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# Adaptive & Blind Equalization in Digital Optical Receivers using Constant Modulus Algorithm (CMA)

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## Abstract

In this work a high precision adaptive equalization method is proposed and analysed using constant modulus algorithm (CMA). It includes blindand adaptive equalization. This proposed algorithm is described and evaluated using quadrature phase shift keying (QPSK) transmission. The QPSK modulation in combination with frequency-domain constant modulus algorithm (CMA) method, which exhibits remarkable robustness to received signal. Complex-valued communication link utilizes new advanced algorithm for blind equalisation as constant module algorithm. The studied Digital Signal Processing algorithm is considered as important building blocks in digital coherent receivers for the future generation of optical communication systems. The simulated results are different in both based on bandwidth and side lobe suppression ratio.

## Key words

Adaptive equalizers, blind equalization, CMA equalizer, Constant modulus algorithm, Error measurement, QPSK.

## 1. Introduction

The advanced high-speed web-services depend on a fiber-optic communication system having high-transmission capacity. It is possible to increase the data transmission ratefurther by using different multiplexing techniques such as wavelength-division multiplexing (WDM), polarization division multiplexing (Pol-DM), and modulation technique like quadrature amplitude modulation (QAM) or quadrature phase shift keying (QPSK) [1, 2].The communication system where high data rate is required, the transmission of training stream is either impractical or expensive with respect to data through out. An optical receiver consists of an optical front end and an equalizer. The front end is designed for receiving an optical signal carrying first and second symbols on respective polarization channels. And the equalizer is designed to select a first and second cost function depending on maximum energy and based on the selected cost function, update coefficients of an adaptive filter designed to de-multiplex and equalize the polarization channels.

Generally adaptive filters are implemented based on least mean-square algorithm. But these filters are not used depending on the pilot sequence. Due to this reason, blind adaptive channel equalization algorithms are based on training sequence is not developed. By using blind algorithms, each receiver can start adapting itself without any help from transmitter. This is one of the advantages of the blind start-up which allows a blind equalizer to regenerate itself from system dis-integration. But the demerit of this method is that it is critical to use in broadcast from one source simultaneously to several receivers on a network where channel variation often occurs. In advanced coherent optical communication systems the key elements are advanced equalization techniques. Blind equalization is the technique in which the equalizer works without receiving any control sequence in advance from the transmitter. And this equalizer is attractive due to its system simplicity. An adaptive equalizer is an equalizer that changes their properties automatically w.r.t time of communication channel. It is generally used with coherent digital modulation like phase shift keying (PSK), reducing the effects of multipath transmission (multipath fading) and Doppler shift [3].

Now-a-days most of all the fiber optic communication systems based on phase-shift keying (PSK) modulation is used and constant modulus algorithm (CMA) is used as widely acceptable algorithm for adaptive equalizer. This equalizer is described to optimize the change in amplitude in received samples. It is analyzed that equalizers based on CMA is providing optimal response in digital modulation formats used systems [4].

In this present paper, equalization technique has been analysed by using an algorithm. A phase shift keying is used as digital modulation to minimize the polarization. It is important to choose proper algorithm to provide optimal response of receiver. So, constant modulus algorithm as shown in Fig.1 is used instead of other used algorithms. By using MATLAB, the model is simulated and the results are shown with respect to single polarization technique.

