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Performance Analysis of Coherent Optical Communication System for M-QAM Higher Modulation Level

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Abstract: In this paper, performance of QAM sequence generator in coherent optical communication system is investigated. Results are obtained for different square constellation types such as 4-QAM, 16-QAM, 64-QAM and 256-QAM using Hyperbolic-secant pulse generator. For the distance of 120 km and bit rate of 10 Gbps, it is investigated that 4-QAM provides maximum Q factor of 33.93 and minimum BER of 6e-253, whereas 16-QAM, 64-QAM & 256-QAM provides Q factor of 31.47, 22.85 & 8 and BER of 5e-218, 3e-116 & 2e-16, respectively. Decrement in Quality factor and increase in BER are observed with increment in the M-value of QAM. It is further observed that Eye opening decreases with increment in levels of QAM.

Keywords: quadrature amplitude modulation, higher order modulation, quality factor, BER

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1 Introduction

High-level modulation formats (amplitude and/or phase), such as 8PSK, 8QAM or 16QAM, can be used to raise the SE. Superior SE has been expected by single-channel communication at lower data rate using PDM-64QAM and 128QAM modulation format at 12 and 14 Gbps, and balanced coherent detection technique over 150 and 160 km of fiber, respectively [1]. 4-QAM, 16-QAM and 64-QAM have been selected for the improvement of the projected classifier. On the other hand, alterations can be simply made to contain other quadrature amplitude modulation (QAM) or wider choice of modulations [2]. Some specific constellations attracted special interest, mainly due to the low complexity demodulation methods required, such as the square-QAM (SQAM) and have found many applications in practical systems. One of the most important applications of QAM is the adaptive modulation technique [3]. Wavelength division multiplexing (WDM) has become the preferred transmission technology in transport network of long distance operators [4]. QAM modulation technique increases the efficiency of transmission by utilizing both amplitude and phase variations. For a specified available bandwidth, QAM permits data broadcast at twice the rate of standard Pulse Amplitude Modulation without any deprivation in the Bit Error Ratio. In the QAM sequence generator, the bit sequence splits into two parallel subsequences and each one is transmitted in two quadrature carriers while building a QAM modulator. This is achieved by using a serial to parallel converter. When transmitting information, the amplitude of a signal could be varied according to the source symbols. For a specified available bandwidth, QAM enables data broadcast at twice the rate of standard pulse amplitude modulation (PAM) without any deprivation in the bit error ratio (BER). QAM uses unique combination of phase & amplitude and each combination assigned a unique digital bit pattern. QAM is one of the most popular M-ary schemes. BER varies as we change the M value [5]. A high-order modulation format, as e. g. 64-QAM, would result in a high spectral efficiency and is thus efficient in terms of bandwidth. However, the noise performance is poor. Vice versa, we achieve high noise resistance if we allow for more bandwidth as, e. g. with binary PSK-modulation [6]. QAM has become common place in bandwidth efficient digital communication systems. It communicates two analog message signals or two digital bit streams [7]. The M-QAM format has received much attention due to the first commercialized usage of 256-QAM modulation. It turns out that the 256-QAM format will be applicable to start a new generation of worldwide communication [8].

Till now, work has been compiled for coherent optical communication system based on QAM, the previous work has been done for coherent optical communication

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system using 4-QAM modulation technique at 50 km transmission distance at bit rate of 10 Gbps using NRZ pulse Generator [9], so that optimization can be done at higher the level of QAM and transmission distance up to 120 km at 10 Gbps using Hyperbolic-pulse Generator.

This paper is organized into the following sections. Section 1 presents the introduction. The system set up of the coherent Optical Communication System with M-QAM and its components are described in Section 2. The detailed results and discussion for system is reported in Section 3. The conclusion is drawn at the end in Section 4.

2 System set up

Figure 1 presents the simulation setup of Coherent Optical Communication System for M-QAM modulation. The bit stream is generated by PRBS generator with a bit rate of 10 Gbps splits into a Hyperbolic-secant pulse generator and QAM sequence generator with different bit per symbol. The signal following QAM is given to two M-ary pulse generators. The signal coming from an M-ary pulse generator splits by the splitter and passes the signal into two electrical biases. Signals coming from the electrical bias are passed to the LiNb Mach-Zehnder modulator. A CW laser with power of 5 dBm and wavelength of 1,550 nm is used. The signal from the two LiNb Mach-Zehnder modulators combined with the power combiner 2 × 1. Then, the signal splits into a loop control (Number of loops = 2). The signal from the loop control goes through a different optical fiber distance and a flat gain EDFA with a gain of 20 dB and a noise figure of 6 dB. The signal returns to the loop control. The signal coming from loop control and is coupled at X Coupler4. Then, the X Coupler4 gives the signal to X Coupler 2 and X Coupler3. At X Coupler1, two signals coming from CW Laser and optical null are coupled, and X Coupler1 passes the signal to two couplers, X Coupler2 and X Coupler3. X Coupler1 passes the signal to X Coupler2 through a phase shifter, to generate a phase shift of 90°, and through X Coupler3. Four different outputs coming from X Coupler2 and X Coupler3 are passed to the four different photodetector PINs (Responsivity 1A/W & Dark Current 1 nA). The outputs of the four photodetectors are combined at two different electrical subtractors. Then, the signal from two electrical subtractors is given to the two low pass Bessel filters. Two M-ary threshold detectors are used; the signal from both M-ary threshold detectors is given to a QAM sequence decoder. QAM decodes the signal, and subsequently, the signal is passed to the Hyperbolic-secant pulse generator. The output of the Hyperbolic-secant pulse generator is analyzed at the BER Analyzer.

