Proposal of A Star-16QAM System Based on Intersymbol Interference (ISI) Suppression and Coherent Detection

Liang Zhang, Xiaofeng Hu, Tao Wang, Qi Liu, Yikai Su
State Key Lab of Advanced Optical Communication Systems and Networks,
Department of Electronic Engineering, Shanghai Jiao Tong University, Shanghai200240
E-mail: yikaisu@sjtu.edu.cn   Phone: 021-34204425

ABSTRACT: We propose a 40Gbit/s star-16QAM(to define) system based on ISI(to define)-suppression technology and coherent detection. ISI-free BPSK optical signals generated by Mach–Zehnder modulators (MZM) and continuous wave (CW) lights are used to realize a star-16QAM signal. As a result, the obtained star-16QAM signal is also ISI-free. It turns out that the proposed ISI free star-16QAM has better performance in terms of eye opening and constellation diagram comparing with two conventional star-16QAM signals transmitted through 80-km standard single-mode fiber (SSMF) and detected by a coherent receiver.

Keyword list: ISI suppression, star-16QAM, coherent detection

1. Introduction

Multi-level modulation formats have become a key technology to increase the transmission capacity, and improve tolerances to chromatic dispersion (CD) and polarization mode dispersion (PMD)[1]. Quadrature phase-shift-keying (QPSK)[2], amplitude-and-phase-shift-keying (APSK) [3] and quadrature-amplitude-modulation(QAM) have been extensively investigated. Among various multi-level modulation formats, 16-QAM, which carries four bits per symbol, is an attractive candidate. With respect to the constellation distributions, 16-QAM can be categorized to two groups, square 16-QAM and star 16-QAM. Recently, most researches focused on square-16QAM and multiple schemes were proposed and experimentally demonstrated [4][5]. However, compared with square 16 -QAM, star-16QAM has a better OSNR performance resulting from the larger minimum Euclidean distance when transmitted with the same power. In Ref [6][7], two different schemes of star-16QAM were proposed, however, they experienced much ISI(to define) mainly induced by non-ideal electrical signals and high-speed electrical driving amplifiers[8].

In this paper, we propose a new scheme of 40Gbit/s star-16QAM transmitter based on ISI-suppression technology. The generated ISI-free star-16QAM signal is transmitted through an 80-km standard single-mode fiber (SSMF), a wide-opening eye diagram and clear constellation map of star-16QAM are observed. In order to demonstrate the advantages of the proposed ISI-free transmitter, we study two conventional schemes of 40-Gbit/s star-16QAM generation, where only two-level signals are used as

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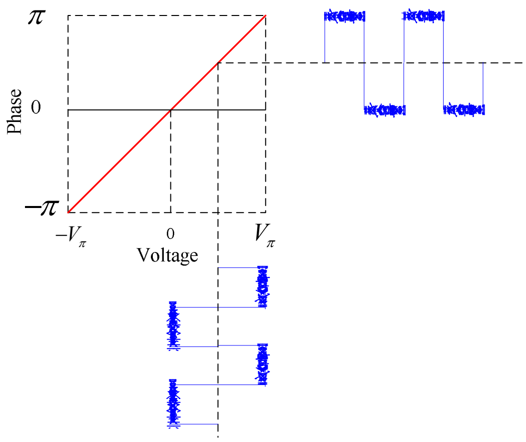
electrical drivers. It turns out that the proposed ISI-free star-16QAM has better performance in terms of eye opening and constellation diagram.

2. Principles

2.1. Principle of ISI free BPSK signal



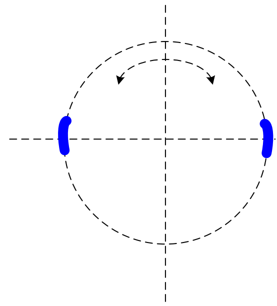
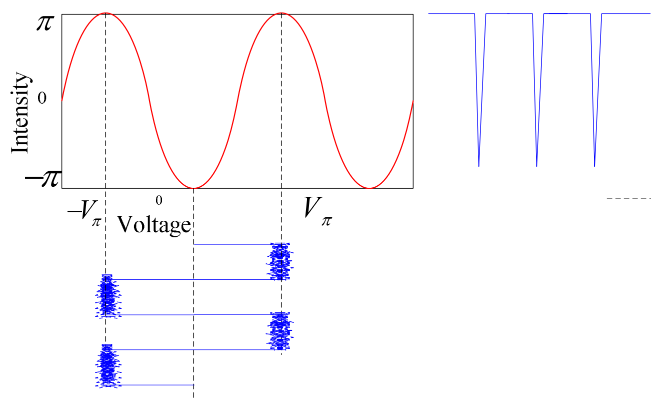


