

PERFORMANCE EVALUATION OF AN EFFICIENT RZ-MQAM MODULATION SCHEME IN ALL-OPTICAL OFDM TRANSMISSION SYSTEMS

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ABSTRACT

All optical orthogonal frequency division multiplexing (AO-OFDM) technique is a promising technique and employed in many military applications for data transmission over long distance. But AO-OFDM signals are very sensitive to nonlinear distortion and these systems suffer from nonlinear impairments. This paper describes a novel nonlinear phase noise reduction technique by decreasing interaction time between subcarriers in AO-OFDM transmission systems. This technique mitigates the effects of nonlinearity on all-optical OFDM transmission systems and improves performance of transmission systems. The proposed AO-OFDM transmission system has been successfully simulated and analyzed for estimating phase noise due to cross-phase modulation, self-phase modulation and four-wave mixing. The proposed RZ-8QAM AO-OFDM system with 29 subcarriers is examined and the transmission distance is fixed at 550km.

Keywords: fiber optic communication; All-optical OFDM; nonlinear fiber impairment; nonlinear phase noise.

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1. INTRODUCTION

AO-OFDM has ability to overcome electronic process limitation and decrease system impairments such as chromatic dispersion. This technique also can decrease power consumption and mitigate different transmission impairments but still suffers from nonlinear phase rotation in each subcarrier due to phase noise. In one OFDM transmission system phase rotation can destroy the orthogonality between subcarriers and consequently results in inter-carrier interference (ICI). AO-OFDM systems are using optical FFT (OFFT) instead of electrical FFT and can implement IFFT in the optical domain [1-2]. Therefore, AO-OFDM can overcome the electronics speed limit and achieve higher data rate.

AO-OFDM technique also can avoid some of the transmission impairments such as polarization modal dispersion (PMD), chromatic dispersion (CD) and inter-symbol interference (ISI) but AO-OFDM transmission systems still suffer from nonlinearity [2-3]. Nonlinear effects may happen in optical transmission systems at the transmitter side, fiber channel or transmission link, and at the receiver side. The number of subcarriers, number of amplifiers, subcarrier power, and transmission length determine the nonlinear phase noise in optical transmission systems [1-2]. Phase noise can limit the transmission distance, restrict the performance and consequently decrease the spectral efficiency (SE) in AO-OFDM transmission systems (Tang et al., 2013).

In one simple AO-OFDM transmission system, comb laser source or Continuous Wave (CW) laser sources generate optical subcarriers, then these subcarriers separated by de-multiplexer. After separation of an optical subcarriers or tones, each tone is independently modulated with various type of modulation such as Quadrature amplitude modulation (QAM) or Quadrature Phase-Shift Keying (QPSK) [3-4]. It is important to note that, the AO-OFDM systems with N optical tones require N independent modulators.

After modulating process finished, the modulated parallel optical streams are combined by multiplexer and transmitted through fiber channel. At the receiver side, the AO-OFDM signal is de-multiplexed and detected [5]. Nowadays, there are different technologies to realize the all-optical IFFT/FFT blocks, technologies such as arrayed waveguide gratings (AWGs), multi-section Sagnac interferometers and cascaded Mach-Zehnder delay interferometers in

planar lightwave circuits [6].

2. METHODOLOGY

This section describes the transmitter side, transmission link and receiver side of the proposed AO-OFDM transmission system.

2.1. All-Optical OFDM Transmitter

Fig. 1 shows the optical comb generator part contains two phase modulators (PMs) and an intensity modulator (IM) to generate subcarriers in the transmitter side. Optical frequency comb generator (OFCG) is fed by a CW laser source, the laser frequency and linewidth is 193 THz and 110 kHz respectively. As shown in Fig. 2, the transmission side includes the wavelength selected switch, optical beam combiner, and OFCG (Hillerkuss, 2010). OFCG can generate 29 subcarriers and these subcarriers are modulated individually with a symbol rate equal to 25Gsymbol/s. To keep orthogonality among the OFDM subcarriers, the frequency spacing is set to $\Delta f = 25$ GHz. Therefore, duration of one OFDM symbol is set to $T_s = 1/\Delta f = 40$ ps.