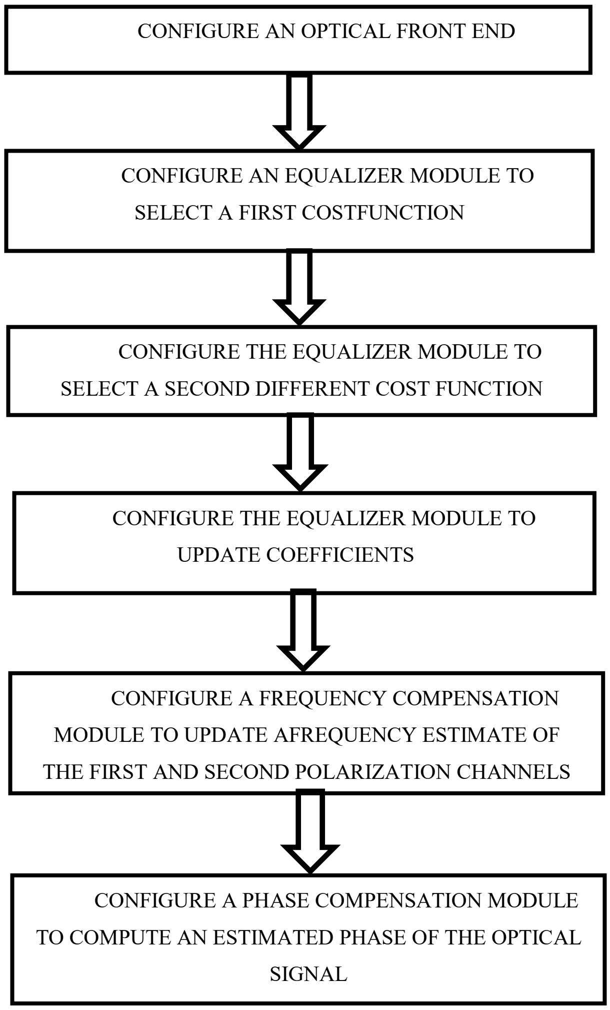


Fig. 1. Steps to form an optical PS-QPSK optical receiver

## 2. Blind Channel Equalization & CMA

A blind adaptive equalizer is used to minimize channel distortions. It is done by transmitting the received signals by using filters (that may be linear or nonlinear filters) as well as reconstructing the transmitted signal independent of the channel impulse response (CIR) function. This method can also be used for the direct gateway to the incoming sequence. The basic objective of a blind adaptive equalizer is to increase or decrease parameters value like cost function, which is based on the filter coefficients selection of the equalizer output [5]. The Zero-Force (ZF) equalization is ideal, when the channel is not affected by the noise. However, when the channel is noisy, the ZF Equalization will amplify the noise greatly where the channel has small magnitude in the attempt to invert the channel completely.

In order to minimize the power of the noise component, MMSE equalization can be employed. The MMSE equalization can be used to estimate the channel effect with varying the decoding matrix in accordance with SNR. Besides, it prevents the noise component from being amplified.

The problem with adaptation methods are its weak convergence property as compared to traditional existing techniques. Hence constant modulus algorithm is proposed as a better option as compared to previous technique. A cost function is used to calculate a cost according to a constant modulus algorithm (CMA) and the equalizer coefficients are updated according to its value.

CMA is a stochastic gradient algorithm that compensates the dispersion of the equalizer output around a circular contour. The CMA algorithm adapts filter coefficients at each time in order to minimize the '2- 2 modulus error".

The cost function CM (q, 2) can be written as [6]

$$\min E\ [(|y_n|^p - \gamma^q)\text{^}2] \tag{1}$$

Where the dispersion constant $\gamma^q$ (acts as an equaliser gain) is obtained as

$$\gamma\text{^}q = E[|a|\text{^}2q\ ]/E[|a|\text{^}q\ ] \tag{2}$$

The equation (1) indicates that it minimizes the dissemination of the modulus of a priori output $y_n$ except a statistical constant $\gamma$ [7, 8].p and q values are chosen such that the parameterized dispersion-directed cost-function leads as compared to the existing algorithms used in blind equalization. The equalizer iteratively minimizes the MSE cost function;

$$E\{|e_n|^2\} = E\{|a(n-\delta) - y(n)|\text{^}2\} \qquad [3]$$

In blind equalization, due to unavailability of channel input a $(n - \delta)$ different minimization criteria are explored. Blind adaptive equalizers are based on recursive algorithms that allow the filter to reconcile and changes in input signal calculation is slow. Such adaptive equalizers begin from certain initial value problems except previous data and then renewal of filter coefficients are performed.The updation of coefficients isbased on the algorithms which have to be used and the sampled datasequence.The widely adopted adaptive blind equalization algorithm is the Constant Modulus Algorithm(CMA) [9,10]. This algorithm can be used for pre-convergence of an equalizer before switching to decision directed mode.it displays better Signal to Noise Ratio tolerance. The ability to separate the functions of equalization and phase and frequency recovery in this equalizers pattern provides an attractive feature for coherent optical communication and adaptations of this algorithm have been made to provide this functionality for modulation formats such as QAM.