Fig. 1(a) transmission curve of PM (b) constellation diagram of BPSK1



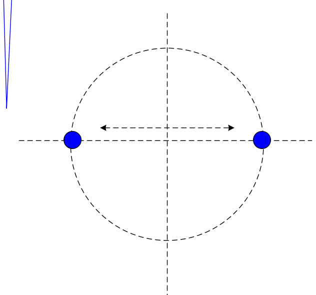


Fig. 2(a) transmission curve of MZM (b) constellation diagram of BPSK2

In this paper, we regard fluctuations of electrical signals, mainly induced by non-ideal electrical signals and high-speed electrical driving amplifiers, as the main cause of ISI. We also define the term “ISI free” as no signal point fluctuations on constellation diagram(better put a reference, as people have different understanding of ISI). The principle of BPSK modulation using phase modulator (PM) is shown in Fig. 1(a). The electrical driver is imperfect and there are significant fluctuations on the two levels (0,V_π). After phase modulation, a BPSK signal is obtained. Due to straight-line transmission curve of a PM, the generated BPSK signal experience much phase noise and is not ISI-free. Another method of performing binary phase modulation is using a Mach–Zehnder modulator (MZM) with transmission curve depicted in Fig. 2(a). A BPSK signal can be obtained when the MZM is biased at null point and driven by an electrical signal with 2Vπ amplitude. Since the phase of the optical field reverses its sign upon transitioning through a minimum in the MZMs power transmission curve, a perfect 180°phase shift is achieved when two neighboring intensity transmission maxima have opposite optical phase. Furthermore, the fluctuations of non-ideal electrical driving signal are suppressed because of the flat voltage-field conversion at the peaks of sinusoidal transmission curve of the MZM. Thus the generated BPSK signal with a MZM is ISI-free. Compared with the constellation diagram depict in Fig. 1(b), the generated BPSK signal has better constellation, shown in Fig. 2(b).

