100Gbps transmission using DSP module for Dispersion Compensation

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Abstract - *This paper explains about the dispersion compensation technique by using DSP for long range transmission by the use of optical fiber. For transmitting signal at a data rate of 100Gbit/s, we are using DP-QPSK. The total process is verified in the OptiSystem software where the total simulation is tested taking various components such that at the receiver side we kept DSP module for the dispersion compensation. As we used Coherent reception technology for Long range transmission of 100Gbit/s so that we will get less or minimum optical signal dispersion loss in the receiver side. Here we have also implemented for the optimization of the received signal by coherent optical detection so to have dispersion compensation. This DP-QPSK is the combination of polarization multiplexing and quadrature phase shift keying for having 100Gbit/s bits transfer rate.*

***Key Words*: Coherent Reception, Digital Signal Processing, DP-QPSK**

1. INTRODUCTION

As we know that the optical fiber was invented in the year of 1970s, with it's high bandwidth and low loss it's demand raised in the telecommunication sector. But now there is huge demand of internet speed which is only for the social media apps and sites and also live streaming of High definition movies, so we need to increase the capacity of the backbone network by raising their speed of Data rate with more no of bits rate and also by avoiding the network traffic. Because for these all Optical fiber plays a vital role for meeting individuals requirement.

If we make the bits rate up to 100 Gbit/s then it will meet the current requirement and also future needs even. But currently this 100 Gbit/s signal transmission can be done using orthogonal phase modulation method (QPSK) because it reduces the baud rate so have greater tolerance value for polarization mode dispersion and chromatic dispersion. But due to high velocity rate and data traffic there will be heavy damage to the signals travelling inside the fiber because of Chromatic Dispersion (CD) and Polarization mode dispersion (PMD) as this was discussed in an International Conference. By which there will be compensation of signal property and these signals can be monitored easily[10].

Here we will be explaining about the DSP technology which has been used in OptiSystem in the reception section to achieve dispersion compensation of polarization multiplexing and methods such as polarization dispersion compensation solutions for reuse and phase estimation by means of sampling software optimization and also for the signal recovery.

2. Principle of DP-QPSK for both transmission and reception

2.1 DP-QPSK SIGNAL MODULATION CONCEPT

Here we implemented QPSK signal in this modulation format which uses polarization multiplexing on each polarization phase as an independent signal. As shown in the below figure 1 which shows the generation circuit of a DP-QPSK signal.

Here the first the input data will deal with the electrical signals, such that there will be four roads for the input signal to the processor so that we can make the precoding directly. The Polarization Beam Splitter (PBS) will separate the light if in the input there is a continuous light into two beams which are at equal power and are orthogonally polarized. Then this two orthogonally polarized lights are getting input to the IQ modulator so to get modulated and to achieve two QPSK signal path so to get DP-QPSK[9]. At last the two QPSK signal are given to a Polarization Beam splitter PBC (Polarization Beam Combiner) which converts them to a DP-QPSK signal.

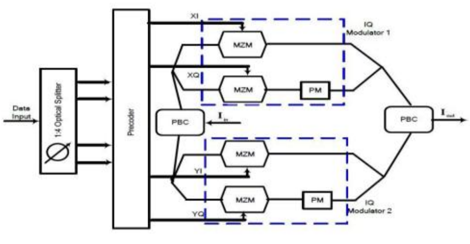


Figure 1. DP-QPSK Modulation Principle Diagram

The continuous input light signal given by,

$$\mathbf{I}_{in} = \sqrt{p_0}\, e^{-jw_0 t}$$

After this the light signal is given to PBC, so in the output to get I_A and I_a.

$$\mathbf{I}_{A} = \frac{\sqrt{2 p_0}}{2} e^{-jwt} \vec{e}_x$$

$$\mathbf{I}_{a} = \frac{\sqrt{2 p_0}}{2} e^{-jwt} \vec{e}_y$$

These two are orthogonally equal polarized light as seen from above. Quaternary phase shift keying (QPSK) is a four digital frequency modulation mode type, as there is presence of two polarized light which are then given input to the IQ modulator to get two orthogonal QPSK signal[2]. Where this IQ modulator consisting of two MZM, two 3 db and one PM of the directional coupler. The QPSK use to have four possible state which are usually π/4, 3π/4, 5π/4, 7π/4 where each carrying two binary notation.

