POLARIZATION CONTROL ALGORITHMS FOR COHERENT QPSK OPTICAL TRANSMISSION

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ABSTRACT

This research "Polarization Control in Coherent QPSK Optical Transmission" mainly aims to analyze and modify the existing polarization control algorithms, non data aided algorithm(CMA) and a data- aided decision-directed algorithm (DPC-CMA, ORIGINAL (ODDA) & MODIFIED (MDDA)) intended for high control speed, low complexity, phase noise and modulation format tolerance in future 100GbE transmission. It was simulated and analyzed CMA and the extended DPC-CMA for QPSK signals. These algorithms work under certain conditions, low cross talk and limited range of transmitting signal amplitude. The DPC-CMA showed improved performance compared to CMA. It increases polarization control speed by enabling common carrier recovery through differential phase compensation and it improves the BER performance of the algorithms comparable to the existing polarization control algorithms using VPIphotonic and Matlab softwares.

Key words: QPSK, CMA, DPC-CMA, ODDA, MDDA

1. INTRODUCTION

Low probability of error is one important goal in the design of a digital communication system. Another important goal is the efficient use of the available bandwidth.

Sending polarization-multiplexed signals will increase the data rate in optical fiber transmission system. It needs coherent digital receivers to demultiplex these signals. Some algorithms are existing for these receivers to compensate the channel distortion and crosstalk and to recover the transmitted signals, they are, constant-modulus algorithm (CMA), data aided algorithm (DDA) and their extensions. The standard CMA can only work with QPSK signals and it needs separate carrier recovery, this algorithm is expanded to differentially phase compensation CMA (DPC-CMA) to enable common carrier recovery (CCR). The next class of algorithm is DDA which has two extensions; original DDA (ODDA) and modified DDA (MDDA), both of these allow working with CCR.

Polarization control algorithms works as follow: let

$$C = \begin{pmatrix} c_1 \\ c_2 \end{pmatrix} \qquad (01)$$

be the transmitted signal vector, the received signal vector (R) is obtained by multiplying the fiber jones matrix (J) with C

$$R=J.C \qquad (02)$$

At the receiving end by multiplying the polarization control matrix M with the received signal vector the corrected signal vector X will be obtained.

$$X=e^{j\theta 1f}R \qquad (03)$$

θ_{1f} is the phase difference between the transmitter and local oscillator laser.

The polarization control matrix (M) is updated as

$$M=M+gT \qquad (04)$$

over the symbol duration, where g is control gain and T is error signal matrix. M is expected to go to a format such that it only introduces a phase shift in the transmitted signal, Therefore, M.J should be in a form as

$$M.J = \begin{pmatrix} e^{j\theta 1} & 0 \\ 0 & e^{j\theta 2} \end{pmatrix} \qquad (05)$$

2. METHODOLOGY

Variations of coherent phase shift keying include binary phase-shift keying (BPSK), QPSK and M-array PSK. QPSK signal was generated by using VPIphotonic software and also its signal diagram, constellation diagram and eye diagram were also obtained for analysis further. These signal diagram , constellation diagram and eye diagram were obtained with distortion .

Investigation of these algorithms has been done with QPSK signals. The performance of the existing algorithms for coherent polarized QPSK signal has been analyzed by adding Additive White Gaussian Noise (AWGN) in VPIphotonic software. These algorithms were compared with different fiber jones matrices, transmitting signal powers and compared with different control gains. The results shows compared to other algorithms MDDA performs well, It can handle large range of Jones matrices and transmitting signal powers. For low control gain, these algorithms perform well but it takes long time to converge, in contrast for high gain the convergence speed is high however compared to low gain it performs worse after the convergence.

A modification suggested overcoming the above-mentioned problem by increasing the convergence speed while maintaining the performance as in low gain and also compared the performance of modified one with the existing one. The results show that the modified algorithm improved the performance compared to the existing one.

3. RESULTS

Standard CMA, DPC-CMA and DDA were tested in extensive QPSK simulations with added white Gaussian noise. Function, transmitting signal power handling capacity and the range of Jones matrices that can be compensated were verified.