2.2. Principle of ISI free star-16QAM signal

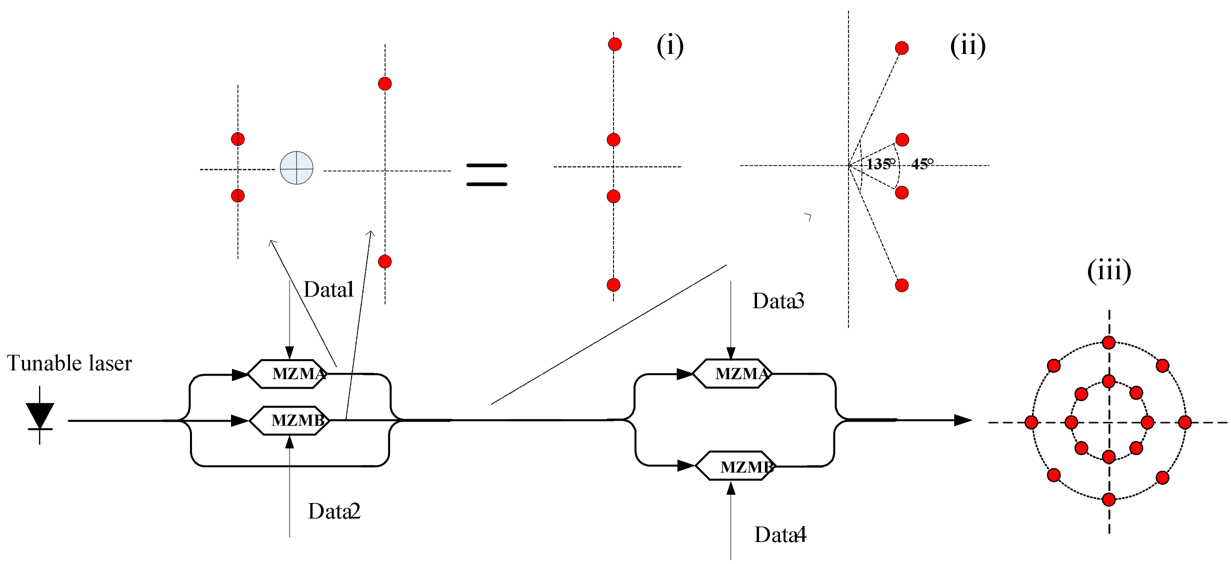


Fig.3 Scheme diagram of the generation of the ISI free star-16QAM

By combining two ISI free BPSK signals with a 90°phase shift, an ISI-free quadrature phase shift key (QPSK) signal can be obtained. Furthermore, one can achieve ISI-free star-16QAM signal by interfering or tandem-modulating ISI-free BPSK signals and continuous wave light (CW). The proposed scheme diagram is shown in Fig. 3, where the transmitter consists of two integrated modulators. Two parallel sub-MZMs and an un-modulated arm compose the first integrated modulator. By constructively interfering two ISI free BPSK signals generated by the two sub-MZMs, respectively, a 4-APSK signal is obtained, as depict in Fig.3 (i). After interfering with the un-modulated CW light with a 90°phase difference, the original 4-APSK signal is shifted to an offset position which is shown in Fig. 3(ii).The second integrated modulator is a dual-parallel MZM. By further QPSK modulating the offset 4-APSK signal in the modulator, a star-

16QAM signal is obtained. Since we use ISI-free BPSK modulators and CW light as building blocks, the star-16QAM signal is ISI-free. All electrical divers used in the transmitter are 10Gbit/s, therefore, the generated star-16QAM is 40Gbit/s.

3. Simulation and results

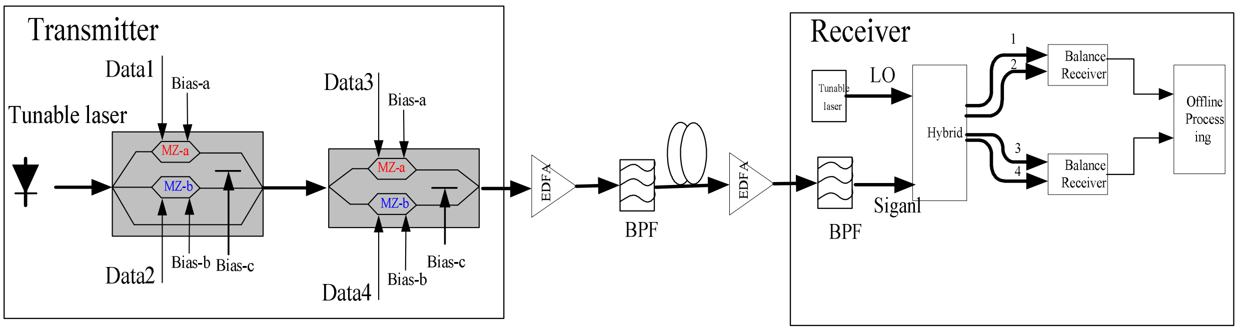


Fig. 4 Setup of the proposed system

To study the feasibility and transmission performance of the proposed transmitter, we perform a simulation with a setup depicted in Fig. 4, using VPI TransmissionMaker. At the transmitting side, a distributed feedback (DFB) laser with a linewidth of 100 KHz is used as continuous wave (CW) light source, which is modulated by the transmitter to produce an ISI-free 40-Gbit/s star-16QAM signal. The electrical drivers used in the transmitter have lots of fluctuations, shown in Fig. 5(a). The output of the transmitter is amplified by an erbium-doped fibre amplifier (EDFA) to 0dBm and filtered by a tunable bandpass filter (BPF) with a bandwidth of 1.6 nm. At the receiving terminal, coherent detection is performed. Another DFB with the same frequency and phase is used as local oscillator (LO), which is mixed with the received star-16QAM signal in an optical 90-degree hybrid. The outputs of the hybrid are detected by two balanced detectors (BDs) with the same performance. The real and imaginary parts of the star-16QAM signal are obtained by simultaneously sampling the outputs of the receivers. The sampled data are then processed off-line, which is realized using MATLAB program, including resampling, carrier phase estimation, and constellation recovery.16384 bits are sampled in the system. The back-to-back (BTB) eye diagram and constellation map of the ISI-free star-16QAM are shown in Fig.5 (b) and Fig. 6(a). One can see that the fluctuations of electrical signals are suppressed. As a result, the feasibility of the proposed scheme of ISI-free star-16QAM is verified.

