DIRECT DETECTION OF OPTICAL BPSK/QAM SIGNAL WITHOUT DIGITAL SIGNAL PROCESSING

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Abstract - We experimentally demonstrate the coherent detection of optical BPSK/QAM signals by direct phase compensation of the phase noise without using a sophisticated digital signal processing algorithm. The phase compensation is achieved by applying simply an error signal to a phase modulator located at the local oscillator for coherent detection, where the error signal is generated to keep the same power level for binary/quadrature signals.

Indexterms - Phase Noise, BPSK, QAM, Coherent Detection, Coherent Optical Communication.

I. INTRODUCTION

Coherent optical modulation based onamplitude and phase modulation provides high spectral efficiency to realize cost-effective optical transmission. For the demodulation of BPSK/QAM signals the optical carrier phase of the received signal is recovered bya high-speed electrical digital signal processor (DSP).To achieve the demodulation of such coherent signals, an optical phase-locked loop (OPLL) [1-3] has been investigated intensively such as Costas loop circuit [4], squaring loop [5], etc. However, conventional coherent demodulation schemes based on the DSP may show limitations for extension to high-order modulation and/or high speed. On contrast to conventional methods using DSP, in the suggested method, the phase noise is compensated directly by a single phase modulator without aid of DSP software. This allows fast demodulation of coherently modulated signal, regardless of its speed. To prove the suggested idea, we transmit BPSK and QAM signals through an optical channel. We show eye diagrams and constellations for 5 Gbit/s BPSK and 5 Gbd/s QAM demodulated signals, respectively.

II. EXPERIMENTS

Figure 1 presents the experimental setup. A continuous optical wave is generated by an external cavity laser with 100 kHz of line width, and divided to form data signal and local oscillator. A pulse pattern generator (PPG) generates pseudo-random binary sequences (2^{31}-1) at 5-Gbit/s. The in-phase (I) and quadrature-phase (Q) channels for the QAM are implemented by applying data output and one-bit delayed data-bar output to a QAM modulator respectively. The BPSK modulation is achieved at the same setup by applying the data output for binary phase modulation only.

A polarization controller (PC) is used to feed 45 degree (to give same power for X and Y orthogonal polarization) polarized light at the coherent receiver. The I and Q channels (XI and XQ) of X-polarized signalare monitored by a fast digital oscilloscope. The other outputs(YI and YQ) for the other (Y) polarized signal are peak detected and fed to a servo loop controller to form OPLL for phase compensation. The Servo loop controller output forces to adjust the phase of the LO signal to keep the power balance between YI and YQ channels. This compensates any phase noise induced by external turbulence during the BPSK/QAM signal transmission, such as temperature, vibration, etc.

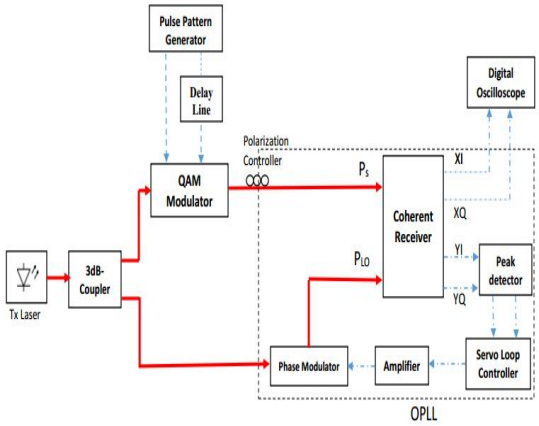


Figure 1: Experimental Setup

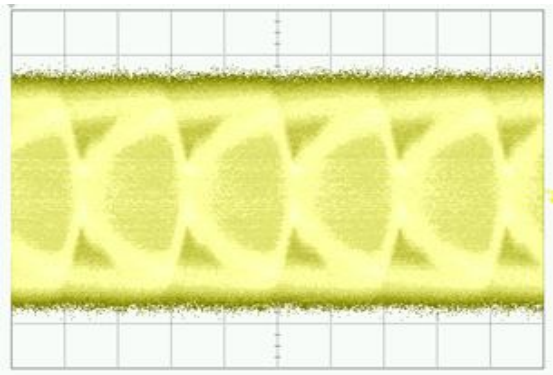
Here we do back-to-back detection, but our method is ready for application to practical transmission through optical fiber.At the presentation we will show the results obtained after practical transmission through optical fiber.

III. EXPERIMENTAL RESULTS AND DISCUSSION

Figure2 shows the eye diagrams without and with phase compensation for 5 Gbp/s BPSK signal. Hereafter, all the persistent traces are obtained for one minute. Without feedback the received eye pattern is almost closed, indicating that the bit error rate (BER) is very high. By the phase compensation, clear eye opening is observed. This proves that our idea is working well.

Figure 3 shows the eye diagrams without (a and b) and with (c and d) phase compensation for I and Q channels of 5 Gbd/s QAM signal, respectively. Without phase compensation, again the eyes are closed, indicating poor BER performance. Wide eye openings can be seen in the eye diagrams after phase noise compensation.