2.2 DP-QPSK SIGNAL DEMODULATION CONCEPT

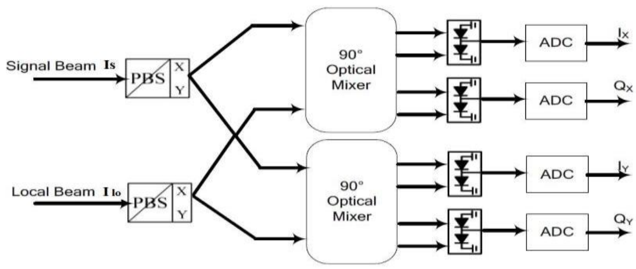


Figure 2. Signal Demodulation

The above figure 2 shows the principle of coherent reception which is used for demodulating the DP-QPSK optical light signal. First the light signal is fed into the PBS Polarization beam splitter), after this it is splitted into the two orthogonal polarized light signal which is then passed through the optical road such that they are mutual to each other. After this this is mixed with the local oscillator laser light of the vibration signal in the 90 degree Optical mixer[6]. Then this is passed through ADC sampler which works at high speed for converting into digital signals and at the end the data is recovered in the Digital Signal Processor.

3. ALGORITHUM PROCESS FOR THE RECOVERY OF DP-QPSK SIGNAL

Here the two orthogonal polarized light IDP-QPSK-X and IDP-QPSK-Y is achieved at the front tip at the coherent optical receiver of PBS and after this the polarized light uses 90 degree optical mixer for coherent reception[5]. As polarization diversity technology is separating the light signal and local oscillator light into two orthogonally polarized signal so to receive the same polarized phase signal in the phase diversity receiver, which are collected and been isolated by DSP module so to have the required orthogonal polarized signal information.

Ax(t), Ay(t) is the electric field amplitude of the received light signals X,Y, and fo is the laser frequency of transmitter. The θwx, θwy are signal phases for X and Y. The 90° mixer provided 4 output road light signal of the electric field components which are given as:

$$\mathbf{I}_{DP-QPSK,X} = A_x(t)\exp(j2\pi f_0 t)\exp[j\theta_{w,x}(t)]$$
$$\mathbf{I}_{DP-QPSK,Y} = A_y(t)\exp(j2\pi f_0 t)\exp[j\theta_{w,y}(t)]$$

$$\frac{\sqrt{2}}{2}\begin{bmatrix} \mathbf{I}_{DP-QPSK,X} + \frac{\sqrt{2}}{2}\mathbf{I}_{LO} \\ \mathbf{I}_{DP-QPSK,X} - \frac{\sqrt{2}}{2}\mathbf{I}_{LO} \\ \mathbf{I}_{DP-QPSK,X} + \frac{j\sqrt{2}}{2}\mathbf{I}_{LO} \\ \mathbf{I}_{DP-QPSK,X} - \frac{j\sqrt{2}}{2}\mathbf{I}_{LO} \end{bmatrix}$$

Thus we performed light detection from 4 roads of signals from the 90° optical mixer. And we got the same phase and orthogonal component from the light