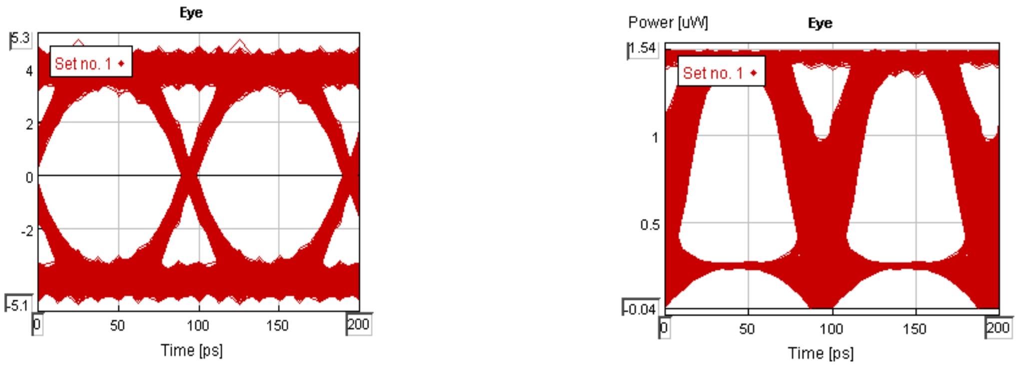


Fig. 5 (a) Eye diagram of 2-level electrical driver (b) eye diagram of ISI free star-16QAM

What's the launched signal power at the input of the transmission fiber? This affects the transmission performance. After transmission through an 80-km standard single-mode fiber (SSMF), the signal is boosted by a second EDFA to 2dBm. A 16-km dispersion compensating fiber (DCF) is used to compensate CD(to define) accumulated through the transmission link. The SSMF has a dispersion D = 16ps/(nm·km), a dispersion slope S = 0.06 ps/(nm2·km), a nonlinear index γ = 1.31W-1/km, and a loss α =0.2dB/km. The DCF parameters are D = −80 ps/(nm·km), S = −0.18 ps/(nm2·km), γ = 2.64W-1/km, and α = 0.6dB/km, respectively. The signal is boosted to 0dBm and then coherently detected in the receiver. It is seen that after 80-km transmission, the constellation map of ISI-free star-16QAM is still clear enough, as depicted in Fig.6 (b).

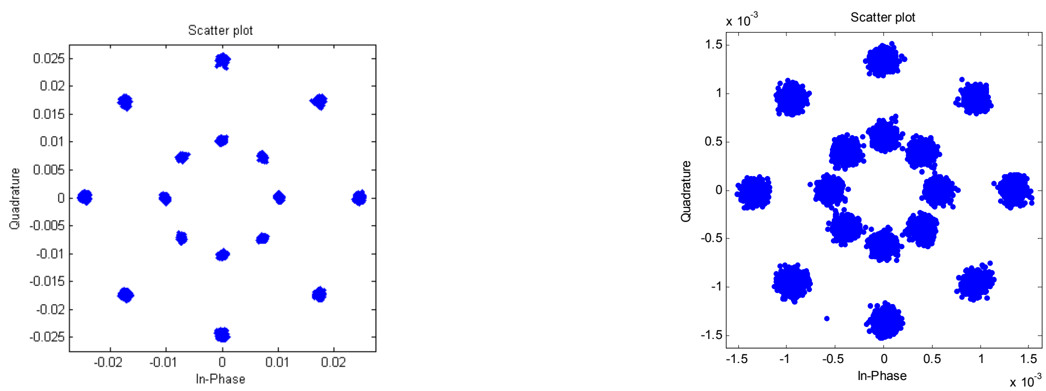


Fig. 6 (a) BTB constellation map of ISI free star-16QAM (b) constellation map after 80-km transmission

In order to compare the performance of the ISI-free star-16QAM signal with that of previously proposed ones, we generate a star-16QAM signal using the scheme demonstrated in Ref [6], where the transmitter was designed with three phase modulators in series to generate an 8PSK signal followed by a MZM as an intensity modulator to achieve a star 16-QAM signal. The back-to-back (BTB) eye diagram and constellation map of the generated star-16QAM are shown in Fig.7 (a) and Fig. 7(b), respectively. The constellation map after the 80-km transmission link is shown in Fig.7 (c).