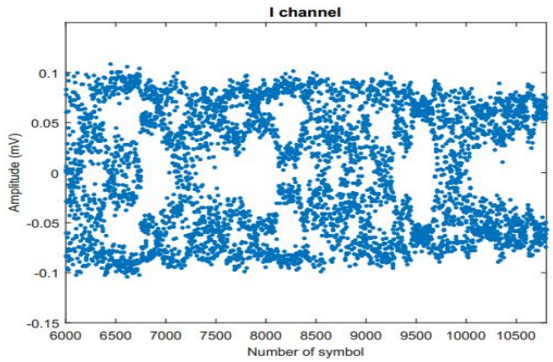
Corresponding constellations after the QAM demodulation are shown in figure 4.The constellation in figure 4(a) shows typical random phase noise, rotating randomly the QAM signal positions. After the phase noise compensation, theQAM signal positions become stable as shown in figure 4(b). Again clear phase noise compensation is confirmed. In this way we are able to reduce phase noise effect without using DSP algorithm.



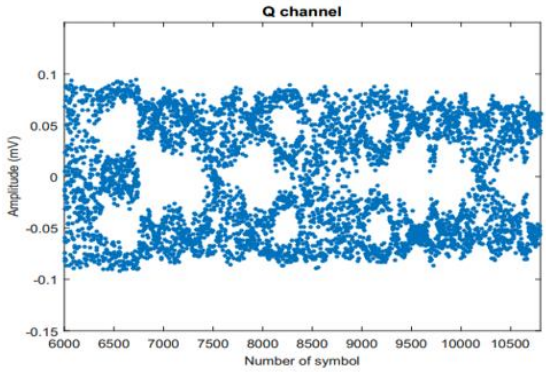
(a)

(b)

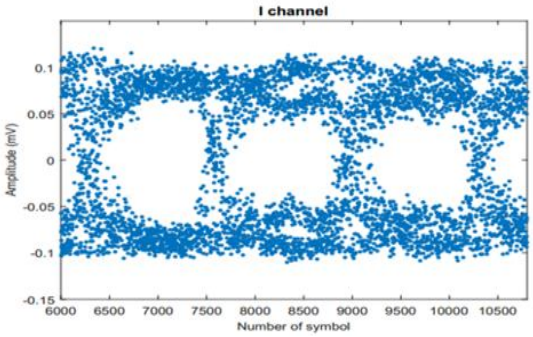
Figure 2:Eye Dagrams of 5 Gbit/s BPSKSignal; (a) Without and (b) With Feedback



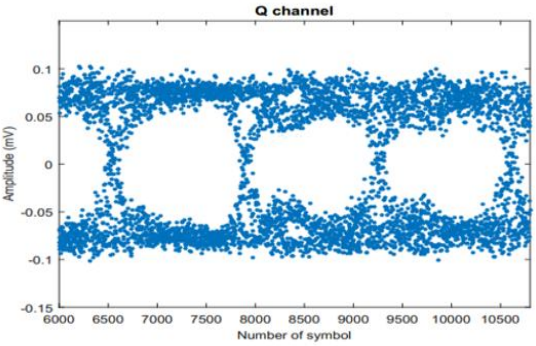
(a)



(b)

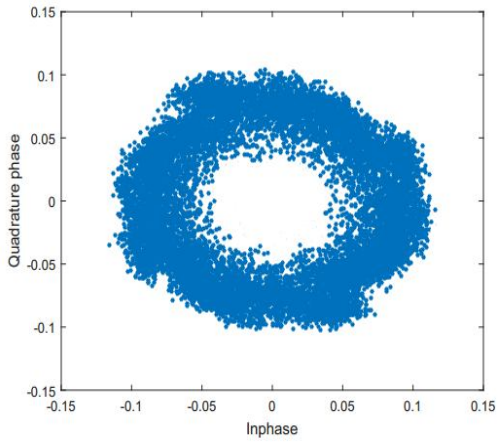


(c)

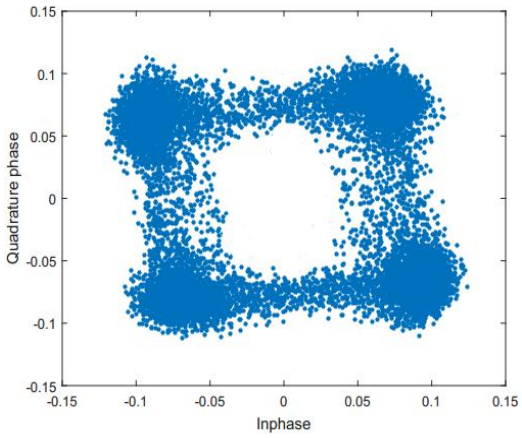


(d)

Figure 3: Eye diagrams of I (a, c) and Q (b, d) channels of 5 Gbd/s QAM signal; (a, b) without feedback, and (c, d) with feedback



(a)



(b)

Figure 4: Constellation diagrams for QAM signal; (a) without and (b) with feedback

CONCLUSION

Real-time coherent demodulation of high-speed optical BPSK/QAM is achieved effectively without complicated DSP, by compensating the phase of the local oscillator through a simple feedback loop. The suggested method is ready for application to multi-QAM signal transmission through a fiber communication channel.

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