3 Results and discussion

To demonstrate the feasibility of coherent optical communication system using high-order QAM transmission, Figure 2(a) and 2(d) depicts the Q factor, BER and eye opening of the system. The performance of the system is investigated for the square QAM formats such as 4-QAM, 16-QAM, 64-QAM and 256-QAM. The system provides better results up to 120 km transmission distance at bit rate of 10 Gbps in terms of Q factor and BER. Table 1 calculated the results of Q factor, BER and Eye Opening for 4-QAM, 16-QAM, 64-QAM and 256-QAM. The value of Quality factor and BER is evaluated by increasing the bit per symbol of QAM. Table 1 shows that with the increment in value of M, Q factor decreases and BER increases. Eye opening is also varying with the value of

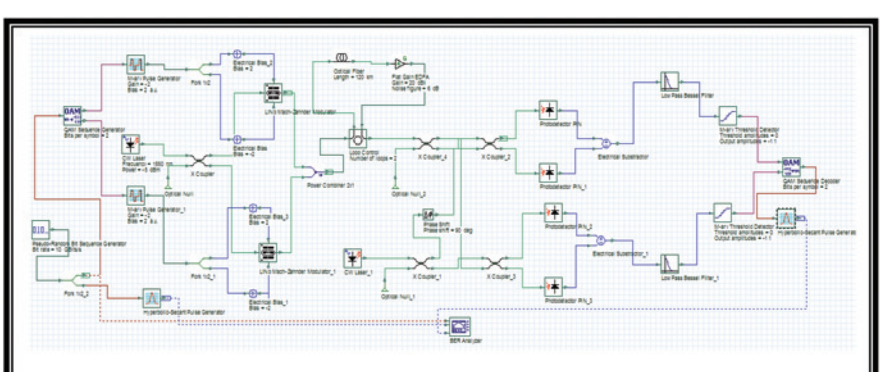

Figure 1: System setup of coherent optical communication system with M-QAM.