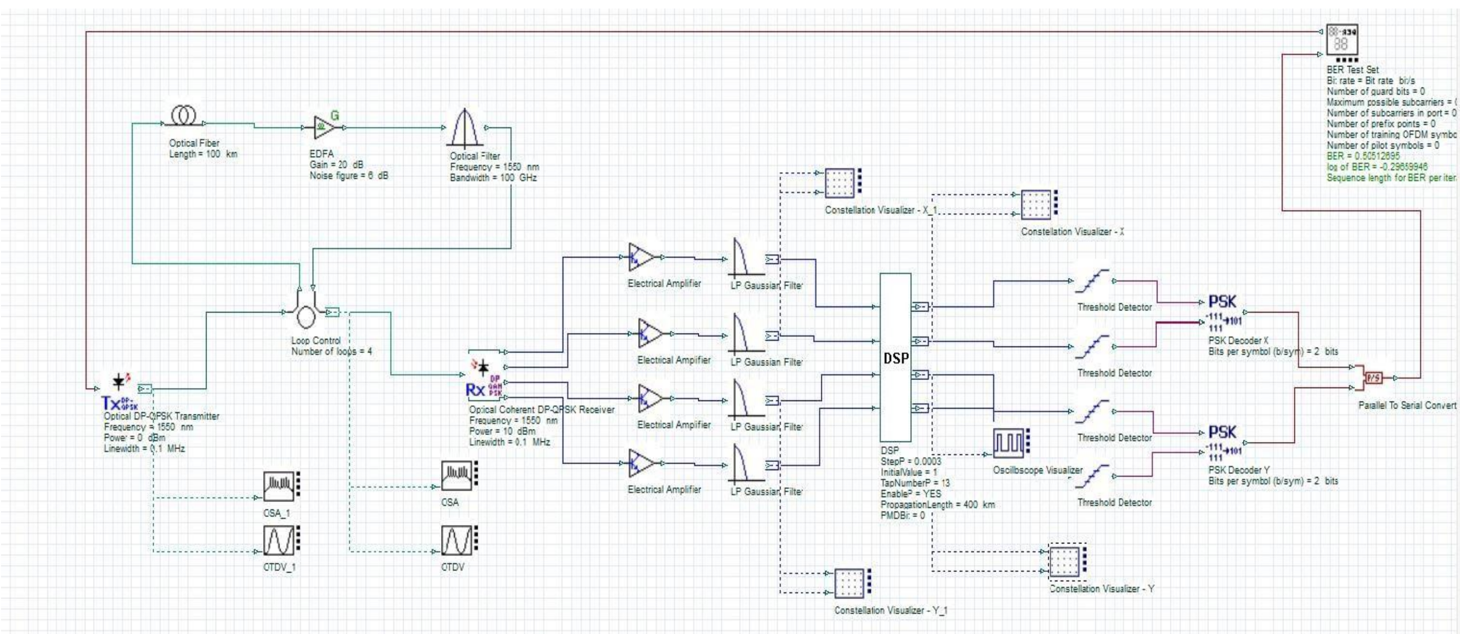
$$X_I = R\sqrt{2P_{LO}}A_s(t)\cos[2\pi(f_0 - f_{LO})t + \theta_{w,x}(t) - \varphi_{LO}(t)]$$
$$X_Q = R\sqrt{2P_{LO}}A_s(t)\sin[2\pi(f_0 - f_{LO})t + \theta_{w,x}(t) - \varphi_{LO}(t)]$$

detection as shown from the above equations[4].

From the above R is taken as the response of the diode. The Electric signal will be managed by the filter and trans-resistance amplifiers and enter to the DSP module. At the end the electric signal being tackled and can demodulate the original information[3].

4. Simulation of DP-QPSK Transmission System

This 100 Gbps transmission using DP-QPSK can be divided into five parts: DP-QPSK Transmitter, Transmission Link, DP-QPSK Coherent Receiver, Digital Signal Processing, and Detection with Decoding[8]. As



the DP-QPSK signal is generated by an optical DPQPSK Transmitter which is then transmitted by the fiber loop in which dispersion and polarization effects is caused. Then this is passed through the Coherent Receiver and then through the DSP for solving distortion effect and compensating it. This dispersion is compensated using a simple digital filter and the adaptive polarization de-multiplexing is done by applying the CMA (Constant modulus algorithm)[1]. Then it is passed through the Viterbi-Viterbi phase estimation algorithm which is used to compensate both the phase and frequency mismatch between the transmitter and local oscillator. Then by this the digital signal processing is completed and the signal is passed to the detector followed by the decoder and at the end to the BER Test Set for direct error counting. And the figure below shows the simulation diagram.