Channel equalization uses the concept of using pilot data for channel estimation. But Blind channel equalization doesn't use the characteristics of the given sequences either for frequency response or for impulse response function (IRF) analysis of communication channel. The block diagram of adaptive equalization is shown in Fig.2.

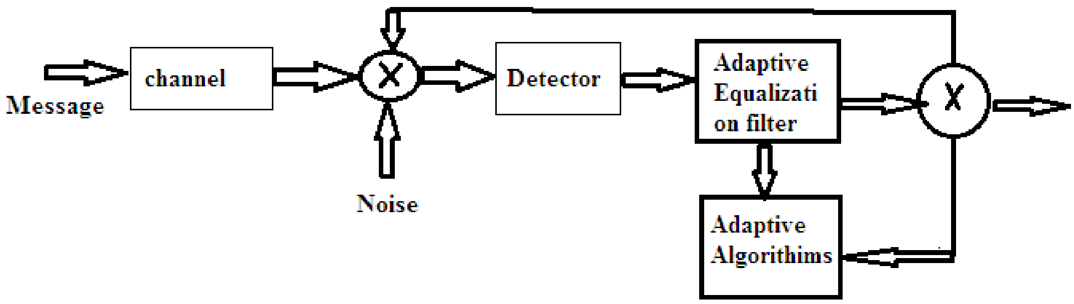


Fig.2. Adaptive Equalization

## 3. Proposed Algorithm

In previous papers one-dimensional (1-D) signal space of the fourth-order cumulants and the auto correlation functions of a non-Gaussianoutput sequence was implemented in the presence of additive Gaussian noise. This algorithm consists to use the BPSK communication signals and a relationship linking cumulants of output signal and the coefficients of the model. This relationship is exploited to build a set of equations that is solved using a Least-Squares (LS) approach [11].

Recently, research work has been done to determine the power efficient most favorable modulation format is four dimensions (4D). But a coherent receiver performs a linear mapping of the four-dimensional (4D) optical signal space to the electrical domain and this provides a roadmap to select modulation format. This can be used, e.g., to make flexible systems with a fine granularity in the trade-off between data throughput and transmission reach [12].

If in any coherent optical system additive white Gaussian noise is introduced in transmission then different modulation techniques can be used. For this type of transmission line Binary Phase Shift Keying (BPSK) modulation is implemented due to its low bit error rate. But in this paper PS-QPSK is implemented.Research based on allocation of additional capacity is being performed by using optimal24 state constellation diagrams as coding overhead. After calculating the equalizer estimate $w_n$, it is required to adapt by considering the following instantaneous optimization problem as shown in equation (4);

$$\frac{min}{w_{n+1}}\left(\left|w_{n+1}^{H}x_{n_a}\right|^{q}-\gamma^{q}\right)^{2} \qquad [4]$$

Where $W_{(n+1)}$^H $X_n$ a posteriori output of the equalizer.

Polarization-switched quadrature phase shift keying (PS-QPSK) modulation consists of a two bits symbol being transmitted on any one of the two polarizations which are orthogonal to each other. It determines the information of third bit, While the spectrum efficiency is reduced from 4 (bits/s per Hz) to 3 (bits/s per Hz) as the resultant output. If the system is affected by additive Gaussian noise (AWGN), then the modulation format can be proposed with receiver sensitivity of 1.76 dB over BPSK. PS-QPSK is a 4-dimensional constellation method, requires a different equalizer and symbol detection scheme. Fig.3 explain constellation diagram for two linearly polarized signals of QPSKwhere a symbol transmitted on the x-polarization & y-polarization is represented by blue and red spots respectively. In first figure triangle describes the symbol transmitted in x-polarization and in second figure dot describes the symbol transmitted in y-polarization

