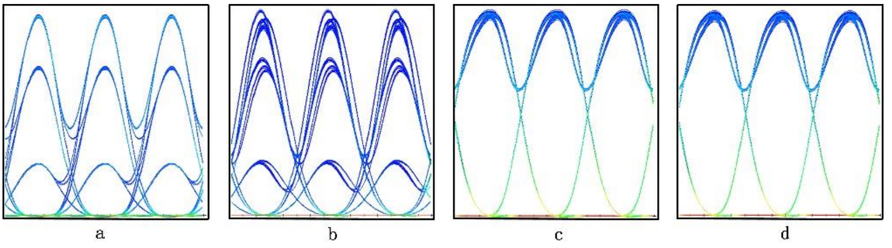

Fig. 4. Eye diagrams of the downlink 67% duty cycle RZ-4PAM and AMI uplink signals before and after transmission.

4 Conclusions

We have demonstrated a novel full-duplex 10Gbit/s FSO transmission system scheme by simulation, which can realize high-speed optical signals transmission, using RZ-4PAM downlink signals with 67% duty cycle and AMI uplink signals. We have measured optical spectrums, time-domain waveforms and eye diagrams, and analyzed the transceiver and transmission performance. The results show that, this scheme can improve the spectral efficiency of signal in the limited bandwidth resource, and complex DSP process has not been adopted. It is a potential application scheme in future FSO transmission systems for realizing high speed, large bandwidth information access.

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