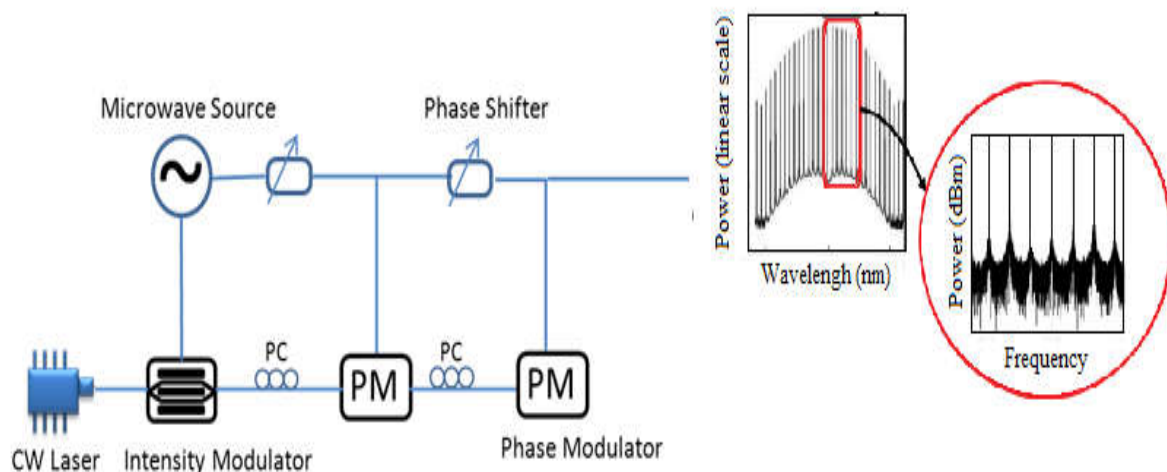


Fig.1. Optical frequency comb generator (OFCG)

In the next step, a wavelength selection switch must split the subcarriers and make them ready for modulation. In the proposed system, all 29 subcarriers are modulated individually with optical QAM modulators then all of modulated subcarriers are directly combined to generate 8QAM OFDM signal. By using one RZ carver behind each modulator system can generate

RZ-8QAM signal. In this system, RZ-8QAM OFDM signal is produced by combining modulated subcarriers. In the next step, resultant signal is launched to transmission link and fiber spans.

2.2. Transmission Link

As shown in Fig. 2, the proposed transmission link employs multi-spans fiber loops. Each fiber span contains optical amplifier (OA), Standard Single Mode Fiber (SSMF) and Dispersion Compensation Fiber (DCF) [2, 10]. By utilizing OA every 55 km, the attenuation and fiber losses is completely compensated but each OA make noise along transmission link. In the proposed system, the noise Fig. of each OA is 6dB. To stop data losses and avoid of impairments such as ICI [7], the accumulated dispersion in transmission link must be compensated. Therefore, in each span DCF is employed after SSMF to compensate dispersion optically [8-9].

2.3. All-Optical OFDM Receiver

Receiver utilizes All Optical FFT (OFFT) to convert serial signals to parallel signals and employs coherent 8QAM to demodulate the transferred signals. For four orders OFFT, 3 cascaded Mach-Zehnder Interferometer (MZI) are employed. First MZI time delay is set to $T_s/2$, but the time delay of second and third MZIs is adjusted to $T_s/4$. In first MZI, phase shift is set to 0 rad, and phase shift of two parallel MZIs is adjusted to $\pi/2$ rad and 0 rad.