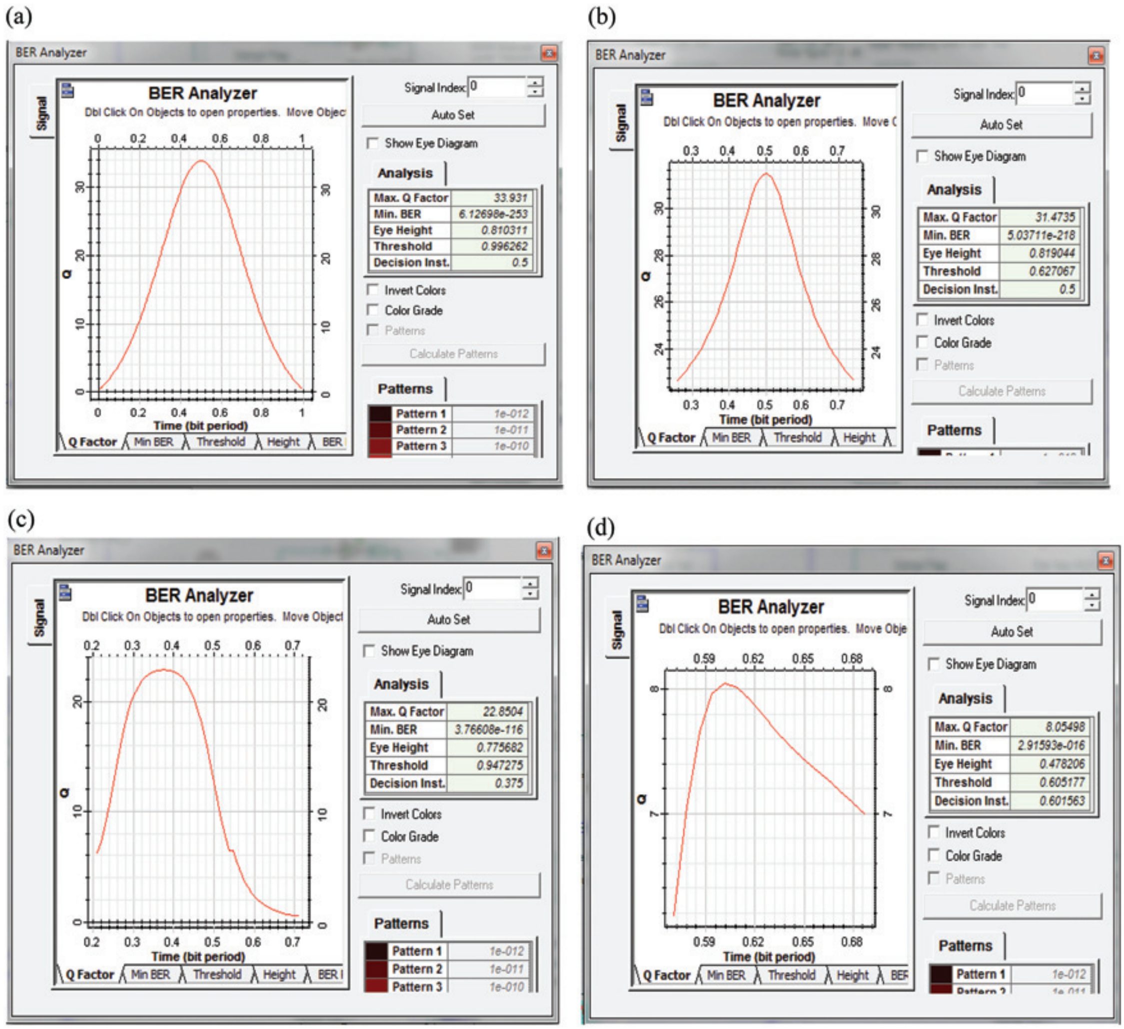

Figure 2: Results of the M-QAM 2 (a) 4-QAM, (b) 16-QAM, (c) 64-QAM, (d) 256-QAM.

Table 1: Q factor, BER and eye opening for 4-QAM, 16-QAM, 64-QAM and 256-QAM.

M-QAM	Q factor	BER	Eye opening
4-QAM	33.93	6e-253	0.810311
16-QAM	31.47	5e-218	0.819044
64-QAM	22.85	3e-116	0.775682
256-QAM	8	2e-016	0.478206

M. Eye opening is decreases with the higher value of M. Combination of bits is known as symbol. Bits per symbol is given by the formula [10]

$$\text{Bit per symbol} = \log_2(M) \tag{1}$$

where "M" is number of symbols or number of possible sequence of binary digits, calculated according to:

$$M = 2^{h/2} \tag{2}$$

where "h" is the number of bits per symbol. The equivalent QAM set is given by the square of M. This means: If $h = 2$ & $M = 2$, then we have a 4-QAM. If $h = 4$ & $M = 4$, then we have a 16-QAM. If $h = 6$ & $M = 8$, then we have a 64-QAM. If $h = 8$ & $M = 16$, then we have a 256-QAM.

Q factor and BER varies as we change the M value. Figure 2 describes the results of Q factor and BER for M-QAM. For the case of (a) 4-QAM value of Q factor is 33.93 and BER is 6e-253, (b) 16-QAM value of Q factor is 31.47 and BER is 5e-218, (c) 64-QAM value of Q factor is 22.85 and BER is 3e-116, (d) 256-QAM value of Q factor is 8 and BER is 2e-016. It is observed that the Q factor decreases and BER increases with the increment in the M-value of QAM. A high-order modulation format would result in a high spectral efficiency and is thus efficient in terms of bandwidth.

In the previous work [9], it was reported that use of 4-QAM is capable to cover a distance of 50 km for bit rate of 10 Gbps by using NRZ pulse Generator. In this paper, we expanded the work upto 120 km transmission distance with higher level of QAM by using Hyperbolic-secant pulse Generator. They have been not discussed about Q factor, BER and Eye Opening. All these measures have been taken in this paper, to have the transmission of signal, as it passes through the optical fiber with bit rate of 10 Gbps by varying the level of QAM up to 120 km transmission distance. These results are analyzed in terms of Q factor, BER and Eye Opening.

4 Conclusion

In this paper, it is concluded that the coherent optical communication system based on QAM provides acceptable results in terms of Q factor and BER at bit rate of 10 Gbps up to 120 km transmission distance using Hyperbolic-secant pulse generator. The results obtained from various QAM orders in terms of Q Factor and BER, it is observed that 4-QAM, 16-QAM, 64-QAM and 256-QAM provides Q factor of 33.93, 31.47, 22.85, 8 and BER of 6e-253, 5e-218, 3e-116, 2e-16 respectively. Decrement in eye opening is observed with increment in levels of QAM. It is observed that 4-QAM provides better results over other QAM orders in terms of Q factor and BER. It is found that, as move toward higher order of QAM value of Q factor decreases and BER increases.

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