**DSP for coherent DP-QPSK optical receivers:**

Digital signal processing is now the most interesting method to compensate for linear impairments of long-haul fiber transmission. After coherent detection of the DP-QPSK signal, four main functions are performed in digital domain before signal detection: 1) Analog to Digital conversion, 2) Dispersion compensation, 3) Polarization de-multiplexing, and 4) Carrier phase estimation.

**1) Analog to Digital conversion:**

The analog to digital conversion is basically a down sampling process. Here we have chosen a 2-bit sampling however sampling rate can be changed.

**2) Dispersion compensation:**

In the absence of fiber nonlinearity, the fiber optic can be modeled as a phase only filter with the following transfer function:



In which the first part is the effect fiber dispersion and the second term is the dispersion slope for multi-channel application. In order to compensate for the dispersion, we multiply the output field to the inverse of the channel transfer function (FIR filter). The order of the filter increases as the amount of dispersion (length of the propagation) increases.

[1] Digital filters for coherent optical receivers, Seb J. Savory, 21 January 2008 / Vol. 16, No. 2 / OPTICS EXPRESS.

[2] 12 Gb/s Co-DP-QPSK Optical Transmission Offline Digital Filtering Analysis. In: 14º Simpósio Brasileiro de Microondas e Optoeletrônica.

**3) Polarization de-multiplexing:**

The Jones matrix of the fiber for transmission can be written as:



Where α and δ denote the power splitting ratio and the phase difference between the two polarization modes. The SOP of the output signal can be written as:



So if we can find the inverse of matrix T, we can do polarization de-multiplexing. The constant modulus algorithm (CMA) is a conventional way in the literature for this. Following figure shows the DSP circuit for channel expression and the corresponding equation:





The matrix elements are updated symbol by symbol according to:



µ is the step-size parameter and n the number of symbol. The p matrix is basically an adaptive FIR filter and we use CMA for blind estimation. The initial values for pxx(0) and pyy(0) are:

pxx(0) = [00…010..00];

pyy(0) = [00…010..00];

pxy(0)=pyx(0)= [00…000..00];

In our simulation we have chosen a 3-tap FIR filter, however the order can be changed.

[1] Kikuchi, K.; , "Polarization de-multiplexing algorithm in the digital coherent receiver," *IEEE/LEOS Summer Topical Meetings, 2008 Digest of the* , vol., no., pp.101-102, 21-23 July 2008.

[2] Ling Liu; Zhenning Tao; Weizhen Yan; Oda, S.; Hoshida, T.; Rasmussen, J.C.; , "Initial tap setup of constant modulus algorithm for polarization de-multiplexing in optical coherent receivers," Optical Fiber Communication - incudes post deadline papers, 2009. OFC 2009. Conference on , vol., no., pp.1-3, 22-26 March 2009.

**4) Carrier phase estimation:**

Phase locking in the hardware domain can be replaced by phase estimation in digital domain by DSP. The received QPSK signal can be presented by



We have used the following algorithm to estimate the phase of the QPSK signal in digital domain:



[1] Guifang Li, "Recent advances in coherent optical communication," Adv. Opt. Photon. 1, 279-307 (2009).