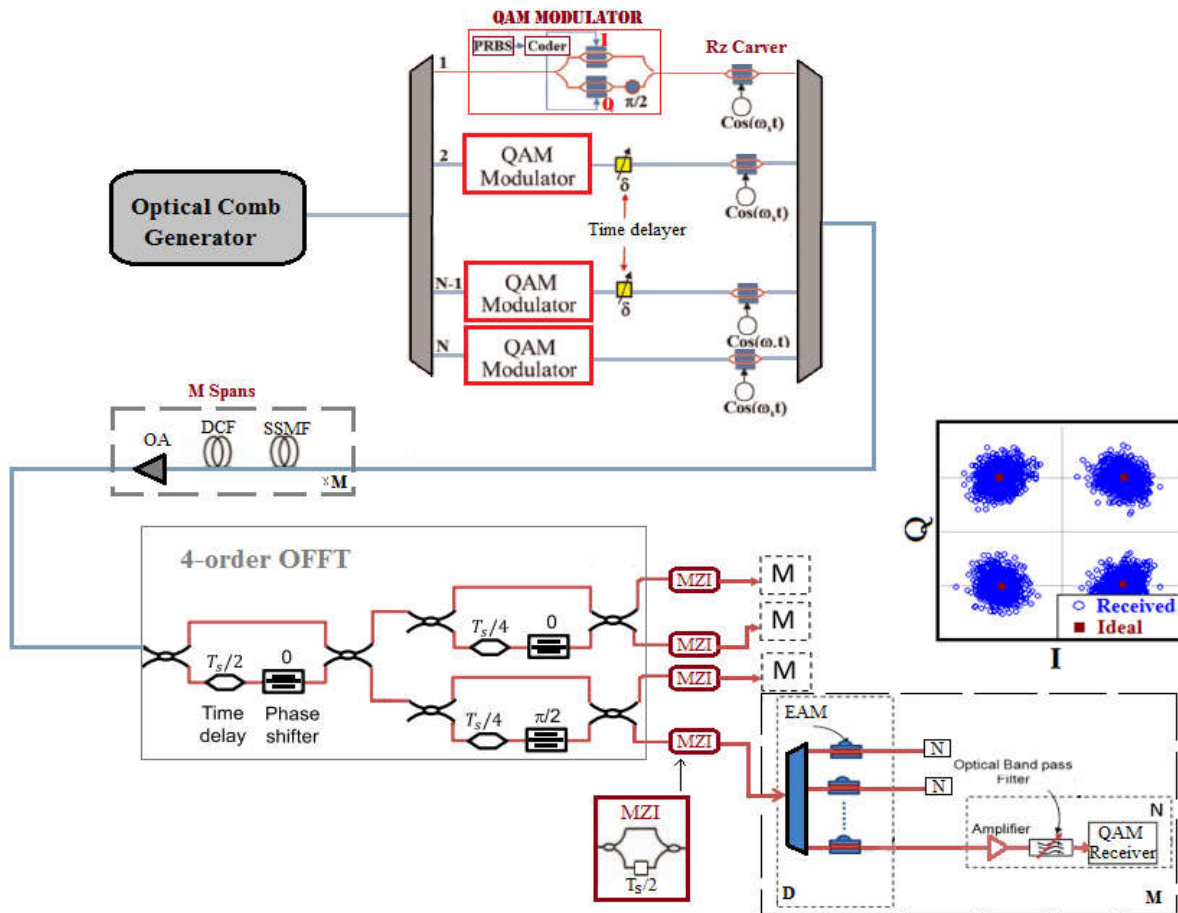


Fig.2 Schematic of an RZ-QAM OFDM transmission system

There are four de-multiplexers used to split the transmitted subcarriers and then signals are sampled by electro absorption modulators (EAMs) sampling gates. By employing one optical band-pass filter before demodulator, each EAM output is filtered before demodulating by QAM. Then, all the resulted signals are detected and then extracted received data by coherent 8QAM optical detector. In this system, there is one MZI added before each EAM and adjusted their delay time to $T/2$ s as shown in Fig. 2. Using RZ pulse effect on the time slot for optimum gating and make it shorter, so by using RZ pulse gating is very difficult. Four MZI at receiver side can receive signal and convert it to 8QAM. The delay time between the arms of the MZI is set to $T_s/2$. Hence, symbols can interfere with their delayed replica. Therefore, at the constructive port, RZ signal can be converted to 8QAM.

3. RESULTS AND DISCUSSION

This section, demonstrates the effect of proposed RZ-8QAM on the performance of AO-OFDM systems. To see the phase noise mitigation in the proposed system, Error Vector

Magnitude (EVM) due to fiber nonlinearity impairments versus the transmission distance and subcarrier power are estimated. The simulation is performed using VPItransmissionMaker software version 9. There are 29 subcarriers modulated RZ-QAM AO-OFDM system and the transmission distance is fixed at 500 km. It is important to note that XPM, SPM and FWM in one optical transmission system can determine the magnitude of EVM. Also the power of subcarriers and the interaction time between subcarriers effect on the magnitude of EVM.