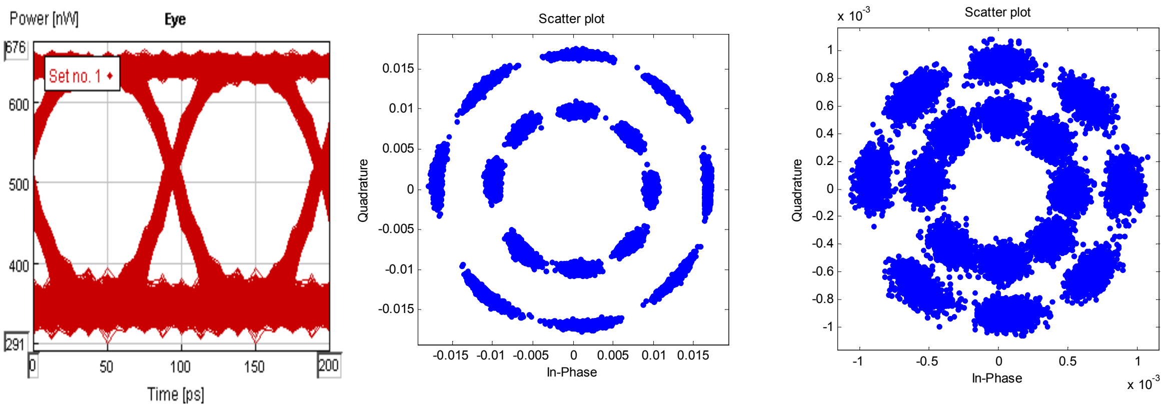


Fig. 7 (a) BTB eye diagram (b) BTB constellation map (c) constellation after 80-km transmission

Another scheme to generate star-16QAM signal was proposed in Ref [7], where the transmitter was composed of three cascaded modulators. The CW was modulated by a Dual-parallel MZM (DPMZM) to generate a QPSK signal, which was further modulated by a PM to obtain an 8PSK signal. A MZM served as an intensity modulator to obtain a star 16-QAM signal. The BTB eye diagram and constellation map of the generated star-16QAM signal are shown in Fig. 8 (a) and Fig. 8 (b), respectively. Note that the constellation map after 80-km transmission, depicted in Fig. 8(c), can not achieve error-free.

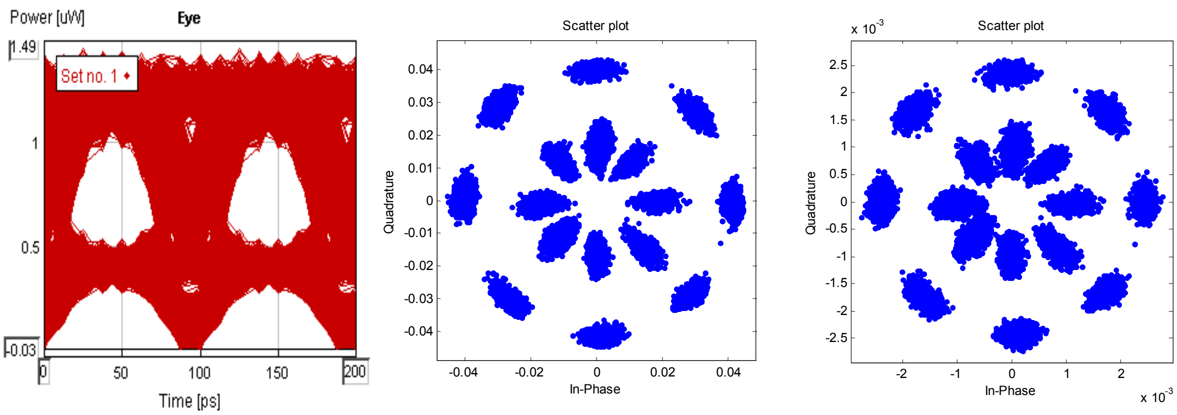


Fig. 8 (a) BTB eye diagram (b) BTB constellation map (c) constellation after 80-km transmission

Compared with two previously proposed schemes of star-16QAM transmitter, We use two-level signals for electrical drivers. The results show that the ISI-free star-16QAM has better tolerance to the fluctuations of electrical drivers. Furthermore, the proposed ISI-free star-16QAM transmitter is practical and can be easily realized by integrating them into a single chip as commercial DQPSK modulators.

4. Conclusion

We have proposed an ISI-free star-16QAM transmitter based on ISI-suppression technology. We also verify the feasibility of the proposed transmitter and investigate the transmission performance of the generated star-16QAM signal. Compared with two previously proposed schemes of star-16QAM, the proposed ISI free star-16QAM has better performance in terms of eye openings and constellation diagrams.

5. Acknowledgement

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6. References

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