From the electrical constellation we got that the Bit rate has 100Gbps with number of samples observed as 1048576 which is taken for the transmission distance of the optical signal for 400km achieving Samples per bit as 31 and having Sequence length of 65536 bits. Below figure 3 shows that the electrical constellation before DSP of Y analyzer and figure 4 shows that the electrical constellation after DSP. Figure 5 shows spectrum analyzer of receiver spectrum with center frequency of 193HTz.

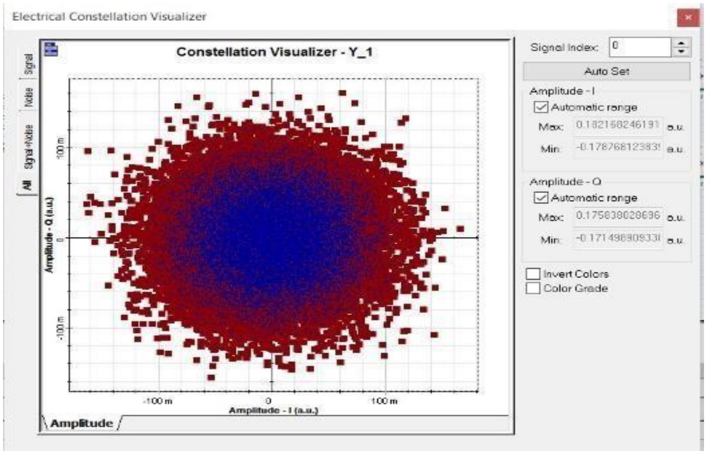


Figure 3

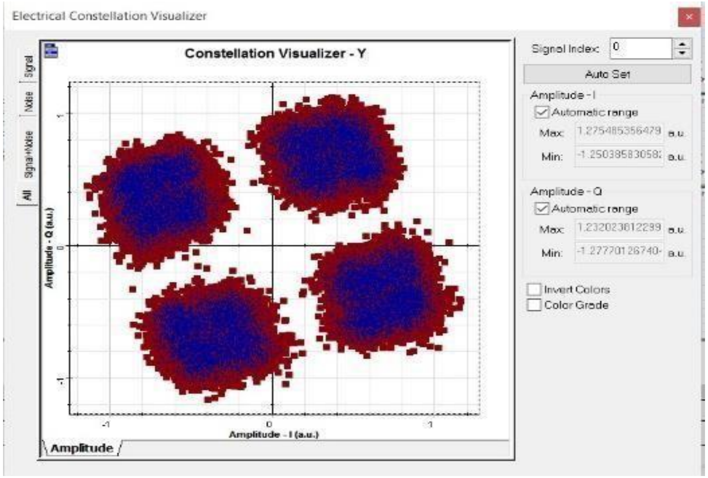


Figure 4

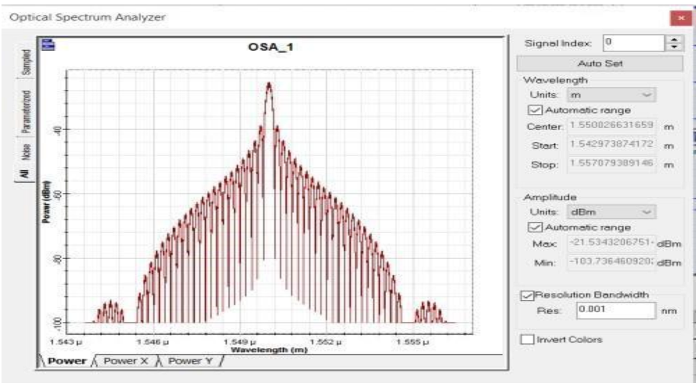


Figure 5

5. Conclusion

We concluded that for high-speed and long-distance optical fiber transmission the coherent optical detection technologies is the boom technology. In this paper we achieved an ideal result from coherent detection optical transmission system so by using DSP module by which we process the received signal. The constellation diagrams are distinguishable and also the data transmission error rate is near about zero. Hence the total proves that the setup is easy and reliable by which there is optimization in coherent optical detecting section.

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