Fig. 3 illustrates EVM versus the subcarrier power for 8QAM and RZ-8QAM AO-OFDM system. As shown in Fig. 3 for RZ-8QAM AO-OFDM system, when subcarrier power increases more than -6dBm and in 8QAM AO-OFDM system when subcarrier power increases beyond -5dBm, EVM is increased because of interaction of XPM and FWM with ASE noise become dominant at higher powers. Minimum EVM for RZ-8QAM system can be obtained 0.109, but in conventional 8QAM system the minimum EVM of 0.130 can be achieved. The results reveal that, when the number of subcarriers is equal and symbol rate is the same, RZ-8QAM signal has higher peak power than QAM signal, and interaction time between subcarriers in RZ-8QAM signal is shorter than interaction time in QAM signal. It is important to note that by decreasing interaction time between subcarriers, the performance of system improves.

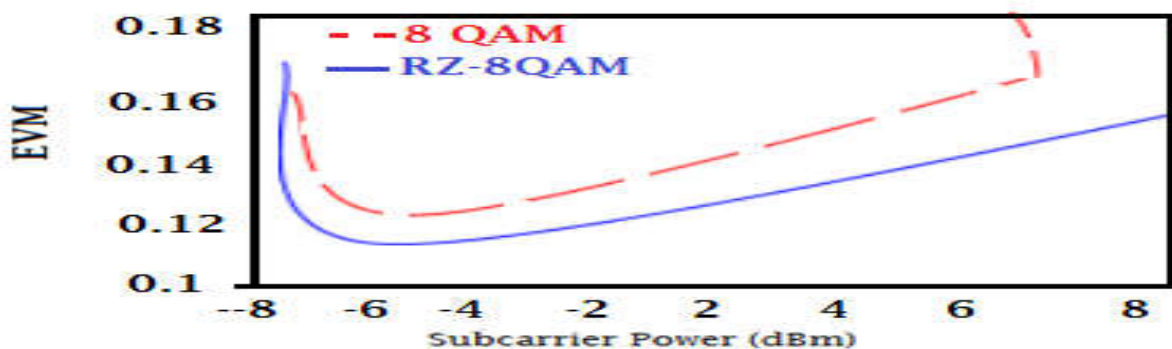


Fig.3. EVM versus subcarrier power

Fig. 4 depicts EVM versus the Transmission length for 8QAM and RZ-8QAM all optical OFDM systems. In Both simulated diagrams, the transmission distance is fixed to 500km and the number of subcarriers is set to 29.

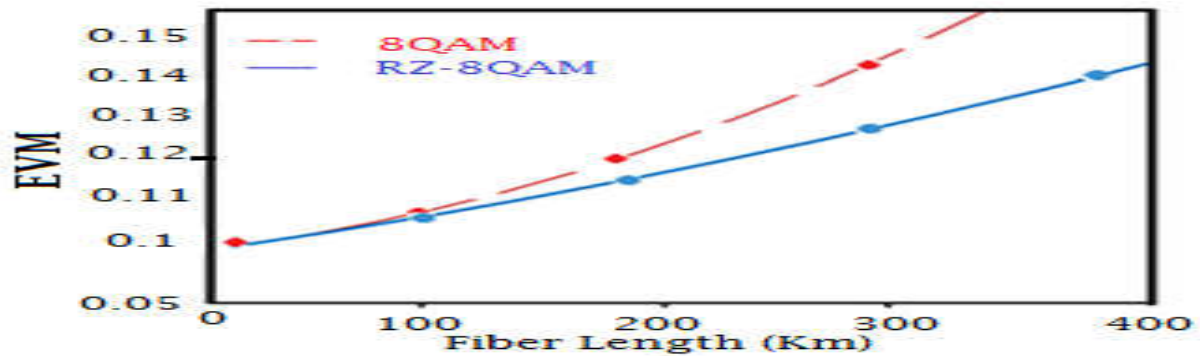


Fig.4. EVM versus subcarrier power

It is shown that RZ-QAM signals produces a clearer constellation diagram compared to conventional 8QAM. Fig. 5 illustrates the constellation diagrams of the RZ-8QAM AO-OFDM and 8QAM AO-OFDM. The constellation diagram of the RZ-8QAM signals is more clearly than constellation diagram of conventional 8QAM signals.