Coherent QPSK is equivalent to two BPSK signals working in parallel. The phase of the carrier takes on one of four equally spaced values: $\pi/4$, $3\pi/4$, $5\pi/4$, $7\pi/4$ .we may choose Gray-encoded set of digits: 10, 00, 01, 11 where only one bit is changed from one digit to the next digit. This is the block diagram used for the further analysis

Bit rate : 1 GHz ,Carrier Frequency :193.1 THz ,Bit per symbol : 2

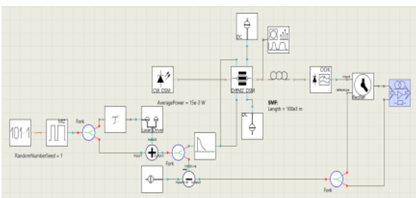

Figure 1: Simulation of Generation QPSK signal

In this section, the performance of the existing algorithms for coherent polarized QPSK signal by adding Additive White Gaussian Noise (AWGN) was analyzed.

Polarized light is represented by a **Jones vector.** When light crosses an optical element the resulting polarization of the emerging light is found by taking the product of the Jones matrix of the optical element and the Jones vector of the incident light. As for the conveniences the Jones matrix to be compensated was chosen as

$$J = \begin{pmatrix} 0.9808 + 0.1951j & 0.4619 - 0.1913j \\ -0.2079 - 0.1389j & 0.7846 - 0.1561j \end{pmatrix} \quad (06)$$

And Let **M** be the electronic polarization control matrix was chosen as

$$M = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \quad (07)$$

Existing algorithms were analyzed one by one. Figure below shows the constellation diagrams for the corrected signal by applying Standard CMA. After the convergence of M for standard CMA both polarizations are converged to separate points (1≠ 2) .Therefore CMA requires separate carrier for signal recovery.

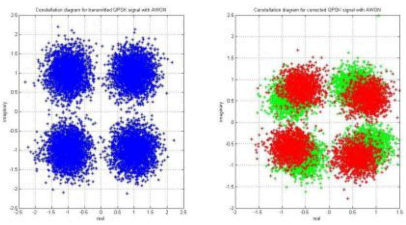

Figure 2: Corrected Signals using Standard CMA with AWGN

In figure 2 it can clearly identify that QPSK signal is spread around original point when we add the noise to the system. Also it is necessary to know about the duration of symbol where it is started to converge. it was checked the speed of convergence by changing the gain. It is shown as with the increasing gain convergence speed is increasing. But At low control gain convergence speed is low but M is less fluctuated.

When we check these algorithms with added white Gaussian noise with the increasing gain convergence speed increases. But M matrix becomes noisy. It is clearly shown here, the noise is considerably reducing when we decrease the gain. But the time taken to settle to a value is increasing.

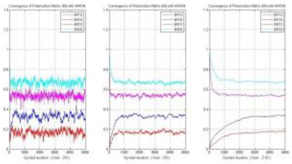

Figure 3: convergence of polarization matrix (M) with AWGN for different gain for CMA Algorithm.

It is clearly shown here, the noise is considerably reducing when gain decreases .But the time taken to settle to a value is increasing at the same time.

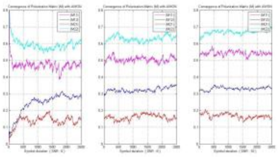

Figure 4: Convergence of polarization matrix (M) with AWGN for different SNR for CMA Algorithm.

When increase the value of SNR, time taken for convergence for each element of M is decreased and also the value of its slightly getting higher.

In DPC-CMA Algorithm**,** the CMA is extended to compensate the phase difference. This enables the use of one carrier for demodulation of both polarizations, which is generated in a CCR. In this DPC-CMA, **M** is updated according to
M = M + g (T + U)

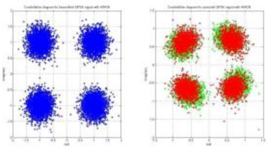

Figure 5: Corrected Signals using Standard DPC-CMA with AWGN

It is clearly shown in the above figure; the convergence of M matrix attenuates with addition of white Gaussian noise.

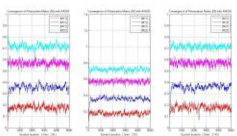

Figure 6: Convergence of polarization matrix (M) with AWGN for different gain for DPC-CMA Algorithm.

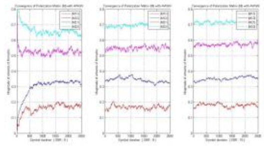

Figure 7: Convergence of polarization matrix (M) with AWGN for different SNR for DPC-CMA Algorithm.

From the figure shown above, it is clearly shown here that there is no considerable variation in noise when value of gain is reduced. But with the SNR changes, the noise is slightly reducing and converges to a value.