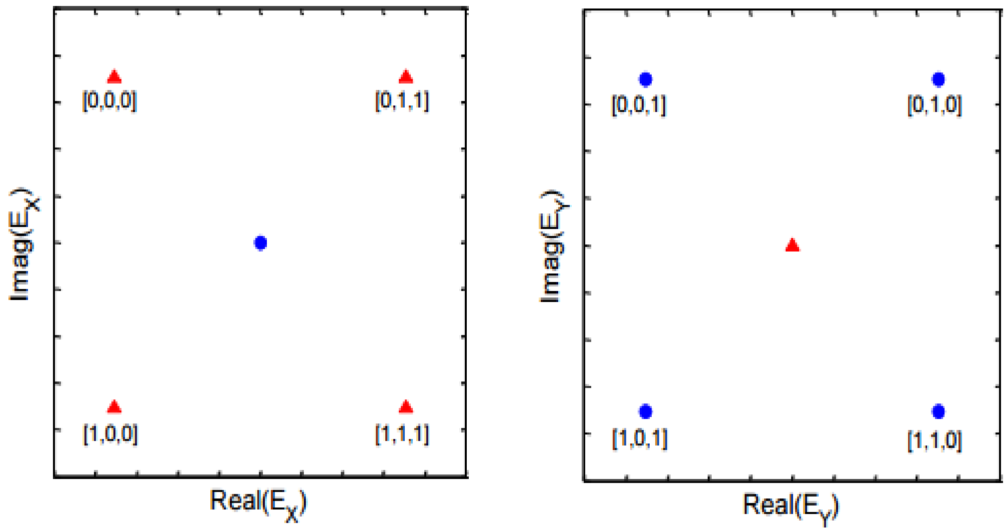


Fig 3. Constellation diagrams of PS-QPSK Signal (linearly polarized).

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Two symbols are received in each symbol period, e.g. a QPSK constellation point and a transmitted 0 (otherwise called the switch symbol) as shown in Fig. 4. A probabilistic choice is identification in between QPSK bit symbol and switch symbol. The polarization with the greater energy is more likely to be the QPSK symbol and while the lower energy polarization is interpreted as the switch symbol [13]. It saves energy. This reduces each symbol period to 3 bits but requires less power.

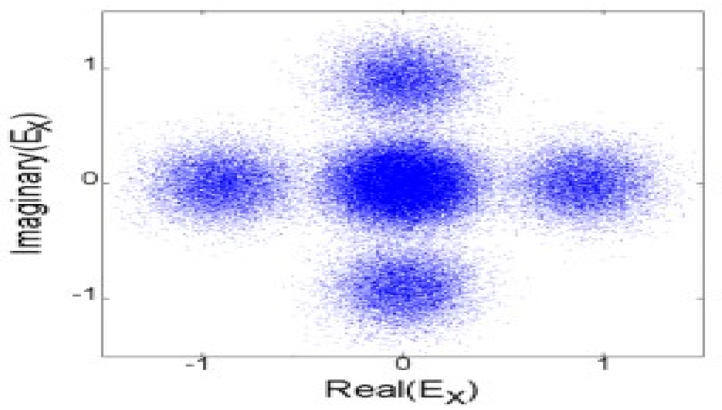


Fig.4. Constellation diagram of a PS-QPSKwith the CMA equalizer (single polarization output)

## 4. Conclusion

PS-QPSK provides the greatest advantage in realization of any of the recent four-dimensional modulation formats for long distance transmission proposed till now. It has remarkable benefits like simple transmitter & receiver circuit, higher data transmission rate. In previous papers Dual polarization-QPSK equalizer was implemented with CMA. The reduced number of bits per symbol from 4 to 3 gives 3/4 of penalty, thus in total a gain of 3/2, or 1.76 dB.

We have implemented the method using polarization switching QPSK with PS-CMA equalizer due to the better noise tolerance capacity. It is required to explore higher order modulation formats for achieving remarkable benefits as compared to existing methods and that methods are meant for high bandwidth efficient system. In this paper the performance of coherent receiver is evaluated with nonlinearity compensationtechniques using DSP module. The proposed algorithm has been described based on dispersion compensation of a priori as well as a posteriori quantity. It is possible by solving a unique optimization prototype, which can be determined.

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