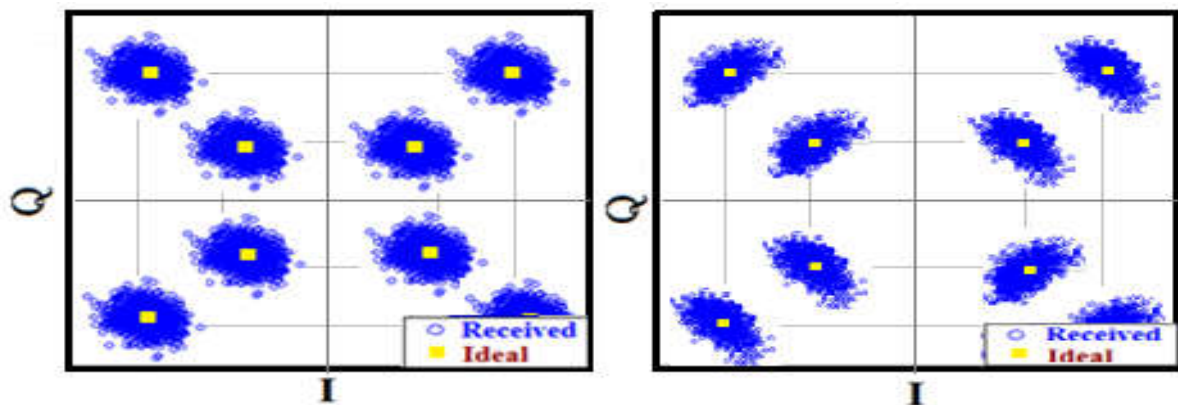


Fig.5. Constellation diagrams of the RZ-4QAM AO-OFDM and 4QAM AO-OFDM

4. CONCLUSION

This paper presents a new RZ-8QAM modulation format to improve the performance of an AO-OFDM system. The performance of AO-OFDM RZ-8QAM is compared by conventional AO-OFDM 8QAM. Results reveal that the performance of proposed system is significantly better than performance of conventional 8QAM AO-OFDM because in the proposed system nonlinear phase noise is mitigated and the effects of fiber nonlinearity have been successfully compensated. The proposed optical transmission system is more reliable and secure than other transmission systems to transmit important military information without any data loss over long distance.

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6. REFERENCES

- [1] Hmood J K, Kamarul A N, Harun S W, Hossam M H S. Mitigation of phase noise in all optical OFDM systems based on minimizing interaction between subcarriers. *Optics Communications*, 2015, 355:313-320
- [2] Hmood J K, Harun S W, Emami S D, Khodaie A, Noordin K A, Ahmad H, Shalaby H M. Performance analysis of an all-optical OFDM system in presence of non-linear phase noise. *Optics Express*, 2015, 23(4):3886-3900
- [3] Mirnia S E, Zarei A, Emami S D, Harun S W, Ahmad H M S. Proposal and performance evaluation of an efficient RZ-DQPSK modulation scheme in all-optical OFDM transmission systems. *Journal of Optical Communications and Networking*, 2013, 5(9):932-944
- [4] Tang J. Transmission performance of a 400 Gbits all-optical orthogonal frequency division multiplexing system. *Journal of Optics*. 2013, 15(5):10-16
- [5] Le S T, Blow K. Power pre-emphasis for suppression of FWM in coherent optical OFDM transmission. *Optics Express*. 2014, 22(6):7238-7248
- [6] Liang X, Yaojun Q, Wei L, Junyao M, Yi Q. Optical transmission systems switching and subsystem. In *Proceedings of the SPIE, Volume 7632*, 2009
- [7] Hillerkuss D. Simple all-optical FFT scheme enabling Tbit s⁻¹ real-time signal processing. *Optics Express*, 2010, 18(9):9324-9340
- [8] Hillerkuss D. 26 Tbit/s⁻¹ line-rate super-channel transmission utilizing all-optical fast Fourier transform processing. *Nature Photonics*, 2011, 5(6):364-371
- [9] Chen H, Chen M, Xie S. All-optical sampling orthogonal frequency division multiplexing scheme for high speed transmission system. *Journal of Lightwave Technology*, 2009, 27(21):4848-4854
- [10] Rizman Z I, Zakaria U N, Latiff A A, Harun S W, Jusoh Z. Continues-wave Brillouin Raman fiber ring laser using 7.7 km long dispersion compensating fiber at 1563 nm

wavelength. In *Materials Science and Engineering Conference Series*, 2017, 210(1):1-5

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