There are two modes of convergence available for ODDA and MDDA on the Jones matrix. The literal implementation in hardware poses a huge challenge, because the calculation of the inverse of a matrix in a digital circuit is very complex.

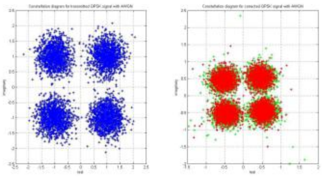

Figure 8: Corrected Signals using Standard ODDA with AWGN

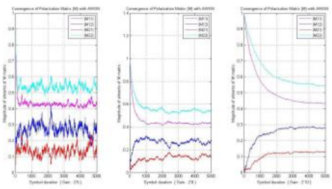

Figure 9: convergence of polarization matrix (M) with AWGN for different gain for ODDA Algorithm.

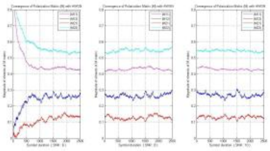

Figure 10: Convergence of polarization matrix (M) with AWGN for different SNR for ODDA Algorithm.

When increase the value of SNR , time taken for convergence for each element of polarization control matrix is decreased and also the value of its slightly getting higher.
The ODDA has the following weakness: on average, it achieves a vanishing average **(1- Q) =0**. **MJ** becomes proportional to the unity matrix and there are no decision errors (in the absence of noise). The corrected signal vector is, with

exception of the phase rotation to be undone in the carrier recovery, already identical with the recovered symbol input **c**. This holds for QPSK
$M: = M + gT$,

For ODDA and MDDA System simulation for QPSK in the presence of polarization dependent loss always correctly recover the received quadrant and M. By enabling the differential encoding at the transmitter we can correctly recover the transmitted signal.

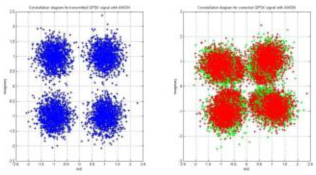

Figure 11: Corrected Signals using Standard MDDA with AWGN with 2^-6

Convergence of M also depends on the amplitude of the transmitted signal. To exemplify this,

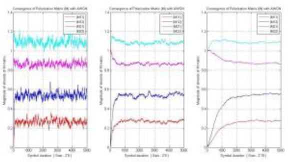

Figure 12: Convergence of polarization matrix (M) with AWGN for different gain for MDDA Algorithm.

Here, when we decrease the critical value of gain, the system noise becomes low and at the same time it takes some larger time to converge.

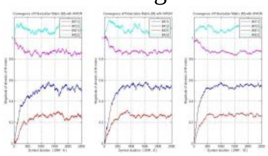

Figure 13: Convergence of polarization matrix (M) with AWGN for different SNR for MDDA Algorithm.

Convergence of M also depends on the amplitude of the transmitted signal.

4. CONCLUSION

The speed of the convergence is increasing when we increase the gain in that algorithm. Also we checked the algorithms to correct the signal with the change for different SNR & Gain. Throughout this simulation, we can see that, the noise is considerably reducing when we decrease the gain. But the time taken to settle to a value is increasing at the same time. For the SNR analysis, when increase the value of SNR , time taken for convergence for each element of polarization control matrix is decreased and also the value of its slightly getting higher.

From the simulation, the critical values for gain are given below

Standard CMA-QPSK ≈ 2-6
DPC-CMA ≈ 2-6
ODDA ≈ 2-6
MDDA ≈ 2-6

Even though the gain can go around to2-4 for ODDA, M becomes so noisy at this gain. Both CMAs tolerate in high control gain up to g≈2-6. By adding DPC features to CMA polarization control speed also increase and increase further on to next algorithms. Hardware implementation of DPC-CMA is little complex than CMA Since the number of complex multiply and addition operations of DPC-CMA is higher than the CMA, In polarization, multiplexed coherent QPSK transmission system the standard CMA can be used only with separate carrier recovery. But, the DPC-CMA compensates the phase difference between the two polarizations. This allows working with a simpler CCR in the receiver and improving symbol error rate.

Therefore, to select between standard CMA and DPC-CMA we need to compensate between the hardware complexity and the improved performance of DPC-CMA. The recommended DPC effort makes the CMA less attractive ODDA and MDDA also enable common carrier recovery and adopt QPSK modulation. But comparing with the other algorithms ODDA performs worse while MDDA is better can perform fast. Therefore, we recommended using the MDDA .

5. REFERENCES

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